Lower Duwamish Waterway Group

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

Lower Duwamish Waterway Remedial Investigation

TASK 5: IDENTIFICATION OF CANDIDATE SITES FOR EARLY ACTION

TECHNICAL MEMORANDUM: DATA ANALYSIS AND CANDIDATE SITE IDENTIFICATION

FINAL

For submittal to

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

The Washington State Department of Ecology
Northwest Regional Office
Bellevue, WA

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Maps

Acronyms

AOC	Administrative Order on Consent
BEHP	bis(2-ethylhexyl)phthalate
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (Superfund)
COC	chemical of concern
COPC	chemical of potential concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CSL	cleanup screening level
CSO	combined sewer overflow
DMMP	Dredged Material Management Program
EBDRP	Elliott Bay / Duwamish Restoration Program
Ecology	Washington State Department of Ecology
EF	exceedance factor
EPA	US Environmental Protection Agency
ERA	ecological risk assessment
FS	Feasibility Study
GIS	geographic information system
HHRA	human health risk assessment
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
MGY	million gallons per year
ML	maximum level
MTCA	Model Toxics Control Act
NCP	National Contingency Plan
NPDES	National Pollutant Discharge Elimination System
NTCRA	non-time-critical removal action
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RI	remedial investigation
RM	river mile
ROC	receptor of concern
SD	storm drain
SMS	Washington Sediment Management Standards
SQS	Sediment Quality Standards

Executive Summary

A remedial investigation (RI) is currently being conducted for the Lower Duwamish Waterway (LDW) in Seattle, Washington, under the US Environmental Protection Agency's (EPA's) Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (commonly referred to as Superfund) program and the Washington State Department of Ecology's (Ecology) Model Toxics Control Act (MTCA), by the Lower Duwamish Waterway Group (LDWG). Members of LDWG include the Port of Seattle, the City of Seattle, King County, and The Boeing Company. A primary goal of the LDW RI is to determine if chemicals in sediments within the LDW pose risks to human health and the environment, and if they do, identify areas that should be remediated to reduce risks. An RI normally requires a large chemistry data set to characterize the nature and extent of chemical contamination. Because a large data set exists for LDW sediments, it is possible to make preliminary human health and ecological risk estimates prior to collecting additional data. The remediation process can take many years under Superfund; thus Phase 1 of the LDW RI was designed to provide these preliminary risk estimates in the expectation that those portions of the LDW that pose relatively higher risks to human health or the environment could be remediated on an accelerated schedule. The risk estimates made in the Phase 1 RI suggest that early actions[1] are warranted in some portions of the LDW. Chemical distributions within the sediments were found to be highly variable, with discrete areas having much higher chemical concentrations than other areas. Risks associated with such discrete areas are considered to be sufficiently high that there is no need to wait for the results of the Phase 2 RI to undertake remedial actions in those areas. Additional areas not recommended for early actions during the Phase 1 RI will be further investigated during the Phase 2 RI. Data collected from these other areas will be evaluated to determine whether long-term remedial actions are warranted. If Phase 2 sampling identifies additional high-risk areas that warrant immediate attention, EPA and Ecology can consider the need for additional early actions.

The identification of candidate sites for early action included both risk-based and management-based criteria. Risk-based criteria were derived from the results of the ecological and human health risk assessments (ERA and HHRA) that were completed as part of the Phase 1 RI. Multiple lines of evidence drawn from those risk assessments were used to identify high priority areas, including locations where concentrations of one or more chemicals met one of the following risk-based criteria:

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[1] Throughout this document, the term "early action" refers to short-term cleanups called "removal actions" under the CERCLA program, "interim actions" under the MTCA program, or "partial cleanup actions" under the Washington State Sediment Management Standards.

- exceeded the Washington Sediment Management Standards (SMS) Cleanup Screening Level (CSL)[2]
- exceeded the human health risk-based concentration equivalent to an estimated cancer risk of 1 in 10,000 or an estimated hazard quotient of 10 for direct sediment exposure pathways (i.e., commercial netfishing and beach play)
- were within the top 5%, by area, of LDW-wide concentrations for chemicals with estimated cancer risks greater than 1 in 10,000 or estimated hazard quotients greater than 10 for indirect sediment exposure pathways (i.e., human consumption of fish and shellfish, and exposure of fish and wildlife to contaminated sediments)

Management criteria used to further evaluate the high priority areas included:

- consistency with methods used by EPA (under the National Contingency Plan [NCP]) and by Ecology (under MTCA) to identify contaminated sites requiring remediation
- ability to prevent unacceptable recontamination at the site
- consistency with remedial alternatives that are likely to be evaluated for the LDW.

Sites within the LDW were identified in a two-step process that applied the risk-based and management-based criteria. In the first step, risk-based criteria were applied to existing data using a geographic information system (GIS) to identify high priority areas. Those high priority areas were then further evaluated using management-based criteria to identify candidate sites for early action.

Based on this evaluation, the following seven high priority areas were identified:

- Area 1 – Area near Duwamish / Diagonal combined sewer overflow and storm drain (CSO / SD) on the east side of the LDW (river mile [RM] 0.4 – 0.6)
- Area 2 – Located at approximately RM 2.2, on the west side of the LDW, just south of the 1st Avenue South bridge
- Area 3 – Slip 4 (RM 2.8)
- Area 4 – Located south of Slip 4, on the east side of the LDW, just offshore of the Boeing Plant 2 and Jorgensen Forge properties (RM 2.9 to 3.7)
- Area 5 – Located at approximately RM 3.6, on the west side of the LDW
- Area 6 – Located at approximately RM 3.8, on the east side of the LDW
- Area 7 – Area near Norfolk CSO (RM 4.9 – 5.0), on the east side of the LDW

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[2] CSLs represent sediment concentrations of individual chemicals above which biological effects to benthic invertebrates are considered to be significant.

All seven high priority areas were subsequently recommended by LDWG as candidate sites for early action (Figure ES-1 and Table ES-1). EPA and Ecology will review these recommendations, along with other available information, and potentially enter into negotiations with one or more LDWG members and/or other parties to conduct early actions for contaminated sediment at those sites.

Table ES-1. Candidate sites proposed by LDWG for early action

HIGH PRIORITY AREA DESIGNATION	STEP 1. NCP/MTCA CONSISTENCY	STEP 2. RECONTAMINATION POTENTIAL	STEP 3. REMEDIAL ACTION CONSISTENCY
1	Yes	Acceptable [a]	Yes
2	Yes	Unknown	Yes
3	Yes	Unknown	Yes
4	Yes	Acceptable [b]	Yes
5	Yes	Unknown	Yes
6	Yes	Unknown	Yes
7	Yes	Unknown	Yes

[a] Acceptability determination made by Ecology (Ecology 2002a) based on documents prepared by early action proponent (King County 2002a,b).

[b] Acceptability determination made in document prepared by early action proponent (Weston 2003a). This determination is being reviewed by EPA and Ecology.

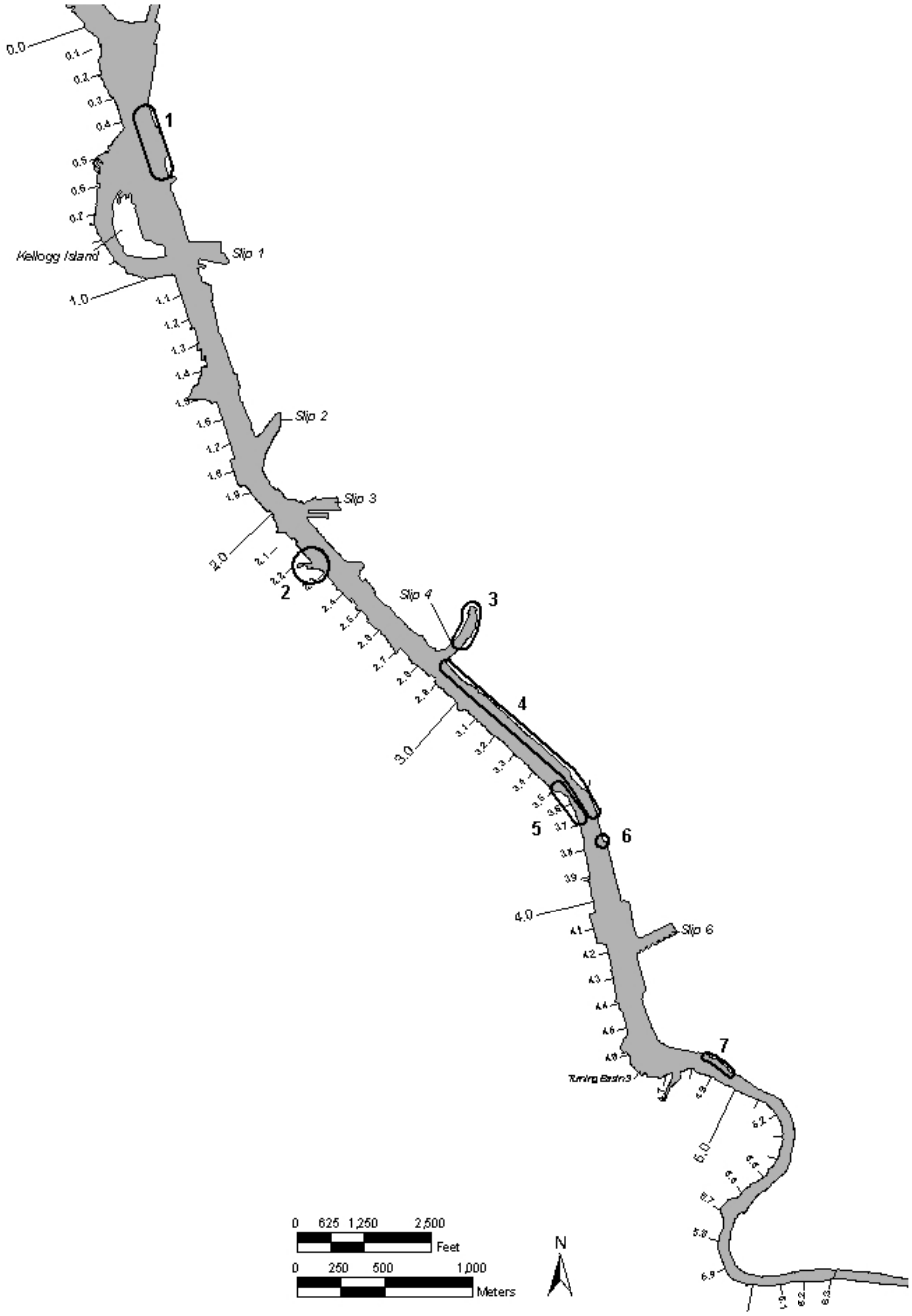

Figure ES-1. Candidate sites proposed by LDWG for early action

1.0 Introduction

One of the goals of the Phase 1 Lower Duwamish Waterway Remedial Investigation (LDW RI) is to identify sites that represent the highest risks to human health or the environment and that consequently warrant remediation on an expedited schedule. Given the availability of a large environmental data set for the LDW, particularly sediment data, there is general acknowledgement that sufficient information currently exists to identify some sites that may require remediation. The candidate site identification process outlined in this memorandum is consistent with the National Contingency Plan (NCP), Washington's Model Toxic Control Act (MTCA), and EPA guidance for non-time-critical removal actions. Early action at these sites could potentially be implemented on accelerated schedules before completion of the Feasibility Study (FS) and Record of Decision for the LDW Superfund site.

The decision process used to identify candidate early action sites is based on a methodology approved by EPA and Ecology in an earlier Phase 1 task (Windward 2002). The document describing the methodology is appended to this technical memorandum (Appendix A), but much of the text has been brought forward into the main text of this memorandum to provide the reader with a clearer understanding of the candidate site selection process.

Candidate site selection was a two-step process (Figure 1). In the first step, existing environmental data for the LDW and results of the Phase 1 risk assessments (Windward 2003) were used to identify high priority areas within the larger study area. The framework of using risk-based analyses to identify high priority areas is consistent with EPA's principles for managing risks from contaminated sediments (EPA 2002b). In the second step, each high priority area was evaluated using management-based criteria to determine the area's suitability as a candidate site for early action. The management criteria include: 1) consistency with methods used by EPA and Ecology to identify contaminated sites requiring remediation, 2) ability to prevent unacceptable recontamination at the site, and 3) consistency between potential early action cleanup methods with remedial alternatives that are likely to be evaluated for the LDW. EPA and Ecology will review LDWG's recommendations, but will make their own determinations on how well the candidate early action sites meet these management criteria.

EPA and Ecology will use the recommendations in this memorandum to determine which sites will undergo early cleanup actions. One or more LDWG member(s) may propose to enter into an agreement with EPA or Ecology to undertake one or more of the early cleanup actions. For cleanup actions LDWG members do not volunteer to undertake, EPA and Ecology will identify appropriate parties to undertake these actions.

The agencies will determine which candidate sites ultimately move forward based on their ability to find viable potentially responsible parties to undertake the action and to negotiate a satisfactory regulatory agreement or order consistent with CERCLA or MTCA. Other factors, such as the risk to human health and the environment posed by these sites, agency resource limitations, and prioritization of source control activities, will also factor into the agencies' decision as to whether and when to go forward with early action site investigations and cleanups.

Additional areas not recommended for early actions during the Phase 1 RI will be further investigated during the Phase 2 RI. Data collected from these other areas will be evaluated to determine whether long-term remedial actions are warranted. If Phase 2 sampling identifies additional high-risk areas that warrant immediate attention, EPA and Ecology can consider the need for additional early actions.

Any early action cleanup work conducted at sites recommended by LDWG in this memorandum will be conducted outside the RI/FS process currently underway for the LDW. The baseline risk assessments to be completed as part of the Phase 2 RI will assess overall risks as well as residual risks expected to remain after completion of the early actions. The Phase 2 RI will assess the need for additional sediment remediation to further reduce risks.

The results of the high priority area identification process are presented in Section 2 of this memorandum, while Section 3 presents the results of applying the management-based criteria to the high priority areas to determine which areas are suitable candidates for early action. The Lower Duwamish Waterway Group's (LDWG's) recommendations for candidate sites are also presented in Section 3 of this memorandum. References are included in Section 4. Appendix A contains the first Task 5 technical memorandum that describes the candidate site selection criteria. This memorandum was approved by EPA and Ecology on June 19, 2002. Appendix B contains additional technical details on the spatial analysis methods that were used in the geographic information system (GIS). Appendix C contains sediment chemistry data for two of the high priority areas. Data for the other high priority areas are shown on maps.

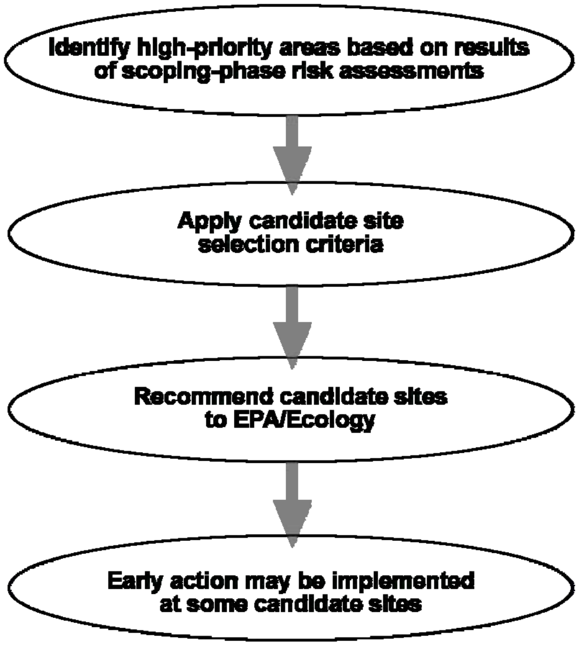

Figure 1. Candidate site selection process overview

2.0 High Priority Area Identification

High priority areas are areas within the LDW associated with relatively higher risks to the environment and human health than other areas within the LDW. Implementing early action at high priority areas is expected to substantially reduce total risks in the LDW by moving those areas into an accelerated remediation process. Three lines of evidence were combined for high priority area identification: 1) sediment chemistry evaluation using Cleanup Screening Levels (CSLs) specified in Washington’s Sediment Management Standards (SMS), 2) direct sediment exposure pathways evaluated in the Phase 1 risk assessments, and 3) indirect sediment exposure pathways evaluated in the Phase 1 risk assessments.

Direct sediment exposure pathways are those in which the primary route of chemical exposure to people, fish, or wildlife is through the sediment either by incidental ingestion or direct contact with the skin. An example of a direct exposure pathway is children playing in intertidal sediments. Indirect sediment exposure pathways are those in which the primary route of chemical exposure to people, fish, or wildlife is through the diet. For example, when people eat fish that were exposed to contaminated sediment, chemicals are transferred from sediment to people via the dietary exposure pathway.

2.1 SEDIMENT CHEMISTRY EVALUATION

The first step in the identification of high priority areas was to compare surface sediment chemistry data from the LDW to CSL values from the SMS. Surface sediment chemistry data were used because most risks to human and ecological receptors are associated with exposures to these sediments. Deeper sediments (i.e., those below the biologically active surface zone) are less likely to be associated with risks due to limited exposure. Approximately 1,100 surface[3] sediment samples have been collected from the LDW since 1990. Older data exist, but data quality objectives for the RI (Windward 2001) considered data collected before 1990 not to be representative of current conditions.

As discussed in the Phase 1 RI, CSLs represent sediment concentrations above which there is an increased likelihood, but not a certainty, for adverse effects to benthic invertebrates. For the purposes of identifying high priority sites, the assumption is made that the likelihood of adverse effects to benthic invertebrates is expected to increase as either the degree to which the CSL is exceeded for a single chemical (i.e., the CSL exceedance factor)[4] increases or the number of chemicals exceeding their respective CSLs increases. For chemicals without a CSL value, the maximum level (ML) from the Dredged Material Management Program (DMMP) was used to calculate an ML exceedance factor.[5]

Table 1 summarizes chemical-specific CSL (or ML) exceedances for chemicals measured in LDW surface sediments. Detected concentrations of 36 chemicals exceeded the CSL (or ML)[6] in at least one sample. The highest number of exceedances were found for two organic chemicals, total polychlorinated biphenyls (PCBs) and bis(2-ethylhexyl)phthalate (BEHP), which exceeded the CSL in 134 (out of 905 locations with detections) and 59 (out of 466 locations with detections) locations, respectively. Four metals (mercury, cadmium, lead, and zinc) also exceeded the CSL at 10 or more locations. All other chemicals had exceedances of the CSL or ML at fewer than 10 locations.

Table 1 also summarizes CSL (or ML) exceedances based on detection limits. High priority area identification was not based on exceedances by detection limits. When detection limits exceed a standard, the true concentration of that chemical relative to

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[3] For the purposes of this assessment, surface sediment samples are those collected from the top 15 cm of the sediment horizon. Sediment samples that include less than 15 cm of sediment are included; samples that include the top 15 cm, but also include deeper sediment in the same sample are not included here.

[4] The CSL exceedance factor for a given chemical represents the detected concentration divided by the CSL value. Although a relationship between a) the number of chemicals that exceed the SQS/CSL, or b) the degree of exceedance of the SQS/CSL and the incidence of unacceptable biological effects has not been shown, the agencies have agreed to this approach to screen for areas of higher risk.

[5] The ML exceedance factor for a given chemical represents the detected concentration divided by the ML value.

[6] Total organic carbon (TOC) normalization, as required for comparison to CSL values for nonpolar organic chemicals, was not done for samples with TOC less than 0.2%. The 0.2% threshold was suggested by DiToro et al (1991) in their paper describing the technical basis for sediment quality criteria for non-polar organic chemicals. Dry-weight concentrations of those chemicals in samples with such low TOC were instead compared to the second-lowest apparent effects threshold (AET) values (Barrick et al. 1988).

the standard is unknown. This uncertainty is better addressed in the Phase 2 RI than in the early action site identification process. Detection limits above standards for these compounds could be due to several factors, including standards that are close to commonly achievable detection limits (e.g., hexachlorobenzene and 1,2,4-trichlorobenzene), sample dilution, low percentage of solids or total organic carbon, matrix interference, and limited method sensitivity due to poor sample treatment and/or analytical instrument sensitivity.

The spatial distribution of CSL/ML exceedances is presented in Maps 1 to 4 using Thiessen polygons. This technique is a method of spatial representation of data that represents each location at which a chemical has been measured as a polygon. The size and shape of the polygon is determined by the proximity of other locations where the chemical has been measured. This method is based on the assumption that the chemical concentration at any point where measurements have not been made is the same as the concentration in the sample closest to that point. The polygon boundaries are halfway between sampling locations. Where multiple samples were collected at some locations, the average concentration was calculated and used for that location.[7] When viewing the maps, note that the size of a polygon is based on the relative density of samples and does not imply that sediment quality represented by that polygon is necessarily equivalent throughout the entire area of the polygon.[8] A detailed discussion of Thiessen polygons is presented in Appendix B.

To begin the process of identifying high priority areas, maps were made of the CSL or ML exceedances for the chemicals in Table 1 as an initial evaluation of patterns in the distribution of chemicals. Examples are presented for PCBs (Map 1) and BEHP (Map 2). All maps referred to in this document are included at the end of this document. For each chemical, the distribution of CSL exceedances is patchy.

In addition to mapping exceedances by single chemicals, maps were produced that provided graphical displays of the number of chemicals with CSL or ML exceedances by location (Map 3) and the maximum CSL (or ML) exceedance factor by location (Map 4). The multiple chemical maps integrated the results from the single chemical maps so that locations with CSL or ML exceedances for any chemical could be identified on a single map. Very few locations had more than three chemicals at concentrations greater than the CSL or ML values (Map 3). Only a single chemical

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[7] Averaging rules were different for each of three scenarios: 1) if all concentrations for a given chemical were above the detection limit, an arithmetic average was calculated; 2) if all concentrations were below the detection limit, the lowest reported detection limit for that chemical was assigned to the location; 3) if a mixture of detects and non-detects occurred for a given chemical, an arithmetic average of the detected concentrations and one-half the detection limit was calculated.

[8] Polygons for chemicals measured at fewer locations (e.g., DDT) would be larger, by definition, than polygons for chemicals measured at a large number of stations (e.g., PCBs). Maps depicting multiple chemicals portray Thiessen polygons defined by locations where any chemical was measured. Thus, chemicals measured less frequently than other chemicals are associated with smaller polygons on the multiple chemical maps than they would otherwise be on a map for that single chemical.

exceeded the CSL or ML at most locations with exceedances. PCBs were the only chemical with exceedances at many of the locations on Map 3, in part because more than 300 of the approximately 1,100 surface sediment samples in the LDWG database were analyzed only for PCBs by NOAA (1998). The majority of the maximum exceedance factors were less then 5 (Map 4). Exceedance factors greater than 10 were calculated for locations at River Mile (RM) 0.0, Slip 1, RM 3.1, Slip 4, and RM 3.3-3.6.

As with the maps produced for individual chemical exceedances of the CSL or ML (e.g., Maps 1 and 2), the distributions presented in Maps 3 and 4 are patchy. A visual comparison of Maps 1 to 4 also indicates that the discrete locations where exceedances were identified in each map are very similar among the four maps, as would be expected given the data presented in Table 1 that indicate that most of the CSL or ML exceedances found in the LDW are for PCBs and BEHP. Cadmium, lead, zinc, and mercury were the only other chemicals that exceeded the CSL at 10 or more locations (Table 1).

Table 1. CSL or ML exceedances by location in LDW surface sediments

Chemical	CSL (or ML)	Detection Frequency by Location	Number of Locations with Detections above CSL or ML	Exceedance Factor Range for Detected Concentrations	Number of Locations with Detection Limits Above CSL or ML	Exceedance Factor Range for Detection Limits
1,2,4-Trichlorobenzene	1.8 mg/kg OC	7/557	1	0.032 – 1.2	105	0.013 – 50
1,2-Dichlorobenzene	2.3 mg/kg OC	35/557	2	0.020 – 4.8	85	0.010 – 40
1,4-Dichlorobenzene	9.0 mg/kg OC	69/557	2	0.0027 – 7.2	19	0.0026 – 11
2,4-Dimethylphenol	29 µg/kg dw	1/553	1	5.4	165	0.20 – 72
2-Methylnaphthalene	64 mg/kg OC	87/557	0	0.0014 – 0.93	3	0.00093 – 1.5
2-Methylphenol	63 µg/kg dw	2/557	0	0.32 – 0.66	79	0.094 – 33
4-Methylphenol	670 µg/kg dw	36/281	6	0.022 – 9.3	6	0.010 – 3.1
Acenaphthene	57 mg/kg OC	229/557	3	0.0012 – 3.0	3	0.0011 – 1.7
Acenaphthylene	66 mg/kg OC	57/557	0	0.0018 – 0.077	2	0.00091 – 1.5
Arsenic	93 mg/kg dw	525/575	1	0.019 – 1.1	0	0.033 – 0.33
Benzo(a)anthracene	270 mg/kg OC	511/557	1	0.0017 – 3.0	0	0.0025 – 0.14
Benzo(a)pyrene	210 mg/kg OC	511/557	4	0.0019 – 3.8	0	0.0026 – 0.18
Benzo(g,h,i)perylene	78 mg/kg OC	489/557	6	0.0028 – 6.9	5	0.0056 – 2.8
Benzoic acid	650 µg/kg dw	30/549	3	0.10 – 9.1	69	0.020 – 3.1
Benzyl alcohol	73 µg/kg dw	7/549	3	0.32 – 23	75	0.081 – 9.5
BEHP	78 mg/kg OC	466/561	59	0.0026 – 6.5	1	0.011 – 1.7
Butyl benzyl phthalate	64 mg/kg OC	336/561	6	0.0011 – 8.3	7	0.00093 – 4.3
Cadmium	6.7 mg/kg dw	430/567	10	0.010 – 18	0	0.0060 – 24
Chromium	270 mg/kg dw	571/571	6	0.019 – 4.1	na	na
Chrysene	460 mg/kg OC	529/557	1	0.0019 – 1.8	0	0.0014 – 0.041
Copper	390 mg/kg dw	575/575	6	0.013 – 31	na	na
DDTs (total-calculated)	69 µg/kg dw	42/102	6	0.014 – 42	0	0.012 – 0.74
Dibenzo(a,h)anthracene	33 mg/kg OC	330/557	5	0.0024 – 8.4	5	0.0057 – 3.0
Dibenzofuran	58 mg/kg OC	188/556	2	0.0019 – 1.7	3	0.0010 – 1.7
Diethyl phthalate	110 mg/kg OC	8/561	0	0.011 – 0.18	4	0.00054 – 27
Dimethyl phthalate	53 mg/kg OC	109/561	0	0.0071 – 0.22	8	0.0011 – 13

Chemical	CSL (or ML)	Detection frequency by Location	Number of Locations with Detections above CSL or ML	Exceedance factor range for Detected Concentrations	Number of Locations with Detection Limits Above CSL or ML	Exceedance factor range for Detection Limits
Ethylbenzene	50 µg/kg dw	1/49	0	0.0098 – 0.0098	1	0.028 – 11
Fluoranthene	1,200 mg/kg OC	540/557	1	0.00078 – 2.0	0	0.00056 – 0.032
Fluorene	79 mg/kg OC	299/557	4	0.0011 – 2.1	0	0.00076 – 0.36
Hexachlorobenzene	2.3 mg/kg OC	41/557	1	0.0078 – 19	87	0.0041 – 39
Hexachlorobutadiene	6.2 mg/kg OC	0/557	0	na	77	0.0096 – 17
Indeno(1,2,3-cd)pyrene	88 mg/kg OC	492/557	7	0.0032 – 6.6	3	0.0080 – 2.8
Lead	530 mg/kg dw	575/575	12	0.0038 – 43	na	na
Mercury	0.59 mg/kg dw	501/572	13	0.034 – 7.8	0	0.034 – 0.37
Nickel	370 mg/kg dw	563/565	3	0.014 – 2.5	0	0.078 – 0.086
N-Nitrosodiphenylamine	11 mg/kg OC	8/557	0	0.18 – 0.69	25	0.0054 – 50
PCBs (total-calculated)	65 mg/kg OC	905/957	134	0.0016 – 163	0	0.00059 – 0.26
Pentachlorophenol	690 µg/kg dw	5/506	0	0.14 – 0.76	10	0.0097 – 7.5
Phenanthrene	480 mg/kg OC	520/557	2	0.00075 – 3.4	0	0.0014 – 0.098
Phenol	1,200 µg/kg dw	197/557	4	0.013 – 3.0	1	0.010 – 1.7
Pyrene	1,400 mg/kg OC	531/557	1	0.00061 – 1.3	0	0.00048 – 0.15
Silver	6.1 mg/kg dw	408/567	8	0.0066 – 44	0	0.033 – 0.54
Tetrachloroethene	210 µg/kg dw	2/49	0	0.0010 – 0.0025	1	0.0067 – 2.5
Total HPAH (calculated)	5,300 mg/kg OC	544/557	1	0.00016 – 1.8	0	0.00020 – 0.0037
Total LPAH (calculated)	780 mg/kg OC	522/557	3	0.00059 – 3.0	0	0.0013 – 0.033
Zinc	960 mg/kg dw	573/575	11	0.017 – 10	0	0.13 – 0.35

HPAH = high molecular weight polycyclic aromatic hydrocarbons

LPAH = low molecular weight polycyclic aromatic hydrocarbons

BEHP = bis(2-ethylhexyl)phthalate

OC = organic carbon

dw = dry weight

CSL = cleanup screening level (SMS)

ML = maximum level (DMMP)

2.2 PHASE 1 RISK ASSESSMENT RESULTS

Following completion of the comparisons with the CSL or ML values, additional risk-based information was used to further define high priority areas. Information used for this step in the process was derived from the results of the ecological and human health risk assessments that were part of the Phase 1 RI (Windward 2003). As discussed earlier, risk estimates for both direct sediment exposure pathways and indirect exposure pathways were used as part of the risk-based process to identify high priority areas. The process is outlined in Figure 2 and briefly described in the following subsections for direct and indirect exposure pathways, respectively. Greater detail about the process used is presented in Appendix A.

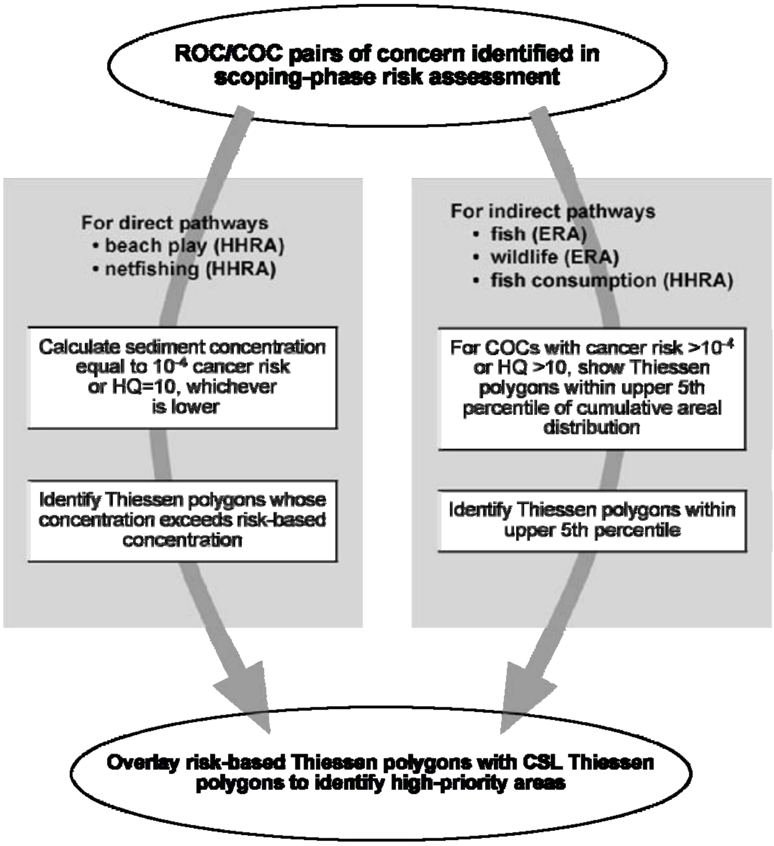

Figure 2.
Use of Phase 1 risk assessment results for identifying high priority areas

2.2.1 Direct sediment exposure pathways

The flowchart presented in Figure 2 describes the process by which chemicals associated with the direct sediment exposure pathway contribute to the identification of high priority areas. If the estimated human health risks associated with individual chemicals of concern (COCs) exceeded an excess cancer risk[9] threshold of 1 in 10,000

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[9] Cancer risk in the HHRA is expressed as a lifetime excess cancer risk. This concept assumes that the risk of developing cancer from a given chemical is in "excess" of the background risk of developing cancer.

or a hazard quotient[10] threshold of 10, that was considered sufficient evidence that early action is warranted. These thresholds were selected because they are within the range of thresholds considered by EPA (1991) in determining whether a site-wide cleanup under CERCLA is warranted. EPA's guidance states that site-wide environmental cleanup is generally not needed if the cumulative cancer risks are less than 1 in 10,000 and the hazard quotient is less than 1, although EPA may take action at lower risk levels based on site-specific circumstances. Thresholds for triggering cleanup are different than cleanup levels. Cleanup levels for the early action site cleanups will be established on a site-specific basis and are not addressed in this document.

Two direct sediment exposure pathways were evaluated in the Phase 1 HHRA: commercial netfishing and beach play. Both of these exposure pathways included incidental ingestion of sediment and direct skin contact with sediment. The exposure pathways evaluated in the Phase 1 ERA for fish and wildlife receptors of concern (ROCs) were not classified as direct because the majority of the chemical intake for these animals is through the diet (i.e., the exposure pathway is indirect). While benthic invertebrates are exposed to sediment chemicals through a direct sediment exposure pathway, this pathway is accounted for in the assessment of risks through comparisons with the CSL or ML, as described in Section 2.1.

No single chemical for either the netfishing or beach play exposure pathways exceeded either of the thresholds established for the direct exposure pathways (see Section 6.4 in the Phase 1 LDW RI report – Windward 2003). The highest single-chemical cancer risks from these exposure pathways were for arsenic, which had an estimated excess cancer risk of 4 in 1,000,000 for the netfishing pathway and 2 in 1,000,000 for the beach play pathway. These estimates are 25 and 50 times lower, respectively, than the risk threshold needed to trigger the area prioritization mapping for direct sediment exposure pathways. Estimated hazard quotients were much less than 1 for all chemicals in these pathways.

2.2.2 Indirect sediment exposure pathways

The thresholds used to trigger high priority area mapping for chemicals via the indirect sediment exposure pathways are the same as the thresholds identified in Section 2.2.1 (i.e., cancer risk of 1 in 10,000 or hazard quotient of 10) (Figure 2). The indirect sediment exposure pathways include fish and shellfish consumption (HHRA). Risks to fish and wildlife species (ERA), specifically chinook salmon, bull trout, English sole, great blue heron, bald eagle, spotted sandpiper, river otter, and harbor seal, were also associated with indirect exposure pathways because most of their exposure to contaminated sediments occurs indirectly through their diet. These animal

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[10] In the HHRA, a hazard quotient is the ratio of the daily chemical intake for a given chemical and the intake that EPA has estimated is likely to be without an appreciable risk of deleterious effects during a lifetime.

species were selected for the ERA because they are considered to be protective (i.e., higher probability of greater exposure to chemicals) of other fish and wildlife species that may be found in the LDW.

Ecological risks to fish and wildlife are also expressed as hazard quotients.[11] Based on existing data, none of the Phase 1 hazard quotients for fish or wildlife were greater than 10 for any chemical in the Phase 1 ERA (see Sections 5.3 and 5.4 in the Phase 1 LDW RI report – Windward 2003).

Three chemicals either met or exceeded the cancer risk threshold of 1 in 10,000 for the human health fish and shellfish consumption pathway: arsenic, carcinogenic polycyclic aromatic hydrocarbons (cPAHs),[12] and PCBs. The estimated cancer risks attributed to these chemicals were 1 in 1,000, 1 in 10,000, and 4 in 10,000, respectively. PCBs also had a hazard quotient of 12, but no other chemical had a hazard quotient higher than 10. These risk estimates are based on the health-protective assumptions used in Phase 1 regarding the amount of seafood ingested per day and the period over which exposure at this level occurs. However, the Phase 1 risk assessment is based on a relatively small amount of existing data on chemical concentrations in LDW fish, shellfish, and benthic invertebrates. Uncertainties around these and other exposure parameters indicate that actual human exposures via this pathway may be different from what was assumed in the Phase 1 risk assessment (see Appendix A, Section A.7, and Appendix B, Section B.6, in the Phase 1 RI report – Windward 2003). More data will be collected in Phase 2 to help reduce some of these uncertainties. Although three chemicals met the risk threshold for the fish and shellfish consumption pathway, only PCBs were used to identify high priority areas. The high uncertainty associated with risk estimates for arsenic and cPAHs did not warrant their use for area identification, as described below.

Arsenic: Arsenic is a naturally occurring element that is found in soils (Ecology 1994, 2002b), sediment (Ecology 2000), and fish tissue (West et al. 2001) throughout Puget Sound. Although the estimated cancer risk from arsenic for the fish consumption pathway in the Phase 1 HHRA was greater than the high priority area risk threshold (i.e., 1 in 10,000), the degree to which arsenic concentrations in LDW fish tissue differ from arsenic fish tissue concentrations outside the LDW has not been determined. The comparison between LDW and background concentrations is necessary for determining the need for remedial action associated with arsenic concentrations in LDW sediment. A quantitative approach for making these comparisons will be developed for the Phase 2 RI using EPA guidance documents (EPA 2002a,c). Until such time as a rigorous quantitative analysis has been conducted of arsenic concentrations both within and outside the LDW, it is not appropriate to use the

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[11] Hazard quotients in the ERA were calculated as the ratio of the exposure concentration (or dose) divided by the lowest concentration (or dose) associated with an adverse effect

[12] Benzo[a]pyrene, benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene

results of the Phase 1 HHRA for arsenic for identifying high priority areas. Although such a quantitative approach has not been developed, some preliminary comparisons have been made. For example, mean (10.9 mg/kg wet weight) and maximum (15.1 mg/kg wet weight) arsenic concentrations for English sole fillets from the LDW are similar to mean (7.7 mg/kg wet weight) and maximum (20 mg/kg wet weight) arsenic concentrations from non-urban areas from Puget Sound (West et al. 2001).

cPAHs: The high priority area risk threshold of 1 in 10,000 was met, but not exceeded, for cPAHs. However, the uncertainty of this risk estimate is very high. These compounds were detected in mussel tissue, which is one of the diet components used in the HHRA, but were not detected in any English sole or crab tissue samples, two other diet components used in the HHRA. Accordingly, cPAH concentrations equivalent to one-half the reported detection limits were used for English sole and crab tissue. This assumption is likely to overestimate the "true" concentrations of these compounds in English sole and crab tissue, because these compounds accumulate to only a limited degree in many aquatic organisms, particularly fish, due to enzyme-mediated biodegradation (Varanasi et al. 1985, 1989; Varanasi and Stein 1991). PAH degradation rates in mussels, however, appear to be lower compared to vertebrates (Stegeman 1985). For example, none of the seven individual cPAHs were detected in over 700 English sole, rockfish, and salmon samples collected throughout Puget Sound during the Puget Sound Ambient Monitoring Program (West et al. 2001). Exclusion of English sole and crab from the risk estimates for cPAHs in the fish and shellfish consumption scenario evaluated in the Phase 1 HHRA would change the excess cancer risk estimate from 1 in 10,000 to 2 in 100,000, dropping it below the threshold for high priority area identification. Additional discussion of this topic is provided in Section B.6.1.2 of the Phase 1 HHRA (Windward 2003). Given the high uncertainty in the risk estimate for cPAHs, these compounds were not used to identify high priority areas. More data will be collected in Phase 2 to help reduce some of these uncertainties.

PCBs: Identification of high priority areas using PCBs is only indirectly based on sediment chemistry data because the exposures and risks are calculated from chemical concentrations in tissue, not from sediment concentrations. Estimation of a sediment concentration associated with a particular risk threshold is not possible for the fish and shellfish consumption pathways without modeling the transfer of chemicals between sediment and tissue. Modeling of this type was not performed in the Phase 1 HHRA.

The high priority area identification method for indirect sediment exposure pathways makes the general assumption that areas of higher sediment concentrations are associated with higher risks. Thus, remediating areas with the highest concentrations will reduce risks. The degree to which the risk would be reduced cannot be estimated at this time without modeling the linkage between chemical concentrations in sediment and tissue. An upper percentile equivalent to 5% of the overall area of the LDW with the highest concentration for a particular chemical was used as a cutoff for identification of high priority areas. PCB concentrations within the upper 5% area contributed to high priority area identification, while concentrations in the remaining 95% area of the LDW did not.

The 5% threshold represents a total PCB concentration of 980 µg/kg dw. This concentration is between the dry-weight concentrations that are functionally equivalent to the SQS (Sediment Quality Standards) and CSL for total PCBs, which are 130 (the lowest Apparent Effects Threshold) and 1,000 µg/kg dw (the second lowest Apparent Effects Threshold), respectively. In contrast, a 10% threshold represents a total PCB concentration of 430 µg/kg dw. The 5% threshold concentration is higher than total PCB concentrations established as cleanup goals at other Puget Sound Superfund areas (e.g., 300 µg/kg dw at Commencement Bay), but overall this threshold falls within the range of PCB cleanup goals that can be selected under Washington State SMS.

The method used to calculate the upper 5th percentile area associated with PCBs was as follows:

1. Thiessen polygons were constructed around each PCB sampling location. The area of each polygon was calculated in the GIS.
2. Polygons were ordered from high to low, based on chemical concentrations.
3. Starting with the polygons with the highest concentration and proceeding to locations with successively lower concentrations, a cumulative sum of polygon areas was calculated, until that sum reached 5% of the total area for all polygons within the LDW.

Map 5 shows the upper 5% of the LDW area that contains the highest PCB concentrations.

2.3 IDENTIFICATION OF HIGH PRIORITY AREAS

This section combines the results of the sediment chemistry evaluation (Section 2.1) and the Phase 1 risk assessments (Section 2.2) to identify high priority areas. High priority areas were identified by three or more contiguous sampling locations identified by: 1) CSL exceedance for any chemical or 2) within the upper 5th percentile of the cumulative areal distribution for PCBs. Areas with three or more sampling locations in close proximity were also considered. No specific definition of "close proximity" was developed; rather, best professional judgment based on sampling density in the area under evaluation and the magnitude of CSL (or ML) exceedances was employed. For example, areas with three CSL exceedances interspersed among sampling locations without CSL exceedances were not identified as high priority areas unless the CSL exceedance factors were high and concentrations very close to the applicable standards (i.e., above SQS or SL) were found at the locations without CSL exceedances. These areas will be further investigated during the Phase 2 RI to determine if remedial action is warranted.

Two examples of this type of best professional judgment are demonstrated in Maps 6 and 7. As shown in Map 6, surface sediment concentrations at three locations at the head of Slip 6 exceeded CSLs for one or more PAHs. These three locations form a triangle; within this triangle are three other locations at which concentrations were all less than the SQS. Consequently, this area was not identified as a high priority because the existing data did not suggest a consistent pattern of chemical concentrations.

Best professional judgment was also applied for areas where samples exceeded applicable standards but were relatively far apart. For example, as shown in Map 7, surface sediment concentrations exceeded applicable CSLs for total PCBs, mercury, BEHP, acenaphthene, and fluorene at three locations near river mile 1.4. None of the concentrations for the individual chemicals exceeded the CSL at more than one location in this area and therefore do not meet the criteria of several stations exhibiting a similar pattern of chemical concentrations (see Appendix A, Section 2.2.1). Moreover, these three locations are located relatively far apart from each other (> 50 m) compared to sampling locations at the areas that were selected as high priority areas. The sediment quality in the areas between these widely dispersed locations is not known. The stations were also located on opposite sides of the navigation channel, raising further questions about any connection between the three locations and suggesting their sources are unrelated. Consequently, these locations were not identified as a high priority area because existing data are insufficient to state with confidence that this area represents a consistent pattern of concentrations. This and other areas where exceedances of criteria were noted, but were not selected as high priority areas, will be further investigated during the Phase 2 RI to determine if remedial action is warranted.

Map 8 shows sample locations with one or more chemical concentrations that exceed applicable CSL or ML values in red and sample locations that fall within the upper 5% concentration range by area for PCBs in yellow. Locations included in both categories are also shown in red. Seven high priority areas, designated 1 through 7, were identified and are shown on Map 8 and listed in Table 2. Each of the seven high priority areas clearly meets the criteria described above for high priority area designation. Best professional judgment was used to evaluate several areas other than those listed in Table 2. None of the other areas warranted designation as high priority areas because of the relatively large distances between locations with CSL (or ML) exceedances, coupled with the intermingled locations without exceedances.

Table 2. High priority areas

AREA DESIGNATION	AREA NAME OR LOCATION	SUMMARY
1	Duwamish/Diagonal CSO/SD (RM 0.4 – 0.6), east side of LDW	Remedial design in progress under sponsorship by the Elliott Bay/Duwamish Restoration Program (EBDRP). Investigations conducted in 1994-1996.
2	RM 2.2, west side of LDW	Sampled in 1998 during EPA Site Inspection.
3	Slip 4 (RM 2.8)	Sampled during several investigations over the last 10 years, but no focused investigation has occurred.

AREA DESIGNATION	AREA NAME OR LOCATION	SUMMARY
4	RM 2.9 – 3.7, east side of LDW	Sediment cleanup design in progress at Boeing Plant 2 under Resource Conservation and Recovery Act (RCRA) Administrative Order on Consent (AOC). Investigations began in 1994. Adjacent areas sampled during several investigations in 1997 and 1998. Additional sediment investigations are planned for areas adjacent to the Boeing Plant 2 and Jorgensen Forge properties.
5	RM 3.6, west side of LDW	Sampled during several investigations in 1997 and 1998.
6	RM 3.8, east side of LDW	Sampled during several investigations in 1997 and 1998.
7	Norfolk CSO (RM 4.9 – 5.0), east side of LDW	Cleanup studies conducted in 1994-1996; cleanup conducted during 1999. Annual monitoring currently being conducted by King County. Inshore area sampled during recontamination investigation in 2002.

Separate discussions are provided for each area below. Maps for each high priority areas were created. The sampling locations labeled on each map are those with CSL (or ML) exceedances that were used for high priority area designation. Locations with SQS (or SL) exceedances are also identified on each map. Although SQS (or SL) exceedances were not a primary factor for high priority area designation, they were considered as part of the best professional judgment process described above. The maps also identify public access points, boat launches, and upland property ownership for each area.

2.3.1 Area 1 – Duwamish/Diagonal

The Duwamish / Diagonal area (RM 0.4 to 0.6 on east side of LDW) was identified as a cleanup priority by the Elliott Bay / Duwamish Restoration Program (EBDRP) in the mid-1990s as a result of concerns associated with contaminated sediments adjacent to the Duwamish / Diagonal combined sewer overflow / storm drain (CSO / SD) outfalls under City of Seattle and King County jurisdiction (Map 9). The Port of Seattle owns the property adjacent to the area. The Duwamish CSO is an emergency bypass that has not overflowed for over 10 years. City of Seattle discharges from the Diagonal Way CSO averaged about 2.5 million gallons per year (MGY) from 1998 to 2001. King County discharges from the Diagonal Way CSO have an estimated average volume of 65 MGY (King County 2002a). The storm drain discharges up to 1,200 MGY from two large drainage basins.

A draft site assessment report and a cleanup study report were prepared by EBDRP (King County 2000, 2001a). Based on the results of cleanup studies conducted in 1994 and 1996, the COCs in the study area were PCBs, mercury, BEHP, and butyl benzyl phthalate. Remedial design is complete at the seven-acre EBRDP cleanup site in this high priority area and remediation will occur at the end of 2003. There is a public access point, but no boat launch, to the south of Area 1 at the end of Diagonal Way.

The data (SQS / SL or CSL / ML exceedances only) associated with the labeled sampling locations shown on Map 9 are shown in Appendix C. Map 9 also shows the boundaries agreed upon by Ecology (2002a) for a partial cleanup at this location. This cleanup boundary is shown for informational purposes only. It is not part of the analyses conducted for the RI or the early action site identification process.

2.3.2 Area 2 – RM 2.2, west side of LDW

Sediments at this area were sampled during one investigation in 1997 (NOAA 1998) and one in 1998 (Weston 1999). The small slip in this area is surrounded by property owned by the Trotsky family, Swan Bay Holdings Inc., and Boyer Towing Inc. (Map 9). The three locations that triggered high priority designation all had CSL exceedances for PCBs (Map 10; maximum EF of 7.3). Two locations also had CSL or ML exceedances for other chemicals (i.e., mercury, BEHP, and DDTs). One other location toward the mouth of the slip had a PCB concentration that exceeded the SQS, but not the CSL. There are no public access points or boat launches in the vicinity of Area 2.

2.3.3 Area 3 – Slip 4

Slip 4 sediments were sampled during two investigations in 1997 (Exponent 1998 and NOAA 1998) and one in 1998 (Weston 1999). Slip 4 is surrounded by property owned by Crowley Marine Services, Pacific Terminals, King County, First South Properties, and the Boeing Company (Map 11). Most of the sampling locations in Slip 4 had CSL exceedances for PCBs (Map 11). The highest CSL EF for PCBs (27.5) was located near the head of the slip. A ML EF was found for total DDTs (41.7) in this area. Three locations had PCB concentrations within the upper 5% by area that did not also exceed the PCB CSL (Map 11). Several other locations toward the mouth of the slip had concentrations of PCBs that exceeded the SQS, but not the CSL. There are five large outfalls at the head of Slip 4: Georgetown flume, I-5 storm drain, King County airport storm drain, King County CSO (emergency overflow), and City of Seattle CSO/SD (emergency overflow). The existence of private storm drain outfalls discharging to Slip 4 has not yet been determined. There is a public walkway on Boeing property near the mouth of Slip 4, although there is no easy access to the shoreline (Map 11).

2.3.4 Area 4 – RM 2.9 to 3.7, east side of LDW

This priority area extends along the east bank of the LDW south from the mouth of Slip 4 (RM 2.9) to approximately RM 3.7. This area includes sediments along the shoreline of the Boeing Plant 2 and Jorgensen Forge properties. Environmental investigations within this area (Map 12) have been underway since 1994, when EPA and Boeing signed an Administrative Order on Consent (AOC) that required Boeing to conduct a RCRA Facility Investigation (RFI). The Boeing Plant 2 facility occupies 107 contiguous acres that border the LDW to the west; Webster Street, Slip 4, and property owned by Crowley Marine Corporation to the north (excluding public streets and ways); the British Oxygen Corporation plant and East Marginal Way South to the east; and the Jorgensen Forge Company to the south (Weston 1998). PCBs were identified as the primary focus in the sediments in this area, although concentrations of phthalates, polycyclic aromatic hydrocarbons (PAHs), and some metals were also elevated in some portions of the area. Boeing has conducted design work for a sediment cleanup project along the property owned by Boeing and has proposed a large area offshore of Plant 2 for sediment remediation. EPA and Boeing are currently engaged in a dispute resolution process involving the extent of the Plant 2 sediment remedial boundaries. Additional sediment investigations, by multiple parties, are planned for areas adjacent to the Boeing Plant 2 and Jorgensen Forge properties. There is a public walkway at the north end of Plant 2 near the mouth of Slip 4, although there is no easy access to the shoreline (Map 12).

The data (SQS / SL or CSL / ML exceedances only) associated with the labeled sampling locations shown on Map 12 are shown in Appendix C. Boeing's proposed boundary for cleanup of a ten-acre portion of this high priority area is also shown on Map 12. This proposed boundary is shown for informational purposes only. It is not part of the analyses conducted for the RI or the early action site identification process.

2.3.5 Area 5 – RM 3.6, west side of LDW

Sediments adjacent to this area were sampled during two investigations in 1997 (Exponent 1998 and NOAA 1998) and one in 1998 (Weston 1999). All samples were collected west of the navigation channel, offshore of property currently owned by the Port of Seattle (Map 13). This property was formerly owned by Malarkey Asphalt and PCB-contaminated soil in the upland portion of the property was removed in an EPA Superfund (CERCLA) cleanup action from October 1999 to February 2000 (Onsite 2000). Five sediment sampling locations had PCB concentrations in excess of the CSL (maximum EF of 12.9). Four other locations at the southern end of the area had PCB concentrations that exceeded the SQS, but not the CSL (Map 13). No locations had PCB concentrations within the upper 5% by area that did not also exceed the PCB CSL (Map 13). There are no public access points or boat launches in the vicinity of Area 5.

2.3.6 Area 6 – RM 3.8, east side of LDW

Sediments from Area 6 were sampled during two investigations in 1997 (Exponent 1998 and NOAA 1998) and one in 1998 (Weston 1999). Samples were collected east of the navigation channel, adjacent to the Isaacson and Thompson properties owned by Boeing and just offshore of an outfall that jointly serves as a City of Seattle emergency overflow and a storm drain that appears to drain upland areas east of the LDW (Map 13). CSL or ML exceedances were found at three locations in close proximity to each other in this area (Map 13). Concentrations of several PAHs and BEHP exceeded the applicable CSLs; the maximum EF was 2.3. There are no public access points or boat launches in the vicinity of Area 6.

2.3.7 Area 7 – Norfolk CSO

The Norfolk CSO area (RM 4.9 to 5.5 on east side of LDW) was identified as a cleanup priority by EBDRP in the mid-1990s as a result of concerns associated with contaminated sediments adjacent to the Norfolk CSO under King County jurisdiction (Map 14). Sediments from Area 7 were sampled during Norfolk CSO cleanup studies in 1994 and 1995. In 1999, a sediment remediation project was conducted, consisting of dredging contaminated sediments and backfilling the area dredged with clean sand. The boundaries of the 1999 remediation area are shown in Map 14. Post-remediation monitoring was conducted in 1999, 2000, and 2001.[13] None of the samples collected prior to 1999 from the remediation area are shown on Map 14 because the sediment characterized by those samples is no longer present. In addition, a single sample was collected at this area in 1997 (Exponent 1998). All samples were collected east of the navigation channel in the vicinity of the Norfolk CSO (Map 14). CSL exceedances were found at six locations in this area. The northernmost location with a CSL exceedance (Location 1093) had the single highest total PCB concentration in the LDW (222,600 µg/kg dw) (Map 14). The areal extent of PCB contamination of this magnitude appears limited. None of the nearby sampling locations exceeded the CSL for total PCBs, although PCB concentrations at 7 locations did exceed the SQS. The other locations with CSL exceedances were located at least 180 m upstream of Location 1093. Locations 5411, 5412, and 5413 are located near a storm drain outfall that drains a parking lot leased to the Boeing Company. Concentrations of total PCBs at these three locations exceeded the CSL by factors ranging from 4.9 to 8.4. Concentrations of total PCBs at Location 1123, located within the remediation area, also exceed the CSL (EF of 5.6). The final location with a CSL exceedance in this area is 971, located upstream of the Norfolk CSO outfall, which had a 1,4-dichlorobenzene concentration that exceeded the CSL by a factor of 7.2. Other chemicals, most notably BEHP, exceeded the SQS at one or more locations. There are no public access points or boat launches in the vicinity of Area 7.

3.0 Candidate Site Selection

Each high priority area identified in Section 2 using the risk-based methods described in Appendix A was sequentially evaluated using the candidate site selection criteria described below. No sites were screened out based on comparisons to these management criteria. Information related to these criteria will be further investigated by EPA and Ecology and will inform their decisions as to whether and when to move forward with early action cleanups.

- **Consistency of Site Identification Methods with NCP and MTCA**: Each identified high priority area was further evaluated before it was identified as a candidate site for early action to ensure that its identification as a high priority

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[13] Sampling was also conducted in 2002, but the data from this event have not been incorporated into the Phase 1 RI or this memorandum because the results were not available until after drafts of these documents had been prepared.

area would be consistent with site identification and early action procedures specified in the NCP and MTCA.

- **Evaluation of Recontamination Potential:** The next step in identifying candidate sites was to assess the probability of recontamination to a level that would constitute an unacceptable risk to human health or the environment. Candidate sites were selected for early action only if they have a low probability of recontamination because: 1) the area is currently contaminated as the result of historical inputs with little or no expectation of current sources, or 2) current sources, if present, can be meaningfully addressed as part of the early action process or under other regulatory programs, even if all source control actions have not been undertaken or completed. Only a preliminary review of recontamination potential based on existing information was conducted for each high priority area. Additional analysis will be conducted during investigation and cleanup activities at the individual high priority areas should they go forward as early action sites. EPA (2002b) guidance indicates that early actions may be warranted prior to completion of source control actions if the benefits to human health and/or the environment are large enough.
- **Consistency with Remedial Actions Evaluated for the LDW:** In addition, the high priority areas were evaluated for the likelihood that the early cleanup actions taken would be consistent with the preferred long-term remedial actions evaluated for the LDW. The NCP requires that, to the extent practicable, all early actions should contribute to the efficient performance of any anticipated long-term remedial action for the LDW (40CFR§300.415).

3.1 CONSISTENCY OF SITE IDENTIFICATION METHODS WITH NCP AND MTCA

Both the NCP and MTCA include criteria for identifying areas that warrant remedial action and for conducting early actions. This section discusses the consistency of the high priority area identification methods described in Section 2 with those criteria.

The high priority area identification methods described in Section 2 are consistent with site hazard assessment procedures specified in both the NCP and MTCA. The NCP requires that decisions on removal actions[14] be based on threats to human or animal populations, sensitive ecosystems, or other significant factors affecting the health or welfare of the public, or the environment (40CFR§300.415). In addition, MTCA defines an interim action as "a remedial action that is technically necessary to reduce a threat to human health or the environment by eliminating or substantially reducing one or more pathways for exposure to a hazardous substance at a facility" (WAC 173-340-430). The Washington State Sediment Management Standards (WAC 173-204-550(3)(d)) define a partial cleanup as an action that may be conducted

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[14] The word "removal" generically refers to remedial action and is not limited to physical removal of contaminated media. Removal may also include capping or treatment.

when 1) a cleanup study has identified and proposed discrete site units and cleanup standards, 2) Ecology has approved the selection of the partial cleanup alternative, and 3) Ecology has determined that awaiting action or decision on conducting a complete site cleanup would have a net detrimental effect on the environment or human health.

The early actions discussed in this document are consistent with the definitions of a non-time-critical removal action (NTCRA), as described by EPA under NCP and CERCLA, and an interim action, as defined by Ecology under MTCA. The Phase 1 risk assessment results were used to identify high priority sites, as described in Section 2.3. Should a high priority area go forward as a candidate site for early action, boundaries will be defined during design of the sediment remediation for each site, which will occur outside the LDW RI/FS process.

3.2 EVALUATION OF RECONTAMINATION POTENTIAL

This section presents an evaluation of the possibility that early action sites could be recontaminated after remediation. The following sources of potential recontamination of sediment were considered: 1) discharge from CSO or stormwater (public or private) outfalls, 2) groundwater discharge, 3) sediment transport from other areas, and 4) dredging during remediation at sites or for channel maintenance. Industrial discharges permitted through the National Pollutant Discharge Elimination System (NPDES) were not considered because there are no monitoring data for permits associated with discharges in the vicinity of high priority areas.[15] Other potential sources, such as atmospheric deposition and spills were not specifically evaluated because few data exist for these pathways as current or potential sources of recontamination.

No sites were screened out based on recontamination potential. EPA and Ecology will consider the potential for recontamination in determining the timing of early action cleanups relative to source control activities. The agencies will endeavor to make the source control and early action cleanup schedules compatible; however, the agencies may decide to proceed with an early action cleanup prior to completion of all source control activities if deemed appropriate to address threats to human health and the environment.

3.2.1 CSO and stormwater discharges

Potential recontamination of sediment as a result of CSO or stormwater discharges has been investigated at two areas in the LDW: the Duwamish/Diagonal CSO/SD

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[15] The three industries with NPDES permits currently requiring monitoring of direct discharges to the LDW are Duwamish Shipyard, Lafarge Corporation, and Boeing Developmental Center. The Duwamish Shipyard and the Lafarge Corporation are located on the east side of the LDW between RM 0.9 and 1.4, and the Boeing Developmental Center is located on the west side of the LDW from RM 4.2 to 5.0.

(Area 1) and the Norfolk CSO (Area 7). There are also known stormwater outfalls in the vicinity of three other high priority areas: Area 3 (Slip 4), Area 4 (RM 2.9 – 3.7 east), and Area 6 (RM 3.8 east), as well as CSOs (emergency overflows only) at Areas 3 and 6, but no modeling has been conducted of the recontamination potential from these sources at those areas. The presence of stormwater outfalls at other high priority areas has not yet been determined.

At the Duwamish/Diagonal CSO/SD and the Norfolk CSO high priority areas (cleanup occurred in 1999 at the latter area under EBDRP), King County initially evaluated potential recontamination of sediment from CSO and stormwater inputs using their METSED model, which is a modification of the Ecology-approved SEDCAM model routinely used for natural attenuation and recontamination modeling (King County 1996, 2000). METSED assumes that chemicals discharged to the LDW are well mixed in a fixed aqueous volume (equivalent to a mixing zone) overlying the sediments. The model computes the exchange between the water column and the underlying sediment to estimate sediment concentrations with input parameters including the ambient flow of water in the LDW, the concentrations of chemicals entering the water column, and the CSO/SD discharge flow rate. Processes modeled include mass accumulation, constituent decay, sediment diffusion, and chemical partitioning.

The model evaluated metals, BEHP, and butyl benzyl phthalate. Recontamination from PCBs was not addressed in the Norfolk or Duwamish/Diagonal CSO/SD models because PCBs (as Aroclors) have not been detected in recent CSO effluent samples. Moreover, LDW-wide water and sediment quality modeling done by King County (1999) suggested that current PCB inputs to the river from specific sources were not high enough to result in sediment PCB concentrations above the SQS at the Duwamish/Diagonal area.

Chemistry input data for METSED modeling at the Duwamish/Diagonal CSO/SD were based on CSO effluent chemistry data from several CSOs in the vicinity. Average chemical concentrations in CSO discharges were higher than average chemical concentrations in stormwater concentrations in the Diagonal storm drainage basin for some chemicals, so the results of the model were considered conservative for those chemicals (King County 2000). The modeling concluded that remediated sediment in the vicinity of the outfall would likely be recontaminated above the SQS by BEHP and butyl benzyl phthalate. However, the modeling results were questionable because two metals were also predicted to recontaminate sediment even though measured surface sediment concentrations of these two metals did not currently exceed the SQS. Therefore, another modeling approach was used to confirm or refute the findings.

The second model used for the Duwamish/Diagonal CSO/SD was a basic mass balance model developed by WEST Consultants. This modeling approach is described in King County (2000). The chemicals modeled included BEHP and butyl benzyl phthalate, but not PCBs. For BEHP, the model, which also assumed input from adjacent sediment, predicted that compliance with the SQS could only occur if greater than 89% of the source from the Duwamish/Diagonal CSOs and SDs was removed.

Modeling for the Norfolk CSO assumed a reduced CSO discharge.[16] The model results suggested that the CSO discharge at Norfolk should not recontaminate sediments with metals or phthalates in the vicinity of the outfall (King County 1996). However, it was discovered that in addition to the CSO discharge, approximately 40 MGY of separated stormwater also discharged from the outfall. Modeling indicated that BEHP in the stormwater could cause sediment concentrations to exceed the CSL in as little as one year.

There has also been post-remediation monitoring conducted on four occasions from 1999 to 2001 at the Norfolk CSO/SD (King County 2001b), although a statistical trend analysis has not yet been conducted with the data. The most recent monitoring data from April 2001 (the second year of a five-year monitoring program) show that concentrations of PCBs, PAHs, BEHP, and butyl benzyl phthalate were higher than those detected during 1999 or 2000 monitoring events, providing evidence that some recontamination is occurring at the cap.

Apparent recontamination by PCBs of the backfill material placed at the Norfolk CSO/SD remediation project area following dredging was observed during sampling conducted in 1999 and 2000. The mostly likely of potential sources of these PCBs is resuspension and subsequent deposition of contaminated sediment from a relatively small area immediately inshore of the backfill that was not removed during the 1999 remediation project. There has been more recent sediment sampling in this area by both King County and Ecology and additional sediment investigations of this area are planned.

In conclusion, the available model results indicated that CSO or storm drain discharges could result in recontamination at the Duwamish/Diagonal and Norfolk areas for phthalates. PCB recontamination appears to be occurring at Norfolk, but the source of these PCBs is most likely erosion of contaminated sediment from relatively small areas immediately adjacent to the remediation area. Although phthalate recontamination from CSO or storm drain discharges is possible at the Duwamish/Diagonal area, plans for remediation are proceeding based on a number of factors. These factors include: 1) the relative difficulty of achieving adequate phthalate source control to prevent recontamination, and 2) the relatively small size of the area potentially recontaminated with phthalates compared to the size of the currently established cleanup area (King County 2002a).

Source control activities are currently underway in anticipation of a planned December 2003 sediment cleanup of a seven-acre portion of the Duwamish/Diagonal

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[16] At the time of the 1996 report, annual CSO discharge was 70 million gallons per year (MGY), although a diversion project was expected to reduce CSO annual discharge to 7-9 MGY. The 7 MGY figure was used in the modeling.

Way high priority area. Source control actions are focusing on sources that could recontaminate this seven-acre cleanup area. Ecology is reviewing information on contaminated upland soils or groundwater that could recontaminate site sediments. The City of Seattle and King County are inspecting 1,200 businesses in the storm drain and combined sewer overflow system that drains to the waterway in this area. Inspectors are enforcing existing regulations that prohibit releases of pollutants to waterbodies and identifying actions such as best management practices that businesses can take to prevent releases and entry of contaminants into the drainage systems. The Port of Seattle has also inspected tenants on properties they manage in this area to promote pollution prevention and best management practices. A Source Control Action Plan describing these activities is now being developed, and is expected to be available by mid-summer of 2003.

The degree to which CSO and stormwater discharges could recontaminate Areas 3 and 6 cannot be determined until further source tracing in these relatively small basins and area-specific modeling are conducted for those areas. Such modeling will be considered as part of the feasibility analysis to be conducted for each early action site.

3.2.2 Groundwater discharge

The potential for groundwater discharge to recontaminate sediment with metals was evaluated at Boeing Plant 2 (Area 4) by Weston (2003a) and is currently being reviewed by EPA under the RCRA program. This evaluation used a total mass loading approach for an initial conservative screening. The approach assumed that each chemical would load the sediment at a rate calculated as the product of the concentration of each chemical and the groundwater discharge rate through the sediment. Two major assumptions were made resulting in a very conservative estimate of potential sediment recontamination: 1) no attenuation of chemical concentrations in groundwater was assumed to occur between the upland monitoring wells and the sediment, and 2) all chemical mass in the discharging groundwater was assumed to sorb to the sediment particles in the uppermost 10 cm. The results of the mass loading calculations indicated that groundwater inputs would not result in exceedance of the SQS for a range of metals for approximately 280 to 6,100 years. Further, by including an analysis of equilibrium partitioning, it was concluded that SQS levels would never be reached as a result of groundwater discharge.

The transport of PCBs via groundwater was not modeled at Boeing Plant 2 because they were only detected in one well in an area that will be remediated (Weston 2003a). In addition, organic compounds such as PCBs sorb readily to soil particles and are not likely to be transported far in groundwater. A primary historical PCB source from Boeing Plant 2 to the river is believed to have been from utility vaults and has been eliminated.

PCBs were recently found in soil approximately 150 ft from the LDW on the east side at RM 3.6. Under EPA's RCRA program, a work plan has been completed to determine the nature and extent of PCB contamination at this area (Weston 2003b). The resulting data will need to be reviewed to evaluate the potential for groundwater from this area to recontaminate sediment. Sediment contamination within the southernmost portion of Area 4 (RM 3.6 to 3.7) may be associated with other sources that have yet to be investigated.

VOCs, such as vinyl chloride or trichloroethene, are more mobile in groundwater than PCBs, but are generally considered non-persistent in sediment because of their high volatility and low tendency to partition onto sediments. For this reason, VOCs were not included in the groundwater recontamination modeling for Boeing Plant 2 (Weston 2003a). EPA (2003) agrees that vinyl chloride is not a sediment cap recontamination concern for the site at this time, but VOCs, including vinyl chloride, may be further considered by EPA in the cap evaluation process in the future.

As part of the Phase 1 RI, upland areas with groundwater data were evaluated for the potential for groundwater COCs to migrate to the LDW and accumulate in sediment at concentrations of concern (see Appendix G of the Phase 1 RI). The upland areas adjacent to high priority sediment areas (in addition to Boeing Plant 2 discussed above) are Terminal 108/Chiyoda, Malarkey, and Boeing Isaacson.

PCBs are the primary COCs in sediment at high priority Areas 1 and 5 (downgradient from the Terminal 108/Chiyoda and Malarkey upland areas, respectively). It was concluded that PCBs are not likely transported to sediment via groundwater at these upland areas because of their low solubility and mobility in groundwater. The primary COCs in sediment at Area 6, downgradient from the Boeing Isaacson upland area, are PAHs and BEHP. These chemicals have not been identified as COCs in groundwater at the Boeing Isaacson area, so it is highly unlikely that groundwater from this area would result in sediment recontamination at Area 6.

Analyses of the potential for groundwater to impact sediments or biota are preliminary and under review by EPA and Ecology. The agencies will be conducting independent analyses of groundwater contamination impacts on the LDW.

3.2.3 Sediment transport

Recontamination of sediment could occur if resuspended sediment from other contaminated areas was deposited over an area after it had been remediated. The potential for recontamination of early action sites from surrounding areas is highly site-specific, and will need to be considered as part of the feasibility analyses to be conducted for each early action site outside the AOC for the LDW RI/FS. The recontamination potential can be evaluated using sediment transport modeling. Such modeling has been conducted at high priority area A (Duwamish/Diagonal), but not at any of the other high priority areas. The modeling results for Duwamish/Diagonal are summarized at the end of this section. General characteristics of the LDW that are relevant for evaluating recontamination potential from resuspended sediment at all high priority areas are summarized below.

Hydrodynamic and sediment characteristics over a broad scale within the LDW are consistent with a net depositional environment (see Section 4.4.2 of the Phase 1 RI report – Windward 2003). Much of the deposition occurs upstream of RM 4.0, particularly in the vicinity of Turning Basin 3, as indicated by the necessity for frequent dredging in this area (Kendall 2002). Sediment deposition rates downstream of this area are much lower, as indicated by the much less frequent need of dredging in the navigation channel downstream of the South Park bridge (RM 3.4). Based on current meter data collected by King County (1999), near-bottom current velocities are very rarely high enough to initiate movement of bedded sediment, suggesting that wide-scale sediment resuspension in the LDW is unlikely during the flow characteristics captured during King County's current meter deployment. These current meters did not capture the most extreme storm events, so the sediment transport potential of current speeds associated with such events is unknown.

Sediment resuspension and transport modeling conducted for the Duwamish / Diagonal CSO / SD area suggested that PCBs located immediately upstream of the area boundary originally proposed by EBDRP could contaminate the cleanup area. However, EBDRP recently expanded the size of the cleanup area so that adjacent elevated concentrations of PCBs will be removed (King County 2002b).

3.2.4 Dredging

Dredging activities performed in the LDW for remediation, channel maintenance, or construction projects have the potential to resuspend contaminated sediments, thereby allowing them to be transported to other areas. This potential can be minimized by scheduling dredging during low flow periods, by using special buckets to contain sediment, and by temporarily stopping dredging during high-flow events. In addition, a plan could be developed to coordinate some dredging projects and sediment remediation projects to occur in the same time frame to minimize the potential for recontamination. These concerns will be addressed during site-specific feasibility analysis to be conducted at each early action site.

3.2.5 Summary

The results of this limited review of available information regarding the potential for recontamination at the high priority areas suggest that recontamination is possible at Duwamish / Diagonal (Area 1) as a result of phthalate contamination in CSO and stormwater discharges. However, source control efforts may be able to reduce this potential and a strategy for further source control efforts is currently being developed by Ecology for the LDW. Source control efforts similar to those now underway for Duwamish / Diagonal (see Section 3.2.1) would also be applied to the assessment of CSO or storm drain discharges at other high priority areas. Analyses conducted by Weston (2003a) for Boeing Plant 2 (Area 4) suggested that there is very little potential for recontamination of the sediments after the proposed remediation. Overall, only very limited data are currently available to assess the potential for sediment recontamination from groundwater discharge, sediment transport, and dredging. Based on the limited data presently available to assess recontamination potential, none of the seven high priority areas was screened out at this step. However, it is assumed that the potential for recontamination at each of the candidate early action sites will be assessed as part of site-specific feasibility analyses to be conducted for each of these sites.

3.3 CONSISTENCY WITH REMEDIAL ACTIONS EVALUATED FOR LDW

Remedial actions have not yet been evaluated for the LDW. This evaluation will occur in the feasibility study that will be conducted as part of the second phase of the LDW RI/FS. Therefore, the consistency evaluation at this time includes a comparison of the physical and chemical characteristics of the chemicals of potential concern (COPCs) at the high priority areas with the COPCs for the LDW as a whole. The underlying assumption in this comparison is that similar chemicals may be remediated using similar remedial actions while chemicals with different characteristics may require different remedial strategies. Strategies will be further evaluated as each site proceeds to remediation.

The two high priority areas (A and D) for which cleanups are being designed have proposed similar remedial actions: to dredge the most contaminated sediments and cap remaining areas of contamination. Sediment remediation to be proposed for any of the early action sites is likely to include consideration of similar remedial actions along with the range of existing remediation techniques (e.g., dredge and fill, capping, natural attenuation). Based on the physical conditions and the COPCs found in the LDW, multiple remediation strategies may have some utility and will likely be considered in each early action site’s feasibility analyses. Thus, the remedial actions likely to be proposed for any of the five other early action sites appear to be consistent with the remedial actions that are likely to be evaluated for the LDW.

3.4 IDENTIFIED CANDIDATE SITES

Table 3 summarizes the results of the application of management criteria discussed in Section 3 and lists the proposed candidate sites for early action. The results of the application of the second management criterion, potential for recontamination, is shown as unknown for most high priority areas because the available data are inadequate to conduct the necessary analyses. However, this step in the candidate site identification process should be thought of as exclusionary (i.e., unacceptably high potential of recontamination could eliminate a high priority area for further consideration), rather than inclusionary (i.e., analysis must be conducted before area can pass the screen), so no high priority areas were eliminated at this step.

Table 3. Candidate sites proposed by LDWG for early action

HIGH PRIORITY AREA DESIGNATION	STEP 1. NCP/MTCA CONSISTENCY	STEP 2. RECONTAMINATION POTENTIAL	STEP 3. REMEDIAL ACTION CONSISTENCY
1	Yes	Acceptable [a]	Yes
2	Yes	Unknown	Yes
3	Yes	Unknown	Yes
4	Yes	Acceptable [b]	Yes
5	Yes	Unknown	Yes
6	Yes	Unknown	Yes
7	Yes	Unknown	Yes

[a] Acceptability determination made by Ecology (Ecology 2002a) based on documents prepared by early action proponent (King County 2002a,b).

[b] Acceptability determination made in document prepared by early action proponent (Weston 2003a). This determination is being reviewed by EPA and Ecology.

With the exception of Area 1 (Duwamish / Diagonal) and Area 4 (Boeing Plant 2), there have not been investigations of the sources of sediment contamination at the high priority areas. It is assumed that the potential for recontamination at each of the other candidate sites will be conducted as part of site-specific feasibility analyses to be conducted for each site. Nevertheless, LDWG recommends seven high priority areas as candidate sites for early action (Figure 3). EPA and Ecology will consider LDWG's recommendations for these sites and may enter into negotiations with potential early action sponsors.

The results of the site prioritization process should not be used to draw any conclusions about whether or not human health or ecological risks are present at areas not identified through this process. There are many reasons why areas with contaminated sediments that may pose a human health or ecological risk may not be identified as early action sites, including:

- The Phase 1 risk assessment is based on a relatively small amount of fish, shellfish, and benthic invertebrate tissue chemistry data. Additional data collected in the Phase 2 RI may alter our current understanding of LDW contamination.
- The site identification process does not include a quantitative process to predict transfer of chemicals from sediments to biota. Instead, it assumes that identification of the upper 5th percentile areal distribution for chemicals of concern will help those reduce indirect pathway risks.
- A baseline risk assessment conducted as part of the Phase 2 RI may consider different risk thresholds for identification of COCs and areas of concern.

The purpose of the Phase 2 RI and baseline risk assessment is to reevaluate risks present at the site after gathering additional information and to determine if additional areas may require remediation.

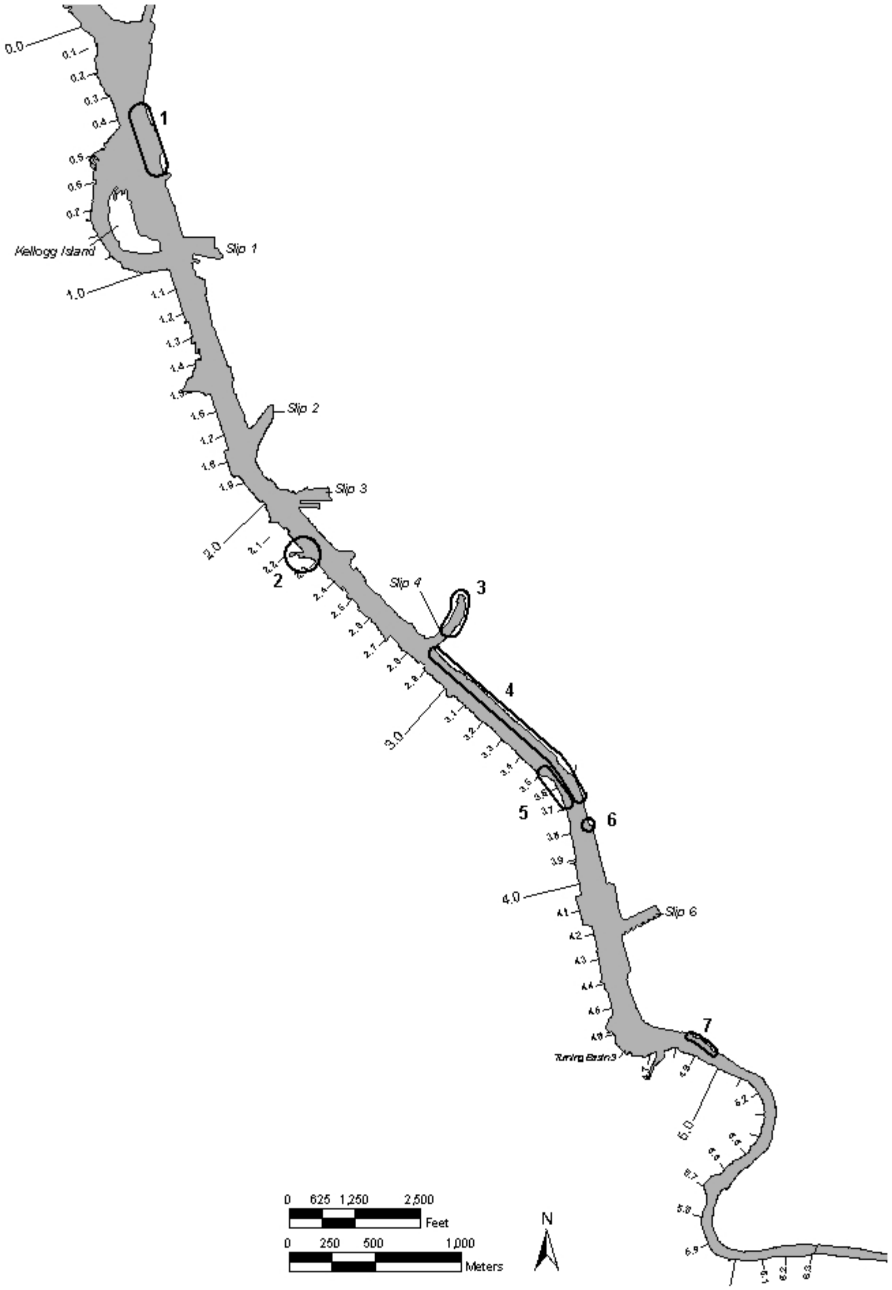

Figure 3. Candidate sites proposed by LDWG for early action

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Appendix A Description of Candidate Site Selection Criteria

The attached memorandum describes the process by which candidate site selection criteria were developed and applied. This memorandum was the first deliverable under Task 5 of the LDW RI Statement of Work. It was approved by EPA and Ecology on June 19, 2002.

Lower Duwamish Waterway Group

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

TASK 5: IDENTIFICATION OF CANDIDATE SITES FOR EARLY ACTIONS – TECHNICAL MEMORANDUM:

DESCRIPTION OF CANDIDATE SITE SELECTION CRITERIA

Prepared for

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

The Washington State Department of Ecology
Northwest Regional Office
Bellevue, WA

FINAL

June 19, 2002

Prepared by: Windward environmental LLC

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Table of Contents

1.0 Introduction

One of the goals of the Phase I Lower Duwamish Waterway Remedial Investigation (LDW RI) is to identify potential sites that may be candidates for early remedial actions. Given the availability of a large environmental data set for the LDW, particularly sediment data, there is general acknowledgement that sufficient information currently exists to identify some sites that may require remediation. The process of identifying candidate early action sites is being undertaken during Phase I in the anticipation that expediting the initiation of remediation at sites with significant risks will reduce those risks on an accelerated schedule. Any candidate sites proposed for early action will be selected in a process that is consistent with the National Contingency Plan (NCP), Washington's Model Toxic Control Act (MTCA), and EPA guidance for non-time critical removal actions. Early remedial action at these sites could be potentially implemented on accelerated schedules well before completion of the Feasibility Study and Record of Decision for the Superfund site.

Identification of candidate sites for early actions is a two-step process (Figure 1). In the first step, existing environmental data for the LDW are used to identify those sites within the study area that can be classified as high priority sites. Site prioritization will be based on the results of the scoping-phase risk assessments, which will be presented as part of the LDW RI report. The risk-based framework proposed for site prioritization is consistent with EPA's principles for managing risks from contaminated sediments (EPA 2002).

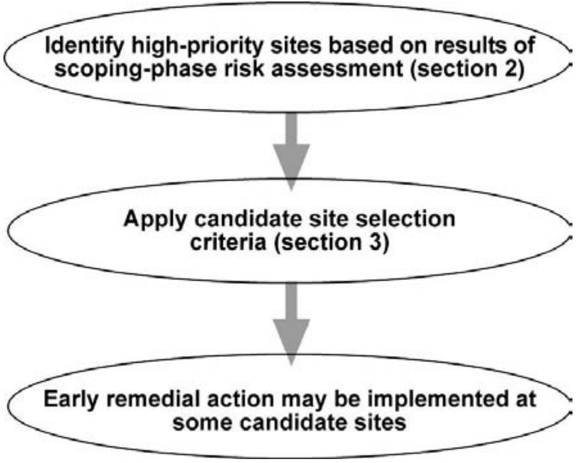


Figure 1.
Candidate site selection process overview

The site prioritization methods are described in Section 2 of this memorandum. These methods were previously described in a separate draft memorandum (Windward Environmental 2001), but they are incorporated into this document to more completely describe the identification process for candidate early action sites.

The second step in the identification process will be to determine which of the high priority sites will be suitable candidate sites for undertaking early remedial actions using management-based criteria. Selection criteria for the second step are described in Section 3. Following agency approval of the methods described in Sections 2 and 3, an additional technical memorandum will be prepared that will identify the candidate sites based on methods outlined in this memorandum. This memorandum, called the Technical Memorandum on Data Analysis and Identification of Candidate Sites

("Candidate Sites Memorandum"), is the second and final deliverable under Statement of Work (SOW) Task 5 (Identification of candidate sites for early remedial action), and will be submitted to EPA and Ecology following completion of the draft RI report.

EPA and Ecology will use the recommendations in the Candidate Sites Memorandum to determine which sites will undergo early cleanup actions. One or more LDWG member(s) may propose to enter into an agreement with EPA or Ecology to undertake one or more of the early remedial actions. For sites LDWG members do not volunteer to undertake, EPA and Ecology will identify appropriate parties to undertake these actions using EPA's potentially responsible party search.

The agencies will determine which non-LDWG candidate sites ultimately move forward based on their ability to find viable potentially responsible parties to undertake the action and to negotiate a regulatory agreement or order.

Decisions on whether candidate sites for early action will be remediated on an accelerated schedule will be made after the completion of the LDW Phase I RI. The LDW Phase II RI will include a baseline risk assessment that will evaluate risks for two exposure regimes: 1) baseline sediment conditions as they exist at the time the RI is completed, and 2) residual sediment conditions expected to exist after completion of early action projects sponsored by individual LDWG members or others. Implementing early remedial action at high priority sites is expected to substantially reduce risks associated with some of the more contaminated sites within the LDW by moving those sites into an accelerated remediation process.

2.0 Site Prioritization Methods

This section describes the proposed risk-based methods that will be used to accomplish the first step in the site identification process: identifying high priority sites within the LDW study area. High priority sites will be identified using a framework that relies on the:

- large amount of available sediment chemistry data for the LDW (data from over 1,200 surface sediment chemistry samples that provide coverage for all sections of the LDW study area)
- results of the scoping-phase human health and ecological risk assessments that are currently being conducted for the site.

The process outlined in this section will be used to identify high priority sites after the risk characterization portions of the scoping-phase risk assessments are completed; the results of the site prioritization process will be presented as part of the scoping-phase risk assessment report.

The SOW for the LDW RI states:

> In identifying high priority sites, the respondents will review sediment site prioritization methodologies that have been used in other similar applications, and will develop a prioritization scheme that adequately represents the range of conditions associated with the potential current risks to human health and the environment. It is anticipated that the selected prioritization methodology will rely on existing environmental data and the results of the scoping-phase risk assessments. Models for prioritizing sediment sites to be evaluated include, among others, those developed by Ecology, EB/DRP, King County, and the Bellingham Bay Pilot Project. The respondents will summarize these approaches and may recommend alternative approaches.

2.1 EXISTING SITE PRIORITIZATION METHODS

LDWG conducted a review of the site prioritization methods cited in the SOW. The documents reviewed included those that provide programmatic guidelines for ranking sites under the state of Washington's Sediment Management Standards (PTI 1990; Ecology 1991), applications for a bay-wide assessment (Bellingham Bay; Anchor Environmental 1999), and site-specific assessments (Elliott Bay/Duwamish Restoration Program; King County 1994). While the objectives and purposes for developing site prioritization methods were different in each of the documents reviewed, all the methods relied on sediment chemistry data as an initial factor in defining site priorities. From there, the methods began to diverge with some of them incorporating risk-based narrative goals, while others applied non-risk-based factors into their analyses (e.g., entity willing to undertake a cleanup project, source control).

King County's Sediment Management Plan (King County 1999) provides an extensive discussion of the site prioritization methods cited in the SOW. A summary of these methods is presented in Table 1, which lists seven categories of goals and criteria that describe the characteristics of the site prioritization methods. The categories include factors that pertain to human and ecological health, habitat, and the status of source control, as well as factors that address site management and technical feasibility issues. Of these, only one category, human and ecological health, is directly relevant to a risk-based process for identifying high priority sites. The other categories are specific to potential remedial actions at the site (i.e., feasibility, resource management) and the site's societal context (e.g., social and cultural factors, economic factors). Such factors, while important, are more relevant to the selection of candidate sites within the LDW for early remedial action than they are for the initial identification of high priority sites. Many of these non-risk-based factors are discussed in detail in Section 3.

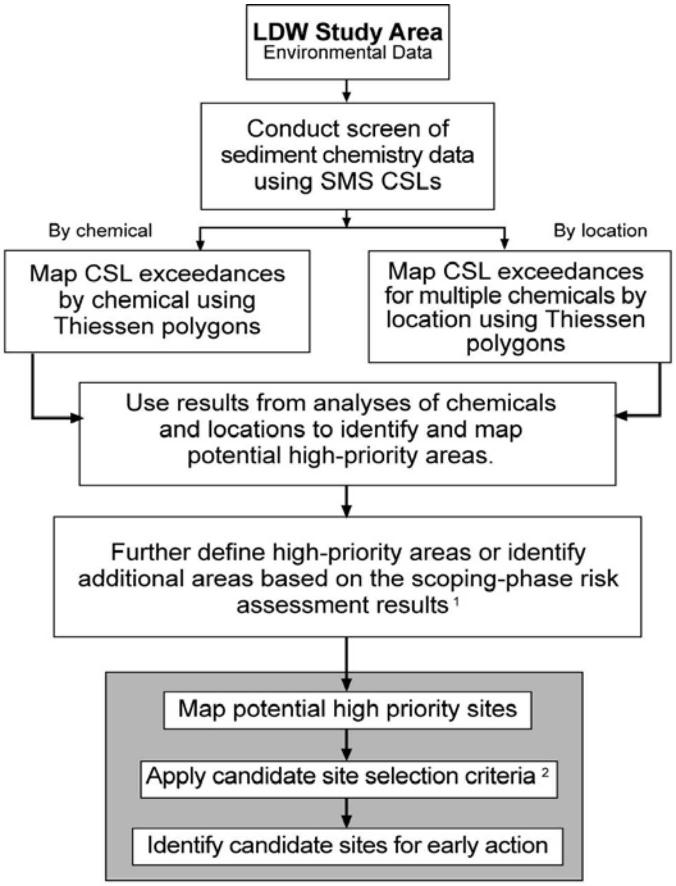
Table 1. Characteristics of existing site prioritization methods

	Bellingham Bay Goal Descriptors	SEDRANK Criteria	EB/DRP Criteria
Category 1: Human and ecological health			
	Enhance or maintain aquatic organism health, ecosystem diversity, productivity, stability, and biological function	Maximum concentration of individual chemicals	Presence of contaminated sediment (high toxicity)
	Protect human health and safety	Area of contaminated sediments	Potential for addressing injury to ecological receptors
	Protect water quality, including drinking water supplies		Potential for human health risk
	Cleanup contaminated sediment posing human or ecological health risk		
	Restore threatened and endangered fish and wildlife species		
Category 2: Source control			
	Control point and non-point sources	Historical versus ongoing sources	Control of combined sewer overflows, storm drains, industrial input and recontamination from adjacent sediment is adequate
Category 3: Habitat			
	Maintain or improve physical integrity of habitats, including shoreline erosion/accretion	Habitat complexity	Potential to incorporate extra habitat improvement
	Avoid/minimize loss of in-water habitats and compensatory mitigation		Proximity to other habitat projects or sediment remediation sites
Category 4: Social and cultural factors			
	Protect spiritual use and location	Proximity to special marine habitats and wildlife refuges	Potential for public education
	Protect/enhance ceremonial and subsistence resource use	Proximity to tribal and other commercial fisheries	
	Ensure compatibility with community goals and property uses	Proximity to recreational fisheries and public access	
	Enhance recreation, aesthetic values, public use and access		
Category 5: Efficiency and technical factors			
	Achieve technical feasibility and implementability	Water depth of contaminated sediments	Coordination with other projects
	Achieve timely completion and cost effectiveness	Net sedimentation rate	
	Integrate multiple land-use and environmental objectives and actions		
	Utilize efficient use of existing built-environment		

	BELLINGHAM BAY GOAL DESCRIPTORS	SEDRANK CRITERIA	EB/DRP CRITERIA
Category 6: Economic factors			
	Encourage water dependent commerce		
	Allow only water dependent discharges		
	Maintain/enhance navigation		
	Develop marine transportation facilities		
	Maintain/enhance commercial property use and redevelopment		
	Enhance economic vitality		
Category 7: Resource Management			
	Utilize renewable resources		
	Use dredged material beneficially		
	Conserve resources		

2.2 LDWG SITE PRIORITIZATION METHODS

Proposed site prioritization methods for the LDW are presented in Figure 2. The approach is based on the first category presented in Table 1, human and ecological health. As discussed previously, the other categories listed in Table 1 are examples of factors that could be included when identifying high priority sites that may become candidate sites for early remedial action (see Section 3).



[1] Additional details on this step are provided in Figure 3 and Section 2.2.2.
[2] Candidate site selection criteria are presented in Section 3.

Figure 2. Site prioritization method overview

The proposed approach for the LDW includes the following steps:

- Compare sediment chemistry data to Washington State Cleanup Screening Level (CSL) values to initially identify high priority areas (Section 2.2.1)
- Further define high priority areas or identify additional areas based on the scoping-phase risk assessment results (Section 2.2.2)
- Combine the CSL maps with the scoping-phase risk assessment results to identify high priority sites (Section 2.2.3)

Additional discussion on these steps is provided below.

2.2.1 Comparison of sediment chemistry data to SMS

The initial site prioritization step is to compare existing surface sediment chemistry data from the LDW to chemical criteria published in Ecology's Sediment Management Standards (SMS). Use of SMS chemical criteria to initially define areas of sediment contamination is consistent with the site-specific applications of site prioritization methods (e.g., Bellingham Bay and EB/DRP) that were described in Section 2.1. There are numeric chemical criteria for 47 individual chemicals or groups of chemicals in the SMS. If the chemical concentrations in a sediment sample are all below their respective sediment quality standard (SQS),[17] that sediment is assumed to cause no acute or chronic adverse effects to benthic invertebrates.[18] If, on the other hand, one or more chemicals are present in a sediment sample at concentrations above the cleanup screening level (CSL), that sediment sample may potentially be used to define a station cluster of potential concern for benthic invertebrates.[19] At chemical concentrations between the SQS and the CSL, sediment samples may contribute to station clusters of low concern.[20]

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[17] The SQS (WAC 173-204-320) and CSL (WAC 173-204-520) are part of the Washington State Sediment Management Standards (SMS) The SQS values represent concentrations below which adverse biological effects are considered to be unlikely. The CSL values represent concentrations above which adverse biological effects are considered to be significant. The SMS contains chemical and biological SQS and CSL standards; however, only the chemical standards are being used in the area-wide identification process because of the very limited biological data (10 surface sediment toxicity samples, 9 surface sediment samples characterized for benthic community) available for this area. The existing biological data may be used by potential early action sponsors outside the LDW RI for delineating the boundaries of a potential early action area.

[18] WAC 173-204-320(1)(a). This assumption, as stated in the SMS, is based on the expectation that potential adverse effects to benthic invertebrates are due primarily to the 47 chemicals with criteria. For the purposes of area prioritization, some of the chemicals without SMS criteria will be evaluated for receptors other than benthic invertebrates. The results of this evaluation will be included in area prioritization, as described in section 2.2.2.

[19] WAC 173-204-520(1)(a)

[20] ibid

Although exceedance of the SQS or CSL is only a predictor of effects (i.e., toxicity tests are necessary to confirm the prediction), comparison of sediment chemistry data to these criteria is one of the primary methods in the SMS for evaluating the potential need for sediment remediation. There is general acceptance that the likelihood of adverse effects to benthic invertebrates increases as either the CSL exceedance magnitude for a single chemical increases or the number of chemicals exceeding their respective CSL increases. Hence, it is reasonable to use comparisons with the CSL as an initial indicator of the potential need for sediment remediation.

One of the objectives for the LDW Phase I RI is to identify those portions of the LDW that clearly represent areas with higher chemical concentrations that may pose unacceptable risks to human health or the environment. The first step in site prioritization is to compare the available sediment chemistry data with the CSL. Consideration will be given both to the magnitude of the exceedance of the CSL for individual chemicals and the number of chemicals exceeding their respective CSL.

Maps of CSL exceedances will provide an overview of the general distribution of chemical-specific contamination with the LDW. The spatial distribution of the surface sediment chemistry data will be plotted both by chemical and by location using Thiessen polygons. Thiessen polygons associate each point in a plane with the closest neighbor for which a measurement is available. This algorithm assumes that the concentration at any point where measurements have not been made is the same as the concentration in the sample closest to that point. Additional GIS data analysis methods, such as Inverse Distance Weighting and Natural Neighbor, may also be used in future spatial analyses. LDWG will meet with EPA and Ecology to discuss the usefulness of these additional techniques for identifying high priority sites.

A series of GIS maps will be produced that depict those areas in which the sediment concentration for an individual chemical is above the respective CSL. These maps will include the exceedance ratio (i.e., concentration divided by CSL) as well. No specific boundaries will be drawn around the high priority sites in the candidate site identification document.

The SMS rule describes a process by which station clusters of potential concern are identified. A cluster of potential concern is defined as several stations that exhibit a similar pattern of chemical contamination. LDWG is adopting a similar convention using Thiessen polygons. A high priority site will be defined as three or more contiguous Thiessen polygons with concentrations in excess of the CSL. Areas with three or more Thiessen polygons with CSL exceedances in close proximity to one another will also be considered. Individual stations with a high risk potential that are otherwise surrounded by much lower risk stations will be further evaluated, potentially including confirmatory sampling and analyses, in the Phase II RI.

Individually, the maps may display patterns of contamination for each chemical, but they do not represent the potential impact that might be associated with having multiple chemicals exceeding their respective CSLs within an area. To address the issue of co-occurrence, GIS maps of multiple chemicals by location will be created using a variety of methods, potentially including: 1) the number of chemicals with CSL exceedances in a given sediment sample, 2) the sum of the CSL exceedance ratios for individual chemicals (i.e., the CSL exceedance ratio for an individual chemical is the concentration of that chemical in a given sediment sample divided by its CSL), and 3) the average[21] CSL exceedance ratio for a given sediment sample. These three methods for addressing multiple chemicals are given as examples. LDWG, EPA, and Ecology will meet prior to completion of the second Task 5 memorandum (candidate site identification) to discuss specific mapping techniques.

Each example mapping method provides a different evaluation of the potential impact that the presence of multiple chemicals may have on identifying high priority sites. The number of chemicals with CSL exceedances will provide useful information concerning the general levels of contamination at a sampling location. The sum of the CSL exceedance ratios and the average CSL exceedance ratio provide an indication of the potential risk posed by sediments that exceed the CSL (i.e., magnitude of CSL exceedance). The single-chemical and multiple-chemical maps will be distilled into a single map displaying initial high priority sites. More complicated analytical methods involving differential weighting of chemicals or locations may also be developed. If such methods are considered, LDWG will submit an addendum to this Technical Memorandum describing the proposed methods and the rationale for their application.

2.2.2 Use of scoping-phase risk assessment results for site prioritization

The comparisons described in Section 2.2.1 focus only on SMS, which are relevant to the health of benthic invertebrate species with limited home ranges. To incorporate potential human health risks or risks to other ecological receptors of concern (ROCs), specific exposure scenarios and pathways will be evaluated on a receptor-specific basis. The applicability of each human health risk exposure scenario or ecological receptor pathway to verifying high priority sites or identifying additional sites depends largely on the site specificity of the activity and the home range or migratory behavior of the organisms involved.

Table 2 classifies each potential human health risk exposure scenario and ecological receptor pathway based on their perceived ability to identify high priority sites. For

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[21] The average and sum of exceedance ratios will be calculated for all chemicals whose concentrations exceeded their respective CSLs; chemicals without exceedances will not be included in the calculations.

site prioritization purposes, exposure scenarios and ecological receptor pathways are classified as representing either direct or indirect exposure. Pathways with direct sediment exposure by the targeted receptor include dermal contact and incidental ingestion during human beach play. Pathways for which indirect exposure to sediment through diet represents the majority of the chemical-specific exposure will also be used for site prioritization, but there is an uncertain relationship between mobile prey items (the primary exposure source) and chemical contamination at a specific location.

Table 2. Use of each receptor of concern in site prioritization

RECEPTOR	EXPOSURE ROUTE	EXPOSURE AREA OF INDIVIDUAL RELATIVE TO POTENTIAL HIGH PRIORITY SITES	USE IN SITE PRIORITIZATION
Benthic invertebrates	Direct – diet and contact	smaller – individuals generally have a limited home range	Screening against CSL polygon by polygon
Juvenile chinook salmon	Indirect – diet	larger – individuals traverse entire study area	Evaluate locations where chemical of concern (COC) concentrations are highest
English sole	Indirect – diet; direct – incidental ingestion and contact	larger – particularly in winter, when individuals migrate outside LDW	Evaluate locations where COC concentrations are highest [a]
Bull trout	Indirect – diet	larger – individuals traverse entire study area	Evaluate locations where COC concentrations are highest
Great blue heron	Indirect – diet; direct – incidental ingestion and contact	larger – individuals forage mobile fish over a wide area	Evaluate locations where COC concentrations are highest [a]
Bald eagle	Indirect – diet	larger – individuals use LDW only occasionally and consume mobile prey	Evaluate locations where COC concentrations are highest
Spotted sandpiper	Indirect – diet; direct – incidental ingestion and contact	larger and smaller – individuals are migratory and forage sessile prey	Evaluate locations where COC concentrations are highest [a]
River otter	Indirect – diet; direct – incidental ingestion and contact	larger – individuals forage mobile prey over wide area	Evaluate locations where COC concentrations are highest [a]
Harbor seal	Indirect – diet; direct – incidental contact	larger – individuals use LDW only occasionally and consume mobile prey	Evaluate locations where COC concentrations are highest [a]
Emergent aquatic plants	Direct – root uptake	smaller – plants are rooted	Due to great uncertainty in effects data, this ROC will not be used in site prioritization
People eating fish	Indirect – diet	larger – some individual people may show high site fidelity, but target fish species may range much further	Evaluate locations where COC concentrations are highest
People netfishing	Direct – incidental ingestion and contact	smaller or larger – individual fishing behavior is quite variable	Thiessen polygons with concentrations in excess of risk threshold will be identified
People playing on beach	Direct – incidental ingestion and contact	smaller or larger – suitable beach play areas may be smaller than priority sites, but individuals may frequent multiple areas	Used in intertidal only; Thiessen polygons with concentrations in excess of risk threshold will be identified

[a] Receptors with both direct and indirect exposure to sediments will be treated the same, with respect to the identification of high priority sites, as receptors with only indirect exposure based on the assumption that the indirect pathway (i.e., diet) contributes more to overall exposure than does the direct pathway

Figure 3 provides additional details on the quantitative process that will be used to evaluate the direct and indirect pathways described in Table 2.

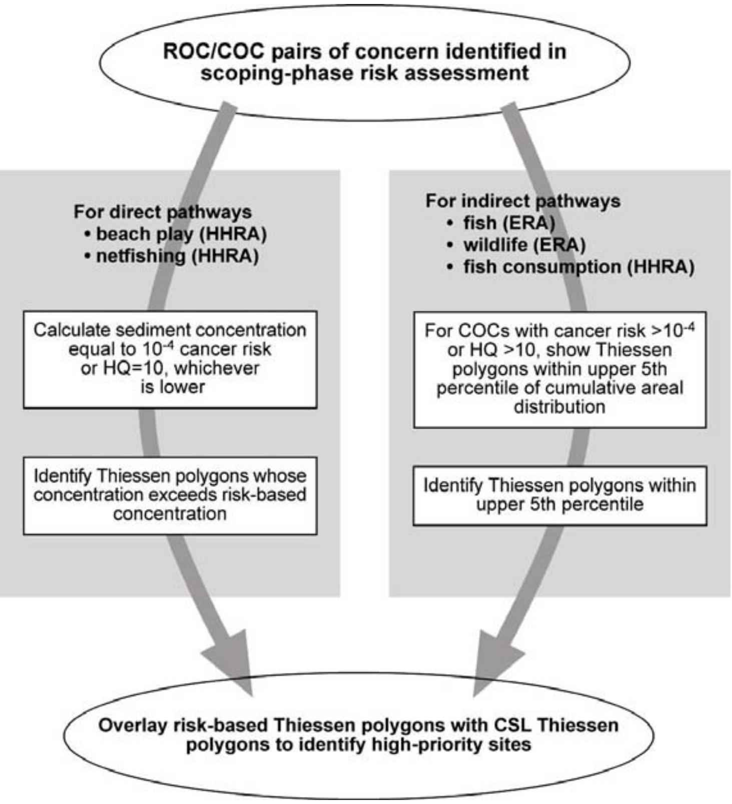

Figure 3.
Use of scoping-phase risk assessment results for site prioritization

2.2.2.1 Direct sediment exposure pathways

Site prioritization for direct sediment exposure pathways will be based on sediment chemistry data. Unlike the methods used to characterize potential effects to the benthic community, however, exposure for other receptors is typically over relatively large areas. As identified in Table 2, there are two direct sediment exposure pathways, other than the benthic community pathway, that will be used to identify high priority sites: exposure of humans to sediment through netfishing and beach play.

For the purposes of identifying high priority sites for direct sediment exposure pathways, risk-based sediment concentrations will be calculated with the equations used to calculate human health risk for the netfishing and beach play scenarios. Combined exposure via the oral and dermal routes will be used for each scenario. For COCs identified in the scoping-phase risk assessment, risk-based sediment concentrations will be calculated for a cancer risk of 10^{-4} and/or a hazard quotient of 10 for non-carcinogenic effects. If cancer and non-cancer endpoints are both applicable for that COC, the lower of the two risk-based sediment concentrations will be used for mapping (Figure 3). The maps will indicate which Thiessen polygons have sediment concentrations exceeding risk-based concentrations. Only intertidal polygons will be evaluated for the beach play scenario. Both intertidal and subtidal polygons will be evaluated for the tribal net fisher scenario. Qualitative evaluation of combined cancer risks and hazard quotients for multiple substances in different regions of the river will be done to assist in ranking the priority of certain sites for early remedial action. The selected risk thresholds reflect the objectives of the site prioritization process, and are only meant to identify areas of concern for early cleanup actions, and not to identify the boundaries of these areas. The risk thresholds are unrelated to any risk-based decisions that may occur in the Phase II RI.

The revised risk-based sediment concentrations for each COC will be compared to concentrations associated with each Thiessen polygon. This comparison is quantitatively identical to the procedures used to construct the CSL maps, although the benchmark concentrations (CSL vs. risk-based sediment concentrations) are different. This information will be used to identify high priority sites using the methods described in Section 2.2.3.

2.2.2.2 Indirect sediment exposure pathways

Site prioritization for indirect exposure pathways will also be based on sediment chemistry data. Indirect exposures cannot be linked directly back to sediment concentrations because the exposures and risks are calculated from chemical concentrations in tissue, not from sediment concentrations. Calculation of a sediment concentration associated with a particular risk threshold is not possible for these pathways without modeling the transfer of chemicals between sediment and tissue. Modeling of this type is not being performed in the scoping-phase risk assessments, but will be performed in the baseline risk assessment during the Phase II RI. In addition, most of the indirect exposure pathways are not related to specific areas of the site, but instead are related to chemicals in sediment throughout the entire site.

Because the scoping phase risk assessments do not include modeling to directly link risks from indirect exposure pathways to sediment chemicals, the proposed site prioritization method for indirect pathways makes the general assumption that areas of higher sediment concentrations are associated with higher risks. Remediating areas with the highest concentrations will reduce potential risks. The proposed method will identify an upper percentile of the overall area with the greatest potential risk. Use of an upper percentile area rather than an upper percentile of concentration accounts for the variable sampling density throughout the LDW.[22] An upper percentile equivalent to 5% of the overall area is proposed as a cutoff for identification of high priority sites.

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[22] Percentile ranking of chemical concentrations without consideration of the area represented by each polygon would yield much higher concentrations compared to the proposed method that incorporates polygon area. For example, there are approximately 1,000 Thiessen polygons for total PCBs. The upper

COCs must exceed the indirect pathways risk thresholds shown in Figure 3 in order to be included in the area analysis. COCs for which the upper percentile area method is applicable will be identified by:

1. Computing the cancer risk and hazard quotient (HQ)[23] for indirect exposure pathways (e.g., fish consumption) using the existing concentration data (either the 95% UCL or the maximum concentration) and the exposure equations and parameter values contained within the scoping-phase risk assessment.
2. Comparing the HQ or cancer risk for a given chemical (or HQ and cancer risk if both are applicable) with threshold values of 10 and 10^{-4}, respectively.
3. Any COC with values exceeding either the HQ or cancer risk thresholds will undergo spatial analysis, as described below.

The proposed method for calculating the upper 5th percentile area associated with each COC is as follows:

1. For each COC identified in the scoping-phase risk assessment, Thiessen polygons will be constructed around each sampling location. The area of each polygon will be calculated in the GIS.
2. Polygons will be ranked from high to low, based on COC concentrations.
3. Starting with the polygons with the highest concentration and proceeding to locations with successively lower concentrations, a cumulative sum of polygon areas will be calculated, until that sum reaches the specified percentile of the total area for all polygons.

Several sets of polygons will be produced using this method. This information will be used to identify high priority sites using the methods described in Section 2.2.3.

2.2.3 Combining CSL maps with other scoping-phase risk assessment results

The maps generated using the procedures described in Sections 2.2.1 and 2.2.2 will all have the same format (i.e., Thiessen polygons) although the definition of polygon categories differs among the three approaches (benthic CSL, other direct sediment pathways, and indirect sediment pathways). Consequently, all the information from

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5th percentile concentration calculated without consideration of polygon area is approximately four times higher than the concentration associated with the upper 5th percentile of the cumulative areal distribution.

[23] A single HQ is calculated for each chemical in the scoping-phase human health risk assessment. Two HQs, one based on a no-effect level and one based on a lowest-effect level, are calculated for each COC in the scoping-phase ecological risk assessment. For indirect pathways leading to ecological receptors, the low-effect level HQ will be used to identify COCs to be considered in identifying high priority areas.

the three different approaches can be mapped simultaneously.[24] Although a single map may be created that shows priority sites identified for any ROC/COC pair, it is likely that multiple maps will be necessary to fully describe the differences between the benthic CSL maps and the maps described in Section 2.2.2. Each map will assign labels to high priority sites. High priority sites will be identified by three or more contiguous polygons identified by any of the methods described above: 1) CSL exceedance, 2) exceedance of risk-based sediment concentration for direct pathways, or 3) within the upper 5th percentile of the cumulative areal distribution for an indirect pathway COC. Areas with three or more polygons in close proximity will also be considered.

Tabular information about each high priority site will be presented so that reviewers can determine how each priority site was identified. The tabular information will include a qualitative description of habitat and human use characteristics. High priority sites will not be ranked or scored relative to one another in the candidate site selection process.

The identification of high priority sites and the subsequent selection of candidate sites for early action during the Phase I RI will not define the spatial area of each site potentially subject to remediation. Rather, the definition of such areas will be conducted as part of subsequent activities for each candidate site outside of the AOC. Those activities are likely to include additional sampling and analyses to more precisely identify the area (and volume) of sediments potentially subject to remediation. The identification of high priority sites is only intended to suggest, based on existing data, those general areas where significant risks occur and where early action may reduce those risks on an accelerated schedule.

The Candidate Sites Memorandum will emphasize that the results of the site prioritization process should not be used to draw any conclusions about whether or not human health or ecological risks are present at areas not identified through this process. There are many reasons why areas with contaminated sediments that pose a human health or ecological risk may not be identified, including:

- The scoping-phase risk assessment is based on limited chemical data, especially fish, shellfish, and benthic invertebrate tissue data.
- The site identification process does not take into account transfer of contaminants from sediments to biota, except through the assumption that identification of the upper 5th percentile areal distribution for some contaminants will address indirect pathway risks.

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[24] Thiessen polygons generated for different chemicals may have different shapes because not all sediment samples were analyzed for all chemicals. Hence, comparison of polygon distributions across chemicals may have to be done qualitatively in some cases.

- A baseline risk assessment conducted as part of the Phase II LDW RI will consider different risk thresholds for identification of COCs and areas of concern and will consider cumulative risks for receptors exposed to contaminants via multiple pathways.

The purpose of the Phase II RI and baseline risk assessment is to reevaluate risks present at the site after gathering additional information and to identify additional areas that may require remediation.

The objective for defining high priority sites is to identify those sites that are sufficiently contaminated that early remediation, if feasible, represents a sound site management decision. Whether an identified high priority site is chosen as a candidate site for early remedial action will be dependent upon the outcome of the candidate site selection process (Section 3). If a high priority site is not selected as a candidate site, that site will be further assessed during the LDW Phase II RI.

3.0 LDWG Candidate Site Selection Criteria

The SOW for the LDW RI states that the candidate site selection criteria should include factors that relate to the relative risks posed by the site, and whether the site can be effectively remediated in such a way that recontamination is minimized. In addition, the SOW recognizes that impediments may exist to identifying a high priority site as a candidate site for early action, such as landowner constraints. Landowner constraints may arise because of a lack of any apparent connection between the identified high priority site and past or ongoing activities of any viable party, or lack of resources to undertake an early action at this time.

Several efforts to develop candidate site selection criteria have been undertaken within the last 10 years in Puget Sound (see Section 2.1). However, because these efforts were not developed specifically for Superfund sites, federal regulations [i.e., CERCLA (42USC§9601) and NCP (40CFR300)], associated federal guidance (e.g., USDOE 1995), and state regulations (MTCA, WAC 173-340) were also reviewed to determine if additional or alternative criteria should be included.

Based on this review, the process outlined in USDOE (1995) was deemed to be the most straightforward and regulatory-based approach available. The process outlined by USDOE is consistent with NCP, EPA, and State of Washington guidance on identifying sites that may be subject to non-time critical removal actions. Using this approach, three general criteria were selected for the proposed candidate site selection process (Figure 4). This flowchart captures the sequential and qualitative nature of the candidate site screen.

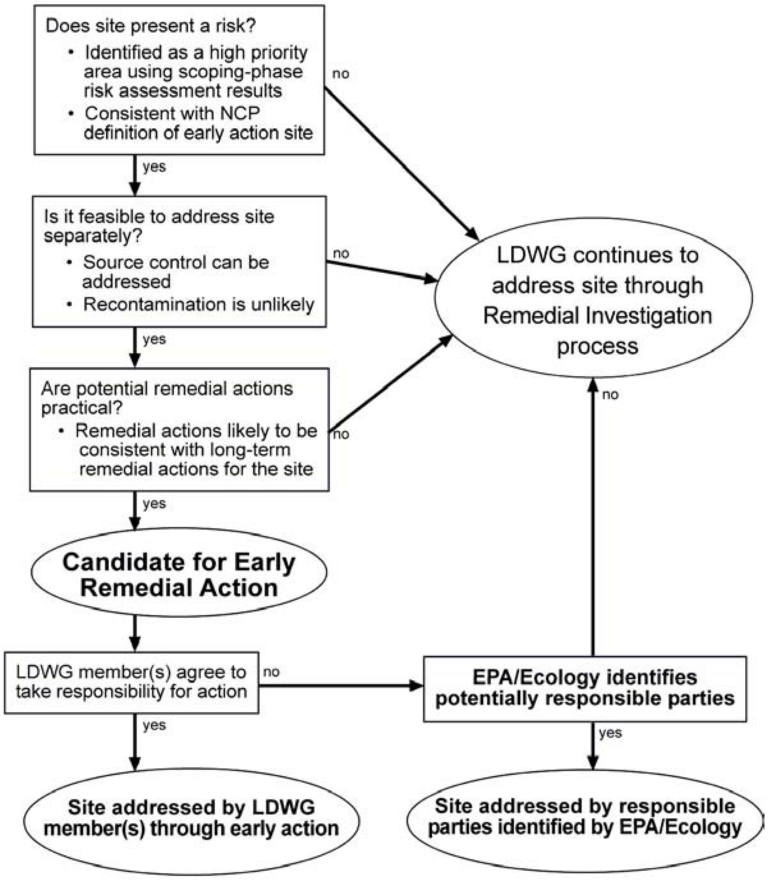

Figure 4. Proposed candidate site selection method

Each high priority site identified using the risk-based methods described in Section 2.2 will be sequentially evaluated using the candidate site selection criteria described below. If a high priority site does not meet all these criteria, then the site will not be identified as a candidate site for early remedial action. LDWG will meet with EPA and Ecology prior to completing the Candidate Sites Memorandum. LDWG will provide draft data and maps developed according to the methods described in Section 2.2, as well as other maps requested by the agencies, to EPA and Ecology for their review prior to the meeting. At the meeting, the maps and data will be reviewed to determine whether areas meeting the screening criteria for high priority sites warrant designation as proposed candidate sites for early action.

- **Risk-based Site Prioritization**: The first step in determining candidate sites for early remedial action is to identify sites associated with elevated risk to the environment and human health. The risk-based approach for identifying high priority sites is outlined in Section 2.2. Each identified high priority site will, in turn, be further evaluated to assure that its identification as a high priority site is consistent with the NCP and MTCA before it is identified as a candidate site for early remedial action. The NCP requires that decisions on removal actions be based on threats to human or animal populations, sensitive ecosystems, or other significant factors affecting the health or welfare of the public, or the environment (40 CFR §300.415).
- **Ability to Isolate Site**: The next step in identifying candidate sites is to assess the probability of recontamination to a level that would constitute an unacceptable risk to human health or the environment. Candidate sites will be selected for early remedial action only if they have a low probability of recontamination because: 1) the site is currently contaminated as the result of historical inputs with little or no expectation of current sources, or 2) current sources, if present, can be meaningfully addressed as part of the early action process or under other regulatory programs, even if all source control actions have not been undertaken or completed. Readily available documents will be reviewed for information on historical site use, as well as ongoing or planned source control activities. This information will be used to evaluate the likelihood that source control measures, if required at an early action site, would be successful. The benefits of an interim action and the ability of other source control programs under development to address potential future recontamination will also be considered. The potential for recontamination from upstream sources, including other high priority sites, will also be qualitatively assessed, relying primarily on analyses from other studies. The source control analysis to be conducted as part of the candidate site selection process will be qualitative in nature. No specific criteria for characterizing source control will be developed during this process. If the qualitative

information reviewed suggests additional source control analysis should be conducted for a particular site, it will be conducted outside the AOC for the LDW Phase I RI. EPA and Ecology will ultimately make determinations of whether and when source control is adequately addressed at a specific site.

- **Consistency with Long-Term Actions**: In addition, the high priority sites will be evaluated for the likelihood that the remedial actions taken will be consistent with the preferred remedial actions identified for the LDW. The NCP requires that, to the extent practicable, all early remedial actions should contribute to the efficient performance of any anticipated long-term remedial action for the site (40 CFR §300.415). A brief qualitative assessment of potential remedial alternatives will be conducted by LDWG for each high priority site to determine whether remediation is possible utilizing remedial alternatives commonly used at sediment remediation sites. The assessment will include an evaluation of the likely technical feasibility of remedial and disposal alternatives, the reliability of the remedial alternatives technology, and the long-term effectiveness and permanence of the alternatives (EPA 1988). For the purposes of this assessment, it is assumed that the primary remedial alternatives will be removal and capping, or some combination of these two alternatives. Natural recovery would also be considered as part of any remedial action plan. A more detailed analysis of this topic will be conducted outside the AOC/SOW by the parties responsible for the site.

Once a site has been determined to be of high priority and low recontamination potential, and the potential remediation alternatives have been shown to be consistent with long-term actions, willing sponsor(s) are needed to further assess the site for early remedial action and to undertake any identified remedial action. Individual LDWG members may propose to take responsibility for specific candidate sites. Early remedial action at these candidate sites may then proceed on an accelerated schedule outside the AOC/SOW, in coordination with EPA and Ecology. Potential candidate sites without a LDWG sponsor will be referred to EPA and Ecology. EPA and Ecology will identify whether there are appropriate parties to undertake those cleanup actions through the Potentially Responsible Party search currently being conducted by EPA. EPA and Ecology will negotiate an Administrative Order on Consent or other regulatory agreement with the appropriate parties to further study and clean up each candidate site. Candidate sites without LDWG or other sponsors will continue to be addressed through the RI/FS process.

4.0 References

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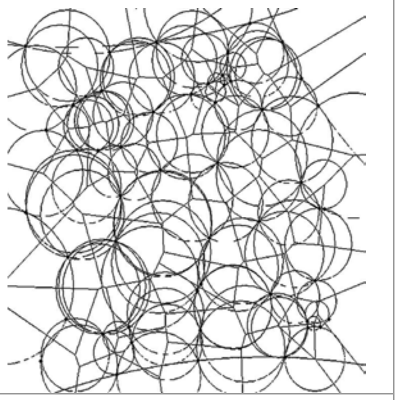
Appendix B Use of Thiessen Polygons for Spatial Analysis

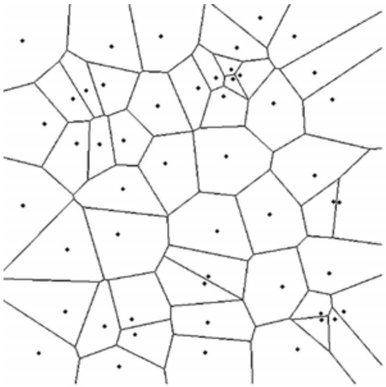
Use of Thiessen polygons (also called Voronoi diagrams) is a relatively simple method used by scientists to account for spatial variability in sampling intensity. The Thiessen polygon associates each point in a plane with the closest sampling location for which a measurement is available (Burmaster and Thompson 1997). In effect, this algorithm assumes that the concentration at any point where measurements have not been made is the same as the concentration in the sample closest to that point.

For example, assume that sampling points exist as shown to the right. The density of the points is uneven, so simply taking averages from all sampling points would yield a result that does not accurately reflect the concentration distribution over the entire area.

Thiessen polygons are defined by circumcircles. Each circumcircle passes through three data points, as shown at right. No sampling points are located within a circumcircle and no other point is closer to the center of the circle than the points that make up the circle.



Polygons are defined by connecting the centers of each circumcircle containing the point about which a polygon is being constructed. The vertices of the polygon are the centers of each circumcircle. Each side of a polygon bisects that line segment joining each pair of points. Concentrations associated with a particular point within the diagram can now be associated with the entire polygon. This allows area-weighted concentrations to be calculated.



There are several advantages and disadvantages to this method compared to more sophisticated methods of spatial analysis. The primary advantage is the relative simplicity of the method. The method does not require any assumptions regarding weighting of adjacent sampling points or the number of adjacent sampling points to incorporate in the interpolation. Consequently, the technical basis for the method can be easily agreed on by multiple parties. The method is computationally simple in the GIS and can be employed quickly in ArcMap® or ArcView® without additional software extensions. The method is best suited for viewing large areas like the LDW where sampling density is relatively high. In such cases, reasonably accurate calculations of area-weighted average concentrations are possible.

The primary disadvantage of the method is that only the nearest sampling point is used to assign concentrations to a polygon. Concentration data from other adjacent sampling points is discarded. Consequently, there can be large discontinuities in concentrations between adjacent polygons. Thiessen polygons are not well-suited for defining contours or boundaries between different concentration ranges, particularly for small areas with only a few sampling points. Since boundaries for early action areas are not being defined in this memorandum, this disadvantage of the Thiessen polygon method is not applicable.

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Appendix C Selected Sediment Chemistry Data Associated with High Priority Areas

The data associated with the labeled sampling locations on Map 9 (high priority area A) and Map 12 (high priority area D) are listed in this appendix because there are too many records to list directly on the maps, as was done for Maps 10, 11, 13, and 14. Each table includes the location numbers corresponding to the map and exceedance factors (EFs) based on SQS (or SL) and CSL (or ML). The exceedance factor is the ratio of the observed concentration at that location to the applicable standard.

Table C-1. Sediment chemistry data associated with high priority area A (Duwamish/Diagonal)

LOCATION #	PARAMETER	SQS EF	CSL EF
51	PCBs (total-calc'd)	6.7	1.2
207	PCBs (total-calc'd)	1.1	0.21
215	PCBs (total-calc'd)	1.1	0.20
350	1,4-Dichlorobenzene	1.0	0.35
350	Bis(2-ethylhexyl)phthalate	3.8	2.3
350	Butyl benzyl phthalate	5.2	0.40
351	2,4-Dimethylphenol	10	10
351	Bis(2-ethylhexyl)phthalate	2.9	1.8
351	Butyl benzyl phthalate	1.2	0.090
352	Bis(2-ethylhexyl)phthalate	2.3	1.4
352	Butyl benzyl phthalate	1.4	0.10
539	PCBs (total-calc'd)	1.8	0.33
539	Phenol	1.3	0.44
572	Bis(2-ethylhexyl)phthalate	1.6	0.95
572	Butyl benzyl phthalate	1.1	0.082
573	Bis(2-ethylhexyl)phthalate	2.1	1.3
573	Butyl benzyl phthalate	1.5	0.11
574	Bis(2-ethylhexyl)phthalate	2.0	1.2
574	Butyl benzyl phthalate	2.3	0.18
575	1,2-Dichlorobenzene	4.8	4.8
575	Bis(2-ethylhexyl)phthalate	4.9	3.0
575	Butyl benzyl phthalate	4.0	0.31
576	Bis(2-ethylhexyl)phthalate	4.2	2.5
576	Butyl benzyl phthalate	2.2	0.17
577	Bis(2-ethylhexyl)phthalate	1.2	0.70
578	Bis(2-ethylhexyl)phthalate	1.0	0.62
578	PCBs (total-calc'd)	5.1	0.95

LOCATION #	PARAMETER	SQS EF	CSL EF
624	Bis(2-ethylhexyl)phthalate	1.1	0.67
624	PCBs (total-calc'd)	11	2.0
625	Bis(2-ethylhexyl)phthalate	1.9	1.2
625	Butyl benzyl phthalate	1.1	0.086
647	Bis(2-ethylhexyl)phthalate	1.8	1.1
647	DDTs (total-calc'd)	1.2	0.12
647	PCBs (total-calc'd)	6.9	1.3
648	Bis(2-ethylhexyl)phthalate	1.3	0.78
648	PCBs (total-calc'd)	1.8	0.34
990	Bis(2-ethylhexyl)phthalate	5.0	3.0
990	Butyl benzyl phthalate	2.1	0.16
990	DDTs (total-calc'd)	1.0	0.10
990	PCBs (total-calc'd)	2.0	0.37
991	Bis(2-ethylhexyl)phthalate	3.4	2.1
991	Butyl benzyl phthalate	1.5	0.11
992	Bis(2-ethylhexyl)phthalate	5.7	3.4
992	Butyl benzyl phthalate	2.7	0.21
993	Bis(2-ethylhexyl)phthalate	6.9	4.1
993	Butyl benzyl phthalate	2.7	0.21
993	DDTs (total-calc'd)	1.7	0.17
993	Mercury	5.1	3.6
993	PCBs (total-calc'd)	1.2	0.21
994	Bis(2-ethylhexyl)phthalate	5.2	3.1
994	Butyl benzyl phthalate	11	0.84
994	Zinc	1.1	0.47
995	Bis(2-ethylhexyl)phthalate	4.8	2.9
995	Butyl benzyl phthalate	2.4	0.18
995	DDTs (total-calc'd)	1.3	0.13
996	Bis(2-ethylhexyl)phthalate	3.0	1.8
996	Butyl benzyl phthalate	2.0	0.15
996	PCBs (total-calc'd)	1.1	0.20
997	Bis(2-ethylhexyl)phthalate	1.1	0.68
997	Butyl benzyl phthalate	1.4	0.11
998	Bis(2-ethylhexyl)phthalate	2.4	1.4
998	Butyl benzyl phthalate	2.3	0.17
998	Chrysene	1.1	0.24
998	Fluoranthene	2.3	0.31
998	Total HPAH (calc'd)	1.1	0.20
999	Bis(2-ethylhexyl)phthalate	2.3	1.4
999	Butyl benzyl phthalate	1.4	0.11

LOCATION #	PARAMETER	SQS EF	CSL EF
999	DDTs (total-calc'd)	1.3	0.13
999	PCBs (total-calc'd)	1.6	0.29
1001	Bis(2-ethylhexyl)phthalate	1.2	0.70
1001	PCBs (total-calc'd)	8.8	1.6
1003	Butyl benzyl phthalate	1.1	0.088
1005	Bis(2-ethylhexyl)phthalate	1.5	0.87
1005	Butyl benzyl phthalate	1.1	0.085
1005	PCBs (total-calc'd)	1.2	0.22
1006	Bis(2-ethylhexyl)phthalate	3.7	2.2
1006	Butyl benzyl phthalate	1.2	0.094
1006	DDTs (total-calc'd)	2.3	0.23
1007	Bis(2-ethylhexyl)phthalate	3.4	2.1
1007	Butyl benzyl phthalate	1.8	0.14
1008	Bis(2-ethylhexyl)phthalate	3.8	2.3
1008	Butyl benzyl phthalate	3.2	0.24
1008	DDTs (total-calc'd)	2.6	0.26
1009	Bis(2-ethylhexyl)phthalate	3.9	2.3
1009	Butyl benzyl phthalate	1.1	0.083
1009	PCBs (total-calc'd)	1.2	0.23
1009	Phenol	2.1	0.73
1010	Bis(2-ethylhexyl)phthalate	4.1	2.5
1010	Butyl benzyl phthalate	2.3	0.18
1010	DDTs (total-calc'd)	6.4	0.64
1011	Bis(2-ethylhexyl)phthalate	11	6.5
1011	Butyl benzyl phthalate	2.1	0.16
1011	DDTs (total-calc'd)	1.2	0.12
1011	PCBs (total-calc'd)	1.5	0.27
1012	Bis(2-ethylhexyl)phthalate	1.7	1.0
1012	PCBs (total-calc'd)	1.5	0.27
1013	Bis(2-ethylhexyl)phthalate	1.9	1.1
1013	Butyl benzyl phthalate	1.3	0.099
1013	PCBs (total-calc'd)	1.0	0.19
1014	Bis(2-ethylhexyl)phthalate	1.8	1.1
1014	Butyl benzyl phthalate	1.6	0.13
1014	PCBs (total-calc'd)	2.2	0.41
1015	Bis(2-ethylhexyl)phthalate	8.2	5.0
1015	Butyl benzyl phthalate	16	1.2
1015	Mercury	1.1	0.78
1015	PCBs (total-calc'd)	47	8.6
1016	1,2,4-Trichlorobenzene	2.7	1.2

LOCATION #	PARAMETER	SQS EF	CSL EF
1016	1,2-Dichlorobenzene	2.8	2.8
1016	1,4-Dichlorobenzene	6.9	2.4
1016	Bis(2-ethylhexyl)phthalate	3.0	1.8
1016	Cadmium	2.3	1.7
1016	Chromium	2.2	2.1
1016	DDTs (total-calc'd)	33	3.3
1016	Lead	1.1	0.94
1016	Mercury	7.2	5.0
1016	PCBs (total-calc'd)	53	9.7
1016	Silver	7.1	7.1
1016	Zinc	2.1	0.91
1017	Bis(2-ethylhexyl)phthalate	1.8	1.1
1017	DDTs (total-calc'd)	1.4	0.14
1017	PCBs (total-calc'd)	9.9	1.8
1017	Zinc	1.2	0.50
1018	Bis(2-ethylhexyl)phthalate	1.2	0.74
1018	Mercury	1.4	0.95
1018	PCBs (total-calc'd)	2.0	0.37
1019	Bis(2-ethylhexyl)phthalate	1.4	0.85
1019	DDTs (total-calc'd)	13	1.3
1019	PCBs (total-calc'd)	4.5	0.83
1020	Bis(2-ethylhexyl)phthalate	1.1	0.64
1020	PCBs (total-calc'd)	2.2	0.40
1021	Arsenic	1.5	0.91
1021	Bis(2-ethylhexyl)phthalate	1.7	1.0
1021	Butyl benzyl phthalate	1.3	0.10
1021	DDTs (total-calc'd)	1.2	0.12
1021	PCBs (total-calc'd)	4.9	0.90
1021	Zinc	1.1	0.45
1022	Bis(2-ethylhexyl)phthalate	1.3	0.79
1022	Butyl benzyl phthalate	1.7	0.13
1022	PCBs (total-calc'd)	1.4	0.27
1023	Bis(2-ethylhexyl)phthalate	1.3	0.77
1023	PCBs (total-calc'd)	1.6	0.3
1024	Bis(2-ethylhexyl)phthalate	1.1	0.67
1024	DDTs (total-calc'd)	6.7	0.67
1024	Mercury	1.4	0.95
1024	PCBs (total-calc'd)	1.8	0.34
1025	Bis(2-ethylhexyl)phthalate	1.2	0.70
1025	PCBs (total-calc'd)	2.7	0.50

LOCATION #	PARAMETER	SQS EF	CSL EF
1027	PCBs (total-calc'd)	3.3	0.62
1028	Hexachlorobenzene	3.6	0.60
1028	PCBs (total-calc'd)	1.1	0.21
1029	Bis(2-ethylhexyl)phthalate	1.1	0.67
1029	PCBs (total-calc'd)	2.5	0.45
1031	Bis(2-ethylhexyl)phthalate	1.7	1.0
1031	Butyl benzyl phthalate	1.1	0.088
1031	PCBs (total-calc'd)	3.5	0.65
1032	Bis(2-ethylhexyl)phthalate	2.6	1.6
1032	Butyl benzyl phthalate	1.3	0.097
1032	PCBs (total-calc'd)	2.3	0.42
1033	Bis(2-ethylhexyl)phthalate	4.4	2.7
1033	Butyl benzyl phthalate	1.2	0.091
1033	Hexachlorobenzene	1.4	0.23
1033	PCBs (total-calc'd)	28	5.1
1034	Bis(2-ethylhexyl)phthalate	1.2	0.72
1034	Butyl benzyl phthalate	1.3	0.10
1034	PCBs (total-calc'd)	2.4	0.43
1035	4-Methylphenol	1.1	1.1
1035	Bis(2-ethylhexyl)phthalate	1.5	0.92
1035	Butyl benzyl phthalate	1.1	0.082
1035	PCBs (total-calc'd)	1.1	0.21
1036	Bis(2-ethylhexyl)phthalate	1.0	0.62
1036	PCBs (total-calc'd)	2.2	0.4
1037	Bis(2-ethylhexyl)phthalate	2.3	1.4
1037	Butyl benzyl phthalate	1.6	0.12
1037	PCBs (total-calc'd)	1.4	0.26
1039	4-Methylphenol	1.1	1.1
1039	Bis(2-ethylhexyl)phthalate	2.1	1.3
1039	Butyl benzyl phthalate	2.6	0.2
1039	PCBs (total-calc'd)	1.0	0.19
1040	4-Methylphenol	2.1	2.1
1040	Bis(2-ethylhexyl)phthalate	1.8	1.1
1040	Butyl benzyl phthalate	1.2	0.089
1040	PCBs (total-calc'd)	1.3	0.25
1042	4-Methylphenol	6.9	6.9
1044	Bis(2-ethylhexyl)phthalate	1.2	0.75
1044	Butyl benzyl phthalate	1.2	0.088
1044	PCBs (total-calc'd)	2.6	0.48
1163	4-Methylphenol	1.1	1.1

LOCATION #	PARAMETER	SQS EF	CSL EF
1163	Benzoic acid	2.1	2.1
1163	Bis(2-ethylhexyl)phthalate	1.2	0.75
1163	PCBs (total-calc'd)	1.6	0.30

Table C-2. Sediment chemistry data associated with high priority area D (Boeing Plant 2)

LOCATION #	PARAMETER	SQS EF	CSL EF
30	PCBs (total-calc'd)	33.7	6.2
31	PCBs (total-calc'd)	3.9	0.7
144	PCBs (total-calc'd)	7.0	1.3
146	PCBs (total-calc'd)	1.2	0.2
148	PCBs (total-calc'd)	1.6	0.3
149	PCBs (total-calc'd)	1.2	0.2
218	PCBs (total-calc'd)	8.8	1.6
219	PCBs (total-calc'd)	16.7	3.1
220	PCBs (total-calc'd)	50.7	9.4
221	PCBs (total-calc'd)	21.4	4.0
222	PCBs (total-calc'd)	10.8	2.0
224	PCBs (total-calc'd)	2.6	0.5
225	PCBs (total-calc'd)	1.6	0.3
367	PCBs (total-calc'd)	10.2	1.9
368	PCBs (total-calc'd)	1.0	0.2
369	PCBs (total-calc'd)	13.6	2.5
370	Phenanthrene	1.1	0.2
370	PCBs (total-calc'd)	81.3	15.0
370	Fluorene	1.6	0.5
370	Dibenzofuran	1.3	0.3
370	Acenaphthene	1.7	0.5
371	PCBs (total-calc'd)	46.0	8.5
371	Bis(2-ethylhexyl)phthalate	3.1	1.9
372	Total LPAH (calc'd)	2.4	1.1
372	Total HPAH (calc'd)	1.0	0.2
372	Phenanthrene	3.8	0.8
372	PCBs (total-calc'd)	92.3	17.0
372	Naphthalene	1.0	0.6
372	Indeno(1,2,3-cd)pyrene	1.0	0.4
372	Fluorene	5.9	1.7
372	Fluoranthene	1.9	0.2
372	Dibenzofuran	6.5	1.7
372	Chrysene	1.2	0.3
372	Bis(2-ethylhexyl)phthalate	3.9	2.4

LOCATION #	PARAMETER	SQS EF	CSL EF
372	Acenaphthene	10.6	3.0
372	2-Methylnaphthalene	1.6	0.9
373	Phenanthrene	1.4	0.3
373	PCBs (total-calc'd)	75.8	14.0
373	Fluorene	2.6	0.7
373	Dibenzofuran	2.7	0.7
373	Acenaphthene	3.4	1.0
374	PCBs (total-calc'd)	28.6	5.3
375	Zinc	1.0	0.4
375	PCBs (total-calc'd)	29.3	5.4
376	Total HPAH (calc'd)	1.0	0.2
376	PCBs (total-calc'd)	65.5	12.1
376	Indeno(1,2,3-cd)pyrene	1.1	0.4
376	Dibenzo(a,h)anthracene	1.3	0.5
376	Chrysene	1.3	0.3
376	Benzo(g,h,i)perylene	1.0	0.4
377	PCBs (total-calc'd)	6.8	1.3
378	PCBs (total-calc'd)	10.0	1.8
379	PCBs (total-calc'd)	3.3	0.6
379	Fluoranthene	1.1	0.1
379	Cadmium	1.0	0.8
379	Acenaphthene	1.6	0.4
380	PCBs (total-calc'd)	19.3	3.6
381	Zinc	1.7	0.7
381	PCBs (total-calc'd)	15.2	2.8
381	Chromium	1.3	1.3
381	Cadmium	2.2	1.6
381	Butyl benzyl phthalate	21.8	1.7
381	Bis(2-ethylhexyl)phthalate	3.2	1.9
382	Zinc	1.8	0.8
382	PCBs (total-calc'd)	64.3	11.9
382	Butyl benzyl phthalate	69.0	5.3
382	Bis(2-ethylhexyl)phthalate	7.1	4.3
383	PCBs (total-calc'd)	15.7	2.9
383	Dibenzo(a,h)anthracene	1.1	0.4
383	Butyl benzyl phthalate	18.1	1.4
383	Bis(2-ethylhexyl)phthalate	5.3	3.2
384	PCBs (total-calc'd)	2.2	0.4
385	PCBs (total-calc'd)	17.5	3.2
386	PCBs (total-calc'd)	5.7	1.1

LOCATION #	PARAMETER	SQS EF	CSL EF
388	PCBs (total-calc'd)	8.3	1.5
389	PCBs (total-calc'd)	2.8	0.5
390	PCBs (total-calc'd)	3.7	0.7
391	PCBs (total-calc'd)	7.6	1.4
392	PCBs (total-calc'd)	7.2	1.3
392	Mercury	5.1	3.6
392	Dibenzo(a,h)anthracene	1.0	0.4
393	PCBs (total-calc'd)	3.6	0.7
393	Mercury	11.2	7.8
393	Butyl benzyl phthalate	1.0	0.1
393	Bis(2-ethylhexyl)phthalate	6.5	3.9
394	PCBs (total-calc'd)	14.8	2.7
394	Mercury	2.3	1.6
395	PCBs (total-calc'd)	38.8	7.2
396	PCBs (total-calc'd)	19.7	3.6
396	Butyl benzyl phthalate	3.0	0.2
397	PCBs (total-calc'd)	5.9	1.1
398	PCBs (total-calc'd)	38.6	7.1
398	Butyl benzyl phthalate	1.0	0.1
399	Zinc	2.0	0.9
399	PCBs (total-calc'd)	69.9	12.9
399	Butyl benzyl phthalate	8.6	0.7
400	PCBs (total-calc'd)	24.8	4.6
401	PCBs (total-calc'd)	10.5	1.9
402	PCBs (total-calc'd)	23.4	4.3
402	Butyl benzyl phthalate	2.1	0.2
403	PCBs (total-calc'd)	2.9	0.5
404	PCBs (total-calc'd)	4.3	0.8
405	PCBs (total-calc'd)	5.4	1.0
406	Total LPAH (calc'd)	1.2	0.6
406	Total HPAH (calc'd)	2.5	0.5
406	Phenanthrene	3.0	0.6
406	PCBs (total-calc'd)	7.9	1.5
406	Indeno(1,2,3-cd)pyrene	3.8	1.5
406	Fluorene	1.0	0.3
406	Fluoranthene	3.6	0.5
406	Dibenzo(a,h)anthracene	2.3	0.8
406	Chrysene	2.8	0.6
406	Benzofluoranthenes (total-calc'd)	1.4	0.7
406	Benzo(g,h,i)perylene	3.4	1.3

LOCATION #	PARAMETER	SQS EF	CSL EF
406	Benzo(a)pyrene	2.3	1.1
406	Benzo(a)anthracene	2.3	0.9
406	Acenaphthene	1.5	0.4
407	PCBs (total-calc'd)	2.7	0.5
408	PCBs (total-calc'd)	6.3	1.2
409	Zinc	2.9	1.3
409	PCBs (total-calc'd)	49.7	9.2
409	Butyl benzyl phthalate	1.6	0.1
410	PCBs (total-calc'd)	49.7	9.2
411	PCBs (total-calc'd)	5.2	1.0
412	PCBs (total-calc'd)	7.1	1.3
413	PCBs (total-calc'd)	5.0	0.9
414	PCBs (total-calc'd)	15.4	2.8
415	PCBs (total-calc'd)	2.5	0.5
416	PCBs (total-calc'd)	6.0	1.1
417	PCBs (total-calc'd)	4.4	0.8
418	PCBs (total-calc'd)	3.6	0.7
419	PCBs (total-calc'd)	8.5	1.6
420	PCBs (total-calc'd)	15.4	2.9
421	PCBs (total-calc'd)	4.2	0.8
422	PCBs (total-calc'd)	4.6	0.8
423	PCBs (total-calc'd)	5.3	1.0
424	PCBs (total-calc'd)	17.2	3.2
425	PCBs (total-calc'd)	9.7	1.8
426	PCBs (total-calc'd)	27.8	5.1
426	Butyl benzyl phthalate	36.7	2.8
426	Bis(2-ethylhexyl)phthalate	4.0	2.4
427	PCBs (total-calc'd)	78.1	14.4
429	PCBs (total-calc'd)	3.1	0.6
430	PCBs (total-calc'd)	19.4	3.6
431	PCBs (total-calc'd)	8.7	1.6
432	PCBs (total-calc'd)	3.2	0.6
433	PCBs (total-calc'd)	5.8	1.1
434	PCBs (total-calc'd)	1.2	0.2
436	PCBs (total-calc'd)	2.1	0.4
437	PCBs (total-calc'd)	10.6	2.0
438	PCBs (total-calc'd)	4.3	0.8
439	PCBs (total-calc'd)	3.6	0.7
440	PCBs (total-calc'd)	2.2	0.4
441	PCBs (total-calc'd)	51.6	9.5

LOCATION #	PARAMETER	SQS EF	CSL EF
442	PCBs (total-calc'd)	5.0	0.9
443	PCBs (total-calc'd)	38.0	7.0
443	Mercury	1.2	0.9
444	PCBs (total-calc'd)	4.1	0.8
445	PCBs (total-calc'd)	12.7	2.3
446	PCBs (total-calc'd)	2.4	0.4
447	PCBs (total-calc'd)	3.1	0.6
448	PCBs (total-calc'd)	19.6	3.6
449	PCBs (total-calc'd)	24.7	4.6
451	PCBs (total-calc'd)	4.6	0.8
452	PCBs (total-calc'd)	3.6	0.7
453	PCBs (total-calc'd)	2.4	0.4
454	PCBs (total-calc'd)	16.7	3.1
454	Acenaphthene	2.3	0.6
455	PCBs (total-calc'd)	14.4	2.7
456	PCBs (total-calc'd)	4.1	0.8
457	PCBs (total-calc'd)	9.7	1.8
458	PCBs (total-calc'd)	10.3	1.9
459	PCBs (total-calc'd)	1.8	0.3
460	PCBs (total-calc'd)	11.3	2.1
461	PCBs (total-calc'd)	1.7	0.3
462	PCBs (total-calc'd)	25.5	4.7
462	Butyl benzyl phthalate	10.7	0.8
462	Bis(2-ethylhexyl)phthalate	1.3	0.8
463	PCBs (total-calc'd)	25.0	4.6
463	Butyl benzyl phthalate	108.3	8.3
463	Bis(2-ethylhexyl)phthalate	3.8	2.3
464	PCBs (total-calc'd)	30.8	5.7
464	Butyl benzyl phthalate	3.7	0.3
465	PCBs (total-calc'd)	33.3	6.2
465	Mercury	1.0	0.7
466	PCBs (total-calc'd)	58.8	10.9
467	PCBs (total-calc'd)	8.5	1.6
468	Zinc	1.4	0.6
468	PCBs (total-calc'd)	4.0	0.7
469	PCBs (total-calc'd)	2.2	0.4
469	Lead	1.4	1.2
470	PCBs (total-calc'd)	1.4	0.3
471	PCBs (total-calc'd)	2.4	0.4
472	PCBs (total-calc'd)	1.2	0.2

LOCATION #	PARAMETER	SQS EF	CSL EF
473	PCBs (total-calc'd)	1.8	0.3
474	PCBs (total-calc'd)	2.0	0.4
475	PCBs (total-calc'd)	1.8	0.3
476	PCBs (total-calc'd)	1.1	0.2
477	PCBs (total-calc'd)	1.7	0.3
478	PCBs (total-calc'd)	1.3	0.2
479	PCBs (total-calc'd)	1.5	0.3
480	PCBs (total-calc'd)	6.4	1.2
481	PCBs (total-calc'd)	2.4	0.4
482	PCBs (total-calc'd)	6.1	1.1
482	Bis(2-ethylhexyl)phthalate	1.2	0.7
483	PCBs (total-calc'd)	2.7	0.5
483	Bis(2-ethylhexyl)phthalate	1.1	0.6
484	PCBs (total-calc'd)	12.4	2.3
485	PCBs (total-calc'd)	1.2	0.2
486	PCBs (total-calc'd)	1.4	0.3
488	PCBs (total-calc'd)	1.5	0.3
499	PCBs (total-calc'd)	5.4	1.0
500	PCBs (total-calc'd)	22.7	4.2
501	PCBs (total-calc'd)	4.9	0.9
502	PCBs (total-calc'd)	1.5	0.3
504	Zinc	8.5	3.6
504	PCBs (total-calc'd)	10.3	1.9
504	Nickel	1.2	0.5
505	PCBs (total-calc'd)	27.1	5.0
505	Lead	2.9	2.5
507	PCBs (total-calc'd)	5.8	1.1
508	PCBs (total-calc'd)	1.5	0.3
509	PCBs (total-calc'd)	18.8	3.5
510	PCBs (total-calc'd)	11.1	2.1
511	Zinc	2.7	1.1
511	Silver	2.8	2.8
511	PCBs (total-calc'd)	62.9	11.6
511	Mercury	1.4	0.9
511	Lead	1.0	0.9
512	Zinc	2.2	1.0
512	PCBs (total-calc'd)	4.5	0.8
513	Zinc	2.7	1.1
513	Silver	1.2	1.2
513	PCBs (total-calc'd)	4.2	0.8

LOCATION #	PARAMETER	SQS EF	CSL EF
513	Nickel	1.2	0.5
513	Lead	7.8	6.6
513	Copper	6.4	6.4
513	Cadmium	4.1	3.1
514	Zinc	2.1	0.9
514	PCBs (total-calc'd)	16.4	3.0
514	Bis(2-ethylhexyl)phthalate	1.1	0.7
515	PCBs (total-calc'd)	1.1	0.2
516	PCBs (total-calc'd)	12.2	2.2
517	PCBs (total-calc'd)	9.6	1.8
517	Lead	1.9	1.6
518	PCBs (total-calc'd)	5.0	0.9
519	Zinc	1.5	0.6
519	PCBs (total-calc'd)	16.7	3.1
520	Zinc	4.4	1.9
520	PCBs (total-calc'd)	2.4	0.4
520	Mercury	2.7	1.9
520	Lead	4.2	3.6
520	Copper	6.4	6.4
520	Cadmium	2.2	1.6
520	Bis(2-ethylhexyl)phthalate	1.3	0.8
521	Zinc	10.2	4.4
521	Silver	1.3	1.3
521	Lead	8.7	7.4
521	Copper	4.9	4.9
521	Cadmium	1.8	1.4
522	Zinc	23.7	10.1
522	Silver	15.9	15.9
522	PCBs (total-calc'd)	1.3	0.2
522	Nickel	3.3	1.2
522	Lead	9.1	7.7
522	Copper	30.8	30.8
522	Chromium	2.9	2.8
522	Cadmium	23.5	17.9
523	Zinc	15.6	6.7
523	Silver	44.3	44.3
523	PCBs (total-calc'd)	8.8	1.6
523	Nickel	2.6	1.0
523	Mercury	4.9	3.4
523	Lead	51.1	43.4

Location #	Parameter	SQS EF	CSL EF
523	Copper	30.8	30.8
523	Chromium	2.3	2.2
523	Cadmium	10.8	8.2
524	Zinc	2.7	1.1
524	Silver	1.3	1.3
524	Nickel	1.3	0.5
524	Mercury	1.7	1.2
524	Lead	1.2	1.1
524	Chromium	1.0	1.0
524	Cadmium	3.1	2.4
525	Zinc	1.9	0.8
525	PCBs (total-calc'd)	5.3	1.0
525	Mercury	2.0	1.4
525	Lead	5.1	4.3
526	Zinc	2.1	0.9
526	PCBs (total-calc'd)	3.1	0.6
526	Nickel	4.9	1.9
526	Chromium	3.5	3.4
526	Cadmium	18.0	13.7
527	Zinc	6.8	2.9
527	Silver	1.3	1.3
527	PCBs (total-calc'd)	1.6	0.3
527	Nickel	6.5	2.5
527	Mercury	1.3	0.9
527	Lead	6.7	5.7
527	Copper	5.9	5.9
527	Chromium	4.2	4.1
527	Cadmium	10.6	8.1
752	PCBs (total-calc'd)	4.9	0.9
782	PCBs (total-calc'd)	1.2	0.2
783	PCBs (total-calc'd)	21.0	3.9
783	Butyl benzyl phthalate	2.4	0.2
783	Bis(2-ethylhexyl)phthalate	1.3	0.8