EAST WATERWAY OPERABLE UNIT
SUPPLEMENTAL REMEDIAL INVESTIGATION/ FEASIBILITY STUDY
EXISTING INFORMATION SUMMARY REPORT

For submittal to

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

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List of Tables

List of Figures

List of Appendices

2-D	two-dimensional
2LAET	second lowest apparent effects threshold
3-D	three-dimensional
ACGs	analytical concentration goals
ADCP	acoustic Doppler current profiler
Anchor	Anchor Environmental, L.L.C.
API	Asian and Pacific Islander
ARAR	Applicable or Relevant and Appropriate Requirements
ASAOC	Administrative Settlement Agreement and Order on Consent
ASTM	American Society for Testing and Materials
AWQC	ambient water quality criteria
BACT	best available control technology
BEHP	bis(2-ethylhexyl)phthalate
BERA	Baseline Ecological Risk Assessment
bgs	below ground surface
BMPs	best management practices
BTEX	benzene, toluene, ethylbenzene, and xylene
CAD	computer-aided design
CDF	Confined Disposal Facility
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cfs	cubic feet per second
City	City of Seattle
COI	chemical of interest
County	King County
cPAHs	carcinogenic polycyclic aromatic hydrocarbons
CPTs	cone penetration tests
CPUE	catch-per-unit-effort
CSL	Cleanup Screening Level
CSM	Conceptual Site Model
CSO	combined sewer overflow
CTA	Cruise Terminals of America
cy	cubic yards
DDT	dichloro-diphenyl-trichloroethane

DGPS	differential global positioning system
DMMP	Dredged Material Management Program
DMMUs	Dredged Material Management Units
DNR	Washington State Department of Natural Resources
DO	dissolved oxygen
DPD	(City of Seattle) Department of Planning and Development
DPM	diesel particulate matter
DPS	distinct population segment
DQOs	Data Quality Objectives
dw	dry weight
EBI	Elliott Bay Interceptor
Ecology	Washington State Department of Ecology
EE/CA	Engineering Evaluation/Cost Analysis
EFDC	Environmental Fluid Dynamics Code
EISR	Existing Information Summary Report
EOF	emergency overflow
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
ESD	Explanation of Significant Differences
ESG	Environmental Solutions Group, Seattle, WA
EVS	EVS Environment Consultants, Seattle, WA
EW	East Waterway
EWG	East Waterway Group (Port of Seattle, City of Seattle, and King County)
FPM	fine particulate matter
FS	feasibility study
FY	fiscal year
GIS	geographic information system
gpd	gallons per day
H:V	horizontal to vertical
HHRA	Human Health Risk Assessment
HPAHs	high molecular weight polycyclic aromatic hydrocarbons
KCDNRP	King County Department of Natural Resources and Parks
KCIA	King County International Airport

KCIW	King County Industrial Waste
Kinder Morgan	Kinder Morgan Energy Partners
LAET	lowest apparent effects threshold
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
LPAHs	low molecular weight polycyclic aromatic hydrocarbons
LUST	leaking underground storage tank
MDL	method detection limit
MHHW	mean higher high water
ML	maximum level
MLLW	mean lower low water
MNR	monitored natural recovery
MOA	Memorandum of Agreement
MSL	mean sea level
MTCA	Model Toxics Control Act
NAPL	nonaqueous phase liquid
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NSPS	New Source Performance Standard
NTCRA	Non-Time Critical Removal Action
O&M	operations and maintenance
OC	organic carbon
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PDM	post-dredge monitoring
PEFs	potency equivalency factors
PM10	fine particulate matter with a diameter equal to or less than 10 micrometers
PMA	Port Management Agreement
Port	Port of Seattle

ppt	parts per thousand
PRG	Preliminary Remediation Goal
PSAMP	Puget Sound Ambient Monitoring Program
PSCAA	Puget Sound Clean Air Agency
PSD	Prevention of Significant Deterioration
PSDDA	Puget Sound Dredged Disposal Analysis
PSEP	Puget Sound Estuary Program
PSMAF	Puget Sound Maritime Air Forum
PSP	post-sand placement
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
RAL	remedial action level
RAO	Remedial Action Objective
RfDs	reference doses
RI	remedial investigation
RL	reporting limit
RM	River Mile
RME	reasonable maximum exposure
ROC	receptor of concern
ROD	Record of Decision
ROW	right-of-way
SAIC	Science Applications International Corporation
SD	storm drain
SDOT	Seattle Department of Transportation
SIC	Standard Industrial Classification
SL	screening level
SMAs	Sediment Management Areas
SMS	Sediment Management Standards
SOW	Statement of Work
SPCC	Spill Prevention, Control, and Countermeasures
SPI	sediment profile imaging
SPU	Seattle Public Utilities

SQS	Sediment Quality Standards
SRI/FS	Supplemental Remedial Investigation/Feasibility Study
SSA	Stevedoring Services of America
SVOC	semivolatile organic compound
SWAC	surface weighted average concentration
SWMP	Stormwater Management Program
SWPPP	Stormwater Pollution Prevention Plan
TBT	tributyltin
TCE	Trichlorothene
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TSS	total suspended solids
TTI	Total Terminals International
U&A	Usual and Accustomed
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UST	underground storage tank
VCP	(Washington State Department of Ecology) Voluntary Cleanup Program
VOC	volatile organic compound
WA WQC	Washington water quality criteria
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
Windward	Windward Environmental, LLC
WQA	King County Water Quality Assessment (King County 1999a)
WQM	water quality monitoring
WRDA	Water Resources Development Act
WSDOT	Washington State Department of Transportation
WSF	Washington State Ferries
WW	West Waterway
WWTP	Wastewater Treatment Plant
ZID	zone of initial dilution

1 INTRODUCTION

This Existing Information Summary Report (EISR) is being prepared as part of the Supplemental Remedial Investigation/Feasibility Study (SRI/FS) for the East Waterway (EW) Operable Unit (OU) of the Harbor Island Superfund Site (Figure 1-1) as ordered by the U.S. Environmental Protection Agency (EPA) per the process defined by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), or Superfund. The SRI/FS will ultimately lead to an EPA Record of Decision (ROD) outlining cleanup actions in the EW.

The EISR is the first of several steps required to complete the SRI/FS, as outlined in the SRI/FS Final Workplan (Workplan) (Anchor and Windward 2007). The main purpose of the EISR is to summarize readily available environmental and other appropriate data collected in the EW that are required to conduct the SRI/FS. The EISR constitutes Task 2 of the Administrative Settlement Agreement and Order on Consent (ASAOC) and Statement of Work (SOW) (EPA 2006a) signed between the Port of Seattle (Port) and EPA for conducting the overall SRI/FS.

The Port is a signatory to a Memorandum of Agreement (MOA; 2006) between the Port, City of Seattle (City), and King County (County), which details responsibilities and allocation between the signatory entities with respect to the EW SRI/FS project. The Port, City, and County form the East Waterway Group (EWG) and they will work jointly to conduct the SRI/FS. For purposes of the SRI/FS, the EWG will be referenced as the entity managing the project under EPA oversight.

1.1 Project Overview

The SRI/FS for the EW will be carried out through a series of RI and FS tasks, and deliverables associated with those tasks. A summary of each task and associated deliverables are included in the Workplan (Anchor and Windward 2007). The approach and schedule presented in the Workplan were developed based on EPA's input and consideration of the supplemental nature of the RI. EWG considers the schedule, which leads to EPA ROD issuance in May 2010, to be expedited. Due to the expedited schedule, the SRI and FS will be conducted in an integrated fashion. Data needs for the SRI and FS will be identified collectively, such that the field investigation data, the outcome of the SRI, and the associated risk assessments can support the development and evaluation of potential remedial alternatives.

The EISR is the initial task, which will summarize readily available data and other site information for use in subsequent SRI and FS steps. Data and information summarized in the EISR will be used to develop the Conceptual Site Model (CSM), which will be presented along with an analysis of data gaps in the CSM and Data Gaps Analysis Report. The Report will identify important physical, chemical, and biological processes within the EW as well as likely current and future exposure scenarios for ecological and human receptors. The analysis of data gaps will identify (and prioritize) gaps in data anticipated to be needed for the SRI, Baseline Ecological Risk Assessment (BERA), Human Health Risk Assessment (HHRA), and FS. The data gaps assessment will include a summary of recommended studies proposed to address the identified data gaps.

Sampling efforts to address data gaps will be identified in individual Quality Assurance Project Plans (QAPPs). Detailed methodologies, approaches, and descriptions of the analyses conducted for each of the required reports will be provided in each respective report and will build upon the results of the EISR and data gaps analysis. The results of the sampling efforts will then be presented in data reports that will provide validated analytical results.

Evaluations of sediment transport and source control will be conducted as separate tasks parallel to other SRI tasks. As outlined in the Workplan, work products for sediment transport and source control will be submitted as stand-alone reports to help minimize delay of SRI tasks. Finally, the results of all SRI tasks, including sediment transport and source control, will be combined and synthesized in the SRI report.

The FS will build upon SRI tasks to develop and evaluate a number of alternative remedial options. Early FS steps include development of the Remedial Action Objective (RAO) Memorandum and Remedial Alternative and Disposal Site Screening Memorandum. The RAO Memorandum will describe what the proposed sediment cleanup is expected to accomplish. Both memoranda will be developed concurrent wth early SRI tasks. The FS

Report will then provide a detailed evaluation and comparative analysis of retained remedial alternatives, concluding with a recommended preferred remedy.

1.2 Purpose of EISR

The purpose of the EISR is to summarize readily available environmental, physical, and ecological studies and information relevant to the EW. This report identifies studies, documents, and other sources of information pertinent to the EW and discusses the applicability of data for use in the SRI/FS. Data Quality Objectives (DQOs) are also presented to designate which data are acceptable for further use in the SRI/FS process (see Appendix F). Information compiled and listed in the EISR will be further evaluated as part of development of the CSM and Data Gaps Analysis Report.

The EISR includes a summary of the nature and extent of contamination in the EW, based on existing environmental media, including surface and subsurface sediment. Additional data that may be collected as part of the SRI/FS process will supplement existing data presented in the EISR and be used to complete the evaluation of nature and extent of contamination in the EW. Existing information summarized in the EISR consists of results from environmental investigations or cleanups along the EW and adjacent to the proposed EW OU study boundaries. These datasets are summarized and assessed for applicability. The appropriateness of each dataset is reviewed in this report using the criteria presented in Section 3.

Existing physical, ecological, and human-use characteristics of the EW based on previous studies and information are described in Section 2. All current property owners and operators of the aquatic areas and adjacent uplands of the EW are identified. Other information includes a summary of sediment transport mechanisms and characterization of sediment stability based on existing data and relevant hydraulic and sediment transport studies (Section 4).

A discussion of potential sources of contamination to the EW is also included in this report. Section 5 identifies known historical and ongoing and potential sources of contamination to the EW, including an overview of completed or ongoing source control activities. Review of potential sources will extend beyond the proposed EW OU study boundaries identified in this report, and will include contributing drainage basins for stormwater and combined sewer overflows (CSOs), nearshore contaminated sites, potential upstream influence from the Duwamish River, and sediment north of the northern proposed EW OU study boundary. More detailed discussion of source control activities will be presented in the Source Control Evaluation Approach Memorandum, as discussed in the Workplan (Anchor and Windward 2007).

1.3 EW Sediment Operable Unit History

The Harbor Island Superfund Site originally included two operable units: the Harbor Island Site Soil and Groundwater OU and the Harbor Island Sediment OU. SRIs were carried out for Harbor Island OU sediments under previous ASAOCs with EPA beginning in 1994. Figure 1-2 shows general locations for each of these OUs. In the West Waterway (WW), three OUs were separated from the Harbor Island OU, two of which received RODs from EPA in 1996 (Lockheed and Todd Shipyard OUs) and the third in 2003 (WW OU). The North Harbor Island Sediment OU was also separated from the Harbor Island OU, which ultimately received a determination of no further action. The EW OU was separated from the Harbor Island OU in 2002 (Figure 1-1). The following summarizes why this SRI/FS is being conducted on the EW OU.

While there have been a number of dredging events in the EW over time, EPA has closely monitored the environmental aspects of two recent dredging events in the EW OU. Navigation dredging was conducted from 1999 to 2000 (Stage 1 dredging) to achieve the federal authorized channel depth of -51 feet mean lower low water (MLLW). EPA was involved in assessing the effectiveness of this dredging to help reduce contaminant concentrations in the EW. Post-dredge sediment monitoring results indicated higher than expected contaminant concentrations in the newly exposed surface sediments. EPA ordered the Port to conduct an additional SRI, which was completed in 2002. Based on further evaluation of remaining contamination in the EW, the Port conducted a Non-Time Critical Removal Action (NTCRA) under EPA oversight in areas that could be removed on an expedited basis.

Dredging of areas with the highest known contaminant concentrations and without slope and structural stability concerns occurred in 2004 and 2005 (Phase 1 dredging). Post-dredge monitoring indicated that some areas were still above cleanup goals, triggering a contingency action that consisted of placing an interim clean sand layer over portions of the Phase 1 area that exceeded Washington State Sediment Quality Standards (SQS). Additional discussion of the chronology of recent dredging events is provided in Section 1.4.4.

1.4 Site Background

1.4.1 Site Description

This section presents a general overview of the physical characteristics of the site. Additional detailed information on the site conditions is presented in Section 2.

The EW is located approximately one mile southwest of downtown Seattle, in King County, Washington. It is part of the greater Duwamish River estuary, which includes the freshwater/salt water interface extending as far as 10 miles upstream. At the southern end of Harbor Island, the river splits into the EW and WW. From there, the EW and WW extend to Elliott Bay at the north end of Harbor Island. The EW runs along the entire eastern shore of Harbor Island (Figure 1-1). The Lower Duwamish Waterway (LDW) Superfund Site is located immediately upstream of the EW (i.e., upstream of Harbor Island).

Figure 1-3 shows the major features of the EW, including the station identification method that was previously established for other EW projects[1]. These stations are based in feet measured from the northernmost end of Harbor Island. This northernmost point is Station 0.

The EW is approximately 7,600 feet long and for most of its length is 750 feet wide. It is channelized and has a south-to-north orientation. Four bridges cross over the EW along the Spokane Street corridor, located approximately at Station 6850. The Spokane Street corridor includes three lower bridges and one high bridge (West Seattle Bridge). The lower bridges include (from north to south) the Spokane Street Bridge (which includes the fishing pier bridge along the north side), the Railroad Bridge, and the Service Road

[1] The station identification on Figure 1-3 will be used throughout the EW SRI/FS project in order to provide a common means of identifying the location at any point within the EW.

Bridge. Immediately north of the Service Road Bridge, the EW is approximately 250 feet wide. It narrows to approximately 150 feet wide south of the Service Road Bridge (see Figure 1-3).

The existing mudline elevation varies from approximately -40 to -60 feet MLLW (near the mouth) in the 750-foot-wide portion of the EW. Mudline elevations rise to between -13 and -6 feet MLLW in the vicinity of the Spokane Street corridor (DEA 2003). The shallow water depths associated with this "sill" along the Spokane Street corridor form a physical constriction across the entry to the EW that causes the Duwamish River to primarily flow through the WW. Based on information available in this report, the sediments comprising the sill under and between the bridges within the Spokane Street corridor have never been dredged. The highly developed shoreline within the EW is primarily composed of piers, riprap, constructed seawalls, and bulkheads constructed for industrial and commercial use.

The EW north of the Spokane Street corridor experiences regular vessel traffic of various sizes and types. Container ships call at Terminals 18 (T-18), 25 (T-25), and 30 (T-30) (see Figure 1-3). Cruise ships currently call at T-30; however, vessels from the National Oceanic and Atmospheric Administration (NOAA) will dock at T-30 from November through March of 2008. U.S. Coast Guard (USCG) vessels frequent Pier 36. The EW also has significant tug and barge traffic, and is used for Tribal Usual and Accustomed (U&A) fishing. A public fishing pier is present along the north side of the Spokane Street Bridge. Additional discussion of human use of the EW is included in Section 2.4.

1.4.2 Proposed East Waterway Operable Unit Study Boundaries

The proposed EW OU study boundaries are shown on Figure 1-3. The proposed southern EW OU study boundary is identical to the northern study area boundary of the LDW Superfund Site. The northern boundary of the EW that was used in the 2003 Phase 1 Remedial Action Engineering Evaluation/Cost Analysis (EE/CA) (Windward 2003a) is shown on Figure 1-1. The current northern proposed EW OU study boundary is also shown on Figures 1-1 and 1-3.

The northern proposed EW OU study boundary has been revised based primarily on bathymetric changes in areas north of the mouth of the EW. As shown on Figure 1-4, the boundary has been moved north to include areas up to the point at which depths steeply slope beyond -60 feet MLLW. The northern proposed EW OU study boundary extends along the western pierhead line to the north until water depths reach -60 feet MLLW. The boundary follows the approximate upper edge of this naturally occurring slope at about -60 feet MLLW, then turns to perpendicularly intersect the bulkhead along Terminal 46 (T-46).

The location of the northern proposed EW OU study boundary that perpendicularly intersects the bulkhead along T-46 is also based on previous dredging events conducted along T-46. Sediment at the northern end of the EW was dredged in 2000 as part of Stage 1 dredging to a depth of -45 feet MLLW (Figure 1-4; see Section 1.4.4 for complete dredge history). The northern proposed EW OU study boundary bisects the northernmost Stage 1 Dredged Material Management Unit (DMMU), which was determined to be suitable for open-water disposal by the Dredged Material Management Program (DMMP) prior to dredging in 2000.

Additional dredging, to a depth of -51 feet MLLW, was conducted along T-46 in the vicinity of the northern proposed EW OU study boundary in 2005 (Figure 1-4). The northern proposed EW OU study boundary bisects the DMMU dredged in 2005, which was also determined to be suitable for open-water disposal by the DMMP. Current sediment elevations are the deepest compared to historical dredging activities (see Section 1.4.4 for complete dredge history). Following dredging in this area as part of the Stage 1 and T-46 projects, the newly exposed sediment surface was established on either side of the northern proposed EW OU study boundary that had never been exposed by dredging (Figure 1-4). Additional discussion of the T-46 dredge data is included in Appendix C. These proposed EW OU study boundaries will be utilized during the SRI/FS. The EW ROD will ultimately establish the cleanup boundary for the site.

1.4.3 Site History

Portions of the former Duwamish River channel and surrounding floodplains were filled and graded to form the present-day topography. Dredging from 1903 to 1905 created the EW and WW. Dredge depths varied throughout the EW, with localized areas dredged to depths greater than -60 feet MLLW, based upon U.S. Army Corps of Engineers (USACE) bathymetric condition surveys. Harbor Island and the land east of the EW and west of the WW was constructed using dredge fill removed from the Duwamish River estuary (and the current location of the EW) (Weston 1993) or sluiced from nearby uplands. As part of these activities, large-scale filling and grading of the Elliott Bay tidelands occurred. Prior to filling, the Elliott Bay tidelands extended east of the site to the current location of Interstate 5. Construction of Harbor Island was completed in 1909 (HistoryLink 2007a). Upstream of Harbor Island, the Duwamish River was straightened and deepened starting in 1913 to allow navigation of ocean-going vessels upriver of Elliott Bay (HistoryLink 2007b).

With the construction of Harbor Island, the EW was initially dredged to a minimum navigable depth of -30 to -40 feet MLLW and 750 feet wide. A turning basin was created along the eastern part of the south end of the EW at approximately Station 5800 (Figure 1-5). Two slips were also dredged along the eastern shore to -28 feet MLLW (currently Slip 27) and -30 feet MLLW (formerly Slip 30). Early industrial and commercial use of the EW consisted of fish processing facilities, shipyards, and facilities with flour mills, grain elevators, lumber yards, and cold storage originally focused on the eastern shore. Wharves constructed on creosoted piles were built by the Port and others in the early 1900s along both sides of the EW. This turning basin was dredged to much deeper depths in 1918 (-54 feet MLLW) than currently exist. More detailed discussion of historical dredging depths is included in Section 4.6.

The federal channel in the EW, WW, and LDW was authorized by Congress on March 2, 1919. The EW was dredged to -40 feet MLLW along most of the 750-foot-wide portion by the mid-1920s. Slip 36 was constructed in 1927 and originally dredged to -35 feet MLLW. Commercial and industrial use continued after the 1940s on both sides of the EW, including oil terminals, shipyards, rail transfer terminals, cold storage, lumber yards, and sand and gravel transfer stations. The eastern portion of the turning basin was filled in 1972, thus straightening the eastern shoreline between Stations 5400 and 6000. That same year, the Port first converted areas to container use on portions of T-18 and along T-25. Slip 30 was filled in 1981. Additional areas were converted to container use in the 1980s, including areas along T-18 and T-30. Additional discussion of current upland uses and ownership is included in Section 2.4.

The previously authorized channel dimensions were approximately 5,800 feet long by 500 feet wide, with a depth of -39 feet MLLW following amendment by the Water Resources Development Act (WRDA) of 1986 (USACE 1998). The passage of the 1996 WRDA increased the authorized channel depth to -51 feet MLLW and reduced the authorized channel width from 500 feet to 450 feet to accommodate wider berth areas (USACE 1998).

1.4.4 Chronology of Dredging and Fills in the East Waterway

Portions of the EW have been dredged multiple times since its original construction in the early 1900s. This section discusses recent dredging and fill activities conducted over the past 10 years. These activities were conducted at various times by the Port, USACE, and USCG to maintain and deepen existing berths and to deepen the federal navigation channel to its authorized depth of -51 feet MLLW. A summary of recent dredging events in the EW from December 1999 to November 2006 is provided in Table 1-1 and is depicted on Figure 1-6. Plan views of each recent dredge event with final dredge depths are provided in Appendix J.

No other major dredging events occurred in the EW in the 1990s beyond those listed in Table 1-1. Other dredging activities before the 1990s included dredging and fill projects associated with pier improvements along T-25 and T-30. Improvements were conducted along T-25 in the 1970s and along T-30 in 1983, as shown in cross sections presented in Appendix A. Sediment was excavated to -54 feet MLLW along T-25 (Figures A-11 and A-12 of Appendix A) and -55 feet MLLW along T-30 (Figures A-15 and A-16 of Appendix A) before being backfilled with riprap. The projects were implemented from Stations 4250 to 6100 along T-25 and from Stations 1600 to 3600 along T-30. Along T-30, sediment was removed to allow for riprap to be placed up to 14 feet from the outermost fender pile, creating a trough with slightly higher sediment in the waterway than along the pier (Figure A-16 of Appendix A). As part of dredging along T-25 in the 1970s, sediment was also removed to -50 feet MLLW up to the federal navigation channel boundary. Further discussion of the dredge prism along T-30 is provided in Section 4.6

(see also Appendix J). Additional dredging along T-30 in 2007-2008 is proposed to remove all sediment to -51 feet MLLW (see Table 1-1).

Table 1-1
Summary of Recent Dredging in the East Waterway

Area	Project	Volume (thousands of cy)	Start Date	Finish Date	Starting Mudline Elevation (feet MLLW)	Finish Mudline Elevation (feet MLLW)	Sponsor	Suitable for Open-Water Disposal (thousands of cy)	Unsuitable for Open-Water Disposal (thousands of cy)
East Waterway	Stage1	224	12/7/1999	2/29/2000	-45 to -60	-51	USACE	137	85
East Waterway	T-30	18	1/28/2002	2/11/2002	-40 to -44	-44	Port of Seattle	18	0
East Waterway	Phase 1 Season 1	39	1/12/2004	3/3/2004	-42 to -51	-51	Port of Seattle	0	39
East Waterway	Phase 1 Season 2	230	7/20/2004	2/28/2005	-42 to -51	-51	Port of Seattle	67	166
East Waterway	Slip 36	52.2	Aug 2004	Feb 2005	-34 to -40	-40	USCG	16	36.2
East Waterway	T-46	11	1/20/2005	2/8/2005	-42 to -48	-51	Port of Seattle	4.3	5.1 sediment 1.5 rock
East Waterway	T-18 Berths 2 to 5	22.6	Jan 2005	Feb 2005	-47	-52	Port of Seattle		
East Waterway	T-18 Berths 3 to 4	4.3	11/5/2005	12/1/2005	-48	-52	Port of Seattle	17.8	10.3
East Waterway	T-18 Berths 2 to 3	1.2	11/7/2006	11/9/2006	-48	-52	Port of Seattle		
East Waterway	T-30	59	Proposed Jan-Feb 2008 and Dec 2008-Feb 2009		-40 to -47	-51	Port of Seattle	59	0

USACE – U.S. Army Corps of Engineers
USCG – U.S. Coast Guard

Stage 1 navigational dredging was conducted by USACE between December 1999 and February 2000 to -51 feet MLLW from the north end of the EW approximately 4,950 feet south. As shown on Figure 1-6, much of the middle and north end of the EW was dredged. Prior to dredging, sediment was as shallow as -45 feet MLLW. Approximately 224,000 cy of sediment were removed as part of this activity.

In early 2002, the Port deepened the cruise ship portion of T-30 from -40 to -44 feet MLLW to deepen cruise ship berths at the terminal. In total, 18,000 cy were dredged from the area along T-30.

The Phase 1 Removal Action was conducted by the Port over the course of two seasons between January 2004 and February 2005 to remove contaminated sediments in the south-central portion of the EW as part of a NTCRA under CERCLA. All material removed during the first season (39,000 cy) was unsuitable for open-water disposal. Of the 233,000 cy removed during the second season, 67,000 cy was suitable for open-water disposal and 166,000 cy was unsuitable. After dredging was completed during the second season, a sand layer was placed over most of the dredge footprint at -52 feet MLLW as an interim measure to cover contamination concentrations detected above SQS during post-dredge monitoring.

Deepening occurred in Berths 2 through 5 along T-18 between January 2005 and November 2006. Prior to dredging, construction work was done to stabilize the riprap slope beneath the terminal to allow for a finished elevation of -51 to -52 feet MLLW at the berth face, allowing safer container ship operations during extreme tides. The total volume removed was approximately 28,100 cy.

USCG sponsored dredging of Slip 36 between August 2004 and February 2005. Dredging was conducted to -40 feet MLLW as part of berth deepening and EW widening; however, no post-dredging bathymetry information has been acquired for this area. The majority of the material (36,200 cy) was unsuitable for open-water disposal, while the remaining 16,000 cy was disposed of at the Elliott Bay open-water disposal site.

The Port conducted maintenance dredging at T-46 in early 2005. Sediment removed from units bisected by the northern proposed EW OU study boundary and further north along T-46 were determined to be suitable for open-water disposal (6,200 cy). Other material from along T-46 (5,300 cy of sediment and 1,500 cy of large riprap) was determined to be unsuitable for open-water disposal.

Proposed dredging along T-30 is planned for January through mid-February 2008, and between December 2008 and February 2009 to deepen areas currently at -40 to -47 feet MLLW. Approximately 59,000 cy of material will be dredged. This project will result in full container ship berthing depths to -51 feet MLLW.

1.5 Sources of Existing Information

Much of the information presented in this report has been summarized in previous documents. In these instances, specific data sources have been cited accordingly. Summary reports that present compiled information include previous Harbor Island OU RIs (Weston 1993; HISWG 1996). Valuable information has also been summarized from LDW documents and cited accordingly. Specifically, habitat and species surveys, sediment transport modeling, and information on potential upstream sediment sources have been included from LDW investigations.

Data contained in the EW SRI/FS database have been summarized in this report. This database was developed specifically for the EW SRI/FS by compiling all previous physical and chemical sediment quality, water quality, and tissue chemistry data. A summary of criteria for data selection, suitability, and reduction is included in Section 3.2.

Historical bathymetry data was acquired through a query of the USACE Engineering Records Branch for historical bathymetric maps and dredge history information (Section 4.7.2). The Port provided current tenant and user information, as well as parcel boundaries (Section 2.4). Structural and utility information (Section 2.4.3) was acquired from the Port; City and County utility maps; Washington State Department of Natural Resources (DNR) lease, easement, and right-of-entry records; and records from the Seattle Department of Transportation (SDOT) and Washington State Department of Transportation (WSDOT).

Available structural information was also acquired from the USCG for their facility at Pier 36.

1.6 Document Organization

The remainder of this document is organized as follows:

- Section 2 presents a summary of the environmental setting, including physical characteristics of the EW, habitat and biological communities, structures and utilities, and human use characteristics for the EW and surrounding land.
- Section 3 summarizes the existing environmental data available for the site. A review of methods for evaluating analytical data quality as applied to EW environmental data is included. Sampling events are described for environmental media including sediment, surface water, tissue chemistry, groundwater, porewater, and toxicity testing.
- Section 4 presents a summary of sediment transport dynamics in the EW based on results from previous studies. This section characterizes sediment stability based on existing conditions in the EW and on studies examining natural and ship-induced events in the vicinity of the EW.
- Section 5 identifies known historical and ongoing and potential sources of contamination to the EW and discusses the types of potential sources and pathways of contamination entering the EW including over-water uses and spills; wastewater, CSO, and stormwater discharges; contaminated upland sites; sediment transport; and atmospheric deposition. Completed or ongoing source control activities are also discussed.
- Section 6 discusses next steps and major deliverables.
- Section 7 presents the references cited in this document.

2 ENVIRONMENTAL SETTING

2.1 Sources of Existing Information

The environmental setting for the EW is described in this section for the area within the proposed EW OU study boundaries (Figure 1-1). All applicable information for this area has been summarized in this section. Applicable information includes the most recent studies and/or information on physical characteristics, habitat, and biological communities that represent current conditions in the EW.

In general, studies cited in this section are the most recent of their kind. However, older studies have been cited if they contain elements applicable to current EW conditions, or if no new information has been collected to update this information. Numerous studies may be cited to describe the same environmental component of the EW. All references cited are thought to contain valuable information helpful in understanding the environmental setting of the EW.

Bathymetry information has been updated using several surveys. A comprehensive bathymetry survey of the EW north of the Spokane Street corridor was conducted in 2003 (DEA 2003), but has been updated with supplemental bathymetry information in 2004. More recent bathymetry information from Slip 36 has been collected but is not yet available from USCG.

Qualitative information has also been included where other quantitative information is unavailable. For example, no recent bathymetry surveys have been conducted south of the Spokane Street corridor, but water depths have been provided based on observations from Global Diving and Salvage boat operators that moor vessels in that portion of the EW.

Use and ownership of the EW and adjacent uplands are presented based on the existing information at the time of this Report's preparation. Port, City, and County records were reviewed to identify current property boundaries and tenant information.

Structure and utility descriptions are based on as-built design drawings whenever possible, with updated information presented for upgraded facilities. Design drawings are presented only when as-built drawings were not available.

2.2 Physical Characteristics

2.2.1 Meteorology

The climate in the EW vicinity is characterized as "Pacific marine," typical of the Puget Sound area. The prevailing winds move moist air inland from the Pacific Ocean, moderating winter and summer temperatures. Winters tend to be mild and wet, and summers are usually dry. Seventy-five percent of the annual precipitation falls from October through March (WRCC 2007a). Annual precipitation ranges between 23.8 and 55.1 inches measured at Sea-Tac International Airport between 1931 and 2007 (WRCC 2007a). Mean annual precipitation for the same period is 38.2 inches (WRCC 2007a). Monthly average winter temperatures range from 2 to 8 degrees Celsius (°C; 36 to 46 degrees Fahrenheit [°F]; WRCC 2007b). Monthly average summer temperatures range from 12 to 23°C (53 to 73°F; WRCC 2007b). Winds are typically from the southwest at 8 to 16 kilometers per hour (km/hr; 5 to 10 miles per hour [mi/hr]) (Canning et al. 1979).

2.2.2 Hydraulics and Hydrology

The EW receives freshwater flows from the Green/Duwamish River watershed (Figure 2-1). The Howard Hanson Dam impounds the Green River at River Mile (RM) 64.5 (USACE 2005) and was constructed to provide flood control in the Lower Green River (USACE 2007). The Green River becomes the Duwamish River at the historical confluence of the Green and former Black Rivers. The Duwamish River estuary flows into Elliott Bay through the EW and the WW. As measured at the Auburn gage (RM 32, U.S. Geological Survey [USGS] Station ID 12113000, see Figure 2-1), the annual average flow of the Green River since 1962 was 1,318 cubic feet per second (cfs) (USGS 2007). With the construction of the Howard Hansen Dam in 1962, the Green River hydrology was altered, and flood frequency is now controlled by reservoir operations. For the period since dam construction, the USACE flood frequency curves predicted the 2-year, 10-year, and 100-year flood flows at the Auburn gage to be 11,500 cfs, 12,200 cfs, and 12,200 cfs, respectively (Brettman 2007) (Figure 2-2). However, the actual 2-year, 10-year, and 100-year flood flows at the Auburn gage were 8,400 cfs, 10,800 cfs, and 12,000 cfs, respectively (Windward and QEA 2007). Daily flow statistics for the Green River at the Auburn gage are shown in Figure 2-2. These data illustrate the seasonal variations in Green River flow. Peak flows occur November through February, and minimum flows occur in August.

The EW is also subject to tidal forcing from Elliott Bay. The average tidal range measured at the Seattle waterfront is 11.36 feet, with an extreme low of -5.04 feet MLLW and an extreme high of +14.48 feet MLLW (NOAA Station ID 9447130, see Figure 2-1). Tidal conditions for 2006 are shown in Figure 2-3.

The sill near the south end of the EW restricts flows between the Duwamish River and the EW and alters the velocity profile. Measurements of the EW velocity profile obtained during two averaging periods from a location in the EW south of the sill are described below.

During one averaging period (King County 1999a), the upper two-thirds of the EW water column exhibited a net downstream flow from the Duwamish River, with an average velocity of about 20 centimeters per second (cm/sec) (King County 1999a). The velocity profile of the lower one-third of the water column measured during the same averaging period exhibited a small net reverse-flow (current flowing upstream from the EW toward the Duwamish River), with an average velocity of about 2 cm/sec. During another averaging period, the velocity profile measured at the same location showed a net downstream velocity from the Duwamish River into the EW throughout the water column, with a maximum velocity of 75 cm/sec. The occurrence of two-layer flow with the small reversed flow is a consequence of the estuarine circulation pattern set up by the interaction of the freshwater flows from the Duwamish River and underlying, denser saline water coming in from Elliott Bay (McLaren and Ren 1994). Further discussion of tidal forcing from Elliott Bay is discussed in Section 2.2.3. A more detailed description of existing hydrodynamic modeling is included in Section 4, along with a table of documents containing information pertinent to the EW.

The EW also receives freshwater discharges from three CSOs and 39 storm drains (see Section 2.4.3.2 for a full description of CSOs and outfalls) (Figure 1-3). Both the CSO and storm drain discharges are intermittent, and the relative contribution of freshwater from the CSOs and storm drains is small in comparison with flows from the Duwamish River.

Periodic discharge flows from CSOs in the EW ranged from 3 to 74 cfs (Breithaupt et al. 2002). Additional discussion of CSO and stormwater discharge is presented in Section 5.

Winds are typically from the northerly or southerly direction (i.e., along rather than across the EW), and wave periods are limited by the fetch across Elliott Bay and in the EW itself. Consequently, wind wave-generated currents within the EW are not expected to exert a significant effect on currents of the EW.

Hydrodynamic modeling has been conducted to support sediment transport analyses for the LDW (Windward and QEA 2007; QEA 2007). The hydrodynamic model grid included the EW, but the EW was treated as a hard bottom that did not influence the model output. These studies are further described in Section 4.3.

2.2.3 Estuarine Features

The EW is influenced by the freshwater flows from the Duwamish River and the tidal conditions of Elliott Bay. The outflow of freshwater from the Duwamish River along with the marine tidal waters entering from Elliott Bay produces the estuarine conditions in the EW with the characteristic increase in salinity with water depth and net outflow to Elliott Bay. The flows are characterized by an outflow to Elliott Bay in the surface layer and inflow to the EW near the bottom. These conditions influence the hydrodynamics and sediment transport in the system.

The freshwater from the Duwamish River overrides the saline waters from Elliott Bay, producing a salt water wedge in the Duwamish River and a thin surface layer of slightly lower salinity water in Elliott Bay (Figure 2-3). The salt water wedge present in the Duwamish River is reported to travel as far as 10 miles upriver (McLaren and Ren 1994). Salinity measurements from the bottom of the channel at the Duwamish Yacht Club (RM 4.1) vary with the tide from near zero to approximately 29 parts per thousand (ppt), indicating the salt water wedge movement with the tide (King County 1999a).

At two stations within the EW (Figure 2-4), velocities were measured approximately 1 meter above the sediment bed during the period March 27 through May 17, 1995[2]. The velocities averaged 2 to 2.5 cm/sec with more than 99 percent of the velocities measuring less than 10 cm/sec and less than 0.01 percent of the velocities measuring greater than 25 cm/sec (HISWG 1996). The velocities measuring greater than 25 cm/sec were attributed to propwash. The net direction of flow at the measurement locations was to the south, in alignment with the EW channel and indicating a net inflow near the bottom. The highest measured velocities (maximums of 85 and 129 cm/sec at the two stations) were attributed to ship passage.

Hydrodynamic and sediment transport analyses have been conducted for the LDW (Windward and QEA 2007; QEA 2007). Although the hydrodynamic model grid included the EW, sediment transport analysis was not evaluated in the EW. These studies are further described in Section 4.3.

2.2.4 Geologic Conditions

This section presents a summary of studies conducted in and near the EW that describe geologic conditions there. Section 2.2.4.2 provides a summary of regional geological characteristics. A detailed summary of physical characteristics of sediments from within the EW is provided in Section 2.2.6.

2.2.4.1 Studies Adjacent to the East Waterway

As discussed in Section 1.4.3, large-scale filling and grading of the Elliott Bay tidelands occurred during the early 1900s. Much of Harbor Island was constructed using fill removed from the lower Duwamish River and the areas that became the EW and the WW.

The geology of nearshore upland areas in the immediate vicinity of the EW has been evaluated during separate RI/FS studies at T-30 (GeoEngineers 1998) and T-18 (Weston 1993), representing the east and west nearshore upland areas, respectively.

[2] During this period, the average daily flow for the Green River was 1,010 cfs, the peak tidal elevation was 11.76 feet MLLW, and the minimum tidal elevation was -3.07 feet MLLW (see Section 4.2.1 for more information).

A separate 2006 data report for T-30 also includes a summary of geologic conditions (RETEC 2006a). Table 2-1 provides a list of key reports with information related to geologic conditions along either side of the EW. Typical upland cross sections of these areas are contained in Appendix A for T-30 (see Figures U-1 and U-2) and T-18 (see Figure U-3).

Table 2-1
Key Reports Examining Geologic Conditions Along the East Waterway

Study	Source
Harbor Island	
Harbor Island RI	Weston 1993
Summary of Geotechnical Testing 1960-1998	Harza 1998
Supplemental Geotechnical Testing (T-18, T-30)	Harza 1999
Eastern Properties	
T-30 Groundwater RI/FS	GeoEngineers 1998
Summary of Geotechnical Testing 1960-1998	Harza 1998
Supplemental Geotechnical Testing (T-18, T-30)	Harza 1999
T-30 Subsurface Exploration and Geotechnical Evaluation Study	Hart Crowser 1984
T-30 Supplemental Data Report	RETEC 2006a
T-25 1989 to 1990 Groundwater Sampling	Landau 1990; Sweet-Edwards 1990
T-104 Vicinity 2005 to 2007 Groundwater Sampling	Environmental Partners 2007
USCG 2003 and 2004 Groundwater Monitoring	Hart Crowser 2004

Soils observed in nearshore upland areas on both shorelines are described as generally similar and consist of fill material overlying native alluvial and tideland sediments. These observations were documented in the respective RI/FS reports (GeoEngineers 1998; Weston 1993) and summarized from upland borings. Most of the fill is hydraulically dredged sediment from the Duwamish River. The fill is difficult to distinguish from native alluvial and tideland sediments. The contact between fill and native sediment is estimated to be approximately 15 to 20 feet below ground surface (bgs; GeoEngineers 1998; Weston 1993). Fill material generally consists of very dark gray sand and gravel with varying amounts of silt, wood, bricks, and construction debris. Native sediments below fill observed during RI activities consisted of very dark gray to black sand with varying amounts of silt. Shell fragments and occasional organic materials were often observed in the sandy native sediment.

Geotechnical studies conducted in and adjacent to the EW were summarized prior to Stage 1 dredging in 1999 to evaluate geotechnical issues related to existing wharfs, upland slopes, and other improvements along T-18, T-25, T-30, and Terminal 37 (T-37) (Harza 1998). Available geotechnical reports include results from borings, cone penetration tests (CPTs), and vibratory borings. The Harza (1998) report provides summaries and complete references of 20 studies completed between 1960 and 1998. Based on those data, Harza (1998) recommended supplemental geotechnical testing along T-18, T-30, and in the EW to further characterize geotechnical conditions in areas near Stage 1 dredging that could influence stability of wharf structures and upland slopes. These tests were completed by Harza, HWA Geosciences, and USACE and summarized by Harza (1999).

Six soil borings were installed to depths greater than 100 feet as part of a geotechnical engineering study completed in support of the construction of the T-30 concrete apron (Hart Crowser 1984). Three borings were located along the western area of the former Chevron terminal (north end of T-30) and three borings were located offshore in the EW. Alluvial sediments were observed beneath approximately 15 to 20 feet of fill material in the upland borings, with silt content generally increasing with depth. As noted above, the fill is difficult to distinguish from native alluvial and tideland sediments. Very dense "till-like" glacial sediments were observed beneath the alluvial sediments at depths ranging from approximately 115 to 135 feet bgs.

Subsurface grain size testing as part of RI activities at T-30 confirmed observed soil characteristics recorded on boring logs. RI activities at T-30 included testing of selected soil samples to evaluate the characteristics of site subsurface soils (RETEC 2006a; GeoEngineers 1998). Twelve samples were collected from seven monitoring well borings for testing. The soil samples were analyzed for grain-size distribution and vertical permeability. These data indicate that most soil samples consisted primarily of sand with less than 10 percent fines (GeoEngineers 1998). Areas characterized as silty sand contained approximately 23 to 45 percent fines, and areas characterized as silt contained approximately 64 to 78 percent fines. Two soil samples collected in the fill material placed during the mid-1980s shoreline reconstruction consisted of relatively well-graded sand with approximately 39 to 48 percent gravel. A deeper sample consisted primarily of medium-grained sand (RETEC 2006a).

Falling head and constant head permeability tests were used to measure vertical permeabilities of the soil samples by American Society for Testing and Materials (ASTM) Method D-5084 as part of the T-30 RI (GeoEngineers 1998). Soil samples characterized on boring logs as silt had average vertical permeabilities ranging from 6.69×10^{-8} to 1.94×10^{-7} cm/sec. Soil samples characterized as silty sand on boring logs had average permeabilities ranging from 2.70×10^{-5} to 4.23×10^{-4} cm/sec. Soil samples containing less than 10 percent fines had average permeabilities ranging from 2.08×10^{-5} to 2.78×10^{-3} cm/sec.

The geology of Harbor Island generally consists of fill overlying alluvium, as described in the RI Report (Weston 1993). Two units of fill were identified, including units of coarse-grained and fine-grained sand. The coarse-grained fill unit consisted of gravelly to coarse sand ranging from 0 to 7 feet in thickness and was placed to create a level subgrade for development on the island. The underlying fine-grained unit was deposited hydraulically from dredge material from the Duwamish River and consists of fine to medium sand ranging in thickness from 3 to 15 feet. The contact between the fine-grained fill unit and underlying deltaic sediments was described as often imperceptible with occasional increase of silt, shell, and wood fragment content. The underlying deltaic sediment consists of unconsolidated sand and silty sand with occasional silt interbeds and an increase in silt content at depth. Physical parameters were collected at one location on Harbor Island (DP-02) within a deeper deltaic sediment silt layer, which contained 45.5 percent fine sand, 49 percent silt, and 6.5 percent clay.

2.2.4.2 Regional Geology

The regional topography of the Puget Sound area is characterized by a series of north-south trending ridges and troughs caused by repeated Pleistocene glaciations. The troughs are generally occupied by marine waters, lakes, marshes, rivers, and/or streams. Major troughs in the King County area are occupied by the waters of Puget Sound, the Duwamish-Green River, Lake Washington, and Lake Sammamish.

Bedrock located beneath the Pleistocene glacial deposits in the Seattle area consists of Tertiary sedimentary and volcanic rocks. The thickness of the glacial deposits overlying the bedrock varies greatly throughout the Seattle area. The depth to bedrock beneath the vicinity of the EW is approximately 1,600 feet bgs (RETEC 2006a).

Evidence of at least five major Pleistocene glacial ice advances have been identified in the sediments deposited in the Puget Sound area (RETEC 2006a). The most recent advance was the Vashon Stade of the Fraser Glaciation, approximately 13,000 years ago (Weston 1993). Glacial ice advanced to the southern end of the Puget Sound Basin (near Olympia, Washington) during the Vashon Stade. The sediments deposited during the glacial and intervening nonglacial intervals consist of a complex sequence of lacustrine deposits, glaciomarine deposits, glacial till, and outwash deposits. The typical sequence of sediments deposited during the Vashon Stade in the Seattle area includes Vashon till (very dense glacially consolidated silty sand with gravel, cobbles, and boulders) underlain by Esperance sand (advance outwash deposits) and Lawton clay (lacustrine deposits). The till is often overlain by recessional outwash deposits.

Post-Pleistocene alluvial, deltaic, and estuarine deposits overlie the Vashon Stade sediments in much of the south Seattle industrial area. These deposits range from gravel and sand to silt and clay with peat and other organic material (Galster and Laprade 1991). The recent native sediments in the vicinity of the EW site are the result of a combination of fluvial and tidal processes occurring near the mouth of the Duwamish River prior to entering the Elliott Bay tidelands.

Regional seismicity has been well documented for the Seattle area (Galster and Laprade 1991). Earthquakes can develop from shallow or deep fault movement, or from subduction zone rupture where the Juan de Fuca and North American tectonic plates converge off the Pacific coast of Washington State in what is called the

Cascadia Subduction Zone. Depending on the source of the earthquake, potential magnitudes ranging from 7.5 to more than 9.0 are possible (PNSN 2007). Actual site response from an earthquake is dependent on the magnitude of the event, the distance from the source to the site, and the dynamic soil properties of the area. The USGS has developed earthquake hazard maps of the Seattle area that incorporate these factors and present ground motion accelerations for three different earthquake events with the following return intervals: 475 years, 975 years, and 2,475 years (Frankel et. al. 2007). This information may be used to determine design seismic ground motions for the EW SRI/FS.

2.2.5 Hydrogeology

The regional hydrogeology in the vicinity of the EW is influenced by topography, natural drainage systems, tidal action, and man-made features. The shallow aquifer in the vicinity is a water table aquifer within the fill and the alluvial, deltaic, and estuarine sediments deposited by the Duwamish River. Shallow groundwater in the adjacent nearshore area flows primarily toward the EW and Elliott Bay. The following discussion provides a summary of hydrogeologic evaluations conducted as part of investigation activities conducted by the Port at nearshore upland sites including T-30 and T-18. These findings are generally thought to be representative of conditions in the EW. Table 2-2 provides a list of key documents that describe hydrogeologic conditions along either side of the EW. Cross sections depicting groundwater flow conditions along T-30 (Figures U-1 and U-2 of Appendix A) and T-18 (Figure U-3 of Appendix A) are provided in Appendix A.

This section summarizes groundwater characteristics around the EW based on existing information; however, ongoing examination of groundwater movement on both sides of the EW continue. Along T-18, the Harbor Island Steering Committee continues to evaluate groundwater flow characteristics, specifically with respect to the relationship and elevations of fresh and saline groundwater intervals. Similarly, along T-30, the Port is working with the Washington State Department of Ecology (Ecology) to fully understand groundwater flow and tidal interaction. Additional details on existing studies in each of these areas are provided below.

Table 2-2
Key Reports Examining Hydrogeologic Conditions Along the East Waterway

Study	Source
Harbor Island	
Harbor Island RI	Weston 1993
Harbor Island 2005 to 2006 Groundwater Monitoring	RETEC 2005; RETEC 2006b
USCG 2003 and 2004 Groundwater Monitoring	Hart Crowser 2004
Eastern Shoreline	
GATX 2003 Groundwater Monitoring	RETEC 2004
T-30 Supplemental Data Report	RETEC 2006a
T-30 Groundwater RI/FS	GeoEngineers 1998
T-30 February 2007 Groundwater Sampling Event	RETEC 2007
T-25 1989 to 1990 Groundwater Sampling	Landau 1990; Sweet-Edwards 1990
T-104 Vicinity 2005 to 2007 Groundwater Sampling	Environmental Partners 2007

2.2.5.1 Terminal 30 Hydrogeology Conditions

Groundwater levels at the T-30 site have been monitored periodically since the early 1990s, and are summarized in the T-30 Data Report and RI/FS (RETEC 2006a and GeoEngineers 1998). The effect of tidal influences was evaluated during two tidal monitoring periods in May 1993 and January 1994. Water level data was collected from 18 wells for a period of 36 hours at 15-minute intervals as part of the 1993 tidal monitoring effort (GeoEngineers 1998). For the 1993 study, peak tidal elevation was +11 feet MLLW, and minimum tidal elevation was -2 feet MLLW (GeoEngineers 1998). The 1994 tidal monitoring effort collected water level data from 14 wells for a period of 40 hours at 15-minute intervals (GeoEngineers 1998). For the 1994 study, peak tidal elevation was +12 feet MLLW, and minimum tidal elevation was approximately -2 feet MLLW (GeoEngineers 1998). During both studies, five wells were determined to have questionable data due to either electrical interference or deteriorated well conditions (RETEC 2006a).

Based on average water levels over a 24-hour period, net groundwater flow is from upland areas and discharges to the EW at the shoreline (GeoEngineers 1998). The net flow occurs independent of tidal effects and represents local recharge and upland flow entering the T-30 property. Because T-30 was capped by the Port as part of early site cleanup and redevelopment actions during the 1980s, local recharge is relatively small and most of the net flow is due to upland groundwater flow onto the T-30 property. This is thought to be the predominant condition along the nearshore of the EW due to the historical placement of hydraulic-dredged sediment fill. The groundwater gradient was estimated at 0.003 feet per feet (ft/ft) towards the EW (GeoEngineers 1998); however, this may be a high estimate due to tidal influence (RETEC 2006a).

Hydraulic conductivity was estimated in the T-30 RI/FS using both grain size analysis and tidal study data (GeoEngineers 1998). Grain size analysis provides only a rough estimate of hydraulic conductivity. The grain size analysis produced hydraulic conductivity values ranging from 0.01 to 0.1 cm/sec. The lower values are from samples with a higher percentage of silt and clay while the higher value is predominantly sand. The RI/FS tidal study evaluation resulted in significantly higher conductivity estimates than were represented by grain-size testing and literature values for the site aquifer matrix. Estimates of hydraulic conductivity computed from tidal data in the RI/FS ranged from 0.2 to 9 cm/sec, much higher than the values developed using site grain size data (GeoEngineers 1998). This range was considered an over-estimate of conductivity because these estimates are representative of a coarse sand and gravel matrix, which is found on the site, to a cobble matrix, which is not found on the site (RETEC 2006a).

Due to uncertainties and limitations identified in the RI/FS tidal study evaluation, calculated conductivities were re-evaluated in the 2006 Data Report (RETEC 2006a). Uncertainties and limitations of the RI/FS tidal study evaluation were identified in the 2006 Data Report and are listed below:

- Overestimate of storage coefficient as specific yield
- Overestimate of aquifer thickness
- Computation of lag time
- Computation of tidal efficiency via stage ratio
- Irregularities in tidal data
- Reliance on regression of stage ratio and time lag with distance from shoreline

The re-evaluation of tidal study data presented in the 2006 Data Report computed a hydraulic conductivity of 0.01 cm/sec (between one and two orders of magnitude lower than those predicted in the RI/FS), which is typical of a medium sand and is consistent with the range of conductivity values developed in the RI/FS using grain size data. Similar to the T-30 RI/FS report (GeoEngineers 1998), the re-evaluation performed by RETEC (2006a) analyzed the data records from the 1993 tidal study used in the RI/FS, specifically calculating hydraulic conductivities for only one well that was determined to contain adequate records for computing hydraulic diffusivity by tidal methods (RETEC 2006a).

In conjunction with the other hydrogeologic and groundwater data, the two tidal studies performed during RI activities in May 1993 and January 1994 (GeoEngineers 1998) were used to estimate the influences of tidal mixing on the dilution and attenuation of site groundwater prior to discharge into adjacent surface waters. The tidal influence on nearshore groundwater was evaluated in the 2006 Data Report (RETEC 2006a), and Appendix H of the Data Report details this evaluation. The Data Report has been submitted to Ecology for review. It was concluded that significant effects of tides and salinity include: 1) the formation of a salt water wedge that causes freshwater to override the more dense salt water, which confines freshwater discharge to the top of the aquifer near MLLW; 2) the formation of a water table trough during high tide that can restrict nonaqueous phase liquid (NAPL) migration; and 3) the dilution of nearshore groundwater with tidal influx prior to discharge to the EW (RETEC 2006a).

2.2.5.2 Terminal 18 Hydrogeology Conditions

Hydrogeology characteristics in the area of T-18 have been investigated extensively as part of work for the Harbor Island Soil and Groundwater OU. The Harbor Island RI (Weston 1993) details the hydrogeology of the Harbor Island Soil and Groundwater Operable Unit. More recently, several years of further investigations and groundwater monitoring have provided additional hydrogeologic information. EPA continues to work with the Harbor Island Steering Committee to characterize groundwater flow on Harbor Island. Provided below is a summary of T-18 hydrogeology as described in the Harbor Island RI (Weston 1993), the Technical

Memorandum regarding proposed compliance monitoring well screen locations on Harbor Island (RETEC 2005), and the *2005-2006 Groundwater Monitoring Report* (RETEC 2006b) (see Figure U-3 in Appendix A).

The groundwater contours on Harbor Island show a pattern of water levels generally typical of a flat island setting (RETEC 2006b). Groundwater elevation is highest in the central portion of the island and lowest at the shoreline. Groundwater elevations at the shoreline are influenced by tidal fluctuations in the surrounding surface water, as described for the T-30 site (Section 2.2.5.1). Overall, groundwater elevation distribution indicates a radial flow condition with recharge in the central portion of the island and discharge to the adjacent waterways. Groundwater recharge on Harbor Island is influenced by the large area of impervious surfaces (e.g., pavement). Groundwater in T-18 generally flows toward the EW.

Shallow, unconfined groundwater is encountered at depths of 2.5 to 11 feet bgs in the fill unit. Soils studied in the RI are continuously saturated throughout the stratigraphic column below the water table to depths of approximately 70 feet bgs. Groundwater at Harbor Island has been shown to behave as a single hydrostratigraphic unit of freshwater floating on a base of saline water (RETEC 2005), which is consistent with the findings presented in the T-30 Data Report for the east area of the EW (RETEC 2006a). The thickness of the freshwater lens exceeds 85 feet in the center of the island and thins to approximately 35 to 40 feet in the shoreline area. The freshwater/salt water interface is assumed to have a boundary effect on groundwater flow due to density differences between the fresh and salt water.

Additional assessments by RETEC were conducted in 2005 to identify the zone of groundwater above saline water (or saline wedge) that discharges to surface water. Results were presented in a Technical Memorandum describing proposed compliance monitoring well screen locations for Harbor Island wells (RETEC 2005). The assessment identified a salinity trend in groundwater at all but one of the proposed monitoring well locations, indicating that the freshwater unit on Harbor Island consists of three zones:

1. First low-salinity zone located at the water table (with salinities ranging from approximately 0.1 to 10 ppt)

2. A high-salinity zone underlying the first low-salinity zone (with salinities ranging from approximately 6 to 30 ppt)
3. Second low-salinity zone underlying the high-salinity zone (with salinities ranging from approximately 1 to 8 ppt)

The RETEC evaluation found that the salt water wedge is located beneath these three zones beginning at approximately 20 to 35 feet bgs (the depth of the saline wedge varies with distance from the shoreline) (RETEC 2005). Generally, groundwater to 20 feet bgs is most influenced by tidal cycles and is referred to as the shallow mixed zone (RETEC 2005). This zone includes the first low-salinity zone and the high-salinity zone. In shoreline monitoring wells along the EW, this shallow groundwater zone receives water from the EW at higher tides and discharges to the EW at lower tides. Groundwater in this zone is most likely to discharge to the EW. The conceptual cross section presented in Appendix A (Figure U-3) has not been updated to reflect the zones described above.

Aquifer testing completed as part of the 1993 RI indicated the hydraulic conductivity was similar to those determined by recent T-30 studies, ranging from 3×10^{-3} cm/sec to 1×10^{-2} cm/sec (Weston 1993).

2.2.6 Morphology

The EW is a straight channel that lies in a north-south direction (Figure 1-3). It is approximately 1.5 miles long and 750 feet wide at mid-length, between T-18 and T-30. At the south end, the channel narrows to a width of approximately 330 feet at the Spokane Street corridor, and to approximately 170 feet just north of the conjunction with the Duwamish River.

There are two slips that adjoin with the EW on the east side of the channel. Slip 27 is located halfway along the EW, and is 850 feet long and 240 feet wide. Slip 36 is located at the north end of the EW, with a length of 1,050 feet and a width of 270 feet.

The channel's cross sections are characterized as relatively flat in the center of the channel with steep side slopes armored with riprap (HISWG 1996). The profile bed elevation generally slopes downward toward the north and the entrance to Elliott Bay, with the bed rising steeply south to the shallow section and in the vicinity of the Spokane Street corridor.

2.2.7 Sediment Physical Properties

Surface sediments within the EW have been extensively reworked as a consequence of dredging and shoreline development. Section 4.7 discusses the changes to the bathymetry from historical dredging activities that have occurred in the EW. This section presents a summary of grain size, total solids, and total organic carbon (TOC) based on existing data from the EW. Table 2-3 presents a summary of physical properties queried from the EW SRI/FS database.

Table 2-3
Summary of Sediment Physical Properties for East Waterway Sediment

Parameter	Units	Number of Samples	Minimum Detect	Maximum Detect	Mean	Median
Surface sediment (0-10cm)						
Fines (percent silt + clay)	% dw	122	2.5 J	90.0	52.2	53.4
Sand	% dw	122	7.0	94.7	44.6	43.1
Gravel	% dw	113	0.01	44.0	3.3	0.3
Total organic carbon	% dw	218	0.56	10.1	1.9	1.7
Total solids	% ww	152	39.7	83.6	58.9	59.1
Subsurface sediment (0-4ft)						
Fines (percent silt + clay)	% dw	94	5.5	95.0	51.3	51.2
Sand	% dw	91	5.4	94.0	45.8	47.0
Gravel	% dw	87	0.01	18.0	2.4	0.6
Total organic carbon	% dw	115	0.27 J	19.0	2.6	1.9
Total solids	% ww	98	26.0	85.1	62.0	62.0
Subsurface sediment (>4ft)						
Fines (percent silt + clay)	% dw	23	10.0	92.1	49.0	41.0
Sand	% dw	23	7.3	90.0	51.0	57.0
Gravel	% dw	23	0.01	2.80	0.30	0.01
Total organic carbon	% dw	36	0.18	3.80	1.2	1.1
Total solids	% ww	10	54.5	76.3	64.5	64.2

Source: EW SRI/FS project database, queried December 5, 2007.
Note: Data collected prior to dredging at a given location have been excluded.
% dw – percent dry weight
% ww – percent wet weight
J - estimated

Figures 2-5 through 2-10 present a summary of EW physical properties data for the 0- to 10-cm (0-10cm) surface layer and the 0- to 4-foot (0-4ft) subsurface layer. Data collected prior to dredging at a given location have been excluded, so the contours represent post-dredge conditions (i.e., existing conditions). Contours were generated by interpolation, so the distribution of sample locations is useful in establishing a context for the contour lines. Data are available for samples collected from sediment depths beyond 4 feet, and are summarized in Table 2-3. However, these data are not presented graphically. Physical parameters for sediment deeper than 4 feet in non-dredged areas are available for 39 samples from 33 locations in the EW SRI/FS database.

Figure 2-5 shows contours of the distribution of percent fines (silt and clay) content of sediment in the 0-10cm surface layer in the EW. Although this figure provides a summary of percent fines, sand and gravel content can be inferred because it comprises the balance of the grain size distribution. In the EW, little to no gravel-sized particles are present (median percent gravel is 0.3 percent). The northern 1,900 feet of the EW tends to contain lower portions of fines (less than 60 percent fines), with higher fines in the vicinity of Station 5200 and 3900. Fines are also generally lower in the vicinity of the Spokane Street corridor (Figure 2-5). The median fines content in surface sediments is 53 percent (Table 2-3). Based on available data, surface sediment (0-10cm) has the following sediment grain size ranges: 0 to 44 percent gravel, 7 to 94.7 percent sand, and 2.5 to 90 percent fines.

Figure 2-6 shows contours of percent fines content for the 0-4ft interval. Patches of fine and coarse material tend to be intermingled along the EW. Fines are highest in the vicinity of the Qwest cable crossing near Station 1800. Other pockets of fines greater than 60 percent are present near Stations 6200 and 5200. Median levels of fines, sand, and gravel are 51.2, 47, and 0.6 percent in the 0-4ft interval, respectively. Sediment in the 0-4ft interval has the following sediment grain size ranges: 0 to 18 percent gravel, 5.4 to 94 percent sand, and 5.5 to 95 percent fines.

Figure 2-7 shows contours of total solids content for the 0-10cm depth interval. Total solids content is generally greater than 60 percent near the head of the EW (north of Station 1650). Most of the remainder of surface sediment is between 40 and 60 percent total solids, with the exception of areas near Station 4600, Station 3600, at the head of Slip 27, and north of the Spokane Street corridor (near Station 6800). Median total solids content in surface sediments is 59 percent (Table 2-3).

The distribution of data points for the 0-4ft interval is not sufficient to achieve small-scale resolution of the contours of total solids content (Figure 2-8). Total solids content of the 0-4ft layer is generally greater than 60 percent over most of the area of the EW. Other areas have solids content lower than 60 percent, including along the eastern side of the EW near the USCG facility (Station 200 to 1400), near Station 2200, and most of the area south of Slip 27 (south of Station 3800). Median total solids content is 62 percent in the 0-4ft interval (Table 2-3).

The TOC content of the 0-10cm layer is less than 2 percent over nearly all of the EW (Figure 2-9), with small patches above 2 percent over the remainder, including Slip 27. One sample near the head of Slip 27 contained a TOC content of 10 percent. Several samples contained less than 1 percent TOC, including near Station 4800 and near the northern portion of the EW. Median TOC in surface sediments is 1.7 percent (Table 2-3).

For the 0-4ft interval, the TOC content is less than 2 percent over the central portion of the EW (between Stations 1400 and 3600) and within the outer portion of Slip 27 (Figure 2-10). The TOC content in most of the remaining area is greater than 2, except for several samples along the northern portion of T-30, a few samples in and around Slip 27, and two samples at Station 5600 along T-18. Median TOC in the 0-4ft interval is 1.9 percent (Table 2-3).

2.2.8 Bathymetry

This section discusses current EW bathymetry and surrounding topography. The EW has experienced numerous dredging events since its original construction, which has altered its bathymetry with each dredge event. A summary of recent dredge events and an analysis of historical dredge depths are discussed in detail in Section 4.7.

The most recent bathymetric survey within the EW was conducted in 2005, following the Phase 1 Removal Action. The remainder of the EW was surveyed prior to the Phase 1

Removal Action in 2003. The two datasets have been combined to provide existing bathymetry, as shown in Figures 2-11A and 2-11B. Slip 36 was dredged to a design elevation of -40 feet MLLW in 2005, but USCG has not provided post-dredge bathymetric information. The most recent topographic survey of surrounding uplands was conducted in 1997.

The EW is 750 feet wide between pierhead lines. The federal navigation channel is 450 feet wide and is authorized to -51 feet MLLW. Current bathymetry within the federal navigation channel generally achieves the authorized depth of -51 feet MLLW from Station 0 to Station 4950, with the exception of a small area near the southern entrance of Slip 27. Some areas within the northern portion of the federal channel reach -60 feet MLLW. Areas north of the northern proposed EW OU study boundary become deeper than -60 feet MLLW, as discussed in Section 1.4.2. Along T-18, water depths along Berths 2 to 5 (between Stations 1000 and 4900) also reach -51 feet MLLW as a result of dredging completed in 2005 and 2006. South of Berth 5 (south of Station 4900), depths along the pierhead line generally decrease to -37 feet MLLW.

The eastern side of the EW is generally shallower than the federal channel. Slip 36 was dredged in 2005 to a design depth of -40 feet MLLW. Depths in the EW along the USCG facility (Pier 36) and T-30 north of the Alaskan Way right-of-way (ROW) (between Stations 150 and 1600) generally slope down from the existing riprap shoreline or bulkhead to -51 feet MLLW at the federal channel boundary, which is located approximately 150 feet from the shoreline. Water depths at the pierhead line along the T-30 apron (Stations 1600 to 3600) are approximately -44 feet MLLW on the northern half to -42 feet MLLW on the southern half.

Within Slip 27, water depths along the northeastern 100 feet and along Pier 28 range from approximately -38 to -40 feet MLLW. The southwestern 200 feet of Slip 27 slopes up to a riprap shoreline. The southern entrance to Slip 27 formerly contained a rail barge loading facility, with water depths of approximately -25 feet MLLW at the federal channel boundary, and reaching -51 feet MLLW at a distance of 100 feet west of the east boundary of the federal channel.

Water depths along the T-25 pierhead line range from -45 to -52 feet MLLW but decrease to -35 to -45 feet MLLW south of the southern boundary of the federal channel. Within the narrower, 400-foot-wide section of the EW (Stations 6150 to 6800), water depths are as shallow as -10 feet MLLW along the east and west boundaries and along the Spokane Street corridor. The deepest portions of the 400-foot-wide section of the EW reach -40 feet MLLW near the north opening to the wider EW section (Station 6300).

The sill located within the Spokane Street corridor is estimated to range in elevation from -13 to -6 feet MLLW (DEA 2003); however, no detailed bathymetry is available in this area. The EW narrows to approximately 150 feet wide south of the corridor (south of Station 7250) and contains riprap shorelines on either side. Mudline elevations are estimated to be approximately -20 feet MLLW based on nautical charts (NOAA 2000), but no detailed bathymetry is available in this area. Operators of vessels moored in the EW along the Harbor Island Marina have indicated that water depths in the center of the channel are likely greater than -20 feet MLLW and are at least -11 feet MLLW adjacent to the dock (Seymour 2007).

The topography of adjacent upland areas is generally in the range of +16 to +22 feet MLLW. Of the entire EW shoreline, approximately 61 percent contains 50- to 100-foot-wide pier aprons over riprap slopes, 30 percent contains armored riprap with no pier apron structure, and 9 percent is characterized as bulkhead. Exposed riprap slopes, generally at 1.75 horizontal to 1 vertical (1.75H:1V), are found at several locations in the EW including just south of T-18 (Station 6150), along the southern portion of T-25 at Pier 24 (between Stations 6150 and 6800), within Slip 27, and in sections along the northern portion of T-30 (Stations 400 to 1200). Both sides of the EW south of the Spokane Street corridor also contain riprap slopes (Stations 6850 to 7250). Typical cross sections for all EW shorelines are provided in Appendix A. Additional detail on EW structures is included in Section 2.4.3.

2.2.9 Sedimentation

Sedimentation is typically estimated from sediment trap sampling and radionuclide dating of sediment cores. Comparative bathymetry, dredge records, and physical and chemical time markers in sediment cores can also be used to estimate net sedimentation.

Sediment trap data can be used to estimate gross sedimentation rates, and radionuclide dating can be used to estimate net sedimentation rates (gross sedimentation rate minus resuspension rate). A discussion of sediment transport dynamics is included in Section 4, along with a list of documents containing key information.

Both sediment trap sampling and radionuclide dating of sediment cores were conducted at two locations in the EW for the Harbor Island SRI (HISWG 1996). One location was near Station 2500 (HI-03), and another was near Station 5400 (HI-04), both located along the centerline of the EW. From the sediment trap data, gross sedimentation rates were estimated at 3.2 and 7.8 centimeters per year (cm/yr) and the gross mass sedimentation rates were estimated at 2.3 and 5.3 grams per square centimeter per year ($g/cm^2/yr$) (Table 2-4). The higher rates were at the more southern station (HI-04). From the radionuclide dating of the sediment cores, the mass net sedimentation rates in the EW were 1.0 and 1.47 to $g/cm^2/yr$. Assuming a bulk density of 1.3 grams per cubic centimeter (g/cm^3), the estimated net sedimentation rate is 0.78 and 1.1 to cm/yr. This is similar to the net sedimentation rate of 0.9 to 1.7 cm/yr determined for the Duwamish River east of the navigation channel at RM 0.2 (near the south end of Harbor Island) as illustrated in Table 2-4 (Windward and QEA 2007).

Table 2-4
Comparison of Sedimentation Rates

Water Body	Gross Mass Sedimentation ($g/cm^2/yr$)	Net Mass Sedimentation ($g/cm^2/yr$)	Net Sedimentation (cm/yr)
Duwamish River	-	-	0.9 to 1.7[1]
East Waterway	2.3 and 5.3[2]	1.0 and 1.47[2]	0.78 and 1.1*
Elliott Bay	0.1 to 1.8[2]	0.1 to 0.72[3]	0.08 to 0.55*

* Estimated from net mass sedimentation rates assuming a bulk density of 1.3 g/cm^3.
1 – Windward and QEA (2007)
2 – HISWG (1996)
3 – Norton and Michelson (1995). A higher rate of 3.7$g/m^2/yr$ was measured in the vicinity of Pier 62/63, but this was during construction activities (Norton 1996).

By comparison, along the Seattle waterfront, the estimated gross mass accumulation rate ranges from 0.1 to 1.8 $g/cm^2/yr$ and the net mass accumulation rate ranges from 0.1 to 0.72 $g/cm^2/yr$ (Norton and Michelsen 1995) (Table 2-4). Assuming a bulk density of 1.3 g/cm^3, the net accumulation rate ranged from 0.08 to 0.55 cm/yr, significantly lower than sedimentation rates in the EW.

The net sediment transport patterns in Elliott Bay, the EW and WW, and the Duwamish River have been estimated by McLaren and Ren (1994). The particle-size distributions measured for their study found 71 percent of the samples classified as mud or sandy mud (greater than 20 percent silt and clay content). Their analysis indicated there was a net southerly transport of mud into and within the EW. This is in agreement with the net southerly flow velocity approximately 1 meter off the bottom in the EW measured by Kurrus and Ebbesmeyer (1995).

2.3 Habitat and Biological Communities

2.3.1 Habitat

The EW is part of the Duwamish River estuary and Elliott Bay. Dredging and development have substantially altered nearshore environments in Elliott Bay and the Duwamish River estuary. The pre-settlement habitat was predominately an intertidal/shallow subtidal mudflat. Of the pre-settlement habitat in the Duwamish River estuary, most (98 percent) of the approximately 5.14 square kilometers (km^2) of tidal marsh and 5.9 km^2 of flats and shallows, and all of about 5 km^2 of tidal wetland, have been either filled or dredged (Blomberg et al. 1988). Currently there is no natural shoreline in the EW. The remaining aquatic habitats found in the EW are intertidal and subtidal bottom, and water column habitats.

The majority of the EW shoreline is composed of riprap, pier aprons, or sheet piling (Tanner 1991). The shoreline of the EW is approximately 16,000 linear feet (excluding Slip 27 and Slip 36). Sixty-one percent of the shoreline is covered by pier aprons with engineered riprap slopes, 30 percent of the shoreline is covered with armored riprap with no pier apron structure, and the remaining shoreline is predominately characterized as bulkhead (9 percent). The shoreline within Slip 27 and Slip 36 is predominately armored riprap slope with limited pier structures.

Shoreline armoring is usually present at the top of the intertidal zone, but a few areas of sloping mud and sandflats can exist below (Battelle et al. 2001). However, due to the shoreline armoring, these intertidal flats are isolated from each other and this isolation degrades the habitat quality of these flats (Battelle et al. 2001). In addition, overwater structures, which are common throughout the EW, shade shallow and intertidal habitats, alter microclimates, and inhibit growth of plant communities, thus further degrading nearshore habitats for native fauna (Battelle et al. 2001). The standard concrete container aprons in the EW are 100 feet deep from the outer edge to the inner bulkhead at +9 feet MLLW. Vertical bulkheads are usually present above +9 feet MLLW due to Washington Department of Fish and Wildlife (WDFW) requirements limiting their intertidal range. Below the bulkhead is an engineered riprap slope (1H:3 or 4V) to approximately -50 feet MLLW (with some areas going to -40 feet MLLW).

An analysis of the available bathymetric data was conducted in order to identify potential areas of intertidal habitat (Figure 2-11A and 2-11B). In addition, the intertidal habitat areas within the EW identified by the U.S. Fish and Wildlife Service (USFWS; 2000) were identified and compared to the bathymetric results. In the area north of the Spokane Street Bridge, the bathymetric results and the USFWS areas generally agreed (Figure 2-11A and 2-11B). In the area south of the Spokane Street Bridge, no current bathymetric data is available so only the areas identified by USFWS are presented (Figure 2-11A). Available bathymetric data suggest that there is limited intertidal habitat in the EW.

2.3.2 Benthic Invertebrates

Benthic invertebrate species are important components of the EW ecosystem because they serve as a major food resource for commercially and recreationally important fish and wildlife, and because they are active in critical nutrient cycling. In general, key physical factors that may influence the distribution and abundance of benthic invertebrates in the EW are salinity, duration of exposure to air or heat (i.e., tidal elevation), substrate composition, organic carbon content, wave and current magnitude, and frequency of disturbance (e.g., flooding, propeller wash, and anchor drag). Limited sampling of the benthic invertebrate community of the Duwamish River estuary has been conducted, and few samples have been located in the EW (Table 2-5). Information from surveys conducted north of Kellogg Island and in Elliott Bay provides a general description of the invertebrates potentially present in the EW because these areas are characterized by more marine conditions that are typical in the EW.

Table 2-5
Summary of Studies Assessing the BenthicCommunity in the East Waterway

Study	Year Completed	EW Location	Sampling Period	Equipment Type	Targeted Organisms
EW fish tissue sampling (Windward 2006a)	2005	throughout the EW	July 20, 2005	otter trawl	crabs
Epibenthic species assessment (Taylor et al. 1999)	1999	Slip 27		epibenthic suction pump	epibenthic invertebrates

RM – river mile

The sediments in the EW are predominantly fine-grained with low TOC (1 to 2 percent). Existing EW epibenthic invertebrate and infauna data are presented in Section 2.3.2.1, while relevant supporting invertebrate information from the northern portion of the Duwamish Waterway and Elliott Bay are discussed in Section 2.3.2.2.

2.3.2.1 Existing East Waterway Epibenthic Invertebrates and Infauna Data

The majority of the EW shoreline is composed of riprap, pier aprons, or sheet piling (Tanner 1991). These hard surfaces support populations of encrusting organisms such as barnacles, and burrowing organisms such as shipworms on wooden structures (Leon 1980).

Taylor et al. (1999) conducted a study of epibenthic invertebrates near Slip 27 in the EW as part of a juvenile salmonid prey assessment in the lower 2 miles (3.2 kilometers [km]) of the Duwamish River estuary and at the northern shore of Elliott Bay (Figure 2-12). Sampling was conducted at three locations between 0 and -2 feet (-0.6 meters) MLLW using an epibenthic suction pump, one of which was located in Slip 27 in the EW. The study only provides a summary list of taxa identified at the three epibenthic survey locations (Table 2-6). The dominant species at Slip 27 were harpacticoid copepods including *Harpacticus uniremis*, *Tisbe* spp, and *Dactylopusia* sp. Other abundant crustaceans were gammarid amphipods such as *Paracalliopeilla pratti*. The highest epibenthic invertebrate density was also observed at Slip 27. Most of the 110 invertebrate taxa collected at the three locations were potential fish prey species. The most diverse taxonomic groups were harpacticoids with 62 taxa and gammarids with 18 taxa.

Table 2-6
Benthic Invertebrate Species Collected by Taylor et al. (1999)

Taxa			
Cnidaria	**Harpacticoida**		**Tanaidacea**
Anthozoa	*Amphiascoides* sp. A	Thalestridae spp.	Tanaidacea
Platyhelminthes	*Bulbamphiascus* sp.	*Dactylopusia* sp.	**Gammaridae**
Turbellaria	*Robertsonia* cf. *knoxi*	*Dactylopusia crassipes*	Anisogammaridae juveniles
Nematoda	Ectinosomatidae	*Datrylopusia tisboides*	*Eogammarus confervicolus*
Annelida	*Harpacticus arcticus*	*Dactylopusia paratisboides*	*Ampithoe* sp.
Polychaeta	*Harpacticus compressus*	*Dactylopusia glacialis*	*Aoroides* sp.
Mollusca	*Harpacticus obscurus* group	*Dactylopusia vulgaris*	*Capelliopius* sp.
Gastropoda juveniles	*Harpacticus spinulosus*	*Diarthrodes* spp.	*Paracallipiella pratti*
Nudibranchia	*Harpacticus uniremis*	*Idomene* sp.	*Corophium* spp.
Bivalvia juveniles	*Harpacticus* sp. A	*Paradactylopodia* spp.	*Hyale* sp.
Acarina	*Harpacticus* sp.	*Parathalestris* spp.	*Gammaropsis* sp.
Halacaridae	*Harpacticus* copepodids	*Rhynchothalestris helgolandica*	*Ischyrocerus sp.*
Calanoida	*Zaus* spp.	*Tisbe* spp	Melitidae
Pseudodiaptomus marinum	*Huntemannia jadensis*	*Scutellidium* spp.	Oedicerotidae
Stephos spp.	Laophontidae spp.	**Copepoda**	*Photis* sp.
Harpacticoida	*Echinolaophonte* sp.	*Hemicyclops* sp.	Pleustidae spp.
Ameira spp	*Heterolaophonte discophora*	Ergasilidae	*Pleusirus secorrus*
Ancorabolidae	*Heterolaophonte longisetigera*	Cyclopoida	*Sympleustes* sp.
Leimia vaga	*Heterolaophonte harmondi*	**Ostracoda**	*Paramoera* sp.
Mesochra spp	*Laophonte cornuta*	Podocopa	*Pontogeneia* cf. *rostrata*
Cletodidae spp	*Laophonte elongate*	**Thoracica**	**Caprellidae**
Acrenhydrosoma sp	*Paralaophonte* sp.	Unidentified nauplii	*Caprella* sp.
Enhydrosoma spp	*Paralaophonte pacifica*	Unidentified cyprids	**Decapoda**
Amonardia perturbata	*Paralaophonte perplexa*	**Cumacea**	Unidentified larvae
Amonardia normani	*Pseudonychocamptus* spp.	*Diastylis santamariensis*	Caridea
Disaccus sp.	*Longipedia* sp.	*Nippoleucon hinumensis*	*Upogebia pugettensis*
Diosaccus spinatus	*Normanella* sp.	*Cumella vulgaris*	**Insecta**
Amphiascopis cinctus	*Parastenhelia spinosa*	**Isopoda**	Chironomidae
Amphiascus spp.	Peltidiidae	*Gnorimosphaeroma oregonense*	Unidentified larvae
Stenhelia spp.	*Tachidius discipes*	*Munna* sp.	
Typhlamphiascus sp.	*Tachidius traingularis*	*Munnogonium* sp.	
Amphiascoides spp.	Tegastidae	*Leptochelia savignyi*	

Very limited information exists on the presence of larger invertebrates in the EW. The only survey documenting larger invertebrates in the EW was done in 2005 using trawls (Windward 2006a) for the purpose of collecting tissue for a bioaccumulation study. The larger epibenthic invertebrates identified in this survey include crab, shrimp, sea stars, anemones, and squids (Table 2-7) (Windward 2006a). Echinoderms are surface detrital- or filter-feeding organisms, whereas anemone, crab, and shrimp are predators and/or scavengers.

Table 2-7
Invertebrate Species Collected Using Trawls and Traps in the East Waterway

Common Name	Scientific Name
Graceful or slender crab	*Cancer gracilis*
Red rock crab	*Cancer productus*
Coonstripe or dock shrimp	*Pandalus danae*
Nudibranch	not documented
Anemone	not documented
Sunflower sea star	*Pycnopodia helianthoides*
Squid	not documented

2.3.2.2 Relevant Supporting Invertebrate Information

Benthic invertebrate information from the northern portion of the Duwamish River estuary and Elliott Bay may provide useful information on benthic invertebrate communities that may be present in the EW.

The benthic communities in the northern portion of the Duwamish River estuary near and downstream of Kellogg Island are generally dominated by annelids, crustaceans, and mollusks (Windward 2005a; Cordell et al. 2001; Williams 1990; Leon 1980). Common intertidal annelids included the subsurface deposit feeders from the *Capitella capitata* complex, the filter feeder *Manayunkia aestuarina*, the surface detrital feeder *Pygospio elegans,* and oligochaetes. Community membership shifts in the subtidal zone, such that the most common annelids are the deposit feeder *Aphelochaeta* cf *glandaria,* the deposit feeder *Lumbrineris californiensis* (which may also ingest tiny organisms that are present in the sediment*)*, the surface deposit/detrital feeder *Scoletoma luti, Prionospio steenstrupi*, and oligochaetes. Common intertidal crustaceans included *Americorophium* and *Grandidierella japonica,* which feed on detrital material on the sediment surface or in the water column (Windward 2005a). The amphipod *Anisogammarus* sp. was among the common crustaceans in subtidal habitats (Leon 1980). Very small invertebrates (meiofauna) in intertidal habitats were generally dominated by nematodes and epibenthic harpacticoid copepods (Cordell et al. 2001). The subtidal epibenthos was dominated by nematodes, oligochaetes, small harpacticoids, and cumaceans (Williams 1990). Mollusks were not common in intertidal habitats. Common bivalves in subtidal habitats included the surface deposit feeders *Axinopsida serricata, Parvilucina tenuisculpta*, and *Macoma* sp. (Windward 2005a). The most common gastropod was *Alvania compacta*.

Numerous species have been reported for Elliott Bay from a wide range of taxa including polychaetes, crustaceans, mollusks, echinoderms, nemerteans, and cnidarians. A large survey conducted in Puget Sound provides relevant information on the benthic invertebrates present in both the outer bay and along the shoreline of Elliott Bay (NOAA and Ecology 2000). These data will be relevant to the EW when collected from locations with similar water depths, substrates, and salinities.

The benthic communities in the outer portion of the bay were generally dominated by polychaete worms such as the surface deposit/detrital feeders *Prionospio steenstrupii* and *Dipolydora socialis* and the suspension feeder *Spiochaetopterus costarum*. In some areas, *Axinopsida serricata,* a small surface deposit-feeding clam, were present in high abundances. Other common bivalves included the suspended detrital feeder *Nemocardium contifilosum* and surface deposit feeder *Parvilucina tenuisculpta*. Crustaceans common in the outer deep-water locations included the surface detrital feeders *Euphilomedes producta*, *Euphilomedes carcharodonta*, and *Eudorellopsis gracilis*. The benthic invertebrates present along the shoreline of Elliott Bay were similar to those taxa found in the outer bay and included polychaetes, bivalves, and crustaceans. In addition to these benthic invertebrates, several other bivalve and polychaete species were abundant. The mollusks *Alvania compacta*, *Tellina modesta*, and *Nutricola lordi*, and the polychaetes *Levinsenia gracilis*, *Lumbrinereis californiensis*, *Scoletoma luti*, and *Chaetozone* nr *setosa* were common in nearshore areas of Elliott Bay. Echinoderms, such as the brittlestar *Amphiodia* sp., were common in a few shoreline locations. Larger predatory and scavenging crustaceans reported from Elliott Bay included Dungeness crab (*Cancer magister*), rock crab (*Cancer* sp.), sidestripe shrimp (*Pandalopsis dispar*), spot shrimp (*Pandalus* *platyceros*), humpback shrimp (*Pandalus goniurus*), and pink shrimp (*Pandalus* sp.) (Dinnel et al. 1986).

Sediment profile imaging (SPI), sediment toxicity testing, and benthic community sampling were conducted by Ecology in the Lower Duwamish River in 2006 (Ecology 2007a) to assess the feasibility of the SPI technology to predict contaminant impacts to benthic communities and habitats, in lieu of more direct testing. Information from stations downstream of Kellogg Island was evaluated to provide an indication of benthic communities that may be present in the EW.

Benthic organisms were abundant and relatively diverse in the seven samples evaluated. The total number of taxa present ranged from 55 to 83 taxa; total abundance ranged from 963 to 1,946 individuals per sample. Polychaete worms were typically the most abundant organisms, followed by mollusks, and then crustaceans. Dominant taxa were similar to those reported in previous studies in the LDW and included the polychaete *Aphelochaeta glandaria*; the mollusks *Axinopsida serricata*, *Macoma carlottensis*, *Nutricola lordi*, and *Parvilucina tenuisculpta*; and the crustacean *Euphilomedes carcharodonta*.

2.3.3 Fish

2.3.3.1 East Waterway Data

Four sampling events conducted since 2000 have collected fish within the EW. The studies are summarized in Table 2-8. The most recent sampling event was associated with the sampling of fish tissue within the EW and was conducted by trawling throughout the waterway. The other three studies were conducted in order to monitor (Taylor Associates 2005; Shannon 2006) and collect (Windward 2002a) juvenile salmonids within the EW, and were conducted by beach seining.

Table 2-8
Summary of Studies Assessing the Fish Community in the East Waterway

Study	Year Completed	EW Location	Sampling Period	Equipment Type	No. of Locations Sampled
EW fish tissue sampling (Windward 2006a)	2005	throughout the EW	July 20, 2005	otter trawl	1 in the EW

Study	Year Completed	EW Location	Sampling Period	Equipment Type	No. of Locations Sampled
EW Phase 1 Removal Action Chinook salmon and bull trout monitoring (Taylor Associates 2005)	2004	head of the EW and Slip 27	February 15 to March 1, 2004	beach seine	2 in the EW 1 at RM 5
East Waterway channel deepening project, juvenile salmonid and epibenthic prey assessment (Shannon 2006)	2003	head of the EW and Slip 27	April to August 1998, 2000, and 2003 (biweekly)	beach seine	6 (2 in the EW)
East Waterway juvenile Chinook salmon tissue chemistry results (Windward 2002a)	2002	Slip 27	June 2002	beach seine	1 in the EW

RM – river mile

The most extensive surveys of fish populations in the EW have been beach seine sampling conducted for the Port by Taylor Associates. Taylor Associates conducted beach seines at the head and mouth of Slip 27 in 1998, 2000, 2002, and 2003. The head of the EW was also sampled in 2000. Sampling was conducted April through August 1998, April through October 2000 and 2002, and February through April 2003 (Shannon 2006). Additional sampling was conducted February 15 through March 2, 2004, at Slip 27 and nearby locations (Taylor Associates 2005) (Figure 2-12). Twenty-two different species of fish were captured in these studies. The top three numerically dominant species at the Slip 27 station were chum salmon, Chinook salmon, and shiner surfperch. Together, these species represented 98 percent of the total catch at Slip 27. Additional species commonly captured in beach seines included coho salmon, sculpin species, Pacific herring, surf smelt, and three-spine stickleback.

One day of trawl sampling throughout the EW was conducted in July 2005 to capture fish for tissue sampling (Windward 2006a). Seventeen different species of fish were captured in this event. English sole was the most abundant species and made up more than 50 percent of the total catch. Pacific tomcod, rock sole, sand sole, and shiner surfperch were also abundant with catch-per-unit-effort (CPUE) greater than or equal to 3 individuals per trawl. Sanddab, Pacific staghorn sculpin, starry flounder, and herring were common with CPUE greater than 1 individual per trawl. Fish species collected in the EW are summarized in Table 2-9.

Table 2-9
Fish Species Collected in the East Waterway

Common Name	Scientific Name	Environment	Habitat	E/H Citation
American shad	*Alosa sapidissima*	anadromous	bays, estuaries, freshwater	1
Bay pipefish	*Syngnathus grisiolineatum*	marine	demersal (associated with eel grass in the intertidal areas)	2
Brown rockfish	*Sebastes auriculatus*	marine	shallow, low-profile, rocky reefs	1
Chinook salmon	*Oncorhynchus tshawytscha*	anadromous	benthopelagic	3
Chum salmon	*Oncorhynchus keta*	anadromous	benthopelagic	3
Coho salmon	*Oncorhynchus kisutch*	anadromous	benthopelagic	3
Cresent gunnel	*Pholis laeta*	marine (estuary)	demersal (intertidal areas, under rocks)	4
Cutthroat trout	*Oncorhynchus clarki*	anadromous	benthopelagic	5
English sole	*Parophrys vetulus*	marine (estuary)	benthic (sand and mud bottoms)	6
Flathead sole	*Hippoglossoides elassodon*	marine	benthic (soft mud bottom, adults below 180 meters)	4
Kelp perch	*Brachyistius frenatus*	marine	among fronds in kelp beds from near surface to depths of about 30 meters	1
Pacific herring	*Clupea pallasi*	marine	benthopelagic (coastal, first year in bays)	7
Pacific sand dab	*Citharichthys sordidus*	marine	over soft sand bottoms	4
Pacific sandlance	*Ammodytes hexapterus*	marine (brackish)	benthopelagic (surface or burrowed in sand)	4
Pacific staghorn sculpin	*Leptocottus armatus*	marine (lower estuary, offshore)	benthic (sandy bottom)	4
Pacific tomcod	*Microgadus proximus*	marine (brackish)	benthic (over sand)	8
Penpoint gunnel	*Apodichthys flavidus*	marine (estuary)	demersal (intertidal tide pools)	4
Pink salmon	*Oncorhynchus gorbuscha*	anadromous	benthopelagic	3
River lamprey	*Lampetra ayresi*	anadromous	demersal	7
Rock sole	*Lepidopsetta bilineata*	marine (estuary)	benthic (more pebbly bottom than most other flatfish)	4

Common Name	Scientific Name	Environment	Habitat	E/H Citation
Rockfish	*Sebastes* spp.	marine	demersal (near structure)	9
Saddleback gunnel	*Pholis ornata*	marine (estuary)	demersal (sandy bottom)	4
Sailfin sculpin	*Nautichthys oculofasciatus*	marine	over rocks from inshore to depths of 110 meters, often with algae	1
Sand sole	*Psettichthys melanostictus*	marine, estuary	benthic (sandy bottom)	7
Shiner surfperch	*Cymatogaster aggregata*	marine (estuary)	demersal (in shallow water; around eelgrass beds, piers, and piles; commonly in bays and quiet back waters)	4
Slendersole	*Lyopsetta exilis*	marine	benthic (greater than 200 meters in depth)	4
Snake prickleback	*Lumpenus saggita*	marine	benthopelagic (shallow bays and offshore waters)	4
Spiny dogfish	*Squalus acanthias*	marine	benthopelagic	10
Starry flounder	*Platichthys stellatus*	marine (estuary, brackish)	benthic	5
Steelhead	*Oncorhynchus mykiss*	anadromous	benthopelagic	11
Striped seaperch	*Embiotoca lateralis*	marine	demersal	4
Surf smelt	*Hypomesus pretiosus*	marine (brackish)	benthopelagic	5
Three-spine stickleback	*Gasterosteus aculeatus*	marine, anadromous	benthopelagic (in/near vegetation)	12
Whitespotted greenling	*Hexagrammos stelleri*	marine (intertidal)	demersal (nearshore near rocks, piles, and eelgrass beds)	8

E/H – Environment/Habitat

Citations			
1.	Gilbert and Williams (2002)	7.	Hart (1973)
2.	Dawson (1985)	8.	Cohen et al. (1990)
3.	Groot and Margolis (1998)	9.	Lamb and Edgel (1986)
4.	Eschmeyer et al. (1983)	10.	Cox and Francis (1997)
5.	Morrow (1980)	11.	Gall and Crandell (1992)
6.	Clemens and Wilbey (1961)	12.	Page and Burr (1991)

2.3.3.1.1 Anadromous Salmonids – Pacific Salmon

Four species of Pacific salmon (Chinook, chum, coho, and pink) juveniles have been documented in the EW with juvenile chum and Chinook the most abundant salmonid species captured in Slip 27 (Taylor Associates 2004; Shannon 2006). Additionally, sockeye salmon have been found in the Duwamish River estuary

(Kerwin and Nelson 2000). These anadromous fish use the estuary for rearing and as a migration corridor for adults and juveniles. Among beneficial uses identified for the EW, habitat for outmigrating juvenile salmonids is one of the most important.

Salmon found in the Duwamish River estuary spawn mainly in the middle reaches of the Green River and its tributaries (Grette and Salo 1986). Juvenile salmon outmigrate through the EW; however, no specific information is available on their residence time in the EW.

Adult salmon generally do not feed to any significant extent once they enter the estuary on their upstream spawning migrations. The peak timing of outmigration for juveniles of all species generally corresponds with March-to-June high flows. Peak outmigration usually lasts from mid-July through early August for most species (Warner and Fritz 1995; Nelson et al. 2004). In the EW, juvenile salmon were caught in seine nets from April through September, with peak numbers occurring from April through July (Shannon 2006). During this time, juveniles have completed their physiological adaptation to higher salinity and they use the estuary to feed on epibenthic and neritic food sources (Salo 1991 and citations therein).

2.3.3.1.2 Non-anadromous Fish

Based on beach seine data, striped perch, bay pipefish, three-spine stickleback, shiner surfperch, and Pacific staghorn sculpin were the most abundant non-anadromous fish species captured in the EW (Shannon 2006). In the EW, English sole were the most abundant species in recent trawl samples, but were absent from beach seine samples (Shannon 2006; Windward 2006b).

2.3.3.2 Relevant Supporting Fish Population Data

Fourteen studies were identified documenting fish species from nearby Duwamish River estuary locations (Table 2-10). The majority of these studies used active capture techniques such as beach seining and otter trawls. These techniques preferentially capture less mobile species and are not effective for rough substrates or near structures. However, passive techniques employed in Duwamish River estuary sampling that included gill nets (Weitkamp and Campbell 1980), shrimp traps, and crab traps (Windward 2005a, 2006b) yielded no additional fish species beyond those observed using beach seines or otter trawls, indicating that the trawl data are generally reflective of the Duwamish River estuary fish community. Five of the 14 studies were conducted prior to 1986 when the Renton Wastewater Treatment Plant outfall was diverted from the Green River to Central Puget Sound. Because the diversion of the wastewater treatment plant effluent decreased summer flows by as much as 25 percent (approximately 56 cfs [1.6 cubic meters per second {m^3/sec}]), the diversity and abundance of fish in the Duwamish River estuary may have changed since these studies were conducted.

Table 2-10
Summary of Studies Assessing the Fish Community in the Vicinity of the East Waterway

Study (Reference)	Year Completed	Location	Sampling Period	Equipment Type	No. of Locations Sampled
LDW RI Phase 2 fish and crab tissue collection and chemical analyses (Windward 2005a, 2006b)	2005	4 areas throughout the Duwamish River estuary	August and September 2004 August and September 2005	otter trawl, beach seine, shrimp traps, crab traps	24
Habitat utilization, migration timing, growth, and diet of juvenile Chinook salmon in the Duwamish River and estuary (Ruggerone et al. 2006)	2005	throughout the Duwamish River estuary	February to July 2005	beach seine	14
Fish assemblages and patterns of juvenile Chinook salmon abundance, diet, and growth at restored sites in the Duwamish River (Cordell et al. 2006)	2005	restoration and reference sites throughout the Duwamish River estuary	February to July 2005	enclosure net	6
Phase 2 juvenile Chinook salmon collection and chemical analyses (Windward 2004)	2003	lower Duwamish Waterway (RM 0.1 to RM 0.9), and mid-Duwamish waterway (RM 1.4 to RM 2.9)	May (2 days) and June (3 days) 2003	beach seine	8
East Waterway channel deepening project, juvenile salmonid and epibenthic prey assessment (Shannon 2006)	2003	Kellogg Island and Harbor Island area	April to August 1998, 2000, and 2003 (biweekly)	beach seine	6 (2 in EW)
East Waterway juvenile Chinook salmon tissue chemistry results (Windward 2002a)	2002	Kellogg Island	June 2002	beach seine	1 in EW
East Waterway sediment operable unit, Harbor Island Superfund site – Assessing human health risks from ingestion of seafood (Robertson 2004)	1998	Harbor Island to south side of 1st Avenue S. Bridge	single visit to each site	SCUBA	8
PSAMP (West et al. 2001)	1997	Kellogg Island	May 1992 to 1997	otter trawl	1
Distribution and growth of Green River Chinook salmon and chum salmon outmigrants in the Duwamish River estuary (Warner and Fritz 1995)	1994	Kellogg Island to above rapids	February to April (biweekly); April to May (weekly); May to September (biweekly) 1994	beach seine	9
Distribution and food habits of juvenile	1980	Kellogg Island and at S.	April to June (weekly); July	purse seine	2

Study (Reference)	Year Completed	Location	Sampling Period	Equipment Type	No. of Locations Sampled
salmonids in the Duwamish River estuary (Meyer et al. 1981)		Kenyon Street (RM 3.0)	(biweekly) 1980	beach seine	2
Port of Seattle T-107 fisheries study (Weitkamp and Campbell 1980)	1978	Kellogg Island and adjacent channel	October 1977 to February, July, and August 1978 (monthly); more frequently from March to June 1978	purse seine	5
				beach seine	5
		South end of Kellogg Island	October 1977 to August 1978 (quarterly)	gill net (surface and bottom)	1
Chemical contaminants and biological abnormalities in central and southern Puget Sound (Malins et al. 1980)	1979	South end of Harbor Island	quarterly	7.5-meter otter trawl	1 in Duwamish River estuary
Ecological survey of demersal fishes in the Duwamish River and at West Point (Miller et al. 1975, 1977a)	1974 and 1975	WW to the upper turning basin	1974 and 1975 (monthly)	5-meter otter trawl	8 (7 in Duwamish River estuary)
Fishes of the Green-Duwamish River (Matsuda et al. 1968)	1966	upper and lower Duwamish River estuary (exact locations unknown)	1964 to 1966 (weekly)	beach seine	2

PSAMP – Puget Sound Ambient Monitoring Program
RM – river mile

Of surveys conducted in the greater Duwamish River estuary, 53 resident and non-resident fish species were captured during recent Phase 2 Duwamish River estuary RI sampling (Windward 2004, 2005a, 2006b). In earlier studies, Warner and Fritz (1995) recorded 33 resident and seasonal fish species, Miller et al. (1975, 1977a) observed a total of 29 species, and Matsuda et al. (1968) recorded a total of 28 species. In these studies, shiner surfperch, snake prickleback, Pacific sandlance, Pacific staghorn sculpin, longfin smelt, English sole, and starry flounder were particularly abundant, as were juvenile Chinook, chum, and coho salmon. Fish numerical abundance reaches its maximum in late summer to early fall and is generally lowest in winter (Miller et al. 1977a; Dexter et al. 1981). Based on otter trawl data, species richness was shown to follow a similar trend but did not vary greatly with season (Miller et al. 1977a).

2.3.3.2.1 .Anadromous Salmonids – Pacific Salmon

Five species of Pacific salmon (Chinook, chum, coho, pink, and sockeye) juveniles have been found in the Duwamish River estuary (Kerwin and Nelson 2000). These anadromous fish use the estuary for rearing and as a migration corridor for adults and juveniles. Salmon found in the Duwamish River estuary spawn mainly in the middle reaches of the Green River and its tributaries (Grette and Salo 1986).

Adult salmon generally do not feed to any significant extent once they enter the estuary on their upstream spawning migrations. The peak timing of outmigration for juveniles of all species generally corresponds with March-to-June high flows. Outmigration usually lasts through mid-July to early August for most species (Warner and Fritz 1995; Nelson et al. 2004). During this time, juveniles use the estuary to feed and begin their physiological adaptation to higher salinity.

2.3.3.3 Non-salmonid Fishes

Of non-salmonid fishes, shiner surfperch, longfin smelt, and Pacific herring are seasonally abundant in the Duwamish River estuary. Pacific herring, Pacific sandlance, surf smelt, and longfin smelt were encountered infrequently in recent beach seine and trawling attempts, but occasionally occurred in large numbers (Shannon 2006; Windward 2005a, 2006b). Three-spine stickleback were abundant in monthly beach seine samples at both the upper turning basin and Kellogg Island sampling locations in June through September, but were uncommon in February through May samples (Shannon 2006). Historical otter trawl data show peaks in longfin smelt abundance in summer, fall, and early winter (Miller et al. 1977a). Miller et al. (1977a) suggest that the fall-winter peak (80- to 115-mm fish) may represent part of a spawning run and that the late summer peak (30- to 50-mm fish) may represent downstream migrant young of the year. Pacific herring were reported in purse seine samples throughout the year (Weitkamp and Campbell 1980), were present in trawl samples in August and September (Windward 2005a, 2006b), and were reported in beach seine samples in May, June, July, November, and December (Weitkamp and Campbell 1980; Shannon 2006). In Puget Sound, three-spine stickleback and surf smelt feed on both epibenthic and pelagic invertebrates. Epibenthic invertebrates constitute a slight majority of their diet (Miller et al. 1977b; Fresh et al. 1979). Pacific herring and longfin smelt generally feed on pelagic invertebrates but also ingest epibenthic invertebrates to a lesser extent (Miller et al. 1977b; Fresh et al. 1979).

Shiner surfperch abundance peaks in summer during the bearing of young (Miller et al. 1975). Taylor Associates recorded abundant shiner surfperch in May through October with peak abundance in July (Shannon 2006). Shiner surfperch are opportunistic omnivores, feeding on zooplankton, small crustaceans, algae, and detritus (Gordon 1965; Bane and Robinson 1970), as well as polychaetes, mollusks, and benthic organisms (Fresh et al. 1979; Wingert et al. 1979; Miller et al. 1977b).

In Puget Sound, English sole are typically found on soft sand or mud bottoms at depths of 25 to 50 meters (Smith 1936). Juvenile English sole (those less than 110 mm) ingest annelids (Smith 1936), copepods, amphipods, and mollusks (Holland 1954). Adult English sole studied in Puget Sound ingest clams, clam siphons, small mollusks, marine worms, small crabs, and small shrimps (Wingert et al. 1979; Fresh et al. 1979). It has been suggested that English sole exist in discrete populations with some site fidelity (Day 1976). Day (1976) conducted a tagging study in Puget Sound that suggested that fish captured and released at the same location remained within an area approximately equal to 5 to 10 km^2. In addition, catch rates for fish captured and released dozens of miles from their original capture site were higher at their original capture site than at the release site or other sites sampled.

English sole migrate seasonally to their spawning grounds in Puget Sound in winter (Forrester 1969) and typically spawn in Puget Sound during February and March (Smith 1936). In central Puget Sound, adult populations of English sole spawn in Elliott Bay and Port Gardner, but disperse after spawning (Pallson 2001). Angell et al. (1975; as cited in King County 1999a) reported off-shore migration in winter and spring of all age groups of central Puget Sound English sole from Meadow Point to Carkeek Park (northwest Seattle) at depths of 3 to 30 meters. Juveniles (10 to 25 mm standard length), not all completely metamorphosed, migrated from spawning areas to nursery grounds as pelagic fish and moved to benthic habitats in December or May and June (King County 1999a). Data from Malins et al. (1982) show that during the winter and spring, greater than 50 percent of the English sole in the Duwamish River estuary are juveniles (less than 150 mm).

Starry flounder are also noted to migrate seasonally between very shallow water and in estuaries during the summer, moving into deeper water in the winter (Morrow 1980). Young and adult starry flounder are tolerant of freshwater and move up rivers as much as 120 km (Morrow 1980). Because they have a larger mouth, starry flounder are capable of consuming somewhat larger organisms than English sole ingest, although their diets greatly overlap. Starry flounder in Puget Sound were found to ingest primarily benthic invertebrates, with bivalves, amphipods, and shrimp serving as important prey items (Fresh et al. 1979).

2.3.4 Birds

2.3.4.1 East Waterway Bird Population Data

There is relatively little information on bird populations that is specific to the EW. The EW contains very little riparian habitat and limited intertidal habitat (Section 2.3.1), which will limit the presence of bird species that depend on those conditions. The aquatic habitat and the presence of fish will attract piscivorous species.

A brief description of the species that have been observed in the EW is provided here. The lists of observed species are based on informal observations on the waterway are not intended to be exhaustive. No studies of bird populations have been conducted in the EW. The bird species are organized into five groups based on habitat and feeding preferences.

Passerine/upland Birds:

- Observed species: American crows, common pigeon, European starling, house sparrow, belted kingfisher
- These birds are generally associated with upland and sometimes freshwater habitats (Canning et al. 1979). Therefore, these species will make limited use of the EW.

Raptors:

- Observed species: osprey, bald eagle
- Cordell et al. (1994) report osprey using Kellogg Island and the restored turning basin sites. An osprey nest is located on a utility pole near T-105 (Luxon 2000). Five osprey nest boxes are located on top of light poles on Port properties within the EW and Elliott Bay, with two nests located within the EW on Terminal 104 (T-104) and T-18 (Blomberg 2007).
- There are five bald eagle nests within 8 km of the EW that were occupied in 1999 (King County 1999a). The closest nest is located in West Seattle, within 1.6 km of the EW. One or two pairs of resident eagles may be found in the EW vicinity during the summer (King County 1999a). Overwintering migrant eagles are routinely observed in the vicinity of the EW from the beginning of October through late March.

Shorebirds/waders:

- Observed species: great blue heron
- A colony of up to 37 active great blue heron nests was located in West Seattle a few hundred meters from Kellogg Island until 1999, but no successful nesting occurred in 2000 or 2001 (Norman 2002). Other

colonies in the vicinity of the EW are located about 14.5 km south in Renton and 12 km northwest near Salmon Bay.

Waterfowl:

- Observed species: common and red-breasted merganser, goldeneye, Canada goose, buffleheads
- Bufflehead, Barrow's goldeneye, and common and red-breasted mergansers are species that dive deeper than the other diving ducks and eat benthic invertebrates and fish; they are more likely to use the EW for foraging than other diving duck species.

Seabirds:

- Observed species: cormorants, grebes (especially western), pigeon guillemont, gulls (especially glaucous-winged)
- Wintering cormorants use the EW from November to May, with large numbers present from December to April (Canning et al. 1979; Cordell et al. 1996)
- Pigeon guillemont nests have been observed under the T-18 piers (Hotchkiss 2007)

The available data for the LDW is presented in the following section. There is more information on the bird populations of the Duwamish River estuary, which is summarized in the following subsections. The relatively large home ranges associated with many bird species make the Duwamish River estuary data relevant to the EW. The limited shallow water and intertidal habitat in the EW limits the presence of species that rely on those specific habitats.

2.3.4.2 Other Relevant Information

Surveys of the bird community of the Duwamish River estuary have been primarily conducted upstream of the EW where there is a greater diversity of habitat. The aquatic and semi-aquatic habitats of the Duwamish River estuary support a diversity of bird species. Formal studies, field observations, and anecdotal reports indicate that up to 87 species of birds utilize the Duwamish River estuary during at least part of the year to feed, rest, or reproduce. This section provides an overview of these bird species and focuses on those that utilize habitats present in the EW. The bird species associated with the Duwamish River estuary are presented in Table 2-11. These birds can be grouped as follows:

- Passerine/upland birds
- Raptors
- Shorebirds/waders
- Waterfowl
- Seabirds

Canning et al. (1979) conducted extensive surveys of the birds of Kellogg Island, as well as occasional surveys of the LDW from Turning Basin 3 (RM 4.6) to the southern end of Harbor Island (RM 0) from September 1977 to July 1978. They recorded a total of 70 species: 26 passerine/upland birds, 3 raptors, 11 shorebirds/waders, 17 waterfowl, and 13 seabirds. They reported that Kellogg Island had a much higher diversity of birds than the rest of the LDW due to its seclusion and greater variety of habitats. Kellogg Island, with its extensive intertidal habitat and upland foliage, is very distinct from the habitat characteristics of the EW; therefore, the Kellogg Island data is of limited use in characterizing EW bird populations.

Cordell et al. (1996, 1997, 1999, 2001) monitored bird populations monthly from 1993 to 2000 at four sites: the two sites closest to the EW were on Kellogg Island and at Terminal 105 (T-105). Two additional sites were located in Turning Basin 3. They recorded 80 species of birds: 34 passerine/upland birds, 7 raptors, 8 shorebirds/waders, 18 waterfowl, and 13 seabirds (Cordell et al. 2001)[3]. Diversity and abundance were highest at the Kellogg Island site, but upstream sites were also consistently used by a wide variety of birds. Birds were most abundant in the spring and least abundant in the summer. The following sections provide a brief summary of site usage by the various types of bird species in the Duwamish River estuary.

[3] Note that Cordell et al. (2001) classified bird species differently than this accounting and Table 2-8.

Table 2-11
Bird Species Using the Lower Duwamish Waterway

Common Name	Latin Name	Common Name	Latin Name
Passerine/Upland Species		**Raptors**	
Blackbird, red-winged	*Agelaius phoeniceus*	Eagle, bald	*Haliaeetus leucocephalus*
Bushtit, common	*Psaltriparus minimus*	Falcon, peregrine	*Falco peregrinus*
Chickadee, black-capped	*Poecile atricapillus*	Hawk, Cooper's	*Accipter cooperii*
Cowbird, brown-headed	*Molothrus ater*	Hawk, red-tailed	*Buteo jamaicensis*
Crow, northwestern	*Corvus corrinus*	Hawk, sharp-shinned	*Accipiter striatus*
Dove, rock	*Columba livia*	Hawk, Swainson's	*Buteo swainsoni*
Finch, house	*Carpodacus mexicanus*	Merlin	*Falco columbarius*
Flicker, northern	*Colaptes auratus*	Osprey	*Pandion haliaetus*
Goldfinch, American	*Spinus tristis*	**Waterfowl**	
Hummingbird, Anna's	*Calypte anna*	Bufflehead	*Bucephala albeola*
Junco, dark-eyed	*Junco hyemalis*	Canvasback	*Aythya valisineria*
Kingfisher, belted	*Ceryle alcyon*	Coot, American	*Fulica Americana*
Kinglet, ruby-crowned	*Regulus calendula*	Duck, domestic	*Anas domesticus*
Martin, purple	*Progne subis*	Gadwall	*Anas strepera*
Quail, California	*Spinus pinus*	Goldeneye, Barrow's	*Bucephala islandica*
Robin, American	*Lophortyx californicus*	Goldeneye, common	*Bucephala clangula*
Shrike, northern	*Turdus migratorius*	Goose, Aleutian	*Branta canadensis*
Siskin, pine	*Lanius excubitor*	Goose, cackling Canada	*Branta canadensis minima*
Sparrow, English (house)	*Passer domesticus*	Goose, Canada	*Branta canadensis*
Sparrow, fox	*Passerella iliaca*	Goose, domestic	*Branta domesticus*
Sparrow, golden-crowned	*Zonotrichia atricapilla*	Mallard	*Anas platyrhynchos*
Sparrow, savannah	*Passerculus sandwichensis*	Merganser, common	*Mergus merganser*
Sparrow, song	*Melospiza melodia*	Merganser, hooded	*Lophodytes cucullatus*
Sparrow, white-crowned	*Zonotrichia leucophrys*	Merganser, red-breasted	*Mergus serrator*
Starling, European	*Sturnus vulgaris*	Pintail, northern	*Anas acuta*
Swallow, barn	*Hirundo rustica*	Scoter, surf	*Melanitta perspicillata*
Swallow, cliff	*Petrochelidon pyrronota*	Shoveler	*Anas clypeata*
Swallow, tree	*Iridoprocne bicolor*	Teal, greenwinged	*Anas carolinensis*
Swallow, violet-green	*Tachycineta thalassina*	Wigeon, American	*Mareca Americana*
Thrush, Swainson's	*Hylocichla ustulata*	**Seabirds**	
Towhee, rufous-sided	*Pipilo erythrophthlamus*	Cormorant, double-crested	*Phalacrocorax auritus*
Warbler, orange-crowned	*Vermivora celata*	Cormorant, pelagic	*Phalacrocorax pelagicus*
Warbler, yellow-rumped	*Dendroica coronata*	Grebe, eared	*Podiceps capsicus*
Wren, Bewick's	*Thryomanes bewickii*	Grebe, horned	*Podiceps auritus*
Wren, house	*Troglodytes aedon*	Grebe, pied-billed	*Podilymbus podiceps*
Shorebirds/Waders		Grebe, red-necked	*Podiceps grisegena*
Dowitcher	*Limnodromus sp.*	Grebe, western	*Aechmophorus occidentalis*
Dunlin	*Erolia alpina*	Guillemot, pigeon	*Cepphus Columba*
Heron, great blue	*Ardea herodias*	Gull, glaucous-winged	*Larus glaucescens*
Heron, green	*Butorides virescens*	Gull, mew	*Larus canus*
Killdeer	*Charadrius vociferus*	Gull, ring-billed	*Larus delawarensis*
Sanderling	*Crocethia alba*	Loon, common	*Gavia immer*
Sandpiper, least	*Calidris minutilla*	Loon, Pacific	*Gavia Pacifica*
Sandpiper, spotted	*Actitis macularia*	Loon, red-throated	*Gavia stellata*
Sandpiper, western	*Calidris mauri*	Murre, common	*Uria aalge*
Yellowlegs, lesser	*Totanus flavipes*	Tern, Caspian	*Hydroprogne caspia*

2.3.4.3 Passerine/Upland Birds

Thirty-five species of passerine/upland birds have been documented in the Duwamish River estuary (Canning et al. 1979; Cordell et al. 1996, 1997, 1999, 2001). These birds are generally associated with upland and sometimes freshwater habitats (Canning et al. 1979). Therefore, these species are unlikely to be found in the EW.

2.3.4.4 Raptors

Eight raptor species have been reported to use the Duwamish River estuary (Cordell et al. 1996, 1997, 1999, 2001). The bald eagle is listed under ESA as a threatened species, but is currently under review for delisting. In Washington, it is also listed as a state threatened species (WDFW 2001).

The bald eagle is an opportunistic forager with site-specific food habits based on available prey species (Buehler 2000). Bald eagles consume dead and live fish, birds, and mammals extensively. In most regions, bald eagles seek out aquatic habitats for foraging and prefer fish (Buehler 2000). Spawned-out salmon are a particularly important food item for eagles in the Pacific Northwest, though not in the EW because returning salmon spawn farther upstream. Of 45 fish identified in a study of prey remains at the base of eagle nest trees throughout Puget Sound, eight were rockfish, 10 were starry flounder, and the remainder included cod, pollock, hake, cabezon, red Irish lord, sculpins, surfperch, salmon, plainfin midshipman, and channel catfish (Knight et al. 1990). Although eagles feed primarily on fish, waterfowl make up a portion of their diet during winter months. Eagles have been reported to kill western grebe in the Duwamish River during winter (Strand 1999, as cited in King County 1999a). Eagles have also been reported to prey on great blue heron chicks (Norman et al. 1989, as cited in King County 1999a).

Cooper's and sharp-shinned hawks have been observed to overwinter in the Duwamish River estuary. These relatively small raptors generally feed on birds up to the size of quail. They may rarely feed on aquatic birds (Canning et al. 1979; Cordell et al. 1999). Red-tailed hawks, a resident species commonly observed along grassland/woodland margins along the Duwamish River estuary, feed primarily on rodents but have been noted to pursue ducklings in the study area. Swainson's hawks and merlin are rare in the Duwamish River estuary and not likely to prey on associated aquatic species (Canning et al. 1979; Cordell et al. 1999).

Ospreys feed opportunistically, almost exclusively on live fish from fresh or salt water. Ospreys can penetrate only about 1 meter below the water surface; therefore, they generally catch only surface fish or those that frequent shallow flats and shorelines.

Reportedly, a female peregrine falcon recently attempted but failed to nest at the West Seattle Bridge and to mate with the male falcon inhabiting the Washington Mutual Tower in downtown Seattle (Anderson 2002). Peregrine falcons prey primarily on songbirds, shorebirds, waterfowl, and seabirds. The peregrine falcon is listed as a species of concern under ESA. WDFW recently downlisted the peregrine falcon from a state endangered species to a state sensitive species due to an increase in their number and distribution throughout the state (WDFW 2002).

2.3.4.5 Shorebirds/Waders

Eight species of shorebirds and wading birds have been documented in the Duwamish River estuary (Cordell et al. 1999), including green heron and great blue heron (Table 2-11). Of the heron species, great blue heron make up the only sizeable or consistent population.

The great blue heron is a semi-aquatic wading bird that has a range from the coasts of southeast Alaska and Northern British Columbia, through Canada and the United States, and south to Belize and Guatemala. The great blue heron is found primarily in natural wetlands and along riverbanks, but can also be found in brackish marshes, lagoons, lakes, and along ocean shores. They were the most abundant shore/wading bird recorded by Cordell et al. (1996) on the Duwamish River estuary, and are a year-round resident. Great blue heron nest in colonies of up to several hundred pairs, preferably on islands or wooded swamps (Butler 1992).

Great blue heron feed in shallow water primarily on small fish, such as juvenile salmonids, but they also take crustaceans, insects, amphibians, reptiles, and occasionally small mammals (Kushlan 1978; Butler 1992). Great blue heron hunt by sight and stalk or ambush their prey. They will also feed by probing, quickly moving their bills in and out of the water and substrate. Great blue heron feed on small fish that range in size from 8 to 33 cm (Kirkpatrick 1940; Alexander 1977; Hoffman 1978). Butler (1992) reports that shiner surfperch, which is frequently found in the EW is a major food source for female and hatchling great blue heron and may be important for juvenile survival.

The two most common shorebirds observed in the Duwamish River estuary are sandpipers and killdeer. These species rely on sand and mudflat habitats that are very rare in the EW. Varying numbers of these species are reported to frequent Kellogg Island from September through May. Most are thought to be migrants, though some overwintering may occur.

Limited shallow water and intertidal habitat (Figure 2-10) in the EW make it likely that shorebirds and wading birds will be less prevalent in the EW relative to the the LDW. An analysis of the spatial extent of shorebird habitat in the EW will be presented in the CSM and Data Gaps Report.

2.3.4.6 Waterfowl

Cordell et al. (2001) reported 18 species of waterfowl utilizing the Duwamish River estuary, including nine species of dabbling ducks. All species are migratory, though some non-migratory populations exist. In general, these birds overwinter in the Puget Sound area (and farther south) and migrate north in the summer. The dabbling ducks feed on aquatic plants, seeds, and grasses and to some extent small aquatic animals and insects. Feeding occurs primarily in shallow water and over intertidal mudflats. Occurrence in the EW is limited by lack of habitat.

Several species of diving ducks are reported to use the Duwamish River estuary Cordell et al. (2001). Species reported include canvasback, greater scaup, bufflehead, common and Barrow's goldeneye, and common, hooded, and red-breasted mergansers. These birds dive for small aquatic animals and plants. Canvasback feed primarily on plants, scaup on equal portions of plants and animals, and bufflehead and goldeneyes exclusively on aquatic animals and insects. Mergansers feed primarily on small fish.

A resident population of approximately 1,000 Canada geese resides in the vicinity of Lake Washington. The Duwamish population is thought to be a part of the Lake Washington population. Migratory Canada geese arrive in the Duwamish River estuary in January and February and remain until the end of July as a spring nesting population. Canada geese swim in the LDW and feed in intertidal habitats. They feed primarily on grass and terrestrial vegetation (Canning et al. 1979), habitats generally lacking in the EW.

Limited shallow water and intertidal habitat in the EW (Figure 2-10) make it likely that some waterfowl, such as dabbling ducks, will be less prevalent in the EW relative to the LDW. However, deeper water habitat is available such that diving ducks that are capable of feeding in deep water are likely to be prevalent in the EW.

2.3.4.7 Seabirds

Thirteen species of seabird have been recorded in the Duwamish River estuary (Canning et al. 1979; Cordell et al. 1999), including two species of cormorants (pelagic and double-crested) (Table 2-11). Cormorants feed primarily on small fish and occasionally crustaceans. Wintering cormorants use the EW from November to May, with large numbers present from December to April (Canning et al. 1979; Cordell et al. 1996).

Several species of gulls are reported to use the Duwamish River estuary. Gulls feed on fish and shellfish and are omnivorous scavengers. Glaucous-winged gulls and mew gulls are the only species reported to use the area in large numbers. Glaucous-winged gulls are reported to use the area throughout the year. Mew gulls frequent the area, occasionally in large numbers, from September through May (Canning et al. 1979).

Caspian terns have been seen using Kellogg Island (Luxon 2004). Pigeon guillemots and common murres have been reported in the Duwamish River estuary. These birds feed primarily on pelagic fish, though bottomfish and crustaceans may also be taken.

Common loons are a state candidate species under review for listing as threatened or endangered (WDFW 2001). They are present in Puget Sound in winter and use local waters for resting during migrations to and from wintering areas farther south. Their diet consists primarily of small fish and other aquatic animals.

Three species of grebe are reported in the Duwamish River estuary. Of these, only western grebes are found in substantial numbers. Grebes and other marine bird species have been declining in recent years (Nysewander et al. 2001). Feeding behavior varies with species. In marine waters, the eared grebe primarily takes crustaceans while the western grebe favors fish. The most common fish species taken by western grebes are Pacific herring, pilchard, stickleback, sculpin, sea perch, and smelt. Western grebes occasionally feed on juvenile salmonids. The Duwamish River estuary population was estimated to comprise about 90 birds in the 1970s (Canning et al. 1979). Grebes arrive from October to November and depart by early May.

Seabirds present in the Duwamish River estuary are likely to be representative of the seabirds present in the EW due to the similarity of the habitat for these species in the EW and the LDW.

2.3.5 Mammals

2.3.5.1 East Waterway Mammal Population Data

Three marine mammal species may occasionally enter the Duwamish River estuary: harbor seal, California sea lion, and harbor porpoise (Dexter et al. 1981). Harbor seals and California sea lions have recently been observed in the EW (WDFW 1999), but recent information on harbor porpoise usage was not available.

A survey of California sea lions and harbor seals was conducted in the Duwamish River estuary from December 1998 to June 1999 (Walker 1999). This survey monitored the presence of California sea lions and harbor seals in the EW, WW, and

LDW up to the 16th Avenue South Bridge for a total of 307 hours in 52 days. In the EW, California sea lions were observed on eight occasions and harbor seals on one occasion. In the WW, California sea lions were observed 69 times and seals six times. Of all observations in the Duwamish River estuary, both species were observed in the WW most frequently.

There is very little information on mammal populations that is specific to the EW. There is more information on the mammal populations of the Duwamish River estuary which is summarized in the following subsections. The relatively large home ranges associated with many mammal species make the Duwamish River estuary data relevant to the EW.

2.3.5.2 Other Relevant Information

Data on the presence of mammals in the EW are limited; therefore, species reported as using the Duwamish River estuary and nearby Elliott Bay are described here.

Harbor seals are opportunistic feeders, selecting prey based on availability and ease of capture (Pitcher and Calkins 1979; Pitcher 1980; Schaffer 1989). Their diet can vary seasonally and includes bottom dwelling fishes, invertebrates, and species that congregate for spawning (Pitcher and Calkins 1979; Everitt et al. 1981; Lowry and Frost 1981; Roffe and Mate 1984). Fish consumed are generally between 40 and 280 mm (Brown and Mate 1983). Harbor seals found in Elliott Bay and the LDW likely prey on sole, crabs, mussels, clams, squid, and adult salmon. Harbor seals have been shown to forage over large areas ranging from 5 km (Stewart et al. 1989) to 55 km (Beach et al. 1985).

California sea lions and harbor porpoises are also opportunistic feeders, consuming various fish species depending on availability (Marine Mammal Center 2000). California sea lions and harbor porpoises will, like harbor seals, also feed on non-fish species such as squid and octopus (Yates 1998).

Three species of semi-aquatic terrestrial mammals use the LDW: raccoons, muskrats, and river otters. Raccoons are reported to be common along the forested ridge slopes to the west of the LDW. Raccoons are scavengers that feed on carrion and occasionally on fish. Muskrat populations were reported to exist at Terminal 107 (T-107) and at Turning Basin 3 (Canning et al. 1979). Muskrats are herbivores, feeding primarily on aquatic and semi-aquatic plants. The EW has limited aquatic and semi-aquatic plant populations due to limited shallow water habitat.

Anecdotal information indicates that a river otter family lives year-round on Kellogg Island in the LDW, although otters were not observed by Cordell during wildlife surveys (Cordell 2001). River otters are almost exclusively aquatic and prefer food-rich habitats such as the lower portions of streams and rivers, estuaries, and lakes and tributaries that feed rivers (Tabor and Wight 1977; Mowbray et al. 1979). Local river otters feed primarily on fish, but will also feed on crabs and sometimes mussels and clams (Strand 1999, as cited in King County 1999a). River otters range over an area sufficiently large enough for foraging and reproduction (Melquist and Dronkert 1987); however, they are typically found in a limited number of activity centers within their overall range. In streams, the river otter's home range can average 30 km (Melquist and Hornnocker 1983).

2.3.6 Plants

Three types of plants play key roles in maintaining high productivity in estuaries: 1) phytoplankton suspended within the photic zone of the water column; 2) benthic microflora (microscopic plants) living on the sediment surface wherever sufficient light reaches the bottom; and 3) macroalgae and periphyton growing in shallow water and along the shoreline. These plants are the foundation of the complex food webs found in estuaries such as the Duwamish River estuary. Phytoplankton are present in the EW water column.

Macroalgae is recognized as a contributor to habitat complexity and primary productivity. Macroalgae readily colonizes all appropriate rocky, cobble, or artificial substrates. Particular macroalgal beds (e.g., kelp forests) have more specific habitat needs. Macroalgae is common throughout the EW on most suitable substrates that are not shaded by piers. The abundance of macroalgae in the EW is likely greater today than under historical conditions due to the increase in hard substrates such as riprap, piles, and floats. Kelp beds (e.g., *Nereocystis and Laminaria*) are found in the south end of the EW. These beds are growing on rubble as well as on substrates enhanced by the Port for kelp growth (PIE 1999).

2.3.7 State and Federal Threatened, Endangered, and Sensitive Species in the East Waterway

Sixteen species reported in the vicinity of Elliott Bay area are listed under either ESA or by the State WDFW as candidate species, threatened species, endangered species, or species of concern (Table 2-12).

Table 2-12
Species Listed Under ESA or by WDFW

Common Name	Scientific Name	Status
Fish		
Bull trout	*Salvelinus confluentes*	FT, SC
Chinook salmon	*Oncorhynchus tshawytscha*	FT, SC
Coho salmon	*Oncorhynchus kisutch*	FC
Pacific cod	*Gadus macrocephalus*	SC
Pacific herring	*Clupea herengus pallasi*	SC
River lamprey	*Lampetra ayresi*	FSC, SC
Rockfish species	*Sebastes* spp.	SC
Steelhead salmon	*Oncorhynchus mykiss*	FT
Walleye pollock	*Theragra chalcogrammus*	SC
Birds		
Bald eagle	*Haliaeetus leucocephalus*	FT [a], ST
Common loon	*Gavia Immer*	SS
Common murre	*Uria aalge*	SC
Merlin	*Falco columbarius*	SC
Peregrine falcon	*Falco peregrinus*	FSC, SS [b]
Western grebe	*Aechmophorus occidentalis*	SC
Marine Mammal		
Killer whale	*Orcinus Orca*	FE

Source – WDFW 2001

a. Listing currently under review for removal.

b. Downlisted from state endangered to state sensitive April 2002.

FE- Federal endangered species

FT – Federal threatened species

FC – Federal candidate species

FSC – Federal species of concern

ST – State threatened species

SC – State candidate species

SS – State sensitive species

Nine of these 16 species are fish, six are birds, and one is a marine mammal. With the exception of bull trout, Chinook salmon, coho salmon, steelhead salmon, bald eagle, western grebe, and perhaps Pacific herring, use of the Duwamish River estuary by these species is rare or incidental, so they are not likely to be frequently present in the EW. Orcas are occasionally found within Elliott Bay. There are no specific reports of orcas within the EW. Reports of peregrine falcon are anecdotal (Anderson 2002). Reports of rare or incidental species in the Duwamish River estuary are from the documents listed in Table 2-13.

Table 2-13
Rare or Incidental Species in the East Waterway

Species	Reference	Rarity
common murre	n/a	believed to be rare
loons	Canning et al. 1979	rare
merlin	Cordell et al. 1996, 1997, 1999, 2001	rare
river lamprey	Matsuda et al. 1968 Warner and Fritz 1995	rare rare
rockfish	Malins et al. 1980 Matsuda et al. 1968	rare rare
walleye pollock	Matsuda et al. 1968 Miller et al. 1975	rare rare
western grebe	Cordell et al. 1996, 1997, 1999, 2001	common

2.4 Human Use Characteristics

2.4.1 Land Use and Ownership

Land use, zoning, and land ownership along the EW are consistent with an active industrial waterway. The entire east and west sides of the EW contain hardened shorelines with extensive overwater structures, commercial and industrial facilities, and other development. The EW is an industrial waterway used primarily for container loading and transport. Table 2-14 provides a summary of land ownership and current users, tenants, or operators. Property boundaries and ownership information are provided in Figure 2-13, and Figure 2-14 shows current operators and tenants. As described below, nearly all properties are owned by the Port.

Table 2-14
Current Land Uses Along the East Waterway

Property	Owner	Tenant	Uses/ Operations	Anticipated Future Uses	Approximate Location (Stations)	Approximate Size
West Shoreline						
T-18	Port of Seattle	Kinder Morgan	Petroleum loading/unloading	Petroleum loading/unloading	0 – 400	1 acre
		SSA	Container storage, intermodal transfer	Container storage, intermodal transfer	400 – 6150	115 acres
		Westway Feed Products	Liquid terminal storage	Liquid terminal storage	6150 – 6800	1 acre
Duwamish Properties	Duwamish Properties	Harley Marine Services	Tug and barge terminal	Tug and barge terminal	6150 – 6800	3.2 acres
T-102	Harbor Real Estate	Various	Industrial park	Industrial park	7250 – 7500	2.5 acres
T-102	Port of Seattle	Various	Industrial park, marina	Industrial park, marina	7200 – 7700	18.5 acres
East Shoreline						
T-104	Port of Seattle (south)	Western Cartage	Container storage, truck parking	Container storage, truck parking	7200 – 7700	13.8 acres
	Port of Seattle (north)	Vacant	Vacant land	Unknown	7000 – 7200	2.7 acres
T-24	Port of Seattle	Seattle Cold Storage	Storage of ground cement/gravel	Frozen seafood facility for fish processing	5850 – 6800	19 acres
T-25	Port of Seattle	SSA	Container storage, intermodal transfer	Container storage, intermodal transfer	4200 – 5850	22.5 acres
T-30	Port of Seattle	SSA	Container storage, intermodal transfer	Container storage, intermodal transfer	3250 – 4200	10 acres
		CTA	Cruise ship terminal	NOAA vessels (until March 2008); Container storage, intermodal transfer (2009)	1800 – 3250	21.5 acres
		SSA	Container storage, intermodal transfer	Container storage, intermodal transfer	800 – 1800	9.5 acres
		Public Access	Public Access	Public Access	750 – 800	2 acres
Pier 36, Pier 37	USCG	USCG	USCG offices, boat maintenance	USCG offices, boat maintenance	-100 – 750	18 acres
T-46	Port of Seattle	TTI	Container storage, intermodal transfer	Container storage, intermodal transfer	north of -100	72 acres

Property	Owner	Tenant	Uses/ Operations	Anticipated Future Uses	Approximate Location (Stations)	Approximate Size
Bridges (parcels on either side of the EW)						
Spokane Street Bridge	City of Seattle	none	Road	Road	6850 – 6950	-
Railroad Bridge	BNSF Railway	BNSF Railway	Railroad	Railroad	7150 – 7200	-
Service Road Bridge	Port of Seattle	none	Fire department access	Fire department access	7200 – 7250	-
West Seattle Bridge	City of Seattle	none	Road	Road	7050 – 7150	-

Notes:
Kinder Morgan - Kinder Morgan Energy Partners
SSA – Stevedoring Services of America
TTI – Total Terminals International
USCG – U.S. Coast Guard
CTA – Cruise Terminals of America

Properties on the west side of the EW consist of two Port-owned parcels, T-18 and Terminal 102 (T-102), and a third parcel owned by Duwamish Properties. T-18 borders the EW from the northern boundary of Harbor Island approximately 6,150 feet to the point where the EW narrows, at which point the property extends away from the water to the Spokane Street corridor. Including recently enlarged areas, T-18 contains approximately 115 acres used for container storage and intermodal transfer. T-18 is operated by Stevedoring Services of America (SSA). The southernmost portion of the T-18 parcel is leased by Westway Feed Products, Inc. Molasses and other liquid food products are stored in numerous above-ground tanks and transferred to and from rail cars in this lease area.

The Port leases a portion of the northeasternmost portion of T-18 to Kinder Morgan Energy Partners (Kinder Morgan). This lease area is approximately 1 acre in size and extends approximately 450 feet along the EW. The lease area extends onto a portion of T-18 and on DNR land (see Section 2.4.2). Kinder Morgan uses this area to load and unload petroleum products.

The property immediately east of the south end of T-18 is owned by Duwamish Properties and extends along the EW to the Spokane Street corridor. This 3.2-acre property is occupied by Harley Marine Services, which owns Olympic Tug and Barge.

Harley Marine Services has an office building and maintenance shop on the property. Its tugs and barges are moored along this parcel in the EW.

The other Port-owned parcel on the west side of the EW is T-102, which contains an office park with numerous office buildings called Harbor Marina Corporate Center. Buildings E and F in the office park are on a 2.5-acre parcel owned by Harbor Real Estate, which is located northeast of the Port-owned parcel. T-102 extends from Spokane Street to the southern tip of Harbor Island, and further south into the LDW (see Figure 2-13 and 2-14). The Port also operates a marina along the EW and LDW.

The four bridges over the EW in the Spokane Street corridor are described in Section 1.4.1. Land on either side of the EW at the Railroad Bridge is owned by BNSF Railway. At the Service Road Bridge, land on either side of the EW is owned by the City.

On the east side of the EW and south of the Spokane Street corridor, the Port owns T-104. T-104 comprises a 13.8-acre property south of the railroad ROW and a 2.7-acre property north of the railroad ROW. The larger parcel is leased to Western Cartage, which is designated as Foreign Trade Zone #5. This property is used for container storage and truck parking. The smaller parcel is currently vacant. No water access is available at T-104 on the north side of the railroad ROW.

North of the Spokane Street corridor the Port owns T-25, which extends north along the EW to Slip 27. The south end of T-25 is Pier 24, which consists of the 19 acres north of Spokane Street, and is currently leased to Seattle Cold Storage. This area is currently used to store gravel and crushed concrete from the demolition of the old Seattle Cold Storage building. The northern portion of this area was also used for loading dredged sediment from barges onto a rail spur in 2005 to 2006. Seattle Cold Storage is currently planning construction of a new freeze facility for fish processing at Pier 24. SSA subleases the eastern portion of Pier 24 from Seattle Cold Storage. The main parcel of T-25 contains 22.5 acres of container storage and intermodal transfer. SSA currently operates T-25.

Pier 27 is located north of T-25 and south of Slip 27. Pier 27 is owned by the Port and contains a railroad spur that is no longer used. A new bridge connects T-25 to T-30 across the head of Slip 27, as discussed in Section 2.4.3. Pier 28 is located on the north side of Slip 27, and is used for miscellaneous vessel moorage. The Port owns the vacated portion of South Forest Street, which constitutes the northern portion of Slip 27.

T-30 is a 31-acre Port-owned property. The southern portion of T-30 is currently being used as container storage and intermodal transfer. This 10-acre area is operated by SSA. The area north of the container terminal is currently utilized as a passenger terminal for cruise ships and is operated by Cruise Terminals of America (CTA). This portion of T-30 is planned to return exclusively to a container terminal in 2009, but NOAA vessels will dock at T-30 from November through March of 2008. The passenger terminal currently extends approximately 1,750 feet along the EW. The northern 9.5 acres of T-30 are used for container storage and intermodal transfer and are operated by SSA.

Jack Perry Memorial Shoreline Public Access is located along the northern extent of T-30. This Public Access extends from East Marginal Way South to the EW. Parking is available along with shoreline and water access. To the north of the Public Access is the Pier 36 USCG station.

The USCG station is located north of T-30 and on either side of Slip 36. This property includes USCG offices and Pier 36 (south of Slip 36) and Pier 37 (north of Slip 36). USCG uses the area on either side of Slip 36 as a training facility and for boat maintenance, USCG offices, and water access. This area is expected to continue to be used in the same capacity by USCG in the future.

T-46 is located north of Pier 37 and used for container storage and intermodal transfer. The south end of T-46 is adjacent to the EW area. T-46 is operated by Total Terminals International (TTI).

2.4.2 Waterway Use and Ownership

The EW provides a critical connection for cargo and other materials moving between water and land. Most vessel traffic consists of shipping companies moving container vessels and assorted tugboats into and out of the EW. As Port container volume increases, there may be a need to accommodate larger container vessels in the future that may require deeper drafts than the current EW depths, especially at the south end of the main 750-foot-wide section because it is currently shallower than -51 feet MLLW.

In 2006, there were approximately 519 arrivals and departures of various types of vessels in the EW, most of which were container and cruise ships (Port of Seattle 2007). Specifically, 338 container ships called on T-18, 56 container ships and barges called on T-25, and 125 cruise ships called on T-30 (Port of Seattle 2007). The Port of Seattle plans to move cruise ship operations from T-30 to Terminal 91 (T-91) in Elliott Bay in 2009 and restore T-30 to a container facility. Vessels from NOAA will temporarily dock at T-30 from November through March of 2008, prior to its conversion to a container facility. In addition to ship traffic, tugboats, barges, and small craft also use the EW. Each container ship requires at least one tugboat to maneuver the ship during docking and undocking. Cruise ships typically maneuver on their own power. Numerous barges and tugboats are moored along Harley Marine Services, at the head of the EW. At the north end, along T-18, tug and barge traffic utilize the Kinder Morgan petroleum products transfer facility.

USCG vessels frequent Slip 36, which serves Pier 36 (south) and Pier 37 (north). Slip 36 extends 1,050 feet to the east of the eastern EW pierhead line. All of Slip 36 is owned by USCG (Figure 2-15). USCG moors numerous vessels in Slip 36, including USCG Icebreakers, Cutters (greater than 65 feet in length), and gunboats. Only USCG vessels use this slip.

Other EW use north of the Spokane Street corridor includes miscellaneous vessel moorage in Slip 27. Slip 27 extends approximately 850 feet in the southeast direction along the east side of the EW and is 240 feet wide. The northern portion is currently used by the Port to moor various vessels. A 34-foot-wide truck bridge has also recently been completed above the eastern portion of Slip 27 that connects T-25 to T-30.

South of the Spokane Street corridor, recreational and commercial boats move in and out of the Harbor Island Marina (T-102) from the LDW. Along the T-102 shoreline within the EW, the Port leases out moorages at a 750-foot-long dock for commercial use.

Figure 2-15 shows aquatic land ownership in the EW and the shoreline generally defined by mean higher high water (MHHW). The main body of aquatic land in the EW is owned by DNR between the pierhead lines. Land located between the inner harbor line (which corresponds to the upland property boundaries) and the pierhead line in the 750-foot-wide portion is state-owned but managed by the Port through a Port Management Agreement (PMA). This area includes all aprons that extend approximately 100 feet from the Port's parcel boundary.

Several aquatic areas within the EW are not state-owned. South of the Spokane Street corridor, the Port owns the entire width of the EW. The eastern parcel boundary for T-102 abuts the western parcel boundary for T-104. The Port also owns all of Slip 27, including the vacated portion of the South Forest Street ROW and Pier 27 (south side of Slip 27). A portion of aquatic area along Pier 24 that formerly contained timber decking is also owned by the Port. All of Slip 36 is owned by USCG.

The EW is not a major area for recreational use compared to other water bodies in and around Seattle (King County 1999a). Recreational boating in the EW occurs on a limited basis. No boat ramps are present in the EW, but water access is provided at Jack Perry Memorial Shoreline Public Access (on the eastern side of the EW, south of Slip 36; see Figure 2-14) for kayakers and other non-motorized watercraft. Harbor Island Marina provides recreational boat moorages along the EW and in the LDW and WW. Harbor Island Marina moorages in the EW are mostly used for commercial boats, but other recreational boats may enter from the LDW. The presence of the Spokane Street Bridge and the Railroad Bridge prohibit any type of boat passage, except at low tide by small, shallow-draft boats (e.g., kayaks and skiffs).

Recreational fishing is conducted from the north side of the Spokane Street Bridge, especially during summer and fall salmon runs. Recreational fishing has also been observed north of the eastern side of the Spokane Street Bridge from the riprap slopes during summer salmon runs.

Commercial netfishing operations are conducted in the EW by the Muckleshoot Tribe. The Muckleshoot Tribe's fishing operation is conducted seasonally on the EW, and it is not associated with a permanent facility on the EW. The EW is part of the Suquamish and Muckleshoot Tribe's U&A fishing grounds; consequently, they are permitted by federal law to harvest salmon in commercial quantities from this area.

Few data have been located quantifying the frequency with which people use the EW for recreational purposes other than fishing. King County (1999a) discussed the human site use of both the Duwamish River and Elliott Bay, but presented quantitative data only for fishing. In the study, approximately 10 percent of the surveys conducted in the summer of 1999 were located in the EW. The number of people fishing and crabbing throughout the entire study area (Duwamish River, EW, Elliott Bay) was high in June and September (more than 400 people) and highest in July and August (more than 700 people). Fewer than 200 people in the study area collected seafood during each of the other months of the year. Of the 209 people that had collected one or more type of seafood in both Elliott Bay and the Duwamish River, 107 people reported collecting salmon, 27 collected crabs, and 21 collected flounder (King County 1999a). For the entire study area, salmon contributed the greatest portion, by weight, of seafood collected (64 percent of the total), followed by crabs (16 percent) and perch (11 percent) (King County 1999a). When just data from the pier along the Spokane Street Bridge were considered, the species caught by most anglers and in the largest quantities included herring and crabs (Mayfield et al. 2007). Other species caught less frequently at the pier included flounder, sculpin, perch, and sole. During the time of the survey, there were fish consumption advisories posted at the Spokane Street Bridge by the Washington Department of Health to warn anglers to limit intake of certain species because of chemical contamination.

The King County report (1999a) also suggested that few, if any, people engage in water activities such as swimming, SCUBA diving, and windsurfing within the EW. The frequency of some of these recreational activities may increase in the future as ongoing remedial efforts and habitat restoration projects are completed, but such uses are likely to continue to be limited by the active commercial use of the EW, the very limited public access due to security requirements of container terminals and the USCG facility, and the availability of nearby areas that provide superior recreational opportunities.

2.4.3 Structures and Utilities

2.4.3.1 Shoreline Structures and Utilities

The EW shoreline is highly developed, primarily composed of over-water piers, riprap slopes, constructed seawalls, and bulkheads for industrial and commercial use (see Figure 2-16). Throughout the entire length of the EW, approximately 61 percent of the EW shoreline contains over-water piers (aprons) above riprap. Another 30 percent contains exposed shoreline armored with riprap (including the entire area south of the Spokane Street corridor). The remaining 9 percent is comprised of steel sheetpile bulkheads. Structural information is described in Table 2-15 and on Figure 2-17. Typical cross sections of shoreline structures are contained in Appendix A.

Four bridge structures pass over the southern end of the EW in the Spokane Street corridor that are operated and maintained by SDOT (Spokane Street Bridge and Service Road Bridge between T-102 and T-104), WSDOT (West Seattle Bridge), and BNSF Railway (Railroad Bridge). An additional bridge has recently been completed across the head of Slip 27 between T-25 and T-30. Structural information has currently been acquired for each of these bridges, with the exception of the Railroad Bridge between T-102 and T-104.

The EW shoreline is predominantly bounded by concrete over-water pier structures (also known as aprons) from the Port's container terminals along T-18, T-25, T-30, and T-46. These piers are composed of pre-cast concrete decks with a top elevation of approximately +18 feet MLLW that were originally constructed as early as the 1960s. Various structural upgrades have been performed since original construction. The decks are typically supported by concrete bents spaced every 20 feet, with 16.5-inch octagonal concrete piles.

An armored riprap slope (1.75H:1V) is present beneath each over-water pier structure (apron). The slope rises to meet a bulkhead that retains the upland soils approximately 100 feet shoreward of the pier face. The top of the embankment, along the bulkhead face, is generally at an elevation between 0 and +10 feet MLLW. Newer structures (post-1975) are generally above +9 feet MLLW. Water depths at the pier face are generally -50 feet MLLW; however, this depth varies for individual piers, as shown in Table 2-15.

Table 2-15
Explanation of Structure and Utility Information

Tag (Fig 2-17)	Data Missing	Property	Structure/Utility Owner	User/Tenant	Structure/Utility Type	Year of Construction	Navigable Depth (MLLW)	Data Source	Project No.	Additional Description
18.01		T-18	Port of Seattle	SSA	Precast concrete deck panels on caps at 20-foot spacing, with 16.5-inch octagonal concrete piles	1966	-50 feet	POS Record Drawings	18-6606	
18.02		T-18	Port of Seattle	SSA	Precast concrete deck panels on caps at 20-foot spacing, with 16.5-inch octagonal concrete piles	1967	-50 feet	POS Record Drawings	18-6701	
18.03		T-18	Port of Seattle	SSA	Precast concrete deck panels on caps at 20-foot spacing, with 16.5-inch octagonal concrete piles	1973	-50 feet	POS Record Drawings	20-7302	
18.04		T-18	Port of Seattle	SSA	Precast concrete deck panels on caps at 20-foot spacing, with 16.5-inch octagonal concrete piles	1963	-50 feet	POS Record Drawings	20-6303	
18.05		T-18	Port of Seattle	SSA	Precast concrete deck panels on caps at 20-foot spacing, with 16.5-inch octagonal concrete piles	1964	-50 feet	POS Record Drawings	20-6405	
18.06		T-18	Port of Seattle	SSA	Precast concrete deck panels on caps at 20-foot spacing, with 16.5-inch octagonal concrete piles	1974	-50 feet	POS Record Drawings	19-7401	
18.07		T-18	Port of Seattle	SSA	Apron upgrade (crane rail)	1996	-50 feet	POS Record Drawings	18-9603	
18.08		T-18	Port of Seattle	SSA	Apron upgrade (crane rail)	1997	-50 feet	POS Record Drawings	18-9705	
18.09		T-18	Port of Seattle	SSA	Underwater sheet pile wall (berth deepening)	2003	-50 feet	POS Record Drawings	18-0302, 18-0304, 18-0402	
M.01	Y	910 SW Spokane Street	Duwamish Properties LLC	Olympic Tug and Boat	Bulkhead	Unknown				
LB.01		Spokane Street ROW	King County		King County CSO main	Original construction information for utilities not available. Location verified in GIS and Spokane Street Bridge drawings.	n/a			
LB.01		Spokane Street ROW	Seattle Public Utilities		Water main		n/a			
LB.01		Spokane Street ROW	Seattle City Light		Power		n/a			
LB.01		Spokane Street ROW	Olympic Pipeline		Petroleum		n/a			
LB.01		Spokane Street ROW	Puget Sound Energy		Natural gas		n/a			
LB.02		Spokane Street ROW	City of Seattle	n/a	Riprap slope on west shore of waterway	1979	n/a	City Record Drawings	782-134	Washington State Ferries (WSF)-EW N. Bridge Replacement
LB.03		East Waterway	Federal	City of Seattle	Concrete bridge deck on concrete piers at 88-foot spacing, with 18-inch steel piles	1979	n/a	City Record Drawings	782-134	
LB.04		Spokane Street ROW	City of Seattle	n/a	Riprap slope on east shore of EW	1979	n/a	City Record Drawings	782-134	WSF-EW N. Bridge Replacement
HB.01		West Seattle Bridge ROW	WSDOT	n/a	Riprap slope on west shore of EW	1980	n/a	City Record Drawings	782-139	WSF-Contract 5 Duwamish Island
HB.02		East Waterway	Federal	State of Washington	High bridge supported on two concrete piers, each on (18) 24-inch concrete piles	1980	n/a	City Record Drawings	782-139	
HB.03		West Seattle Bridge ROW	WSDOT	n/a	Riprap slope on east shore of EW	1980	n/a	City Record Drawings	782-139	WSF-Contract 5 Duwamish Island
RRB.01		Railroad Bridge ROW	BNSF Railway	n/a	Concrete abutment on west shore of EW	1999	n/a	POS Record Drawings	5-9513	
RRB.02		East Waterway	Federal	BNSF Railway	Railroad Bridge supported on concrete caps at 32-foot spacing with 30-inch steel piles	1999	n/a	POS Record Drawings	5-9513	
RRB.03		Railroad Bridge ROW	BNSF Railway	n/a	Concrete abutment on east shore of EW	1999	n/a	POS Record Drawings	5-9513	
RRB.04	Y	Railroad Bridge ROW	BNSF Railway	n/a	Timber bulkhead on west shore of EW	Unknown	n/a			
RRB.05	Y	East Waterway	Federal	BNSF Railway	Railroad Bridge supported on timber caps at 16-foot spacing, with timber piling	Unknown	n/a			
RRB.06	Y	Railroad Bridge ROW	BNSF Railway	n/a	Timber bulkhead on east shore of EW	Unknown	n/a			
SB.01		T-102	Port of Seattle	Port of Seattle	Concrete abutment on west shore of EW	Unknown	n/a		5-9513	
SB.02		East Waterway	Port of Seattle	Port of Seattle	Service Road Bridge supported on concrete caps at 48-foot spacing, with 30-inch steel piles	1999	n/a	POS Record Drawings	5-9513	T-102 Access Bridge

Tag (Fig 2-17)	Data Missing	Property	Structure/Utility Owner	User/Tenant	Structure/Utility Type	Year of Construction	Navigable Depth (MLLW)	Data Source	Project No.	Additional Description
SB.03		T-104	Port of Seatte	Port of Seattle	Concrete abutment on east shore of EW	1999	n/a	POS Record Drawings	5-9513	
102.01	Y	T-102	Port of Seattle	Harbor Island Marina	Timber foundation and guide piles supporting fixed and floating marina walkways	1970s				
102.02		T-102	Port of Seattle	Harbor Island Marina	Riprap slope	1969	n/a	POS Record Drawings	102-6900	
104.01		T-104	Port of Seattle		Riprap slope	1969	n/a	POS Record Drawings	102-6900	
25.01		T-25	Port of Seattle	n/a	Riprap slope		n/a			
25.02		T-25	Port of Seattle	Seattle Cold Storage	Timber bulkhead	1914	-30 to -50 feet	POS Record Drawings	25-1400	
25.03		T-25	Port of Seattle	n/a	Timber pier piling	1914	-42 feet	POS Record Drawings	25-1400	
25.04		T-25	City of Seattle		54-inch Hinds CSO outfall - reinforced concrete pipe	1971	-50 feet	City Record Drawings	861-26	S. Hind Street Outfall
25.05		T-25	Port of Seattle	SSA	Precast concrete deck panels on caps at 20-foot spacing, with 16.5-inch octagonal concrete piles	1971	-50 feet	POS Record Drawings	25-7100, 25-7201	
25.06		T-25	King County		King County Hanford CSO outfall - concrete box culvert on timber piles	Rebuilt in 1974	-50 feet	POS Record Drawings	25-7201, 777-8	W. Hanford Street Trunk Sewer
25.07		T-25	Port of Seattle	n/a	Riprap slope		-50 feet			
27.01		P-27	Port of Seattle	n/a	Riprap slope		n/a			
27.02		Slip 27 bridge	Port of Seattle	SSA	Precast concrete deck panels on caps at 25-foot spacing, with 24-inch octagonal concrete piles	2007	n/a	POS Record Drawings	25-0603	T25/T30 Expansion and Connecting Bridge
28.01		P-28	Port of Seattle	SSA	Precast concrete deck panels on caps at 20-foot spacing, with 14-inch square concrete piles (minimum)	1960	-40 feet	POS Record Drawings	28-6000	
30.01		T-30	Port of Seattle	SSA	Precast concrete deck panels on caps at 20-foot spacing, with mostly 16.5-inch octagonal concrete piles	1994	-42 feet	POS Record Drawings	30-9401	
30.02		T-30	King County		King County Lander CSO outfall - concrete box culvert on timber piles	1953	-42 feet	City Record Drawings	851-37	W. Lander Street Extension of Sewer Outfall
30.03		T-30	Port of Seattle	SSA	Precast concrete deck panels on caps at 20-foot spacing, with mostly 16.5-inch octagonal concrete piles	1984	-42 feet	POS Record Drawings	30-8404	
30.04		T-30	Port of Seattle	SSA	Precast concrete deck panels on caps at 20-foot spacing, with mostly 16.5-inch octagonal concrete piles	1983	-44 feet	POS Record Drawings	30-8302	
30.05		T-30	Port of Seattle	SSA	Precast concrete deck panels on caps at 20-foot spacing, with mostly 16.5-inch octagonal concrete piles	1984	-44 feet	POS Record Drawings	30-8404	
30.06		T-30	Port of Seattle	n/a	Riprap slope	1998	n/a	POS Record Drawings	30-9802	
30.07		East Waterway, T30 and T18	Qwest	n/a	Buried telephone cable		n/a	POS Record Drawings	30-9802	
30.08		T-30	Port of Seattle	SSA	Steel sheetpile bulkhead	1953	-30 feet	Record Drawings	1953 0317-D452	Blue Line Drawing
30.09		T-30	Port of Seattle	n/a	Condemned timber pier and piling					
30.10		T-30	Port of Seattle	SSA	Bulkhead	1998		POS Record Drawings		KPFF Project 98610, 2.16.01
30.11		T-30	Port of Seattle	SSA	Apron upgrade (crane rail)	2008		Berger/ABAM		
CG.01		USCG	USCG	n/a	Riprap slope					
CG.02	Y	USCG	USCG	USCG	Condemned timber pier and piling					
CG.03		USCG	USCG	USCG	Concrete apron	2004	-40 feet	Berger/ABAM		
CG.04	Y	USCG	USCG	USCG	Timber pier on upgraded piles and pony bents	1923	-35 feet	Berger/ABAM and POS Record Drawings		Repaired 36-5002, 5500, 5800, 7200
CG.05	Y	USCG	USCG	USCG	Timber pier on upgraded piles and pony bents	1923	-35 feet	Berger/ABAM and POS Record Drawings		Repaired 36-7200
37.01		T-37	Port of Seattle	TTI (Hanjin)	6-inch concrete deck with 18- or 20-inch octagonal concrete piles at 10-foot O.C.	1941	-34 feet	POS Record Drawings	37-4100	
37.02		T-37	Port of Seattle	TTI (Hanjin)	Concrete deck bearing on CIP retaining wall and 16.5-inch piles (original loading dock)	1977	-34 feet	POS Record Drawings	37-7706	
37.03		T-37	Port of Seattle	TTI (Hanjin)	Precast concrete deck panels on caps at 20-foot spacing, with 16.5-inch octagonal concrete piles	1977	-50 feet	POS Record Drawings	37-7706	
37.04		T-37	Port of Seattle	King County	King County Connecticut CSO outfall - reinforced concrete pipe	1977	-50 feet	City Record Drawings	870-36	S. Connecticut Street Outfall

Note: See Figure 2-17 for locations of tags.

A timber bulkhead and timber piles are present along the southern shoreline of Pier 24 (see Tags 25.02 and 25.03 in Table 2-15 and on Figure 2-17). The Port is proposing to remove these piles plus a small concrete pier and in-water debris, which currently occupy approximately 2.1 acres of aquatic and shoreline area, for fish and wildlife habitat improvements. This project is expected to be carried out during the 2008-2009 construction season.

There are additional unique shoreline sections along the EW, including but not limited to, over-water timber piers, abandoned creosote-treated wood piling, riprap, bulkheads, vessel mooring piles, and various bridge foundation piles. A high density of abandonded creosote-treated wood piling is located on both sides of the public access along the east side of the EW. In addition, numerous wood piles have been recently cut off at the mudline along the south side of the mouth of Slip 27. A complete summary of existing structures along the EW are described in Table 2-15 and shown in Figure 2-17. Design and/or as-built drawings that have been acquired are also described in Table 2-15.

Other utilities include buried Qwest communications cables crossing the EW between T-18 and the northern portion of T-30. These cables were originally buried between -61 and -66 feet MLLW in 1972 in an armored trench. The location shown on Figure 2-17 is based on design drawings; however, this cable may have been moved slightly from that location by a vessel anchor based on reports from contractors that located the cable as part of underwater bulkhead construction in 2003 (Oates 2007). North of the northern proposed EW OU study boundary, the Connecticut Street CSO outfall discharges along T-37 in Elliott Bay.

Most data presented in this section were obtained from archived record drawings obtained from the Port, City, and other property owners. Record drawings were not readily available for Pier 36 (USCG), the Railroad Bridge (BNSF Railway), the Harley Marine Services bulkhead (Duwamish Properties), and the Harbor Island Marina concrete guide piles for the marina floats (Port), but may be obtained at a later date.

2.4.3.2 CSOs and Storm Drains

Three CSOs and 39 stormwater outfalls are present along the EW. Details on outfall sizes and locations are presented in an Outfall Verification Report that included T-18, T-25, and T-30 (Phoinix 2007). This section presents a summary of details on stormwater and CSO outfall structures. CSO outfall details were acquired from Port, City, and County files. Stormwater outfall details were acquired from the Outfall Verification Report (Phoinix 2007).

The 39 stormwater outfalls are present along both the east and west shorelines of the EW. Stormwater outfalls are generally concrete pipes ranging in diameter from 6 to 100 inches. Most pipes are 6, 24, or 36 inches in diameter. Stormwater outfalls may also be made of metal or plastic. Additional information on stormwater discharges is contained in Section 5.2.4.

The three CSOs are all present along the eastern shoreline of the EW, in addition to the Connecticut Street CSO that is located north of the northern proposed EW OU study boundary. The Hinds CSO outfall is a 54-inch-diameter reinforced concrete outfall located at the bulkhead at Pier 24. This outfall discharges at approximately -17 feet MLLW. The outfall is supported by a riprap slope that descends to a depth of approximately -50 feet MLLW at the pier head line.

The Hanford CSO discharges along T-25 at approximately -5 feet MLLW through a 60-inch-diameter concrete box culvert at the riprap bank. Its original design extended to the center of the EW, descending from -23 feet MLLW at the inner harbor line to -60 feet MLLW at the mid-point of the EW. It contained multiple outlet locations along the EW floor along the western 100 feet of pipe length. However, it was shortened in 1974 to its current dimensions as part of T-25 reconstruction.

The Lander CSO discharges along T-30 through an 8-foot by 8-foot concrete box culvert located under the pier near 0 feet MLLW. As part of an outfall reconstruction and sewer separation project in 1994, a 20-inch-diameter stormwater pipe was extended from within a 2.5-foot-tall spillway within the box culvert to the pierhead line at approximately -40 feet MLLW.

3 SUMMARY OF EXISTING EAST WATERWAY CHEMISTRY AND BIOASSAY DATA

The chemistry and bioassay data generated by investigations conducted in the EW since 1990 are summarized in this section. The process for selecting and evaluating the data is discussed in Sections 3.1 and 3.2. All of the data are summarized in Section 3.3 in the following subsections: surface and subsurface sediment chemistry data and porewater chemistry data (Section 3.3.1), bioassay investigations (Section 3.3.2), surface water chemistry data (Section 3.3.3), tissue chemistry data (Section 3.3.4), and groundwater investigations (Section 3.3.5). A more detailed discussion of groundwater investigations is located in Section 5.

3.1 Application of Existing Information

3.1.1 Sediment Chemistry and Bioassay Data

The existing sediment chemistry and bioassay data for the EW will be presented for three depth horizons. Surface sediment samples are those samples collected from the 0-10cm depth horizon. Subsurface sediment samples consist of core samples of either composited cores representing DMMUs or discrete intervals collected from an individual core location for the purpose of characterizing the vertical extent of contamination. Both composite and discrete subsurface samples are presented by depths of 0-4ft and depths greater than 4 feet (>4ft).

Much of the EW sediment chemistry and bioassay data were collected for the purpose of dredged material characterization. Therefore, much of the data are associated with sediment that has since been dredged. The SRI/FS dataset will identify data associated with material that has been dredged. The summary of existing data (Section 3.3) primarily focuses on data associated with sediment that has not been dredged. In addition to the summaries of detected chemicals in Section 3.3, Appendix B contains summaries of all chemicals and presents all of the results of chemical concentrations of non-dredged sediment compared to applicable criteria. The data associated with dredged material are summarized in Section 3.3.1.2.4 and are presented by each dredge event in Appendix C. In addition to characterizing the material to be dredged, the sediment surface post-dredging is often characterized prior to dredging through the collection of sediment samples at the projected depth of dredging. These samples are commonly referred to as "z-samples." There were 15 z-samples collected in the EW.

Nine samples were collected in areas that were subsequently dredged and the new sediment surface was characterized by post-dredge monitoring. Figure 3-1 shows the locations of z-samples collected in areas that have been dredged, and the subsequent post-dredge monitoring samples. Two z-samples were collected in the vicinity of T-30 with no subsequent post-dredge monitoring sampling. Dredging has been proposed for this area in 2008 with extensive recontamination monitoring sampling. The remaining six samples are located in the southern portion of the EW that has not been dredged and represent deep subsurface samples. Z-samples will not be discussed in Section 3.3 but are presented in Appendix C. The post-dredge sediment surfaces are more accurately characterized by post-dredge samples.

Following the completion of the Phase I Removal Action (2003 to 2005) (Section 4.7.1), a layer of clean sand was placed over the final dredged surface as an interim remedy. The clean sand layer was required to be a minimum of 10 cm thick, but the actual thickness exceeded this amount. The thickness of the clean sand layer was verified during two rounds of recontamination montoring (2006 and 2007). The sediment data for this area presented in Section 3.3 are the data collected prior to the placement of the sand layer. Additional surface sediment samples have been collected following the sand layer placement as part of the recontamination monitoring studies (2006 and 2007). The data associated with these samples are not presented in Section 3.3, but are discussed in Section 5 of this report and presented in Appendix D. Further discussion between EPA and EWG will be necessary to determine how to use the sediment data collected in this area to characterize the surface sediment for the purposes of the EW SRI/FS.

3.1.2 Tissue Chemistry Data

All available tissue chemistry data for the EW is relevant to the SRI/FS and is presented in Section 3.3.4.

3.1.3 Surface Water, Porewater, and Groundwater Data

Surface water data from all of the investigations discussed in Section 3.3.3 are considered applicable and relevant with the exception of samples collected within a dredge plume during a dredging water quality monitoring event. Water quality monitoring was conducted during the Phase 1 Removal Action (2003 to 2005) and the

Stage 1 (1999 to 2000) removal. The samples collected to characterize ambient conditions upstream and downstream of the dredging have been identified as relevant for the SRI/FS. The data collected from locations within the area influenced by the dredging are not applicable due to the potential influence of the dredging on the results.

Porewater results are presented in Section 3.3.1. Results associated with locations that have been dredged are presented in Appendix C. Groundwater data have been compiled as part of the Source Control evaluation presented in Section 5. A brief summary is presented in Section 3.3.

3.2 Data Selection, Suitability, and Reduction

This section presents the DQOs and available chemical and toxicity data for the EW and describes how these data were selected as applicable for use in the SRI. It also describes how raw data from the laboratories were managed, which will determine the suitability of the data for use in the risk assessments and in the evaluation of the nature and extent of contamination. This section provides a summary of information provided in Appendices E and F, the Data Management and Historical Data Quality Review Memoranda appendices, respectively.

3.2.1 Data Selection

Many environmental investigations conducted within the EW have included the collection of chemistry data from samples of surface sediment, subsurface sediment, fish or shellfish tissue, surface water, or sediment porewater. This section describes the datasets selected for these sample types for use in the SRI/FS.

3.2.1.1 Surface Sediment

A surface sediment chemistry dataset was compiled from all sampling events considered appropriate for use in the SRI. This dataset includes all sediment sampling events conducted since 1990. The criteria for including surface sediment data in the dataset were as follows:

- Surface sediment data were included if they met the DQOs, as described in Appendix E.

- Surface data collected in areas that have since been dredged, as noted in Table 3-1, do not represent existing conditions. The data that represent existing conditions are presented in Section 3.3.1. Dredged samples are summarized in Section 3.3.1.2.4 and in Appendix C.
- Sediment samples were categorized as surface grab sediment samples if they represent sediment depths of 10 cm or less.
- Recontamination monitoring data associated with the Phase 1 Removal Action are discussed in Section 5 and presented in Appendix D. These data are not in the summary of existing conditions in Section 3. The post-dredge monitoring data for the Phase 1 Removal Action area are presented in Section 3 for this area. Further discussion with EPA will be required to determine the most appropriate baseline surface sediment dataset for this dredged area.

Data quality reviews were conducted on each dataset that met the above criteria and was thus considered for use in the SRI. Appendix E presents a more detailed description of the process for selecting data. The surface sediment sampling events included in the dataset are listed in Table 3-1. The locations of the surface sediment samples are shown in Figure 3-2. The locations of the dredged surface samples are presented on Figure C-1 in Appendix C.

3.2.1.2 Subsurface Sediment

Numerous subsurface sediment (0-4ft and >4ft) sampling events have been conducted since 1990. As a federally authorized navigation channel, the EW has been dredged for berth and channel deepening and maintenance. For this reason, many of the subsurface sediment characterization investigations within the EW have been focused on collecting data required for maintenance navigation dredging projects. The criteria for including subsurface sediment data in the dataset were as follows:

- Subsurface sediment data were included if they met the DQOs, as described in Appendix E.
- Subsurface data collected in areas that have since been dredged, as noted in Table 3-1, do not represent existing conditions. These data are not included

in data summary tables in Section 3.3.1. However, dredged samples are summarized in Section 3.3.1.2.4 and in Appendix C.

- Sediment samples were categorized as subsurface sediment samples if they represent sediment depths greater than 10 cm.

Data quality reviews were conducted on each dataset that met the above criteria and was thus considered for use in the EW SRI/FS. Appendix E presents a more detailed description of the process for selecting data. The subsurface sediment sampling events included in the dataset are listed in Table 3-1.

The locations of the subsurface (0-4ft and >4ft) sediment samples, which are representative of current conditions, are shown on Figures 3-2 and 3-3, respectively. The locations of the dredged subsurface samples are presented on Figure C-1 in Appendix C.

Table 3-1
Sediment Characterization Investigations Conducted in the East Waterway since 1990

Event Name	Reference Source	Sampling Dates	Collection Method	Total Samples Analyzed [a]	Analyses	Sediment Samples			TBT Porewater	Bioassay Samples [a]	Dredged Samples
						Surface (0-10cm)	Subsurface (0-4ft) [b]	Subsurface (>4ft)			
EW – Recontamination Monitoring 2007	Windward (2007a)	Feb 7, 2007	0.1 m^2 van Veen	24	DMMP	24	0	0	0	0	0
EW – Slip 27	Windward (2007b)	Jan 10 and 12, 2007	0.1 m^2 van Veen and Vibracorer	19	SMS, pesticides, TBT	7	12	0	0	0	0
T-30 Sediment Characterization	Anchor (2006)	Oct 2006	Vibracorer	6	DMMP	0	6	0	0	1	0
EW – Recontamination Monitoring 2006	Windward (2007c)	Jan 12 and 23-24, 2006	0.1 m^2 van Veen	21	DMMP	21	0	0	0	0	0
USCG (Pier 36-37 slip and Berth Alpha)	Hart Crowser (2005)	May 11, 2005	0.1 m^2 van Veen	13	SMS	13	0	0	0	0	0
Phase 1A Removal Post-dredge Monitoring	Anchor and Windward (2005)	Jan 25 to Mar 1, 2005	0.1 m^2 van Veen	53	SMS DMMP	53	0	0	23	0	0
Pier 36 Suitability Confirmation Sampling	GeoEngineers (2004)	Nov 17, 2004	Vibracorer	11	DMMP	0	11	0	0	0	11
EW/Harbor Island Nature and Extent Recency	Windward (2003b)	Feb 11-12, 2003	Pneumatic corer	4	SMS DMMP	0	4	0	0	0	0
Pier 36 Dredging Additional Sampling	GeoEngineers (2003)	Nov 14, 2002	Vibracorer	3	DMMP	0	3	0	3	3	3
T-46 Sediment Characterization	(Anchor 2004)	March 22 and 25, 2004 and April 13, 2004	Vibracorer and diver-assisted spoon	2	SMS DMMP	0	0	2	1	0	2
EW T-18 Stage 1A, Rounds 1 and 2	Anchor (2002)	Apr 16-17, 2002 Sep 3-4, 2002	Vibracorer	5	DMMP	0	5	0	5	4	5
EW/Harbor Island Nature and Extent-Phase 3b	Windward (2002b)	Dec 19-20, 2001	Pneumatic corer	33	SMS DMMP	0	33	0	0	0	1
EW/Harbor Island Nature and Extent-Phase 3a	Windward (2002b)	Dec 7-11, 2001	Pneumatic corer	24 (z samples)	SMS DMMP	0	0	0	0	0	24
EW/Harbor Island Nature and Extent-Phases 1 and 2	Windward (2002c)	Sep 25-28, 2001	0.1 m^2 van Veen	86 [c]	SMS DMMP	86 [c]	0	0	43	41	1
USCG Pier 36	GeoEngineers (2001)	Mar 15-19, 2001	Hollow stem auger	12	SMS DMMP	0	4	8	2	2	12

Event Name	Reference Source	Sampling Dates	Collection Method	Total Samples Analyzed [a]	Analyses	Sediment Samples			TBT Porewater	Bioassay Samples [a]	Dredged Samples
						Surface	Subsurface				
						(0-10cm)	(0-4ft) [b]	(>4ft)			
T-18 – PDM	Windward (2001)	Mar 29, 2000	0.1 m^2 van Veen	13	SMS DMMP	13	0	0	7	9	0
Pier 36 Characterization	SAIC (1999a)	Aug 18-26, 1998	Vibracorer	9	SMS DMMP	0	8	0	8	8	9
EW Stage 1 Channel Deepening	SAIC (1999b)	Jul 27-Aug 28, 1998	Vibracorer	99 (4 z-samples)	SMS DMMP	0	67	32	99	99	44
Pier 36/37 - surface	Tetra Tech (1997)	May 19, 1997	0.1 m^2 van Veen	3	SMS	3	0	0	0	0	3
Pier 36 - preliminary	Berger/ABAM (1997)	Apr 28-30, 1997	Vibracorer	4	SMS	0	0	4	3	0	2
T-18 Dredging - Phase 2	EVS (1998)	May 27-Jun 12, 1996	Vibracorer	45	SMS DMMP	0	40	5	15	13	44
T-18 Dredging - Phase 1	EVS (1998)	Mar 11-31, 1996	Vibracorer	86	SMS DMMP	0	67	19	16	86	77
Pier 36 - underpier	Tetra Tech (1996)	Oct 23-24, 1996	Ponar grab	3	SMS	3	0	0	0	0	0
King County CSO 96	King County (1996)	Sep 24-30, 1996	0.1 m^2 van Veen	6	SMS	6	0	0	0	6	1
King County CSO 95	King County (1995)	Jun 26-29, 1995	0.1 m^2 van Veen	7	SMS	7	0	0	0	0	2
Harbor Island SRI	EVS (1996a, 1996b)	Mar 10-23, 1995	0.1 m^2 van Veen and Vibracorer	21	SMS	12	4	5	0	3	15
Pier 36	Shannon and Wilson (1992)	Mar 19-27, 1992	Hollow stem auger drilling	3	SMS	0	1	2	0	2	0
Harbor Island RI	Weston 1993	Sep 23-Oct 31, 1991	0.1 m^2 van Veen	30	SMS	24	6	0	4	0	15
Pier 27	Smolski et al. (1991)	Jun 27-28, 1990	0.1 m^2 van Veen and Vibracorer	39	SMS	15	9	15	0	7	0

a The total number of samples analyzed as part of the original investigation within the proposed EW OU study boundary, dredged samples are not removed
b Sample count does not include samples from the 0-10cm horizon.
c Samples were collected from 43 locations. Unhomogenized sediment for volatile organic compound (VOC) analysis was given a unique sample identifier, different than the homogenized sample submitted for other chemical analyses.
SMS – polychlorinated biphenyls (PCBs), semivolatile organic compounds (SVOCs), VOCs, and metals: arsenic, cadmium, chromium, copper, lead, mercury, silver, zinc, total organic carbon (TOC), and grain size.
DMMP – PCBs, pesticides, SVOCs, tributyltin (TBT), metals (antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc), TOC, and grain size.
PDM – post-dredge monitoring
PSP – post-sand placement
z-samples – samples collected at depth prior to dredging to characterize the new (post-dredge) sediment surface (results discussed in Appendix D).

3.2.1.3 Fish and Shellfish Tissue

Tissue chemistry data for the study area are available for six fish species and one species each of crab and mussels collected as part of several sampling events conducted since 1995. Data from five events, for a total of 59 samples of fish and shellfish tissue were considered appropriate for use in the SRI, as listed in Table 3-2. Collection locations for fish tissue and shellfish samples are shown on Figure 3-5.

Table 3-2
Summary of East Waterway Tissue Datasets Used for the SRI/FS

Study	Collection Year	Species	Sample Count	Individuals per Sample	Sample Type
East Waterway, Harbor Island Superfund site: Tissue chemistry results (Windward 2006a)	2005	English sole	6	5	skinless fillet
			2	5	remainder
		rockfish	2	1	whole-body
		sand sole	6	1	whole-body
		shiner surfperch	3	6 to 8	whole-body
East Waterway, Harbor Island Superfund site: Tissue chemistry results for juvenile Chinook salmon (Windward 2002a)	2002	Chinook salmon	6	7 to 8	whole body
Waterway Sediment Operable Unit (WSOU) Harbor Island Superfund site – Assessing human health risks from the consumption of seafood (ESG 1999)	1998	striped perch	3	2 to 8	skinless fillet
		striped perch	3	2 to 8	skin-on fillet
		red rock crab	3	5	edible meat
King County CSO Water Quality Assessment (WQA) for the Duwamish River and Elliott Bay (King County 1999a)	1996 to 1997	mussels	22	50 to 100	edible meat
Elliott Bay/Duwamish River fish tissue investigation (Battelle 1996; Frontier Geosciences 1996)	1995	English sole	3	6 to 8	skinless fillet

3.2.1.4 Surface Water

EW surface water data are available from sampling events conducted for the King County Water Quality Assessment (WQA) (King County 1999a) and for two water quality monitoring (WQM) events conducted during dredging activities (Anchor and Windward 2005; SEA 2000). Data from the three events, for a total of 234 samples of surface water, were considered appropriate for use in the SRI, as listed in

Table 3-3. Sampling locations from the surface water events are shown on Figure 3-6.

Table 3-3
Summary of East Waterway Surface Water Datasets Used for the SRI/FS

Event Name	Reference Source	Sampling Dates	Collection Method	Total Samples Analyzed
King County Water Quality Assessment	King County 1999a	1996 to 1997	VanDorn or Niskin bottle	192
2000 EW Water Quality Monitoring	SEA 2000	2000	Niskin bottle	6
2005 EW Water Quality Monitoring	Anchor and Windward 2005	2004 to 2005	Niskin bottle	36

Sampling for the WQA was conducted in the vicinity of the Hanford CSO at three sampling locations, corresponding to the east and west banks and the center of the channel. Two depths were sampled at each location: 1 meter below the surface and 1 meter above the EW bottom (King County 1999a).

In 2000 and 2004 to 2005, WQM events were conducted during dredge events. Both dredge events collected water samples from within areas of elevated turbidity associated with the dredging activities as well as from ambient locations, which were at least 800 feet from the dredging activities. The chemistry samples collected from the ambient locations are considered relevant in the SRI. Samples collected from the ambient locations were selected because they were collected to characterize background conditions and were located outside of the area potentially affected by the dredging activities. Samples collected within the turbidity plume were representative of conditions associated with dredging activities and likely contained suspended particulates resulting from dredging activities, and thus are excluded from the SRI dataset.

3.2.1.5 Porewater

A porewater chemistry dataset was compiled from all sampling events considered appropriate for use in the EW SRI/FS. This dataset includes all sediment sampling events conducted since 1990. The criteria for including porewater in the dataset were the same as those discussed previously for sediment, because porewater samples are extracted from the sediment samples. The porewater samples included in the dataset are listed in Table 3-1. The locations of the porewater samples are shown in Figure 3-7. Porewater samples associated with dredged sediments will not be presented in Section 3.3.4. The porewater data associated with dredged sediments are presented in Appendix C.

3.2.2 Data Suitability

There are several factors to consider in assessing the suitability of environmental data for risk assessments (EPA 1989a, 1989b, 1992). These factors are also relevant for determining the adequacy of existing data for nature and extent considerations. Of primary importance is the degree to which the data adequately represent site-related chemical concentrations. Also important to consider are the data quality criteria goals, age of the data, and the source, documentation, analytical methods/detection limits, and level of review associated with the data. Because data from many different investigations were available for the EW, the factors described above had to be evaluated for each dataset to determine whether it was reasonable to combine all data for use in the SRI. A detailed review of the data quality for all of the existing datasets is provided in Appendix F. Very few data were rejected due to failure to meet DQOs. No comparative or statistical methods were used to salvage data that failed to meet DQOs. The removal of these data does not substantially change the dataset.

3.2.3 Data Reduction

Data reduction refers to methods used to aggregate raw data received from the laboratory for use in the SRI. A detailed discussion of the data reduction methods is presented in Appendix E, and briefly summarized as follows:

- Chemical concentrations obtained from the analysis of laboratory duplicates or replicates (i.e., two or more analyses of the same sample) were averaged for a closer representation of the "true" concentration as compared to the results of a single analysis.
- Field duplicates, which are discrete samples collected simultaneously at a single sampling location that were submitted to the laboratory as individual samples

and analyzed separately were averaged and evaluated as a single sample, as outlined in Appendix E.

- In some instances, the laboratory generated more than one result for a chemical for a given sample if reanalysis was conducted or if two different analytical methods were used for that chemical. The procedures for selecting the best result are described in Appendix E.
- The precision of each result was stored in the project database by recording the number of significant figures assigned by the laboratory. Significant figures were tracked according to methods described in Appendix E.
- Total polychlorinated biphenyls (PCBs), total dichloro-diphenyl-trichloroethanes (DDTs), total polycyclic aromatic hydrocarbons (PAHs), and total chlordane were calculated by summing the detected concentrations for the individual components. The individual components of each calculated sum are provided in Appendix E. For samples in which none of the individual components were detected, the total concentration was given a value equal to the highest reporting limit (RL) for an individual component and assigned a U-qualifier, indicating the lack of detected concentrations.
- Results from locations sampled at different times (e.g., sampled annually as part of monitoring events) were averaged in order to graphically present a single result on the figures. Locations with averaged results are identified in the figures, and all data are presented in text boxes on the figure.

3.3 Summary of Existing Data

This section compiles all recent (post-1990) sediment and toxicity testing (bioassay), fish tissue chemistry data, and water chemistry data collected in the EW. This data will be used to develop baseline datasets for the SRI, BERA, and HHRA.

3.3.1 Sediment Chemistry Data

The EW has been the subject of several intensive sediment investigations in recent years (Table 3-1). The studies conducted since 1990 are summarized in the Data Summary Report completed for EPA in 2003 (Windward 2003c). The majority of sediment samples collected in the EW were part of the T-18 sediment characterization (EVS 1998) and the EW Stage 1 channel deepening characterization (SAIC 1999b). Both studies were conducted under DMMP oversight and included the collection of subsurface (0-4ft and >4ft) sediment samples. A significant portion of this sediment has been removed and the data associated with dredged sediment are described in Appendix C. DMMP compositing protocols are designed to provide an estimate of the average sediment concentration within the dredged management unit. The 0-4ft and >4ft composites are not particularly useful for the purposes of describing nature and extent in the SRI because they do not represent surface conditions. They can be used to determine potential analytes of concern and sampling frequency in areas where additional data will be collected.

For each sediment investigation, the number of samples originally collected, as well as the subset of samples associated with material that has been dredged, are presented in Table 3-1. All data presented in Section 3.3 represents non-dredged sediments. Studies conducted for reasons other than dredge material characterization also included sediment cores, but most of these studies focused on the collection of surface sediment samples (0-10cm) using a van Veen grab sampler. Three recent sampling events have been conducted since the 2003 Data Summary Report involving the collection and analysis of surface sediment samples (Windward 2003c). In addition, post-dredge monitoring was conducted following the completion of the Phase 1 Removal Action in 2005 (Anchor and Windward 2005) and the completion of dredging and post-dredge monitoring in Slip 36 also in 2005 (Hart Crowser 2005). Table 3-2 summarizes the sediment investigations conducted in the EW.

In the following sections, the results are presented for each sediment depth horizon, 0-10cm, 0-4ft, and >4ft. The spatial distribution of the locations of sediment samples are discussed in Section 3.3.1.1, analytical summaries with comparison to the corresponding standards are discussed in Section 3.3.1.2, and bioassay results discussed in Section 3.3.2.

3.3.1.1 Spatial Distribution

This section describes the spatial distribution and density of sampling locations for each depth horizon. Sampling locations are presented in Figures 3-2, 3-3, and 3-4. The locations are identified with a unique location number. Each location number may be associated with one or more unique samples. The samples associated with each location number are identified in Tables B-1 to B-3 of Appendix B. The section only presents the sample locations that are representative of current conditions. Samples that have been dredged are discussed in Section 3.3.1.2.4 and are presented on Figure A-1.

3.3.1.1.1 Surface Sediment (0-10cm) Results

Fourteen investigations have collected surface sediment (0-10 cm) samples in the EW, for a total of 287 samples. These sediment samples have been collected as part of post-dredge monitoring or nature and extent of contamination investigations. Nearly all of the surface sediment sampling locations are still considered relevant and representative of current conditions. Only 32 surface samples represent areas that have been dredged, and 34 samples were collected as part of the recontamination monitoring sampling events in 2006 and 2007 in locations with contingency dredging and sand placement in the Phase 1A Removal Action, leaving 221 samples considered for use in the EW SRI/FS dataset. The data quality for these 221 samples is discussed in Appendix F. These 221 samples cover a range of sampling depths: two samples were collected from 0-1cm, 32 samples were collected from 0-2cm, and 187 samples were collected from 0-10cm. There is no information available on the typical depth of the biotic zone in the sediments of EW.

3.3.1.1.2 Subsurface Sediment (0-4ft) Results

Sixteen investigations have collected subsurface sediment (0-4ft) samples in the EW, for a total of 280 samples. These sediment samples have typically been collected for dredge material characterization, so more than half of these samples have since been removed because of dredge activities. The locations for the remaining 118 non-dredged samples from 84 locations are shown on Figure 3-3. Subsurface samples have been collected throughout the EW at 0-4ft with the highest density of remaining locations in two areas in the southern half of the EW from Station 3800 to 4400 and from Station 5000 to 5800. Two recent dredging events, the 2004 to 2005 Phase 1 Removal Action and the USCG 2005 dredging and Berth Alpha rebuild, have removed the sediment associated with all of the 0-4ft samples in these areas (Figure 3-3). Dredging currently scheduled for December 2008 in front of T-30 will remove an additional eight 0-4ft samples.

Most of the 0-4ft samples are composite samples collected for the purposes of dredge material characterization (105 samples). In addition, 14 locations were sampled for 0-4ft cores that were analyzed in segmented intervals (e.g., four 1-foot interval samples or two 2-foot interval samples).

3.3.1.1.3 Subsurface Sediment (>4ft) Results

Eight investigations have collected subsurface sediment (>4ft) samples, for a total of 90 samples in the EW. These sediment samples have typically been collected for dredge characterization, so more than half of these samples have since been removed. There are significantly fewer >4ft samples relative to the 0-10cm and 0-4ft samples. The locations for the remaining 37 non-dredged samples from 32 locations are shown on Figure 3-4. Subsurface samples have been collected at depths greater than 4 feet throughout the EW with the highest density of remaining locations in two areas in the southern half of the EW from Station 3800 to 4400 and from Station 5000 to 5800. Two recent dredging events, the 2004 to 2005 Phase 1 Removal Action and the USCG 2005 dredging and Berth Alpha rebuild, have removed all of the sediment associated with the >4ft samples in these areas (Figure 3-4). Two >4ft samples located off of T-30 will be removed during the planned T-30 dredging currently scheduled for December 2008. There is a range of depths represented by the >4ft cores that varies depending on the depth to which the dredging was planed. Twenty of the 37 total samples were collected to depths of 11 feet of sediment or less, with a minimum of 6 feet of sediment. Ten composites were collected to depths of 12 feet (five samples) and 13 feet (five samples). The remaining seven samples were collected to the following depths with one sample at each depth: 14, 15, 16, 18, 20, 26, and 34 feet.

3.3.1.2 Chemistry

This section summarizes the analytical results for each depth horizon. In the following sections the results are presented in terms of the number of discreet samples. When the data are presented graphically in figures, points represent locations, not samples. In several cases, multiple samples were collected at the same location either as intervals in a sediment core or by resampling an existing station. In cases where multiple samples were collected at a location, the individual samples are summarized in the tables and the location is represented by the average of the reported concentrations on the figures (this occurs on every chemistry figure except for Figure 3-13). The locations where multiple samples have been averaged are indicated on the figures. Whenever an exceedance is reported for an averaged location, the individual sample results are also presented. A detailed discussion of the hierarchical approach used in averaging laboratory replicates and field duplicates as well as multiple samples at a location is presented in Appendix E. In addition, a summary of the number of samples collected at each location is presented in Tables B-1 to B-3 of Appendix B.

Sediment chemistry results were compared to the Washington State Sediment Management Standards (SMS; Washington Administrative Code [WAC] 173-204) SQS, and Cleanup Screening Level (CSL). These values are presented in Table 3-4. For chemicals without SMS criteria, sample concentrations are compared to the DMMP guidelines (USACE et al. 2000), the screening level (SL), and the maximum level (ML). Several organic chemicals have SMS criteria that are based on organic carbon normalized concentrations (i.e., PAHs, PCBs, and phthalates). Results for these chemicals in samples with TOC concentrations below 0.5 percent or greater than 4.0 percent were not organic carbon normalized consistent with guidelines on normalization using TOC results outside this range (Windward 2006c). Samples with no TOC data were not organic carbon normalized. The concentrations associated with samples with either no TOC or out-of-range TOC samples were compared to the dry weight lowest apparent effects threshold (LAET) and the second lowest AET (2LAET) values presented in Table 3-5. A list of the 42 samples that were compared to AET values is presented in Table B-16 of Appendix B. In the following tables and on the figures, exceedance of the LAET value is presented as an SQS exceedance and exceedance of the 2LAET value is presented as a CSL exceedance.

Table 3-4
Sediment Management Regulatory Standards or DMMP Criteria for Chemicals of Interest

Chemical	Unit	SQS/SL	CSL/ML
Metals			
Antimony [a]	mg/kg dw	150 [a]	200 [a]
Arsenic	mg/kg dw	57	93
Cadmium	mg/kg dw	5.1	6.7
Chromium	mg/kg dw	260	270
Copper	mg/kg dw	390	390
Lead	mg/kg dw	450	530
Mercury	mg/kg dw	0.41	0.59
Nickel [a]	mg/kg dw	140 [a]	370 [a]
Silver	mg/kg dw	6.1	6.1
Zinc	mg/kg dw	410	960
Organometal (porewater)			
Tributyltin [a]	µg/L	0.15 [a]	NC
PAHs			
2-Methylnaphthalene	mg/kg OC	38	64
Acenaphthene	mg/kg OC	16	57
Acenaphthylene	mg/kg OC	66	66
Anthracene	mg/kg OC	220	1,200
Benzo(a)anthracene	mg/kg OC	110	270
Benzo(a)pyrene	mg/kg OC	99	210
Benzo(g,h,i)perylene	mg/kg OC	31	78
Total benzofluoranthenes	mg/kg OC	230	450
Chrysene	mg/kg OC	110	460
Dibenzo(a,h)anthracene	mg/kg OC	12	33
Dibenzofuran	mg/kg OC	15	58
Fluoranthene	mg/kg OC	160	1,200
Fluorene	mg/kg OC	23	79
Indeno(1,2,3-cd)pyrene	mg/kg OC	34	88
Naphthalene	mg/kg OC	99	170
Phenanthrene	mg/kg OC	100	480
Pyrene	mg/kg OC	1,000	1,400
Total HPAH	mg/kg OC	960	5,300
Total LPAH	mg/kg OC	370	780
Phthalates			
Bis(2-ethylhexyl) phthalate	mg/kg OC	47	78
Butyl benzyl phthalate	mg/kg OC	4.9	64
Diethyl phthalate	mg/kg OC	61	110
Dimethyl phthalate	mg/kg OC	53	53
Di-n-butyl phthalate	mg/kg OC	220	1,700
Di-n-octyl phthalate	mg/kg OC	58	4,500
Other SVOCs			
1,2,4-Trichlorobenzene	mg/kg OC	0.81	1.8
1,2-Dichlorobenzene	mg/kg OC	2.3	2.3
1,3-Dichlorobenzene [a]	µg/kg dw	170 [a]	NC

Chemical	Unit	SQS/SL	CSL/ML
1,4-Dichlorobenzene	mg/kg OC	3.1	9.0
2,4-Dimethylphenol	µg/kg dw	29	29
2-Methylphenol	µg/kg dw	63	63
4-Methylphenol	µg/kg dw	670	670
Benzoic acid	µg/kg dw	650	650
Benzyl alcohol	µg/kg dw	57	73
Hexachloroethane [a]	µg/kg dw	1,400 [a]	14,000 [a]
Hexachlorobenzene	mg/kg OC	0.38	2.3
Hexachlorobutadiene	mg/kg OC	3.9	6.2
n-Nitrosodiphenylamine	mg/kg OC	11	11
Pentachlorophenol	µg/kg dw	360	690
Phenol	µg/kg dw	420	1,200
PCBs			
Total PCBs	mg/kg OC	12	65
Pesticides			
Total DDTs [a]	µg/kg dw	6.9 [a]	69 [a]
Aldrin [a]	µg/kg dw	10 [a]	NC
Alpha-chlordane [a]	µg/kg dw	10 [a]	NC
Dieldrin [a]	µg/kg dw	10 [a]	NC
Heptachlor [a]	µg/kg dw	10 [a]	NC
VOCs			
Trichloroethene [a]	µg/kg dw	160 [a]	1,600 [a]
Trichloroethene [a]	µg/kg dw	57 [a]	210 [a]
Ethylbenzene [a]	µg/kg dw	10 [a]	50 [a]
Total xylenes [a]	µg/kg dw	40 [a]	160 [a]

a DMMP criteria
µg/kg – micrograms per kilogram
CSL – cleanup screening level
dw – dry weight
mg/kg – milligrams per kilogram
ML – maximum level
NC – no criteria; no CSL/ML is available for this chemical
SL – screening level
SMS – Washington State Sediment Management Standards
SQS – Sediment Quality Standards

Table 3-5
Dry Weight LAET Value Alternates for Chemicals with Organic Carbon-Normalized SMS Criteria

Chemical	Concentration (µg/kg dw)	
	LAET	2LAET
PAHs		
2-Methylnaphthalene	670	1,400
Acenaphthene	500	730
Acenaphthylene	1,300	1,300
Anthracene	960	4,400
Benzo(a)anthracene	1,300	1,600
Benzo(a)pyrene	1,600	3,000
Benzo(g,h,i)perylene	670	720
Total benzofluoranthenes	3,200	3,600
Chrysene	1,400	2,800
Dibenzo(a,h)anthracene	230	540
Dibenzofuran	540	700
Fluoranthene	1,700	2,500
Fluorene	540	1,000
Indeno(1,2,3-cd)pyrene	600	690
Naphthalene	2,100	2,400
Phenanthrene	1,500	5,400
Pyrene	2,600	3,300
Total HPAH	12,000	17,000
Total LPAH	5,200	13,000
Phthalates		
Bis(2-ethylhexyl) phthalate	1,300	1,900
Butyl benzyl phthalate	63	900
Diethyl phthalate	200	1,200
Dimethyl phthalate	71	160
Di-n-butyl phthalate	1,400	5,100
Di-n-octyl phthalate	6,200	NC
Other SVOCs		
1,2,4-Trichlorobenzene	31	51
1,2-Dichlorobenzene	35	50
1,4-Dichlorobenzene	110	120
Hexachlorobenzene	22	70
Hexachlorobutadiene	11	120
n-Nitrosodiphenylamine	28	40
PCBs		
Total PCBs	130	1,000

µg/kg dw – micrograms per kilogram dry weight
2LAET – second lowest apparent effects threshold
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LAET – lowest apparent effects threshold
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
NC – no criteria; there is no 2LAET value for this chemical

PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound

The primary criterion for selecting chemicals for mapping was the number of CSL exceedances. Chemicals that had five or more CSL exceedances in the 0-10cm and 0-4ft sediment horizons were mapped. For the >4ft horizon, chemicals with two or more exceedances were mapped because there are so few exceedances of the CSL in that sediment depth horizon. For all three depth horizons, TBT was mapped both by sediment concentration ranges and as porewater concentrations compared to the SL. A discussion of the non-detected results with RLs above the SMS and DMMP values is presented in Section 3.3.1.2.4.

The sample identification information corresponding to each sampling location number as well as the number of samples collected at each location and the number of samples collected in each sediment horizon are presented in Tables B-1 to B-3 of Appendix B. The chemical summary tables present results for all analytes that were detected at concentrations above the SMS or DMMP values in at least one sample. The detection frequencies for each chemical in each sediment horizon have also been calculated and are presented in Appendix B. The complete sediment chemistry dataset for all samples and sediment horizons is available in Appendix B.

3.3.1.2.1 Surface Sediment (0-10cm) Results

In the 0-10cm sediment horizon, surface sediment samples have been analyzed for a variety of SMS or DMMP chemicals. Table 3-6 summarizes the chemicals that have been detected in EW sediments exceeding either the SMS criteria or DMMP guidelines. The exceedances of SMS criteria for each location are presented in Figure 3-8. The total number of chemicals exceeding the SQS and CSL in the surface sediment are presented on Figures 3-9 and 3-10, respectively. The areas in the EW with the most exceedances of both the SQS and CSL are located on the eastern side of the EW from Station 3800 to 5000 and at Station 200, also towards the east. Detected sediment concentrations of total PCBs, indeno(1,2,3-cd)pyrene, acenaphthene, bis(2-ethylhexyl)phthalate (BEHP), and mercury were selected for mapping because detected concentrations exceeded the corresponding CSL at least five times in the 0-10cm horizon (Figures 3-11 through 3-13, 3-15, and 3-16). In cases where exceedances were reported for locations with multiple samples, the data for each individual sample is provided on the figure.

Table 3-6
Summary of Detected Chemicals with Exceedances in the Surface (0-10cm) Sediment Horizon

Chemical	Units	Detection Frequency (DF)	DF %	Minimum Detect	Maximum Detect	Number of Detected SQS/SL Exceedances	Number of Detected CSL /ML Exceedances
Metals							
Arsenic	mg/kg dw	90/127	71	3.44	241	2	2
Cadmium	mg/kg dw	103/118	87	0.126	6.08	2	0
Lead	mg/kg dw	127/127	100	5.0	519	1	0
Mercury	mg/kg dw	173/175	99	0.053	10.9	80	36
Zinc	mg/kg dw	127/127	100	25.3 J	1,103	17	1
TBT							
TBT (sediment)	µg/kg dw	26/26	100	1.6 J	6,000	n/a	n/a
TBT (porewater)	µg/L	48/69	70	0.019 J	28	19	n/a
PAHs							
2-Methylnaphthalene	mg/kg OC	70/152	46	0.79 J	19	1	0
Acenaphthene	mg/kg OC	95/152	62	0.78 J	340	15	7
Anthracene	mg/kg OC	135/152	89	0.75	230	2	1
Benzo(a)anthracene	mg/kg OC	143/152	94	0.93	250 J	9	2
Benzo(a)pyrene	mg/kg OC	143/152	94	1.1	280 J	8	2
Benzo(g,h,i)perylene	mg/kg OC	124/152	82	1.3	160 J	5	2
Benzofluoranthenes (total-calc'd)	mg/kg OC	146/152	96	1.1	500 J	9	4
Chrysene	mg/kg OC	148/152	97	1.1	330	11	1
Dibenzo(a,h)anthracene	mg/kg OC	88/152	58	0.90 J	65 J	13	3
Dibenzofuran	mg/kg OC	71/152	47	0.86	250	9	3
Fluoranthene	mg/kg OC	151/152	99	1.9	740	17	3
Fluorene	mg/kg OC	100/152	66	0.75	360	11	3
Indeno(1,2,3-cd)pyrene	mg/kg OC	125/152	82	1.4	160 J	14	5
Phenanthrene	mg/kg OC	148/152	97	1.1	1,000	15	3
Pyrene	mg/kg OC	151/152	99	2.0	550 J	2	2
Total HPAH (calc'd)	mg/kg OC	151/152	99	3.9	2,800 J	13	2
Total LPAH (calc'd)	mg/kg OC	148/152	97	1.1	1,900	8	3
Carcinogenic PAHs	µg/kg dw	148/152	97	18	38,000 J	n/a	n/a
Phthalates							
Bis(2-ethylhexyl)phthalate	mg/kg OC	122/139	88	1.3	620	18	8
Butyl benzyl phthalate	mg/kg OC	41/138	30	0.56 J	15	6	0
Other SVOCs							
1,2,4-Trichlorobenzene	mg/kg OC	28/163	17	0.092 J	160 J	10	4
1,4-Dichlorobenzene	mg/kg OC	78/163	48	0.11 J	45	20	4
2,4-Dimethylphenol	µg/kg dw	4/139	3	6.8	90 J	1	1
Benzoic acid	µg/kg dw	13/130	10	76 J	728	1	1
N-Nitrosodiphenylamine	mg/kg OC	2/124	2	2.1 J	2.1 J	1	1
Phenol	µg/kg dw	54/139	39	13 J	3,330	10	4
Polychlorinated Biphenyls							
PCBs (total calc'd)	mg/kg OC	171/176	97	0.58 J	860	151	26

Chemical	Units	Detection Frequency (DF)	DF %	Minimum Detect	Maximum Detect	Number of Detected SQS/SL Exceedances	Number of Detected CSL /ML Exceedances
Pesticides							
DDTs (total-calc'd)	µg/kg dw	12/127	9	3.0	62.0 J	9	0
Heptachlor	µg/kg dw	2/72	3	1.5 JN	10.2	1	n/a

a SMS criteria is not available for this chemical; sample concentrations are compared to DMMP criteria
J – estimated value
N – tentative identification and estimated value
n/a – not applicable
shaded cell indicates that the chemical is presented on a figure

Metals

Five metals were detected exceeding SMS criteria at least once (Table 3-6): arsenic, cadmium, lead, mercury, and zinc. The greatest number of samples with concentrations above the SQS and CSL was reported for mercury (80 samples above SQS, 36 samples above CSL) (Table 3-6). Most of the samples with mercury CSL exceedances were located from Station 3600 to 5000 in the middle and eastern portion of the EW (Figure 3-11).

SVOCs

While a number of SVOCs exceeded SMS in at least one location, only three exceeded the CSL in at least five samples (Table 3-6). The only PAHs with sediment concentrations above the CSL in at least five samples were acenaphthene and indeno(1,2,3-c,d)pyrene. Half of the acenaphthene SQS and CSL exceedances were reported for samples from Station 0 to 200 on the eastern side of the EW (Figure 3-12). Indeno(1,2,3-c,d)pyrene concentrations exceeded both the SQS and CSL in at Station 200 and from Station 4000 to 4400 on the eastern side of the EW (Figure 3-13). The sediment carcinogenic PAH (cPAH) concentrations are presented in Figure 3-14. The cPAH concentrations were calculated as benzo(a)pyrene equivalents with potency equivalency factors (PEFs) from CalEPA (1994).

BEHP concentrations exceeded the SQS in 18 samples, and 8 detected concentrations also exceeded the CSL (Figure 3-15). Most of the samples with BEHP CSL exceedances were located from Station 3600 to 5000 in the middle and eastern portion of the EW. Summaries of other phthalates and SVOCs with detected values exceeding sediment quality values are presented in Table 3-6.

PCBs

Total PCBs were detected in nearly every surface sediment sample. Total PCB concentrations above the SQS were reported in 151 samples. Twenty-six samples contained total PCB concentrations above the CSL. PCB exceedances were found throughout the EW in the 0-10cm horizon. Most of the samples with PCB CSL exceedances were located from Station 3600 to 5000 in the middle and eastern portion of the EW and from Station 1600 to 1800 in the middle and northern portion of the EW (Figure 3-16).

TBT

TBT was analyzed in both sediment and porewater. TBT was detected in all 26 sediment samples in the 0-10cm depth horizon, with concentrations ranging from 1.6 to 6,000 µg/kg dw. TBT was detected in more than half of the porewater samples analyzed; however, only 19 samples exceeded the SL. Figure 3-17 presents concentration ranges of TBT analyzed in sediment and porewater concentrations relative to the SL. TBT concentrations above 100 µg/kg dw are found in discrete locations throughout the EW, whereas TBT concentration exceeding the SL are located in the northern portion of the EW from Station 0 to 2000 and in the southern portion from Station 5400 to 5600.

3.3.1.2.2 Subsurface Sediment (0-4ft) Results

In the 0-4ft sediment horizon, subsurface sediment samples have been analyzed for a range of chemicals. Table 3-7 summarizes the chemicals that have been detected in the EW exceeding either the SMS criteria or DMMP values. The exceedances of SMS criteria for each location are presented in Figure 3-18. The total number of chemicals exceeding the SQS and CSL in the subsurface (0-4ft) sediment are presented on Figures 3-19 and 3-20, respectively. The areas in the EW with the most exceedances of both the SQS and CSL are located on the eastern side of the EW from Station 3800 to 5000, and at Station 200, also towards the east. Detected sediment concentrations of total PCBs, total HPAH, acenaphthene, BEHP, and cadmium, mercury, silver, and zinc were selected for mapping based on sediment concentrations above the CSL in at least 5 samples. Figures 3-21 through 3-26, 3-28, and 3-29 illustrate the locations where SQS and CSL exceedances were seen for these chemicals in the 0-4ft sediment horizon. In cases where exceedances were reported for locations with multiple samples, the data for each individual sample is provided on the figure.

Table 3-7
Summary of Detected Chemicals with Exceedances in the Subsurface (0-4ft) Sediment Horizon

Parameter	Unit	Detection Frequency (DF)	DF %	Minimum Detect	Maximum Detect	Number of Detected SQS/SL Exceedances	Number of Detected CSL/ML Exceedances
Metals							
Arsenic	mg/kg dw	101/113	89	1.5	96	1	1
Cadmium	mg/kg dw	96/113	85	0.04	91.9	10	7
Copper	mg/kg dw	113/113	100	8.6	655	2	2
Lead	mg/kg dw	110/113	97	0.19	744	1	1
Mercury	mg/kg dw	102/115	89	0.01 J	2.03	58	38
Silver	mg/kg dw	81/109	74	0.2 J	10	5	5
Zinc	mg/kg dw	113/113	100	20.9	16,100	17	5
TBT							
TBT (porewater)	µg/L	41/51	80	0.040	0.83	17	n/a
TBT (sediment)	mg/kg dw	34/54	63	0.40 JN	21,000	n/a	n/a
PAHs							
2-Methylnaphthalene	mg/kg OC	50/111	45	0.56 J	33	4	2
Acenaphthene	mg/kg OC	74/111	67	0.78	55	14	7
Acenaphthylene	mg/kg OC	46/111	41	0.44 J	5.3 J	1	1
Anthracene	mg/kg OC	96/111	86	1.2 J	100	7	2
Benzo(a)anthracene	mg/kg OC	100/111	90	1.8	130	11	7
Benzo(a)pyrene	mg/kg OC	99/111	89	1.7 J	91 J	7	5
Benzo(g,h,i)perylene	mg/kg OC	95/111	86	0.74	50 J	8	6
Benzofluoranthenes (total-calc'd)	mg/kg OC	102/111	92	1.9 J	250	10	8
Chrysene	mg/kg OC	101/111	91	1.4	160	13	8
Dibenzo(a,h)anthracene	mg/kg OC	74/111	67	0.79	27 J	6	2
Dibenzofuran	mg/kg OC	66/111	59	0.63 J	34	6	3
Fluoranthene	mg/kg OC	103/111	93	2.0	470	20	11
Fluorene	mg/kg OC	82/111	74	0.36 J	63	10	3
Indeno(1,2,3-cd)pyrene	mg/kg OC	94/111	85	0.85	50	9	8
Naphthalene	mg/kg OC	79/111	71	0.37 J	64	2	2
Phenanthrene	mg/kg OC	102/111	92	1.3	380	9	3
Pyrene	mg/kg OC	106/111	95	1.8 J	630	10	9
Total HPAH	mg/kg OC	107/111	96	1.8 J	1,600	16	9
Total LPAH	mg/kg OC	103/111	93	1.6 J	640 J	9	4
Carcinogenic PAHs	µg/kg dw	102/111	92	18 J	23,000	n/a	n/a
Phthalates							
Bis(2-ethylhexyl)phthalate	mg/kg OC	82/111	74	1.4	190	32	18

Parameter	Unit	Detection Frequency (DF)	DF %	Minimum Detect	Maximum Detect	Number of Detected SQS/SL Exceedances	Number of Detected CSL/ML Exceedances
Butyl benzyl phthalate	mg/kg OC	34/111	31	0.63	7.3	9	0
Dimethyl phthalate	mg/kg OC	3/111	3	2.5	2.9	1	1
Other SVOCs							
1,2-Dichlorobenzene	mg/kg OC	3/112	3	0.13 J	0.13 J	1	1
1,4-Dichlorobenzene	mg/kg OC	19/112	17	0.039	16	5	3
2,4-Dimethylphenol	µg/kg dw	3/111	3	14	1,400	2	2
2-Methylphenol	µg/kg dw	1/111	1	620	620	1	1
4-Methylphenol	µg/kg dw	34/111	31	6.6 J	2,000	2	2
Phenol	µg/kg dw	34/111	31	13 J	620	1	0
PCBs							
Total PCBs	mg/kg OC	103/115	90	0.56 J	240	80	32
Pesticides							
Total DDTs	µg/kg dw	23/113	20	2.3	1,600	20	9
Dieldrin	µg/kg dw	6/83	7	7.4	23	4	n/a
Total chlordane	µg/kg dw	3/82	4	11	50	3	n/a
VOCs							
Ethylbenzene	µg/kg dw	8/62	13	1.0 J	24	1	0
Total xylenes	µg/kg dw	10/62	16	1.3 J	56 J	1	0

J – estimated value
N – tentative identification at estimated concentration
n/a – no criteria value available
shaded cell indicates that the chemical is presented on a figure

Metals

Seven metals were detected exceeding SMS criteria at least once (Table 3-7): arsenic, cadmium, copper, lead, mercury, silver, and zinc. Of these metals, cadmium, mercury, silver, and zinc exceeded the CSL in at least five samples. Cadmium concentrations exceeded the SQS in 10 samples, with seven sample concentrations above the CSL. Cadmium only exceeded criteria from Station 3800 to 4400 on the eastern side of the EW (Figure 3-21).

Mercury concentrations exceeded the SQS in 58 samples, with 38 sample concentrations above the CSL. Mercury exceedances were found throughout the EW in the 0-4ft sediment samples (Figure 3-22).

Silver concentrations exceeded the SQS and CSL in five samples. Sediment silver concentrations above the SQS and CSL were located in only four locations: on the easternmost portion of the EW at Stations 400, 4400, and 4800 and in the middle of the EW at Station 6000 (Figure 3-23).

Zinc concentrations exceeded the SQS for 17 samples. Five samples had zinc concentrations above the CSL. Zinc exceeded criteria primarily from Station 4400 to 4800 along the eastern side of the EW. Exceedances were found near the eastern side of the EW from Station 400 to 1000 (Figure 3-24).

SVOCs

All PAHs were detected and exceeded SMS values in at least one sample in the 0-4ft surface sediment horizon. Individual HPAHs exceeded the SQS values more often than individual LPAHs. The only LPAH to exceed the CSL in at least five samples was acenaphthene. Acenaphthene results compared to SMS criteria are presented on Figure 3-25. Acenaphthene exceeded the SQS and CSL primarily from Station 4400 to 5000 along the eastern side of the EW. Exceedances of the CSL were also found near the eastern side of the EW from Station 400 to 1000.

Each individual HPAH that are summed to calculate total HPAH exceeded the CSL at least five times. Instead of mapping each individual PAH, for simplicity only total HPAH is presented on Figure 3-26. Total HPAH concentrations exceeded the SQS in 16 samples; nine samples exceeded the CSL. Total HPAH exceeded the SQS and CSL from Station 4400 to 4800 along the eastern side of the EW. Exceedances of the CSL were also found near the eastern side of the EW from Station 400 to 1000. The sediment cPAH concentrations are presented on Figure 3-27.

BEHP concentrations exceeded the SQS in 32 samples, 18 of which also exceeded the CSL. Figure 3-28 presents the BEHP results compared to SMS criteria. As illustrated in Figure 3-28, BEHP exceedances were found throughout the EW in the 0-4ft horizon. Summaries of other phthalates and SVOCs with detected values exceeding criteria are presented in Table 3-7.

PCBs and Pesticides

Total PCB concentrations above the SQS were detected in 80 samples. Thirty-two of these samples had concentrations above the CSL. PCB concentrations above the SQS and CSL were reported throughout the EW in the 0-4ft sediment horizon (Figure 3-29). Detected total DDT concentrations were reported above the SL in 20 samples; nine samples had total DDT concentrations above the ML. The total DDT results were not mapped due to quality concerns with the pesticide data discussed in Section 3.3.1.2.5.

TBT

TBT was measured in 54 sediment samples in the 0-4ft depth. Thirty-four samples (63 percent) had detected concentrations ranging from 0.40 to 21,000 μg/kg dw. Figure 3-30 presents concentration ranges of TBT analyzed in sediment and porewater concentrations relative to the SL. Only three TBT concentrations above 100 μg/kg dw are found in discrete locations throughout the EW at Stations 1200 (west side), 4600 (east side), and 6500 (central). TBT concentrations exceeding the SL are located in the southern portion of the EW from Station 4800 to 5800 and along the eastern side of the EW from Station 3000 to 4400.

3.3.1.2.3 Subsurface Sediment (>4ft) Results

In the >4ft sediment horizon, subsurface sediment samples have been analyzed for a variety of SMS or DMMP chemicals. Table 3-8 summarizes the chemicals that have been detected in the EW exceeding either the SMS criteria or DMMP guidelines. The total number of chemicals exceeding the SQS and CSL in the subsurface (>4ft) sediment are presented on Figures 3-31 and 3-32, respectively. The areas in the EW with the most exceedances of both the SQS and CSL are located on the eastern side of the EW from Station 3800 to 5000 and at Station 200, also on the east side of the EW.

Multiple depth samples were collected for 24 core locations. In addition, there are 25 locations from which only a >4ft sample was collected. Figure 3-33 presents exceedance information for all locations with multiple depth intervals and all >4ft samples based on comparison to SMS.

Detected sediment concentrations of total PCBs and mercury exceed SMS criteria more than other chemicals by exceeding the CSL in at least two samples in the >4ft horizon. Figures 3-34 and 3-35 illustrate the locations where SQS and CSL exceedances were detected for these chemicals in the >4ft sediment horizon.

Table 3-8
Summary of Detected Chemicals with Exceedances in the Subsurface (>4ft) Sediment Horizon

Parameter	Unit	Detection Frequency (DF)	DF %	Minimum Detect	Maximum Detect	Number of Detected SQS/SL Exceedances	Number of Detected CSL/ML Exceedances
Metals							
Copper	mg/kg dw	37/37	100	12	730	1	1
Mercury	mg/kg dw	37/38	97	0.0035	0.755	8	3
Silver	mg/kg dw	28/37	76	0.026	6.5	1	1
TBT							
TBT (porewater)	µg/L	6/16	38	0.028 J	0.088	0	0
TBT (sediment)	µg/kg dw	0/1	0	-	-	n/a	n/a
PAHs							
Acenaphthene	mg/kg OC	19/36	53	1.9	23	2	0
Dibenzofuran	mg/kg OC	18/36	50	1.1	20	1	0
Carcinogenic PAHs	µg/kg dw	27/36	75	10 J	700 J	n/a	n/a
PCBs							
PCBs (total calc'd)	mg/kg OC	17/34	50	0.55 J	100	7	2
Pesticides							
DDTs (total-calc'd)	µg/kg dw	7/36	19	1.8	130	3	1

J – estimated
n/a – not applicable
shaded cell indicates that the chemical is presented on a figure

Metals

Copper, mercury, and silver were the only metals with detected concentrations above the SMS criteria in deeper subsurface sediment. Mercury concentrations exceeded the SQS in eight samples, of which three samples also exceeded the CSL. Figure 3-34 presents detected mercury concentrations in subsurface sediment as compared to SMS criteria. The mercury exceedances are located at discrete locations throughout the EW, but are generally within the navigation channel.

SVOCs

Only two PAHs, acenaphthene and dibenzofuran, were detected and exceeded SMS criteria in at least one subsurface sediment sample. BEHP was detected in

65 percent of subsurface sediment samples but none of these samples exceeded SMS criteria in any subsurface sediment sample analyzed for this chemical.

PCBs and Pesticides

PCBs were detected and exceeded the SQS in seven samples, of which two also exceeded the CSL. Figure 3-35 presents the PCB exceedances as compared to SMS criteria. As seen on the figure, PCB exceedances in the subsurface sediment horizon are located in the navigation channel from Station 5200 to 5400 and along the eastern side of the EW from Station 3200 to 4400. Detected total DDT concentrations were reported above the SL in three samples, with one detected concentration reported above the ML. The total DDT results were not mapped due to quality concerns with the pesticide data discussed in Section 3.3.1.2.5.

TBT

One subsurface sediment sample was analyzed for TBT, which was not detected in the sample. Sixteen subsurface porewater samples were analyzed for TBT. TBT was detected in six samples, with no concentrations above the SL. One sample had a non-detected result with an RL (1 µg/L) above the SL (0.15 µg/L).

3.3.1.2.4 Dredged Sediment

As a federally authorized navigation channel, the EW has been dredged for berth and channel deepening and maintenance. For this reason, many of the sediment characterization investigations within the EW have been focused on collecting data required for maintenance navigation dredging projects. A significant portion of these dredge characterization sediment samples have subsequently been dredged, as well as samples collected from other investigations that were either in the vicinity of the dredge event or conducted prior to the dredge investigation. Table 3-1 presented the number of samples that have been dredged from each sampling event conducted since 1990. Table 3-9 summarizes the results of those dredged samples. These samples are no longer representative of current conditions, but they are useful for characterizing historical conditions in the EW.

Table 3-9
Summary of Chemicals with SMS and/or DMMP Criteria in East Waterway Dredged Sediments

Chemical	Units	Detection Frequency (DF)	DF (%)	Minimum Detect	Maximum Detect	Number of Detected SQS/SL Exceedances	Number of Detected CSL/ML Exceedances
Metals and Trace Elements							
Antimony [a]	mg/kg dw	99/166	60	0.09 J	73	0	0
Arsenic	mg/kg dw	180/192	94	1.9 J	96	2	1
Cadmium	mg/kg dw	170/179	95	0.059 J	7.9	9	3
Chromium	mg/kg dw	36/36	100	10.1	83.3	0	0
Copper	mg/kg dw	184/192	96	11.3	749	2	2
Lead	mg/kg dw	188/192	98	2.1 J	680	4	3
Mercury	mg/kg dw	187/198	94	0.029	12.7	83	54
Nickel [a]	mg/kg dw	185/188	98	3.3	82 J	0	0
Silver	mg/kg dw	111/179	62	0.13	12	4	4
Zinc	mg/kg dw	192/192	100	19.8	840	15	0
PAHs							
2-Methylnaphthalene	mg/kg OC	121/201	60	0.52 J	280	16	8
Acenaphthene	mg/kg OC	151/202	75	1.2	440	27	11
Acenaphthylene	mg/kg OC	59/202	29	0.74 J	20	1	1
Anthracene	mg/kg OC	176/202	87	1.9 J	190	6	4
Benzo(a)anthracene	mg/kg OC	185/202	92	1.7	390	9	6
Benzo(a)pyrene	mg/kg OC	183/202	91	2.1	260	10	6
Benzo(g,h,i)perylene	mg/kg OC	163/202	81	1.8	64	8	4
Benzofluoranthenes (total-calc'd)	mg/kg OC	183/202	91	2.2	420	9	5
Chrysene	mg/kg OC	188/202	93	1.8	390	11	5
Dibenzo(a,h)anthracene	mg/kg OC	95/202	47	0.80	24	10	2
Dibenzofuran	mg/kg OC	125/202	62	0.91	440	15	8
Fluoranthene	mg/kg OC	193/202	96	2.1	1,700	24	9
Fluorene	mg/kg OC	167/202	83	1.5	500	25	10
Indeno(1,2,3-cd)pyrene	mg/kg OC	170/202	84	0.75	62 J	12	5
Naphthalene	mg/kg OC	159/202	79	1.3	520	4	3
Phenanthrene	mg/kg OC	193/202	96	1.5	1,300	22	6
Pyrene	mg/kg OC	195/202	97	2.9	1,300	9	7
Total HPAH	mg/kg OC	195/202	97	4.6	4,300	14	5
Total LPAH	mg/kg OC	194/202	96	1.5	2,800	14	6
cPAHs	µg/kg dw	188/202	93	6.0	74,000	n/a	n/a
Phthalates							
Bis(2-ethylhexyl)phthalate	mg/kg OC	144/191	75	2.0	470 J	37	25
Butyl benzyl phthalate	mg/kg OC	32/188	17	1.0 J	230	9	1
Diethyl phthalate	mg/kg OC	1/186	1	2.5	2.5	0	0
Dimethyl phthalate	mg/kg OC	4/191	2	0.97 J	2.5	0	0
Di-n-butyl phthalate	mg/kg OC	29/191	15	0.71	45 J	0	0
Di-n-octyl phthalate	mg/kg OC	9/191	5	1.3	3.7 J	0	0
Other SVOCs							
1,2,4-Trichlorobenzene	mg/kg OC	11/191	6	0.252 J	2.3	5	2
1,2-Dichlorobenzene	mg/kg OC	8/182	4	0.050 J	0.47	1	1
1,3-Dichlorobenzene [a]	µg/kg dw	11/181	6	1.1	160	0	n/a
1,4-Dichlorobenzene	mg/kg OC	38/182	21	0.048	34 J	9	2
2,4-Dimethylphenol	µg/kg dw	6/184	3	49	210	6	6
2-Methylphenol	µg/kg dw	2/191	1	19 J	36	0	0
4-Methylphenol	µg/kg dw	39/191	20	8.0 J	190	0	0
Benzoic acid	µg/kg dw	1/132	1	555	555	0	0
Benzyl alcohol	µg/kg dw	3/180	2	16	150	2	2
Hexachlorobenzene	mg/kg OC	0/191	0	nd	nd	0	0

Chemical	Units	Detection Frequency (DF)	DF (%)	Minimum Detect	Maximum Detect	Number of Detected SQS/SL Exceedances	Number of Detected CSL/ML Exceedances
Hexachlorobutadiene	mg/kg OC	0/191	0	nd	nd	0	0
Hexachloroethane [a]	µg/kg dw	0/174	0	nd	nd	0	0
N-Nitrosodiphenylamine	mg/kg OC	0/191	0	nd	nd	0	0
Pentachlorophenol	µg/kg dw	0/164	0	nd	nd	0	0
Phenol	µg/kg dw	75/191	39	19	1,600	4	2
Polychlorinated Biphenyls							
PCBs (total calc'd)	mg/kg OC	199/224	89	0.89 J	380	150	35
Pesticides							
DDTs (total-calc'd) [a]	µg/kg dw	115/204	56	1.2	300	89	25
Aldrin [a]	µg/kg dw	68/196	35	1.5	44	25	n/a
Dieldrin [a]	µg/kg dw	83/200	42	1.3	140	49	n/a
gamma-BHC [a]	µg/kg dw	3/196	2	0.97	5.0	0	n/a
Heptachlor [a]	µg/kg dw	2/196	1	0.57	1.4	0	n/a
Total Chlordane (calc'd) [a]	µg/kg dw	31/193	16	2.3	100	21	n/a
Volatile Organic Compounds							
Ethylbenzene [a]	µg/kg dw	16/154	10	3.1	200	6	3
Tetrachloroethene [a]	µg/kg dw	0/154	0	nd	nd	0	0
Trichloroethene [a]	µg/kg dw	0/153	0	nd	nd	0	0
Total Xylenes [a]	µg/kg dw	24/152	16	1.3 J	290	6	3

a DMMP criteria
J – estimated
n/a - not applicable
nd - not detected

3.3.1.2.5 Evaluation of Reporting Limits Associated with Non-detected Results

Thirty-seven chemicals had non-detected results with RLs greater than the corresponding SMS and DMMP chemical criteria in at least one sediment sample in the EW sediment dataset. These chemicals can be divided into six groups: metals (1 chemical), PAHs (9 chemicals), phthalates (5 chemicals), other SVOCs (15 chemicals), pesticides (6 chemicals), and VOCs (1 chemical).

The sample-specific RL is based on the lowest point of the calibration curve associated with each analytical batch of samples. The most common reason for elevated RL values is sample extract dilution. For example, elevated RLs for some chemicals in some areas reflect the greater degree of analytical dilution required for quantification of other analytes, such as PCBs. In addition, there are analytes known to be analytically difficult to detect at criteria levels.

Arsenic is detected with a detection frequency of 71 percent in the 0-10cm sediment samples. However, one sample had an elevated RL above the SQS.

This is the only RL associated with metals and trace elements in the entire dataset that exceeds the SQS.

PAHs and phthalates were detected relatively frequently in surface sediments. For chemicals with at least one RL exceeding the SQS, the detection frequencies range from 46 to 82 percent for PAHs and from 0 to 88 percent for phthalates (Table 3-10). PAHs and phthalates were also detected relatively frequently in subsurface sediments, with detection frequencies ranging from 45 to 67 percent for PAHs and from 2 to 74 percent for phthalates for chemicals with at least one RL above the SQS. The majority of the RL values reported for these compounds were below the SQS and CSL chemical criteria. RLs greater than the SQS chemical criteria for PAHs and phthalates primarily resulted from analytical dilution of the sample extracts.

Table 3-10
Summary of PAHs and Phthalates with RL Values Above SMS Criteria
(mg/kg OC)

Parameter	Detection Frequency (DF)	DF %	Minimum RL	Maximum RL	Count RLs > SQS	Count RLs > CSL
0-10cm surface sediment						
PAHs						
2-Methylnaphthalene	70/152	46	0.51	200	1	1
Acenaphthene	95/152	62	0.51	200	1	1
Acenaphthylene	79/152	52	0.51	200	2	2
Benzo(g,h,i)perylene	124/152	82	0.51	200	2	2
Dibenzo(a,h)anthracene	88/152	58	0.51	200	9	5
Dibenzofuran	71/152	47	0.51	200	3	2
Fluorene	100/152	66	0.51	95	1	1
Indeno(1,2,3-cd)pyrene	125/152	82	0.51	200	2	2
Naphthalene	91/152	60	0.51	200	1	1
Phthalates						
Bis(2-ethylhexyl)phthalate	122/139	88	0.51	110	4	2
Butyl benzyl phthalate	41/138	30	0.50	200	22	2
Diethyl phthalate	0/139	0	0.50	200	2	1
Dimethyl phthalate	12/139	9	0.23	200	2	2
Di-n-octyl phthalate	2/139	1	0.50	200	2	0
0-4ft subsurface sediment						
PAHs						
2-Methylnaphthalene	50/111	45	0.56	13	1	0
Dibenzo(a,h)anthracene	74/111	67	0.70	13	5	1
Dibenzofuran	66/111	59	0.70	25	1	0

Parameter	Detection Frequency (DF)	DF %	Minimum RL	Maximum RL	Count RLs > SQS	Count RLs > CSL
Phthalates						
Bis(2-ethylhexyl)phthalate	82/111	74	1.4	110	4	2
Butyl benzyl phthalate	34/111	31	0.35	13	14	0
Diethyl phthalate	2/111	2	0.56	13	7	0
Dimethyl phthalate	3/111	3	0.35	13	11	8

The group of compounds labeled as "other SVOCs" included the following chemicals: chlorobenzenes, phenol, methyl phenols, pentachlorophenol, benzoic acid, benzyl alcohol, hexachlorobutadiene, hexachlorobenzene, and N-nitrosodiphenylamine. This group includes compounds that are analytically difficult to quantify at the levels required for comparison to SQS and DMMP chemical criteria and are generally rarely detected (Table 3-11). These compounds tend to have chemical characteristics that differ from those of other analytes being analyzed using the same method. For example, benzoic acid, benzyl alcohol, phenols, and n-nitrosodiphenylamine are all more chemically reactive than the other SVOCs analyzed by EPA (2003). More reactive compounds can be difficult to extract and often degrade during analysis.

Table 3-11
Summary of SVOCs with RL Values Above SMS Criteria

Chemical	Detection Frequency (DF)	DF %	Units	Minimum RL	Maximum RL	Count RLs > SQS	Count RLs > CSL
0-10cm surface sediment							
1,2,4-Trichlorobenzene	28/163	17	mg/kg OC	0.21	200	48	28
1,2-Dichlorobenzene	13/163	8	mg/kg OC	0.043	200	31	31
1,3-Dichlorobenzene [a]	24/141	17	µg/kg dw	0.90	4,100	12	n/a
1,4-Dichlorobenzene	78/163	48	mg/kg OC	0.056	200	19	8
2,4-Dimethylphenol	4/139	3	µg/kg dw	6.1	4,100	80	80
2-Methylphenol	2/139	1	µg/kg dw	6.1	4,100	32	32
4-Methylphenol	28/139	20	µg/kg dw	9.8	4,100	3	3
Benzoic acid	13/130	10	µg/kg dw	160	2,000	22	22
Benzyl alcohol	0/130	0	µg/kg dw	9.8	930	35	29
Hexachlorobenzene	0/140	0	mg/kg OC	0.028	200	58	30
Hexachlorobutadiene	0/140	0	mg/kg OC	0.030	200	26	23
Hexachloroethane [a]	0/50	0	µg/kg dw	20	4,100	2	0
N-Nitrosodiphenylamine	2/124	2	mg/kg OC	0.24	200	11	11
Pentachlorophenol	8/139	6	µg/kg dw	58	10,000	32	19

Chemical	Detection Frequency (DF)	DF %	Units	Minimum RL	Maximum RL	Count RLs > SQS	Count RLs > CSL
Phenol	54/139	39	µg/kg dw	18	2,000	3	1
0-4ft subsurface sediment							
1,2,4-Trichlorobenzene	2/112	2	mg/kg OC	0.18	13	37	22
1,2-Dichlorobenzene	3/112	3	mg/kg OC	0.037	13	19	19
1,3-Dichlorobenzene [a]	4/112	4	µg/kg dw	0.90	780	10	n/a
1,4-Dichlorobenzene	19/112	17	mg/kg OC	0.037	13	14	10
2,4-Dimethylphenol	3/111	3	µg/kg dw	9.1	780	31	31
2-Methylphenol	1/111	1	µg/kg dw	9.1	780	16	16
Benzoic acid	3/99	3	µg/kg dw	100	7,800	19	19
Benzyl alcohol	1/107	1	µg/kg dw	15	780	27	22
Hexachlorobenzene	1/111	1	mg/kg OC	0.028	13	57	9
Hexachlorobutadiene	2/111	2	mg/kg OC	0.026	14	13	4
N-Nitrosodiphenylamine	0/102	0	mg/kg OC	0.27	13	16	14
Pentachlorophenol	2/89	2	µg/kg dw	46	3,900	13	10
Phenol	34/111	31	µg/kg dw	18	780	2	0
>4ft subsurface sediment							
1,2,4-Trichlorobenzene	0/36	0	mg/kg OC	0.23	2.7	5	1
2,4-Dimethylphenol	0/36	0	µg/kg dw	10	130	1	1
2-Methylphenol	0/35	0	µg/kg dw	10	64	1	1
Benzyl alcohol	0/36	0	µg/kg dw	12	320	6	1
Hexachlorobenzene	0/36	0	mg/kg OC	0.26	2.7	23	2
Hexachlorobutadiene	0/36	0	mg/kg OC	0.53	5.6	13	0

a There is no SMS criteria for this chemical. RLs were compared to DMMP SL and ML.
n/a - not applicable

Organochlorine pesticides were rarely detected in the EW sediments. Total DDTs have the highest detection frequency of all the pesticides and were detected in 9 percent of the 0-10cm sediment samples and 20 percent of the 0-4ft samples and >4ft samples. Reporting limits for these compounds were compared to the DMMP SL value (Table 3-12). Elevated RL values for organochlorine pesticides generally reflect the presence of probable analytical interference in the analysis because of the presence of PCB congeners. This issue was present in the Duwamish dataset and additional analyses confirmed that the elevated RLs associated with pesticides were due to the presence of PCB congeners (Windward 2005b). The relationship between elevated pesticide RLs and total PCB concentrations was further evaluated in EW sediment samples for total DDTs. Of the 58 surface samples with total DDT RLs above the SL, only one of these samples had total PCB concentrations less than the SQS. Of the two samples with total DDT RLs above the ML, both samples had PCB concentrations below the SQS. Similarly, for the 0-4ft samples, 42 samples had RLs above the SL and only three of those samples had PCB concentrations below the SQS. Overall, DDT RLs tended to exceed the DMMP criteria when PCBs were found greater than the SQS.

Table 3-12
Summary of Pesticide RLs Compared to DMMP Criteria
(µg/kg dw)

Chemical	Detection Frequency (DF)	DF %	Minimum RL	Maximum RL	Count RLs > SL	Count RLs > ML
0-10cm surface sediment						
Total DDTs	12/127	9	1.1	100	58	2
Aldrin	3/72	4	0.53	20	4	n/a
Dieldrin	0/72	0	1.1	51	25	n/a
Gamma-BHC	0/72	0	0.53	20	4	n/a
Heptachlor	2/72	3	0.82	20	4	n/a
Total Chlordane	2/66	3	0.96	190	14	n/a
0-4ft subsurface sediment						
Total DDTs	23/113	20	0.61	210	42	5
Aldrin	4/82	5	0.30	42	12	n/a
Dieldrin	6/83	7	0.61	120	20	n/a
Heptachlor	0/83	0	0.30	42	9	n/a
Total Chlordane	3/82	4	0.90	200	24	n/a
>4ft subsurface sediment						
Total DDTs	7/36	19	1.7	77	4	1
Dieldrin	0/36	0	0.9	46	3	n/a
Total Chlordane	1/33	3	0.87	52	3	n/a

n/a - not applicable

3.3.2 Bioassay Data

This section summarizes bioassay analyses of EW sediment samples. Results from the bioassay tests are used in conjunction with the chemistry results to evaluate sediment quality at a location. Results from tests conducted with sediments that were removed during dredging events are not included. Bioassay test results were used only if the tests were conducted in accordance with Puget Sound Estuary Program (PSEP) protocols (PSEP 1995). The following bioassay tests were included: acute 10-day amphipod test using *Eohaustorius estuarius*, *Ampelisca abdita*, or *Rhepoxynius abronius* (amphipod test); acute 48-hour bivalve larval combined mortality test using the blue mussel, *Mytilus galloprovincialis*, or echinoderm embryo, *Strongylocentrotus spp* (larval test); and the chronic 20-day juvenile polychaete biomass test using *Neanthes arenaceodentata*

(*Neanthes* test). Results of toxicity tests from 10 studies are summarized in Table 3-13. Results for each depth horizon, 0-10cm, 0-4ft, and >4ft, are presented on Figures 3-36, 3-37, and 3-38, respectively. Results of each toxicity test are presented in Tables G-5 through G-7 of Appendix G for each depth horizon. SMS biological effects standards are also presented in Table G-4 of Appendix G.

Table 3-13
Percentage of Bioassay Test Results Passing the SMS

Depth Horizon	Sample Count	Amphipod (%)		*Neanthes* (%)		Larval (%)		Station (%)	
		SQS	CSL	SQS	CSL	SQS	CSL	SQS	CSL
0-10cm	55	85	87	85	98	47	67	45	56
0-4ft	57	89	95	69 [a]	86 [a]	33 [b]	83 [b]	28	67
>4ft	20	90	95	53 [c]	65 [c]	50 [d]	89 [d]	45	60

a based on 51 samples due to *Neanthes* endpoint of survival used for 6 samples
b based on 52 samples due to larval not tested for 5 samples
c based on 17 samples due to *Neanthes* endpoint of survival
d based on 18 samples due to larval not tested for 2 samples

Most of the sediment samples were tested using three kinds test organisms (i.e., amphipod, larval, and *Neanthes*). The test results for each sediment sample are combined to determine whether the overall SQS and CSL have been exceeded for that sample (WAC 173-204). A sediment sample is considered to fail in comparison to the SQS if one of the tests exceeds the SQS. A sediment sample is considered to fail in comparison to the CSL if two of the biological tests exceed the SQS or one of tests exceeds the CSL.

3.3.2.1 Surface Sediment (0-10cm) Results

Fifty-five sediment samples from the 0-10cm sediment horizon have bioassay results. The results for the amphipod and *Neanthes* tests were very similar with most of the samples passing. The greatest number of failures was seen for the larval bioassay. The bioassay failures were typically located along the margins of the EW; exceedances of the CSL predominated in the northern half of the EW, whereas only larval exceedances of the SQS predominated in the southern portion of the EW. The SQS and CSL failures for each test are summarized in Table G-5 of Appendix G and on Figure 3-36.

3.3.2.2 Subsurface Sediment (0-4ft) Results

Subsurface bioassays were run for 0-4ft samples and >4ft samples as a requirement of DMMP evaluations. There maybe some limited use of these data in the nature and extent discussions of the RI and for the FS.

A total of 57 sediment samples had bioassay results in the 0-4ft sediment horizon. The greatest number of failures was seen for the larval bioassay, and the amphipod test had the greatest number passing. The larval test failures occurred in more than half of the samples throughout the EW. The most CSL exceedances of all tests occurred on the eastern side of the EW from Station 3800 to 4200 and in the navigation channel in the northern portion of the EW from Station 800 to 2400. The northern portion also had the greatest number of samples failing both the SQS and CSL for all three bioassays. The SQS and CSL failures for each test are in presented Table G-6 of Appendix G and on Figure 3-37.

3.3.2.3 Subsurface Sediment (>4ft) Results

Eighteen sediment samples from the >4ft sediment horizon have bioassay results that were conducted as part of the DMMP evaluation process. The amphipod test had the greatest percent passing of both the SQS and CSL in this horizon. The greatest CSL failures were located on the eastern side of the EW from Station 3800 to 4200 and in the navigation channel in the northern portion of the EW at Station 1300. The SQS and CSL failures are presented for each test in Table G-7 of Appendix G and on Figure 3-38.

3.3.3 Surface Water Data

The surface water chemistry data for the EW is limited to three investigations. One event was conducted by the County as part of their CSO WQA for the Duwamish River and Elliott Bay (King County 1999a) and the other two events were water quality monitoring conducted during dredging events. Each sampling event is described in the following subsections with summaries of the results. The locations of the surface water sampling events are shown on Figure 3-6.

3.3.3.1 King County Water Quality Assessment

In 1999, King County conducted a WQA of CSOs for the Duwamish River and Elliott Bay (King County 1999a). Receiving water samples from three locations along a transect across the EW off of the Hanford Street CSO were collected as part of this sampling event. CSO effluent samples were also collected and analyzed and are discussed in greater detail in Section 5.2.3.

Receiving water samples were collected as discrete grab samples at 1 meter below the water's surface and 1 meter above the bottom of the EW. Samples were collected over a 26-week period between October 1996 and June 1997. Field measurements recorded during sampling included dissolved oxygen, temperature, conductivity/salinity, and pH. Samples were collected weekly except during storm conditions, when they were collected daily for a period of 3 days following a CSO discharge event. Receiving water was analyzed for TOC, volatile suspended solids, ammonia nitrogen, nitrate/nitrite nitrogen, total suspended solids (TSS), metals, SVOCs, and microbiological parameters. No chemicals exceeded acute or chronic Washington water quality criteria (WA WQC) during this investigation. The results from only detected chemicals are summarized in Table 3-14. All results are presented in Appendix H.

Table 3-14
Summary of Chemicals Detected in the King County Water Quality Assessment

Parameter	Detection Frequency (DF)	DF %	Minimum Detect	Maximum Detect	Minimum Non-Detect	Maximum Non-Detect	Acute WA WQC	Chronic WA WQC	Detected Acute Exceedances	Detected Chronic Exceedances	Count RL > Acute WA WQC	Count RL > Chronic WA WQC
Metals and Trace Elements (µg/L)												
Antimony (dissolved)	65/65	100	0.0340 J	0.121	n/a	n/a	NC	NC	n/a	n/a	n/a	n/a
Antimony (total)	168/168	100	0.0150	0.119	n/a	n/a	NC	NC	n/a	n/a	n/a	n/a
Arsenic (dissolved)	71/71	100	0.507	1.43	n/a	n/a	69	36	0	0	0	0
Arsenic (total)	168/168	100	0.287	1.47	n/a	n/a	NC	NC	0	0	0	0
Beryllium (total)	1/163	1	0.0150	0.0150	0.014	0.016	NC	NC	n/a	n/a	n/a	n/a
Cadmium (dissolved)	71/71	100	0.0300	0.0827	n/a	n/a	42	9.3	0	0	0	0
Cadmium (total)	174/174	100	0.0320	0.0958	n/a	n/a	NC	NC	0	0	0	0
Chromium (dissolved)	59/59	100	0.140 J	0.612 J	n/a	n/a	1,100	50	0	0	0	0
Chromium (total)	156/156	100	0.160 J	0.629 J	n/a	n/a	NC	NC	0	0	0	0
Cobalt (dissolved)	71/71	100	0.0180	0.0598	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cobalt (total)	156/156	100	0.0140	0.298	n/a	n/a	NC	NC	n/a	n/a	n/a	n/a
Copper (dissolved)	66/66	100	0.327 J	0.964 J	n/a	n/a	4.8	3.1	0	0	0	0
Copper (total)	169/169	100	0.434 J	1.84 J	n/a	n/a	NC	NC	0	0	0	0
Lead (dissolved)	71/71	100	0.00740 J	0.814 J	n/a	n/a	210	8.1	0	0	0	0
Lead (total)	174/174	100	0.0200 J	8.04 J	n/a	n/a	NC	NC	0	0	0	0
Mercury (dissolved)	8/9	89	0.000130	0.000690	0.0001	0.0001	1.8	0.025	0	0	0	0
Mercury (total)	8/15	53	0.000100	0.00116	0.0001	0.20	NC	NC	0	0	0	6
Nickel (dissolved)	60/66	91	0.315 J	0.855 J	0.294	0.385	74	8.2	0	0	0	0
Nickel (total)	157/163	96	0.360 J	0.814 J	0.402	0.529	NC	NC	0	0	0	0
Thallium (dissolved)	70/71	99	0.00520	0.0120	0.0046	0.0046	NC	NC	n/a	n/a	n/a	n/a
Thallium (total)	172/174	99	0.00500	0.0120	0.0048	0.0050	NC	NC	n/a	n/a	n/a	n/a
Vanadium (dissolved)	53/53	100	0.376	1.48	n/a	n/a	NC	NC	n/a	n/a	n/a	n/a
Vanadium (Total)	132/132	100	0.618	1.66	n/a	n/a	NC	NC	n/a	n/a	n/a	n/a
Zinc (dissolved)	70/70	100	0.832 J	3.34 J	n/a	n/a	90	81	0	0	0	0
Zinc (total)	174/174	100	0.620 J	4.87 J	n/a	n/a	90	81	0	0	0	0
SVOCs (µg/L)												
Bis(2-ethylhexyl)phthalate	8/41	20	0.150	4.85	0.14	1.06	NC	NC	n/a	n/a	n/a	n/a
Di-n-butyl phthalate	2/41	5	0.270	0.390	0.24	0.24	NC	NC	n/a	n/a	n/a	n/a

Parameter	Detection Frequency (DF)	DF %	Minimum Detect	Maximum Detect	Minimum Non-Detect	Maximum Non-Detect	Acute WA WQC	Chronic WA WQC	Detected Acute Exceedances	Detected Chronic Exceedances	Count RL > Acute WA WQC	Count RL > Chronic WA WQC
Benzoic acid	1/41	2	1.30	1.30	0.94	0.97	NC	NC	n/a	n/a	n/a	n/a
Caffeine	4/41	10	0.0490	0.0660	0.047	0.049	NC	NC	n/a	n/a	n/a	n/a
Conventional Parameters												
Total suspended solids (mg/L)	192/192	100	1.50	32.0	n/a	n/a	NC	NC	n/a	n/a	n/a	n/a
Volatile suspended solids (mg/L)	131/132	99	0.500	4.20	0.50	0.50	NC	NC	n/a	n/a	n/a	n/a
Total dissolved solids (mg/L)	192/192	100	0.790	41.3	n/a	n/a	NC	NC	n/a	n/a	n/a	n/a
Ammonia (mg/L)	121/192	63	0.0200	0.493	0.02	0.02	NC*	NC*	n/a	n/a	n/a	n/a
Chemical oxygen demand (mg/L)	6/6	100	198	580	n/a	n/a	NC	NC	n/a	n/a	n/a	n/a
Hardness (mg/L $CaCO_3$)	6/6	100	1,950	6,120	n/a	n/a	NC	NC	n/a	n/a	n/a	n/a
Total as nitrogen (mg/L)	132/132	100	0.0770	0.490	n/a	n/a	NC	NC	n/a	n/a	n/a	n/a
pH	192/192	100	7.41	8.40	n/a	n/a	NC	NC	n/a	n/a	n/a	n/a
Specific conductance (umhos/cm)	192/192	100	30.4	58,100	n/a	n/a	NC	NC	n/a	n/a	n/a	n/a
Temperature (°C)	199/199	100	5.1	15.3	n/a	n/a	NC	NC	n/a	n/a	n/a	n/a

J – estimated
mg/L – milligrams per liter
n/a – not applicable
NC – no criteria
NC* – critera are available, but they are calculated based on temperature, pH, and salinity, and were not calculated for this summary

3.3.3.2 Water Quality Monitoring Events

WQM events occurred in conjunction with dredge events in the EW. Striplin Environmental Associates conducted WQM for dredging along T-18 in 2000, and in 2004 to 2005 Windward conducted WQM for the Stage 1A dredge event. For both of these WQM events, only the analytical results from the reference stations are summarized because these locations were not influenced by suspended dredge material and should be considered representative of ambient conditions.

3.3.3.2.1 Windward Water Quality Monitoring

In 2004 and 2005, WQM was conducted during the dredging activities for the EW Phase 1A Removal Action (Anchor and Windward 2005). Water quality field measurements of turbidity, dissolved oxygen, temperature, conductivity/salinity, and pH were routinely collected. Chemistry samples were periodically collected as part of the WQM activities. Thirty-six water samples were taken from locations 1,300 feet upstream of dredging operations to determine ambient conditions. Monitoring was conducted during both a flood and an ebb tide. At each location, in situ measurements were collected 1 meter below the surface, in the middle of the water column, and 1 meter above the mudline. Chemistry samples were taken from any one of these various depths in the water column ranging from 3 to 60 feet below the water surface, but were typically below the freshwater lens. These samples were analyzed for metals (cadmium, copper, lead, mercury, silver, and zinc), TBT ion, total PCBs (as Aroclors), dieldrin, and total DDTs. Results from the ambient locations from this WQM investigation are summarized in Table 3-15. Copper was detected in all samples at concentrations greater than the acute and chronic WA WQC. No correction was made for potential saltwater interferences.

3.3.3.2.2 Striplin Water Quality Monitoring

In 2000, water quality monitoring was conducted during the dredging activities for the Phase 1 dredge event along T-18 (SEA 2000). Water quality field measurements of turbidity, dissolved oxygen, temperature, and salinity were routinely collected. Chemistry samples were collected twice as part of the WQM activities. Six water samples were taken from locations 800 feet upstream of dredging operations to determine ambient conditions. At each location, in situ and chemistry measurements were collected 1 meter below the surface, in the middle of the water column, and 1 meter above the mudline. Chemistry samples were taken from each of the depths in the water column ranging from 3 to 60 feet below the water surface, but were typically below the freshwater lens. These samples were analyzed for TSS, dissolved oxygen, metals (cadmium, lead, mercury, silver, and zinc), TBT ion, total PCBs (as aroclors), dieldrin, aldrin, chlordane, and total DDTs. Mercury was the only chemical detected in all six ambient samples but at concentrations that were well below (order of magnitude) the chronic WA WQC for mercury. Lead was also detected in one sample, but was also below the chronic WA WQC. Results from the ambient locations from this WQM investigation are summarized in Table 3-16.

Table 3-15
Summary of Chemicals Analyzed from Ambient Locations During Windward Water Quality Monitoring (Phase 1 and Phase 2)

Chemical (µg/L)	Detection Frequency (DF)	DF %	Minimum Detect	Maximum Detect	Minimum RL	Maximum RL	Acute WA WQC	Chronic WA WQC	Detected Acute Exceedances	Detected Chronic Exceedances	Count RL > Acute WA WQC	Count RL > Chronic WA WQC
Metals												
Cadmium	0/36	0	ND	ND	2.0	2.0	42	9.3	0	0	0	0
Copper	36/36	100	6	15	n/a	n/a	4.8	3.1	36	36	0	0
Lead	0/36	0	ND	ND	10	11	210	8.1	0	0	0	36
Mercury	0/36	0	ND	ND	0.1	0.1	1.8	0.025	0	0	0	36
Silver	0/36	0	ND	ND	2.0	5.0	1.9	n/a	0	n/a	36	n/a
Zinc	0/36	0	ND	ND	40	40	90	81	0	0	0	0
Total PCBs [a]	0/36	0	ND	ND	0.040	0.60	10	0.03	0	0	0	36
Pesticides												
Dieldrin	0/36	0	ND	ND	0.10	0.11	0.71	0.002	0	0	0	36
Total DDT	0/36	0	ND	ND	0.10	0.11	0.13	0.001	0	0	0	36
Organometals												
TBT ion	0/36	0	ND	ND	0.022	0.022	0.42	0.0074	0	0	0	36
Conventionals												
TSS (mg/L)	36/36	100	5.8	42.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Turbidity (NTU)	28/28	100	0.59	11.2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
TOC (mg/L)	8/29	28	1.5	3.81	1.50	1.50	n/a	n/a	n/a	n/a	n/a	n/a
In Situ Parameters												
Dissolved Oxygen (mg/L)	756/756	100	4.47	11.01	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
pH	756/756	100	6.60	8.04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Salinity (ppt)	756/756	100	10.5	39.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Temperature (°C)	756/756	100	7.04	16.61	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Turbidity (NTU)	756/756	100	0.62	63.10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

a Total PCBs are the sum of Aroclors

DF – detection frequency

n/a – not applicable

ND – not detected

RL – reporting limit

WA WQC – Washington water quality criteria

Table 3-16
Summary of Chemicals Analyzed from Ambient Locations During Striplin Water Quality Monitoring

Chemical (µg/L)	Detection Frequency (DF)	DF %	Minimum Detect	Maximum Detect	Minimum RL	Maximum RL	Acute WA WQC	Chronic WA WQC	Detected Acute Exceedances	Detected Chronic Exceedances	Count RL > Acute WA WQC	Count RL > Chronic WA WQC
Metals												
Cadmium	0/6	0	ND	ND	4	4	42	9.3	0	0	0	0
Lead	1/6	17	10 J	10 J	5	5	210	8.1	0	1	0	0
Mercury	6/6	100	0.001470	0.003630	n/a	n/a	1.8	0.025	0	0	0	0
Silver	0/6	0	ND	ND	1	1	1.9	n/a	0	n/a	0	n/a
Zinc	0/6	0	ND	ND	10	10	90	81	0	0	0	0
Total PCBs[a]	0/6	0	ND	ND	0.03	0.03	10	0.03	0	0	0	0
Pesticides												
Aldrin	0/6	0	ND	ND	0.0008	0.0008	0.71	0.002	0	0	0	0
Dieldrin	0/6	0	ND	ND	0.0015	0.0017	0.71	0.002	0	0	0	0
Total DDT	0/6	0	ND	ND	0.0015	0.0017	0.13	0.001	0	0	0	6
Total Chlordane	0/6	0	ND	ND	0.0008	0.0008	0.09	0.004	0	0	0	0
Organometals												
TBT ion	1/6	17	0.005 J	0.005 J	0.020	0.022	0.42	0.0074	0	0	0	5
Conventionals												
TSS (mg/L)	6/6	100	5.4	10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
DO (mg/L))	6/6	100	6.8	8.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
In situ Parameters												
DO (mg/L)	7/7	100	6.30	9.62	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Salinity (ppt)	7/7	100	15.5	33.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Temp (°C)	7/7	100	4.52	9.15	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Turbidity (NTU)	7/7	100	8.5	26.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

a Total PCBs are the sum of Aroclors
DF – detection frequency
J – estimated
n/a – not applicable
ND – not detected
RL – reporting limit
WA WQC – Washington water quality criteria

3.3.4 Tissue Chemistry Data

Five studies have reported tissue concentrations for fish and shellfish captured throughout the EW. English sole were analyzed by EVS Environmental Consultants (EVS; unpublished), transplanted mussels were analyzed by the County (King County 1999a); red rock crab and striped perch were analyzed by Environmental Solutions Group (ESG; 1999), and Windward analyzed juvenile Chinook (Windward 2002a) and English sole, shiner surfperch, rock fish, and sand sole (Windward 2006a). PCBs, mercury, and TBT were the most frequently analyzed chemicals in tissue samples. The County (King County 1999a) conducted the only study with an extensive analytical list including metals, organometals, SVOCs, PCBs, and pesticides. Additional details on each of these events are described below. A summary of only detected results is presented in Table 3-17. All tissue chemistry results are presented in Appendix I. The locations of samples collected from each of the events described below are shown on Figure 3-5.

Skinless fillets of English sole were analyzed for PCBs (as Aroclors), mercury, and TBT (EVS unpublished). All chemicals were detected. PCBs, mercury, and TBT were also measured in the edible tissue of red rock crab and fillets of striped perch, both with and without skin (ESG 1999). PCBs and mercury were detected in all three tissue types. TBT was detected in the perch fillets but, was not detected in the red rock crab tissue. Edible tissues from mussels were analyzed for 114 chemicals (King County 1999a). Only 16 of the 114 chemicals were detected. The detected chemicals include nine metals, TBT, PAHs, PCBs, benzoic acid, and 2-methyl phenol. Mercury was not detected in the mussel tissue samples. Out-migrant juvenile Chinook salmon collected from Slip 27 and English sole, shiner surfperch, rock fish, and sand sole from throughout the EW were analyzed for mercury and PCBs. Mercury and PCBs were detected in each of the samples analyzed.

Table 3-17
Detected Tissue Chemistry Concentrations for Samples Collected from the East Waterway

Reference Source	Species	Sample Type	Number of Samples	Detection Frequency (%)	Chemical	Detected Concentration		Unit (wet weight)
						Minimum	Maximum	
EVS (unpublished)	English sole	Skinless fillet	3	100	PCBs	409	640	µg/kg
			3	100	mercury	0.0259	0.0343	mg/kg
			3	100	methylmercury	0.0231	0.0368	mg/kg
			3	66	TBT as ion	1.63	1.85	µg /kg
ESG (1999)	Red rock crab	Edible tissue	3	100	PCBs	132.5 J	204 J	µg/kg
			3	100	mercury	0.05 J	0.13 J	mg/kg
	Striped perch	Fillet with skin	3	100	PCBs	179	203	µg/kg
			3	33	mercury	0.07 J	0.07 J	mg/kg
			3	100	TBT as ion	5 J	31 J	µg/kg
	Striped perch	Skinless fillet	3	100	PCBs	104	135	µg/kg
			3	33	mercury	0.06 J	0.06 J	mg/kg
			3	100	TBT as ion	10 J	25 J	µg/kg
King County (1999a)	Mussels	Edible tissue	6	50	PCBs	28.4	32.6	µg/kg
			6	100	TBT as ion	58.7	92.8	µg/kg
			3	100	dibutyltin as ion	18.5	25.3	µg/kg
			3	100	monobutyltin as ion	2.87 J	3.17 J	µg/kg
			6	100	arsenic	0.745	1.85 J	mg/kg
			6	100	cadmium	0.368	0.616 J	mg/kg
			6	100	chromium	0.11	0.934	mg/kg
			6	100	copper	1.23	2.18 J	mg/kg
			3	100	cobalt	0.061	0.073	mg/kg
			6	100	lead	0.426	0.833	mg/kg
			6	100	mercury	0.0098	0.015	mg/kg
			6	100	nickel	0.106	0.230 J	mg/kg
			6	100	zinc	35.8	49.1	mg/kg
			6	17	acenapthene	14	14	µg/kg
			6	50	benzo(a)anthracene	20	23	µg/kg
			6	83	chrysene	17	32.1	µg/kg
			6	100	fluoranthene	23	45.9	µg/kg

Reference Source	Species	Sample Type	Number of Samples	Detection Frequency (%)	Chemical	Detected Concentration		Unit (wet weight)
						Minimum	Maximum	
			6	67	pyrene	24	29.5	µg/kg
			6	50	phenanthrene	16	22	µg/kg
			6	100	Total HPAH	32.6	123	µg/kg
			6	50	Total LPAH	16	36	µg/kg
			6	100	Total PAH	45	159	µg/kg
			6	100	2-methylphenol	44	87.9	µg/kg
			6	100	benzoic acid	1,050 J	4,720	µg/kg
Windward (2002a)	Juvenile Chinook salmon (wild)	Whole body [a]	3	100	mercury	0.024	0.028	mg/kg
			3	100	PCBs	46.3	72.0	µg/kg
	Juvenile Chinook salmon (hatchery)	Whole body [a]	3	100	mercury	0.026	0.028	mg/kg
			3	100	PCBs	58.9	87.4	µg/kg
Windward (2006a)	English sole	Fillet [b]	6	100	mercury	0.03 J	0.04 J	mg/kg
			6	100	PCBs	1,900	5,700	µg/kg
	Sand sole	Whole-body	6	100	mercury	0.03 J	0.119 J	mg/kg
			6	83	PCBs	167	1,310	µg/kg
	Shiner surfperch	Whole-body	3	100	mercury	0.02 J	0.03 J	mg/kg
			3	100	PCBs	1,380	5,400	µg/kg
	Rockfish	Whole-body	2	100	mercury	0.07 J	0.235	mg/kg
			2	100	PCBs	2,900	6,200	µg/kg

a Otoliths and digestive tracts were removed from whole-body samples (Windward 2002a).

b All remaining tissue and fluids after fillets were removed from the specimens for two English sole composite samples ("remainder samples") were also analyzed so that whole-body concentrations could be calculated. Concentrations in these calculated "whole-body" samples were estimated using results from separate analyses of fillet and remainder composite samples, using the relative weights and chemical concentrations in skin-on fillet and remainder tissues. The calculated whole-body minimum and maximum mercury concentrations are 0.02 and 0.03 mg/kg wet weight, respectively, and minimum and maximum total PCB "whole body" concentrations are 3,100 and 7,800 µg/kg wet weight, respectively.

J – estimated concentration

3.3.5 Groundwater Investigations

Numerous groundwater investigations have been conducted along upland areas adjacent to the EW. Groundwater investigations have been performed in coordination with EPA and Ecology programs and voluntarily as part of area planning and/or development activities. Upland cleanup sites are discussed in detail in Section 5 and include a summary of groundwater conditions at each identified cleanup site. A general discussion of these sites and groundwater conditions along the west and east nearshore boundaries of the EW is presented below.

The Harbor Island Soil and Groundwater OU, a component of the larger Harbor Island Superfund Site, comprises the majority of the western boundary of the EW. In addition, two voluntary underground storage tank (UST) removals are located on the southeast portion of Harbor Island. A ROD was issued for Harbor Island in 1993, which was followed by completion of several investigation and cleanup actions. The majority of the remedial actions were completed in 2004 (Section 5.2.5).

The Harbor Island Soil and Groundwater OU has been managed under a groundwater compliance monitoring program since 2005. The groundwater monitoring report for 2005 and 2006 (RETEC 2006b) identified nickel, copper, zinc, and cyanide as the only constituents exceeding the ROD-specified cleanup goals, with only zinc identified in the eastern portion of Harbor Island (adjacent to the EW).

Cleanup sites along the eastern boundary of the EW include a variety of historical and current industrial properties. These sites include areas of Pier 36 (USCG facility), Pier 34 (GATX), T-30, T-25, and T-104. T-30 is currently the only site with ongoing groundwater monitoring activities under the direction of Ecology.

The groundwater monitoring events conducted at locations adjacent to the EW are summarized in Tables 3-18 through 3-26. These investigations are discussed in detail in Section 5. The data are provided in Appendix D, and the monitoring well locations are shown on Figures 5-6 and 5-7.

Table 3-18
Groundwater Monitoring Events Conducted Adjacent to the East Waterway

Event	Source	Number of Nearshore and/or Downgradient Wells [a]	Number of Groundwater Samples	Chemical Analyzed	Analytes Detected Above Site-Specific Action Level	Basis of Site-Specific Action Levels
Harbor Island 2005 to 2006 Groundwater Monitoring	RETEC 2006b	7	14 [b]	metals, PCBs, VOCs, cyanide	Copper (1) zinc (1), total cyanide (1) [d]	ROD-specified levels to be protective of surface water quality; referenced in the groundwater monitoring report (RETEC 2006b)
T-102 Underground Storage Tank Decommissioning	RETEC 1997	6	6	diesel range hydrocarbons	None	MTCA Method A groundwater cleanup levels applicable at the time and referenced in the report (RETEC 1997)
USCG (Pier 36) 2003 and 2004 Groundwater Monitoring	Hart Crowser 2004	7	7	metals, petroleum, VOCs, SVOCs	Arsenic (5), 1,1,2-Trichloroethane (1) [c]	MTCA Method A and Method B groundwater cleanup levels applicable at the time and referenced in the report (Hart Crowser 2004).
GATX 2003 Groundwater Monitoring	RETEC 2004	6 [e]	12	metals, petroleum, BTEX, PAHs	Arsenic (2), copper (2), diesel range hydrocarbons (4) [f]	Site-specified surface water criteria at the time, which is based on MTCA Method C, AWQC (Marine Chronic Criteria), and MTCA Method A groundwater cleanup levels (for petroleum).
T-30 February 2007 Groundwater Sampling Event	RETEC 2007	5	5	petroleum, BTEX, PAHs, 2-methylnaphthalene	None	Site-specified surface water ARARs as described in the RETEC 2006 Draft T-30 Data Report. The site-specified surface water ARAR was determined using the lowest value of applicable criteria at the time including Washington State Surface Water Criteria, National Water Quality Criteria (Ecological and Human Health), and MTCA Method A/B Groundwater Criteria.
T-25 1989 to 1990 Groundwater Sampling	Landau 1990; Sweet-Edwards 1990	7	7	petroleum, BTEX	None	MTCA Method A groundwater cleanup levels applicable at the time and referenced in the reports (Landau 1990) and (Sweet-Edwards 1990).
T-104 Vicinity 2005 to 2007 Groundwater Sampling	Environmental Partners 2007	12	12	Selective metals, petroleum, PCBs, VOCs, PAHs	None	MTCA Method A and Method C groundwater cleanup levels applicable at the time and referenced in the report (Environmental Partners 2007).

Notes:

(Numbers in parentheses indicates number of wells in which chemical was detected above the action level.)

a Located in areas where groundwater is known to flow towards the EW.

b Quarterly monitoring on each well for the groundwater sampling conducted during March and June 2006.

c 1,1,2-Trichloroethane was detected (6.6 μg/L) in sample location MW-1C in October 2003. More recent groundwater sampling at location MW-1C in November 2004 showed a non-detect concentration at less than 1.0 μg/L.

d Ongoing analytical method identification in-process for cyanide. Previous cyanide analytical method for total cyanide, whereas criteria based on free (available) cyanide.

e Groundwater monitoring at GATX included one seep sample and all chemical concentrations at this seep sample were below the site-specific reference value. Monitoring for each well and seep sample for the groundwater sampling conducted during April and August 2003.

f Chemical concentrations were below the site-specific trigger levels identified for the nearshore wells.

BTEX – benzene, toluene, ethylbenzene, and xylene

PAHs – polycyclic aromatic hydrocarbons

PCBs - polychlorinated biphenyls

SVOCs – semivolatile organic compounds

4 SEDIMENT TRANSPORT DYNAMICS

This section reviews the available information on hydrodynamics and sediment transport in the EW, and includes information for the LDW that is relevant to the sediment transport dynamics of the EW. Note that few studies have been conducted that directly address sediment transport processes in the EW. Those that have been conducted are discussed in Section 4.2. There is some information on erosion, sedimentation, and sediment trapping efficiency from studies of the LDW that include a small section at the southern end of the EW south of the sill. These are presented in Section 4.3. Also, the studies conducted on the LDW have produced data of the type that may be useful for examination of sediment transport in the EW (such as net sedimentation rates and bed shear strength) if such an examination is determined to be necessary by the Data Gaps Analysis. These are mentioned here for future reference only and are not reviewed in this report. Other studies important to understanding sediment transport dynamics in the EW are presented for ship-induced scour, sediment mixing rates, and sediment accumulation in Sections 4.4, 4.5, and 4.6, respectively. Table 4-1 provides a list of documents that contain key information related to sediment transport dynamics.

Table 4-1
Reports Examining Sediment Transport Dynamics Within the East Waterway and Nearby Areas

Study	Information	Source
East Waterway		
Harbor Island RI	Velocity measurements, sedimentation	HISWG 1996
Harbor Island RI	Sedimentation	HISWG 1996; Weston 1993
CSO WQA of the Duwamish River Estuary-Elliott Bay	Velocity measurements, hydrodynamic modeling	King County 1999a
LDW Sediment Transport Analysis	Hydrodynamic modeling	QEA 2007; Windward and QEA 2007
Sediment Transport in Elliott Bay and the Duwamish River	Net sediment transport	McLaren and Ren, 1994
Nearby Areas		
LDW Sediment Transport Analysis	Hydrodynamic modeling, erosion potential, bed scour, sedimentation	QEA 2007; Windward and QEA 2007

This section lists and compiles applicable sediment transport information that may be used in subsequent steps in the EW SRI/FS process. Further assessment and review of this information will occur in the Sediment Transport Evaluation Approach Memorandum and Data Gaps

Analysis in the context of the CSM. Final interpretation of the data will occur in the Sediment Transport Report.

4.1 Overview of Sediment Transport Hydrodynamic Processes

Sediment transport in the EW is influenced by the hydrodynamic characteristics of the system and the physical characteristics of the sediments. Overall hydrodynamics are driven by downstream flow into the EW from the LDW and upstream tidal flow from Elliott Bay. The hydrodynamic characteristics include natural and vessel-caused currents and circulation patterns, as well as natural changes in water depth due to tidal exchange and freshwater inflows[4]. The hydrodynamics are also influenced by density stratification from vertical variation in the water column salinity and by physical features that guide currents including the shoreline, bulkheads, piling, and the cross-channel sill that underlies the Spokane Street corridor. The stratification is the result of freshwater inflows in the surface layers that originate from the Green-Duwamish River and salt water inflows in the bottom layers from Elliott Bay. The amount of freshwater flow entering the EW is influenced by the flow in the LDW and the depth of water over the sill that allows LDW inflow. Water depth over the sill also depends on the tidal elevation. Salt water inflows depend on the tidal exchange with Elliott Bay. Fundamentally, the hydrodynamics and the supply of sediment are the two drivers of sediment transport and sedimentation within the EW. In addition, overlying the natural transport mechanisms are the short-term and localized impacts from vessels in the EW.

The sediment characteristics that affect sediment transport processes include the mass inflow from the LDW, Elliott Bay, and lateral loads[5]; the mass outflow from the EW to Elliott Bay; the sediment size class distribution; the ability of the sediment bed to resist erosion (bed shear strength including any effect from bioturbation); and the erosion rate of the sediment bed. The mass inflow is the amount of sediment that is potentially available to settle in the EW. The mass outflow is the sediment mass that either did not settle or was resuspended from the sediment bed and that exits from the EW. The fraction of sediment

[4] Surface water inflows are only considered at this time. The magnitude of surface water inflows are expected to be larger than groundwater inflows, resulting in a small effect of groundwater on hydrodynamics.

[5] Lateral loads include storm drains and CSOs.

retained within the EW is the trapping efficiency and is the difference between the sediment mass inflow and outflow. The size class distribution influences the potential rate that the sediment could settle from the water column to the sediment bed. The bed shear strength determines the minimum fluid shear stress needed before erosion of the bed begins. The erosion rate is the mass rate of sediment resuspension and depends on the fluid shear stress. The sediment characteristics combined with the hydrodynamic characteristics determine the sedimentation rates and patterns within the EW.

4.2 East Waterway Information

4.2.1 Hydrodynamics

The available data for hydrodynamic characteristics in the EW are from the Harbor Island RI (HISWG 1996) and from the CSO WQA of the Duwamish River estuary-Elliott Bay system (King County 1999a). The relevant data are limited to current (velocity) measurements at two locations in the 750-foot-wide section of the EW north of the sill and one location south of the sill (Figure 2-4).

For the Harbor Island RI (HISWG 1996), near-bottom currents were measured at two stations (HI-03 and HI-04, see Section 2.2.8 and Figure 2-4) in the navigation channel of the EW using S4 current meters. These meters record velocities at a single depth and location over the duration of the deployment of the meter. They were deployed March 27 through May 17, 1995, and were placed 1 meter off the bottom in the same location as sediment traps that were deployed for gross sedimentation sampling (Section 4.2). The S4 current meters measured speed and direction at 1 second intervals. The net flow (average velocity) in the EW measured near the bottom was to the south. The mean speed at the northern station (HI-03) was 2.0 cm/sec with a maximum of 130 cm/sec; speeds greater than 25 cm/sec occurred in less than 0.01 percent of the data. The mean speed at the southern station (HI-04) was 2.5 cm/sec with a maximum of 86 cm/sec; speeds greater than 25 cm/sec occurred in less than 0.01 percent of the data. Table 4-2 summarizes the frequency of occurrence of the measured velocities. Field observations during deployment of the current meters suggested that the spikes in velocity correlated with passage of vessels through the EW in the vicinity of the current meter. Flow for the Green River during the current meter deployment averaged 1,010 cfs (Figure 4-1).

Table 4-2
Percent Occurrence of Near-Bottom Velocity at Two Stations in the East Waterway

Station	0.0 to 2.5 cm/sec	2.5 to 5.0 cm/sec	5.0 to 7.5 cm/sec	7.5 to 10 cm/sec	Greater than 10 cm/sec
HI-03 (north)	73.5	22.3	3.1	0.7	0.4
HI-04 (south)	60.4	35.1	3.6	0.4	0.5

Source: HISWG 1996

During the WQA study, velocities were measured at several locations in the Elliott Bay-Duwamish River estuary system, but it included only one station (named EWW) near the EW south of the sill (King County 1999a) (Figure 2-4). The data were collected using an acoustic Doppler current profiler (ADCP), which records velocities at multiple depths over the duration of the deployment of the meter. The ADCP meter for the EWW station only recorded for a portion of the deployment, so only the depth profile of mean velocities was analyzed and presented in the report. (Other stations also had harmonic analyses done for ADCP velocity measurements.) Two net-average velocity profiles are presented. The velocity profile from one averaging period showed a net flow to the north into the EW from the LDW throughout the water column. During another averaging period, the velocity profile had a slight net flow to the south from the EW to the LDW in the lower one-third of the water column, with the upper two-thirds flowing to the north from the LDW to the EW. For the former profile, the maximum net-average velocity of approximately 75 cm/sec northward into the EW was at the surface and the net-average velocity at the bottom was 0 cm/sec. In the latter profile, the maximum net-average velocity from the EW was approximately 5 cm/sec southward just off the bottom (absolute elevations or depths of the measurements were not reported). For this profile, the maximum net-average velocity into the EW at the surface was approximately 40 cm/sec northward.

In addition to these measured data, hydrodynamic modeling has been conducted in studies that include the EW in the model domain. These studies include the WQA conducted by King County (1999a) and the sediment transport analyses for the LDW (QEA 2007; Windward and QEA 2007). The model domains for all of these studies included Elliott Bay, the EW, the WW, the LDW, and the lower Green River to accurately describe the hydrodynamics of the system. However, current, water level, and salinity model results specifically for the EW were not reported. Assuming that the calibrated models are available, the hydrodynamic data could be generated for the EW, though it should be noted that these models were not specifically calibrated for the EW.

4.2.2 Sedimentation

Sedimentation rates have been measured in the EW and include gross sedimentation, net sedimentation, and resuspension[6]. These rates were characterized for the Harbor Island RI (Weston 1993 and HISWG 1996). The sedimentation rates in the EW were estimated from cross-sectional data (Weston 1993) and from field studies at two locations (HISWG 1996).

The initial studies for the Harbor Island RI conducted by Weston (1993) estimated a net sedimentation rate from historical cross-sectional data. For the EW, the rate was estimated to be 7.6 cm/yr, which is much larger than estimates from other studies (see Table 2-4), and is likely due to limited data from the cross sections. Specifically, only three tracklines were within the EW and a limited number of survey points were present in each cross section.

Additional sedimentation analyses for the Harbor Island RI were conducted at stations HI-03 (north) and HI-04 (south) in the EW (Figure 2-4), and the results are reported in HISWG (1996). At both stations, sediment traps were deployed and geochronological cores were taken and analyzed for radioisotope and chemical signatures.

The sediment trap measurements were used to estimate gross sedimentation rates at the two stations in the navigation channel of the EW (HISWG 1996). Sediment traps were deployed at the northern station from March 27 through May 16, 1995, and at the southern station from April 13 through May 17, 1995. A second round of deployment

[6] Gross sedimentation is the process of removal of suspended sediment particles from the water column by settling and accumulating the sediment particles on the bed. Resuspension is the process of moving the sediment particles from the sediment bed into the water column. The rates for these processes are typically given in terms of mass flux ($g/cm^2/yr$) or in terms of sediment depth (cm/yr). The difference between gross sedimentation and resuspension is defined as net sedimentation. Net sedimentation will be positive if the gross sedimentation rate is greater than the resuspension rate, and negative if the gross sedimentation rate is less than the resuspension rate.

was made at the southern station from May 17 through August 21, 1995. The sediment traps were moored at approximately 1 meter above the bottom.

Radioisotope and chemical analyses were used to estimate the net sedimentation rate from cores collected at the same two locations in the EW where the sediment traps were moored (HISWG 1996) (Figure 2-4). The core from HI-03 was analyzed down to a depth of 107 cm, and the core from HI-04 was analyzed down to a depth of 102 cm. Each core was analyzed at approximately 2-cm intervals in the top 20 cm and at larger intervals (5 to 20 cm) below the top 20 cm. Table 4-3 summarizes the sedimentation rates from the sediment traps and the geochronological dating.

Table 4-3
Comparison of Sedimentation Rates for the East Waterway

Station	Gross Mass Sedimentation ($g/cm^2/yr$)	Net Mass Sedimentation[1] ($g/cm^2/yr$)	Net Sedimentation[2] (cm/yr)	Resuspension[3] ($g/cm^2/yr$)
HI-03 (north)	2.3	1.47	1.13	0.83
HI-04 (south)	5.3	1.01	0.78	4.29

Source: HISWG 1996
1 – The average of lead-210, Cesium-137 (1950 and 1965), and PCB (1974) sedimentation rates
2 – Computed from the net mass accumulation rate assuming a bulk density of 1.3 g/cm^3
3 – The difference between gross and net mass accumulation rates
$g/cm^2/yr$ – grams per square centimeter per year

Both the gross and net mass sedimentation rates in the EW are greater than those in Elliott Bay (compare to Table 2-4). The net sedimentation in the EW is also greater than in Elliott Bay, but less than in the LDW near the EW and WW divide (Table 2-4). The resuspension rate was estimated by calculating the difference between the gross and net mass accumulation rates. These data indicate a significant amount of resuspension (81 percent of gross mass sedimentation) occurs at the south station (HI-04). At the north station (HI-03), 36 percent of the gross sedimentation is resuspended. These figures suggest that even though the stations have net sedimentation rates that fall between those seen in the LDW and Elliott Bay, resuspension appears to be greater. Note that empirically derived velocities required to initiate motion of Puget Sound sediments range from 25 to 50 cm/sec (USACE 1988).

4.2.3 Net Sediment Transport

A study of net sediment transport was conducted by McLaren and Ren (1994) in the Elliott Bay-Duwamish River estuary system. The study collected samples from the top 10 to 15 cm of sediment from a gridded network of stations across Elliott Bay, the EW, the WW, and the LDW. Statistical analyses of sediment size distribution in lines of cores samples were conducted to determine if the sediment was transported from one grid point to another. The pathways of net sediment transport were based solely on the statistical analyses of the sediment data. The net sediment transport patterns obtained from the statistical analyses were accepted only if a coherent pattern was found over the entire sampling region. Seven sediment size classes were examined (though the sizes that define these classes were not given) and ranged from gravel to mud. Mud and sand were the primary size classes discussed in the report, as they constituted 98 percent of the sediment distribution of the 533 samples collected.

McLaren and Ren (1994) concluded that the direction of net transport of fine-grained sediment (mud) in the EW was upriver to the south, which they suggested was caused by the flood tide dominating the transport of fine sediment. The patterns for coarse-grained sediment (sand) in the EW did not show a similar upriver movement. Overall, their analyses show the fine-grained sediment in the EW originating from a net clockwise transport of sediment in Elliott Bay, which in turn, they attribute to extreme storm events from the south setting up a clockwise gyre in Elliott Bay that includes southerly motion along the Seattle waterfront. Any sediment resuspended in Elliott Bay during the extreme storm event and transported along the Seattle waterfront could then enter the EW on flood tides.

4.3 Related Information

The most recent studies in the LDW that have data pertinent to the EW are those by Windward and QEA (2007) and QEA (2007), in which hydrodynamic and sediment transport modeling were used to evaluate sediment transport. These modeling studies included hydrodynamic simulations and evaluation of erosion potential, net and maximum bed scour depths, sedimentation rate estimates, and estimation of sediment flux through the water column. The model domain included Elliott Bay, the EW, the WW, the LDW, and the lower Green River to provide an accurate description of the system. However, no site-specific data for model calibration were collected in the EW and no model output was compiled for the EW portion of the model domain, though a small section of the EW south of the sill was included in the sediment transport evaluation. The northern portion of the grid used for the modeling studies is shown in Figure 4-2. The grid is two cells wide for the length of the EW, but the evaluations only included a very small portion of the first cell that extended into the EW from the LDW. The portion evaluated does not include any portions of the sill or any areas north of the sill. In this section, this modeled area will be referred to as the very southern portion of the EW south of the sill. Sediment transport characteristics in the remaining cells of the EW were not evaluated. The modeling results in this short portion within the EW are discussed in this section.

Erosion potential was evaluated as part of the LDW analysis (Windward and QEA 2007). The evaluation used results from the hydrodynamic model in combination with measured erosion rate data for the LDW. In the very southern portion of the EW south of the sill, the hydrodynamic modeling analysis for the 100-year extreme flow event in the LDW showed that the maximum bed shear stress was less than 0.16 Pascals (Pa), which was a first-order estimate determined from Sedflume erosion rate data for the LDW and was assumed to be the minimum shear stress necessary to induce erosion.

Evaluation of scour depth during extreme flow events in the LDW was also conducted (QEA 2007). The evaluation used the hydrodynamic and sediment transport models calibrated for the LDW. For the 100-year event, the evaluation showed that in the very southern portion of the EW south of the sill, net sediment deposition occurred over the duration of the event. Also, no net scour was produced within the very southern portion of the EW south of the sill during the course of the 100-year event.

Net sedimentation in the LDW was evaluated over a 30-year simulation period (QEA 2007). The evaluation used the hydrodynamic and sediment transport models calibrated for the LDW. In the very southern portion of the EW south of the sill, the estimate for net sedimentation rate ranged from 0.5 to 1.0 cm/yr. These model estimates are generally consistent with empirical estimates of net sedimentation for the EW (Table 2-4), though they are slightly lower, and they do not account for potential sedimentation in the EW north of the sill that may be derived from lateral sources (lateral load) in the EW or potential transport from Elliott Bay into the EW. In the downstream reach of the LDW (RM 0.0 to 2.2), it was estimated that the source of the sediment in the top 10 cm of the bed after the 30-year simulation period was largely derived from the Green River sediments (Figure 4-3). Green River sediment accounted for 94 percent of the surface sediment present. The original bed-source sediment accounted for 3 percent of surface sediment present. The lateral-load sediment accounted for the remaining 3 percent of the surface sediment present (see Sections 5.2.3 and 5.2.4 for available existing information on lateral loads).

The overall mass balance and trapping efficiency of the LDW is of interest for study of the EW, as this provides an estimate of the potential mass of sediment that could enter the EW from the LDW. Note however, that the sediment mass entering the EW was not reported in QEA (2007). The sediment mass entering the EW is determined by the division of flow between the EW and WW, though is is not reported[7]. The trapping efficiency is defined as the percentage of sediment that is deposited in a reach (QEA 2007). For the LDW over the 30-year simulation period, the estimated influx of sediment from the Green River (RM 4.8) was 6,220,000 metric tons. The model-estimated transport downstream from the LDW was 3,213,700 metric tons, which gives an overall trapping efficiency of 49 percent for the LDW. Lateral loads accounted for 36,200 metric tons of the sediment influx to the LDW, with 17,100 metric tons of the lateral load sediment transported downstream from the LDW[8]. Of the sediment transported downstream of the LDW over the 30-year period, 99 percent of the mass was derived from the Green River. For the analysis of the high-flow event (100-year return period), 97 percent of the sediment from the Green River was computed to be transported downstream of the LDW past RM 0.0; the remainder was from bed and lateral sources.

4.4 Effects of Ship-Induced Bed Scour

Ship-induced bed scour may result from propeller-induced currents (propwash), vessel wake, and ship-induced pressure field effects (also known as drawdown or Bernoulli effects). Propwash can resuspend sediment anywhere in the channel, whereas vessel wake

[7] The division of flow and sediment mass between the EW and WW can be obtained from the calibrated models.

[8] Based on these quantities, the calculated lateral-source trapping efficiency of the LDW is 47percent.

and pressure fields can resuspend sediment in nearshore shallow areas and banks of the waterway.

Propwash and pressure field modeling are generally performed in two steps: hydrodynamic modeling and sediment stability/scour analysis. The first step includes hydrodynamic modeling to determine propwash and pressure field velocities impacting the harbor bottom (or cap material). The second step includes determining stability of the bottom sediment (or cap material) and depth of potential scour, if material is found to be unstable.

Hydrodynamic modeling for propwash is generally conducted (if required) using numerical models. The most common models are JETWASH and VH-PU. JETWASH is a 2-dimensional (2-D) steady state condition numerical model that simulates propeller-generated velocity at 0.8 feet above the bottom surface elevation. VH-PU is a 3-dimensional (3-D) unsteady state numerical model that simulates velocities generated by ship propellers (including turbulence intensity and length scale in a given domain of arbitrary bottom and coastal topography).

Hydrodynamic modeling for pressure field velocities is generally conducted using the 2-D model VH-LU. The VH-LU model simulates water surface elevations and velocities in the modeling domain during passage of a vessel through a channel. Input parameters include 3-D channel modeling grid and 3-D vessel geometry to accurately model the effects of the hull on the flow field.

Propwash and pressure field modeling both include simulation of current velocities generated by the propeller of representative ships and tugboats. A comparison is made of the velocity pattern on the seabed with threshold velocities for bottom sediment resuspension. Model outputs include estimated areas of seabed subject to resuspension and estimated maximum scour depth at which sediment resuspension will not occur.

As discussed in Section 2.4.2, container and cruise ships, tugboats, towboats, barges, and other small craft use the EW. Sediment physical properties also factor into the analysis, and are discussed in Section 2.2.6. This section reviews pertinent information from the EW and vicinity that may be of use in evaluating the potential impacts of ship-induced impacts on EW sediment.

4.4.1 Propwash Studies

The EWG is not aware of any propwash field studies specific to the EW. However, propwash studies have been performed in Elliott Bay and nearby waters for the Port of Seattle, Port of Tacoma, WSF terminals, and others. Elements of each of these studies may be relevant for future evaluation. Studies closest to the project site are described below.

4.4.1.1 T-91 Cruise Ship Berths Under-Wharf Thruster Wash Scour Analysis (CHE 2007)

CHE performed modeling and analysis of bow thruster propwash for a Voyager Class cruise ship for the proposed new cruise facility at T-91 in Seattle. The ship has four bow thrusters (each 4,100 horsepower [HP]), two stern azipod propellers (each 18,775 HP), and one fixed-pod propeller (18,775 HP). The 3-D VH-PS model was used to simulate the velocity field on the harbor bottom and side slopes under T-91. An analysis of scour, sediment stability, and side slope armoring requirements was performed.

4.4.1.2 East Blair One Wharf Under-Wharf Scour Analysis (CHE 2006a)

CHE performed modeling and analysis of thruster propwash currents for a Maersk-S-class container ship (17 containers wide) and a future 22-container-wide vessel, and for the propeller of a tugboat (1,500 HP). The 3-D VH-PS model was used to simulate the velocity field on the side slopes under the East Blair One Wharf. Analysis of stone stability was performed to determine armor stone parameters for the slopes.

4.4.1.3 TRC Sediment Remediation – Lockheed Shipyard No. 1 Sediment OU-Armor Layer Coastal Engineering Analysis (CHE 2004)

CHE performed numerical modeling and analysis for two sizes of tugboats (800 and 3,000 HP) for docking barges at the Lockheed Shipyard on the east side of the WW. The 2-D JETWASH model was used to determine near-bottom water velocities. The purpose was to determine sediment grain size stability for the propwash velocity field and to determine the stone gradation for armoring the side slope under the pier. This project considered propwash imposed on the upper part of the slope and did not account for the bottom scour.

4.4.1.4 Propeller Wash Measurements and Model Comparison – Maury Island Barge-Loading Dock (CHE 2003)

CHE conducted field measurements of propeller currents for a tugboat having dual Z-drives (each 1,250 HP). The measured current data from the test runs of the tugboat were used to verify the results from the 2-D JETWASH model previously used in the analysis of propwash at the Maury Island gravel loading facility. Results of the analysis indicated that the JETWASH model, as originally calibrated for the Maury Island study, provided valid results. This project considers propwash impact on eel eelgrass habitat and did not account for bottom scour.

4.4.1.5 LDW Propwash Analysis (Windward and QEA 2007)

A propeller current and bed scour analysis for the LDW evaluated the potential for ship-induced bed scour within the LDW, to provide ship-induced scour evaluation for the LDW CSM, and to evaluate the relative importance of anthropogenic effects on bed stability. The study used an empirical model developed for tugboats and barges operating on the Mississippi River.

The analysis included (1) determination of spatial distribution of vessel (ship and tugboat)-induced time-variable current velocities over the bottom, (2) time-variable shear stress at specific LDW transects, (3) extent of bottom scour at specific LDW transects, and (4) estimates of potential gross bed scour, including scour depth, at specific LDW transects. Specific parameters and operating procedures were used for two tugboats. These two tugboats were used in various combinations of barges and ships to determine the combined bottom velocities from propellers and hull wakes. It should be noted that only the tugboats were under power when maneuvering ships or barges.

4.4.1.6 Duwamish/Diagonal Way CSO Propwash Analysis (King County 2005a)

An analysis of propwash for the Duwamish/Diagonal Way CSO was performed as part of the King County Elliott Bay Duwamish Restoration Program in 2005. The Duwamish/Diagonal Way CSO is located at approximately RM 0.5 in the LDW. The analysis used standard formulas with the spreadsheet model PROPWASH to estimate propeller-induced current velocities from a dual Z-drive tugboat (each 1,200 HP) at the bottom of the waterway. Specific parameters and operating procedures were used for the largest tugboat likely to operate in the area. Conservative estimates of required particle size were estimated to prevent sediment resuspension in the area within 630 feet of the pier face.

4.4.2 Relevant Pressure Field Studies

The EWG is not aware of any studies directly concerning sediment resuspension from pressure fields in the EW. However, other studies performed for other narrow waterways similar to the EW indicate that these phenomena can erode unarmored channel banks and resuspend sediment if ship speeds are high enough. Channel size and ship size also influence the likelihood of erosion. Although results from the studies listed below do not directly apply to the EW, the studies provide methodology that may be pertinent to the EW SRI/FS. These studies are listed below, along with a brief description.

4.4.2.1 Deep-Draft Vessels in Narrow Waterway – Port of Oakland 50-foot Deepening Project (Shepsis et al. 2001)

Field data collection and numerical modeling of pressure fields and vessel wakes generated by deep-draft vessels similar to those that operate in the EW were conducted in the Inner and Outer Harbor Waterways of the Port of Oakland, San Francisco Bay, California. The Inner Harbor Waterway is similar in depth to the EW, but is nearly twice as wide. The study showed that hydrodynamic forces exerted on the banks of the waterways due to the pressure fields from deep-draft vessels can be significant if the vessel speed exceeds 5 to 6 knots.

4.4.2.2 Evaluation of Hydraulics and Sediment Processes at Alternative Disposal Sites, Bradwood LNG Terminal, Columbia River (CHE 2006b)

CHE conducted numerical modeling of vessel wakes and pressure fields from deep-draft vessels similar to those that operate in the EW and their effects on shoreline erosion along the Columbia River Navigation Channel. The Columbia River Navigation Channel is much wider than the EW. The study found that the combination of pressure fields and vessel wakes has caused scouring of sand and shoreline erosion on the river banks.

4.5 Sediment Mixing Rates

Sediment mixing rates as a result of bioturbation can influence sediment transport dynamics. Bioturbation from benthic infauna can result in displacement and mixing of sediment particles, possibly bringing particles to the surface that would be susceptable to resuspension. Bioturbation can also result in a surface layer with lower bulk density compared to deeper sediments, decreasing the shear strength and increasing the relative erosion potential of the surface layer.

Few site-specific studies are available on bioturbation for the EW; however, studies from other similar sites may provide useful information. A preliminary evaluation of natural recovery was conducted for the WW and the EW as part of the Harbor Island OU SRI/FS (EVS and Hart Crowser 1996). The evaluation included the WW, portions of the EW, and the North Shore of Harbor Island. A one-dimensional analytical model of sediment dispersion incorporated sedimentation, resuspension, bioturbation, and vertical sediment contaminant transport (Officer and Lynch 1989). Referencing previous studies in Puget Sound (Carpenter et al. 1985; Patmont and Crecelius 1991), bioturbation was assumed to be 30 square centimeters per year (cm^2/yr). This rate is an estimate of the area of sediment dispersion or mixing in a given year. Sediment mixing was assumed to result from bioturbation and tidal- or propeller-induced currents. At stations HI-03 and HI-04, profiling using cesium-137 and lead-210 was used to estimate sedimentation rates and the thickness of the upper-most mixed layer, respectively (HISWG 1996). However, data collected from stations in the EW were uninterpretable based on both cesium-137 and lead-210 profiles. For this study, the mixing layer was assumed to be 10 cm, which is the depth to which the majority of benthic macroinvertebrates are generally found (Ecology 2003). Ecology's sediment sampling guidance describes the uppermost 10 cm of the sediments to represent a reasonable estimate of the biologically active zone based on past studies in Puget Sound (Ecology 2003).

No other studies contained information pertinent to bioturbation in the EW. Additional studies related to natural recovery have been performed on other sites throughout Puget Sound, including Bellingham Bay and Commencement Bay (Patmont et al. 2004; Templeton et al. 1993). These studies yielded bioturbation/mixing in the range of 34 cm^2/yr.

4.6 Deepest Historical Dredge Depths

Analysis of historical dredging records can provide information helpful in understanding historical sediment accumulation and overall sediment transport dynamics. Deepest historical dredge depths were mapped for the EW based on historical dredge records and bathymetric surveys in an effort to estimate current sediment thickness above these depths. Historical records and maps of dredging activities and bathymetry measurements were requested from USACE for the EW area. A total of 92 maps were requested from USACE, of which 13 could not be located despite being listed in USACE archives. Forty maps contained depth information for all or part of the EW, each of which were scanned to electronic files and converted to identical scales. Only two historical maps, from 1918 and 1921, contained bathymetry information for areas south of the Spokane Street Bridge in the EW. The area south of the Spokane Street corridor is thought to be deeper now than depths shown on these historical maps.

Historical EW depths were compared to the most recent bathymetry information available (Figure 2-11A and 2-11B). In instances where historical bathymetry was shown to be deeper than current bathymetry, each area was identified by year and depth soundings were digitized using computer-aided design (CAD) software. These soundings were then used to interpolate depth contours for each area that was historically deeper than current depths.

Figure 4-4 shows areas in the EW that contained historically deeper depths than existing conditions. Each of these areas is labeled by year and shows historical depths within each area. As shown, the majority of the EW contains water depths that are currently deeper than any previous historical dredging, as a result of the recent Phase 1 and Stage 1 dredging.

However, the EW is currently much shallower in areas adjacent to T-25 and T-30 than historical depths. Another area with deeper historical depths includes the area around the Qwest communication cable crossing and in the central EW to the north. In addition, the turning basin (Station 5800) and Slip 30 (Station 3000) were formerly submerged areas that have been filled and converted to upland areas (Figure 1-5). Other areas with historical dredge depths deeper than current depths include narrow areas of removal to approximately -54 to -55 feet MLLW at the pierhead line at the base of the riprap slopes located beneath the aprons on T-25 and T-30. As shown on typical cross sections contained in Appendix A (Figures A-11, A-12, A-15, and A-16), these "keyways" were backfilled with rock up to -50 feet MLLW to stabilize the toe of the riprap slope.

Figure 4-5 describes current approximate sediment thicknesses above deepest historical dredge depths. Substantial shoaling can be seen in the southern EW, including within the narrower portion north of the Spokane Street corridor. In this area, sediment thickness since the deepest dredge events is generally between 10 to 20 feet. Other areas that are currently shallower than historical conditions include much of the area along T-30 and in the vicinity of the Qwest communications cable. Sediment thickness since the deepest dredge events in this area ranges from 1 to 15 feet.

5 SEDIMENT SOURCE CONTROL INFORMATION

Source control is a critical part of EPA's Contaminated Sediments Management Strategy (EPA 1998) and Contaminated Sediment Remediation Guidance (EPA 2005), and is an important part of the overall effort for the cleanup of the EW sediments. Where ongoing contaminant sources to the EW remain, sediment recontamination may occur after completion of remedial actions. The assessment of potential recontamination sources to the EW involves the work of multiple agencies operating under their respective, individual regulatory programs, and multiple parties operating on their own property and within their own infrastructure to ensure the adequacy and consistency of source evaluation data. The EWG recognizes the need to evaluate potential ongoing sources to post-remediation sediment recontamination and to coordinate source control evaluation activities with the SRI/FS.

This section provides a summary of available information regarding potential ongoing sources of sediment recontamination in the EW. This includes a discussion of completed or ongoing source control activities relevant to the EW. The subsections are as follows:

- Section 5.1 presents an introduction to source control concepts, and provides a summary of the potential types of sources that have been identified and evaluated for the EW.
- Section 5.2 identifies potential ongoing pollutant sources to the EW, including information about each source and completed and ongoing source control activities.
- Section 5.3 discusses the results of sediment recontamination monitoring that has been performed within the EW since completion of the Phase 1 Removal Action in 2005.
- Section 5.4 provides a brief summary of the source information evaluated. Additional information relevant to source control may be defined in future SRI/FS activities, and if this occurs, the new information will be presented to EPA in subsequent SRI/FS deliverables.

5.1 Relevant Source Control Information

Sediment contamination can result from both historical contaminant discharges (i.e., those that no longer occur due to changes in land use or pollution control practices) or ongoing contaminant discharges. Due to the improvements in environmental practices and increasing regulatory controls on pollution discharges, historical contaminant discharges frequently predominate as the cause of sediment contamination problems (EPA 2005). However, known contamination from historical sources within the EW is being addressed through the site cleanup process. The source control information presented in this section focuses not on historical sources, but rather on potential ongoing contamination sources to the EW sediments. Data that are considered relevant and which are described in this document include those that describe the current status of source control efforts, and that describe the potential for ongoing releases of hazardous substances to the EW. In general, recent datasets (e.g., less than 10 years old) tend to be more relevant to characterization of potential ongoing releases than older data, due to potential changes in land use and pollution control practices that may reduce the relevance of older datasets for this purpose. In some cases, the relevance of certain older datasets may also be compromised due to use of sampling and analysis methods that have since been improved to correct for artifacts or other problems. In addition, the redevelopment of shorelines within the EW (including dredging and shoreline armoring projects) may have made older source characterization data irrelevant to current site conditions.

The different types of potential sources are shown conceptually in Figure 5-1. The types of sources illustrated in Figure 5-1 are common to most industrialized river/estuary systems. Some of the sources shown in the figure may not be relevant to the EW, but are shown to illustrate the full range of ongoing sources that were considered in preparation of this document. A brief description of these types of sources commonly present in industrialized river/estuary systems is provided below:

- **Over-water Uses and Spills:** Sediment contamination can occur through direct discharge of pollutants to the water body from over-water uses and spills. Historically, over-water uses and spills may have occurred, especially where materials containing pollutants were used in large quantities or were handled in bulk. General examples of these types of uses include shipyard painting and sand-blasting activities, bulk ore handling between vessels and shore facilities, and bulk handling of chemicals or petroleum products between vessels and shore facilities. The potential for spills and unintentional discharges from over-water uses have been generally reduced through improved material and cargo handling technologies and methods; centralizing of fuel/product transfers at specialized and controlled facilities; spill contingency planning and spill prevention and countermeasure regulations managed by various federal, state, and local regulatory programs; and pollution control measures implemented by industries. These measures require reporting of spill events and implementation of cleanup measures after spills are reported. Section 5.2.1 presents information on over-water uses within the EW and summarizes recent reported spills of petroleum and hazardous substances.

- **Wastewater Discharges:** The term “wastewater” is used here to describe wastewaters other than combined sewer overflows and stormwater discharges. Historically, wastewater discharges were frequently discharged untreated to surface water bodies. For example, prior to development of modern sewage treatment techniques, municipal conveyances discharged untreated sewage to the EW, including at the Hanford street outfall location (USACE 1966). Historical industrial discharges may also have occurred within the EW, though records for such discharges are not readily available. Many direct surface water discharges have been terminated and are instead discharged to sanitary sewers regulated by pretreatment permit requirements and local ordinances. Currently, there are no reported permitted municipal or industrial wastewater outfalls within the EW. Domestic and industrial wastewater discharged to local sanitary sewers is conveyed to the County’s West Point Wastewater Treatment Plant (WWTP) in the Magnolia neighborhood of Seattle, where these wastewaters are treated prior to final discharge at the West Point WWTP outfall in Puget Sound. An evaluation of wastewater discharges to the EW is discussed in Section 5.2.2.
- **Combined Sewer Overflows:** Municipal sewer systems collect wastewater from a variety of industrial, commercial, and residential facilities. Historically, sewer systems in most industrial areas collected sanitary and industrial wastewater (sewage) and stormwater, discharging the combined untreated water to surface waters. Later, central treatment facilities were constructed to treat the collected sewage and stormwater. More recently, to address flows and overtaxed capacity, stormwater and sewer systems have been separated to manage stormwater separate from sewage. Where separated, stormwater typically flows directly to surface waters untreated. In portions of older urban areas, including portions of the EW drainage basin, the sewer and stormwater systems are not completely separated and the flows of sewage and stormwater can exceed the capacity of the sewer system during extreme rain events. To prevent system failures (e.g., sewage backflows onto streets) overflow outfalls are used to discharge combined flows of sewage and stormwater to surface waters when the flow volume exceeds the storage and

transport capacity of the combined sewer. These CSO structures are regulated by state permits. In the vicinity of the EW, City and County CSO control programs are intended to ultimately reduce overflow discharge frequency and severity. Section 5.2.3 discusses CSO locations within the EW and discusses source control information relevant to these CSOs.

- **Stormwater Discharges:** Municipal and private stormwater systems have been installed in urban areas to convey excess rainfall or snowmelt runoff from developed areas to surface water discharge points. In some cases, these systems are completely separate from municipal sanitary sewer and CSO systems (i.e., separated stormwater piping and discrete stormwater outfall locations), but in other cases, they are combined. Stormwater discharged to combined sewer systems is discussed above as part of CSO sources. Stormwater can entrain pollutants from the atmosphere, and can become contaminated through contact with pollutants on the ground. Stormwater regulations and permit programs have been developed to regulate stormwater quality. These regulations include requirements for stormwater source control and treatment applicable to different types of land uses and site conditions. Although stormwater regulations and permitting programs have implemented some effluent monitoring requirements, monitoring may not always be sufficient to identify discharges that could potentially contribute to sediment recontamination. Section 5.2.4 presents information relevant to existing stormwater discharges to the EW.
- **Nearshore Contaminated Sites:** In some cases, contaminated sites located in nearshore areas can result in recontamination of adjacent sediments through one of three mechanisms. Where the shoreline is actively eroding, contaminated soils may enter the water body directly, potentially resulting in localized sediment contamination. At most locations within the EW, the existing sea walls and armoring of shorelines minimize the potential for this type of contamination by controlling shoreline erosion. The second potential mechanism is the discharge of contaminants via groundwater, either as dissolved contaminants or as product seepages in locations where NAPLs may be present in proximity to the shoreline. The third mechanism by which contaminated sites can affect sediment quality is through discharge of soil-adsorbed pollutants through overland flow, into stormwater, or through seepage of contaminated groundwater into damaged storm

drainage systems. Section 5.2.5 discusses available data for nearshore cleanup sites (i.e., contaminated soil and groundwater sites that have been identified and are undergoing cleanup actions under state and/or federal authorities) and information potentially relevant to EW conditions.

- **Sediment Transport:** Resuspension, transport, redeposition, and accumulation of aquatic sediments can result through a combination of processes. Sediments can be disturbed, resuspended in the water column, and then carried by currents and waves to redeposit in new locations. For the EW, sediment transport could potentially include transport of upriver sediments into the EW from the Green/Duwamish River system, from the LDW, or inshore from Elliott Bay during flood tides. Similarly, sediments could potentially be transported from the EW to Elliott Bay. Section 4 of this report discusses available information related to sediment transport in the EW.
- **Atmospheric Deposition:** Airborne pollutants can reach sediments through the deposition of airborne particulate matter directly onto the water or onto surfaces within the drainage basin. This can occur directly (e.g., settling of dust onto the water body or entrainment of dust into precipitation that falls on the water body) or indirectly (e.g., transport of atmospheric contaminants to the water body through stormwater). Section 5.2.6 discusses available information regarding atmospheric deposition.

It should be noted that recontamination of waterway sediments can be the result of two contributing processes. In the first process, recontamination can occur when new pollutants are introduced *into* the waterway, such as through one of the above-listed processes. In these cases, reductions of source inputs may reduce or eliminate the recontamination occurrence. In the second type of process, recontamination can occur through redistribution of contaminants inside the waterway. The differentiation of these two types of recontamination processes can be complex and often requires the evaluation of multiple lines of evidence (EPA 2005).

5.2 Information on Potential Sources and Pathways

The following subsections summarize information relevant to each of the potential ongoing source inputs to the EW introduced in Section 5.1, with the exception of sediment transport from the LDW or Elliott Bay. Refer to Section 4 for a discussion of sediment transport processes.

5.2.1 Over-Water Uses and Spills

Current land uses within the EW are described in Section 2. The predominant land use in nearshore areas is the handling of containerized cargo and associated activities. This activity occurs along both sides of the EW.

Bulk handling facilities for petroleum products were formerly located at Terminal 34 (T-34), T-30, and T-18. However, these petroleum handling facilities have been closed and cleanup actions have been implemented to address soil and groundwater contamination located in these areas following facility closure (refer to Section 5.2.5). Shipyard activities, including operation of floating drydocks and shore-side ship building and repair activities were historically conducted within the EW, but all of these activities have been terminated.

Creosote-treated piles were historically used for the construction of wharves and piling along the EW; however, the use of creosote-treated piles has been terminated and most creosoted piles have been removed from the EW. Some creosoted pilings remain in the vicinity of T-25 (see Figure 5-6) and in areas offshore of the former T-34 (former GATX) facility and the USCG facility located south of Slip 36 (see Figure 5-7). Modern dock and wharf structures are constructed using predominantly concrete pilings.

Current over-water handling of hazardous substances and petroleum products is largely limited to containerized cargo handling, petroleum use (including lubricants or hydraulic fluids) by vessels within the EW, and petroleum handling by marine fueling barges. Only one shore-based bulk petroleum handling facility remains along the EW. It is operated by Kinder Morgan and is located at the northern proposed EW OU study boundary. The Kinder Morgan facility transfers petroleum products between upland storage facilities and marine fuel barges. Marine fuel lightering barges may also be present within the EW, including those operated by Olympic Tug and Barge, which has an office and mooring facilities on Harbor Island near the head of the EW.

A search of federal, state, and local spill reporting databases was conducted to assess the recent history of reported spills within and adjacent to the EW. These databases include the federal Emergency Response Notification System maintained by USCG, and the spills database maintained by Ecology's Spill Prevention, Preparedness, and Response Program.

To provide a representative sample of recent spill activity, the output of the database search was summarized for the period 1988 to the present (Table 5-1). During this 20-year period (1988 to 2007) a total of 96 spill reports were recorded within and adjacent to the EW. The vast majority (88, or 92 percent) of the reports related to petroleum releases. Most of these releases (71 of 88) consisted of small quantities (a sheen to less than 1 gallon) of petroleum. There were relatively few (7 of 88) spills of medium quantities (1 to 10 gallons) of petroleum, and also relatively few (10 of 88) spills of large quantities (10 to 200 gallons) of petroleum.

There were eight spill reports relating to non-petroleum products reported during the past 20 years. These included three releases of sewage or human waste (each spill less than 1 gallon); three releases of paints, thinners, or xylenes/cresols (each less than 1 gallon); one release of potassium hydroxide and silver (42 gallons); and one release of a hazardous material not specified.

Table 5-1
Summary of Spill Reports in the Vicinity of the East Waterway (Last 20 Years: 1988 to 2007)

Date of Spill Report	Reported Location	Company Name	Reported Environmental Media	Material Description	Reported Quantity	Quantity Units	Notes
5/19/2007 14:45	Pier 23 910 SW Spokane Street	NR		unknown oil	NR	NR	The caller is reporting a discovery of an unknown sheen sighting in the East Waterway of the Duwamish River.
4/22/2007 21:20	Unknown sheen incident, 1519 Alaskan Way South, in between Piers 36 and 37	NR		unknown oil	NR	NR	The caller is reporting an unknown sheen discovery in Elliott Bay.
3/15/2007 17:00	Duwamish River East Waterway	NR		unknown oil	NR	NR	The caller is reporting a unknown sheen sighting in the Duwamish River East Waterway.
3/11/2007 9:30	East Waterway on the Duwamish River	NR		unknown oil	NR	NR	Caller is reporting an unknown sheen.
3/10/2007 15:20	East Waterway	NR		unknown oil	NR	NR	The caller is reporting a unknown sheen sighting in Puget Sound.
2/6/2007	1519 Alaskan Way S	NR	Storm drain pipe	petroleum - gasoline	NR	NR	
12/4/2006	1519 Alaskan Way S	NR	Surface water - marine	unknown	55	gallon	
11/11/2006 8:30	Unknown sheen incident Pier 36	NR		unknown oil	NR	NR	Caller stated that an unknown sheen was discovered near the vessel.
11/7/2006	1519 Alaskan Way S	NR	Surface water - marine	petroleum - unknown	1	sheen	
9/4/2006	910 SW Spokane St	Olympic Tug & Barge	Surface water - marine	petroleum - diesel fuel	50	gallon	
8/29/2006	2720 13th Avenue	Kinder Morgan Energy Partners	Water - Puget Sound	petroleum - drill oil	50	gallon	
8/11/2006	1519 Alaskan Way S	NR	Surface water - marine	petroleum - unknown	1	drum	
7/28/2006 6:25	East Waterway Pier 23	Olympic Tug & Barge		bilge slops	NR	NR	The caller stated that the engineer was cleaning the engine room when the wrong valve was turned and bilge slop was discharged.
6/29/2006 8:35	T-23/East Waterway of the Duwamish River	Olympic Tug & Barge		hydraulic oil	NR	NR	The caller stated that a maintenance crew was pumping water out of a tank when some residual oil was pumped overboard.
6/22/2006	2701 Utah Ave S	Home Depot	Storm drain pipe	other	20	gallon	
5/25/2006	910 SW Spokane St	NR	Surface water - fresh	petroleum - unknown	1	sheen	
5/12/2006	1519 Alaskan Way South	USCG Maritime Safety Team	Water - Elliott Bay	petroleum - engine oil	1	ounce	

Date of Spill Report	Reported Location	Company Name	Reported Environmental Media	Material Description	Reported Quantity	Quantity Units	Notes
4/29/2006 18:45	South end of T-25, Duwamish Waterway, down the road from the USCG base	NR		unknown oil	NR	NR	Caller is reporting an unknown sheen sighting. Source of the release is unknown at this time. Caller states the release could possibly be coming from a construction area nearby the location (exact source is unknown).
4/16/2006 7:22	1100 Southwest Massachusetts St.	Crowley Marine Services		hydraulic oil	1	cup	Caller reporting a hydraulic line was blown on a crane on board a vessel spilling a cup of oil in the water.
3/17/2006 7:31	Unknown sheen incident Elliott Bay	NR		unknown oil	NR	NR	The Washington State Maritime Coop overheard the vessel *Rodon Amarandon* reporting a sheen on the water in Elliott Bay in Seattle. No further information was known by the reporting source.
3/17/2006 7:10	Unknown sheen incident Elliott Bay	NR		unknown oil	NR	NR	Caller stated there is a significant sheen on the water that has been sighted by four different aircraft.
1/2/2006 16:01	Puget Sound, in Elliott Bay	NR		unknown oil	NR	NR	Reporting an unknown sheen sighting.
11/30/2005	2720 13th Ave SW	Kinder Morgan Energy Partners	Water - Puget Sound	petroleum - diesel fuel	NR	NR	
11/6/2005 7:45	T-18/East Waterway	NR		unknown oil	NR	NR	The caller is reporting an unknown sheen.
9/30/2005 9:00	Unknown sheen incident T-18, Berth #4 Harbor Island	NR		unknown oil	NR	NR	Caller is reporting an unknown sheen coming from an outfall.
9/25/2005	2431 East Marginal Way South	NR	Water - Elliott Bay	petroleum - oil other	1	quart	
9/25/2005	2431 E Marginal Way S	Cruise Terminals Of America	Surface water - marine	petroleum - oil other	2	pint	
9/17/2005 7:00	East Waterway Pier 30, Duwamish River	NR		unknown oil	NR	NR	The caller is reporting an unknown sheen.
9/10/2005	3241 Marginal Way S	NR	Surface water - marine	petroleum - unknown	1	sheen	
8/17/2005 3:20	East Waterway/ Duwamish River	NR		unknown oil	NR	NR	The caller is reporting an unknown sheen.
6/7/2005 19:00	T-18, Harbor Island, Elliott Bay	NR		xylene cresols	NR	NR	Reporting a material release from a container on the terminal due to operator error.
5/14/2005 13:06	Unknown sheen incident, Elliott Bay, inside East Waterway	NR		human waste	NR	NR	Third party information reporting human waste in Elliott Bay.
5/13/2005	2431 East Marginal Way South	Rainier Petroleum	Dock	petroleum - lube oil	15	gallon	
4/27/2005	910 SW Spokane St	NR	Surface water - fresh	petroleum - diesel fuel	1	sheen	
4/21/2005 9:30	Elliott Bay > East Waterway	NR		unknown oil	NR	NR	Reporting an unknown sheen sighting.

Date of Spill Report	Reported Location	Company Name	Reported Environmental Media	Material Description	Reported Quantity	Quantity Units	Notes
1/13/2005	2431 East Marginal Way	FV Sea Freeze Alaska	Surface water - marine	petroleum - hydraulic oil	2	gallon	
12/3/2004	1101 SW Massachusetts St	Crowley Marine Services	Surface water - fresh	petroleum - waste/used oil	1	cup	
10/15/2004	1519 Alaskan Way S	USCG	Surface water - marine	other hazardous	NR	NR	
10/6/2004	1519 Alaskan Way South	NR	Water - Elliott Bay	petroleum - unknown	NR	NR	
10/6/2004	1519 Alaskan Way S	NR	Surface water - marine	petroleum - unknown	NR	NR	
10/5/2004	1st / Spokane	Metro Transit	Storm drain pipe	petroleum - unknown	6	gallon	
10/1/2004	1519 Alaskan Way S	USCG	Surface water - marine	petroleum - oil other	1	gallon	
10/1/2004	1519 Alaskan Way S	USCG Polar Sea	Water - Elliott Bay	oily water	1	gallon	
7/30/2004	1519 Alaskan Way S	NR	Surface water - marine	petroleum - motor oil	8	quart	
7/25/2004	2431 East Marginal Way South	Holland American Lines	Water - Elliott Bay	paint thinner	1	cup	
6/30/2004	910 Southwest Spokane St	Olympic Tug & Barge	East Duwamish Waterway	bunker fuel	2	gallon	
6/26/2004	2431 East Marginal Way South	Princess Cruises	Water - Storm Drain	potassium hydroxide and silver	42	gallon	
4/29/2004	1519 Alaskan Way S	USCG	Surface water - marine	petroleum - hydraulic oil	2	cup	
1/18/2004	1519 Alaskan Way South	Schaffner	Storm drain	gasoline, automotive unleaded	NR	NR	
12/24/2003	1519 Alaskan Way S	USCG	Surface water - marine	petroleum - motor oil	3	pint	
12/10/2003	1519 Alaskan Way S	American Civil Contractors West Coast	Surface water - marine	petroleum - hydraulic oil	200	gallon	
12/4/2003	1519 Alaskan Way South	American Civil Contractors West Coast	Water - Puget Sound	petroleum - hydraulic oil	200	gallon	
11/21/2003	1100 SW Massachusetts St	Crowley Marine Services	Surface water - marine	petroleum - hydraulic oil	4	ounce	
10/28/2003 10:55	Kinder Morgan Terminal	Evros		unknown oil	NR	NR	Caller is reporting an unknown sheen in the water around a vessel.
10/26/2003	1317 SW Spokane St	Citizen	Surface water - fresh	petroleum - hydraulic oil	2	quart	

Date of Spill Report	Reported Location	Company Name	Reported Environmental Media	Material Description	Reported Quantity	Quantity Units	Notes
9/7/2003	2720 13th Ave SW	SSA Marine	Surface water - marine	petroleum - hydraulic oil	100	gallon	
7/14/2003	1100 SW Massachusetts St	Crowley Marine Services	Surface water - marine	petroleum - lube oil	2	quart	
7/14/2003	1100 SW Massachusetts St	Crowley Marine Services	Water - Elliott Bay	petroleum - lube oil	1	cup	
7/12/2003	1519 Alaskan Way S	USCG	Surface water - marine	sewage/sludge	1	quart	
6/23/2003 6:30	East Duwamish Waterway at Pier 36	NR		unknown material	NR	NR	Caller is reporting a mystery drum found in the east Duwamish Waterway.
6/19/2003	2720 13th Ave SW	Olympic Tug & Barge	Surface water - marine	petroleum - crude oil	1	gallon	
6/13/2003	1519 Alaskan Way S	USCG	Surface water - marine	petroleum - oil other	1	sheen	
5/7/2003	1519 Alaskan Way S	NR	Surface water - marine	unknown	1	sheen	
2/11/2003	1519 ALASKAN WAY S.	USCG Polar Star	Water - Puget Sound	petroleum - fuel oil	1	tsp	
10/22/2002	1519 Alaskan Way S	NR	Water - Puget Sound	petroleum - unknown	NR	NR	
6/22/2002	2715 Marginal Way	Marine Vacuum Service	Surface water - marine	petroleum - waste/used oil	2	gallon	
5/2/2002	1535 Alaskan Way S	NR	Surface water - marine	petroleum - unknown	1	sheen	
1/31/2002	1534 Alaskan Way S	USCG	Surface water - marine	petroleum - hydraulic oil	8	ounce	
1/4/2002	1533 Alaskan Way S	NR	Surface water - marine	petroleum - diesel fuel	1	sheen	
11/19/2001	2720 13th Ave SW	Unknown trucking company	Surface water - marine	petroleum - diesel fuel	2	gallon	
11/8/2001	2720 13th Ave SW	Kinder Morgan Energy Partners	Other	petroleum - diesel fuel	NR	NR	
8/17/2001	910 Sw Spokane St	Olympic Tug & Barge	Surface water - fresh	petroleum - oil other	1	sheen	
6/8/2001	1519 Alaskan Way S.	USCG Polar Sea	Water - Puget Sound	petroleum - unknown	NR	NR	
5/21/2001	1524 Alaskan Way S	USCG	Surface water - marine	petroleum - diesel fuel	2	ounce	
5/21/2001	1519 Alaskan Way South	USCG	Water - Elliott Bay	petroleum - fuel oil	3	cup	
5/17/2001	1523 Alaskan Way S	USCG	Surface water - marine	petroleum - hydraulic oil	2	quart	
4/26/2001	910 SW Spokane St	NR	Surface water - fresh	petroleum - unknown	1	sheen	

Date of Spill Report	Reported Location	Company Name	Reported Environmental Media	Material Description	Reported Quantity	Quantity Units	Notes
3/19/2001	1522 Alaskan Way S	NR	Surface water - marine	petroleum - unknown	1	sheen	
2/21/2001	1519 Alaskan Way	USCG Polar Star	Water - Puget Sound	petroleum - diesel fuel	2	gallon	
2/12/2001	910 SW Spokane St	NR	East Duwamish Waterway	petroleum - unknown	1	sheen	
1/21/2001	1528 Alaskan Way S	NR	Surface water - fresh	petroleum - unknown	1	sheen	
10/31/2000	1527 Alaskan Way S	USCG	Surface water - fresh	other hazardous	2	cup	
10/30/2000	910 Southwest Spokane St	NR	East Duwamish Waterway	petroleum - unknown	1	sheen	
8/17/2000	1526 Alaskan Way S	NR	Surface water - marine	petroleum - oil other	1	sheen	
8/17/2000	1519 Alaskan Way South	NR	Water - Puget Sound	petroleum - unknown	NR	NR	
7/31/2000	1529 Alaskan Way S	USCG	Surface water - marine	petroleum - diesel fuel	NR	NR	
7/31/2000	1519 Alaskan Way	USCG Polar Sea	Water - Puget Sound	petroleum - fuel oil	NR	NR	
6/16/2000	1519 Alaskan Way South	USCG	Water - Elliott Bay	paint	4	ounce	
11/13/1999	1519 Alaskan Way S	USCG	Surface water - marine	petroleum - unknown	1	cup	
9/23/1998	1519 Alaskan Way South Pier 36	USCG Polar Sea	Water - Puget Sound	petroleum - unknown	NR	NR	
5/11/1998	1519 Alaskan Way South	USCG	Water - Puget Sound	petroleum - hydraulic oil	1	cup	
3/20/1998	1521 Alaskan Way S	USCG	Surface water - marine	petroleum - diesel fuel	2	gallon	
3/20/1998	1519 Alaskan Way South	USCG	Water - Puget Sound	petroleum - diesel fuel	2	gallon	
7/3/1994	2431 East Marginal Way S Pier 30	NR	Duwamish River	petroleum - unknown	NR	NR	
3/21/1991	3225 East Marginal Way So	NR	Water - Elliott Bay	raw sewage	1	gallon	
6/19/1990	1113 Southwest Manning	Kiewit-Global	Duwamish Waterway	petroleum - hydraulic oil	1	gallon	

NR = Not Reported

5.2.2 NPDES-Permitted Industrial Wastewater Discharges

The National Pollutant Discharge Elimination System (NPDES) permit program regulates industrial and municipal wastewater and stormwater discharges to surface waters. The program is authorized by the Clean Water Act (EPA 2006b) and in Washington State it is administered by Ecology.

A search was conducted for NPDES-permitted industrial wastewater discharges that discharge directly to the EW. This included a review of Ecology's Water Quality Permit Life Cycle System and Ecology's Water Quality website (Ecology 2007b). The Duwamish Waterway is listed as the receiving water body for all facilities discharging to the LDW, the EW, or the WW (Powell 2007). Facility street addresses, a general knowledge of properties bordering the EW, and tenant-related information being developed by the Port as part of its NPDES compliance program were used as the means for identifying NPDES-permitted facilities along the EW.

Nine general industrial stormwater NPDES permits and two municipal stormwater (Phase 1) permits with discharges to the EW were identified. Information about these discharges is described in Section 5.2.4. No other NPDES-permitted stormwater discharges to the EW were identified. The only permitted wastewater discharges directly to the EW that were identified were those held by the City and the County for CSO discharges. Information relevant to CSO discharges is contained in Section 5.2.3.

5.2.3 CSO Discharges to Surface Water

A number of references include information describing the City and County CSO systems and estimates of contaminants associated with CSO discharges. A summary of key documents is included in Table 5-2.

Table 5-2
Summary of Key Documents – CSOs

Date	Title or Description	Author	Prepared for	Notes
1997	Denny Way/Lake Union CSO Control Project Monitoring Report	Herrera Environmental Consultants	KCDNRP	Provides summaries of settling velocity data for King County CSOs.
1998	Henderson/M.L. King CSO Control Project Monitoring Report	Herrera Environmental Consultants	KCDNRP	Provides summaries of settling velocity data for King County CSOs.
1998	CSO sampling and monitoring data inventory, task 5 report, Sediment management plan	KCDNRP	King County	Report includes an inventory of sampling and monitoring data collected in the vicinity of seven King County CSOs, including the Lander and Hanford systems.
1999	King County Combined Sewer Overflow Water Quality Assessment for the Duwamish River and Elliott Bay	KCDNRP and Parametrix	King County	Summary of water quality sampling for King County CSOs, including evaluation of the potential water quality impacts of the CSOs on receiving water bodies and receptors.
1999	King County Department of Natural Resources, Year 2000 CSO Plan Update Project: Sediment Management Plan	Anchor Environmental, L.L.C., Herrera Environmental Consultants, and KCDNRP	King County	Summary of modeling performed to evaluate the potential for CSO discharges to affect sediment quality near seven CSO discharge locations near identified sediment cleanup sites. Document included in Appendix K.
2000	Report of findings, City of Seattle, Seattle Public Utilities CSO characterization project	Environmental Solutions Group	SPU	Develops an estimate of City CSO effluent contaminant concentrations based on a statistical synthesis of CSO effluent data from King County (WA), Bremerton (WA), and Vancouver (British Columbia). Five indicator chemicals were evaluated: copper, zinc, fluoranthene, phenanthrene, and bis(2-ethylhexyl)phthalate.
2002	Memorandum: Discharge Modeling for Contaminated Sediment Cleanup Decisions, Phase I – Identification of Critical Processes and Development of an Approach. Task 201: Review of CSO Conveyance and Outfall Structure Designs	Foster Wheeler	King County	Provides outfall structure characterization and data on discharge and loading for various CSOs.
2002	Memorandum: Discharge Modeling for Contaminated Sediment Cleanup Decisions, Phase I – Identification of Critical Processes and Development of an Approach. Task 202: effluent,	Foster Wheeler	King County	Includes summaries of previous CSO effluent monitoring data for the Lander Street, Hanford #2, and Connecticut Street CSOs. The Memorandum describes the County's on-going CSO modeling activities, including in-pipe CSO transport

Date	Title or Description	Author	Prepared for	Notes
	sediment and receiving water characterization review			estimates.
2002	Memorandum: Discharge Modeling for Contaminated Sediment Cleanup Decisions, Phase I – Identification of Critical Processes and Development of an Approach. Task 203: Conceptual Model for Sediment Contamination Evaluation	Foster Wheeler	King County	Presents a conceptual framework for the development of the model to analyze sediment contamination from CSO discharges based on the information provide in the Task 201 and 202 memoranda.
2003	NPDES Waste Discharge Permit No. WA-002918-1. King County Wastewater Treatment Division	Ecology	King County	Permit describes NPDES-related requirements for County's CSOs, including those discharging to the EW.
2004	King County and SPU source control program for the LDW, June 2004 progress report	KCIW and SPU	Ecology	Summarizes the status of source control efforts in the EW drainage basin.
2001-2005	CSO Control Program Annual Reports providing information for monitoring years 2000-2005	King County	KCDNRP	Reports provide annual summaries and descriptions of ongoing control programs, as well as reports of untreated CSO discharge volumes and frequencies. Excerpts of CSO Control Program Annual Reports for years 2001-2005 providing CSO event frequency and discharge volume information included in Appendix K.
2005	King County and SPU source control program for the LDW, January 2005 progress report	KCIW and SPU	Ecology	Summarizes the status of source control efforts in the EW drainage basin. Also includes business inspections in areas that discharge to the EW and figures showing business locations and areas discharging to the EW.
2005	King County and SPU source control program for the LDW, June 2005 progress report	KCIW and SPU	Ecology	Summarizes the status of source control efforts in the EW drainage basin. Also includes catch basin sediment samples in areas that discharge to the EW, and potential additional business inspections in the EW since the January 2005 progress report.
2006	SPU CSO supplemental characterization study: selection of monitoring stations, Final technical memorandum	Taylor Associates	SPU	Identifies City CSOs selected for upcoming sampling in compliance with the City's NPDES permit.
2006	Sampling and Analysis Plan, CSO Supplemental Characterization Study (draft)	Taylor Associates	SPU	Describes data collection, analysis, quality assurance/quality control, and assessment activities that will be conducted to evaluate the quality of CSO discharges from the City of Seattle combined sewer system as required by its NPDES permit.

Date	Title or Description	Author	Prepared for	Notes
2006	2005 CSO control program review	King County	KCDNRP	Overview of King County's CSO control program, including specific control projects and planned CSO control activities. Document included in Appendix K.
2006	Investigation of the Capabilities of the EFDC model for use in the Evaluation of Sediment Contamination, Discharge Modeling for Contaminated Sediment Cleanup Decisions	Battelle Memorial Institute	KCDNRP	Summarizes recent ongoing CSO modeling work by King County including the evaluation of the EFDC model to simulate sediment transport and deposition of contaminants associated with CSOs.
2007	LDW, Lateral Load Analysis for Stormwater and City-owned CSOs	SPU	SPU	Estimates of annual discharge volume and TSS loads for both stormwater and CSO discharges to the LDW are used together with available data from source sampling efforts to estimate the concentrations of chemicals of concern associated with the discharged CSO particulate size fractions.
2007	LDW CSO data for Lateral Load Analysis	Bruce Nairn	King County	Summaries of the data to characterize King County's CSO in the LDW. Data was provided for CSO discharge volumes, TSS, arsenic, total polychlorinated biphenyls, and particle size distribution.
2007	King County Whole-Water CSO Effluent Sampling Data for the Hanford #2, Lander, and Connecticut Street CSOs	KCDNR	n/a	Provides TSS and chemistry data for whole-water effluent samples collected at the Hanford #2, Lander, and Connecticut CSOs from 1988 and 1996-2004. Data is included in Appendix K.
2008	KCIW permit information for facilities in the East Waterway CSO drainage basins authorized to discharge to the sanitary sewer system	KCIW	n/a	Database information provided by Bruce Tiffany, KCIW, to Jenny Buening, Windward Environmental.

CSO – Combined sewer overflow
Ecology – Washington State Department of Ecology
EFDC – Environmental Fluid Dynamics Code
KCDNRP – King County Department of Natural Resources and Parks
KCIW – King County Industrial Waste Program
LDW – Lower Duwamish Waterway
NPDES – National Pollutant Discharge Elimination System
SPU – Seattle Public Utilities (a City of Seattle department)
TSS – total suspended solids

5.2.3.1 CSO Overview

The sewer system in the vicinity of the EW is illustrated in Figure 5-2. Two County CSOs and one City CSO discharge to the EW along the east shoreline. The two County structures are the Lander Street and Hanford #2 outfalls located on either side of Slip 27. The City structure, known as the Hinds Street outfall (NPDES CSO 107), is a submerged outfall structure located near the south end of T-25 where the EW widens. A third County CSO structure, the Connecticut Street outfall, is located north of the northern proposed EW OU study boundary. The Connecticut Street outfall is included in this summary due to its proximity to the boundary. All of these CSO outfalls discharge at the east shore of the EW and Elliott Bay through a riprap shore bank or sheetpile walls beneath terminal aprons. There are no CSOs that discharge to the EW from Harbor Island.

The Hanford CSO discharges along T-25 at approximately -5 feet MLLW through a 60-inch-diameter concrete box culvert at the riprap bank. Its original design extended to the center of the EW, descending from -23 feet MLLW at the inner harbor line to -60 feet MLLW at the mid-point of the EW. It contained multiple outlet locations along the EW floor along the western 100 feet of pipe length. However, the Hanford CSO was shortened to its current dimensions in 1974 as part of T-25 reconstruction.

The Lander CSO discharges along T-30 through an 8-foot by 8-foot concrete box culvert located under the pier near 0 feet MLLW. As part of an outfall reconstruction and sewer separation project in 1994, a 20-inch-diameter stormwater pipe was extended from within a 2.5-foot-tall spillway within the box culvert to the pierhead line. A description of the Lander Street regulator station (METRO 1992) indicates that the lowest invert elevation of the "Lander Street Storm Drain" is -20 feet mean sea level (MSL) at the outfall to the Duwamish Waterway.

The City-owned Hinds Street CSO consists of a 54-inch-diameter pipe discharging to the EW. According to City records, sewage enters the system from an overflow located in a manhole adjacent to storm system manhole (D056-076) at the intersection of SW Spokane Street and Alaskan Way. The Hinds CSO outfall

(No. 107) also serves as a stormwater outfall (NPDES No. 547). The outfall is positioned relatively deep in the EW, at approximately -17 feet MLLW under a concrete apron dock and extends into the EW approximately 26 feet.

The Connecticut Street regulator station regulates flow from the Connecticut Street Trunk through a 36-inch-diameter line into the Elliott Bay Interceptor (EBI). During overflow conditions, flow is bypassed to the CSO outfall at Elliott Bay in the vicinity of Terminal 48 (T-48) and T-46. The Connecticut Street outfall is also the discharge point for the recently constructed Kingdome regulator (King County 2006b). The Connecticut Street outfall is situated at approximately the same elevation (-5 feet MLLW) as the Hanford #2 outfall based on field observations.

The approximate service areas (drainage basins) associated with the Lander Street, Hanford #2, Connecticut Street, and Hinds Street CSOs are shown on Figure 5-2. Land use within the service areas is shown on Figure 5-3. The Hanford #2, Lander Street, and Connecticut Street CSO drainage basins include a large portion of Seattle's downtown area, Central District, and residential areas to the east along Beacon Hill. The majority of the Hanford #2 and Lander CSO drainage basins overlap (Figure 5-2). Drainage from the overlapping basin area could be discharged to either outfall in the event of a CSO discharge. On a basin-wide scale, the County's CSO collector and transfer piping system (Figure 5-2) is designed to allow for maximum flexibility and the ability to store wastewater in the system to minimize CSO releases. Detailed descriptions of the regulator stations, tributary systems, and the means by which the Lander Street station was designed to regulate flows to the EBI (the main transfer line conveying wastewater north to the West Point WWTP) are described in Appendix K. Approximate drainage basin size and discharge information for each of the EW CSOs is summarized in Table 5-3. The area of the Hinds Street CSO drainage basin compared to the others is comparatively small (approximately 56 acres), and although the Hanford #2 and Lander Street CSO basins are approximately the same size (and cover much of the same area), the Hanford #2 CSO overflows more frequently (Table 5-3).

Table 5-3
East Waterway CSO Basin and Service Area Information and Untreated CSO Volume and Event Frequency[a] Summary for Discharges to the East Waterway and Vicinity

Station	Approximate Basin Size (acres)	Service Area	Operating Agency	Discharge Number	1981-1983 Baseline		2001 (Jan - Dec)		2002 (Jan - Dec)		2003 (Jan - Dec)		2004 (Jan - Dec)		2005 (Jan - Dec)	
					Vol.*	Events	Vol.*	Events	Vol.*	Events	Vol.*	Events	Vol.*	Events	Vol.*	Events
Connecticut/ Kingdome [b,e]	915	South	King County	029	90	23	1.42	3	1.15	1	0	0	1.26	2	27.26 [g]	5 [g]
Hanford #2 [b,d]	4,980	South	King County	031/2 [d]	644	63	91.15 [f]	8[f]	79.8 [f]	13 [f]	64.02	16	78.23	16	91.33	15
Lander [b]	4,890	South	King County	030	143	22	86.72	10	47.73	10	293.88	12	35.44	9	57.56	8
Hinds [c]	56	East Waterway	City of Seattle	107	na	na	0.6	6	0.11	5	0.02	1	33.67	7	0.62	1

Vol* = volume, in millions of gallons

a Event frequency based on 24-hour inter-event interval.

b Hanford, Lander, and Connecticut annual discharge and event frequency data adapted from King County Department of Natural Resources and Parks Wastewater Treatment Division Annual Combined Sewer Overflow Reports (1999-2000 through 2005-2006).

c Annual values through 2004 adapted from Fact Sheet for NPDES Permit WA-0031068-2; City of Seattle Combined Sewer Overflow. Data from 2005 obtained from SPU personnel.

d June 2000 through June 2003 values include discharge and event data for both Hanford #1 and Hanford #2 combined CSO discharges (combined total presented in annual reports). Hanford #1 does not discharge to the East Waterway.

e Values shown represent totals listed in annual reports for discharge #029, including "Connecticut" and "Kingdome" discharges.

f Hanford June 2001 - May 2002 values flagged in the Annual Combined Sewer Overflow Report with a Partial Data (PD) qualifier.

g Connecticut/Kingdome discharges reported as not measured from June 2005 through December 2005. Annual values based on total of available data for 2004 and 2005.

na not available

The sources, frequencies, volumes, and characteristics of wastewater discharging to the EW from CSOs are highly dependent on the operating parameters of the regulating system and seasonal rainfall quantities/storm events. For this reason, average or annual-based discharge and effluent data for CSOs are likely to be more representative of long-term loading than observations made during a single storm event. The County has collected whole-water effluent samples from the Hanford #2, Lander, and Connecticut Street CSOs during discharge events. In addition, SPU has collected sediment from on-site and ROW catch basins within the CSO drainage basins as part of their source tracing investigations. Table 5-4 presents a summary of available effluent data and source tracing sediment data available for each CSO in the EW drainage basin.

Table 5-4
Available CSO Whole-water Effluent and Source Tracing Sediment Data Available for the East Waterway CSOs

Available Data	Whole-Water Effluent [a]				Source Tracing Sediment [b]				
	Sample Count [c]	Sampling Dates	TSS	Chemistry	Sample Count: CB	Sample Count: RCB	Sample Count: MH	Sampling Dates	Chemistry
Hanford Street (#2)	45	1996-2004	yes	yes	2 [d]	1 [d]	0	2003-2006	yes
Lander Street	1	1988	yes	yes	33	26	0	2003-2006	yes
Connecticut Street	9	1996-1997	yes	yes	na	na	na	na	na
Hinds Street	0	not sampled	na	na	2	0	0	2005	yes

a Whole-water effluent data for the Hanford #2, Lander, and Connecticut Street/Kingdome CSOs provided by the King County Department of Natural Resources and Parks (KCDNRP); data are summarized in Tables 5-6 and 5-7, and the complete dataset is presented in Appendix K.

b Source tracing sediment data were provided by SPU on 6/27/07; data are summarized in Tables 5-8 and 5-9, and the complete dataset is presented in Appendix K. Allocation of source tracing samples to specific CSO basins is preliminary and may be modified as additional analysis is completed.

c Sample counts presented represent the number of whole-water effluent samples collected at each CSO; however, not every sample was analyzed for each chemical. Sample counts by analyte are presented as detection frequencies in Tables 5-6 and 5-7.

d Source tracing sediment sample counts in the Lander basin are also in the Hanford basin since this basin overlaps with the Lander basin in its entirety. However, the sample counts in the Hanford basin represent the samples that are only in the Hanford basin, and not in the Lander basin.

CB – on-site catch basin sample
MH – manhole (inline sediment sample)
na – not available
RCB – right-of-way catch basin
TSS – total suspended solids
yes – indicates that data are available

CSO whole-water effluent data are summarized in Section 5.2.3.3 for TSS (Table 5-6) and chemistry (Table 5-7). The data, as provided by the King County Department of Natural Resources and Parks (KCDNRP), are also presented in Appendix K. Source tracing sediment sampling data consisting of on-site and ROW catch basin samples data are also summarized in Section 5.2.3.3 in Tables 5-8 and 5-9, respectively. The complete set of results, as presented by SPU, is included in Appendix K for catch basins located within the CSO service area. These data will be useful in future source control evaluations of these CSOs.

5.2.3.2 Completed and Ongoing Source Control Activities

As mentioned previously, both the City and the County have permits for CSOs including those discharging to the EW issued under Ecology's NPDES CSO permitting program. As part of the City and County NPDES CSO permits, Ecology requires "the greatest reasonable reduction of combined sewer overflows at the earliest possible date" (WAC 173-245-010). The City and the County both have plans for reducing CSO discharges. Since 1988, when monitoring and measuring of CSO flows began, these and other control efforts have reduced CSO volumes in the greater Seattle and surrounding areas from an estimated 2.4 billion gallons per year to approximately 900 million gallons per year system-wide (King County 2006b).

Construction of County CSO control facilities in the region began in the late 1970s. To date, about $320 million has been spent to control CSOs throughout King County and another $383 million is planned to implement further CSO control projects over the next 25 years (King County 2006a). Of primary significance to the EW is the Handford/Bayview/Lander Separation Project completed in 1992. This work included reactivation of the Bayview Tunnel (joint project with the City of Seattle) and served as the precursor for additional planned separation projects for the Hanford basin in 2017 and the Lander basin in 2019. Most current and future projects involve construction of conveyance improvements, increased storage capacities, and treatment facilities (King County 2006a).

The City and County prepare and routinely update their CSO control plans to reflect the current state of science and regulation and to integrate CSO control with other capital improvement programs. Examples of ongoing and completed CSO control measures with relevance to the EW include the following:

- **Computerized Flow-Controls:** In order to maximize the amount of wastewater conveyed to the West Point WWTP, the County operates its system so that to the maximum extent possible, wastewater is retained in the interceptor and trunk-line pipes for eventual treatment. An automated control system manages flows through the conveyance system so that the maximum amount of flow is contained in pipelines and storage facilities until it can be conveyed to the plant.
- **Storm System Separation Projects:** One example of CSO control in the EW vicinity was the completion of the partial separation of the Lander combined system in 1992. This project effectively removed stormwater from within the area know as the "Lander Separation Basin" into its own, non-combined storm conveyance system, thus reducing the amount of stormwater entering the combined sewers during high flow events (King County 1994). Another example is the previously mentioned modifications to the Connecticut system, which was replaced by a new combined system flowing to the Kingdome Regulator. Under that project, the old Connecticut system was left in place to handle separated stormwater (King County 2006b). The Connecticut Regulator Station was left in place to provide only a low-flow diversion of stormwater to the EBI in order to capture any "first flush" stormwater flows. Finally, there have been additional separation projects to reduce the storm flows to the Hanford basin, discharging separated stormwater instead via the Diagonal Way system.
- **Business Inspections:** In December 2004, Seattle Public Utilities (SPU), a department within the City, and King County Industrial Waste (KCIW) began a business inspection program to enforce the pollution source control requirements of the City's stormwater, grading, and drainage control code (SMC 22.800), the pretreatment permitting program, and the Local Hazardous Waste program. Inspections have occurred on both publicly- and privately-owned facilities, including Port facilities. As of May 2006, SPU inspected 184 businesses; 41 were screening inspections, and 143 were full site inspections in the EW drainage basin (Rheaume 2007). Five of the

businesses inspected with full site inspections were not in compliance with City stormwater source control requirements and required corrective action. Most businesses were in compliance, but still required some sort of corrective action. The most common corrective actions requested were with spills or spill prevention (47 percent) and stormwater management (44 percent), and were primarily due to inadequate maintenance of on-site drainage facilities, lacking proper spill prevention or cleanup materials, inadequate spill cleanup materials present on-site, and inadequate employee training on spill prevention and cleanup procedures. SPU and KCIW inspectors have been working, and continue to work, with the business owners to improve their stormwater pollution prevention practices. Figure 5-3 shows the locations of business inspections that have occurred within the EW CSO and storm drainage basin areas (King County and SPU 2005a).

- **Discharge Authorizations and Pretreatment Programs:** Certain industrial wastewater discharges into the combined and sanitary sewers are regulated by KCIW through the issuance of permits and discharge authorizations, including sampling and pretreatment requirements (King County 2006a). In conjunction with permit enforcement and business inspections, these provisions seek to reduce the pollutant loading in municipal wastewaters, including wastewaters contributing to CSO events. Table 5-5 summarizes the number and type of KCIW discharge permits and authorizations in each of the CSO basins.
- **Storage and Treatment Enhancements:** The County CSO Control Plan and associated annual reports have identified dates for planned implementation of additional storage and treatment capacity for specific outfalls. Planned dates for addition of storage and treatment capacity at the Hanford #2, Lander Street, and Connecticut Street CSOs are 2017, 2019, and 2026, respectively (King County 2005b).
- **Community Involvement and Reporting:** The County publishes a number of CSO Control Program reports and makes them available by internet (http://dnr.metrokc.gov/wtd/cso/library.htm). These include Annual Reports, Plans, Updates, and Reviews, and a report on the 1998 CSO WQA (King

County 1999a). Annual reports have been prepared by the County each year since 1987.

Table 5-5
Number and Type of KCIW Sanitary Sewer Discharge Permits and Authorizations in each of the CSO Basins

Permit Type	Number of Permits in Basin
Hanford #2/Lander CSO Basin Overlap	
Waste Discharge Permit	6
Major Discharge Authorization	15
Hanford #2 CSO Basin	
Minor Discharge Authorization	1
Lander CSO Basin	
Minor Discharge Authorization	1
Connecticut St. CSO Basin	
Waste Discharge Permit	1
Major Discharge Authorization	2
Hinds Street CSO Basin	NR
Waste Discharge Permit	NR
Major Discharge Authorization	NR

Note: information was provided by Bruce Tiffany of the KCIW Program (2008)
Waste Discharge Permit – Permit for a wastewater discharge that is generally greater than 25,000 gallons per day (gpd)
Major Discharge Authorization – Authorization issued for a wastewater discharge between 5,000 and 25,000 gpd
Minor Discharge Authorization – Authorization issued for a wastewater discharge between 1,000 and 5,000 gpd
NR – none reported

The majority of the facilities in the EW drainage basin that maintain a KCIW sanitary sewer discharge permit are located in the portions of the Hanford #2 and Lander CSO basins that overlap. More detailed information about the individual KCIW sanitary sewer discharge permits, including facility names and street addresses, is presented in Appendix K.

5.2.3.3 CSO Information Summary

Information on EW CSOs relevant to the evaluation of potential sediment recontamination is summarized below. Most of this information was developed as part of City and County monitoring activities.

Flow and Discharge Event Data: Discharges from CSOs are sporadic and are a function of multiple operational and weather-related factors. Both the City and County monitor CSO discharges and routinely publish data on the number of CSO events and the total volume of CSO discharges each year. Annual CSO event and flow discharge data for City and County CSOs in and near the EW are summarized in Table 5-3.

TSS Data: The TSS content of the majority of County CSO discharge effluent was evaluated during studies in the late 1990s. TSS concentrations were reported for the Hanford #2 and Connecticut Streets CSOs as part of the WQA (King County 1999a) and were obtained from King County's Laboratory Information Management System. One sampling event is available for the Lander Street CSO in 1988 as part of the pre-separation study. A summary of the TSS data is included in Table 5-6.

Table 5-6
Whole-Water Effluent Sampling Data for Total Suspended Solids for the Hanford #2, Lander, and Connecticut Street CSOs

CSO	Detection Frequency	Concentration Range	Units
Hanford Street (#2)			
Total Suspended Solids	21/21	65.6-153	mg/L
Total Suspended Solids, 0.45 µm	45/45	40-187	mg/L
Lander Street			
Total Suspended Solids	1/1	106	mg/L
Total Suspended Solids, 0.45 µm	na	na	mg/L
Connecticut Street			
Total Suspended Solids	3/3	61-156	mg/L
Total Suspended Solids, 0.45 µm	8/8	48.5-182	mg/L

Note: Original data were acquired from the King County Department of Natural Resources and Parks (KCDNRP) marine and sediment assessment group, and are presented in Appendix K.
na – not analyzed

There are presently no TSS data for the City outfall at Hinds Street. General information on TSS composition in City storm drains and County CSOs is presented in SPU Lateral Load Analysis for Stormwater and City-owned CSOs in the LDW (SPU 2007a). The report cites an average TSS concentration in County CSO discharges of approximately 122 milligrams per liter (mg/L; lognormal mean of 99 samples) based on data collected from County CSO monitoring. The City has not been required to characterize the quality of its CSO discharge at the Hinds Street outfall under its existing permit, so no TSS data for that discharge are currently available. Information from other similar sources (i.e., County CSOs) is available for use in evaluating the City's CSO-related lateral loads to the LDW (SPU 2007a), including data provided by the County and included for use in evaluating the Environmental Fluid Dynamics Code (EFDC) Model for the LDW (Nairn 2007).

Effluent Contaminant Data: Contaminant-level monitoring data are available for whole-effluent water samples obtained from the Hanford #2, Lander Street, and Connecticut Street CSOs. Most of the data were collected in the late 1990s as part of the County's WQA (King County 1999a) and subsequent monitoring data (through 2004) were obtained from the County Laboratory Information Management System. Table 5-7 presents a summary of the County Laboratory Information Management System data for the three County CSOs, and the complete dataset is presented in Appendix K.

Table 5-7
Summary Data for Chemicals Detected in King County CSO Whole-Water Effluent Samples [a]

Chemical [b]	Unit	Detected MDL Concentration Range for All Three CSOs	Hanford Street (#2)		Lander Street		Connecticut Street/Kingdome	
			Detection Frequency	Detected Concentration or Range of Detected Concentrations	Detection Frequency	Detected Concentration	Detection Frequency	Detected Concentration or Range of Detected Concentrations
Metals								
Aluminum, Total		3.48	na	na	1/1	3.48[c]	na	na
Antimony, Total	mg/L	0.00094-0.00247	31/31	0.00063-0.00245	1/1	0.003[c]	8/8	0.00094-0.00247
Antimony, Dissolved	mg/L	0.0005-0.001	31/31	0.00059-0.0016	na	na	7/8	0.0005-0.001
Arsenic, Total	mg/L	0.0015-0.00364	31/31	0.0016-0.00364	1/1	0.0032[c]	8/9	0.0015-0.00352
Arsenic, Dissolved	mg/L	0.00079-0.00257	31/31	0.00093-0.00257	na	na	8/8	0.00079-0.0014
Barium, Total	mg/L	0.0243-0.0901	31/31	0.0243-0.0505	na	na	8/8	0.0288-0.0901
Barium, Dissolved	mg/L	0.00556-0.0164	24/24	0.00782-0.0164	na	na	5/5	0.00556-0.00892
Cadmium, Total	mg/L	0.00029-0.0013	29/32	0.00025-0.00089	1/1	0.004[c]	8/9	0.00029-0.0013
Cadmium, Dissolved	mg/L	na	1/31	0.0002	na	na	0/8	nd
Chromium, Total	mg/L	0.00308-0.0173	32/32	0.00308-0.00879	1/1	0.018[c]	9/9	0.0043-0.0173
Chromium, Dissolved	mg/L	0.00054-0.00207	31/31	0.00059-0.00207	na	na	8/8	0.00054-0.0017
Cobalt, Total	mg/L	0.0011-0.00352	31/31	0.00085-0.0019	na	na	7/7	0.0011-0.00352
Cobalt, Dissolved	mg/L	na	5/26	0.00032-0.00073	na	na	0/5	nd
Copper, Total	mg/L	0.019-0.0728	32/32	0.0192-0.0416	1/1	0.089[c]	9/9	0.0217-0.0728
Copper, Dissolved	mg/L	0.00267-0.0214	31/31	0.00267-0.00661	na	na	8/8	0.00349-0.0214
Iron, Total	mg/L	1.79-8.79	14/14	1.79-4.4	1/1	5.23[c]	6/6	2.3-8.79
Iron, Dissolved	mg/L	0.054-0.493	14/14	0.056-0.493	na	na	4/6	0.054-0.075
Lead, Total	mg/L	0.0128-0.101	31/32	0.0128-0.039	1/1	0.12[c]	8/9	0.017-0.101
Lead, Dissolved	mg/L	0.00051-0.00238	30/31	0.00047-0.00238	na	na	4/8	0.00051-0.0013
Magnesium, Total	mg/L	2.68	1/1	2.68	na	na	na	na
Manganese, Total	mg/L	0.0822	1/1	0.0822	1/1	0.108[c]	na	na
Mercury, Total	mg/L	0.0000488-0.00028	4/31	0.0000488-0.000075	0/1	nd	1/8	0.00028
Mercury, Dissolved	mg/L	na	1/31	0.0000057	na	na	0/8	nd
Molybdenum, Total	mg/L	0.0017-0.00953	31/32	0.0015-0.00953	na	na	8/9	0.0017-0.00752
Molybdenum, Dissolved	mg/L	0.001-0.00884	24/24	0.0018-0.00884	na	na	5/5	0.001-0.00695

Chemical [b]	Unit	Detected MDL Concentration Range for All Three CSOs	Hanford Street (#2)		Lander Street		Connecticut Street/Kingdome	
			Detection Frequency	Detected Concentration or Range of Detected Concentrations	Detection Frequency	Detected Concentration	Detection Frequency	Detected Concentration or Range of Detected Concentrations
Nickel, Total	mg/L	0.00447-0.0121	31/32	0.0042-0.00924	1/1	0.02 [c]	8/9	0.00447-0.0121
Nickel, Dissolved	mg/L	0.00097-0.0057	31/31	0.00178-0.00333	na	na	8/8	0.00097-0.0057
Selenium, Total		na	na	na	0/1	nd	na	na
Selenium, Dissolved	mg/L	0.0011	1/31	0.0011	na	na	0/8	nd
Silver, Total	mg/L	0.00033-0.0011	21/32	0.00023-0.0016	0/1	nd	5/9	0.00033-0.0011
Silver, Dissolved	mg/L	0.00049	5/31	0.00031-0.0005	na	na	1/8	0.00049
Sodium, Total	mg/L	5.2	na	na	na	na	1/1	5.2
Tin, Total	mg/L	0.00052	0/2	nd	na	na	1/1	0.00052
Vanadium, Total	mg/L	0.00285-0.00999	27/27	0.00285-0.00821	na	na	6/6	0.00406-0.00999
Vanadium, Dissolved	mg/L	0.00086-0.00171	20/20	0.0009-0.00171	na	na	4/4	0.00086-0.0015
Zinc, Total	mg/L	0.0794-0.331	32/32	0.0838-0.157	1/1	0.228 [c]	9/9	0.0794-0.331
Zinc, Dissolved	mg/L	0.0172-0.091	31/31	0.0172-0.0493	na	na	8/8	0.0225-0.091
PAHs								
2-Methylnaphthalene	µg/L	0.55-010.2	19/28	0.39-10.2	1/1	3.6	3/7	0.55-8.09
Acenaphthene	µg/L	0.098-0.281	9/28	0.098-0.13	1/1	0.22	2/7	0.098-0.281
Anthracene	µg/L	0.15-0.317	0/28	nd	0/1	nd	2/7	0.15-0.317
Benzo(a)anthracene	µg/L	0.17-0.443	1/28	0.14	0/1	nd	4/7	0.17-0.443
Benzo(a)pyrene	µg/L	0.26-0.571	0/28	nd	0/1	nd	4/7	0.26-0.571
Benzo(b)fluoranthene	µg/L	0.42-1.05	0/28	nd	0/1	nd	4/7	0.42-1.05
Benzo(g,h,i)perylene	µg/L	0.42-0.509	0/28	nd	0/1	nd	2/7	0.42-0.509
Benzo(k)fluoranthene	µg/L	0.4	0/28	nd	0/1	nd	1/7	0.4
Chrysene	µg/L	0.2-0.958	1/28	0.18	1/1	0.61	5/7	0.2-0.958
Dibenzofuran	µg/L	0.37-0.623	0/28	nd	1/1	0.37	1/7	0.623
Fluoranthene	µg/L	0.284-1.96	16/28	0.1-0.364	1/1	1.2	7/7	0.37-1.96
Fluorene	µg/L	0.15-1.06	10/28	0.14-0.267	1/1	0.58	5/7	0.15-1.06
Indeno(1,2,3-Cd)Pyrene	µg/L	0.4-0.492	0/28	nd	0/1	nd	2/7	0.4-0.492
Naphthalene	µg/L	0.57-3.47	16/28	0.38-2.35	1/1	1.2	3/7	0.57-3.47
Phenanthrene	µg/L	0.242-2.38	26/28	0.16-0.743	1/1	1.4	6/7	0.36-2.38
Pyrene	µg/L	0.245-1.25	16/28	0.13-0.287	1/1	1	7/7	0.355-1.25
Phthalates								

Chemical [b]	Unit	Detected MDL Concentration Range for All Three CSOs	Hanford Street (#2)		Lander Street		Connecticut Street/Kingdome	
			Detection Frequency	Detected Concentration or Range of Detected Concentrations	Detection Frequency	Detected Concentration	Detection Frequency	Detected Concentration or Range of Detected Concentrations
Benzyl Butyl Phthalate	µg/L	0.414-1.11	10/28	0.414-1.11	1/1	1.1	2/7	0.58-0.645
Bis(2-Ethylhexyl)Phthalate	µg/L	1.94-11.6	23/28	1.94-11.6	1/1	6.3	7/7	3.67-8.08
Diethyl Phthalate	µg/L	0.4-4.6	28/28	0.4-4.6	1/1	0.42	7/7	0.4-0.88
Dimethyl Phthalate	µg/L	0.098-0.322	18/26	0.098-0.55	0/1	nd	3/7	0.098-0.163
Di-N-Butyl Phthalate	µg/L	0.41-2.3	15/28	0.46-2.3	0/1	nd	5/7	0.41-0.817
Di-N-Octyl Phthalate	µg/L	0.252-0.818	20/26	0.17-0.662	0/1	nd	5/7	0.29-0.818
Other SVOCs								
1,4-Dichlorobenzene	µg/L	0.241-78.5	28/28	0.21-78.5	0/1	nd	3/7	0.307-0.598
2,4-Dimethylphenol	µg/L	0.627	0/26	nd	0/1	nd	1/7	0.627
2-Methylphenol	µg/L	0.545-1.41	8/26	0.26-0.59	na	na	3/7	0.652-1.41
4-Chloro-3-Methylphenol	µg/L	0.71-1.27	3/26	0.62-1.27	1/1	0.71	1/7	0.83
4-Methylphenol	µg/L	1.14-46.5	26/26	1.14-46.5	na	na	4/7	2-10.3
4-Nitrophenol	µg/L	0.81-1.13	2/26	0.72-1.13	0/1	nd	1/7	0.81
Benzoic Acid	µg/L	4.69-67.6	26/26	4.69-67.6	0/1	nd	4/7	8.34-28
Benzyl Alcohol	µg/L	0.503-24.2	21/26	0.44-24.2	0/1	nd	5/7	0.591-2.85
Bis(2-ethylhexyl)adipate	µg/L	na	2/3	0.45-0.48	na	na	na	na
Bisphenol A	µg/L	1.26-1.35	3/3	0.42-1.35	na	na	na	na
Carbazole	µg/L	0.29	0/28	nd	na	na	2/7	0.29[d]
Coprostanol	µg/L	10.7-123	26/26	10.9-123	na	na	7/7	10.7-48.8
N-Nitrosodiphenylamine	µg/L	0.953	1/26	0.3	0/1	nd	1/7	0.953
Pentachlorophenol	µg/L	0.26-0.481	9/28	0.24-0.4	0/1	nd	5/7	0.26-0.481
Phenol	µg/L	1.74-9.62	24/28	1-9.62	1/1	3.2	3/7	2.92-4.35
Total 4-Nonylphenol	µg/L	12.3-13.6	3/3	4.19-13.6	na	na	na	na
n-Octadecane	µg/L	3.62-4.18	2/2	3.62-4.18	na	na	na	na
Pesticides								
Gamma-BHC (Lindane)	µg/L	na	1/10	0.0047	0/1	nd	0/4	nd
VOCs								
1,1,2-Trichloroethylene	µg/L	2	0/4	nd	1/1	2	na	na
Acetone	µg/L	4-106	4/4	19.8-106	1/1	4	na	na
Chlorobenzene	µg/L	na	1/4	1	0/1	nd	na	na

Chemical [b]	Unit	Detected MDL Concentration Range for All Three CSOs	Hanford Street (#2) Detection Frequency	Hanford Street (#2) Detected Concentration or Range of Detected Concentrations	Lander Street Detection Frequency	Lander Street Detected Concentration	Connecticut Street/Kingdome Detection Frequency	Connecticut Street/Kingdome Detected Concentration or Range of Detected Concentrations
Chloroform	µg/L	na	2/4	1.3 [d]	0/1	nd	na	na
Methylene Chloride	µg/L	3	0/4	nd	1/1	3	na	na
Toluene	µg/L	2-5.97	2/4	5.61-5.97	1/1	2	na	na
Petroleum Hydrocarbons								
Oil and Grease, Total	mg/L	6.9	na	na	1/1	6.9	na	na

a Data presented in this table was provided by the King County Department of Natural Resources and Parks (KCDNRP) marine and sediment assessment group (2007).

b Results presented in this table are for chemicals detected in effluent samples from at least one of the three CSOs sampled. Chemicals not detected in any of the CSOs are not represented in this table. For the non-detected chemical results, see the entire dataset for each CSO, as provided by KCDNRP in Appendix K. Samples qualified with a "B" indicating blank contamination with sample results within five times the blank were treated as non-detects consistent with National Functional Guideline validation rules; results for these samples are presented in Appendix K.

c In the original dataset for the Lander CSO, metals results were presented in two separate groupings, one designated as the total metals result and the other without a total or dissolved designation. The non-designated results are total metals results based on a naming convention used for older analyses.

d Both of the detected results had the same concentration.

na – not analyzed

nd – not detected

nr - not reported

In addition to the chemicals listed in Table 5-7, CSO effluent samples were analyzed for several chemicals that were not detected in effluent samples from any of the CSOs. Results for non-detected chemicals are presented in Appendix K. Non-detected chemicals included PCB aroclors (with method detection limits [MDLs] ranging from 0.026 micrograms per liter [μg/L] to 0.8 μg/L). CSO effluent samples were analyzed for several pesticides and Gamma-BHC was the only one detected in CSO effluent (detected once in a sample from the Hanford CSO). Phthalates, some PAHs, and other other SVOCs, such as phenolic compounds, were the most commonly detected chemicals in samples from all three County CSOs (Table 5-7). Most metals were detected in at least a portion of the samples for which they were analyzed from each CSO; however, beryllium and thallium were not detected in any samples. Petroleum hydrocarbons were analyzed for and detected in one sample from each of the Hanford and Lander CSOs. Numerous VOCs were analyzed, but most were not detected (Appendix K). Of the six detected VOCs presented in Table 5-7, acetone was the only VOC consistently detected in CSO effluent samples.

To date, no CSO effluent samples have been obtained by the City from the Hinds Street outfall, as monitoring at that location is not specifically required by permit and the outfall is submerged. The City is currently sampling City-owned and -operated CSOs in compliance with its CSO NPDES permit. The CSO Supplemental Characterization Study requirement of the permit is a one-time study that requires specific criteria of the CSO for monitoring. The Hinds Street CSO is so infrequent and small that it could not qualify as a sample location (Taylor Associates 2006a). The Hinds Street CSO did not meet the selection criteria for outfalls to be included in the study (Taylor Associates 2006b), which included discharge volumes and frequencies, accessibility and structural attributes, land uses in the basins, and receiving waters. Nevertheless, the results of the characterization study should provide useful general water quality information relative to discharges from the larger population of City-owned CSOs. In addition, County CSO data may be useful when based on similar drainage basins to the Hinds Street CSO.

Data for several effluent samples collected in 1988 are also available from the Lander Street CSO. These samples were collected as part of the Lander Street CSO pre-separation study and another sample was collected as part of the NPDES permit baseline testing.

Conveyance Systems Sediment: Since 2003, catch basin sediment from on-site (private) catch basins, ROW catch basins, and sediment collected in conveyance pipes discharging within the Lander, Hanford, and Hinds Street CSO service area have been sampled by SPU. These samples were analyzed for metals, PCBs, SVOCs, TPH, TOC, and grain size. Since there are no regulatory standards for conveyance system sediment, sample results were compared to the SMS. Results from SPU sampling efforts are reported in regular progress reports (King County and SPU 2004, 2005a, 2005b) for the Lower Duwamish Early Action Area. The complete set of results is included in Appendix K for catch basins located within the CSO service area. The sampling locations are presented in Figure 5-2. Table 5-8 summarizes the most commonly detected chemicals in the EW CSO basin exceeding the SMS in on-site catch basins, and Table 5-9 summarizes the results from the ROW catch basins.

Tables 5-8 and 5-9 provide a summary of data collected as part of the City's source control program for the LDW. Data summarized in the tables are sediment samples collected while trying to locate sources of contaminants. The samples were not collected in a sample design attempting to identify the central tendency/typical sediment chemistry concentrations in conveyance systems. The data summary should be considered a "worst case" representation of conveyance sediment, and not typical of what discharges from the stormwater/CSO systems. Lastly, SMS are provided in the tables for comparison purposes only. Chemical concentration standards for sediment in conveyance systems are not established in the State of Washington.

Table 5-8
Summary of On-site CSO Catch Basin Detected Results Exceeding SMS

Chemical	Unit	Detection Frequency	Minimum Detected Value	Maximum Detected Value	Number of SQS Exceedances	Number of CSL Exceedances [a]
Copper	mg/kg dw	8/37	405	5,010	8	8
Lead	mg/kg dw	8/37	476	5,830	8	5
Mercury	mg/kg dw	6/37	0.5	2.05	6	5

Chemical	Unit	Detection Frequency	Minimum Detected Value	Maximum Detected Value	Number of SQS Exceedances	Number of CSL Exceedances [a]
Zinc	mg/kg dw	27/37	412	1,810	27	10
4-Methylphenol [a]	µg/kg dw	15/37	930	89,000	15	15
Benzoic acid [a]	µg/kg dw	3/37	2,700	12,000	3	3
Phenol [a]	µg/kg dw	7/37	650	4,900	7	5
Acenaphthene	mg/kg OC	1/37	41	41	1	0
Fluorene	mg/kg OC	1/37	53	53	1	0
Phenanthrene	mg/kg OC	1/37	500	500	1	1
Benzo(a)anthracene	mg/kg OC	2/37	180	203	2	0
Benzo(a)pyrene	mg/kg OC	2/37	172	200	2	1
Benzo(g,h,i)perylene	mg/kg OC	2/37	59	80	2	0
Chrysene	mg/kg OC	2/37	173	219	2	0
Dibenz(a,h)anthracene	mg/kg OC	2/37	27	45	2	1
Fluoranthene	mg/kg OC	2/37	333	672	2	0
Indeno(1,2,3-cd)pyrene	mg/kg OC	2/37	77	107	2	1
Bis(2-ethylhexyl)phthalate	mg/kg OC	32/7	78	1,441	33	33
Butylbenzylphthalate	mg/kg OC	23/37	6	306	22	5
Dimethylphthalate	mg/kg OC	1/37	55	55	1	1
Di-n-butylphthalate	mg/kg OC	1/37	433	433	1	0
Di-n-octyl phthalate	mg/kg OC	2/37	63	205	2	0
Total PCBs	mg/kg OC	2/37	165	266.7	2	2
1,2-Dichlorobenzene	mg/kg OC	1/37	13	13	1	1
1,4-Dichlorobenzene	mg/kg OC	2/37	6	43,333	2	1
2-Methylnaphthalene	mg/kg OC	7/37	58	290	7	6
Dibenzofuran	mg/kg OC	1/37	19	19	1	0

a The number of CSL exceedances also includes the number of SQS exceedances since SQS is also exceeded when the CSL is exceeded

CSL – Cleanup Screening Level

dw – dry weight

na – not applicable

OC – organic carbon normalized

SQS – Sediment Quality Standards

Table 5-9
Summary of Right-of-Way Catch Basin Detected Results Exceeding SMS in the CSO Basins

Chemical	Unit	Detection Frequency	Minimum Detected Value	Maximum Detected Value	Number of SQS Exceedances	Number of CSL Exceedances [a]
Zinc	mg/kg dw	27/27	84.7	851	4	0
Fluorene	mg/kg OC	6/27	1	65	2	0
Phenanthrene	mg/kg OC	25/27	1	127	1	0

Chemical	Unit	Detection Frequency	Minimum Detected Value	Maximum Detected Value	Number of SQS Exceedances	Number of CSL Exceedances [a]
Bis(2-ethylhexyl)phthalate	mg/kg OC	27/27	15	389	16	12
Butylbenzylphthalate	mg/kg OC	20/27	0.8	77.1	11	9
Total PCBs	mg/kg OC	15/27	0.1	322	1	1
1,4-Dichlorobenzene	mg/kg OC	3/27	0.5	46	2	1
2-Methylnaphthalene	mg/kg OC	5/27	1	91	2	1
Hexachlorobenzene	mg/kg OC	1/27	0.7	46	0	1

a The number of CSL exceedances also includes the number of SQS exceedances since SQS is also exceeded when the CSL is exceeded

CSL – Cleanup Screening Level

dw – dry weight

na – not applicable

OC – organic carbon normalized

SQS – Sediment Quality Standards

Previous and Ongoing Modeling Studies: The County and the Elliott Bay/Duwamish Restoration Program have conducted several modeling evaluations related to CSOs. Sediment recontamination evaluations were performed for the EW and adjacent areas using the County's WQA model (King County 1999a). Near-field probability analyses conducted by King County (1999b) predicted a localized zone (i.e., often less than 1 acre) immediately adjacent to many regional CSO outfalls with a higher probability for sediment recontamination. In order to develop a more definitive model with which to evaluate the extent of recontamination in the near-field area around CSO and storm drain outfalls, King County has evaluated the influence of specific processes of recontamination. Several studies conducted in 2002 evaluated CSO outfall structure characteristics and conveyance systems (Foster Wheeler 2002a); and summarized effluent, receiving water, and sediment characterization data (Foster Wheeler 2002b), which were used to develop a conceptual framework for a model to analyze sediment contamination from CSO discharges (Foster Wheeler 2002c). An EFDC model was developed, and ongoing work by the County includes the evaluation of this model to simulate sediment transport and deposition of contaminants associated with CSOs (Battelle 2006). A preliminary evaluation of the EFDC concluded that processes (i.e., initial dilution, flocculation, and bed processes) important to sediment contamination, needed to be further examined to effectively model CSO sediment contamination. The County and City have also been participating in modeling activities performed as part of the LDW RI/FS process. CSO discharges are included as lateral loads in the sediment transport model for the LDW project area. A draft sediment transport modeling report (QEA 2007) was recently issued summarizing results of that work, as described in Section 4.

5.2.4 Stormwater Discharges

Separated storm drain outfalls discharge stormwater to the EW. Stormwater discharges may carry pollutants that accumulate throughout the EW drainage basin from spills, illicit discharges, automotive sources, atmospheric deposition, improper handling and storage of pollutants, contaminated soil on properties and ROWs from which the stormwater originates, groundwater pollutants infiltrating into stormwater conveyance systems, and pollutants residing within the stormwater conveyance system bed load. Key documents used in this summary that included information relevant to stormwater discharges to the EW are listed in Table 5-10.

Table 5-10
Summary of Key Documents – Stormwater Discharges to Surface Water

Date	Title or Description	Author	Prepared for	Notes
1998	Elliott Bay/Duwamish Source Control Project	SPU	SPU and Ecology	Report includes assessment of potential contaminants, review and summary of existing data in drainage basins, conducted NPDES field screening analyses, and evaluation of existing source control efforts.
2004	King County and SPU source control program for the LDW, June 2004 progress report	KCIW and SPU	Ecology	Summarizes the status of source control efforts in the EW drainage basin.
2005	King County and SPU source control program for the LDW, January 2005 progress report	KCIW and SPU	Ecology	Summarizes the status of source control efforts in the EW drainage basin. Also includes business inspections in areas that discharge to the EW and figures showing business locations and areas discharging to the EW.
2005	King County and SPU source control program for the LDW, June 2005 progress report	KCIW and SPU	Ecology	Summarizes the status of source control efforts in the EW drainage basin. Also includes catch basin sediment samples from 19 locations in areas that discharge to the EW, inline sediment sample results for the EW, and potential additional business inspections in the EW since the January 2005 progress report.
2006	NPDES Phase 1 Municipal Stormwater Permit (preliminary draft) – full permit plus accompanying factsheet	Ecology	n/a	Summarizes stormwater management requirements applicable to City, County, and Port municipal stormwater systems.
2007	Port of Seattle stormwater mapping inspection reports and maps	Phoinix Corporation and Aspect Environmental	Port of Seattle	Ongoing development of stormwater drainage maps and outfall surveys for use in complying with Phase 1 Municipal Stormwater Permit requirements.
2007	List of Ecology's general stormwater industrial permit holders discharging to the Duwamish River	Ecology (received through email from Becky Powell of the Water Quality Program)	n/a	List of industrial stormwater general permit holders.
2007	NPDES data pages downloaded from Ecology's Water Quality Permit Life Cycle System	Ecology	n/a	Lists of general stormwater, industrial, boatyard, municipal, and aquatic pesticide NPDES permit holders.
2007	Stormwater Pollution Prevention Plans for T-18 and T-25	SSA	Ecology	Describe and map various outfalls discharging from the SSA-occupied portion of the terminals.

Date	Title or Description	Author	Prepared for	Notes
2007	LDW Lateral Load Analysis for Stormwater and City-owned CSOs	SPU	SPU	Estimates of annual discharge volume and TSS loads for both stormwater and CSO discharges to the LDW are used together with available data from source sampling efforts to estimate the concentrations of chemicals of concern associated with the discharged CSO particulate size fractions.

Ecology – Washington State Department of Ecology
KCIW – King County Industrial Waste
LDW – Lower Duwamish Waterway
n/a – not applicable
NPDES – National Pollutant Discharge Elimination System
SPU – Seattle Public Utilities
SSA – Stevedoring Services of America
TSS – total suspended solids

5.2.4.1 Overview

The stormwater drainage area for the EW is approximately 820 acres (King County and SPU 2004) from both private and municipal separated stormwater drainages. Figure 5-4 shows the approximate boundaries of storm drainage areas discharging to the EW and identified stormwater outfalls. These are areas typically separate from the larger CSO drainage basins described in the previous section.

As shown in Figure 5-4, the EW stormwater drainage can be divided into two general stormwater drainage areas. The Lander Drainage Basin, which includes the Lander separation area, drains stormwater from a significant, predominantly-industrial area approximately 450 acres in size. The basin extends from the EW to Interstate 5, and includes a small area on Beacon Hill. The 90-inch-diameter Lander Street Storm Drain collects drainage from the separation area. The drain flows parallel to the Lander Street Trunk (serving the larger CSO basin). The CSO discharge from the Lander regulator enters the Lander Street Storm Drain prior to discharge at the storm outfall location just north of Slip 27 at T-30. The original design for the separated drain system allowed discharge of low-flow stormwater to the sanitary sewer, but this connection was terminated due to excessive salt water intrusion into the sanitary sewer during high tide events.

The second general drainage area (shown on Figure 5-4) consists of the nearshore drainage basins located along the west side (approximately the eastern one-third of Harbor Island) and the east side of the EW that are not included in the Lander storm system. Most of this area consists of nearshore properties owned by the Port, where the stormwater conveyances discharge directly to the EW. The nearshore drainage areas are industrial and represent a combined area of approximately 350 acres. About half of this area is located on Harbor Island, and about half is located along the east side of the EW.

Most of the properties located within the nearshore stormwater drainage areas consist of container terminals and associated transportation facilities. These areas and the associated ROWs are drained by 39 identified stormwater outfalls (Figure 5-4). The Port and SPU are conducting ongoing outfall and drainage area mapping as part of Phase 1 NPDES stormwater permit requirements to verify location and ownership, which is currently being implemented. Currently, only the ownership status of one outfall is unknown. This outfall is located on the west side, near the head of the EW. Two stormwater outfalls on the east side of the EW, Hinds Street and Lander, also operate as CSO outfalls. A detailed inventory to verify precisely how many outfalls are currently present in the EW has not been completed. The Port is currently developing an inventory of stormwater outfalls serving the Port-owned properties along both shorelines.

Additional stormwater outfalls are located just north of the northern proposed EW OU study boundary, at Terminal 42 (T-42) and T-46. Separated stormwater is also discharged through a separate stormwater conveyance at the Connecticut Street CSO outfall at T-46.

Land use information for stormwater drainage basins is important to understanding the potential types of contaminants and drainage systems that can discharge to the receiving environment. The land use within the EW storm drainage area consists predominantly of industrially zoned property and associated ROWs (Figure 5-3). Land use types within the EW stormwater drainage areas, as identified by SPU, are summarized in Table 5-11.

Table 5-11
Land use in the East Waterway Sub-basin

Land Use Type	Land Use (percent)
Single-family residential	2
Multi-family residential	2
Industrial	56
Right-of-way	27
Commercial	9
Vacant	3
Open space/parks	1

Source: Adapted from King County and SPU 2004

5.2.4.2 Completed and Ongoing Source Control Activities

Stormwater discharges are regulated under Ecology's NPDES General Stormwater and Industrial permitting program. Table 5-12 lists the NPDES permit holders discharging to the EW. A number of different permits affect stormwater discharges. These include the following:

- **Municipal Permits:** Washington State's Phase I Municipal Stormwater Permit regulates discharges from municipal separate storm sewers owned or operated by Clark, King, Pierce, and Snohomish Counties, and the cities of Seattle and Tacoma. Recently, Ecology issued a Phase 1 Municipal Stormwater Permit for discharges from Large and Medium Municipal Separate Stormwater Sewer Systems that specifically includes the Port of Seattle as a secondary permittee and is applicable to Port-owned stormwater conveyances (except Seattle-Tacoma International Airport).
- **Industrial Permits:** These permits affect certain industrial land uses and require management of stormwater in compliance with a general or individual permit.
- **Construction Permits:** Stormwater permits are also required for certain construction activities. In Seattle, the Department of Planning and Development (DPD) regulates discharges from construction sites to the storm drain system per the stormwater, grading, and drainage control code (SMC 22.800). The code requires developers to control soil erosion and runoff from all construction projects. In addition, a NPDES Construction Stormwater general permit is required from Ecology for projects larger than 1 acre in size or projects discharging stormwater to a surface water body either directly or via a storm drain.
- **CSO Permits:** When co-located with a stormwater outfall, see Section 5.2.3.

Table 5-12
Reported NPDES Industrial, Construction, and Municipal Stormwater Permits for the East Waterway Nearshore Drainage Area

Facility Name	Facility Address	Permit Type	Permit No.
Port of Seattle Marine Maintenance Shop	25 S Horton Street	industrial stormwater (general)	SO3002517C
Harbor Island Machine Works Inc.	3431 11th Avenue SW	industrial stormwater (general)	SO3000054D
Asahipen America Inc.	1128 SW Spokane Street	industrial stormwater (general)	SO3000089D
Stevedoring Services of America T-18 and T-25	2400 11th Avenue SW	industrial stormwater (general)	SO3000467D

Facility Name	Facility Address	Permit Type	Permit No.
Lee and Eastes Tank Lines Inc.	1416 E Hagerman Street	industrial stormwater (general)	SO3000748D
Westway Feed Products Co Inc. (a.k.a. United Molasses)	1002 SW Spokane Street	industrial stormwater (general)	SO3004526B
Hanjin Shipping Co T-46 (Port of Seattle Co-permittee)	401 Alaskan Way S	Industrial stormwater (general)	SO3000465D
Pac Rail	44 S Hanford Street	Industrial stormwater (general)	SO3000484D
Colorado Street Facility Rainier Petroleum	40 S Spokane Street	Industrial stormwater (general)	SO3005619A
T-25/T-30 Improvement	2431/3225 E Marginal Way S	construction stormwater (general)	WAR007087A
East Marginal Way Grade Separation	Marginal Way and S Spokane Street	construction stormwater (general)	WAR007112A
Port of Seattle T-18 N Apron	2400 11th Avenue SW	construction stormwater (general)	WAR006122B
City of Seattle	n/a	Phase I Municipal Stormwater	-
Port of Seattle	n/a	Phase I Municipal Stormwater	-

Sources: Powell (2007) and data sheets available at Ecology's website (Ecology 2007c).
n/a – not applicable (these permits cover all municipal stormwater discharges and not specific facilities).

Stormwater permits and associated requirements are the principal regulatory mechanism for regulating stormwater quality. Implementation measures set forth in stormwater permits typically include:

- **Standards for New Development:** Standards for stormwater collection and treatment are regulated through the building permit process. New development and redevelopment require compliance with the adopted version of the Stormwater Management Manual for Western Washington (Ecology 2005) or equivalent.
- **Stormwater Pollution Prevention Plans:** Where required by permits, Stormwater Pollution Prevention Plans (SWPPPs) must be maintained and implemented. The SWPPPs document patterns of stormwater runoff and the measures taken by property owners or tenants to manage stormwater quality consistent with regulatory requirements.
- **Best Management Practices (BMPs):** BMPs are activities such as spill prevention, housekeeping, or surface sweeping that have been shown to reduce pollutant loading to stormwater. These activities are an integral part of stormwater management and are specified as part of SWPPPs. BMPs are

detailed in the adopted Stormwater Management Manual for Western Washington (Ecology 2005).

- **Stormwater System Maintenance**: Stormwater management activities include extensive maintenance requirements. For conventional older systems, this can include periodic cleaning of system catch basins and replacement of storm filters. For newer or upgraded stormwater systems and stormwater BMPs this can include cleaning and maintenance of stormwater treatment system components such as filter vaults or biofiltration swales.
- **Stormwater Monitoring:** Monitoring requirements are included in most stormwater permits. The type and scope of monitoring varies from permit to permit. Permits frequently specify bench-mark or action-level concentrations above which actions must be taken to correct stormwater quality exceedances. For EW permits, monitoring is typically required for TSS, turbidity, pH, oil and grease, and zinc. Other facility-specific parameters such as fecal coliform, nitrate, or phosphorus are also required. Stormwater monitoring conducted in compliance with discharge permits may not be sufficient to evaluate the full range of potential sediment quality parameters for EW source control.
- **Inspections:** Industrial, stormwater, and construction stormwater permits include requirements for the permittee and/or regulatory entities to conduct periodic inspections to assess stormwater system performance and/or verify compliance with permit conditions. The Municipal Stormwater Permits, including those for secondary permittees, require development of inspection programs to additionally identify and eliminate non-stormwater discharges that may be connected to stormwater systems. In 2004, SPU and KCIW began a city-wide business inspection program to enforce the pollution source control requirements of the City's stormwater, grading, and drainage control code (SMC 82.200). These inspections are used to assess compliance with source control requirements, identify any non-stormwater discharges, and to specify required corrective actions (see "Business Inspections" in Section 5.2.3.2 for a summary of findings). In addition to the SPU and KCIW inspections, the Port is developing a stormwater inspection program for their

tenants consistent with Port requirements under the new Ecology Phase 1 Municipal Stormwater Permit.

- **General Permit Requirements:** In accordance with the NPDES Municipal Permit, the permittees must develop and implement a Stormwater Management Program (SWMP). The SWMP must be designed to reduce the discharge of pollutants to the "Maximum Extent Possible." Permittees must also record the cost of development and implementation of the SWMP. The SMWP includes the following components:
  - Education program
  - Public involvement and participation
  - Illicit discharge detection and elimination
  - Construction site stormwater runoff control
  - Post-construction stormwater management for new development and redevelopment
  - Operation and maintenance program
  - Source control in existing developed areas
  - Mapping and verification of stormwater systems
  - Structural stormwater controls
  - Internal and external coordination

5.2.4.3 Stormwater Information Summary

Information regarding the potential quantity and recent quality of stormwater discharged to the EW is summarized below:

- **Flow Measurements:** No flow monitoring data are available for the Lander or nearshore drainage areas. The lateral load analysis recently conducted by the City (SPU 2007a) for the LDW contains a technical appendix (included here as Appendix L) summarizing methods for estimating the amount of runoff generated from a property during a given rain event, based on land use type and soil type. Historical rainfall patterns in the LDW area are summarized in that document for the period 1979 to 2005. These data, in conjunction with the drainage basin areas, can be used to estimate potential stormwater discharge rates for the EW.

- **Stormwater TSS Loadings:** No TSS monitoring data have been identified for EW stormwater drainage. A lateral load analysis has recently been conducted by the City (SPU 2007a) for stormwater and CSO discharges to the LDW for use in the LDW sediment transport model. Estimated TSS concentrations in stormwater from different types of land use and different stormwater treatment facilities were reported. The report estimates the average TSS loading of stormwater from industrial and ROW areas (which make up the majority of the EW storm drainage basin as presented in Figure 5-3 and Table 5-11) are 82.2 and 84.9 mg/L, respectively. Chemistry results from stormwater solids sampling are discussed below.
- **1980s Stormwater Sampling Studies:** Stormwater sampling conducted by SPU in 1989 from Harbor Island showed that copper, lead, and zinc frequently exceeded Washington State Water Quality Criteria (City of Seattle 1998), which was only used for informational purposes because the criteria is only applicable to surface water and not stormwater effluent. These results are presented in Appendix L. A study was also conducted in the 1980s by Tetra Tech (Tetra Tech 1988) to evaluate potential sources of chemicals to Elliott Bay and the LDW. These stormwater outfalls were located on Harbor Island (the SW Hanford CSO/Storm Drain [removed], the SW Lander Storm Drain [existing], the SW Florida Storm Drain [existing], the 11th Avenue SW CSO/Storm Drain [existing, but only as a storm drain], and the SW Spokane Street CSO/Storm Drain [existing, but only as a storm drain]). This study identified and ranked CSO and storm drain source potential, primarily based on sediment data collected from within the drains. These results are presented in Appendix L. The results from both of these studies do not represent current conditions, and should only be used to provide information on the historical input from Harbor Island to the EW since several remedial and capping actions have occurred on Harbor Island, as well as infrastructure redevelopment, which has removed or re-routed several of these drains.
- **Permit-Associated Sampling: Permit-Associated Sampling:** Stormwater monitoring associated with industrial stormwater permits (e.g., the SSA stormwater permit and associated SWPPP for T-18) is generally limited to monitoring for turbidity and selected total metals (usually zinc, with

contingent copper and/or lead sampling) analyses related to site use. These data are collected using whole-water samples and they typically lack TSS measurements and are, therefore, generally not useful to the source control evaluation in this context. To date, these results have not been obtained.

- **Recent Sampling of Stormwater Infrastructure Sediment:** Since 2005, SPU has been collecting samples from ROW catch basins, privately owned catch basins, and in-line sediment traps (sediment residing inside storm drainage lines) as part of their ongoing source control program. The samples were analyzed for metals, PCBs, SVOCs, TPH, TOC, and grain size, and were compared to the SMS. However, there are no regulatory standards for storm drain sediment. Results from SPU sampling efforts are reported in regular progress reports (King County and SPU 2004, 2005a, 2005b). Figure 5-4 shows the 2005 SPU sampling locations. The complete set of results is included in Appendix L.
- **On-site Catch Basin Samples:** The contaminants most commonly detected in the catch basin sediments above the SQS included BEHP, BBP, and zinc. PCBs were frequently detected, but concentrations were generally below the SQS. The results of chemicals exceeding the SQS from the 19 on-site (private) catch basins that discharge to the EW are presented in Table 5-13.
- **In-line Sediment Samples:** Results from the two in-line maintenance samples collected from T-18 are also presented on Table 5-13. BEHP, BBP, and zinc were the only chemicals with detected results greater than the SMS. PCBs were detected but at a concentrations below the SQS. All other organics were not detected.
- **Right-of-Way Catch Basin Samples:** Results from the four ROW catch basin samples are also presented on Table 5-13. BEHP, BBP, and zinc were the only chemicals with detected results greater than the SMS. PCBs were detected, but at a concentrations (0.4 to 5.4 mg/kg-OC) below the SQS. All other organic compounds were either detected at low concentrations or not detected.

The following table provides a summary of data collected as part of the City's source control program for the LDW. Data summarized in the table are sediment samples collected while trying to locate sources of contaminants. The samples were not collected in a sample design attempting to identify the central tendency/typical sediment chemistry concentrations in conveyance systems. The data summary should be considered a "worst case" representation of conveyance sediment, and not typical of what discharges from the stormwater/CSO systems. Lastly, SMS are provided in the table for comparison purposes only. Chemical concentration standards for sediment in conveyance systems are not established in the State of Washington.

Table 5-13
Summary of Stormwater Catch Basin and In-line Samples Detected Results Exceeding SMS

Chemical	Unit	Detection Frequency	Minimum Detected Value	Maximum Detected Value	Number of SQS Exceedances	Number of CSL Exceedances[a]
On-site						
Bis(2-ethylhexyl) phthalate	mg/kg OC	19/19	81	1,441	19	19
Butylbenzyl phthalate	mg/kg OC	18/19	4.0	306	15	4
2-Methylnaphthalene	mg/kg OC	8/19	3.0	290	3	3
PCBs	mg/kg OC	14/19	0.1	27	1	0
4-methyphenol	mg/kg dw	12/19	300	110,00	9	9
Benzoic acid	mg/kg dw	4/19	5,100	13,000	4	4
Phenol	mg/kg dw	8/19	180	8,400	6	5
Copper	mg/kg dw	19/19	44.1	5,010	8	8
Mercury	mg/kg dw	17/19	0.07	0.5	1	0
Lead	mg/kg dw	19/19	33	600	3	0
Zinc	mg/kg dw	19/19	152	2,730	17	10
Right-of-way						
Bis(2-ethylhexyl) phthalate	mg/kg OC	4/4	65	153	4	2
Butylbenzyl phthalate	mg/kg OC	4/4	3.4	24.4	3	0
Zinc	mg/kg dw	4/4	176	645	2	0
In-line						
Bis(2-ethylhexyl) phthalate	mg/kg OC	2/2	30	76	1	0
Butylbenzyl phthalate	mg/kg OC	2/2	32	95	2	1
Zinc	mg/kg dw	2/2	280	1,380	0	1

a The number of CSL exceedances also includes the number of SQS exceedances since SQS is also exceeded when the CSL is exceeded
CSL – Cleanup Screening Level
dw – dry weight
OC – organic carbon normalized
SQS – Sediment Quality Standards
Note: Results include catch basin sampling stations located within the EW separate stormwater drainage areas.

5.2.5 Nearshore Cleanup Sites

An analysis of potential sources of contamination to EW sediments includes evaluating the potential for nearshore upland cleanup sites to contribute contaminants through transport mechanisms such as groundwater, stormwater conveyance, and erosion. The characterization and remediation of nearshore cleanup sites identified along the EW are being conducted under federal (CERCLA), and state (Model Toxics Control Act [MTCA]) authority.

CERCLA is the basis for the federal program to cleanup hazardous waste sites identified by the EPA on the National Priorities List (NPL). The Harbor Island Superfund Site was initially listed on the NPL in 1983 (ID WAD980722839) and has subsequently been separated into multiple OUs. The Soil and Groundwater OU encompasses the majority of upland nearshore areas west of the EW project area, as shown in Figure 5-5. Nearshore areas located on Harbor Island south of Spokane Street are not included within the Harbor Island Superfund Site.

A number of cleanup sites located along the EW are being cleaned up under MTCA. These sites include projects performed under Ecology's Voluntary Cleanup Program (VCP) or under the direction of Ecology via an Agreed Order or Consent Decree. In addition, a limited number of upland sites have also been registered in Ecology's UST program and have been identified as leaking UST (LUST) sites.

The following presents a summary of upland nearshore cleanup sites identified along the EW project area. For each site, the background and regulatory context, contaminants identified, and the status of investigation and related cleanup activities are described. Table 5-14 provides a list of the nearshore cleanup sites identified during this information review and presents the key documents containing information potentially relevant to the EW. Findings from recent groundwater monitoring events at these nearshore cleanup sites are summarized in Table 5-15.

A review of cleanup sites located away from the EW shoreline (i.e., within the Hanford/Lander drainage basins) was not conducted as part of the EISR development.

Contaminated and cleanup sites located further from the EW shoreline have the potential to affect the EW if contaminated groundwater or stormwater runoff from these sites discharges to the EW through storm drains and CSOs. Ongoing source-tracing studies being performed by the City and the County are evaluating stormwater and CSO discharges to the EW, and are assessing the existence of pollutants entrained in the conveyance systems and potential inland sources thereof. Information on CSO and storm drain discharge characterization will be used to assess the potential for inland cleanup sites to affect the EW through these pathways. Information available to characterize storm drain and CSO discharges is described in Sections 5.2.4 and 5.2.3, respectively. Groundwater monitoring at the shoreline sites also indirectly evaluates the potential for contaminants to be transported via groundwater to the EW.

Table 5-14
Summary of Key Documents – Nearshore Cleanup Sites (1)

Date	Title or Description	Author	Prepared for	Notes
West Nearshore Upland Cleanup Sites				
Harbor Island Superfund Site Soil and Groundwater Operable Unit				
1993	Harbor Island Remedial Investigation Report (Part 1 - air, soil, and groundwater), Volume 1 – report	Roy F. Weston, Inc	EPA	Remedial Investigation of the soil and groundwater operable unit of Harbor Island.
1993	Record of Decision: Declaration, Decision Summary, and Responsiveness Summary for Harbor Island Soil and Groundwater	EPA	n/a	Decision document for final remediation action (including monitoring requirements) for Harbor Island Superfund Site Soil and Groundwater OU.
1996	Amended Record of Decision, decision summary: the revised remedial action for the soil and groundwater operable unit of the Harbor Island Superfund site in Seattle, Washington	EPA	n/a	Modification of remedial action established in 1993 ROD regarding treatment of petroleum-contaminated soil.
1999	T-18 Hot Spot Removal Construction Documents, 100 percent specifications submitted to Gary Wallinder, Port of Seattle, Project No. 1-2911-410	RETEC	Port of Seattle	Specifications for T-18 Hot Spot removal project. Work included removal of existing pavement, removal and disposal of contaminated soils, utility modifications, and installation of a pavement cap.
2001	Explanation of Significant Differences Number 2 (ESD #2) for the Harbor Island Superfund Site Soil and Groundwater Operable Unit, Seattle, WA	EPA	n/a	Documents a change to the selected remedy for the Harbor Island Soil and Groundwater OU that allows an alternative TPH action level of 20,000 mg/kg to be applied instead of 10,000 mg/kg for soil hot spots that meet certain criteria.
2002	Findings of the investigation of the oil spill involving Port of Seattle/T-18/Kinder-Morgan dock pipelines, Seattle, Washington, November 18, 2001	Ecology	n/a	Summary of spill event and estimations of impact of spill to EW.
2002	T-18 Hot Spot Removal Remedial Action Implementation Report	RETEC	Harbor Island Soil and Groundwater Operable Unit Steering Committee	Report documenting the design for the T-18 total petroleum hydrocarbon Hot Spot removal work, including excavation and off-site disposal of hot spot soil, utility replacement, and cap construction. Document included in Appendix N.
2002	T-18 Redevelopment Tank Closure Reports	Morrison Knudsen Corporation	Port of Seattle	Documentation of the decommissioning of 19 underground storage tanks identified on T-18 during terminal redevelopment and expansion. Documentation for UST #19 from Tank Closure Report provided in Appendix N.

Date	Title or Description	Author	Prepared for	Notes
2005	Memorandum dated July 22, 2005 to N. Thompson, EPA, from K. Hendrickson and L. Baker regarding proposed compliance monitoring well screen locations	RETEC	Harbor Island Soil and Groundwater Operable Unit Settling Defendants	Investigation of groundwater conditions (non-analytical) and the presence or absence/extent of bulkheads at six locations on Harbor Island selected for groundwater monitoring well installation.
2006	2005-2006 groundwater monitoring report, Harbor Island Superfund Site - Soil and Groundwater Operable Unit, Seattle, Washington	RETEC	Harbor Island Soil and Groundwater Operable Unit Settling Defendants	Results of the first post-remediation groundwater monitoring event at the Harbor Island Superfund Site Soil and Groundwater OU. Document included in Appendix N.
2006	Design set #2 capping implementation report – T-18 expansion, Harbor Island Superfund Site, Seattle, Washington	RETEC	Port of Seattle and Harbor Island Steering Committee	Report documenting the completion of T-18 remedial action capping and terminal expansion and redevelopment project.
Southern Harbor Island Land Use Information and Harbor Marina UST Excavation				
1997	Underground storage tank decommissioning, Harbor Marina Corporate Center	RETEC	Wahl & Associates	Documentation of decommissioning of three underground storage tanks at the Harbor Marina as well as soil and groundwater testing and results. Document included in Appendix N.
2007	Department of Ecology Underground Storage Tank (UST) database report generated November 8, 2007	Ecology	n/a	Database report summarizing Ecology's UST records for the Pioneer Construction Materials Company (now Olympic Tug and Barge) property.
2007	Department of Ecology Leaking Underground Storage Tank (LUST) database report generated November 8, 2007	Ecology	n/a	Database report summarizing Ecology's LUST records for the Pioneer Construction Materials Company (now Olympic Tug and Barge) property.
East Nearshore Upland Cleanup Sites				
Pier 35 and Vicinity				
United States Coast Guard				
1989	Evaluation of Upland Soil and Groundwater Contamination Data - Support Center Seattle Consolidation Pier 35 and 36	Dames & Moore	USCG	Summary of early soil and groundwater investigation for USCG facility development.
2004	Draft - Sampling and Analysis Report - USCG ISC Seattle Pier 36 Site Investigation	Hart Crowser	USCG	Summary of soil and groundwater investigation for property development planning.
2004	Focused Phase I Environmental Review and Limited Phase II Subsurface Assessment	Hart Crowser	AKS, P.S., Inc.	Information review and Phase 2 soil and groundwater investigation in preparation for property facility development.

Date	Title or Description	Author	Prepared for	Notes
2005	UST Closure Report	Professional Services Industries, Inc.	Howard S. Wright Construction Company	Documentation of decommissioning of one UST and confirmation soil and groundwater sampling.
2006	UST Closure Report	Professional Services Industries, Inc.	Howard S. Wright Construction Company	Documentation of decommissioning of one UST and confirmation soil and groundwater sampling.
Terminal 34 and Vicinity				
GATX Terminal Facility				
1997	Soil and Groundwater Remedial Action Implementation Report – GATX Pier 34	Remediation Technologies	GATX Terminals Corporation	Report documenting soil and groundwater remedial actions performed as required by a Purchase and Sale Agreement between GATX and the Port of Seattle.
2004	Letter Re: Pier 34 Annual Groundwater Compliance Monitoring Summary for 2003 and 5-Year Review	RETEC	Port of Seattle	Summary of groundwater and surface water compliance monitoring and 5-year post-remediation review as required in the GATX Groundwater Compliance Monitoring Plan.
Flint Ink Corporation				
2000	Underground Storage Tank Decommissioning	URS Greiner Woodward Clyde	Flint Ink Corporation	Documentation of decommissioning of one UST and summary of confirmation soil sampling.
Terminal 30				
1998	Final Report Remedial Investigation/Focused Feasibility Study	GeoEngineers, Inc.	Port of Seattle	Report documenting RI/FS activities at the site. This report was not finalized by Ecology and subsequent sampling and assessment updated the findings of this report.
2006	Draft Terminal 30 Data Report	RETEC	Port of Seattle	Provides summary of previous environmental investigations and remedial actions performed at the site. Includes a site conceptual model and evaluation of current conditions in relation to adjacent waterway receptors.
2006	November 2006 Groundwater Sampling Event	RETEC	Port of Seattle	Third quarterly groundwater sampling event for the year 2006 in accordance with the site proposed Compliance Groundwater Monitoring Plan for the protection of adjacent waterway surface water and sediments.
2007	February 2007 Groundwater Sampling Event	RETEC	Port of Seattle	First quarterly groundwater sampling event for the year 2007 in accordance with the site proposed Compliance Groundwater Monitoring Plan for the protection of adjacent waterway surface water and sediments.

Date	Title or Description	Author	Prepared for	Notes
Terminal 25				
1989	Phase I Environmental Site Assessment	Blymyer Engineers, Inc.	Port of Seattle	Phase I report evaluating the T-25 property including limited soil borings and chemical analyses. Report for Matson prior to lease to document potential pre-existing conditions.
1990	Soil and Groundwater Investigation	Landau Associates, Inc.	Port of Seattle	Soil and groundwater testing in the area of the UST removal and nearshore areas.
1990	Subsurface Investigation Report	Sweet Edwards/Emcon, Inc.	Port of Seattle	Soil and groundwater testing in the area of the UST removal area.
2003	Phase I Environmental Site Assessment Terminal 25, South Section	Pinnacle GeoSciences, Inc.	Port of Seattle	Phase I report evaluated the southern portion of T-25 in the cold storage area and in areas of the former UST removal and sampling.
Terminal 104 and Vicinity				
Terminal 104				
2005	Environmental Investigation - Stage 1 East Marginal Way Grade Separation Project Port of Seattle Terminals 104 and 106	Shannon & Wilson, Inc.	David Evans & Associates, Inc.	Terminal 104-specific soil and groundwater investigation to support development of the East Marginal Way Grade Separation Project.
2007	Supplemental Investigation and Data Summary Report – East Marginal Way Grade Separation Project	Environmental Partners, Inc.	Port of Seattle	Supplemental soil and groundwater investigation to support development as part of the East Marginal Way Grade Separation Project.
Poncho's Legacy Property				
2005	Environmental Investigation - Stage 1 East Marginal Way Grade Separation Project - Poncho's Legacy Property	Shannon & Wilson, Inc.	David Evans & Associates, Inc.	Poncho's Legacy property-specific soil and groundwater investigation to support development of the East Marginal Way Grade Separation Project.
2006	Phase II Environmental Site Assessment East Marginal Way Grade Separation Project - Poncho's Legacy Property	Environmental Partners, Inc.	Port of Seattle	Additional Phase II soil and groundwater investigation at the Poncho's Legacy property-specific soil and groundwater investigation to support development of the East Marginal Way Grade Separation Project.
2007	Supplemental Investigation and Data Summary Report – East Marginal Way Grade Separation Project	Environmental Partners, Inc.	Port of Seattle	Supplemental soil and groundwater investigation to support development as part of the East Marginal Way Grade Separation Project.
Moss G. Milan Property				
2005	Environmental Investigation - Stage 1 East Marginal Way Grade Separation Project – Moss G. Milan Property	Shannon & Wilson, Inc.	David Evans & Associates, Inc.	Moss G. Milan property-specific soil and groundwater investigation to support development of the East Marginal Way Grade Separation Project.

Date	Title or Description	Author	Prepared for	Notes
2007	Cleanup Action Plan - East Marginal Way Grade Separation Project - Moss G. Milan Property	Environmental Partners, Inc.	Port of Seattle	Summary of soil management requirements to support development of the East Marginal Way Grade Separation Project.
2007	Supplemental Investigation and Data Summary Report - East Marginal Way Grade Separation Project	Environmental Partners, Inc.	Port of Seattle	Supplemental soil and groundwater investigation to support development as part of the East Marginal Way Grade Separation Project.

1. Site locations are shown in Figures 5-5 and 5-6.

USCG – United States Coast Guard

UST – underground storage tank

Table 5-15
Summary of Recent Groundwater Monitoring at Nearshore Cleanup Sites

Site and Release Type	Cleanup Status	Site-Specific Groundwater Monitoring Performed	Recent Monitoring Reports and Scope	Groundwater Monitoring Parameters and Reference Values [1]	Findings of Recent Monitoring for Nearshore Areas [2]
Harbor Island Soil and Groundwater OU: Multi-parcel cleanup addressed under EPA oversight by Harbor Island Soil and Groundwater OU Group. Site contaminants of concern determined through RI/FS and risk assessment process.	Cleanup activities completed consistent with Soil and Groundwater OU Record of Decision, including soil removals and upland capping. Site is undergoing long-term groundwater monitoring.	Monitoring is performed consistent with an EPA-approved groundwater monitoring plan. Groundwater monitoring network includes 7 nearshore wells along the EW shoreline, and additional monitoring wells located in inland areas and in areas adjacent to the West Waterway.	First groundwater monitoring report summarizes results from two quarterly monitoring events in late 2005 and two monitoring events in early 2006 (RETEC 2006c)	Groundwater was monitored for heavy metals, PCBs, VOCs, cyanide. Site-specific reference values are specified in the ROD and are based on protection of surface water quality.	Five of seven EW nearshore wells were in compliance with all ROD-specified criteria for the 2006 monitoring events. One of seven wells had exceedances (1 event only) of copper and zinc cleanup goals. One of seven wells had exceedances of cyanide cleanup goals. Further evaluation is being conducted as part of 2006-2007 groundwater monitoring.
T-102 LUST Site: MTCA soil and groundwater cleanup related to diesel release from former UST.	Tanks and excavated soil were removed from the site, with capping of remaining impacted soils. Groundwater sampling performed at time of soil removal.	Groundwater monitoring was performed at time of tank and soil removal, including sampling of six temporary soil borings.	Groundwater monitoring data for six temporary soil borings are described in UST Decommissioning report (RETEC 1997a).	Groundwater sampling included testing for total petroleum hydrocarbons (as diesel). Monitoring data were compared to MTCA Method A cleanup levels for groundwater applicable at the time of UST decommissioning.	All groundwater results were non-detect, and below the applicable Method A groundwater cleanup levels.
Coast Guard (Pier 35): MTCA soil and groundwater cleanup related to petroleum USTs formerly used for truck refueling. Contaminants of concern include petroleum (gasoline and diesel) and arsenic.	Former USTs and associated soil contamination have been removed under an independent remedial action.	Groundwater monitoring was last performed in 2003-2004 as part of a site investigation report. Groundwater monitoring at that time included 7 sampling locations (2 wells and 5 temporary borings), all of which were located in upland site areas over 300 feet from the EW.	Environmental sampling report summarizes results of 2003-2004 groundwater monitoring event (Hart Crowser 2004).	Groundwater monitoring included heavy metals (5 locations), petroleum hydrocarbons, and VOCs (all locations). Groundwater criteria were compared to MTCA Method A and Method B groundwater cleanup levels.	All parameters monitored were below site-specific reference values with the exception of arsenic. Arsenic was detected at concentrations ranging from less than 0.005 mg/L to 0.019 mg/L (4 of 5 monitoring locations) and 0.180 mg/L in one location.
Former-GATX (Pier 34): MTCA soil and groundwater cleanup related to former bulk fuel handling facility. Site contaminants of concern determined through RI/FS process and include petroleum and associated constituents (petroleum, BTEX and PAH) and selected heavy metals (arsenic, copper and lead).	Cleanup action was performed as independent remedial action after completion of an RI/FS and Compliance Monitoring Plan. Cleanup included plant demolition, removal of contaminated soils, capping, groundwater treatment (by air sparging and vapor extraction), and groundwater monitoring.	Groundwater monitoring performed as part of site cleanup included periodic monitoring of five nearshore wells and multiple groundwater seep locations. Groundwater monitoring was also performed at additional upland groundwater well locations.	Remedial action included five years of groundwater monitoring, as summarized in 5-year review report (RETEC 2004). Most recent event from April and August 2003 included monitoring of all nearshore wells and one groundwater seep.	Groundwater monitoring included selected metals (Arsenic, copper and lead), petroleum, BTEX compounds and PAH compounds. Seep data are compared to AWQC (marine chronic) values, MTCA Method A groundwater cleanup levels (for petroleum) and Method C surface water criteria. For the nearshore monitoring wells, site-specific groundwater trigger levels are used to assess the need for contingent remedial actions; these values are based on multiples (10x) of the surface water values applied to the groundwater seeps. Trigger levels also consider background waterway sampling (for metals).	All five nearshore groundwater wells and the waterway seep sample complied with applicable trigger levels as defined in the Groundwater Compliance Monitoring Plan. Of monitored parameters in nearshore groundwater wells, only copper (2 wells), arsenic (2 wells) and diesel (4 wells) exceeded target surface water criteria (concentrations did not exceed site trigger levels). Concentrations of gasoline, BTEX and PAH compounds were below target surface water criteria in all nearshore wells.
Former Chevron (Terminal 30): MTCA soil and groundwater cleanup related to petroleum releases (primarily diesel) at the former Chevron bulk fuel handling facility. Site contaminants of concern determined through RI/FS process and include petroleum, BTEX compounds, and PAH compounds.	Initial cleanup action performed during the late 1980s included plant demolition, product recovery, nearshore sediment dredging and capping and upland capping. RI/FS completed in 1998 under an Agreed Order to determine any other required remedial actions. Groundwater monitoring and other site cleanup actions are being implemented by the Port consistent with a draft Compliance Monitoring Plan.	Monitoring is performed quarterly consistent with draft Compliance Monitoring Plan. The groundwater compliance monitoring program includes 5 nearshore wells. Groundwater monitoring is also performed at 7 additional upland locations, and product recovery and gauging is performed at 13 additional upland well locations.	Site is undergoing quarterly groundwater monitoring consistent with draft Compliance Monitoring Plan. Results of February 2007 groundwater monitoring event were summarized in quarterly monitoring report (RETEC 2007).	Groundwater monitoring includes testing for petroleum hydrocarbons, BTEX compounds and PAH compounds. Site cleanup levels are based on state and federal water quality criteria, MTCA Method A cleanup levels (for petroleum and xylenes), and MTCA Method B surface water criteria. The need for contingent remedial actions is assessed using site-specific standards known as "Level 1" and "Level 2" cleanup standards that take into account site-specific contaminant fate and transport characteristics.	No exceedances of surface water protection values were noted in any of the nearshore groundwater monitoring wells. Groundwater quality in these wells also complied with the site-specific Level 1 and Level 2 cleanup standards.
Terminal 25: MTCA petroleum cleanup associated with former underground diesel storage tanks at former Rainier Cold Storage site.	Former USTs and associated soil contamination have been removed under an independent remedial action.	Groundwater monitoring was last performed in 1989 and 1990 as part of upland site investigations. Monitoring included seven upland sampling locations.	Results of 1989 and 1990 groundwater sampling summarized in 1990 reports (Landau 1990; Sweet-Edward 1990)	Groundwater monitoring included total petroleum hydrocarbons (all locations) and BTEX (4 locations). Groundwater measurements were compared to MTCA Method A groundwater cleanup levels applicable at the time of the report.	No exceedances of site-specific reference values were noted for any groundwater sampling locations.

Site and Release Type	Cleanup Status	Site-Specific Groundwater Monitoring Performed	Recent Monitoring Reports and Scope	Groundwater Monitoring Parameters and Reference Values [1]	Findings of Recent Monitoring for Nearshore Areas [2]
Terminal 104 and Vicinity: Localized groundwater contamination areas were identified during recent environmental assessment activities. Groundwater contamination with TCE and arsenic was identified in a localized area on the "Poncho's Legacy property," and localized areas of petroleum contamination were identified adjacent to the Sawdust Supply Company property.	Site cleanup is currently being conducted by the Port under the voluntary cleanup program. Cleanup includes in situ groundwater treatment (within the localized TCE-impacted area), soil removal (in the petroleum-impacted area), and groundwater monitoring.	Extensive groundwater testing was performed as part of recent environmental assessment activities. Sampling included monitoring of groundwater at 13 upland wells and 49 additional temporary borings. Sampling delineated all contaminated groundwater areas. No contamination extending to the EW shoreline was identified. Sampling at 12 groundwater locations provides water quality information downgradient of site cleanup areas.	Groundwater monitoring data for the period 2005 to 2007 are summarized in an environmental assessment report (Environmental Partners 2007). Additional monitoring is to be conducted as part of ongoing site cleanup.	Groundwater monitoring parameters included testing for heavy metals, petroleum, PCBs, VOCs and PAHs. Groundwater monitoring results were compared to MTCA Method A and Method C groundwater cleanup levels.	No exceedances of site-specific reference values were noted in any of the downgradient monitoring well locations. No contaminant plumes were identified as extending to the EW shoreline. Cleanup and monitoring activities are ongoing for upland site areas.

Notes:

1. Site-specific reference values are those against which groundwater data are compared in the referenced report(s).
2. Refer to Tables 5-16 through 5-23 for a detailed summary of groundwater sampling data.

BTEX – benzene, toluene, ethylbenzene, and xylene
MTCA – Model Toxics Control Act
PAHs – polycyclic aromatic hydrocarbons
PCBs – polychlorinated biphenyls
UST – underground storage tank
TCE – trichloroethene
VOCs – volatile organic compounds

5.2.5.1 Harbor Island Soil and Groundwater Operable Unit

Harbor Island was listed on the NPL due to former lead smelter operations as well as elevated concentrations of organic and inorganic chemicals in soil and groundwater. A Phase I RI of Harbor Island was completed in 1990 and an RI/FS for the Soil and Groundwater OU, a component of the larger Harbor Island Superfund Site, was completed in 1993 (Weston).

The 1993 RI Report included a review of Harbor Island History (Weston 1993). Harbor Island was initially developed by filling tide flats with dredged materials during the early 1900s. It was subsequently developed for industrial uses, including shipyards, cargo terminals, bulk petroleum terminals, food products terminals, and manufacturing activities. Based on a review of Port terminal development records, the shoreline along the northern and central portion of the EW federal navigation channel (see Figure 2-11) was developed for deep-draft navigation uses with berth dredging to depths of -50 feet MLLW and subsequent slope armoring between 1966 and 1974. The apron area was extended further to the south in 1982. The berth along the Harbor Island shoreline at the southern portion of the EW federal navigation channel (i.e., south of channel marker 50+00) has not been deepened since at least 1966, and remains the shallowest portion of the Harbor Island Shoreline along the federal channel.

The Soil and Groundwater OU is one of seven that are part of the Harbor Island Superfund Site. Due to its proximity to (bordering) the EW, the Harbor Island Soil and Groundwater OU has been considered a potential source of contaminants to the EW. The Port's T-18 is located on the portion of the Harbor Island Soil and Groundwater OU adjacent to the EW. The location of the Harbor Island Soil and Groundwater OU boundary and T-18 are shown on Figure 5-5 in relation to the EW project area.

A ROD outlining the cleanup plan and remediation goals for the Harbor Island Soil and Groundwater OU was issued in 1993 (EPA 1993), initiating several cleanup projects to remove and cap contaminated soils. An amended ROD was issued in

1996 to allow off-site disposal of contaminated soil (EPA 1996). The ROD defined TPH Hot Spots as areas with soil TPH concentrations above 10,000 mg/kg.

An "Explanation of Significant Differences" (ESD) amendment was added to the ROD in 2001 (EPA 2001a), allowing an increase in the soil TPH action level from 10,000 mg/kg to 20,000 mg/kg for TPH Hot Spots that met certain criteria. One such TPH Hot Spot was identified on the eastern portion of T-18 near the EW. The TPH Hot Spot was in the location of a former bulk fuel terminal and is outlined on Figure 5-5. Cleanup of the soil Hot Spot to below 20,000 mg/kg TPH and capping of the area was completed in 2000. Petroleum products were observed in soils and groundwater during remedial activities. The petroleum products were removed using absorbent pads and vacuum trucks. No product was observed in the test pits dug to investigate the extent of the seeps. Groundwater monitoring is ongoing within the Harbor Island Soil and Groundwater OU, including monitoring at a sampling location (well HI-16) immediately downgradient of the TPH Hot Spot. Groundwater monitoring results for Harbor Island are discussed below.

During T-18 redevelopment activities, existing USTs were located and decommissioned. One UST was identified on the eastern portion of T-18 in 2002, and is identified in Port records as UST #19 (Figure 5-5). UST #19 was a 750-gallon tank that contained only trace amounts of oil. It was removed and taken off-site for disposal. No staining was observed in the UST excavation.

A majority of the Harbor Island Soil and Groundwater OU remedial actions, including soil remediation and capping, were completed in 2004. To date, all actions are complete and the groundwater compliance monitoring program is ongoing.

The Harbor Island ROD concluded most contaminants in groundwater would not migrate to the Harbor Island shoreline within at least 50 years (EPA 1993). A 30-year groundwater monitoring program was established in the ROD and has been initiated on Harbor Island to determine whether concentrations of contaminants in groundwater exceed surface water cleanup goals, which are protective of aquatic life.

The groundwater compliance monitoring program was initiated in 2005 and includes sampling at 20 monitoring well locations that consist of early warning wells, boundary wells, and compliance wells. Eleven wells are in locations applicable to monitoring of groundwater migrating toward the EW. These 11 wells (HI-1, HI-2, HI-3, HI-4, HI-5, AC-06A, HI-12, HI-13, HI-14, HI-15, and HI-16) are located along the eastern side of Harbor Island (along the EW). Seven of these wells are located adjacent to the EW shoreline (HI-1, HI-2, HI-3, HI-4, HI-5, HI-12, and HI-16). The groundwater monitoring report for 2005 to 2006 is attached in Appendix N. The groundwater compliance monitoring program well locations are shown on Figure 5-5. Table 3-18 summarizes parameters monitored during recent sampling events.

Four rounds of groundwater samples were collected and analyzed during the first monitoring year (2005/2006). Samples were analyzed for PCBs, selected VOCs (1,1,1-trichloroethane; 1,1,2-trichloroethane; benzene; carbon tetrachloride; and tetrachloroethene), cyanide, and selected metals (arsenic, cadmium, copper, lead, mercury, nickel, silver, thallium, and zinc).

The groundwater monitoring report for 2005 and 2006 identified nickel, cadmium, copper, zinc, and cyanide as constituents exceeding the ROD-specified cleanup goals in at least one sample from any of the 20 Harbor Island wells. Of these, only copper, zinc, and cyanide were detected in excess of cleanup goals in the seven wells along the EW shoreline.

As described in the groundwater monitoring report (RETEC 2006b), groundwater metals results reported for 2005 were determined to be unrepresentative of groundwater conditions at the site due to salt water interferences. Work coordinated by the Harbor Island Soil and Groundwater OU Steering Committee[9] identified

[9] The Harbor Island Soil and Groundwater OU Steering Committee members are the defendants listed on the Harbor Island Soil and Groundwater OU Consent Decree: the Port of Seattle, Todd Pacific Shipyards Corp., Seattle Iron and Metals Corp., Mobil Oil Corp., Shell Oil Co., Atlantic Richfield Co., Asahipen America, Inc., Burlington Northern Railroad, Michael R. Butler and William Butler, M.R.

brackish groundwater interferences and the laboratory method was modified to use the reductive precipitate preparation for metals analyses on brackish groundwater samples.

The 2006 data from the seven monitoring wells located along the EW shoreline are considered the most representative dataset applicable to monitoring groundwater migrating toward the EW (Table 5-16). In the 2006 monitoring data, zinc and copper exceeded the ROD-specified cleanup goals in one of the seven nearshore monitoring wells, at concentrations less than twice the cleanup goals. Exceedances of cleanup goals for cyanide were also noted in one of the seven nearshore monitoring wells during the 2006 monitoring events. Additional work is being performed during the 2006/2007 monitoring period to assess cyanide fractionation using multiple analytical methods.

Table 5-16
Harbor Island Nearshore Groundwater Chemical Conditions

Constituent	Reference Value: ROD-Specified Action Level (µg/L)	Chemical Concentration Detected (µg/L)	Detected Chemical Concentration Range (µg/L)	Nearshore Chemical Concentration Exceeds Reference Value
Metals (Total) [1]				
Arsenic	36	7 of 7	0.03 to 3	0 of 7
Cadmium	8	7 of 7	0.008 to 0.535	0 of 7
Copper	2.9	7 of 7	0.058 to 3.42	1 of 7
Lead	5.8	7 of 7	0.008 to 0.414	0 of 7
Mercury	0.025	3 of 7	0.00025 to 0.00179	0 of 7
Nickel	7.9	7 of 7	0.4 to 3.68	0 of 7
Silver	1.2	3 of 7	0.003 to 0.116	0 of 7
Thallium	6.3	2 of 7	0.002 to 0.005	0 of 7
Zinc	76.6	7 of 7	0.24 to 111	1 of 7
Cyanide [2]				
Total Cyanide	1	1 of 7	32 and 40	1 of 7 [2]
Volatile Organic Compounds				
1,1,1-Trichloroethane	42	0 of 7	--	0 of 7
1,1,2-Trichloroethane	42	0 of 7	--	0 of 7

Butler Construction Co., Fisher Companies, Inc., Fisher Mills, Inc., Fisher Properties, Inc., Harbor Island Machine Works, Inc., Harbor Island Supply Corp., Hardware Specialty Co., Don Lundberg, Lundberg Construction Co., John W. and Joann McGee, Virginia McAlister, Non-ferrous Metals, Inc., McCall Oil and Chemical Co., NL Industries, Olympic Pipe Line Co., Performance Contracting, Inc., Pruzan Building Co., J-T Properties, Ltd., Seafab Metal Corporation, The Shalmar Group, David M. Sidell, Texaco, Inc., Union Pacific Railroad, Weyerhaeuser Co., Hal Holdings, Inc., and fka Lang Manufacturing Co.

Constituent	Reference Value: ROD-Specified Action Level (µg/L)	Chemical Concentration Detected (µg/L)	Detected Chemical Concentration Range (µg/L)	Nearshore Chemical Concentration Exceeds Reference Value
Benzene	71	1 of 7	1.2	0 of 7
Carbon Tetrachloride	4.4	0 of 7	--	0 of 7
Tetrachloroethene	8.8	0 of 7	--	0 of 7
Polychlorinated Biphenyls				
Aroclor 1016	0.03	0 of 7	--	0 of 7
Aroclor 1221	0.03	0 of 7	--	0 of 7
Aroclor 1232	0.03	0 of 7	--	0 of 7
Aroclor 1242	0.03	0 of 7	--	0 of 7
Aroclor 1248	0.03	0 of 7	--	0 of 7
Aroclor 1254	0.03	0 of 7	--	0 of 7
Aroclor 1260	0.03	0 of 7	--	0 of 7
Aroclor 1262	0.03	0 of 7	--	0 of 7
Aroclor 1268	0.03	0 of 7	--	0 of 7

Notes:

[1] Metals results for March and June 2006 analyzed for total metals using reductive precipitate preparation.

[2] Ongoing analytical method identification in-process for cyanide. Previous cyanide analytical method for total cyanide, whereas criteria based on free (available) cyanide.

- Results presented above were evaluated on a location-by-location basis and there may be multiple sampling events (dates) per location.
- The presence of NAPL was not identified at any groundwater monitoring well location.
- Quarterly groundwater monitoring from the periods of March and June 2006 are summarized above.
- **Type of Site and Release:** Harbor Island was listed on the National Priorities List (NPL) due to former lead smelter operations as well as elevated concentrations of organic and inorganic chemicals in soil and groundwater. The Soil and Groundwater Operational Unit (OU), a component of the larger Harbor Island Superfund Site is one of seven that are part of the Harbor Island Superfund Site. The Soil and Groundwater OU borders the west nearshore area of the East Waterway.
- **Document Presenting Groundwater Results:** RETEC 2006b. (2005-2006 Groundwater Monitoring Report, Harbor Island Superfund Site - Soil and Groundwater Operable Unit, Seattle, Washington.)
- **Groundwater Sampling Network and Rationale:** Groundwater sampling results from the March and June 2006 quarterly monitoring events are summarized below for those monitoring wells within the Harbor Island Soil and Groundwater OU network located along the nearshore area of the East Waterway. The evaluation below includes seven nearshore monitoring wells along the East Waterway. These monitoring well locations are presented on Figure 5-7. Ongoing groundwater monitoring is being performed at the Harbor Island Soil and Groundwater OU consistent with the Site ROD.
- **Site-specific Groundwater Reference Value Rationale:** The reference value for Harbor Island is the Action Level specified in the ROD for the protection of surface water applicable at the time and referenced in the report (RETEC 2006b).

5.2.5.2 Southern Harbor Island UST Removals

Two LUST sites were identified in the southeast and south areas of Harbor Island, separate from the Harbor Island Soil and Groundwater OU (RETEC 1997a). These LUST sites are shown on Figure 5-5 and include the former property of Pioneer Construction Materials Company (now Olympic Tug and Barge) and the Port's T-102/Harbor Island Marina.

The former Pioneer Construction Materials Company property is currently owned by Olympic Tug and Barge, which operates an office and warehouse at the property and which moors tugs and lightering barges adjacent to the property within the EW. This property is located adjacent the EW shoreline toward the south portion of the EW project area According to Ecology's UST database, two USTs installed in 1964 were formerly present on the property (Ecology 2007d). One tank contained unleaded gasoline; the substance stored in the second tank was not identified. The capacity of the tanks was not reported in the UST database, and information regarding the precise locations of the USTs is not readily available. Based onEcology's LUST database, it appears that one of the two USTs formerly located on the property was reported leaking in 1989; both soil and groundwater were listed as affected media (Ecology 2007e). The leaking tank and associated contaminated media was reported as cleaned up in 2002.

The Port's T-102 is located at the southern tip of Harbor Island. Currently, the Harbor Island Marina and several office and warehouse buildings are located at this property. Three USTs were removed from the marina property in 1996 (RETEC 1997a). These tanks were used for marina operations and included a 10,000-gallon diesel tank, a 10,000-gallon leaded gasoline tank, and a 2,000-gallon waste oil tank. At the time of the tank removals, it was observed that all three tanks were in good condition. Soil and groundwater monitoring was conducted as part of the UST decommissioning. Residual petroleum-related (diesel and oil) contamination was identified during the UST removals. A subsequent investigation was conducted to delineate potential impacts. Groundwater samples were collected from six geoprobe locations (Figure 5-5 and Table 5-17).

This additional testing indicated that petroleum-related contamination from the USTs was limited to the UST area and groundwater sampling confirmed the absence of potential petroleum impacted groundwater migration to the EW (RETEC 1997a).

Table 5-17
Terminal 102 and Vicinity Downgradient Groundwater Chemical Conditions

Constituent	Reference Value: MTCA Method A Groundwater Criteria (µg/L)	Chemical Concentration Detected (µg/L)	Detected Chemical Concentration Range (µg/L)	Downgradient Chemical Concentration Exceeds Reference Value
Petroleum Hydrocarbons				
Diesel range hydrocarbons	1,000	0 of 6	--	0 of 6

Notes:

- The T-102 groundwater sampling locations included in the evaluation are: GP-2, GP-5, GP-6, GP-7, GP-8, and GP-9.
- **Type of Site and Release:** T-102 is located at the southern tip of Harbor Island. Currently, the Harbor Island Marina and several office and warehouse buildings are located at this property. Three USTs were removed from the marina property in 1996. These tanks were used for marina operations and included a 10,000-gallon diesel tank, a 10,000-gallon leaded gasoline tank, and a 2,000-gallon waste oil tank. Soil and groundwater monitoring was conducted as part of the UST decommissioning. Testing performed after decommissioning activities indicated that petroleum-related contamination from the USTs was limited to the UST area and groundwater sampling confirmed the absence of potential petroleum impacted groundwater migration to the EW.
- **Document Presenting Groundwater Results:** RETEC 1997a. (Underground Storage Tank Decommissioning.)
- **Groundwater Sampling Network and Rationale:** Groundwater sampling results from the RETEC October 1996 groundwater sampling event are summarized below. All groundwater sampling locations were used in the evaluation below. Previous groundwater sampling performed by GeoEngineers was collected prior to tank decommissioning activities and was not used in the evaluation. The GeoEngineers groundwater sampling indicated that BTEX compounds were not present.
- **Site-specific Groundwater Reference Value Rationale:** The reference value for T-102 is based on the MTCA Method A groundwater cleanup levels applicable at the time and referenced in the report (RETEC 1997a).

5.2.5.3 Pier 35 and Vicinity

The properties located at Pier 35 and vicinity include several listings related to the cleanup of contamination from LUSTs at properties now owned by USCG. The Pier 35 site location is shown on Figure 5-6 and is located at the addresses of 1519 and 1555 Alaskan Way South. The USCG facility is located along the northeast nearshore area of the EW and near the northern proposed EW OU study boundary.

The history of the Pier 35 USCG property is presented in the Focused Phase I Environmental Review and Limited Phase II Subsurface Assessment Report (Hart Crowser 2004). The environmental review reported that the property along the south side of Slip 36 has been occupied since at least 1916. Early operations of the property included a milling company (Albers Bros. Milling Company), which included various large storage tanks (contents were not identified), a molasses tank, an office building, and a boiler house. The buildings were mostly demolished by the mid-1960s. Subsequent property use in the mid-1960s was by the Seattle Disposal

Company, which built a paper sorting, storage, and transfer facility;, a scale house; and two scale platforms.

Prior features at the property used by the transfer facility included three petroleum USTs used for truck refueling. The tanks were reported to be used for diesel (20,000 gallons), unleaded gasoline (6,000 gallons), and leaded gasoline (3,000 gallons). The transfer station buildings and tanks were demolished and removed in 1990 when USCG acquired the property. The USCG facility was subsequently built in 1992 (Hart Crowser 2004).

Slip 36 has been a feature of the waterfront navigation uses since the 1920s (USACE 1927), when the slip was dredged to a depth of -35 feet MLLW. However, detailed records of dredging events within the slip since that time are more limited than for other EW project areas. Detailed bathymetry for the slip is available from 1975 (USACE 1976). The land to the north of Slip 36 was constructed with imported fill material in the 1970s (Shannon & Wilson 2002), and developed for the construction of T-46. Fill materials were obtained from a Hood Canal dredging project. The area within Slip 36 was later dredged by USCG, with completion in 2005.

Environmental and geotechnical investigations have been performed in upland areas of the USCG facility between 1987 and 2004. These investigations include an EPA environmental evaluation of Pier 35 in 1988, shallow soil investigation in 1989 (Dames & Moore 1989), UST removal activities in 1990, a Phase 1 environmental review and limited subsurface Phase 2 investigation in 2003, and additional environmental sampling reported in a 2004 Sampling and Analysis Report (Hart Crowser 2004). In addition, two separate UST closures were performed and documented in 2005 (Professional Services Industries 2005) and 2006 (Professional Services Industries 2006).

Previous environmental sampling events at the USCG property have included both soil and groundwater analyses. Recent groundwater monitoring was performed during 2003 and 2004. Groundwater sampling was performed to inform redevelopment decisions and confirm downgradient conditions from potential historical upland sources. All groundwater sampling locations from 2003 and 2004 were used in the data summarized in Table 5-18. The groundwater reference values used for the USCG facility were based on the MTCA Method A and Method B groundwater cleanup levels applicable at the time and referenced in the report (Hart Crowser 2004).

Results of 2003 and 2004 groundwater environmental investigations at the USCG site demonstrated that petroleum concentrations do not exceed applicable cleanup levels in downgradient areas. One VOC, 1,1,2-Trichloroethane, was detected above the MTCA Method B cleanup level during the 2003 groundwater sampling; however, the 2004 groundwater sampling at the same location showed a nondetect concentration of less than 1.0 µg/L. Groundwater investigations identified arsenic as the only chemical exceeding the MTCA groundwater cleanup level. Concentrations of arsenic in groundwater samples ranged from 7 to 180 µg/L (Hart Crowser 2004). In 2001, USCG performed development dredging adjacent to their facility, and arsenic was not identified as a sediment contaminant as part of the Puget Sound Dredged Disposal Analysis (PSDDA) characterization project (GeoEngineers 2001).

Table 5-18
USCG (Pier 35) Downgradient Groundwater Chemical Conditions

Constituent (µg/L)	Reference Value: MTCA Method A/B Groundwater Criteria	Chemical Concentration Detected	Detected Chemical Concentration Range	Downgradient Chemical Concentration Exceeds Reference Value
Metals (Dissolved)				
Arsenic	5	5 of 5	7 to 180	5 of 5
Cadmium	5	--	--	--
Copper	592b	0 of 5	--	0 of 5
Chromium	50	0 of 5	--	0 of 5
Lead	15	4 of 5	2 to 5	0 of 5
Mercury	2	--	--	--
Nickel	--	2 of 5 [2]	20 to 30	0 of 5
Zinc	4,800b	3 of 5 [2]	2	0 of 5
Petroleum Hydrocarbons				
Gasoline range hydrocarbons	1,000	2 of 7	210 to 350	0 of 5
Diesel range hydrocarbons	500	0 of 7	--	0 of 7
Heavy oil	500	0 of 7	--	0 of 7
Volatile Organic Compounds				
1,1,2-Trichloroethane	0.768b	1 of 7	6.6 [1]	1 of 7 [1]
Xylenes	1,000	2 of 7	1.1 to 5.3	0 of 7
Isopropylbenzene	800b	1 of 7	1.5 to 2.1	0 of 7
n-Propylbenzene	320b	1 of 7	7.2 to 8.9	0 of 7
4-Chlorotoluene	160b	1 of 7	2.0	0 of 7

Constituent (µg/L)	Reference Value: MTCA Method A/B Groundwater Criteria	Chemical Concentration Detected	Detected Chemical Concentration Range	Downgradient Chemical Concentration Exceeds Reference Value
1,3,5-Trimethylbenzene	400b	2 of 7	1.5 to 18	0 of 7
tert-Butylbenzene	320b	1 of 7	11	0 of 7
1,2,4-Trimethylbenzene	400b	2 of 7	2.0 to 11	0 of 7
sec-Butylbenzene	320b	1 of 7	3.7 to 4.6	0 of 7
Isopropyltoluene	400b	1 of 7	3.1	0 of 7
n-Butylbenzene	320b	2 of 7	1.3 to 12	0 of 7
Naphthalene	160	2 of 7	2.3 to 3.9	0 of 7
Semivolatile Organic Compounds	--	0 of 2	--	0 of 2

Notes:

[1] 1,1,2-Trichloroethane was detected (6.6 µg/L) in sample location MW-1C in October 2003. More recent groundwater sampling at location MW-1C in November 2004 showed a nondetect concentration at less than 1.0 µg/L.

[2] The field duplicate sample (QC-1) collected in 2004 was a duplicate of groundwater sample SB-SC-07. Nickel and Zinc were detected in the duplicate groundwater sample, however not detected in the original groundwater sample. The detected concentrations in the duplicate sample were low-level and well below the reference value.

b: Indicates MTCA Method B criteria.

- All criteria presented in µg/L
- Results presented above were evaluated on a location-by-location basis and there may be mulitple sampling events (dates) per location.
- The USCG groundwater sampling locations included in the evaluation are: MW-1C-03, MW-2-03, SB-SC-02, SB-SC-03, SB-SC-05, SB-SC-07, and SB-SC-08.
- **Type of Site and Release:** The USCG facility is located along the northeast nearshore area of the EW and near the northern proposed EW OU study boundary. Previous operations of the property included a milling company and a solid waste transfer company. Prior features at the property included three petroleum USTs used for truck refueling. The transfer station buildings and tanks were demolished and removed in 1990, and the USCG facility was subsequently built in 1992.
- **Document Presenting Groundwater Results:** Hart Crowser 2004. (Draft - Sampling and Analysis Report - USCG ISC Seattle Pier 36 Site Investigation, December 27, 2004.)
- **Groundwater Sampling Network and Rationale:** Groundwater sampling results from the 2003 and 2004 sampling events are summarized below. Groundwater sampling was performed to inform redevelopment decisions and confirm downgradient conditions from potential upland sources. All groundwater sampling locations were used in the evaluation below. Groundwater investigations identified arsenic as the only chemical exceeding the MTCA groundwater cleanup level. Concentrations of arsenic in groundwater samples ranged from 7 to 180 µg/L. In 2001, USCG performed development dredging adjacent to their facility, and arsenic was not identified as a sediment contaminant as part of the Puget Sound Dredged Disposal Analysis (PSDDA) characterization project.
- **Site-specific Groundwater Reference Value Rationale:** The reference value for the USCG (Pier 35) facility is based on the MTCA Method A and Method B groundwater cleanup levels applicable at the time and referenced in the report (Hart Crowser 2004).

5.2.5.4 Pier 34 and Vicinity

Pier 34 is the location of the former GATX Terminals bulk petroleum facility located at 1733 Alaskan Way South. The Flint Ink Corporation site is located at 1727 Alaskan Way South, just east of the former GATX site (Figure 5-6).

Historical operations at the Flint Ink property included an ink processing plant that was closed in 1992. Structures at the property included a building used for the ink processing plant and a UST located within the footprint of the building. The UST was removed in February of 2000 and observations of the tank conditions showed the tank to be in good condition with no apparent holes or signs of releases. Six confirmation samples of the excavation area indicated that soils in the area of the UST excavation were at petroleum concentrations well below the MTCA cleanup level for petroleum at that time (200 milligrams per kilogram [mg/kg]) (URS 2000).

The GATX terminal property had been operating as an active bulk fuel terminal from the 1920s to 1995 under a variety of ownerships. Prior property uses during the early 1900s included flour mills, grain storage, boiler works, a lumber yard, and a gas station. Marine piers located in front of the facility have been shown on EW maps since at least 1929 (USACE 1929). Port records do not document dredging events in the berth areas in front of the facility.

The bulk petroleum terminal facility stored a variety of petroleum products, including but not limited to gasoline, jet fuel, diesel fuel, and heavy marine fuels. The terminal consisted of two tank farms and an operational area that included three oil-water separators, a railroad spur, a covered truck loading area, a pipe trestle manifold trench, an office area, a lube boiler room, container storage, drum storage, and an automotive shop. Key reports describing environmental conditions at the GATX Terminal site are listed in Table 5-14. These reports include references to other previous investigations performed at the site.

The Port entered into an agreement in 1993 to purchase the property from GATX. Terminal operations were terminated in 1995. The purchase agreement stipulated that GATX would implement a cleanup action addressing the cleanup of contamination present at the property. Extensive environmental investigations were performed at the GATX property beginning in the 1980s. The nature and extent of contamination at the site is described in the site RI/FS. Principal contaminants of concern at the site included petroleum in soils and groundwater, petroleum-associated aromatic hydrocarbons (benzene, toluene, ethylbenzene, and xylene

[BTEX] and PAH compounds), and localized lead impacts in soil from tank painting and sandblasting.

The primary remedial objective of the GATX property cleanup was to reduce the volume of contaminated soil, and to achieve groundwater cleanup levels protective of human health and the environment, specifically to protect aquatic life in the adjacent EW. The site cleanup was conducted as an independent remedial action by GATX/Kinder Morgan, with participation of Ecology in the development and implementation of the cleanup plan. The cleanup performed by GATX included terminal demolition, excavation of hydrocarbon- and lead-impacted soil, treatment of groundwater using an air sparging system, and installation and monitoring of a network of groundwater compliance monitoring wells. The soil cleanup was completed in 1996. Excavated soils were managed by off-site soil recycling using a low-temperature thermal desorption process. Groundwater treatment was then initiated using an air sparging system, which began operation in October of 1996. Remedial activities at the site were described in detail in the GATX Completion Report (RETEC 1997b). The air sparging system was operated for two years. After shutdown of that system, groundwater and seep monitoring was continued to evaluate the quality of groundwater discharging to the EW.

The groundwater monitoring program included a 5-year review requirement upon completion of active remediation activities and subsequent monitoring. Five years of groundwater monitoring data has been collected after completion of air sparging. Recent groundwater and seep monitoring parameters are listed in Table 5-19 and Table 5-20. Final groundwater monitoring was completed in 2003 and monitoring data have indicated that site trigger levels were satisfied for all five years since the air sparging was ceased, and the presence of free product has not been detected. The trigger levels were based on 1) ambient surface water quality criteria (AWQC) as identified in the compliance monitoring plan, and 2) location-specific 10x multiplier of the surface water values as identified in the compliance monitoring plan. The location-specific multipliers took into account mixing and attenuation processes at nearshore areas. Table 5-19 presents both the site-specified surface water criteria and the site-specified trigger level when utilized. Three chemicals (arsenic, copper, and diesel-range hydrocarbons) were detected above the site-specified surface water criteria, without the consideration of the site-specified trigger level. The seep sample criteria was based only on the site-specific surface water criteria (without location-specific 10x multiplier), and all chemical concentrations were below criteria as presented in Table 5-20.

Table 5-19
GATX (Pier 34) Nearshore Groundwater Chemical Conditions

Constituent (µg/L)	Reference Value: Site Specified Surface Water Criteria (AWQC)	Site Specified Trigger Level (AWQCx10)	Chemical Concentration Detected	Detected Chemical Concentration Range	Chemical Concentration Exceeds Reference Value	Chemical Concentration Exceeds Site-Specified Trigger Level
Metals (Dissolved)						
Arsenic	2.1	21	3 of 5	1 to 9	2 of 5	0 of 5
Copper	2.9	29	4 of 5	2 to 7	2 of 5	0 of 5
Lead	5.6	56	1 of 5	3	0 of 5	0 of 5
Petroleum Hydrocarbons						
Gasoline Range Hydrocarbons	1,000	10,000	1 of 5	460	0 of 5	0 of 5
Diesel Range Hydrocarbons	1,000	10,000	5 of 5	380 to 5,400	4 of 5	0 of 5
BTEX Compounds						
Benzene	700	--	1 of 5	18 to 29	0 of 5	0 of 5
Ethylbenzene	430	--	1 of 5	3.4	0 of 5	0 of 5
m,p-Xylene	--	--	1 of 5	3.5	0 of 5	0 of 5
o-Xylene	--	--	1 of 5	1.5	0 of 5	0 of 5
Toluene	5,000	--	1 of 5	1.2	0 of 5	0 of 5
PAH Compounds						
Acenaphthene	710	--	2 of 5	4.8 to 24	0 of 5	0 of 5
Acenaphthylene	--	--	0 of 5	--	0 of 5	0 of 5
Anthracene	--		1 of 5	1.8	0 of 5	0 of 5
Benzo(a)anthracene	0.93	9.3	0 of 5	--	0 of 5	0 of 5
Benzo(a)pyrene	0.93	9.3	0 of 5	--	0 of 5	0 of 5
Benzo(b)fluoranthene	0.93	9.3	0 of 5	--	0 of 5	0 of 5
Benzo(g,h,i)perylene	--	--	0 of 5	--	0 of 5	0 of 5
Benzo(k)fluoranthene	0.93	9.3	0 of 5	--	0 of 5	0 of 5
Chrysene	0.93	9.3	0 of 5	--	0 of 5	0 of 5
Dibenzo(a,h)anthracene	0.93	9.3	0 of 5	--	0 of 5	0 of 5
Fluoranthene	16	160	1 of 5	2.7	0 of 5	0 of 5
Fluorene	1,400	--	1 of 5	16	0 of 5	0 of 5
Indeno(1,2,3-cd)pyrene	0.93	9.3	0 of 5	--	0 of 5	0 of 5
Naphthalene	2,470	--	2 of 5	2.5 to 93	0 of 5	0 of 5
Phenanthrene	--	--	1 of 5	11	0 of 5	0 of 5
Pyrene	6,480	--	3 of 5	0.62 to 1.6	0 of 5	0 of 5

Notes:

- Results presented above were evaluated on a location-by-location basis and there may be multiple sampling events (dates) per location.
- GATX nearshore monitoring wells included in the evaluation are: GMW-12, B-1, B-2, B-11, and CW-1.

- **Type of Site and Release:** The GATX terminal was an active bulk fuel terminal from the 1920s to 1995. The facility stored a variety of petroleum products, including but not limited to gasoline, jet fuel, diesel fuel, and heavy marine fuels. Extensive environmental investigations were performed at the GATX property beginning in the 1980s. The nature and extent of contamination at the site is described in the site RI/FS. The cleanup performed by GATX included terminal demolition, excavation of hydrocarbon- and lead-impacted soil, treatment of groundwater using an air sparging system, and installation and monitoring of a network of groundwater compliance monitoring wells.
- **Document Presenting Groundwater Results:** RETEC 2004. (Letter Re: Pier 34 Annual Groundwater Compliance Monitoring Summary for 2003 and 5-Year Review.)
- **Groundwater Sampling Network and Rationale:** Groundwater sampling results from the April and August 2003 groundwater monitoring event are summarized below for those monitoring wells within nearshore area of the East Waterway. The GATX groundwater monitoring program included a 5-year review requirement upon completion of active remediation activities and subsequent monitoring. Five years of groundwater monitoring data has been collected after completion of air sparging. Final groundwater monitoring was completed in 2003 and monitoring data have indicated that site-specific trigger levels were satisfied for all five years since the air sparging was ceased, and the presence of free product has not been detected.
- **Site-specific Groundwater Reference Value Rationale:** The reference value for GATX is the Site-specified surface water criteria at the time, which is based on MTCA Method C, AWQC (Marine Chronic Criteria), and MTCA Method A groundwater cleanup levels (for petroleum). The Site-specified trigger level is either the Site-specified surface water criteria or a 10x factor (or 10x increase from previous sample). The Site-specified trigger level takes into account mixing and attenuation processes at nearshore areas.

Table 5-20
GATX (Pier 34) Shoreline Seep Chemical Conditions

Constituent (µg/L)	Reference Value: Site Specified Surface Water Criteria (AWQC)	Chemical Concentration Detected	Detected Chemical Concentration Range	Chemical Concentration Exceeds Reference Value
Metals (Dissolved)				
Arsenic	2.1	0 of 1	--	0 of 1
Copper	2.9	1 of 1	4 [1]	0 of 1 [1]
Lead	5.6	0 of 1	--	0 of 1
Petroleum Hydrocarbons				
Gasoline range hydrocarbons	1,000	0 of 1	--	0 of 1
Diesel range hydrocarbons	1,000	0 of 1	--	0 of 1
BTEX Compounds				
Benzene	700	0 of 1	--	0 of 1
Ethylbenzene	430	0 of 1	--	0 of 1
m,p-Xylene	--	0 of 1	--	0 of 1
o-Xylene	--	0 of 1	--	0 of 1
Toluene	5,000	0 of 1	--	0 of 1
PAH Compounds				
Acenaphthene	710	0 of 1	--	0 of 1
Acenaphthylene	--	0 of 1	--	0 of 1
Anthracene	--	0 of 1	--	0 of 1
Benzo(a)anthracene	0.93	0 of 1	--	0 of 1
Benzo(a)pyrene	0.93	0 of 1	--	0 of 1
Benzo(b)fluoranthene	0.93	0 of 1	--	0 of 1
Benzo(g,h,i)perylene	--	0 of 1	--	0 of 1
Benzo(k)fluoranthene	0.93	0 of 1	--	0 of 1
Chrysene	0.93	0 of 1	--	0 of 1
Dibenzo(a,h)anthracene	0.93	0 of 1	--	0 of 1
Fluoranthene	16	0 of 1	--	0 of 1
Fluorene	1,400	0 of 1	--	0 of 1
Indeno(1,2,3-cd)pyrene	0.93	0 of 1	--	0 of 1
Naphthalene	2,470	0 of 1	--	0 of 1
Phenanthrene	--	0 of 1	--	0 of 1
Pyrene	6,480	0 of 1	--	0 of 1

Notes:

[1] The seep sample (S-2) exceeded the Site-specified surface water criteria at a concentration of 4 µg/L for April 2003; however, it was determined that the analysis was performed for total metals rather than dissolved metals.

- Results presented above were evaluated on a location-by-location basis and there may be multiple sampling events (dates) per location.
- **Type of Site and Release:** The GATX terminal was an active bulk fuel terminal from the 1920s to 1995. The facility stored a variety of petroleum products, including but not limited to gasoline, jet fuel, diesel fuel, and heavy marine fuels. Extensive environmental investigations were performed at the GATX property beginning in the 1980s. The nature and extent of contamination at the site is described in the site RI/FS. The cleanup performed by GATX included terminal demolition, excavation of hydrocarbon- and lead-impacted soil, treatment of groundwater using an air sparging system, and installation and monitoring of a network of groundwater compliance monitoring wells.
- **Document Presenting Groundwater Results:** RETEC 2004. (Letter Re: Pier 34 Annual Groundwater Compliance Monitoring Summary for 2003 and 5-Year Review.)
- **Seep Sampling Network and Rationale:** Seep sampling results from the April and August 2003 groundwater monitoring event are summarized below for the seep sample (S-2) at the shoreline of the East Waterway. The GATX groundwater monitoring program included a 5-year review requirement upon completion of active remediation activities and subsequent monitoring. Five years of monitoring data, including the seep sampling,

has been collected after completion of air sparging. Final seep monitoring was completed in 2003 and monitoring data have indicated that site-specific trigger levels were satisfied for all five years since the air sparging was ceased.

- **Site-specific Groundwater Reference Value Rationale:** The reference value for GATX seep sampling is the Site-specified surface water criteria at the time, which is based on MTCA Method C, AWQC (Marine Chronic Criteria), and MTCA Method A groundwater cleanup levels (for petroleum). The Site-specified trigger level for seep sampling is also the Site-specified surface water criteria and is not subject to a multiple factor.

Current conditions at the GATX terminal, as reported in the 5-year review, indicate that "the site cleanup performed by GATX in 1996 and operation of the air sparging system for two years have been effective at removing source areas and reducing groundwater concentrations to a level protective of surface water quality and industrial site use" (RETEC 2004). Active cleanup measures at the property are complete. Based on subsequent groundwater monitoring, as summarized in the 5-year review, no contingent remedial actions were initiated.

The Port has completed improvements at the property including shoreline bulkhead upgrades, installation of a stormwater collection system, raising of surface grades and paving of the property to support development of a container storage and transfer facility.

5.2.5.5 Terminal 30

The T-30 site is located at 2431 and 2715 East Marginal Way South (Figure 5-6). The Port acquired the property subsequently known as the "Terminal 30 Cleanup Site" from Chevron in January 1985. This area was formerly known as Pier 32 and was used by Chevron as a bulk petroleum storage and transfer terminal since the early 1900s. The Standard Oil facility is noted on EW survey maps from at least 1915 (USACE 1915). A wharf was included as part of the facility since that time. Detailed dredge records for the berth areas are not available until the 1980s.

The facility was demolished by Chevron during 1984 and 1985 prior to property ownership transfer to the Port. In the mid 1980s, the Port developed the site for use as a deep-draft shipping terminal and storage facility. That work included implementation of a cleanup action prior to promulgation of the MTCA cleanup regulations. Recovery of free-phase hydrocarbons present on the groundwater, capping of the site, and dredging and capping of sediments along the shoreline were conducted as part of that cleanup action (RETEC 2006a). The berth areas were dredged and armored at that time to provide berth areas with effective water depths of -50 feet MLLW (USACE 1985).

The Port and Ecology subsequently entered into a MTCA Agreed Order on August 30, 1991, to complete an RI/FS at the site. The purpose of the RI/FS was to document the nature and extent of hydrocarbon contamination remaining at the site, and to define the scope of any additional required cleanup actions beyond those already implemented. The RI/FS was completed in 1998 (GeoEngineers 1998). Extensive chemical sampling and analysis during the RI field investigations identified site-specific chemicals of interest (COIs) associated with historical bulk petroleum handling activities at the site. These COIs included TPH (gasoline, diesel, and motor oil), benzene, and PAHs. The RI/FS identified continued product recovery, containment of residual soil contamination, and monitored natural attenuation of site groundwater as the preferred remedial alternative for the site.

In 1999, Ecology requested that additional information be collected at the site following the RI/FS to confirm the effectiveness of the preferred remedial alternative, and to provide the information necessary for development of a compliance monitoring plan. Consistent with this request, the Port conducted a series of additional investigations between 1999 and 2004. The findings of these investigations are contained in a Data Report (RETEC 2006a). These investigations demonstrated that "Monitoring data show that site conditions downgradient of the historical LNAPL area comply with applicable Level 1 cleanup levels, and that protection of surface water quality at the point of discharge is being protected. No additional restoration timeframe is required to ensure protection of aquatic receptors" (RETEC 2006a). Ongoing groundwater compliance monitoring is currently being performed by the Port. Recent compliance monitoring reports for T-30 are included in Appendix N.

Recent groundwater monitoring results for wells located in T-30 nearshore areas are summarized in Table 5-21. All nearshore groundwater monitoring data are below applicable reference values, which are based on surface water criteria.

Table 5-21
Terminal 30 Nearshore Groundwater Chemical Conditions

Constituent (μg/L)	Reference Value: Site Specified Surface Water ARAR	Chemical Concentration Detected	Detected Chemical Concentration Range	Chemical Concentration Exceeds Reference Value
Petroleum Hydrocarbons				
Gasoline range hydrocarbons	800	0 of 5	--	0 of 5
Diesel range hydrocarbons	500	0 of 5	--	0 of 5
Motor oil range hydrocarbons	500	0 of 5	--	0 of 5
BTEX Compounds				
Benzene	23	0 of 5	--	0 of 5
Ethylbenzene	6,910	0 of 5	--	0 of 5
o-Xylene	--	0 of 5	--	0 of 5
mp-Xylene	--	0 of 5	--	0 of 5
Total Xylene	1,000	0 of 5	--	0 of 5
Toluene	48,500	0 of 5	--	0 of 5
Semivolatile Organic Compounds				
2-Methylnaphthalene	--	0 of 5	--	0 of 5
PAH Compounds				
Acenaphthene	643	5 of 5	0.074 to 2.1	0 of 5
Acenaphthylene	--	1 of 5	0.012	0 of 5
Anthracene	25,900	2 of 5	0.012 to 0.021	0 of 5
Benzo(a)anthracene	0.018	0 of 5	--	0 of 5
Benzo(a)pyrene	0.018	0 of 5	--	0 of 5
Benzo(b)fluoranthene	0.018	0 of 5	--	0 of 5
Benzo(g,h,i)perylene	--	0 of 5	--	0 of 5
Benzo(k)fluoranthene	0.018	0 of 5	--	0 of 5
Chrysene	0.018	0 of 5	--	0 of 5
Dibenzo(a,h)anthracene	0.018	0 of 5	--	0 of 5
Dibenzofuran	--	0 of 5	--	0 of 5
Fluoranthene	90	4 of 5	0.058 to 0.091	0 of 5
Fluorene	3,460	2 of 5	0.012 to 0.084	0 of 5
Indeno(1,2,3-cd)pyrene	0.018	0 of 5	--	0 of 5
Naphthalene	4,940	0 of 5	--	0 of 5
Phenanthrene	--	0 of 5	--	0 of 5
Pyrene	2,590	4 of 5	0.051 to 0.76	0 of 5

Notes:
[1] Surface water ARAR for petroleum is based on MTCA Method A groundwater criteria. Gasoline criteria of 800 μg/L based on the presence of benzene.

- T-30 nearshore monitoring wells included in the evaluation are: MW-72, MW-84, MW-85, MW-86, and MW-87.
- **Type of Site and Release:** The Port acquired the T-30 Site property from Chevron in January 1985. This area was formerly known as Pier 32 and was used by Chevron as a bulk petroleum storage and transfer terminal since the early 1900s. The facility was demolished by Chevron during 1984 and 1985 prior to property ownership transfer to the Port. In the mid 1980s, the Port developed the site for use as a deep-draft shipping terminal and storage facility. That work included implementation of a cleanup action prior to promulgation of the MTCA cleanup regulations. Recovery of free-phase hydrocarbons present on the groundwater, capping of the site, and dredging and capping of sediments along the shoreline were conducted as part of that cleanup action.
- **Documents Presenting Groundwater Results:** RETEC 2006a (Draft Terminal 30 Data Report) and RETEC 2007 (February 2007 Groundwater Sampling Event).
- **Groundwater Sampling Network and Rationale:** Groundwater sampling results from the February 2007 quarterly monitoring event are summarized below for those monitoring wells within the nearshore area of the EW. Groundwater analytical results showed that current conditions are below Site controlling ARARs proposed as cleanup levels based on the protection of surface water. Level 1 and Level 2 groundwater standards have been

developed for T-30 that take into account mixing and attenuation processes at nearshore areas. These levels were developed to calculate concentrations of Site COCs to be protective of surface water. Ongoing groundwater compliance monitoring is currently being performed by the Port.

- **Site-specific Groundwater Reference Value Rationale:** The reference value for T-30 is the Site-specified surface water ARAR as described in the 2006 Data Report. The Site-specified surface water ARAR was determined using the lowest value of applicable criteria at the time including Washington State Surface Water Criteria, National Water Quality Criteria (Ecological and Human Health) and MTCA Method A/B Groundwater Criteria.

T-30 has continued to be used by the Port as a deep-draft shipping facility since the mid 1980s. Between 1999 and 2002, a cruise ship berthing facility was constructed along the southern proposed EW OU study boundary. The T-30 property remains in use as a cruise ship facility. However, the facility is to be redeveloped for container terminal operations following completion of project permits associated with the relocation of the cruise ship facilities.

5.2.5.6 Terminal 25

T-25 is a 35-acre parcel owned by the Port of Seattle and located adjacent to the EW situated between T-30 to the north and Spokane Street to the south (Figure 5-7).

The area occupied by T-25 included a turning basin at the head of the EW as early as 1911 (USACE 1915). The basin was deepened by 1918 (USACE 1918), and remained in place through the 1970s, when it was filled (USACE 1981). Historical uses of the T-25 property are documented in a Phase 1 Environmental Assessment Report (Blymer Engineers 1989), and include operation of a cargo terminal, a grain terminal, a foundry, and the APL container terminal. The berth areas of T-25 were modernized by 1981 (USACE 1981) with dredging and armoring to create berths with effective depths of -50 feet MLLW. The upland property has been used for container and cargo terminal operations since that time.

Betweeen 2003 and 2006, a paved area within T-25 was leased to TAU LLC for development and operation of a temporary sediment offloading facility (Wang 2008). The facility design included stormwater collection, treatment, and discharge to the sanitary sewer. After termination of the lease, all facility components were removed.

The southern portion of T-25, known as T-25 South (T-24) (Figure 5-6), consists of approximately 18 acres and is the area of the former Rainier Cold Storage warehouse and freezer facility and the SeaBlends seafood processing company. The T-25 property was listed in the environmental database search as a leaking UST site.

A 3,000 gallon gasoline UST was formerly located at a former maintenance and repair facility and an area in the south-central portion of the property. The UST area was investigated in 1989 and 1990 including the removal and excavation sampling of the UST. Groundwater monitoring wells were installed and sampled for petroleum and related constituents at the upland UST area and nearshore area (former maintenance and repair building). Groundwater monitoring parameters are listed in Table 3-18. Groundwater sampling results were all below MTCA groundwater cleanup levels and groundwater concentrations of petroleum and related constituents at the nearshore wells were below method detection limits (Landau 1990; Sweet Edwards 1990). Groundwater data for the T-25 facility are summarized in Table 5-22. All groundwater monitoring results are below applicable cleanup levels.

Table 5-22
Terminal 25 Downgradient Groundwater Chemical Conditions

Constituent (µg/L)	Reference Value: MTCA Method A Groundwater Criteria	Chemical Concentration Detected	Detected Chemical Concentration Range	Downgradient Chemical Concentration Exceeds Reference Value
Petroleum Hydrocarbons				
Total petroleum hydrocarbons	1,000	0 of 7	--	0 of 7
BTEX Compounds				
Benzene	5	0 of 4	--	0 of 4
Ethylbenzene	700	0 of 4	--	0 of 4
Toluene	1,000	0 of 4	--	0 of 4
Total Xylenes	1,000	2 of 4	1.1 to 1.3	0 of 4

Notes:

- The T-25 groundwater sampling locations included in the evaluation are: MW-1, MW-2, MW-3, MW-4, LW-1, LW-2, and LW-3.
- **Type of Site and Release:** T-25 is a 35-acre parcel owned by the Port of Seattle and located adjacent to the EW situated between T-30 to the north and Spokane Street to the south. The north areas of T-25 recently underwent an extensive modernization project and are utilized as a container transfer and storage facility. The southern portion of T-25, known as T-25 South (T-24), consists of approximately 18 acres and is the area of the former Rainier Cold Storage warehouse and freezer facility and the SeaBlends seafood processing company. The T-25 property was listed in the environmental database search as a leaking UST site.
- **Documents Presenting Groundwater Results:** Landau 1990 (Soil and Groundwater Investigation) and Sweet-Edwards 1990 (Subsurface Investigation Report).
- **Groundwater Sampling Network and Rationale:** Groundwater sampling results from the 1989 groundwater sampling events are summarized below. All groundwater sampling locations were used in the evaluation below, except for groundwater sample PS-7. Groundwater sample PS-7 was collected using a bailer directly from the

excavation during UST removal activities. Additional groundwater sampling was performed to confirm downgradient conditions from upland UST sources.

- **Site-specific Groundwater Reference Value Rationale:** The reference value for T-25 is based on the MTCA Method A groundwater cleanup levels applicable at the time and referenced in the report (Landau 1990; Sweet-Edwards 1990).

5.2.5.7 Terminal 104 and Vicinity

The T-104 property is owned by the Port. It is located at 625 West Spokane Street and 3627 Duwamish Avenue South (Figure 5-6). Environmental investigations have been performed at the T-104 property as part of preparations for transportation improvements in the area.

Historical property uses are documented in Stage 1 Environmental Assessments performed as part of a recent grade separation project (Shannon & Wilson 2005a, 2005b, 2005c).

The northern area of T-104 is vacant and undeveloped consisting of mostly unpaved gravel surface. The southern area of T-104 is occupied by three warehouses that are used by the Port for storage and truck storage and maintenance. The property has historically been used by a paper bag manufacturer, a lumber storage yard, an auto repair shop, a restaurant, a foundry supply warehouse, and a cargo transfer and storage yard.

Environmental sampling has been performed at the T-104 property in conjunction with the East Marginal Way Grade Separation project (Environmental Partners 2007). A Stage 1 Environmental Assessment and an additional supplemental area-wide investigation have been conducted at the site. Results of groundwater sampling as part of these investigations indicated that arsenic, chromium, lead, and total petroleum hydrocarbons exceeded MTCA groundwater cleanup levels in the southeast and northeast portion of the site, located away from the EW shoreline and adjacent to the Poncho's Legacy and Moss G. Milan properties (Figure 5-7). The supplemental investigation confirmed these exceedances of groundwater cleanup levels, but demonstrated that contaminants had not migrated to the EW shoreline. Recent groundwater monitoring data for wells and groundwater monitoring locations located downgradient of identified source areas are summarized in

Table 5-23. None of the measured concentrations exceeded site-specific reference values.

Table 5-23
Terminal 104 and Vicinity Downgradient Groundwater Chemical Conditions

Constituent (µg/L)	Reference Value: MTCA Method A/C Groundwater Criteria	Chemical Concentration Detected	Detected Chemical Concentration Range	Downgradient Chemical Concentration Exceeds Reference Value
Metals (Dissolved)				
Arsenic	5	2 of 11	4.7 [1] to 4.9	0 of 11
Barium	--	2 of 11	32 [1] to 52 [1]	0 of 11
Cadmium	5	0 of 11	--	0 of 11
Chromium	50	1 of 11	13 [1]	0 of 11
Lead	15	3 of 11	1.8 [1] to 4.1 [1]	0 of 11
Mercury	2	0 of 11	--	0 of 11
Selenium	180c	0 of 11	--	0 of 11
Silver	180c	0 of 11	--	0 of 11
Petroleum Hydrocarbons				
Gasoline range hydrocarbons	1,000	0 of 7	--	0 of 7
Diesel range hydrocarbons	500	0 of 10	--	0 of 10
Lube oil range hydrocarbons	500	0 of 10	--	0 of 10
Volatile Organic Compounds				
1,2-Dichlorobenzene	1,600c	0 of 8	--	0 of 8
1,1-Dichloroethane	1,800c	0 of 8	--	0 of 8
cis-1,2-Dichloroethene	180c	1 of 8	0.4	0 of 8
trans-1,2-Dichloroethene	350c	0 of 8	--	0 of 8
Ethylbenzene	700	0 of 9	--	0 of 9
Trichlorothene (TCE)	5	1 of 8	0.89 to 4	0 of 8
Toluene [4]	1,000	4 of 9	0.27 to 0.75	0 of 9
Xylenes [4]	35,000c	1 of 9	0.52	0 of 9
PAH Compounds	--	0 of 6	--	0 of 6
PCBs (all locations)	--	0 of 11	--	0 of 11

Notes:

[1] The metals detected at these locations were all from a temporary geoprobe and analyzed for total metals.

c: Indicates MTCA Method C criteria.

- Results presented above were evaluated on a location-by-location basis and there may be multiple sampling events (dates) per location.
- T-104 and vicinity downgradient groundwater sampling locations included in the evaluation are: MW-13, MW-15, MW-16, MW-17, P-10, P-11, P-12, P-13, SW-6, SW-7, SW-8, and SW-9. Analytical testing at each groundwater sampling locations was selective. All groundwater sampling locations for PCBs were used.
- **Type of Site and Release:** Environmental sampling has been performed at the T-104 property and vicinity in conjunction with the East Marginal Way Grade Separation project. Properties included in the East Marginal Way Grade Separation project include an area of T-104, Poncho's Legacy, and Moss G. Milan properties.
- **Document Presenting Groundwater Results:** Environmental Partners 2007. (Supplemental Investigation and Data Summary Report – East Marginal Way Grade Separation Project.)
- **Groundwater Sampling Network and Rationale:** Groundwater sampling results from 2005 and 2006 investigation events are summarized below for those monitoring wells downgradient of potential source areas identified for the project area. A majority of groundwater sampling at these properties was performed using temporary geoprobes and when available, adjacent monitoring well analytical results took precedence over geoprobe groundwater samples. Additional investigative groundwater sampling was conducted after the initial 2005 sampling to confirm downgradient conditions and better delineate area contaminants of concern.

- **Site-specific Groundwater Reference Value Rationale:** The reference value for the T-104 and vicinity is based on the MTCA Method A and Method C groundwater cleanup levels applicable at the time and referenced in the report (Environmental Partners 2007).

The Poncho's Legacy Property is located at 3685 Duwamish Avenue South and adjacent to the T-104 property (Figure 5-7). Historical operations at the property have included an iron works, a welded iron mesh manufacturing facility, a real estate business, and the operations currently of International Belt and Rubber Supply, a rubber belt supply and retrofitting company. Structures at the property include a masonry warehouse, a wood frame office building, and a paved yard to the north used for rubber supply storage. The Poncho's Legacy property is currently undergoing cleanup under Ecology's VCP.

Previous environmental investigations at the Poncho's Legacy property include a Stage 1 Environmental investigation and Phase II Environmental Site Assessment. Additional on-site sampling was included in an area-wide supplemental investigation reported in March 2007. Results of recent groundwater monitoring data are summarized in Table 5-23. Groundwater analytical results from these studies indicated that low-level Trichlorothene (TCE) and arsenic in one monitoring well are the only contaminants above applicable MTCA groundwater cleanup levels. Low-level TCE and arsenic impacts were additionally investigated during the supplemental investigation and results indicated that TCE impacts were limited to areas beneath the property warehouse. Downgradient concentrations of TCE in groundwater were below the MTCA groundwater cleanup level. Elevated arsenic concentrations were also reported to be primarily beneath the property warehouse with concentrations just slightly above cleanup levels in the adjacent downgradient area. Remediation activities at the Poncho's Legacy property are ongoing (Bahnick 2007) and include the use of in situ groundwater treatment using chemical oxidation.

The Moss G. Milan property is located at 537 West Spokane Street adjacent to T-104 (Figure 5-7). Environmental investigations ware performed at this property as part of area development. Historical uses at this property included a foundry and pattern shop (1929 to 1949), a warehouse and restaurant (1949 to 1985), and a sawdust supply company (1985 to present). Environmental sampling has been performed at the property in conjunction with the East Marginal Way Grade Separation project, including an on-site Phase 2 investigation and an area-wide supplemental investigation (Environmental Partners 2007). Arsenic and low-level PAHs were the only contaminates identified in groundwater at the site and were detected above the MTCA Method A groundwater cleanup level at only one sampling location respectively. Arsenic was reported to likely be associated with background arsenic concentrations in the project area and the CPAH concentration was just above cleanup level. No contamination was detected in downgradient groundwater sampling locations toward the EW (see Table 5-23). The findings of these studies are presented in a site cleanup action plan (Environmental Partners 2007) that describes soil management procedures to be performed during planned construction activities.

5.2.6 Atmospheric Deposition

Airborne pollutants can reach sediments through the deposition of airborne particulate matter directly (i.e., onto the water surface) and indirectly (i.e., through deposition on terrestrial surfaces from which stormwater conveys them through drainage systems to the water body); because of the much larger surface area for collection, the greatest volume of airborne particulates is expected to come through the stormwater pathway. Key documents containing information relevant to atmospheric deposition in the vicinity of the EW are listed in Table 5-24.

Table 5-24
Summary of Key Documents – Atmospheric Deposition

Date	Title or Description	Author	Prepared for	Notes
General Information about Various Air Pollutants and Their Presence in the Puget Sound Area				
2006	Next Ten Years fact sheet: fine particulate matter (available online)	PSCAA	n/a	Information about fine particulate matter in the Puget Sound area.
2006	Air Toxics. Next Ten Years fact sheet. Pub. No. 20-9 KH 2/22/06	PSCAA	n/a	Information about air toxics in the Puget Sound area.
Air Monitoring and Deposition Data for Stations/Locations in the Vicinity of the EW				
2003	Final Report: Puget Sound Air Toxics Evaluation	PSCAA	n/a	General information and monitoring data for air toxics collected at the Beacon Hill and Georgetown monitoring stations.
2004	King County and Seattle Public Utilities source control program for the Lower Duwamish Waterway: June 2004 progress report	King County, SPU	n/a	Results of the Tacoma Dome roof phthalate sampling.
2005	King County and Seattle Public Utilities source control program for the Lower Duwamish Waterway: June 2005 progress report	King County, SPU	n/a	Program information and monitoring data for Phase I phthalate air monitoring, including monitoring data for PAHs from 4 monitoring stations in the vicinity of the LDW and EW.
2006	2005 Air Quality Data Summary	PSCAA	n/a	General information and monitoring data on fine particulate matter and lead.
2007	Personal communication (e-mail dated May 16, 2007 to Warren Hansen, Windward Environmental, LLC), regarding Phase 2 LDW passive air deposition sampling	Bruce Tiffany, King County Industrial Waste Program	n/a	Email contained a narrative describing Phase II sampling procedures and data tables presenting monitoring results for phthalates, PCBs, and PAHs from 5 monitoring stations in the vicinity of the LDW and EW.
Information about the Sediment Phthalates Work Group and Work Group Findings				
2007	Toxics Cleanup: Sediment Phthalates Work Group (available online)	Ecology	n/a	General information about the establishment, activities, and purposes of the Sediment Phthalates Work Group.
2006 and 2007	Sediment Phthalates Work Group Meeting Notes (available online)	Floyd|Snider	Sediment Phthalates Work Group	Detailed information on the activities and findings of the Sediment Phthalates Work Group.

n/a – not applicable
PSCAA – Puget Sound Clean Air Agency

5.2.6.1 Overview

Currently, air quality and atmospheric deposition monitoring data are being collected in the LDW and at other locations in Seattle by several groups including the Puget Sound Clean Air Agency (PSCAA), Ecology, and King County. Information collected through these monitoring programs can be used to assess the potential impact of atmospheric deposition in the EW given the proximity of these monitoring stations to the EW and the wide-spread nature of atmospheric contaminants.

There are multiple ways to measure rates of atmospheric deposition. Generally the methods include measurement of both wet deposition (measurement of particulates and contaminants contained within precipitation) and dry deposition (i.e., particles settling as dust). Pollutant deposition rates are ultimately expressed as average flux rates (e.g., $ng/m^2/day$ or $\mu g/m^2/day$) during a measured time interval.

Direct deposition of air pollutants could occur over the entire surface area of the EW. Wet deposition rates can be measured with a precipitation sampler (EPA 2001b). Dry deposition can be measured by collecting dry particles and gases on a sampling surface, or by measuring deposition at a specific location with a dry collector. Dry deposition can also be calculated through ambient air monitoring, where the concentration of particles and gases in the air is measured and the deposition rate is calculated using models (EPA 2001b). The total atmospheric deposition rate is the sum of the wet and dry deposition rates.

5.2.6.2 Completed and Ongoing Source Control Measures

The PSCAA considers over 400 chemicals to be toxic air pollutants, including PAHs, PCBs, diesel particulate matter (DPM; a subset of fine particulate matter [FPM]), and suspended particulates of some metals such as lead. Sources of air toxics include motor vehicles, diesel-powered marine vessels and rail cars, wood smoke, solid waste incinerators, and a variety of industrial facilities (PSCAA 2006b, 2006c). PSCAA requires dischargers of air pollutants to use best available control technology (BACT), described in their regulations, in order to minimize emissions and protect human health. In 2004, EPA delegated authority to Ecology and PSCAA as well as other local agencies to enforce New Source Performance Standards (NSPS) for many air pollutants. Ecology and PSCAA also have the authority to enforce National Emissions Standards for Hazardous Air Pollutants (NESHAP). Except for FPM and ozone, concentrations of criteria air pollutants in Puget Sound have been in compliance with regulatory standards for nearly a decade (PSCAA 2006a).

Ongoing anthropogenic sources of air pollutants include combustion of fossil fuels in vehicles, power plants, and industrial processes; and manufacturing, waste incineration, wood burning, and agricultural activities. Local sources of these pollutants can be more readily controlled than global sources, because existing regulatory programs are limited in their impact to affect air quality beyond regional and/or national borders.

Several local agencies and jurisdictions are working to control sources of air emissions. The Port of Seattle is helping to lead the Puget Sound Maritime Air Forum, a group of private and public organizations that have regulatory responsibilities related to air pollutant emissions, in a goal to identify, quantify, and reduce maritime sources of air pollutants. The primary goals of the forum are to help the Georgia Basin-Puget Sound airshed continue to meet ambient air quality standards, and to reduce port-related air quality impacts on human health and climate change (PSMAF 2007). The forum will work to reduce FPM emitted by ships at berth by 70 percent by 2010 through the use of cleaner burning fuels, cleaner engines, and other technology. The group will also work to reduce emissions from port-related truck, train and harbor craft activity.

A Sediment Phthalates Work Group existed from 2006 to 2007 to research how phthalates reach sediments in the Puget Sound region (Ecology 2007f). The work group included representatives from the City of Seattle, the City of Tacoma, King County, Ecology, and EPA. After conducting research of existing information, the Sediment Phthalates Work Group concluded that phthalates enter the environment primarily through off-gassing from a variety of manufactured products—primarily those containing plasticized polyvinyl chloride (PVC) (Floyd|Snider 2007). Once in the atmosphere, they attach to particulate matter and reach land and water surfaces through direct and indirect atmospheric deposition. Phthalates deposited throughout a watershed can be conveyed to the receiving water body through storm drain and CSO discharges. One of the key recommendations from the Sediment Phthalates Work Group is the need for research on ways to control sources of phthalates (Floyd|Snider 2007).

The PSCAA will continue to regularly monitor air quality in the region and make their data available through annual reports. The Washington State Department of Health is also in the process of completing a study of air quality and emission sources in the South Seattle area, and Ecology is initiating a study of the sources of toxic chemicals to Puget Sound. Thus, more information available in the near future should help determine the potential for atmospheric deposition to impact EW sediments.

5.2.6.3 Information Summary

Several groups monitor air quality in the Puget Sound region. Air monitoring reports with monitoring stations in the vicinity of the EW were used to obtain information about the concentrations and deposition potential of some pollutants.

- **Trends for Atmospheric FPM:** FPM is generated through the burning of wood, fossil fuels, and other materials and can also be formed when pollutant gases react in the atmosphere. FPM can provide a transport pathway for chemicals in the atmosphere that attach to FPM. Wood burning and dust from roadways and construction sites are the largest sources of FPM; motor vehicles and marine vessels are also significant sources of FPM in the region (King County and SPU 2005b; PSCAA 2006a, 2006d). Monitoring stations in Beacon Hill, the Duwamish valley, and Olive Street are used to monitor FPM among other air pollutants in central and south Seattle. PSCAA also has a monitoring station for the smallest fractions of FPM (PM2.5 – the FPM with a diameter equal to or less than 2.5 micrometers) in the South Park neighborhood. A map of monitoring stations from the PSCAA 2005 air quality data summary (PSCAA 2006a) is included in Appendix M. Between 2000 and 2005, daily average concentrations of PM 2.5

in the air in the Duwamish valley between 2000 and 2005 ranged from approximately 29 to 38 micrograms per cubic meter ($\mu g/m^3$), with concentrations generally decreasing over time (PSCAA 2006d). All PM2.5 concentrations reported for the Duwamish Valley between 2001 and 2005 were below the federal standard of 35 $\mu g/m^3$. Three-year maximum daily average concentrations of PM10 (FPM with a diameter equal to or less than 10 micrometers) in the Duwamish ranged from approximately 70 to 80 $\mu g/m^3$ between 2000 and 2005 (PSCAA 2006a). Data charts for FPM monitoring results are provided in Appendix M.

- **Phthalates Source Testing:** Phthalates are plasticizers used in a variety of manufactured products. In the environment they may be present in air, water, soil, and sediment, and phthalates in the air have the potential to be transported to sediment (Floyd|Snider 2007). In 2003, the County, SPU, and the City of Tacoma investigated potential sources of phthalates to the Thea Foss Waterway and LDW, by testing the phthalate content of a variety of manufactured materials. Various materials and commonly used consumer products were tested for phthalates. King County and City of Tacoma laboratories analyzed various liquid products (soaps, inks, used and unused motor oil) and solid products (plastic bottles, automotive belts, brake pads and dust, packing peanuts, tires, cigarette butts). High concentrations of BEHP (one of the phthalates most commonly detected in EW sediments) were found in some automotive belts, brake pads, and tires; liquid products generally contained lower concentrations of BEHP (King County and SPU 2005b). A literature review conducted as part of the study also suggested that some vehicle fuel products, such as diesel, contain BEHP that may be released into the atmosphere in exhaust (King County and SPU 2005b, citing California Air Resources Board 1997). Dust samples were collected from the Tacoma Dome roof both before it was cleaned and after to assess whether atmospheric deposition was a source of phthalates. Results of the roof sampling were provided in the June 2004 progress report for the King County and SPU Source Control Program for the Lower Duwamish Waterway and suggested that atmospheric deposition was a source of phthalates in the region (King County and SPU 2004 and 2005b). Phthalate concentrations in wipe samples collected prior to cleaning were approximately 600 micrograms per square feet (μg/ft^2), and samples collected after cleaning indicated concentrations were approximately 42 μg/ft^2 (these were the only concentrations reported in the progress reports).

- **Phase 1 Testing for Phthalates and PAHs:** In 2005, atmospheric deposition monitoring was conducted by the County at four monitoring stations near the LDW: Beacon Hill, East Marginal Way South, the Georgetown neighborhood, and South Park. Appendix M includes a map showing the Phase 1 phthalate air monitoring stations. The first phase of data was collected between January and May 2005 to assess the potential for phthalates and PAHs in the atmosphere to impact source control in the LDW. The passive samplers collected both wet and dry deposits. Additional information describing field collection and laboratory analytical methods used during this monitoring effort, as summarized in the *King County and Seattle Public Utilities Source Control Program for the Lower Duwamish Waterway June 2005 Progress Report* (King County and SPU 2005b), is located in Appendix M. Air deposition flux values indicating each chemical's mass deposition/area/time were provided in the Phase I study. Results showed that PAH, BBP, and BEHP deposition flux values were between approximately one and five times higher at the East Marginal Way South, Georgetown, and South Park monitoring stations than at the Beacon Hill station (see Appendix M for Phase 1 data tables) (King County and SPU 2005b). The Phase 1 sampling results for the four Seattle monitoring stations were compared to passive deposition sampling conducted in other areas (British Columbia, Denmark, the greater Puget Sound area, and the Great Lakes region). Phase 1 deposition values for most chemicals were similar to ranges in deposition flux values calculated from the other studies (see data tables in Appendix M). Similar ranges in atmospheric deposition flux values from all studies compared indicate there may be a regional or even global background concentration for some PAHs and phthalates in the atmosphere, however more research would be necessary to investigate the background condition further (King County and SPU 2005b).

- **Phase 2 Testing for Phthalates, PAHs, and PCBs:** Between October 2005 and December 2006, the County conducted a second phase of atmospheric deposition sampling. An additional monitoring station was added at the King County International Airport (KCIA). A map of the King County/SPU Phase 2 air deposition monitoring stations is included in Appendix M. Samples were analyzed for PCB Aroclors in addition to phthalates and PAHs in Phase 2. A narrative of sampling activities as well as data tables containing atmospheric deposition flux results were provided by the County (Tiffany 2007) and are contained in Appendix M. Air deposition flux data for Phase 2 showed that median concentrations of BEHP, DMP, and Di-n-butyl-phthalate were highest at the Duwamish monitoring station, the median Di-n-octyl phthalate concentration was highest at the Georgetown station, and the median concentration of BBP was highest at the South Park station. Total PCBs were generally detected near the laboratory MDLs, which ranged from 0.011 to 0.063 $\mu g/m^2/day$. The highest air deposition flux value for total PCBs (0.064 $\mu g/m^2/day$) was detected at the Georgetown station. Total PCBs were detected in at least one sampling round at every station except the Beacon Hill station.
- **Monitoring Data for Other Air Toxics:** Ecology and PSCAA have also monitored several air toxics since 2000, including some PAHs, VOCs, and metals. The results of monitoring data for formaldehyde, carbon tetrachloride, chloroform, benzene, acetaldehyde, 1,3-butadiene, tetrachloroethylene, trichloroethylene, and chromium concentrations are presented in PSCAA's 2005 Air Quality Data Summary (2006a). The report stated that the mean annual concentrations of most of these air toxics decreased between the years of 2000 and 2005, with the exception of tetrachloroethylene, which has remained constant. PSCAA and Ecology monitor several metals including arsenic, cadmium, chromium, lead, manganese, and nickel at monitoring stations throughout the greater Seattle area (see Figure 3-1 of PSCAA Air Toxics Data in Appendix M for the air toxics monitoring stations). Concentrations of metals in the atmosphere measured between 2000 and 2001 are presented in PSCAA's Puget Sound Air Toxics Evaluation Report (PSCAA 2003). A data table containing

atmospheric concentrations of these metals for several monitoring stations, including the Beacon Hill station and the Georgetown station, is included in Appendix M. PSCAA is in the process of developing an air toxics emissions summary for data collected in 2005. The report is not yet available.

5.3 Recontamination Monitoring Data

Monitoring data generated as part of the Phase 1 Removal Action since placement of an interim sediment sand layer in 2005 provides empirical evidence of recontamination potential for the central portion of the EW.

Post-dredge surface sediment monitoring was performed within the removal area following completion of the Phase 1 Removal Action in 2004 and 2005 (Anchor and Windward 2005). No samples were collected outside the perimeter of the dredge site. Sediment concentrations above CSL values were measured in surface sediments within portions of the removal area. As an interim remedy, a clean sand cover material was placed over these areas during March of 2005.

Recontamination monitoring was performed during the first (Windward 2006) and second (Windward 2007d) years after the sand layer placement. This monitoring included sampling throughout the Phase 1 removal action area, including both sand layer and non-sand layer areas. The 2006 and 2007 Recontamination Monitoring Data Reports include maps of sampling locations and data and are attached as part of Appendix D. Table 5-25 provides a summary of recontamination monitoring results.

The first monitoring event was conducted in January 2006 (Windward 2006d), and the second was conducted in February 2007 (Windward 2007d). Monitoring demonstrated that the interim sand layer remained in place with the sand thickness remaining greater than 10 centimeters (cm) at all sampling locations where cover layer thickness was measured.

In sand layer areas, exceedances of the SQS or CSL were noted in surface sediments (0 to 10 cm) for several contaminants, including total PCBs, 1,4-dichlorobenzene, BBP, and mercury. In non-sand layer areas, exceedances of the SQS or CSL in surface sediments were limited to total PCBs, 1,4-dichlorobenzene, and phenol.

Table 5-25
Summary of Detected Concentrations above the Sediment Management Standards in the Recontamination Monitoring Data for the Phase 1 Removal Area

Chemical	2006 Monitoring of Surface Sediments (0-10 cm)			2007 Monitoring of Surface Sediments (0-10 cm)		
	Detection Frequency	Number of SQS Exceedances	Number of CSL Exceedances	Detection Frequency	Number of SQS Exceedances	Number of CSL Exceedances
Areas with Sand Cover Placement						
Total PCBs	13/15	6	1	16/17	10	1
1,4-Dichlorobenzene	10/15	5 [a]	0	17/17	4	4
Bis(2-ethylhexyl)phthalate	14/15	1	1	17/17	0	0
Butylbenzylphthalate	3/15	0	0	17/17	1	0
Phenol	12/15	3	0	2/17	0	0
Copper	15/15	0	0	17/17	0	0
Mercury	10/15	2	2	16/17	1	0
Zinc	15/15	0	0	17/17	0	0
Areas without Sand Cover Placement						
Total PCBs	5/5	5	1	5/5	5	1
1,4-Dichlorobenzene	5/5	0	0	5/5	3	0
Bis(2-ethylhexyl)phthalate	5/5	0	0	5/5	0	0
Butylbenzylphthalate	1/5	0	0	5/5	0	0
Phenol	5/5	4	0	2/5	0	0
Copper	5/5	0	0	5/5	0	0
Mercury	5/5	0	0	5/5	0	0
Zinc	5/5	0	0	5/5	0	0

Sources: Windward 2006d, 2007d

Note: The number of CSL exceedances also includes the number of SQS exceedances, since SQS is also exceeded when the CSL is exceeded.

a Two additional samples were non-detect with detection limits slightly greater than the SQS.

5.4 Summary

Table 5-26 provides a concise summary of the information evaluated in the previous subsections. For additional details, refer to the information attached to the Existing Information Summary Report as appendices.

Table 5-26
Summary of Existing Information Relevant to Evaluated Sources [1]

Information Type	EW Investigation and Monitoring Data		Information Regarding Potential Ongoing Sources						
	Surface and Shallow Subsurface Sediment Data	Phase 1 Cover Recontamination Monitoring	Over-Water Uses and Spills	Wastewater Discharges	CSO Discharges	Stormwater Discharges	Nearshore Cleanup Sites	Atmospheric Deposition	Sediment Transport
EISR Section	2 and 3	5.3	5.2.1	5.2.2	5.2.3	5.2.4	5.2.5	5.2.6	4.0
Overview	Characteristics of current sediments within the EW	Monitoring of recontamination for Phase 1 Removal Area	Recent reported releases of petroleum and hazardous materials to the EW	Documented wastewater discharges to the EW	Permitted discharges from combined sewer overflows in and adjacent to the EW	Stormwater discharges to the EW, including potential discharges of stormwater-entrained pollutants	Migration of groundwater from upland cleanup sites located along the EW into the EW	Direct deposition of atmospheric pollutants onto the EW, and indirect deposition onto adjacent areas draining to the EW	Potential transport of impacted sediments from the LDW or Elliott Bay into the EW
Relevant Regulatory Authorities	Ongoing CERCLA RI/FS process	Ongoing CERCLA RI/FS process and non-time- critical removal action	State and federal spill prevention and reporting regulations	State and federal waste discharge permitting with primary oversight by Ecology	NPDES permitting and associated CSO control programs	State, federal, and local stormwater regulations	CERCLA (Harbor Island) and MTCA (other sites) cleanup programs	Federal, state, and local air quality regulations	LDW RI/FS and CERCLA cleanup process (LDW sediments) and CERCLA and MTCA cleanup programs (Elliott Bay sediments)
Lead Regulatory Agencies	EPA	EPA	Ecology, U.S. Coast Guard, EPA	Ecology	Ecology	Ecology	EPA (CERCLA projects) and Ecology (MTCA projects)	EPA, Ecology, Puget Sound Clean Air Agency	EPA and Ecology (cleanup and water quality regulatory authorities)
Lead Parties Associated with Completed and Ongoing Source Control Activities	EWG and other potentially responsible parties	EWG and other potentially responsible parties	Parties handling petroleum and hazardous substances	Industrial or municipal dischargers	City (Hinds Street CSO) and County (Lander, Hanford #2, and Connecticut Street CSOs)	City, County, and Port in coordination with the Washington State Department of Transportation, property owners, and private businesses within the stormwater drainage basins	Harbor Island Soil and Groundwater OU Group (Harbor Island), Port of Seattle (multiple sites), U.S. Coast Guard (Pier 35)	Operators of regional air pollution point sources, operators of global point sources, and contributors to non-point source air pollution	Various parties including LDWG members and other potential responsible parties for LDW sediments, parties associated with point and non-point sources for LDW water quality, and parties associated with sediments located in Elliott Bay
Time Period of Relevant Information	Relevant site investigations and cleanup activity (1983-2007). Sediments include historically-deposited materials.	Year 1 and Year 2 Monitoring Events (2006-2007)	Spill history last 5 years (2003-2007)	Current permitted discharges (2006-2007)	Recent CSO program and monitoring information (1997-2007)	Recent stormwater system and sampling data (1998-2007)	Relevant site cleanup and sampling information (1985-2007)	Recent regional studies (2004-2007)	Relevant transport studies and supporting information (1970s-2007)
Information Regarding Quantity, Frequency, or Solids Loadings	Evaluations of sedimentation patterns	Measurements of thicknesses of accumulated sediments within monitoring area	Documented release history for evaluation period including estimated quantities reported	No confirmed discharges identified	CSO flow monitoring performed by City and County. Whole-water TSS measurements as part of 1996-2004 sampling. SPU estimates average CSO solids loadings as 122 mg/L.	Drainage basin mapping land use information and rainfall data are available (can be used to estimate stormwater quantities). Literature reviews identify typical stormwater TSS loadings as 82 to 85 mg/L.	Eleven cleanup sites identified in EW nearshore area. Detailed groundwater studies performed as part of Harbor Island and T-30 sites.	Monitoring of airborne particulate matter concentrations and measurements of pollutant flux during regional studies	Previous studies are available regarding hydrodynamic and sediment transport behavior within the LDW, EW, and Elliott Bay
Available Information Regarding Contaminants	Frequently detected contaminants include PCBs, BEHP, BBP, 1,4-dichlorobenzene, mercury, indeno(123-cd)pyrene, and acenaphthene	Contaminants frequently detected in excess of SQS in cover materials include PCBs and 1,4-dichlorobenzene. Other exceedances detected include mercury, BEHP, BBP, and phenol.	Most (57 of 64) releases associated with petroleum products. Additional releases reported for sewage/human waste, sodium hydroxide and silver, paint thinner, xylene and cresols, and unidentified drum contents.	No data (no identified ongoing discharges)	Whole-water sampling data are available for three County CSOs from 1997-1998 sampling period. Catch basin sampling data are available for areas within the Hanford/Lander CSO drainage basin.	Catch basin and in-line sampling data are available for the Lander and nearshore drainage basins. Contaminants frequently detected in excess of SQS include BEHP, BBP, copper, and zinc. Localized exceedances of SQS noted for PCBs, mercury, and lead.	Contaminants of concern vary with site. Most common contaminant of concern at nearshore sites is petroleum, though no exceedances of cleanup levels were identified in shoreline areas. Other groundwater contaminants (copper, zinc, cyanide) identified in one nearshore area at Harbor Island.	Deposition sampling data available for phthalates, PCBs, and PAH compounds. Airborne pollutant information available for heavy metals and selected other toxic pollutants.	Sediment contaminant data available from LDW, EW, and Elliott Bay studies. Sediment trap and deposition measurements available from EW studies.

1. Refer to the EISR narrative for reference citations for information listed in this table.

BBP – butylbenzyl phthalate
BEHP – bis(2-ethylhexyl)phthalate
PCBs – polychlorinated biphenyls
SPU – Seattle Public Utilities
SQS – Sediment Quality Standards
TSS – total suspended solids

6 NEXT STEPS AND FUTURE DELIVERABLES

Following completion of the EISR, SRI and FS activities will be conducted as described in the Workplan (Anchor and Windward 2007). Subsequent SRI activities include developing the CSM and Data Gaps Analysis Report based on information presented in the EISR and information needs to complete the SRI. Next steps for the SRI following the CSM and Data Gaps Analysis Report include development of QAPPs for field sampling necessary to address information needs, and development of Baseline Ecological and Human Health Risk Assessment Technical Memoranda.

Due to the expedited schedule, other SRI and FS tasks will be conducted in parallel with the CSM and Data Gaps Analysis Report. Other concurrent SRI activities include preparation of the Sediment Transport Evaluation Approach Memorandum, followed by implementation of the sediment transport evaluation activities. Concurrent FS activities will include preparation of the Source Control Evaluation Approach Memorandum, followed by implementation of the source control evaluation process. The other FS task conducted after the Source Control Evaluation Approach Memorandum will be preparation of the RAO Memorandum.

The current SRI/FS schedule is included as Figure 6-1. Currently, the EPA ROD is expected to be issued in May 2010. As described in the Workplan, this schedule assumes expedited timeframes for EPA reviews and shows SRI and FS activities to be conducted concurrently in order to expedite the overall schedule. Draft and final deliverables submitted to EPA are due to EPA as noted on Figure 6-1, unless deadline extensions are requested by the Port and are approved by EPA. Opportunities to reassess the schedule have been incorporated into Figure 6-1 following approval of the CSM and Data Gaps Analysis Report and after the Data Reports have been finalized. In addition, the project schedule will continue to be reviewed in consultation with EPA on a routine basis (e.g., monthly) and at key project milestones. Key milestones consist of each draft and final deliverable to EPA as well as EPA approvals. Any necessary changes to the project schedule will be developed by the EWG, in close coordination with EPA.

7 REFERENCES

Alexander G. 1977. Food of vertebrate predators on trout waters in north central lower Michigan. Mich Academ 10:181-195.

Anchor. 2002. East Waterway Terminal 18 Stage 1a, Rounds 1 and 2 chemical and biological characterization: Sampling and analysis results. Prepared for the Port of Seattle. Anchor Environmental, L.L.C., Seattle, WA.

Anchor. 2006. Sediment characterization report, Port of Seattle Terminal 30. Prepared for the Port of Seattle. Anchor Environmental, L.L.C., Seattle, WA.

Anchor and Windward. 2005. East Waterway Operable Unit, Phase 1 Removal Action completion report. Appendix C: East Waterway Phase 1 removal post-dredge monitoring report. Anchor Environmental, L.L.C. and Windward Environmental, L.L.C., Seattle, WA.

Anchor and Windward. 2007. East Waterway Operable Unit Supplemental Remedial Investigation/Feasibility Study Final Workplan. Prepared for the U.S. Environmental Protection Agency, Region 10, Seattle. July 6, 2007.

Anderson B. 2002. Personal communication (telephone conversation with Berit Bergquist, Windward Environmental LLC, regarding raptors in the LDW). Falcon Research Group, Bow, WA. March 22.

Angell C.L., Miller B.S., and Wellings S.R. 1975. Epizootiology of tumors in a population of juvenile English sole (*Parophrys vetulus*) from Puget Sound, Washington. J Fish Res Bd Can 32:1723-1732.

Bagley, C.B. 1916. History of Seattle from the Earliest Settlement to the Present Time. Volumes I and II. The S.J. Clarke Publishing Company. Chicago.

Bahnick, K. 2007. Personal communication regarding ongoing upland cleanup activities. Senior Environmental Program Manager, Port of Seattle, Seattle, WA.

Bane G. and Robinson M. 1970. Studies on the shiner perch, *Cymatogaster aggregata* Gibbons, in upper Newport Bay, California. Wasmann J Biol 28(2):259-268.

Battelle. 1996. Final report for the PCB Aroclor and congener analyses on fish tissue samples from the Elliott Bay/Duwamish River project. Pacific Northwest Division, Battelle Marine Research Laboratory, Sequim, WA.

Battelle. 2006. Investigation of the Capabilities of the Model EFDC for use in the Evaluation of Sediment Contamination, Discharge Modeling for Contaminated Sediment Cleanup Decisions. Project Memorandum from S. Breithaupt and C. Lee to Jeffrey Stern, King County Department of Natural Resources. April 12, 2006.

Battelle, Pentec, Striplin, Shapiro, KCDNR. 2001. Reconnaissance assessment of the state of the nearshore ecosystem: Eastern shore of central Puget Sound, including Vashon and Maury Islands (WRIAs 8 and 9). Prepared for King County Department of Natural Resources, Seattle, WA. Battelle Marine Sciences Laboratory, Pentec Environmental, Striplin Environmental Associates, Shapiro Associates, Inc., King County Department of Natural Resources, Seattle, WA.

Beach R.A., Geiger C., Jeffries S.J., Treacy S.D., and Troutman B.L. 1985. Marine mammals and their interactions with fisheries of the Columbia River and adjacent waters, 1980-1982. Third annual report. Wildlife Management Division, Washington Department of Wildlife, Olympia, WA.

Berger/ABAM. 1997. Pier 36 preliminary sampling and dredging/disposal analysis. Prepared for U.S. Coast Guard Integrated Support Command, Seattle. Berger/ABAM Engineers Inc., Federal Way, WA.

Blomberg. 2007. Personal communication with S. McGroddy of Windward Environmental LLC. July 25, 2007.

Blomberg G., Simenstad C., and Hickey P. 1988. Changes in Duwamish River estuary habitat over the past 125 years. Proceedings of the First Annual Meeting on Puget Sound Research, Seattle, WA.

Blymer Engineers. 1989. Phase 1 Environmental Site Assessment – Terminal 25.

Boulva J. and I.A. McLaren. 1979. Biology of the harbor seal, Phoca vitulina, in eastern Canada. Fish Res Board Can Bulletin 200:1-24.

Breithaupt, S., T. Khangaonkar and L. Williams. 2002. Task 202: Effluent, Sediment, and Receiving Water characterization Review. Technical Memorandum to King County Department of Natural Resources from Foster Wheeler Environmental Corporation. July 2, 2002.

Brettman, K. 2007. Personal communication: Green River flood frequency flows at the Auburn gage. U.S. Army Corps of Engineers, Seattle District, Seattle, Washington.

Brown R.F. and B.R Mate. 1983. Abundance, movements, and feeding habits of harbor seals, Phoca vitulina, at Nearts and Tillamook Bays, Oregon. USNMFS Fish Bull 81:291-301.

Buehler D.A. 2000. Bald eagle (Haliaeetus leucocephalus). In: Poole A, Gill F, eds, The birds of North America, no. 506. Academy of Natural Sciences, Philadelphia, PA, and American Ornithologists' Union, Washington, DC.

Butler R.W. 1992. Great blue heron (Ardea herodias). In: Poole A, Stettenheim P, Gill F, eds, The birds of North America, no. 25. Academy of Natural Sciences, Philadelphia, PA, and American Ornithologists' Union, Washington, DC.

CalEPA. 1994. Health effects of benzo(a)pyrene. Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Berkeley, CA.

Canning D.J., Herman S.G., Shea G.B. 1979. Terminal 107 Environmental Studies, Wildlife Study. Prepared for the Port of Seattle Planning and Research Department. Oceanographic Institute of Washington and Northwest Environmental, Seattle, WA.

Carpenter, R., M.L. Peterson, and J.T. Bennett. 1985. PB-210-derived sediment accumulation and mixing rates for the greater Puget Sound region. Marine Geology 64: 291-312.

CHE. 2003. Technical Memorandum Propeller Wash Measurements and Model Comparison- Maury Island Barge-Loading Dock. Coast & Harbor Engineering, Edmonds, WA. August 14.

CHE. 2004. Technical Memorandum TRC Sediment Remediation Lockheed Shipyard No. 1 Sediment Operable Unit-Armor Layer Coastal Engineering Analysis. Coast & Harbor Engineering, Edmonds, WA. October 22, 2004.

CHE. 2006a. Technical Memorandum East Blair One Wharf Under-Wharf Scour Analysis. Coast & Harbor Engineering, Edmonds, WA. July 17.

CHE. 2006b. Technical Report, Evaluation of Hydraulics and Sediment Processes at Alternative Disposal Sites, Bradwood LNG Terminal, Columbia River. Coast & Harbor Engineering, Edmonds, WA. June.

CHE. 2007. Technical Memorandum-Draft Terminal 91 Cruise Ship Berths Under-Wharf Thruster Wash Scour Analysis. Coast & Harbor Engineering, Edmonds, WA. April 2.

City of Seattle. 1998. Elliott Bay/Duwamish source control project: Final report. City of Seattle Public Utilities, Seattle, WA.

Clemens W.A. and Wilby G.V. 1961. Fishes of the Pacific coast of Canada. Second edition. Publication no. 68. Fisheries Resources Board of Canada.

Cohen D.M., Inada T., Iwamoto T., and Scialabba N. 1990. Gadiform fishes of the world (Order Gadiformes). An annotated and illustrated catalogue of cods, hakes, grenadiers and other gadiform fishes known to date. FAO species catalogue. FAO Fish Synopses 125, vol 10. Food and Agriculture Organization of the United Nations, Rome, Italy.

Cordell J., Toft J., Cooksey M., and Gray A. 2006. Fish assemblages and patterns of chinook salmon abundance, diet, and growth at restored sites in the Duwamish River. Funded by the King Conservation District Salmon Recovery Funding Board, Seattle, WA.

Cordell J.R. 2001. Personal communication (e-mail to Matt Luxon, Windward Environmental LLC regarding observations of juvenile chinook and other wildlife in the LDW). Researcher, Department of Fisheries, University of Washington, Seattle, WA. July 9.

Cordell J.R., Tear L.M., and Jensen K. 2001. Biological monitoring at Duwamish River coastal America restoration and reference sites: A seven-year retrospective. SAFS-UW-0108. Wetlands Ecosystem Team, School of Aquatic and Fisheries Sciences, University of Washington, Seattle, WA.

Cordell J.R., Tear L.M., Jensen K., and Higgins H.H. 1999. Duwamish River coastal America restoration and reference sites: Results from 1997 monitoring studies. FRI-UW-9903. Fisheries Research Institute, University of Washington, Seattle, WA.

Cordell J.R., Tear L.M., Jensen K., and Luiting V. 1997. Duwamish river coastal America restoration and reference sites: Results from 1996 monitoring studies. Fisheries Research Institute, University of Washington, Seattle, WA.

Cordell J.R., Tear L.M., Jensen K., Simenstad C.A., and Hood W.G. 1994. Duwamish River coastal America restoration and reference sites: results and recommendations from year one pilot and monitoring studies. FRI-UW-9416. Fisheries Research Institute, University of Washington, Seattle, WA.

Cordell J.R., Tear L.M., Simenstad C.A., and Hood W.G. 1996. Duwamish river coastal America restoration and reference sites: Results from 1995 monitoring studies. Fish Research Institute, University of Washington, Seattle, WA.

Cox G., and Francis M. 1997. Sharks and rays of New Zealand. Canterbury University Press, Christchurch, New Zealand.

Dames & Moore. 1989. Evaluation of Upland Soil and Groundwater Contamination Data Support Center Seattle Consolidation Piers 35 and 36, Seattle, Washington. Prepared for United States Coast Guard. Dames & Moore, Inc., Seattle, WA. June 19, 1989.

Dawson C.E. 1985. Indo-Pacific pipefishes (Red Sea to the Americas). The Gulf Coast Research Laboratory, Ocean Springs, MS.

Day D.E. 1976. Homing behavior and population stratification in central Puget Sound English sole (*Parophrys vetulus*). J Fish Res Board Can 33:287-282.

DEA. 2003. Bathymetric survey East Duwamish Waterway. Prepared for Windward Environmental, L.L.C. by David Evans and Associates, Inc. January 8, 2003.

Dexter R.N., Anderson D.E., Quinlan E.A., Goldstein L.S., Stickland R.M., Pavlou S.P., Clayton J.R., Kocan R.M., and Landolt M. 1981. A summary of knowledge of Puget Sound related to chemical contaminants. NOAA technical memorandum OMPA-13. Office of Marine Pollution Assessment, National Oceanic and Atmospheric Administration, Boulder, CO.

Dinnel PA, Armstrong DA, Miller BS, Donnelly RF. 1986. Puget Sound dredge disposal analysis (PSDDA) disposal site investigations: Phase 1 trawl studies in Saratoga Passage, Port Gardner, Elliott Bay and Commencement Bay, Washington. Parts 1 and 2. Prepared for Washington Sea Grant Program. Fisheries Research Institute, University of Washington, Seattle, WA.

Ecology. 2002. Findings of the investigation of the oil spill involving Port of Seattle/Terminal 18/Kinder-Morgan dock pipelines, Seattle, Washington, November 18, 2001. Washington Department of Ecology, Bellevue, WA.

Ecology. 2003. Sediment Sampling and Analysis Plan Appendix. Guidance on the Development of Sediment Sampling and Analysis Plans Meeting the Requirements of the Sediment Management Standards (Chapter 173-204 WAC). Washington Department of Ecology Publication No. 03-09-043. Revised April 2003.

Ecology. 2005. Stormwater Management Manual for Western Washington, Multi-volume. Publication No. 05-10-32. February 2005.

Ecology. 2007a. Using Sediment Profile Imaging (SPI) to Evaluate Sediment Quality at Two Cleanup Sites in Puget Sound. Part I – Lower Duwamish Waterway. Environmental Assessment Program. Olympia, WA. Publication 07-03-025. July. 102 pp.

Ecology. 2007b. Water quality permits - point source pollution [online]. Washington Department of Ecology, Olympia, WA. [Cited 6/4/07]. Available from: http://www.ecy.wa.gov/programs/wq/permits/.

Ecology. 2007c. Water quality/Stormwater: Information on Ecology's water quality permit life cycle system (WPLCS) [online]. Washington Department of Ecology, Olympia, WA. [Cited 6/7/07]. Available from: http://www.ecy.wa.gov/PROGRAMS/WQ/permits/wplcs/index.html.

Ecology. 2007d. Underground Storage Tank List [online]. Washington Department of Ecology, Olympia, WA. [Cited 1/22/08]. Available from: http://www.ecy.wa.gov/PROGRAMS/tcp/ust-lust/ust-lst2.html.

Ecology. 2007e. Leaking Underground Storage Tank List [online]. Washington Department of Ecology, Olympia, WA. [Cited 1/22/08]. Available from: http://www.ecy.wa.gov/PROGRAMS/tcp/ust-lust/ust-lst2.html.

Ecology. 2007f. Toxics Cleanup: Sediment Phthalates Work Group [online]. Washington Department of Ecology, Olympia, WA. [Cited 6/14/07]. Available from: http://www.ecy.wa.gov/programs/tcp/smu/phthalates/phthlates_hp.htm.

Environmental Partners. 2007. Supplemental Investigation and Data Summary Report, East Marginal Way Grade Separation Project. Prepared for Port of Seattle. Environmental Partners, Inc., Issaquah, WA.

EPA. 1989a. Risk assessment guidance for Superfund, volume 1: Human health evaluation manual, Part A. EPA/540/1-89/002. Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, DC.

EPA. 1989b. Risk management guidance for Superfund, volume 2: Environmental evaluation manual. EPA 540/1-89/001. U.S. Environmental Protection Agency, Washington, DC.

EPA. 1992. Guidance for data useability in risk assessments (Part A). PB92 - 963356. Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, DC.

EPA. 1993. Record of Decision: declaration, decision summary, and responsiveness summary for Harbor Island soil and groundwater, Seattle, Washington. U.S. Environmental Protection Agency Region 10, Seattle, WA.

EPA. 1996. Amended Record of Decision, decision summary: the revised remedial action for the soil and groundwater operable unit of the Harbor Island Superfund site in Seattle, Washington. U.S. Environmental Protection Agency Region 10, Seattle, WA.

EPA. 1998. EPA's Contaminated Sediment Management Strategy. EPA-823-R-98-001. Office of Water, U.S. Environmental Protection Agency, Washington, DC. April 1998.

EPA. 2001a. Explanation of Significant Differences Number 2 (ESD #2) for the Harbor Island Superfund Site Soil and Groundwater Operable Unit, Seattle, WA. Signed by Michael F. Gearheard, Director of Environmental Cleanup Office. September 26.

EPA. 2001b. Frequently asked questions about atmospheric deposition. EPA-453/R-01/009. Office of Wetlands, Oceans, and Watersheds and Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Washington, DC.

EPA. 2003. Analyses of laboratory and field studies of reproductive toxicity in birds exposed to dioxin-like compounds for use in ecological risk assessment. EPA/600/R-03/114F. National Center for Environmental Assessment, U.S. Environmental Protection Agency, Cincinnati, OH.

EPA. 2005. Contaminated Sediment Remediation Guidance for Hazardous Waste Sites. December 2005. http://www.epa.gov/superfund/resources/sediment

EPA. 2006a. Administrative settlement agreement and order on consent for the supplemental remedial investigation and feasibility study of the East Waterway Operable Unit of the Harbor Island Superfund site. U.S. Environmental Protection Agency, Region 10, Seattle, WA.

EPA. 2006b. NPDES Permit Program basics [online]. Office of Wastewater Management, U.S. Environmental Protection Agency, Washington, DC. Updated 7/5/06. [Cited 6/4/07]. Available from: http://www.epa.gov/owm/ (click on National Pollutant Discharge Elimination System permits link).

Eschmeyer W.N., Herald E.S., and Hammann H. 1983. Pacific coast fishes. Peterson Field Guide Series. Houghton Mifflin, Boston, MA.

ESG. 1999. Waterway sediment operable unit, Harbor Island Superfund site. Assessing human health risks from the consumption of seafood: human health risk assessment report. Prepared for Port of Seattle, Todd Shipyards, and Lockheed-Martin for submittal to U.S. Environmental Protection Agency, Region 10, Seattle, WA. Environmental Solutions Group, Inc., Seattle, WA.

ESG. 2000. Report of findings, City of Seattle, Seattle Public Utilities CSO characterization project. Prepared for Seattle Public Utilities. Environmental Solutions Group, Seattle, WA.

Everitt R.D., Gearin P., and Skidmore J.S. 1981. Prey items of harbor seals and California sea lions in Puget Sound, Washington. Murrelet 62: 83-8.

EVS. 1996a. Harbor Island sediment operable unit. Supplemental remedial investigation. Volume 1 of 2. EVS Consultants, Seattle, WA.

EVS. 1996b. Harbor Island sediment operable unit. Supplementary remedial investigation. Appendices, Vol 2 of 2. EVS Consultants, Seattle, WA.

EVS. 1998. Port of Seattle Terminal 18 sediment characterization. Sampling and analysis results. Final. EVS Environment Consultants, Inc., Seattle, WA.

EVS. unpublished. Elliott Bay/Duwamish River fish tissue investigation, 1995. Fish collection field log. EVS Environment Consultants, Inc., Seattle, WA.

EVS and Hart Crowser. 1996. Harbor Island Supplementary remedial investigation. EVS Environment Consultants and Hart Crowser, Seattle, WA.

Floyd|Snider. 2006. Sediment Phthalates Work Group Meeting Notes. Prepared for the Sediment Phthalates Work Group. Floyd|Snider Inc., Seattle, WA.

Floyd|Snider. 2007. Sediment Phthalates Work Group Meeting Notes. Prepared for the Sediment Phthalates Work Group. Floyd|Snider Inc., Seattle, WA.

Forrester C.R. 1969. Life history on some ground fish species. Fish Res Bd Can Technical Report 105:1-17.

Foster Wheeler. 2002a. Memorandum: discharge modeling for contaminated sediment cleanup decisions, Phase I: Identification of critical processes and development of an approach. Task 201: Review of CSO Conveyance and Outfall Structure Designs. Foster Wheeler Environmental Corporation. April 4.

Foster Wheeler. 2002b. Memorandum: discharge modeling for contaminated sediment cleanup decisions, Phase I: Identification of critical processes and development of an approach. Task 202: effluent, sediment and receiving water characterization review. July 2, 2002, Foster Wheeler Environmental Corporation.

Foster Wheeler. 2002c. Memorandum: discharge modeling for contaminated sediment cleanup decisions, Phase I: Identification of critical processes and development of an approach. Task 203: Conceptual Model for Sediment Contamination Evaluation. Foster Wheeler Environmental Corporation. September 5.

Frankel A.D., Stephenson W.J., Carver D.L., Williams R.A., Odum J.K., and Rhea S. 2007. Seismic Hazard Map of Seattle Washington. U.S. Department of the Interior, U.S. Geological Survey. Report 2007-1175.

Fresh K.L., Rabin D., Simenstad C.A., Salo E.O., Garrison K., and Matheson L. 1979. Fish ecology studies in the Nisqually Reach area of southern Puget Sound, Washington. FRI-UW-7904. Prepared for Weyerhauser Company. Fisheries Research Institute, University of Washington, Seattle, WA.

Frontier Geosciences. 1996. Mercury results in 18 fish samples for the Elliott Bay/Duwamish River project. Frontier Geosciences, Seattle, WA.

Gall G.A.E., and Crandell P.A. 1992. The rainbow trout. Aquaculture 100:1-10.

Galster R.W. and Laprade, W.T. 1991. Geology of Seattle, Washington, USA. Bulletin of the Association of Engineering Geologists. Vol. 28, No. 3.

GeoEngineers. 1998. Terminal 30. Final Report Remedial Investigation/Focused Feasibility Study. Prepared for the Port of Seattle, Seattle, WA. GeoEngineers Inc. December 21.

GeoEngineers. 2001. Dredge material characterization, U.S. Coast Guard rebuild Pier 36 (Berth Alpha), Seattle, Washington. Prepared for U.S. Coast Guard and Berger/Abam Engineers, Inc. GeoEngineers, Inc., Seattle, WA. November 30.

GeoEngineers. 2003. Dredge material characterization, additional sampling, Pier 36 Slip Dredging, U.S. Coast Guard Support Center, Seattle, Washington. Prepared for U.S. Coast Guard. GeoEngineers, Inc., Seattle, WA.

GeoEngineers. 2004. Pier 36, suitability confirmation sampling results. Memorandum prepared for U.S. Coast Guard. GeoEngineers, Inc., Tacoma, WA.

Gilbert C.R., and Williams J.D. 2002. National Audobon Society field guide to fishes. Alfred A. Knopf, Inc., New York, NY.

Gordon C.D. 1965. Aspects of the life-history of *Cymatogaster aggregata* Gibbons. MS thesis. University of British Columbia, Victoria, BC.

Grette G.B. and E.O. Salo. 1986. The status of anadromous fishes of the Green/Duwamish River system. Prepared for U.S. Army Corps of Engineers, Seattle District. Evans-Hamilton, Inc., Seattle, WA.

Groot C., Margolis L., eds. 1998. Pacific salmon life histories. UBC Press, Vancouver, BC.

Hart Crowser. 1984. Subsurface Exploration and Geotechnical Evaluation Study, Terminal 30 Apron and Yard Expansion, Port of Seattle, WA. Hart Crowser & Associates, Inc. January 1984.

Hart Crowser. 2004. Draft Sampling and Analysis Report, U.S. Coast Guard ISC Seattle Pier 36 Site Investigation. Prepared for U.S. Coast Guard. Hart Crowser, Inc., Seattle, WA.

Hart Crowser. 2005. Post-dredge sediment characterization, Integrated Support Command, Seattle Pier 36 Facility, U.S. Coast Guard, Facilities Design and Construction Center, Seattle, Washington. Hart Crowser, Inc., Seattle, WA.

Hart J.L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada, Ottawa, ON.

Harza. 1998. East Waterway Deepening Project Upland Geotechnical Services, Phase 1. Prepared for WD Ritchie & Associates. Harza Project No. 7230-G. Harza Engineering Company. March 25.

Harza. 1999. East Waterway Deepening Project Upland Geotechnical Services, Phase 2. Prepared for WD Ritchie & Associates. Harza Project No. 7230-G. Harza Engineering Company. January 13.

Herrera. 1997. Monitoring Report, Denny Way/Lake Union CSO Control Project. Submitted to King County Department of Natural Resources. Herrera Environmental Consultants, Seattle, WA.

Herrera. 1998. Monitoring Report, Henderson/M.L. King CSO Control Project. Submitted to King County Department of Natural Resources. Herrera Environmental Consultants, Seattle, WA.

HistoryLink. 2007a. Harbor Island, at the Time the World's Largest Artificial Island, is Completed in 1909. HistoryLink essay 3631. http://www.historylink.org/essays/output.cfm?file_id=3631

HistoryLink. 2007b. Straightening of Duwamish River begins on October 14, 1913. HistoryLink essay 2986. http://www.historylink.org/essays/output.cfm?file_id=2986

HISWG. 1996. Harbor Island Sediment Operable Unit – Supplemental Remedial Investigation – Draft Volumes 1 and 2. Submitted to U.S. Environmental Protection Agency, Seattle, WA. Prepared by EVS Consultants, Seattle, WA. Harbor Island Sediment Work Group. March.

Hoffman R.D. 1978. The diets of herons and egrets in southwestern Lake Erie. In: Sprunt A, Oge J, Winckler S, eds, Wading birds. Research report No. 7. National Audubon Society, New York, NY, pp 365-369.

Holland G.A. 1954. A preliminary study of the populations of English sole in Carr Inlet and other locations in Puget Sound. MS thesis. University of Washington, Seattle, WA.

Hotchkiss. 2007. Personal communication (reports from dock workers regarding the presence of pigeon guillemot nests under the pier at T-18). Project manager, Port of Seattle, Seattle WA.

Hoover A. 1988. Harbor seal, Phoca vitulina. In: Lentfor JW, ed, Selected marine mammals of Alaska: Species accounts with research and management recommendations. Marine Mammal Commission, Washington, DC, pp 125-157.

Kerwin J., and Nelson T.S., eds. 2000. Habitat limiting factors and reconnaissance assessment report, Green/Duwamish and Central Puget Sound watersheds (WRIA 9 and Vashon Island) [online]. Washington Conservation Commission, Lacey, WA, and King County Department of Natural Resources, Seattle, WA. Available from: http://dnr.metrokc.gov/WRIAS/9/Recon.htm.

King County. 1994. 1993/1994 annual combined sewer overflow (CSO) report. King County Department of Metropolitan Services, Seattle, WA.

King County. 1995. Chelan, Connecticut, and Hanford CSO sediment sampling results. King County Department of Natural Resources, Seattle, WA.

King County. 1996. Sampling for bioassay and subsequent analysis for chemistry. Prepared for Elliott Bay/Duwamish Restoration Program. King County Department of Natural Resources, Seattle, WA.

King County. 1998. CSO sampling and monitoring data inventory, task 5 report. Sediment management plan. Sediment Management Plan Project Team, King County Department of Natural Resources, Seattle, WA.

King County. 1999a. King County combined sewer overflow water quality assessment for the Duwamish River and Elliott Bay. Vol 1: Overview and interpretation, plus appendices. King County Department of Natural Resources, Seattle, WA.

King County. 1999b. King County Department of Natural Resources, Year 2000 CSO Plan Update Project: Sediment Management Plan. Prepared by Anchor Environmental, L.L.C. and Herrera Environmental Consultants in collaboration with King County. June 1999.

King County. 2004. Combined sewer overflow control program 2003-2004 annual report. Wastewater Treatment Division, King County Department of Natural Resources and Parks, Seattle, WA.

King County. 2005a. Propwash analysis prepared in support of Duwamish/Diagonal Way Combined Sewer Overflow/Storm Drain Sediment Remediation Project Closure Report. Prepared for King County Department of Natural Resources and Parks and Elliott Bay/Duwamish Restoration Program Panel. July.

King County. 2005b. Combined sewer overflow control program 2004-2005 annual report. Wastewater Treatment Division, King County Department of Natural Resources and Parks, Seattle, WA.

King County. 2006a. 2005 combined sewer overflow control program review. Wastewater Treatment Division, King County Department of Natural Resources and Parks, Seattle, WA.

King County. 2006b. Combined sewer overflow control program 2005-2006 annual report. Wastewater Treatment Division, King County Department of Natural Resources and Parks, Seattle, WA.

King County and SPU. 2004. King County and Seattle Public Utilities source control program for the Lower Duwamish Waterway. June 2004 progress report. King County Industrial Waste and Seattle Public Utilities, Seattle, WA.

King County and SPU. 2005a. King County and Seattle Public Utilities source control program for the Lower Duwamish Waterway: January 2005 progress report. King County Department of Natural Resources and Parks and Seattle Public Utilities, Seattle, WA.

King County and SPU. 2005b. King County and Seattle Public Utilities source control program for the Lower Duwamish Waterway: June 2005 progress report. King County Department of Natural Resources and Parks and Seattle Public Utilities, Seattle, WA.

Kirkpatrick C.M. 1940. Some foods of young great blue herons. Am Midl Nat 24:594-601.

Knight R.L., Randolph P.J., Allen G.T., Young L.S., Wigen R.J. 1990. Diets of nesting bald eagles, Haliaeetus leucocephalus, in western Washington. Can Field-Nat 104(4):545-551.

Kurrus, K. and C. Ebbesmeyer. 1995. Currents measured in the West and East Waterways one meter above the seafloor at one-second intervals during April-May 1995. Evans-Hamilton, Seattle. Prepared for Hart-Crowser. July.

Kushlan J.A. 1978. Feeding ecology of wading birds. In: Sprunt A, Oge J, Winckler S, eds, Wading birds, research report No. 7. National Audubon Society, New York, NY, pp 249-297.

Lamb A., and Edgell P. 1986. Coastal fishes of the Pacific Northwest. Harbour Publishing Co. Ltd., Madeira Park, BC.

Landau. 1990. Soil and Groundwater Investigation, Maintenance Building Terminal 25. Prepared for Port of Seattle. Landau Associates, Inc., Edmonds, WA.

Leon H. 1980. Final Report: Terminal 107 environmental studies. Benthic community impact study for terminal 107 (Kellogg Island) and vicinity. Prepared for Port of Seattle Planning and Research Department. Pacific Rim Planners, Inc., Seattle, WA.

Lowry L.F. and K.J Frost. 1981. Feeding and trophic relationships of phocid seals and walruses in the Eastern Bering Sea. In: Hood DW, Calder JA, eds, The Eastern Bering Sea shelf: oceanography and resources, Vol 2. Department of Commerce, Washington, DC, pp 813-824.

Luxon M. 2000. Personal communication (observation of osprey nest near Terminal 105 in June 2000). Environmental scientist, Windward Environmental LLC, Seattle, WA.

Luxon M. 2004. Personal communication (direct observation of Caspian terns foraging at the north end of Kellogg Island during a fish sampling event in July 2004). Environmental scientist, Windward Environmental LLC, Seattle, WA.

Malins D.C., McCain B.B., Brown D.W., Sparks A.K., and Hodgins H.O. 1980. Chemical contaminants and biological abnormalities in central and southern Puget Sound. NOAA Technical Memorandum OMPA-2. Environmental Conservation Division, National Marine Fisheries Service, Seattle, WA.

Malins D.C., McCain B.B., Brown D.W., Sparks A.K., Hodgins H.O., and Chan S. 1982. Chemical contaminants and abnormalities in fish and invertebrates from Puget Sound. Environmental Conservation Division, National Marine Fisheries Service, Seattle, WA.

Marine Mammal Center. 2000. California sea lion. Online circular at http://www.tmmc.org/csealion.htm. Updated June 2000; accessed May 9, 2001.

Matsuda R.I., Isaac G.W., and Dalseg R.D. 1968. Fishes of the Green-Duwamish River. Water Quality Series No. 4. Municipality of Metropolitan Seattle, Seattle, WA.

Mayfield D., Robinson S., and Simmonds J. 2007. Survey of fish consumption patterns of King County (Washington) recreational anglers. Journal of Exposure Analysis and Environmental Epidemiology (1-9).

McLaren P. and P. Ren. 1994. Sediment transport in Elliott Bay and the Duwamish River, Seattle: Implications to estuarine management. Prepared for Washington Department of Ecology. GeoSea Consulting (Canada) Ltd., Salt Spring Island, BC. May.

Melquist W.E. and A.E. Dronkert. 1987. River otter. In: Novak M, Bailer JA, Obbarel ME, eds, Wild furbearer management and conservation in North America. Ontario Trappers' Association and Ontario Ministry of Natural Resources, Ottawa, ON, pp 627-641.

Melquist W.E. and M.G. Hornocker. 1983. Ecology of river otters in west central Idaho. In: Kirkpatrick RL, ed, Wildlife monographs, Vol 83. The Wildlife Society, Bethesda, MD, p 60.

METRO. 1992. Lander Street Regulator Station – Operation and Maintenance Manual, Publication 409. Municipality of Metropolitan Seattle. Seattle, WA.

Meyer J.H., Pearce T.A., and Patlan S.B. 1981. Distribution and food habits of juvenile salmonids in the Duwamish Estuary. Prepared for Seattle District, U.S. Army Corps of Engineers. U.S. Fish and Wildlife Service, Olympia, WA.

Miller B.S., Wingert R.C., and Borton S.F. 1975. Ecological survey of demersal fishes in the Duwamish River and at West Point 1974. Prepared for Municipality of Metropolitan Seattle. Report no. FRI-UW-7509. Fisheries Research Institute, University of Washington, Seattle, WA.

Miller B.S., Wingert R.C., Borton S.F., and Griggs D.T. 1977a. Ecological survey of demersal fishes in the Duwamish River and at West Point, 1975. Prepared for Municipality of Metropolitan Seattle. Fisheries Research Institute, University of Washington, Seattle, WA.

Miller B.S., Simenstad C.A., Moulton L.L., Fresh K.L., Funk F.C., Karp W.A., and Borton S.F. 1977b. Puget Sound baseline program nearshore fish survey. Final report, July 1974-June 1977. Prepared for Washington Department of Ecology. Fisheries Research Institute, University of Washington, Seattle, WA.

MOA. 2006. Memorandum of agreement between the Port of Seattle, the City of Seattle, and King County regarding the East Waterway Operable Unit of the Harbor Island Superfund site supplemental remedial investigation/feasibility study. Effective date March 27, 2006.

Morrison Knudsen Corporation. 2002. Terminal 18 Redevelopment Tank Closure Reports. Prepared for the Port of Seattle.

Morrow J.E. 1980. The freshwater fishes of Alaska. Animal Resources Ecology Library, University of British Columbia, Vancouver, BC.

Mowbray E.E., Pursley D., and Chapman J.A. 1979. The status, population characteristics, and harvest of river otters in Maryland. Maryland Wildlife Administration. Waverly Press, Bethesda, MD.

Nairn, B. 2007. Memorandum to Jeff Stern titled "CSO data provided to LDWG," distributed at October 24, 2007 meeting). Comprehensive Planning & Technical Resources Group, King County Department of Natural Resources and Parks.

Nelson T.S., Ruggerone G., Kim H., Schaefer R., and Boles M. 2004. Juvenile chinook migration, growth and habitat use in the Lower Green River, Duwamish River and nearshore of Elliott Bay, 2001–2003. Draft. King County Department of Natural Resources and Parks Seattle, WA.

NOAA. 2000. Historic nautical map of Elliott Bay and Duwamish Waterway. Chart # 18450. Downloaded from http://historicals.ncd.noaa.gov/historicals/histmap.asp. National Oceanic and Atmospheric Administration. June 14, 2007.

NOAA and Ecology. 2000. Sediment quality in Puget Sound. Year 2 - central Puget Sound. Ecology publication no. 00-03-055. National Oceanic and Atmospheric Administration, Silver Spring, MD; and Washington Department of Ecology, Olympia, WA.

Norman D. 2002. Personal communication (email on 4/5/02 to Berit Bergquist, Windward Environmental LLC, regarding great blue herons in the LDW). Norman Wildlife Consulting, Shoreline, WA. April 5.

Norton, D. and T. Michelsen. 1995. Elliott Bay Waterfront Contamination Study – Volume 1: Field Investigation Report. Prepared for the Elliott Bay/Duwamish Restoration Program Panel. Washington State Department of Ecology Report # 95-335. July.

Norton, D. 1996. Results of Sediment Trap Monitoring During Pier Maintenance along the Seattle Waterfront at Piers 62/63. Washington State Department of Ecology Report # 96-334. September.

Nysewander D., Evenson J.R., Murphie B.L., and Cyra T.A. 2001. Status and trends for a suite of key diving marine bird species characteristic of greater Puget Sound, as examined by the marine bird component, Puget Sound Ambient Monitoring Program (PSAMP). In: Puget Sound Research 2001: Abstracts & Biographies. Proceedings, meeting of the Puget Sound Water Quality Action Team, Bellevue, WA, February 12-14, 2001. Puget Sound Water Quality Action Team, Office of the Governor, Olympia, WA.

Oates, D. 2007. Personal communication (conversation with Anchor Environmental, L.L.C. staff regarding utility locate of underwater cables as part of T-18 bulkhead construction in 2003). KPFF Consulting Engineers, Olympia, WA.

Officer, C.B. and D.R. Lynch. 1989. "Bioturbation, Sedimentation and Sediment-Water Exchanges." Estuarine, Coastal and Shelf Science 28:1-12.

Page L.M., and Burr B.M. 1991. A field guide to freshwater fishes of North America north of Mexico. Peterson Field Guides, Houghton Mifflin Company, Boston, MA.

Pallson W. 2001. Personal communication (conversation with Windward Environmental, L.L.C. staff regarding English sole population dynamics in Elliott Bay). Washington Department of Fish and Wildlife, Olympia, WA.

Patmont, C.R. and E.A. Crecelius. 1991. Natural sediment recovery in contaminated embayments of Puget Sound. Vol. 1 Puget Sound Research Proceedings. Puget Sound Water Quality Authority, Seattle, WA.

Patmont, C., J.W. Davis, T. Dekker, M. Erickson, V. Magar, and M. Swindoll. 2004. Natural Recovery: Monitoring Declines in Sediment Chemical Concentrations and Biological Endpoints. Working Draft. June.

Payne P.M. and L.A. Selzer. 1989. The distribution, abundance and selected prey of the harbor seal, Phoca vitulina concolor, in southern New England. Mar Mammal Sci 5:173-192.

Phoinix. 2006a. Terminal 30 Stormwater Inspection Report. Prepared for the Port of Seattle. Phoinix Corporation, Lynnwood, WA. October 19, 2006

Phoinix. 2006b. Terminal 102 Stormwater Inspection Report. Prepared for the Port of Seattle. Phoinix Corporation, Lynnwood, WA. November 19, 2006

Phoinix. 2007. Outfall Verification Report. *Includes Terminals 18, 25, 30, 46, Pier 48, Alaska Square Park, and Harbor Island. Prepared for Port of Seattle. Submitted July 5.

PIE. 1999. Biological evaluation, East Waterway Channel Deepening, Stage 1, Seattle Harbor, Washington. Prepared for U.S. Army Corps of Engineers Seattle District. Pacific International Engineering, PLLC, Edmonds, WA.

Pitcher K.W. 1980. Food of the harbor seal, Phoca vitulina richardsi, in the Gulf of Alaska. USNMFS Bull 78:544-549.

Pitcher K.W. and O.G. Calkins. 1979. Biology of the harbor seal, Phoca vitulina richardsi, in the Gulf of Alaska. Final. Outer Continental Shelf Environmental Assessment Program Research Unit 229. Bureau of Land Management, U.S. Department of the Interior, Washington, DC.

PNSN. 2007. Executive Summary of Pacific Northwest Earthquake Risks. Prepared by Pacific Northwest Seismic Network. http://www.pnsn.org/CascadiaEQs.pdf

Port of Seattle. 2007. Number of Vessel Calls at Port of Seattle Facilities. http://www.portseattle.org/seaport/statistics/vesselcalls.shtml#type. June 15, 2007.

Powell, B. 2007. Personal communication (e-mail to Jenny Buening, Windward Environmental, regarding NPDES permits in Duwamish Waterway. Water Quality Program, Washington Department of Ecology, Lacey, WA. June 7, 2007.

Professional Services Industries. 2005. Underground Storage Tank Closure Report for the United States Coast Guard Shore Operations ICS Seattle, Seattle, Washington. Prepared for Howard S. Wright Construction Company. Professional Services Industries, Inc., Mountlake Terrace, WA. November 4, 2005.

Professional Services Industries. 2006. Underground Storage Tank Closure Report for the United States Coast Guard Shore Operations ICS Seattle, Seattle, Washington. Prepared for Howard S. Wright Construction Company. Professional Services Industries, Inc., Mountlake Terrace, WA. May 17, 2006.

PSCAA. 2003. Final report: Puget Sound air toxics evaluation. Puget Sound Clean Air Agency, Seattle, WA.

PSCAA. 2006a. 2005 air quality data summary. Puget Sound Clean Air Agency, Seattle, WA.

PSCAA. 2006b. Air Toxics. Next Ten Years fact sheet. Pub. No. 20-9 KH 2/22/06. Puget Sound Clean Air Agency, Seattle, WA.

PSCAA. 2006c. Environmental Protection Agency 1999 National Air Toxics assessment overview. Pub. No. 20-9 KH 2/22/06. Puget Sound Clean Air Agency, Seattle, WA.

PSCAA. 2006d. Next Ten Years fact sheet: fine particulate matter [online]. Puget Sound Clean Air Agency, Seattle, WA. [Cited 1/15/07]. Available from: http://www.pscleanair.org/news/library/factsheets/next10/FineParticulateMatter.pdf.

PSEP. 1995. Recommended guidelines for conducting laboratory bioassays on Puget Sound sediments. Final Report. Prepared for the Puget Sound Estuary Program, U.S. Environmental Protection Agency, Region 10, Office of Puget Sound; and U.S. Army Corps of Engineers, Seattle District, Seattle, WA. PTI Environmental Services, Inc., Seattle, WA.

PSMAF. 2007. Puget Sound Maritime Air Forum website [online]. Puget Sound Maritime Air Forum, Seattle, WA. [Cited 6/4/07]. Available from: http://www.maritimeairforum.org/index.shtml.

QEA. 2007. Lower Duwamish Waterway Sediment Transport Modeling Report – Draft. Prepared for U.S. Environmental Protection Agency, Region 10 and Washington State Department of Ecology – Northwest Regional Office. July.

RETEC. 1997a. Underground storage tank decommissioning, Harbor Marina Corporate Center. Prepared for Wahl and Associates. Remediation Technologies (RETEC), Inc., Seattle, WA.

RETEC. 1997b. Soil and Groundwater Remedial Action Implementation Report with Appendices A and B, GATX Pier 34, Seattle, Washington. Prepared for GATX Terminals Corporation. Remediation Technologies, Inc., Seattle, WA. February 1997.

RETEC. 2002. T18 Hot Spot Removal Remedial Action Implementation Report, Harbor Island Soil and Groundwater OU Superfund Site, Seattle, Washington. Prepared for the Harbor Island Soil and Groundwater OU Steering Committee and the Port of Seattle. The RETEC Group, Inc., Seattle, WA. September 6.

RETEC. 2004. Pier 34 Annual Groundwater Compliance Monitoring Summary for 2003 and 5-Year Review. Prepared for Port of Seattle. The RETEC Group, Inc., Seattle, WA.

RETEC. 2005. Memorandum dated July 22, 2005 to N. Thompson, EPA, from K. Hendrickson and L. Baker regarding proposed compliance monitoring well screen locations. Prepared for Harbor Island Soil and Groundwater Operable Unit Settling Defendants. The RETEC Group, Inc., Seattle, WA.

RETEC. 2006a. Supplemental Data Report, Revision 1, Terminal 30, Seattle, Washington. Prepared for Port of Seattle. The RETEC Group, Inc., Seattle, WA. January 30.

RETEC. 2006b. 2005-2006 groundwater monitoring report, Harbor Island Superfund Site - Soil and Groundwater Operable Unit, Seattle, Washington. Prepared for Harbor Island Steering Committee. The RETEC Group, Inc., Seattle, WA. September 26.

RETEC. 2006c. Design set #2 capping implementation report. Terminal 18 expansion, Harbor Island Superfund Site, Seattle, Washington. Prepared for Port of Seattle and Harbor Island Steering Committee. The RETEC Group, Inc., Seattle, WA.

RETEC. 2007. February 2007 Groundwater Sampling Event, Terminal 30, Port of Seattle. Prepared for Port of Seattle. The RETEC Group, Inc., Seattle, WA.

Rheaume, A. 2007. Personal communication (email to Joanna Florer, Windward Environmental LLC, regarding East Waterway testing, with attached Excel file "EWW Inspections with prioritization.xls"). Senior Water Quality Scientist, Seattle Public Utilities, Seattle, WA. June 8, 2007.

Robertson B. 2004. Personal communication (telephone conversation with Matt Luxon, Windward Environmental, L.L.C., regarding rockfish observations in the LDW during SCUBA perch collection effort). Diver, The Seattle Aquarium, Seattle, WA. April 16, 2004.

Roffe T.J. and B.R. Mate. 1984. Abundances and feeding habits of pinnipeds in the Rogue River, Oregon. J Wildl Manage 48:1262-1274.

Ruggerone G.T., Nelson T.S., Hall J., and Jeanes E. 2006. Habitat utilization, migration timing, growth, and diet of juvenile chinook salmon in the Duwamish River and Estuary. King Conservation District and Salmon Recovery Funding Board, Seattle, WA.

SAIC. 1999a. Sediment characterization of Slip 36, East Waterway, Coast Guard Station, Seattle, Washington. Prepared for U.S. Army Corps of Engineers, Seattle District. Science Applications International Corporation, Bothell, WA.

SAIC. 1999b. East Waterway channel deepening sediment characterization, Duwamish Waterway, Seattle, Washington. Prepared for U.S. Army Corps of Engineers, Seattle District. Science Applications International Corporation, Bothell, WA.

Salo EO. 1991. Life history of chum salmon (Oncorhynchus keta). In: Groot C, Margolis L, eds, Pacific salmon life histories. UBC Press, Vancouver, BC, pp 231-310.

Schaffer K.E. 1989. Seasonal and size variations in diets of harbor seals. 8th Biennial Conference on the Biology of Marine Mammals, December 7-11, 1989, Pacific Groves, CA, p 62.

SEA. 2000. East Waterway channel deepening project, Stage 1. Data report: water quality monitoring during dredging at Terminal 18, East Waterway, Seattle, Washington. Prepared for U.S. Army Corps of Engineers, Seattle District. Striplin Environmental Associates, Inc., Olympia, WA.

Seymour, B. 2007. Personal communication regarding water depths along the Harbor Island Marina in the East Waterway. June 15.

Shannon and Wilson Inc. 1992. Hazardous materials survey for Pier 35 replacement, U.S. Coast Guard Support Center, Seattle, Washington. Shannon and Wilson, Inc., Seattle, WA.

Shannon & Wilson. 2002. Port of Seattle Terminal 46 Redevelopment Geotechnical Engineering Report, Apron Strengthening and Electrical Upgrade. Prepared for Moffatt & Nichol Engineers. May

Shannon & Wilson 2005a. Environmental Investigation - Stage 1 East Marginal Way Grade Separation Project Port of Seattle Terminals 104 and 106. Prepared for David Evans & Associates and the Port of Seattle.

Shannon & Wilson 2005b. Environmental Investigation - Stage 1 East Marginal Way Grade Separation Project - Poncho's Legacy Property. Prepared for David Evans & Associates and the Port of Seattle.

Shannon & Wilson 2005c. Environmental Investigation - Stage 1 East Marginal Way Grade Separation Project – Moss G. Milan Property. Prepared for David Evans & Associates and the Port of Seattle.

Shannon J. 2006. Personal communication (e-mails to Matt Luxon, Windward Environmental, L.L.C., regarding Duwamish-Elliott beach seine data collected by Taylor Associates in 1998, 2000, and 2002-2003. Biologist, Taylor Associates, Seattle, WA. March 30.

Shepsis, V., S. Fenical, B. Hawkins-Bowman, E. Dohm, and F. Yang. 2001. Deep-Draft Vessels in Narrow Waterway, Port of Oakland 50-foot Deepening Project. Conference Proceedings PORT 2001. PIANC. Norfolk, VA.

Smith R.T. 1936. Report on the Puget Sound otter trawl investigations. Wash Dep. Fish. Rep 36. Washington Department of Fisheries, Olympia, WA.

Smolski E.M., Lefkowitz L.F., Thom R.M., and Word J.Q. 1991. Port of Seattle Pier 27 report on field sampling, sediment chemistry, and biological analyses. Prepared for Port of Seattle. Battelle Marine Sciences Laboratory, Sequim, WA.

SPU. 2007a. Lower Duwamish Waterway, lateral load analysis for stormwater and city-owned CSO. Seattle Public Utilities, Seattle, WA.

SPU. 2007b. East Waterway source control strategy/plan. May 10, 2007 draft. Seattle Public Utilities, Seattle, WA.

SSA. 2006a. Stormwater Pollution Prevention Plan for SSA Marine Terminal 18. URS, Seattle, WA.

SSA. 2006b. Stormwater Pollution Prevention Plan for SSA Marine Terminal 25. URS, Seattle, WA.

Stewart B.S., Leatherwood S.L., and Yochem P.K. 1989. Harbor seal tracking and telemetry by satellite. Mar Mam Sci 5:361-375.

Sweet-Edwards. 1990. Subsurface Investigation Report, Port of Seattle Terminal 25. Prepared for Port of Seattle. Sweet-Edwards/EMCON, Inc., Bothell, WA.

Tabor J.E. and H.M. Wight. 1977. Population status of river otter in western Oregon. J Wildl Manage 41:692-699.

Tanner C.D. 1991. Potential intertidal habitat restoration sites in the Duwamish River Estuary. EPA 910/9-91-050. U.S. Environmental Protection Agency, Region 10, Seattle, WA.

Taylor Associates. 2004. Memorandum dated June 3, 2004 to S. McGroddy, Windward Environmental, L.L.C., from J. Shannon regarding Duwamish/Diagonal sediment remediation project fish monitoring. Taylor Associates, Seattle, WA.

Taylor Associates. 2005. Memorandum dated May 13, 2005 to M. McLaughlin, Port of Seattle, from J. Shannon regarding East Waterway dredge and cleanup fish monitoring project summary report 2005. Taylor Associates, Seattle, WA.

Taylor Associates. 2006a. Sampling & analysis plan, combined sewer overflow supplemental characterization study. Combined Sewer Overflow Control Program, quality management system planning document. Draft. Prepared for Seattle Public Utilities. Taylor Associates, Inc., Seattle, WA.

Taylor Associates. 2006b. Sampling and Analysis Plan – Combined Sewer Overflow Supplemental Characterization Study [draft]. Taylor Associates, Seattle, WA.

Taylor W.J., Shreffler D.K., and Cordell J.R. 1999. Duwamish East Waterway channel deepening project: alternative dredge disposal sites juvenile salmonid and epibenthic prey assessment. Technical report. Preliminary draft. Prepared for Port of Seattle. Taylor Associates, Seattle, WA.

Templeton, D.W., Y. Chun, and P.A. Spadaro. 1993. "Natural Recovery as a Remedial Option in the Sitcum Waterway, Puget Sound, Washington." Paper presented at First International Specialized Conference on Contaminated Aquatic Sediments: Historical Records, Environmental Impact, and Remediation. June 14-16, 1993. Milwaukee, WI.

Tetra Tech. 1996. Preliminary sediment survey for Pier 36 modification, U.S. Coast Guard Support Center, Seattle, Washington. Tetra Tech, Inc., Bellevue, WA.

Tetra Tech. 1997. Surface sediment investigation, Piers 36 and 37, U.S. Coast Guard Integrated Support Center, Seattle, Washington. Tetra Tech, Inc., Bellevue, WA.

Tetra Tech. 1988. Elliott Bay action program: evaluation of potential contaminant sources. Prepared for Puget Sound Estuary Program, U.S. Environmental Protection Agency, Region 10. Tetra Tech, Inc., Bellevue, WA.

Tiffany, B. 2007. Personal communication (e-mail dated June 5, 2007 to Jenny Buening, Windward Environmental, regarding results of Phase 2 LDW passive air deposition sampling). King County Industrial Waste Program, Seattle, WA.

Tiffany, B. 2008. Personal communication (e-mail dated January 15, 2008 to Jenny Buening, Windward Environmental, providing list of King County Industrial Waste permittees in the East Waterway CSO drainage basins). King County Industrial Waste Program, Seattle, WA.

URS. 2000. Underground Storage Tank Decommissioning. Prepared for Flint Ink Corporation. URS Greiner Woodward Clyde, Seattle, WA. March.

USACE. 1915. Seattle Harbor Washington – Examination of East and West Waterways. Map E/2/2/11.

USACE. 1918. East and West Waterways and the Duwamish Waterways. Map E/2/2/16.

USACE. 1927. Condition of East and West Waterways October 29, 1927. Map E/12/2/26.

USACE. 1929. Condition of East Waterway February 1929. Map E/12/2/30.

USACE. 1966. East Waterway Conditions Survey May and August 1966. Map E/12/6.1/20.

USACE. 1976. East Waterway Condition April 20, 1976. Map E/12/6.1/30.

USACE. 1981. East Waterway Condition Survey April 1981. Map E/12/6.1/34.

USACE. 1985. Permit 071-0YB-2-009711 for dredging, berm, fill, riprap, apron, two cranes and outfall pipe at Terminal 30.

USACE. 1988. Disposal Site Selection Technical Appendix – Phase 1(Central Puget Sound). Volume 3. Prepared by the Department of the Army, Corps of Engineers, Northwest Division, Seattle District, Seattle, Washington. June.

USACE. 1998. East Waterway Channel Deepening, Seattle Harbor, Washington, Stage I Project Report. Prepared by the Department of the Army, Corps of Engineers, Northwest Division, Seattle District, Seattle, Washington. December.

USACE. 2005. Howard Hanson Dam Reservoir Operations and Sediment Management Plan for Water Year 2006, Appendix C: Water Quality Sampling and Analysis Plan. Prepared by U.S. Army Corps of Engineers, Seattle District, Water Management Section, Seattle, Washington. December.

USACE. 2007. Howard Hanson Dam. http://www.nws.usace.army.mil/PublicMenu/Menu.cfm?sitename=HHD&pagename=mainpage. Accessed: November 30, 2007.

USACE, EPA, WDNR, Ecology. 2000. Dredged material evaluation and disposal procedures. A user's manual for the Puget Sound Dredged Disposal Analysis (PSDDA) Program. U.S. Army Corps of Engineers, Seattle District, Seattle, WA; U.S. Environmental Protection Agency, Region 10, Seattle, WA; Washington Department of Natural Resources; and Washington Department of Ecology.

USFWS. 2000. GIS coverage of Duwamish intertidal habitats. Contact: Carol Langston, GIS Analyst; Curtis Tanner, Fish and Wildlife Biologist. U.S. Fish and Wildlife Service, Lacey, WA.

USGS. 2007. Flow and gage-height data in the Green River, Washington, Station IDs: 12113000 and 12113350. http://nwis.waterdata.usgs.gov/. United States Geological Survey.

Walker B. 1999. Monitoring of 1998-99 California sea lion predation in the Lake Washington estuary and the lower Duwamish River. Washington Department of Fish and Wildlife, Lacey, WA.

Wang, T. 2008. Personal communication regarding TAU LLC facility operation at Terminal 25. February.

Warner E.J. and Fritz R.L. 1995. The distribution and growth of Green River chinook salmon (*Oncorhynchus tshawytscha*) and chum salmon (*Oncorhynchus keta*) outmigrants in the Duwamish estuary as a function of water quality and substrate. Water Resources Division, Muckleshoot Indian Tribe, Auburn, WA.

WDFW. 1999. Monitoring of 1998-99 California sea lion predation in the Lake Washington Estuary and the Lower Duwamish River. Washington Department of Fish and Wildlife, Olympia, Washington.

WDFW. 2001. Species of concern in Washington State: Bald eagle. Current through October 2001. Available from: http://www.wa.gov/wdfw/wlm/diversty/soc/soc.htm. Accessed 4/8/2002.

WDFW. 2002. Final peregrine falcon status report [online]. Endangered Species Program, Washington Department of Fish and Wildlife, Olympia, WA. Available from: http://wdfw.wa.gov/wlm/diversty/soc/status/peregrine/.

Weitkamp D.E. and Campbell R.F. 1980. Port of Seattle Terminal 107 fisheries study. Parametrix, Inc., Bellevue, WA.

West J.E. 2001. Personal communication (data transmittal to Tad Deshler, Windward Environmental, L.L.C., Seattle, WA). Marine Resources Division, Washington Department of Fish and Wildlife, Olympia, WA. March 14.

West J.E, O'Neill S.M., Lippert G., and Quinnell S. 2001. Toxic contaminants in marine and anadromous fishes from Puget Sound, Washington. Results of the Puget Sound ambient monitoring program fish component 1989-1999. Washington Department of Fish and Wildlife, Olympia, WA.

Weston. 1993. Harbor Island remedial investigation report. Prepared for U.S. Environmental Protection Agency, Region 10. Roy F. Weston, Inc., Seattle, WA.

Williams M.S. 1990. Port of Seattle Terminal 107 (Kellogg Island), biological assessment – 1989. Parametrix, Inc, Bellevue, WA.

Windward. 2001. Terminal 18 deepening project. Post-dredge monitoring of Port of Seattle East Waterway deepening, stage 1 dredging area. Data report. Prepared for Port of Seattle. Windward Environmental LLC, Seattle, WA.

Windward. 2002a. East Waterway, Harbor Island Superfund site: Technical memorandum: Tissue chemistry results for juvenile chinook salmon collected from Kellogg Island and

East Waterway. Prepared for the Port of Seattle. Windward Environmental LLC, Seattle, WA.

Windward. 2002b. East Waterway, Harbor Island Superfund site: Nature and extent of contamination. Subsurface sediment data report - phase 3. Prepared for the Port of Seattle. Windward Environmental LLC, Seattle, WA.

Windward. 2002c. East Waterway, Harbor Island Superfund site: Nature and extent of contamination. Surface sediment data report - phases 1 and 2. Prepared for the Port of Seattle. Windward Environmental LLC, Seattle, WA.

Windward. 2003a. Engineering Evaluation/Cost Analysis for the East Waterway Operable Unit, Harbor Island Superfund Site. Final. Submitted to US EPA Region 10. July 29, 2003.

Windward. 2003b. East Waterway, Harbor Island Superfund site: Recency data report. Prepared for the Port of Seattle. Windward Environmental LLC, Seattle, WA.

Windward. 2003c. East Waterway, Harbor Island Superfund site: Nature and extent of sediment contamination. Data summary report. Prepared for the Port of Seattle. Windward Environmental LLC, Seattle, WA.

Windward. 2004. Lower Duwamish Waterway remedial investigation. Juvenile chinook salmon data report. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2005a. Lower Duwamish Waterway remedial investigation. Data report: Taxonomic identifications of benthic invertebrate communities. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2005b. Lower Duwamish Waterway remedial investigation. Fish and crab data report addendum: PCB congener data, MS/MSD analyses, and DDT confirmation.

Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2006a. East Waterway, Harbor Island Superfund site. Technical memorandum: tissue chemistry results for East Waterway fish tissue samples. Windward Environmental LLC, Seattle, WA.

Windward. 2006b. Lower Duwamish Waterway remedial investigation. Data report: chemical analyses of fish and crab tissue samples collected in 2005. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2006c. Lower Duwamish Waterway remedial investigation. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2006d. East Waterway Phase 1 Removal Action: recontamination monitoring 2006 data report. Windward Environmental LLC, Seattle, WA.

Windward. 2007a. East Waterway Phase 1 removal action: recontamination monitoring 2007 data report. Windward Environmental LLC, Seattle, WA.

Windward. 2007b. Slip 27 sediment sampling results. Windward Environmental LLC, Seattle, WA.

Windward. 2007c. East Waterway Phase 1 removal action: recontamination monitoring 2006 data report. Windward Environmental LLC, Seattle, WA.

Windward. 2007d. East Waterway Phase 1 Removal Action: recontamination monitoring 2007 data report. Windward Environmental LLC, Seattle, WA.

Windward and QEA. 2007. Sediment Transport Modeling Report Appendix G – Sediment Transport Analysis Report – Draft Final. Prepared for U.S. Environmental Protection Agency, Region 10 and Washington State Department of Ecology – Northwest Regional Office. July.

Wingert R.C., Terry C.B., and Miller B.S. 1979. Food and feeding habits of ecologically important nearshore and demersal fishes in central Puget Sound. FRI-UW-7903. Prepared for Washington Department of Ecology. Fisheries Research Institute, University of Washington, Seattle, WA.

WRCC. 2007a. Period of Record General Climate Summary – Precipitation, Seattle Tacoma Station 457473. Period of Record 1931 through July 26, 2007. Western Regional Climate Center. http://www.wrcc.dri.edu/cgi-bin/cliGCStP.pl?wa7473

WRCC. 2007b. Period of Record General Climate Summary – Temperature, Seattle Tacoma Station 457473. Period of Record 1931 through July 26, 2007. Western Regional Climate Center. http://www.wrcc.dri.edu/cgi-bin/cliGCStT.pl?wa7473

Yates S. 1998. Marine wildlife from Puget Sound through the Inside Passage. Sasquatch Books, Seattle, WA.