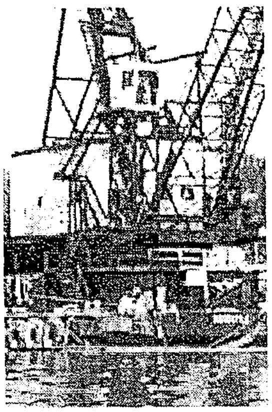
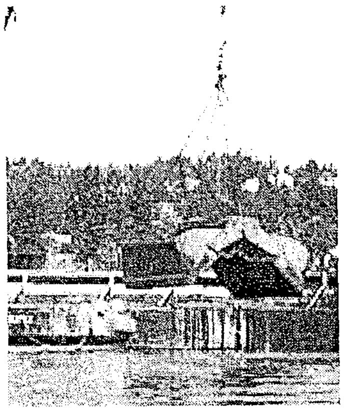
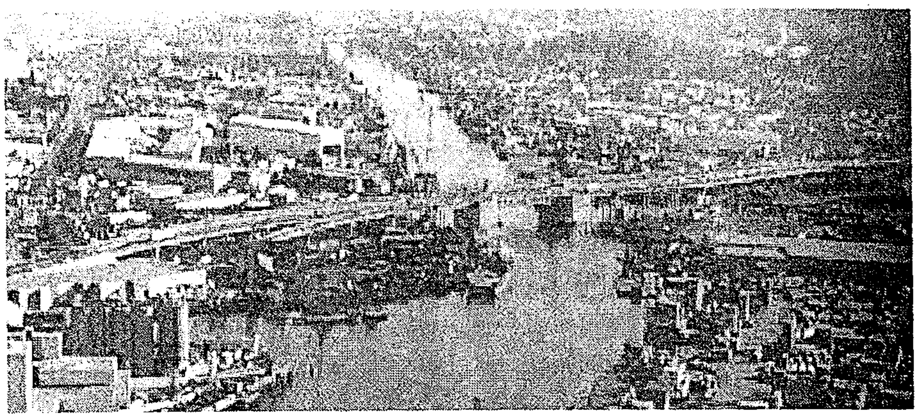
Lower Duwamish Waterway Group

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







Executive Summary

Draft Feasibility Study

Lower Duwamish Waterway
Seattle, Washington

PREPARED BY:

ENSR | AECOM

710 SECOND AVE, SUITE 1000
SEATTLE, WA 98104

APRIL 24, 2009

FOR SUBMITTAL TO:

THE U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION 10
SEATTLE, WA

THE WASHINGTON STATE DEPARTMENT OF ECOLOGY
NORTHWEST FIELD OFFICE
BELLEVUE, WA

ACRONYMS USED IN THE EXECUTIVE SUMMARY

ARAR	applicable or relevant and appropriate requirement
CAP	Cleanup Action Plan
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	chemical of concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CSL	cleanup screening level
EAA	early action area
Ecology	Washington State Department of Ecology
ENR	enhanced natural recovery
EPA	U.S. Environmental Protection Agency
FS	Feasibility Study
MNR	monitored natural recovery
MTCA	Model Toxics Control Act
PCB	polychlorinated biphenyl
PRG	preliminary remediation goal
RAL	remedial action level
RAO	remedial action objective
RI	Remedial Investigation
ROD	Record of Decision
SMS	Sediment Management Standards
SQS	sediment quality standards

All elements of this Draft Feasibility Study, including information on how and where to provide comments, have been made available online at: www.ldwg.org.

Introduction

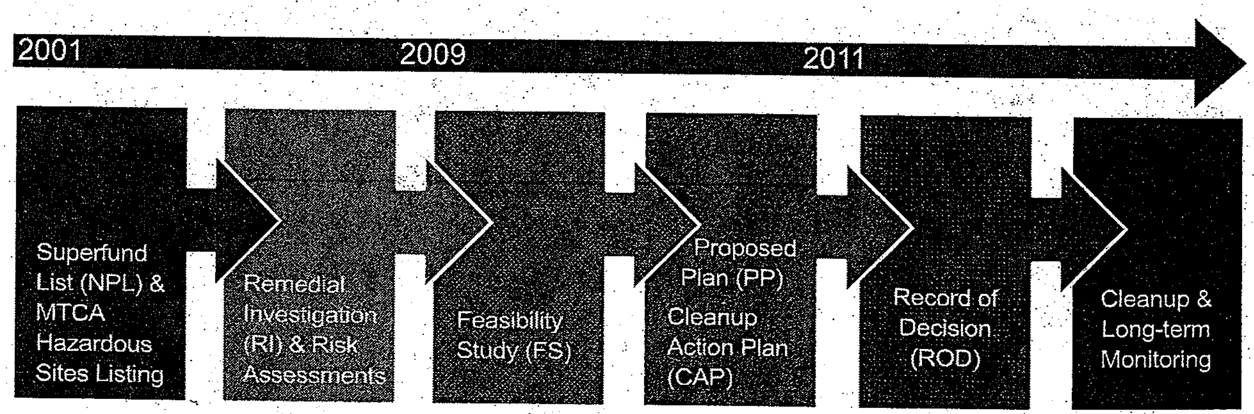
This report presents the draft feasibility study (FS) for the Lower Duwamish Waterway (LDW) Superfund Site in Seattle, Washington (Figure ES-1). This report has been prepared on behalf of the Lower Duwamish Waterway Group (LDWG), consisting of the City of Seattle, King County, the Port of Seattle, and The Boeing Company. The LDWG signed an Administrative Order on Consent in December 2000 with the U.S. Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology) to conduct a remedial investigation/feasibility study (RI/FS) for the LDW (EPA, Ecology, and LDWG 2000). The LDW was subsequently added to EPA's National Priorities List (also known as Superfund) on September 13, 2001. The LDW was added to Ecology's Hazardous Sites List on February 26, 2002.

The draft FS evaluates the LDW as a whole (i.e., on a waterway-wide basis), which includes the entire five miles of the LDW (river mile 0 to river mile 5), starting just south of Harbor Island to just beyond the Upper Turning Basin at the Norfolk Area. The FS presents an array of LDW-wide remedial alternatives for cleaning up contaminated sediments. The relative costs, benefits, and tradeoffs of the alternatives are evaluated according to the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Washington State Model Toxics Control Act (MTCA).

The draft FS is being made available for public input. The agencies will consider this input in their review and comment on this draft. A draft final FS will then be prepared for additional public input and agency review and the FS will then be finalized. EPA and Ecology will then issue a proposed plan that identifies a preferred remedial alternative for the LDW. Formal public comment will be received on the proposed plan. After public comments on the proposed plan are received and evaluated, the agencies will select the final remedial alternative and publish the decision in their respective decision documents.

The FS builds on a series of studies completed over the past seven years. These studies are documented in the following reports:

- The *Draft Final Remedial Investigation* (RI) (Windward 2008), which developed a conceptual

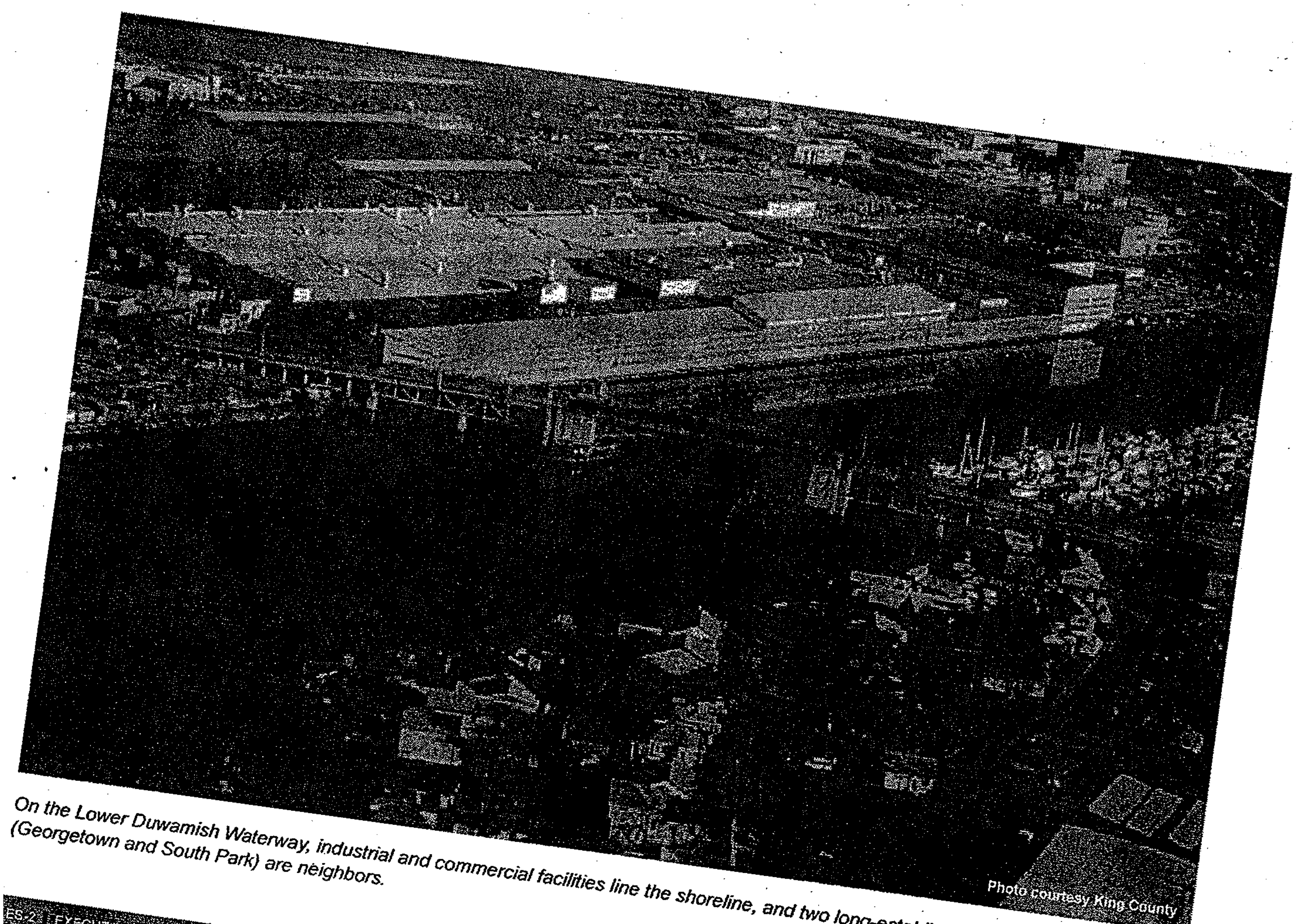


This first draft Feasibility Study identifies alternatives for the cleanup and compares these alternatives. EPA, Ecology, and LDWG are making this document widely available in order to obtain public input early in the process, before EPA issues a proposed plan.

site model for the LDW. The model summarizes the physical and biological interactions of the system, the nature and extent of the contamination in the LDW, and the associated risk that contamination represents to people and animals that use the LDW.

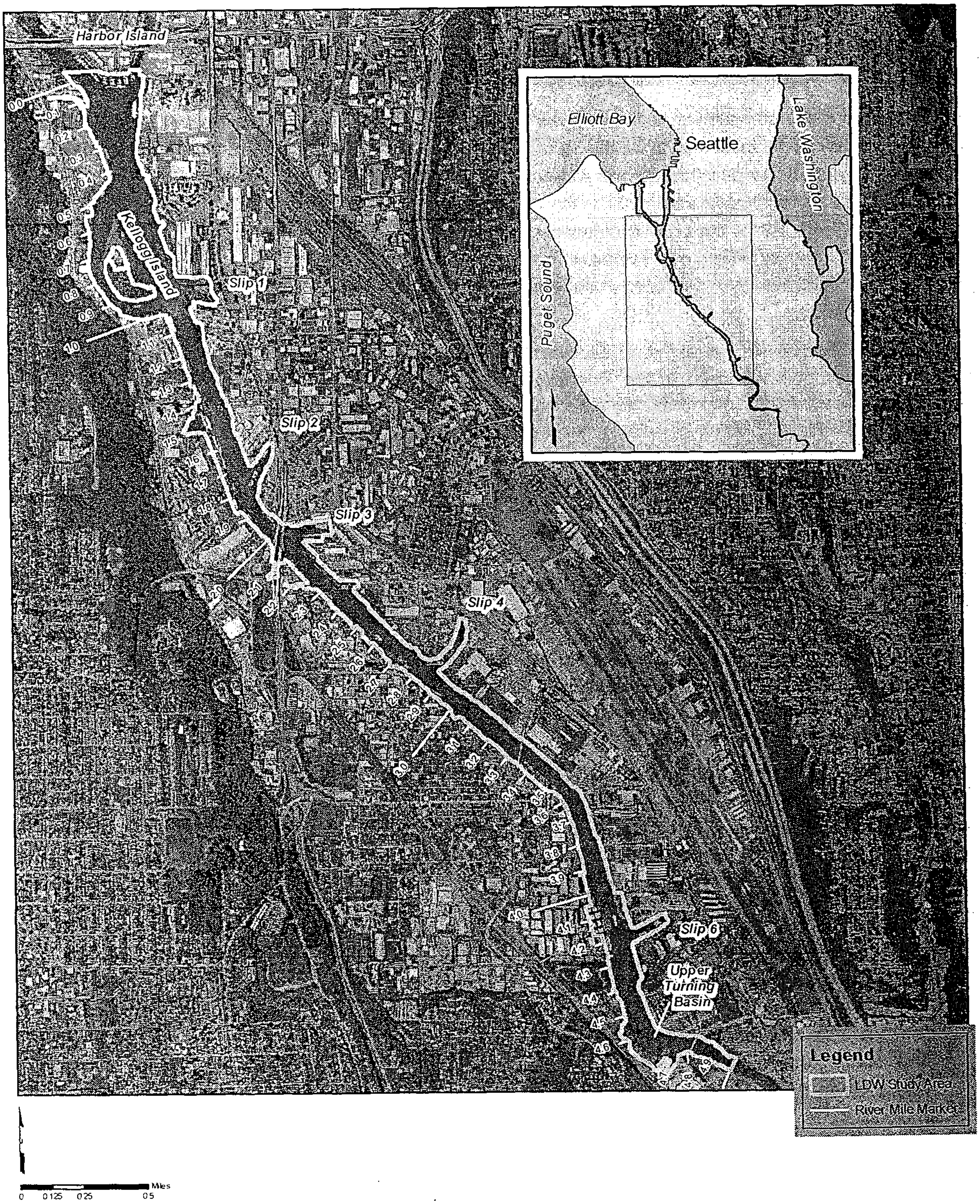
- The *Human Health and Ecological Risk Assessments* (Windward 2007a and 2007b), which evaluated risks to humans and ecological receptors from exposure to chemicals of concern (COCs) from sediments in the LDW.
- The *Sediment Transport Modeling Report* (QEA 2008), which presented the results of physical testing and modeling of sediment transport processes in the LDW.
- The *Candidate Technologies Memorandum* (RETEC 2005), which identified and screened remedial technologies that could be applicable to the LDW.
- The *Draft Preliminary Screening of Alternatives* (RETEC 2006), which identified and screened remedial alternatives for consideration in the LDW.

Parallel with the FS process, Ecology is leading a source control program to identify and control ongoing sources of chemical contamination in the areas that drain to the LDW. The goal of this program is to identify and manage sources of chemicals to waterway sediments in coordination with sediment cleanups (Ecology 2004).



On the Lower Duwamish Waterway, industrial and commercial facilities line the shoreline, and two long-established residential communities (Georgetown and South Park) are neighbors.

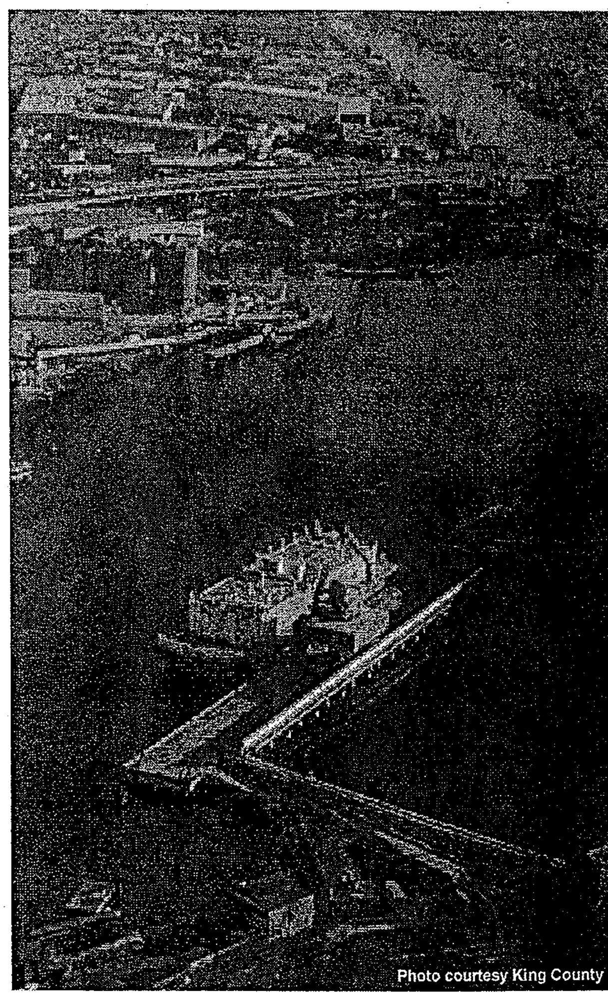
Figure ES-1: The Lower Duwamish Waterway Superfund Site in Seattle, Washington



Site Description

The LDW is an engineered waterway built in the early 1900s to serve developing industries in Seattle. It is a saltwater wedge-type estuary influenced by river flow and tidal effects, both of which fluctuate seasonally. In the FS study area (see Figure ES-1), the LDW encompasses approximately 441 acres extending over five miles, with an average width of 440 feet (ft). A brief description of the LDW is provided below:

- **Habitat:** Most of the natural habitat (wetlands, marshlands, and mudflats) of the Duwamish River Estuary was lost during construction of the LDW in the early 1900s and in subsequent land development over the years. Much of the present shoreline consists of riprap, pier aprons, and sheet pile walls. Despite significant alterations in habitat, the LDW contains a diverse assemblage of aquatic and wildlife species and a robust food web that includes top predators. Some intertidal habitat remains in small isolated patches, with the area around Kellogg Island being the largest contiguous area. The remaining habitat is important to various species, including the threatened Puget Sound chinook salmon that use the LDW as a migration corridor.
- **Uses:** Industrial and commercial facilities occupy a large portion of the shoreline; two residential communities are located near or along the shoreline. The LDW is currently used primarily as an industrial navigational corridor with some recreational uses. The banks of the LDW are predominantly engineered with bulkheads, riprap slopes, and overwater structures, with scattered public access areas and several stretches of intertidal habitat restoration areas. It also supports a salmon fishery for the Muckleshoot Tribe and is part of tribal usual and accustomed fishing areas.
- **Navigation:** The LDW includes a federally-maintained navigation channel and numerous maintained berthing areas. Many of the berthing areas and the upper reach of the navigation channel are periodically dredged to remove sediments that are deposited from upstream. Water depths in the navigation channel vary from approximately -56 ft mean lower low water near the mouth of the LDW to -10 ft mean lower low water near the Upper Turning Basin.



The LDW serves primarily as an industrial and navigational corridor, with some recreational uses. It is a migration corridor for salmon and supports a fishery for the Muckleshoot Tribe. The LDW area will continue to support diverse uses into the future, as the heart of a still-growing urban area.

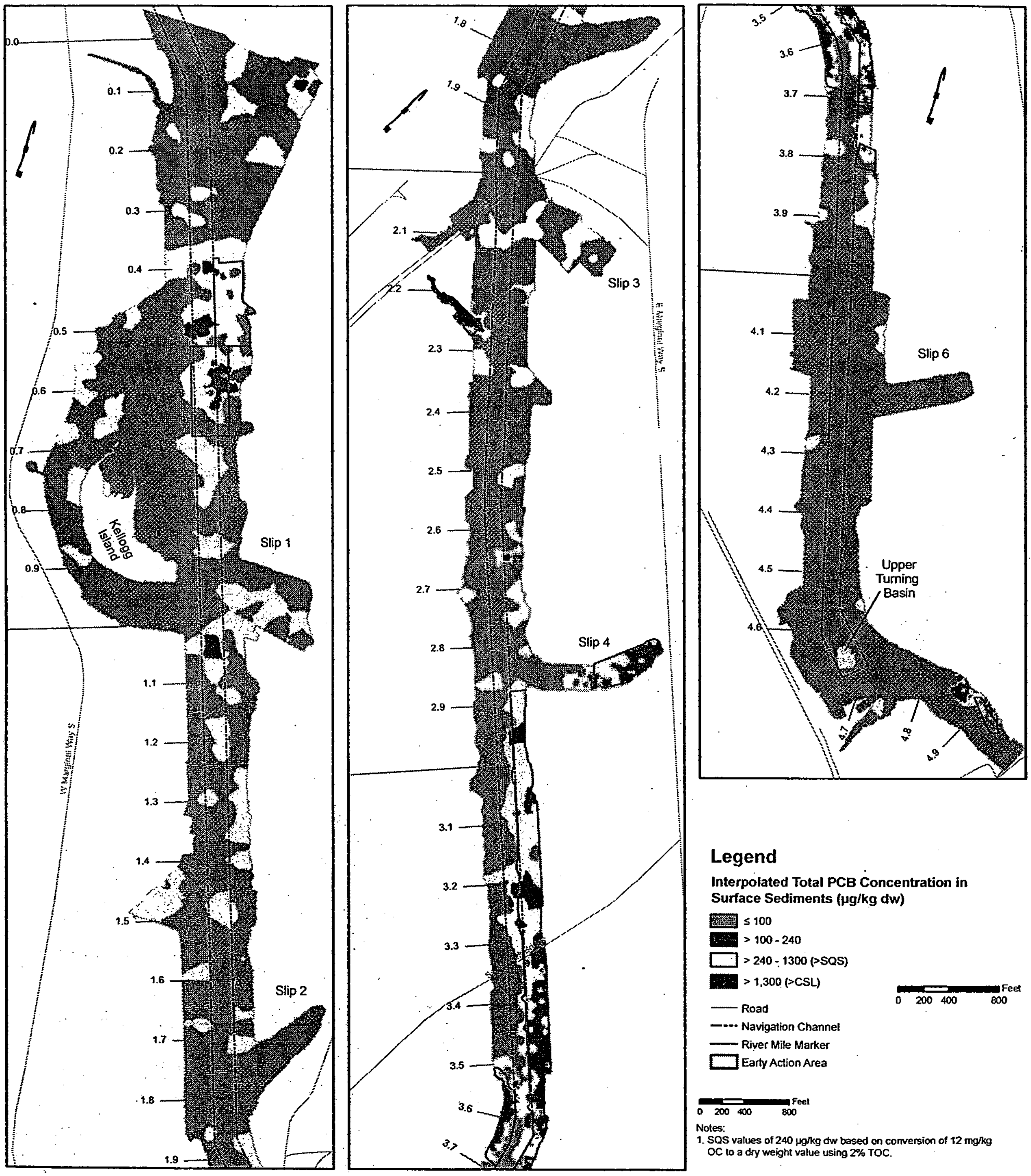
Summary of the Remedial Investigation

The RI (Windward 2008) collected and analyzed information about the nature and extent of chemical contamination in the waterway, evaluated sediment transport processes, and assessed current conditions within the LDW, including risks to people and animals that use the waterway. The RI findings included the following:

- A conceptual site model was developed in the RI, considering physical, chemical, and exposure factors. The physical conceptual site model has been confirmed by several lines of evidence, including chemistry profiles in sediment. The model provides a basis for understanding the LDW and analyzing cleanup alternatives.
- Historical releases of chemicals have contributed much of the sediment contamination in the LDW. Sediment is continually depositing within the LDW, with almost all new sediment (99 percent) originating from the Green/Duwamish River. As a result, the LDW surface sediment is gradually becoming more similar in chemical composition to the sediment from the Green/Duwamish River on an LDW-wide scale. Localized areas may continue to be influenced by inputs from sources in those areas.
- A number of chemicals in the sediments were found to exceed state criteria for sediment quality presented in the Sediment Management Standards (SMS) of the Washington Administrative Code (WAC 173-204); these criteria include both sediment quality standards (SQS) and cleanup screening levels (CSL).
- In general, high concentrations of risk-driver chemicals (see risk summary) were detected in surface sediment in well-defined areas, referred to as hot spots. These areas are separated by large areas of the LDW that have relatively lower concentrations.
- The distribution of chemicals within cores shows that peak chemical concentrations are often at depth (two to four feet below mudline surface) in many areas of the LDW, and that net sedimentation by cleaner material from upstream is contributing to the burial and recovery of sediments. Net sedimentation rates average one to three cm/yr in most of the subtidal areas, and range up to > 70 cm/yr in the Upper Turning Basin, which acts as a natural sediment trap for incoming sediment. While burial and recovery is occurring in many areas, localized hot-spot areas are not showing recovery.
- Early cleanup actions are already planned at three areas and have been completed at two other areas within the LDW. These five areas total 34 acres and are referred to as the sponsored early action areas (EAAs).

The Remedial Investigation included extensive sampling of sediments, fish, and shellfish.

Figure ES-2: Distribution of Total PCB Concentration in LDW Surface Sediments



Historical releases of chemicals have contributed much of the sediment contamination in the LDW. High concentrations of chemicals, such as PCBs, arsenic, and dioxins/furans are detected in surface sediment in well-defined areas. However, large areas of the LDW have lower concentrations.

Risk Summary

The baseline risk assessments were completed to estimate risks to humans and ecological receptors (e.g., benthic invertebrates, fish, and wildlife), resulting from exposure to contaminated sediments in the LDW in the absence of any cleanup measures. The risk assessments found that:

- Total polychlorinated biphenyls (PCBs), arsenic, carcinogenic polycyclic aromatic hydrocarbons [cPAHs], and dioxins/furans are the risk drivers for human health.
- Risks to humans are mostly associated with consumption of resident fish[1], crabs, and clams. Subsistence seafood consumption rates (e.g., those of Native American tribal members or Asian and Pacific Islanders) of resident fish, crabs, and clams result in a lifetime excess cancer risk that exceeds the EPA target risk range of 10^{-4} to 10^{-6}. Noncancer risks are also associated with consumption of resident seafood. A portion of the risk is related to anthropogenic background concentrations of chemicals.
- Lower risks are associated with activities that involve direct contact with sediment, such as netfishing, tribal clamming, and beach play. The risks for these activities fall within the EPA target excess cancer risk range of 10^{-4} to 10^{-6}. A portion of these risks is related to anthropogenic background concentrations of chemicals. Noncancer risks were below the EPA risk threshold for all of the direct contact scenarios.
- Forty-one chemicals were identified as risk drivers for benthic invertebrates because detected concentrations of these chemicals exceeded the SQS in surface sediments at one or more locations.
- Ecological risks to crabs, fish, and most wildlife were found to be relatively low, with the exception of river otters. River otters have a higher risk attributable to the presence of PCBs in resident seafood, which is the primary component of their diet.
- Chemical concentrations in surface sediments indicate that harmful effects to the benthic community are not likely in approximately 75 percent of the LDW area. A higher likelihood for adverse effects was identified in approximately seven percent of the LDW area, where chemical concentrations or biological effects were found to be in excess of the CSL criteria of the SMS. The remaining 18 percent of the LDW area had chemical concentrations or minor biological effects falling between the SQS and CSL criteria.

The greatest risks to people are associated with eating resident fish, crabs, and clams. Lower risks are associated with activities that involve direct contact with sediment, such as tribal clamming, netfishing, and beach play. There are also risks for ecological receptors, such as benthic organisms and river otters.

[1] The term resident fish does not include salmon. Salmon and other anadromous species use the LDW for limited time periods during their life cycles.

Remedial Action Objectives (RAOs) and Preliminary Remediation Goals (PRGs)

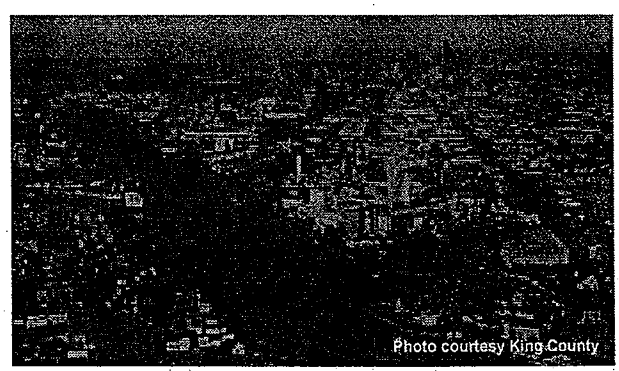
Four remedial action objectives (RAOs) have been identified based on the results of the risk assessments. The RAOs describe the objectives the sediment cleanup actions in the LDW should accomplish. The RAOs are:

- **RAO 1:** Reduce human health risks associated with the consumption of resident LDW seafood by reducing surface sediment concentrations of COCs to protective levels.
- **RAO 2:** Reduce human health risks associated with exposure to COCs through direct contact with sediments and incidental sediment ingestion by reducing surface sediment concentrations of COCs to protective levels.
- **RAO 3:** Reduce risks to benthic invertebrates by reducing surface sediment concentrations of COCs to comply with the Washington State SMS.
- **RAO 4:** Reduce risks to crabs, fish, birds, and mammals from exposure to COCs in surface sediment by reducing surface sediment concentrations of COCs to protective levels.

Numeric preliminary remediation goals (PRGs) were developed for each RAO. PRGs are the chemical endpoint concentrations associated with each RAO that are considered protective of human health and the environment. The PRGs for a given chemical may be applied to all locations (i.e., point-based), or in other cases, be applied as an average–either LDW-wide or over a specific exposure area. In some instances, the risk-based concentrations were lower than anthropogenic background concentrations. [2]

The four human health risk-driver chemicals are commonly found in urban environments and create an "anthropogenic background level" of these chemicals that is not site-related (i.e., referred to as anthropogenic or area background). PRGs are not established below anthropogenic background concentrations because it is not possible to clean up and maintain the site at concentrations below anthropogenic background. Multiple lines of evidence were used to assess sediment anthropogenic background concentrations. For the FS, anthropogenic background is presented as a range of sediment concentrations that considers the limitations and variability of the available anthropogenic background data.

Given the uncertainty in the true value of anthropogenic background, the highly urbanized nature of the LDW, and the fact that anthropogenic background values are subject to spatial and temporal variability, the PRGs (that are based on anthropogenic background) are expressed as a range. The upper end of the range is used as a threshold for evaluating the minimum time required to attain anthropogenic background. Setting the PRG at the lower end of the anthropogenic background range could result in a goal that is not achievable because of the more urbanized nature of the LDW compared to the Green/Duwamish River, which was the source of the anthropogenic background data.



Although the concentrations of four chemicals that drive human health risks are elevated within the LDW, they are also commonly found in urban environments at "background" concentrations that are not site-related, referred to as anthropogenic or area background. Therefore, it is not possible to entirely eliminate the risks associated with these chemicals.

[2] **Area background**, a term specific to MTCA, represents the concentrations of hazardous substances that are consistently present in the environment in the vicinity of the site as a result of human activities unrelated to releases from the site (WAC 173-340-200). CERCLA uses the term anthropogenic (man-made) background (EPA 1997b), and EPA's sediment remediation guidance (EPA 2005) states that cleanup levels will normally not be set below natural or **anthropogenic** background concentrations.

Table ES-1: Preliminary Remediation Goals for Total PCBs, Arsenic, cPAHs, and Dioxins/ Furans in LDW Surface Sediment

Risk-Driver Chemical	Anthro-pogenic Background	Preliminary Remediation Goals (PRGs)				
		Spatial Scale of Exposure[a]	RAO 1: Human Seafood Consumption	RAO 2: Human Direct Contact	RAO 3: Benthic Organisms	RAO 4: Ecological (River Otter)
Total PCBs (µg/kg dw)	50 – 100	LDW-wide	50-100 (bg)	1,300[b]	n/a	128
		Clamming	n/a	500[c]	n/a	n/a
		Beach Play	n/a	1,700	n/a	n/a
		Point	n/a	n/a	12 (oc)	n/a
Arsenic (mg/kg dw)	10 – 15	LDW-wide	10-15 (bg)	10-15 (bg)[b]	n/a	n/a
		Clamming	n/a	10-15 (bg)	n/a	n/a
		Beach Play	n/a	10-15 (bg)	n/a	n/a
		Point	n/a	n/a	57	n/a
cPAHs (µg TEQ/kg dw)	100 – 300	LDW-wide	100-300 (bg)	380[b]	n/a	n/a
		Clamming	n/a	150[c]	n/a	n/a
		Beach Play	n/a	100-300 (bg)	n/a	n/a
		Point	n/a	n/a	use SMS[d]	n/a
Dioxins/Furans (ng TEQ/kg dw)	5 – 10	LDW-wide	5-10 (bg)	37[b]	n/a	n/a
		Clamming	n/a	13[c]	n/a	n/a
		Beach Play	n/a	28	n/a	n/a
		Point	n/a	n/a	n/a	n/a
SMS Chemicals	n/a	Point	n/a	n/a	SQS[e]	n/a

[a] *The spatial scale of site-wide exposure is RAO-specific. Statistical metric for LDW-wide, clamming, and beach play areas is the SWAC or UCL 95.*

[b] *LDW-wide PRG based on netfishing scenario.*

[c] *PRG based on tribal clamming scenario.*

[d] *Low- and high-molecular weight PAHs are addressed by the SMS criteria. Criteria are set for both groupings and for individual compounds.*

[e] *Under the SMS, sediment cleanup standards are established on a site-specific basis within an allowable range. The SQS and CSL define this range. However, the final cleanup level will be set in consideration of the net environmental effects, cost, and technical feasibility of different cleanup alternatives (WAC 173-204-570(4)).*

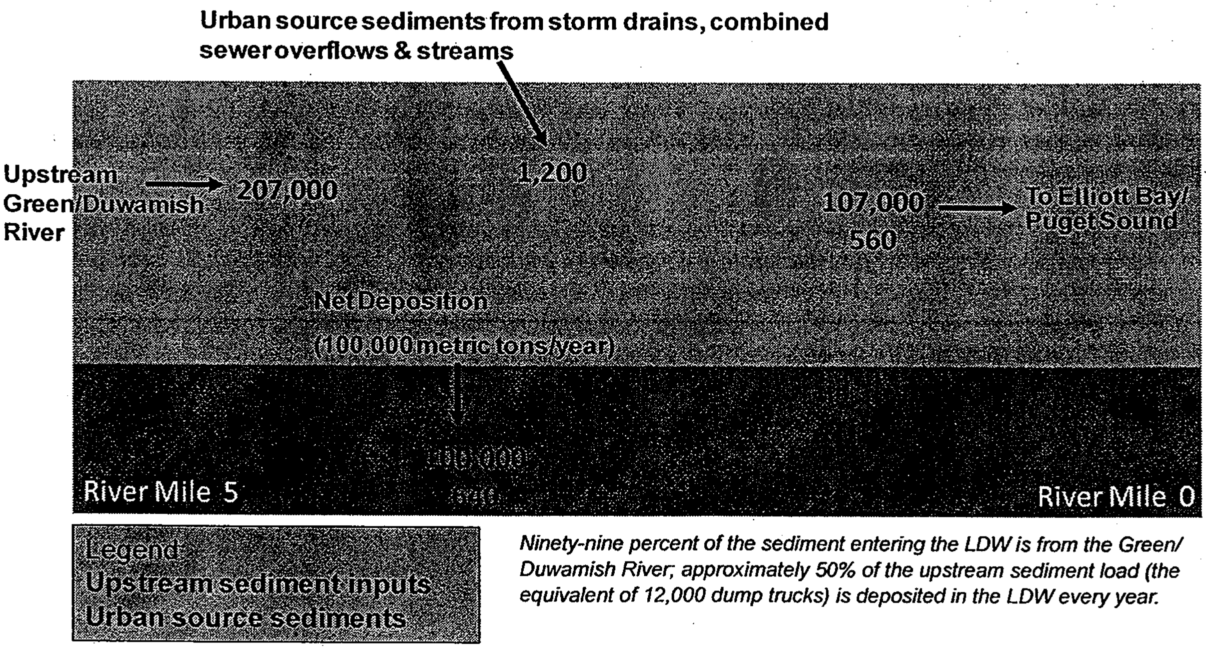
bg = background; cPAH = carcinogenic polycyclic aromatic hydrocarbon; CSL = cleanup screening level; dw = dry weight; LDW = Lower Duwamish Waterway; µg/kg = micrograms per kilogram; mg/kg = milligrams per kilogram; n/a = not applicable; ng/kg = nanograms per kilogram; oc = organic carbon; PAH = polycyclic aromatic hydrocarbon; PCB = polychlorinated biphenyl; RAO = remedial action objective; SMS = Sediment Management Standards (WAC 173-204); SQS = sediment quality standard; SWAC = spatially weighted average concentration; TEQ = toxic equivalent; UCL95 = upper confidence limit of the 95th percentile.

A sediment transport model was developed to evaluate long-term sediment transport processes in the LDW. The model findings included the following:

- It is estimated that more than 100,000 metric tons of sediment are deposited within the LDW each year. Almost all new sediment (more than 99 percent) that deposits in the LDW originates upstream in the Green/Duwamish River; less than one percent originates from storm drains, combined sewer overflows, and streams that discharge directly into the LDW. These newly deposited sediments are mixed with the existing surface sediments over much of the area through bioturbation and the processes of resuspension and redeposition associated with ship-induced bed scour.
- Ship-induced bed scour is viewed as an erosion-deposition process that tends to behave like a mixing process for surficial bed sediment. This reworked surface layer from passing vessels is limited to the upper few centimeters (about one to two cm). In certain localized areas, the reworked surface layer from maneuvering vessels operating in berthing areas is greater (up to 30 cm deep).
- Erosion of the sediment bed by river flow is limited, even during high-flow events. Net erosion occurs over about 18 percent or less of the LDW bed area during high-flow events. Most of the bed erosion is less than 10 cm in depth and maximum net erosion depths are 22 cm or less. The majority of eroded sediment resettles within the LDW.

To evaluate changes in sediment concentrations over time (natural recovery and recontamination potential), the sediment transport model results were combined with an understanding of the chemical concentrations

Sediment inputs to the LDW (metric tons/year)



Ninety-nine percent of the sediment entering the LDW is from the Green/ Duwamish River; approximately 50% of the upstream sediment load (the equivalent of 12,000 dump trucks) is deposited in the LDW every year.

entering the LDW in solids loads from upstream, as well as from storm drains, combined sewer overflows, and small streams that discharge directly into the LDW. This analysis included both quantitative modeling and analyses of multiple lines of empirical evidence, and yielded the following results:

- Chemical concentrations in upstream sediments are lower than the concentrations found, on average, in LDW sediments. Because more than 99 percent of the sediments deposited in the LDW come from upstream as suspended solids or bed load, the COC concentrations in LDW surface sediments are generally expected to be lowered gradually to levels close to those found in the upstream sediment and suspended solids.
- Following active cleanup of hot spots, many areas with moderate chemical concentrations will likely achieve the RAOs within 10 to 15 years after active remedy completion.
- Localized areas near large storm drains, combined sewer overflows, or other upland sources may not equilibrate as quickly, or may have persistently elevated concentrations of some chemicals, regardless of upland source control actions.

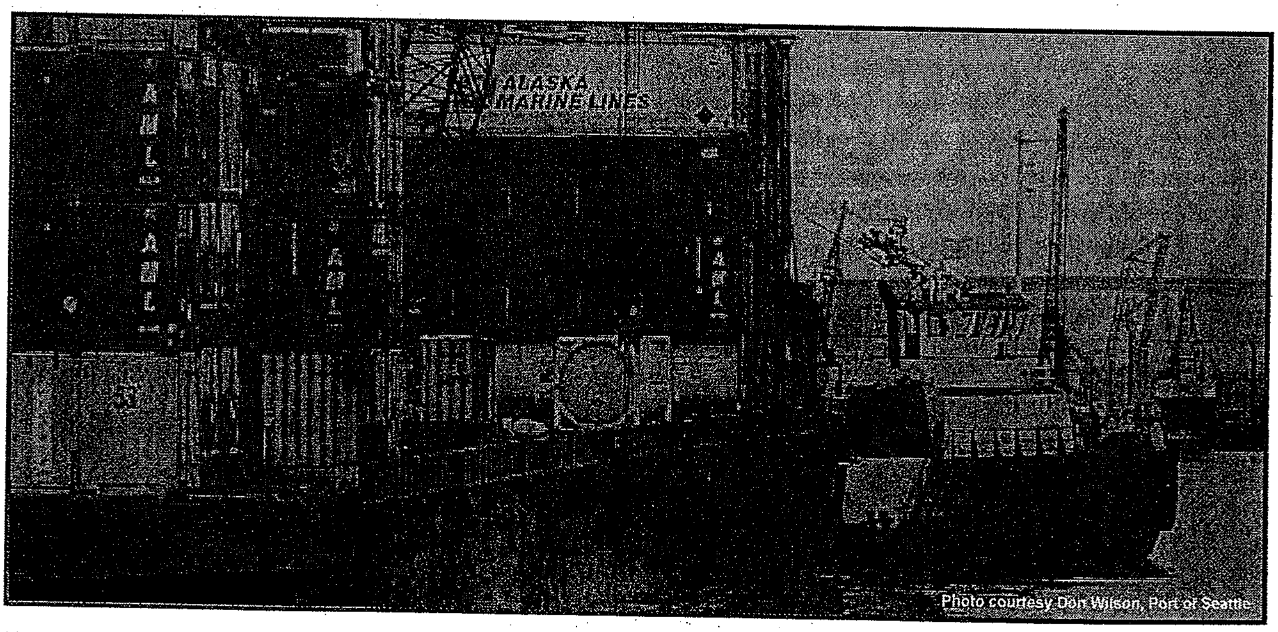


Photo courtesy Don Wilson, Port of Seattle

The effects of ship traffic on sediment transport were evaluated in this Draft Feasibility Study.

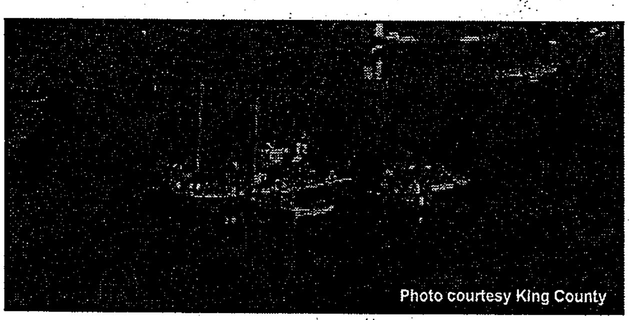
Early Action Areas (EAAs) and Sediment Management Areas (SMAs)

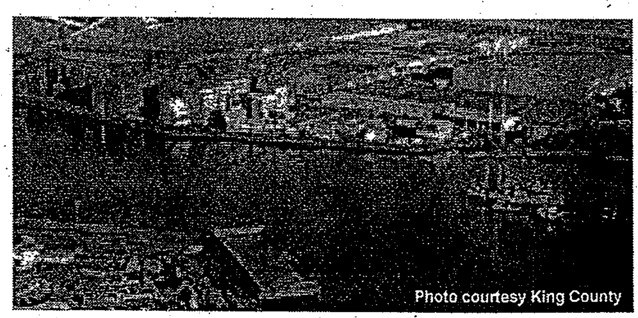
Early in the RI/FS process, seven EAAs were identified that represented more contaminated areas that should be considered candidates for non-time critical removal actions (Windward 2003). Those actions have either been completed or are in the planning stages at the five EAAs managed by LDWG members.

A first step in the alternative development process was to map other sediment management areas (SMAs) that are likely to require remediation. SMAs represent areas with common physical, chemical, and biological characteristics in which a remedial approach may be applied independently of adjacent areas. The output from this step was the identification of 49 SMAs, which, together with the five EAAs being managed by LDWG members, cover approximately 193 acres. Modeling and empirical data indicate that some of these SMAs have the potential to recover naturally over time as sediments from the Green/Duwamish River deposit in the LDW, while others will need to be actively remediated to achieve the RAOs. The available baseline surface sediment data used to map the SMAs span over 15 years. For this reason, some uncertainty exists regarding existing chemical concentrations in the LDW. With the passage of 15 years, some areas may have already recovered naturally. Therefore, using the total area that exceeds the SQS or risk-based action levels to develop the SMAs is considered conservative. The SMA boundaries will need to be refined during remedial design.

Figure ES-3 shows the five LDWG-sponsored EAAs and the three categories of SMAs within the LDW. The categories were defined based on their physical and chemical characteristics:

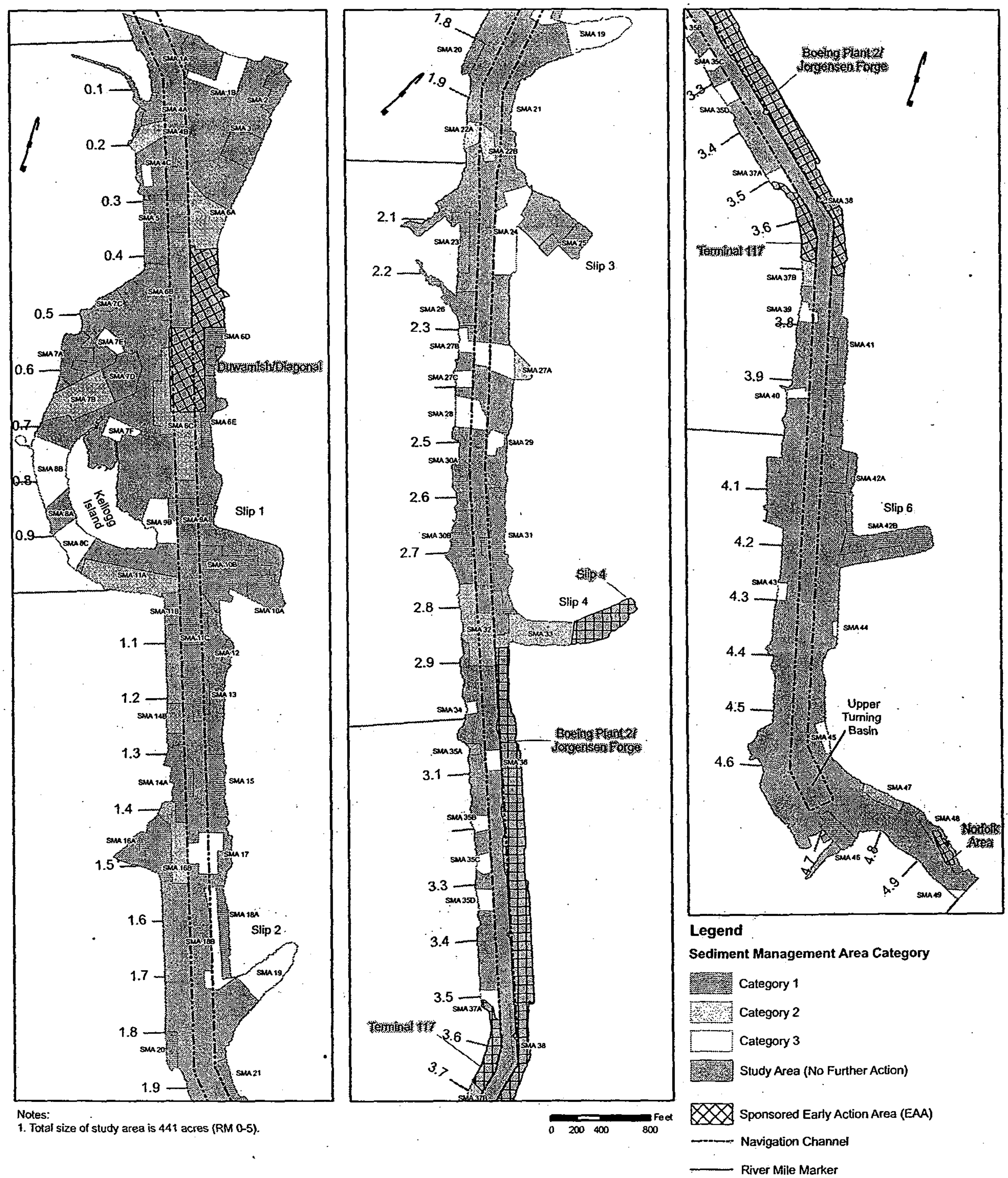
- Category 1 SMAs (covering 80 acres) have moderate to high levels of chemical concentrations and include areas that are expected to recover to the CSL in 10 years or less following active cleanup of hot spots.
- Category 2 SMAs (covering 45 acres) have moderate to low levels of chemical concentrations that will be considered in the alternative development process for both active and passive remediation, depending on the expected time frame for recovery. If not actively remediated, the Category 2 SMAs are expected to recover naturally to below the SQS within 10 years following active cleanup of hot spots.
- Category 3 SMAs (covering 35 acres) have relatively low chemical concentrations and isolated chemical concentrations above the SQS, and are generally recommended for monitored natural recovery, based on the age (most data are > 10 years old) and magnitude of the data showing exceedances above the SQS. Recovery to below the SQS is already expected to have occurred in these SMAs, but will require verification.





Removal actions have been completed at the Duwamish/Diagonal and Norfolk Early Action Areas and are in the design stage for three other Early Action Areas sponsored by LDWG members.

Figure ES-3: Sediment Management Areas



Notes:
1. Total size of study area is 441 acres (RM 0-5).

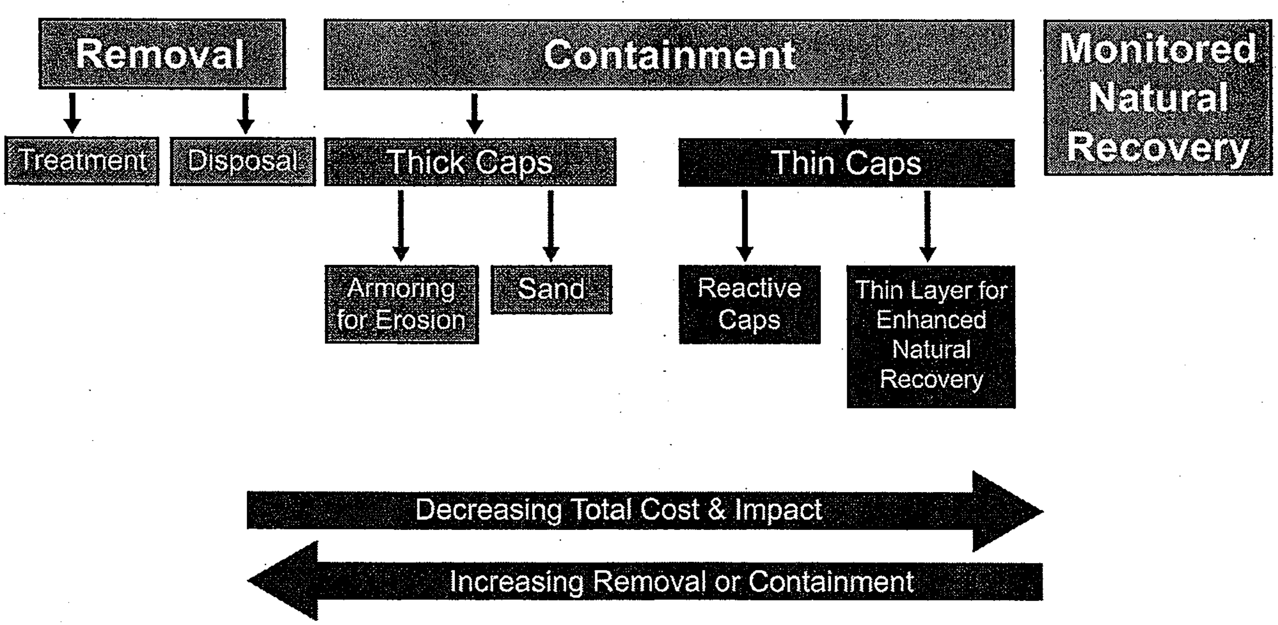
Evaluation and Screening of Technologies

Several general response actions are applicable for remediating contaminated sediments in the LDW. These include:

- Institutional controls such as advisories not to eat resident seafood from the LDW or restrictions on dredging or anchoring in certain areas.
- Monitored natural recovery (MNR) that relies on natural processes to reduce concentrations. MNR includes monitoring and additional measures if needed to ensure that the PRGs are met as expected.
- Enhanced natural recovery (ENR) that uses a thin-layer placement of materials (e.g., sand) to enhance natural recovery processes.
- Isolation capping of contaminated sediments, typically using engineered layers of sand, gravel, or rock.
- Physical removal (e.g., dredging) of contaminated sediments.
- Treatment involving physical separation of dredged materials prior to disposal.
- On- and off-site disposal of dredged material.

The LDW-wide remedial alternatives selected for evaluation in this FS include various combinations of these general response actions. For each general response action, a number of different technologies and process options can be used. The draft FS selects representative process options for evaluation, but other combinations of similar process options may be considered during the remedial design stage.

Technologies for Management of Contaminated Sediments



Various technologies are available to clean up the LDW. Combinations of dredging, containment, and natural recovery are evaluated as cleanup alternatives.

Development of Remedial Alternatives and Remedial Action Levels

The remedial alternatives evaluated in the FS are all designed to achieve the same RAOs and PRGs. However, each alternative differs in the amount of active cleanup (dredging or containment) versus the use of monitored natural recovery. The relative amounts of active cleanup and monitored natural recovery affect the duration of construction activities and how much time it will ultimately take to reach the PRGs.

Remedial action levels (RALs) are chemical-specific sediment concentrations that trigger the need for active remediation within an SMA. Different alternatives use different RALs, and RALs are only applied to define areas requiring active remediation. RALs are not the same as PRGs. PRGs are the long-term cleanup levels and goals for the project, whereas RALs are used to manage active remediation and are applicable only in the short term to define where to begin and when you have reached the end of active remedial actions. RALs can also be the compliance concentrations used to verify that active remediation is complete, or successful, before equipment is demobilized from a site.

For this FS, ranges of RALs have been developed for the four primary risk-driver chemicals (total PCBs[3], arsenic, cPAHs, and dioxins/furans) as well as the risk-driver chemicals identified by the state SMS for protection of benthic organisms. RALs were developed with the understanding that remediation of these risk-driver chemicals will also address the other COCs.

Five remedial alternatives (Alternatives 1 through 5) were assembled to evaluate the effect of varying the RALs and to consider the differences between containment (capping and ENR) and removal (dredging). Table ES-2 summarizes the alternatives and the corresponding RALs. Alternative 1, the baseline alternative under CERCLA, assumes no further action after completing the planned actions in the five LDWG-sponsored EAAs. Each alternative thereafter builds on the previous one, by expanding the active remediation footprint of the preceding alternative. A brief description for each alternative is provided below, and Figure ES-4 provides a summary of acres, technologies, years, and costs associated with each.

ALTERNATIVE 1: NO FURTHER ACTION (COMPLETION OF EAAS)

Alternative 1 consists of completing removal actions at the five sponsored EAAs (~34 acres), which were previously identified as containing some of the highest levels of chemical concentrations in the LDW. No further management would occur outside the EAAs. This alternative is not formulated with specific risk reduction goals in mind. However, it does provide a basis to compare the relative effectiveness of other alternatives (see Section 10). Under CERCLA, a no action alternative is required as a baseline for comparison with the active alternatives. For this reason, Alternative 1 is included in the FS and considered in the evaluation and comparison analysis presented in Sections 9 and 10 respectively.

ALTERNATIVE 2: FOCUSED REMOVAL AND CONTAINED AQUATIC DISPOSAL

Alternative 2 manages a total of 193 acres (including the sponsored EAAs and all 49 SMAs) and actively remediates 69 acres. In addition to the sponsored EAAs, Alternative 2 would actively remediate SMAs that exceed the Alternative 2 RALs (see Table ES-2), including identified hot spots and areas not predicted to recover naturally to the CSL within 10 years. The technology

[3] PCBs are also a risk-driver chemical for the benthic community (RAO 3) and river otters (RAO 4).

Table ES-2: Summary of Alternatives and Remedial Action Levels

Alternative Number and Description		Risk-Driver Chemicals Remedial Action Levels (RALs)				
		Total PCBs (µg/kg dw)	Arsenic (mg/kg dw)	cPAH (µg TEQ/kg dw)	Dioxins/Furans (ng TEQ/kg dw)	Benthic SMS (41 Chemicals)
Alternative 1: No Further Action (Completion of Sponsored EAAs)		n/a	n/a	n/a	n/a	n/a
Alternative 2: Focused Removal and Contained Aquatic Disposal		2,200	93	3,100	120	Achieve CSL compliance within 10 years
Alternative 3 (Increasing Active Cleanup w/Emphasis on Containment) Alternative 4 (Increasing Active Cleanup w/Emphasis on Removal and Upland Disposal).	3a & 4a : RALs - Achieve CSL Compliance and Individual Beach Play Area Goals Immediately after Construction	1,300[a]	93	1,500 (clamming) 900 (beach play areas)[b]	49	Compliance with CSL
	3b & 4b: RALs - Achieve SQS Compliance within 10 Years after Construction	700	88	1,500 (clamming) 900 (beach play areas)[b]	49	Achieve SQS compliance within 10 years
	3c & 4c: RALs - Achieve SQS Compliance and Lower Maximum Values within 10 Years after Construction	480	57	900[b]	28	Same as for Alternatives 3b & 4b
	3d & 4d: RALs - Achieve SQS Compliance Immediately after Construction	240[c]	57	900[b]	28	Compliance with SQS
Alternative 5: Maximum Removal and Upland Disposal		100	30	900[b]	28	SQS

[a] *RAL is expressed on a dry-weight basis corresponding to the CSL (which is expressed on an organic carbon-normalized basis), assuming 2% total organic carbon.*

[b] *LDW-wide cPAH RAL for beach play areas is 900 (mg/kg dw) except for Beach 3 (600 mg/kg dw) and Beach 6 (400 mg/kg dw).*

[c] *RAL is expressed on a dry-weight basis corresponding to the SQS (which is expressed on an organic carbon-normalized basis), assuming 2% total organic carbon.*

Five site-wide alternatives were evaluated, representing a wide range of cleanup options. Some would take many years to construct, and there are multiple advantages and disadvantages among the alternatives.

emphasis for this alternative is mechanical dredging followed by contained aquatic disposal. If capacity were reached at the contained aquatic disposal site, the remaining sediment would be disposed of in an off-site regional landfill. In addition to dredging and disposal, Alternative 2 relies on natural remediation processes (i.e., MNR) and adaptive management to achieve RAOs.

ALTERNATIVE 3: INCREASING ACTIVE CLEANUP WITH EMPHASIS ON CONTAINMENT

Alternative 3 (consisting of four subalternatives labeled 3a, 3b, 3c, and 3d) emphasizes containment. Alternative 3 manages a total of 193 acres (including the sponsored EAAs and all 49 SMAs) and actively remediates 111 to 154 acres under the range of subalternatives. Active remediation of SMAs is triggered by exceedances of subalternative-specific RALs within the SMA footprint. Each subalternative has progressively lower RALs and larger active remedial footprints. Alternative 3 is the only alternative that emphasizes containment over removal. As such, the technology preferences are capping and ENR. However, removal and disposal are still significant components of the alternative because they are used where containment is determined to be impracticable. The subalternatives include:

- *Alternative 3a: Achieve CSL Compliance and Individual Beach Play Area Goals Immediately after Construction.* Alternative 3a actively remediates 111 acres.
- *Alternative 3b: Achieve SQS Compliance within 10 Years after Construction.* Alternative 3b actively remediates 122 acres.
- *Alternative 3c: Achieve SQS Compliance and Lower Maximum Values within 10 Years after Construction.* Alternative 3c actively remediates 139 acres.
- *Alternative 3d: Achieve SQS Compliance Immediately after Construction.* Alternative 3d actively remediates 154 acres.

ALTERNATIVE 4: INCREASING ACTIVE CLEANUP WITH EMPHASIS ON REMOVAL AND UPLAND DISPOSAL

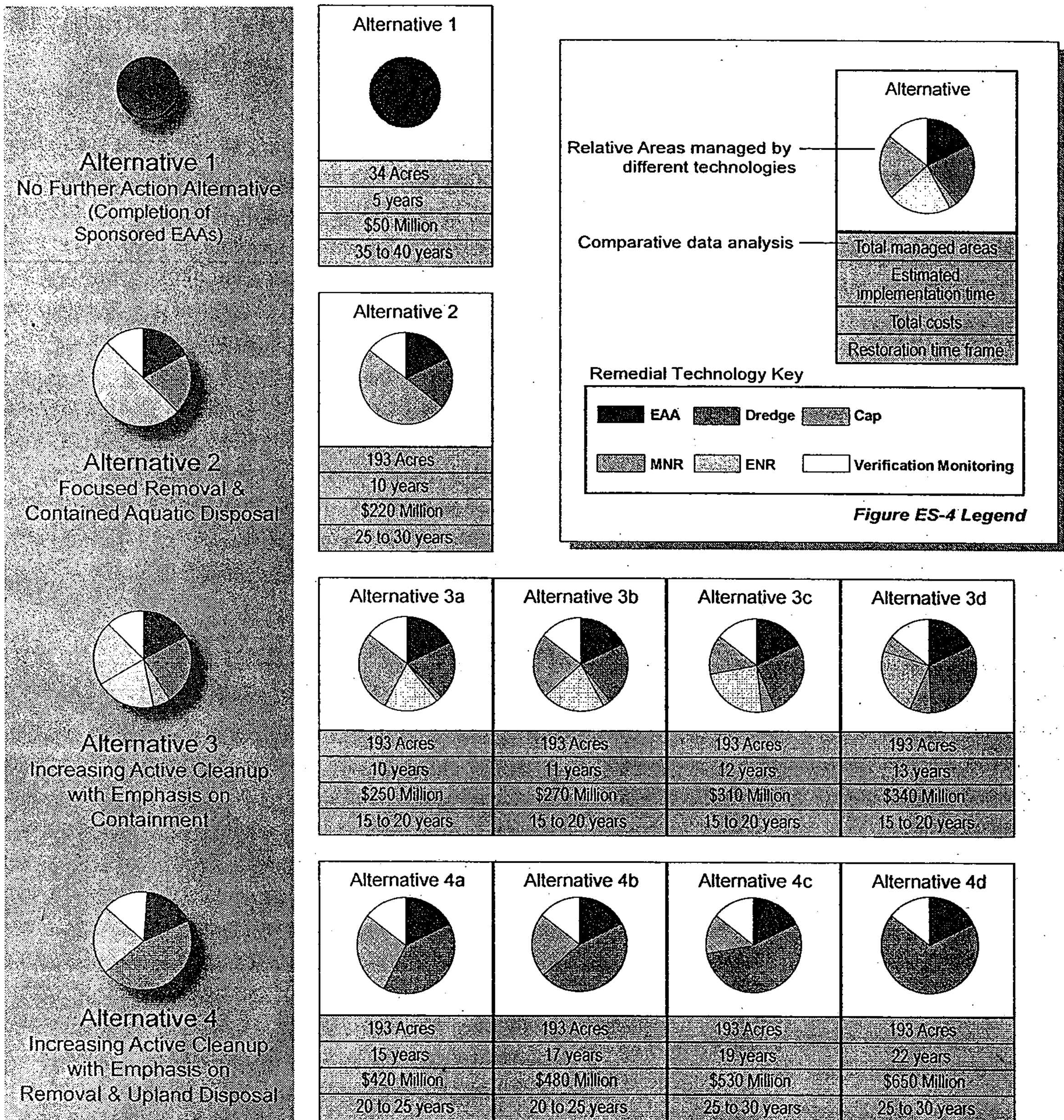
Alternative 4 manages a total of 193 acres (including the sponsored EAAs and all 49 SMAs) and emphasizes removal by dredging or excavation, with an off-site regional landfill disposal. It parallels Alternative 3 in that it also has four subalternatives (4a through 4d), one for each set of RALs applied to Alternative 3. Alternative 4d also considers treatment component (soil washing). The areas managed by Alternatives 3 and 4 are the same. For SMAs that exceed the RALs, sediments are removed to the full lateral extent of the SMA (and extent of SQS exceedances). Dredged or excavated material would be disposed of in an off-site regional landfill. Capping and ENR would be applied only where removal is technically impractical or very difficult to implement.

ALTERNATIVE 5: MAXIMUM REMOVAL AND UPLAND DISPOSAL

Alternative 5 is designed to remove all PCBs greater than 100 µg/kg dw and thereby meet the anthropogenic background range for total PCBs, arsenic, cPAHs, and dioxins/furans following the completion of construction. Alternative 5 actively remediates a total of 315 acres that includes all SMAs and substantial areas outside the defined SMAs. This alternative has the lowest PCB RAL and emphasizes removal by dredging or excavation to achieve RAOs at the end of construction. Capping and ENR may be used only where removal is technically infeasible or very difficult to implement. Dredged or excavated material would be disposed of at an off-site regional landfill. Alternative 5 does not include MNR, adaptive management, or verification monitoring.

A central factor in evaluating Alternatives 1 through 4 is that natural recovery will complement active cleanup measures (e.g., dredging, capping, ENR) and will be responsible for continued reductions in chemical concentrations over time. Natural recovery is expected to occur in the LDW, and the rate of natural recovery can be estimated but is subject to uncertainty. One

Figure ES-4: Summary of Alternatives



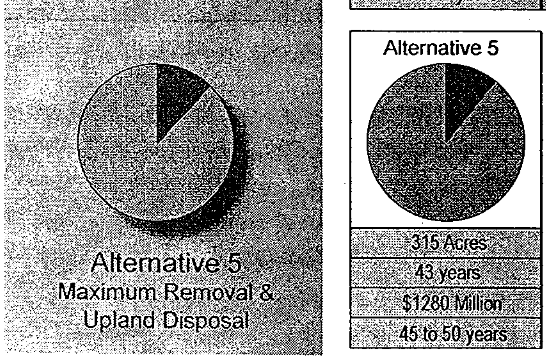
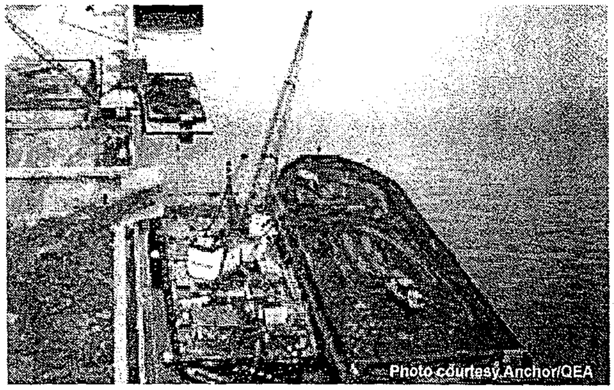


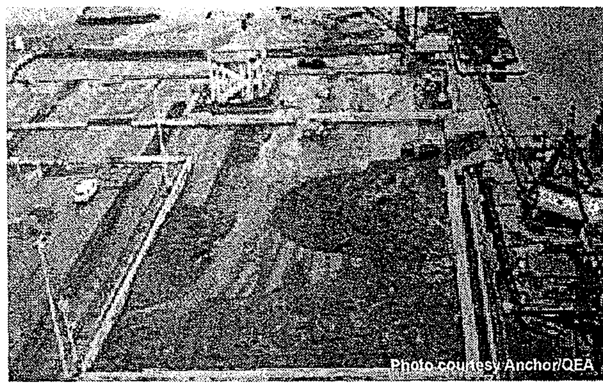
Figure ES-4 presents the range of alternatives and the relative areas managed through dredging, containment actions, and natural recovery, and shows the estimated time and costs to achieve the RAOs.

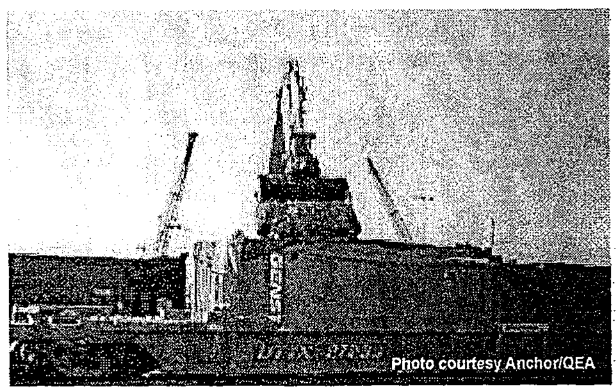
means of managing this uncertainty is to apply adaptive management concepts to the remedial alternatives. An example adaptive management element could involve identifying an active cleanup action that would be applied as a contingency, should monitoring indicate that MNR is not proceeding as expected.

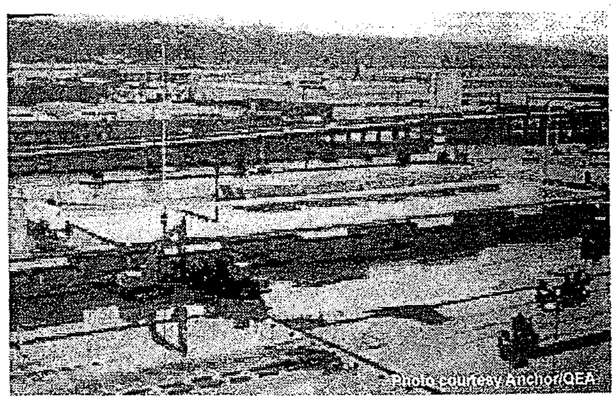
Applying increasingly more conservative RALs is another means of accommodating uncertainty associated with the rate of recovery. In this latter approach, the degree of reliance on MNR and adaptive management diminishes as lower RALs are applied. That is, lower RALs have a greater reliance on active remedial actions, thereby reducing the need for and contribution from natural recovery and adaptive management.

In summary, all of the alternatives (except No Further Action) are expected to achieve the PRGs and remediate all of the SMAs within a reasonable period of time. The alternatives vary in the amount of active versus passive remediation actions implemented to achieve the RAOs.





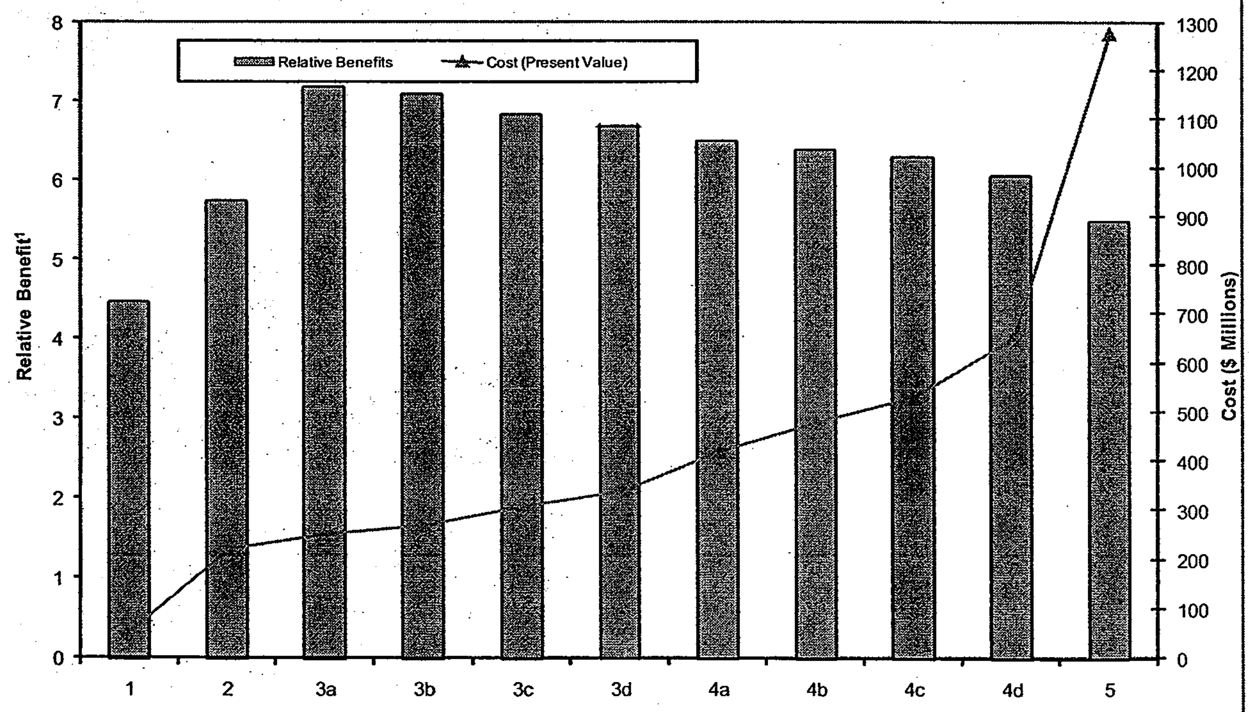




Removal with upland disposal would involve transporting the dredged sediment by barge to a staging area where the sediment would be loaded into rail cars for transport to an off-site regional landfill.

The alternatives were evaluated using the two threshold and five balancing criteria defined by CERCLA (see Table ES-3). The modifying criteria of state, tribal, and community acceptance have not yet been evaluated; they will be evaluated following formal public comment on the draft FS and EPA's proposed plan. These alternatives were also evaluated using the MTCA criteria with similar results (see Appendix J). Figure ES-5 summarizes the total benefits and costs of the alternatives using the MTCA criteria. Alternative 5 was screened out from further consideration because of its disproportionate costs (greater than $1.2 billion), lower overall benefits, and long implementation time frame (43 years). Alternative 1 was retained in the detailed and comparative analyses as the CERCLA baseline alternative for comparison with the other alternatives.

Figure ES-5: Total Benefits and Costs of Cleanup Alternatives



[1] Benefits consider protectiveness, permanence, long-term effectiveness, management of short-term risk, and implementability, as described in Appendix J.

All alternatives involve active cleanup, and all reach similar risk reduction endpoints. They vary, however, in terms of the time to meet those endpoints, costs, construction impacts, and overall benefits. All of the alternatives are expected to achieve anthropogenic or area background concentrations for the risk-driver chemicals throughout the LDW.

Table ES-3: NCP Evaluation Criteria for Detailed Analysis of LDW Remedial Alternatives

	Criteria	FS Evaluation Factors
Threshold	1. Overall Protection of Human Health and the Environment	Controls used to reduce risks
		Effectiveness summary
	2. Compliance with ARARs[a]	Chemical-specific
		Location-specific
		Action-specific
Balancing	3. Long-Term Effectiveness and Permanence	Magnitude and type of residual risk
		Adequacy and reliability of controls
	4. Reduction in Toxicity, Mobility, or Volume Through Treatment (applies only to Alternative 4d)	Treatment process used
		Amount of hazardous material destroyed or treated
		Reduction in toxicity, mobility, or volume
		Treatment irreversibility
		Nature and quantity of post-treatment residuals
	5. Short-Term Effectiveness	Community protection
		Protection of workers
		Environmental impacts
		Time to achieve RAOs
	6. Implementability	Ability to construct and operate technology
		Reliability of the technology
		Ease of undertaking additional remedial actions
		Monitoring considerations
		Ability to coordinate and obtain approval from agencies
		Availability of transloading and offsite disposal services and capacity
		Availability of technology, equipment, and specialists
	7. Cost	Capital
		Operations, maintenance, and monitoring
		Total present value
Modifying	8/9. State, Tribal, and Community Acceptance	Will be evaluated in the ROD following the public comment period on the RI/FS

Source: Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, EPA October 1988.

[a] *ARARs = Applicable or Relevant and Appropriate Requirements*

Figures ES-6a and ES-6b rank the alternatives according to both the CERCLA and MTCA criteria. As mentioned above, Alternative 5 was screened from further consideration and is not considered in the comparative analysis. The following summarizes the key points of the comparative analysis.

PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT & COMPLIANCE WITH ARARS

Alternative 1 provides the least protection of human health and the environment and is not expected to meet the SMS requirement to achieve site cleanup standards within 10 years after construction. All other alternatives are considered protective of human health and the environment and comply with applicable or relevant and appropriate requirements (ARARs). Alternative 2 addresses approximately twice the remedial footprint area as Alternative 1 and all of the higher priority SMAs, but relies much more on natural recovery of the SMAs with lower chemical concentrations than Alternatives 3 and 4. Alternative 2 also includes a contained aquatic disposal option that could avoid many of the short-term impacts associated with truck and rail transport that would occur with any of the other alternatives. Alternative 2 has fewer short-term impacts to the community, workers, and the environment than Alternatives 3 and 4. Overall, Alternative 2 ranks lower in short-term effectiveness than Alternative 3 due to the longer restoration time frame, and it ranks lower in long-term effectiveness than either Alternative 3 or 4. For these reasons, Alternative 2 is ranked in the middle of the alternatives for *Protection of Human Health and the Environment.*

Figure ES-6a: Comparative Analysis of Cleanup Alternatives

Alternative	Cost (Net Present Value)	CERCLA Evaluation of Alternatives[a]						
		Overall Protection of Human Health and the Environment	Compliance with ARARs	Reduction in Toxicity, Mobility or Volume Through Treatment[b]	Long-term Effectiveness	Short-term Effectiveness	Implementability	Cost
1	$50 M	●	●	●	●	◒	◍	◍
2	$220 M	○	◍	●	○	○	◒	◍
3a	$250 M	◍	◍	●	◓	◍	◍	◍
3b	$270 M	◍	◍	●	◓	◍	◍	◍
3c	$310 M	◓	◍	●	◓	◓	◓	◓
3d	$340 M	◓	◍	●	◓	◓	◓	◓
4a	$420 M	◓	◍	●	◍	○	◓	○
4b	$480 M	◓	◍	●	◍	○	○	○
4c	$530 M	○	◍	●	◍	◒	○	◒
4d	$650 M	○	◓	◒	◍	◒	◒	◒

Notes:
State, tribal, and community acceptance will be evaluated following formal public comment on the FS and EPA's proposed plan.

[a] *Ratings based on rankings shown in Table 10-1.*

[b] *Treatment is only a component of Alternative 4d, which uses soil washing technology.*

◍ - *Ranks very high compared to other alternatives*
◓ - *Ranks relatively high compared to other alternatives*
○ - *Ranks average compared to other alternatives*
◒ - *Ranks low-moderate compared to other alternatives*
● - *Ranks low compared to other alternatives*

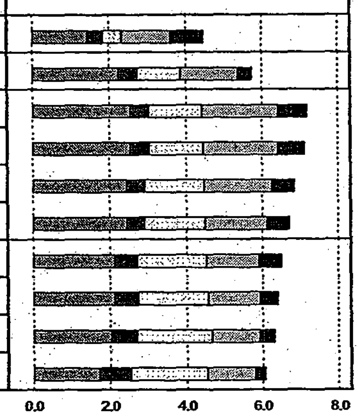
The Alternative 3 series (3a through 3d) uses various combinations of dredging, capping, ENR, and MNR to address all of the SMAs, but emphasizes the use of containment over dredging when feasible. Because containment technologies can be implemented more rapidly and less intrusively than dredging, the Alternative 3 series has significantly fewer short-term impacts than the corresponding Alternative 4 series. Alternatives 3a through 3d are also expected to achieve the RAOs 5 to 10 years earlier than Alternatives 2 and 4. Alternatives 3a and 3b are ranked the highest of all the alternatives for *Protection of Human Health and the Environment*, because they provide the best balance between long- and short-term effectiveness.

The Alternative 4 series provides greater long-term effectiveness than the corresponding Alternative 3 series and Alternatives 1 and 2 because it removes larger volumes of sediment. However, the extended time required to complete the dredging activities and their intrusive nature makes implementation progressively more difficult and disruptive as the dredged area increases. The extended period of disruptions also means that Alternatives 4c and 4d have the highest short-term impacts. For these reasons, Alternatives 4c and 4d are ranked similar to Alternative 2, whereas Alternatives 4a and 4b are ranked similar to Alternatives 3c and 3d.

Alternatives 2, 3, and 4 can meet ARARs and are ranked the same for this criterion, with the exception of Alternative 4d. Alternative 4d ranks slightly lower than the other alternatives because of its lengthy implementation period and associated potential for significant ARAR compliance and permitting issues related to the soil washing technology and the beneficial reuse of the treated sand fraction.

Figure ES-6b: Comparative MTCA Ratings

Alternative	Cost (Net Present Value)	Weighted Ratings Under MTCA Total Benefits by Criterion [a]
1	$50 M	
2	$220 M	
3a	$250 M	
3b	$270 M	
3c	$310 M	
3d	$340 M	
4a	$420 M	
4b	$480 M	
4c	$530 M	
4d	$650 M	



Notes:
[a] See Appendix J for detailed evaluation

- Overall Protectiveness
- Permanence
- Long-Term Effectiveness
- Management of short-term risks
- Implementability

LONG-TERM EFFECTIVENESS AND PERMANENCE

Long-term effectiveness and permanence consider the residual risks that remain after the RAOs have been achieved, and the controls that can be used to manage these residual risks. The comparative analysis found:

- All of the alternatives are predicted to achieve anthropogenic background concentrations for the risk-driver chemicals on an LDW-wide basis and achieve similar risk endpoints once RAOs have been achieved. The differences in the long-term effectiveness of the alternatives are related to the adequacy and reliability of controls for managing residual subsurface contamination.
- Alternative 4 is ranked higher than the other alternatives because the Alternative 4 series involves the most extensive removal of contaminated sediment and therefore has a lower potential for future exposure.
- Alternative 3 includes a significant component of capping, ENR, and MNR, which will require long-term monitoring and other controls once the RAOs are achieved. Alternative 3 is ranked lower than Alternative 4 for this reason.

- Alternative 2 includes a contained aquatic disposal option for managing dredged material and includes 96 acres of MNR. The magnitude of the risks of remediation failure are more significant than for Alternative 3. Therefore, Alternative 2 is ranked lower than Alternative 3.
- Alternative 1 is ranked lowest because it removes the least contaminated sediment and includes no long-term reliable controls to manage residual risks for areas outside of the sponsored EAAs.
- Institutional controls will be required under any alternative to manage risks remaining from anthropogenic background chemical concentrations.

REDUCTIONS IN MOBILITY, TOXICITY, OR VOLUME THROUGH TREATMENT

This criterion considers the reduction of contaminant mobility, toxicity, or volume achieved through treatment. Treatment is generally preferred to address principal threat wastes (e.g., highly toxic or highly mobile waste) that are not found in the LDW. However, use of other institutional and engineering controls is also acceptable for the low-level threats present in the LDW (40 CFR Section 300.430 (a)(1)(iii)). The comparative analysis made these key findings regarding reduction in mobility, toxicity, or volume through treatment:

- Alternative 4d is the only one to include a treatment component (soil washing) and therefore it is ranked slightly higher compared to the other alternatives. However, this treatment also generates residuals and does not destroy chemicals. Site-specific applications of ex-situ treatment (such as stabilization or sediment washing) may be considered during remedial design for any of the alternatives. Also, site-specific applications of in-situ treatment using reactive caps may be considered during remedial design as an additional process option for ENR and capping. These options are not accounted for in the rankings. If used, they would increase ratings of alternatives with ENR and capping (primarily Alternative 3).
- All of the alternatives include some combination of removal, disposal, containment, and natural recovery. While none of these technologies actually treat contaminated sediment, they do reduce the toxicity, mobility, and volume of chemicals remaining in surface sediment compared to Alternative 1.

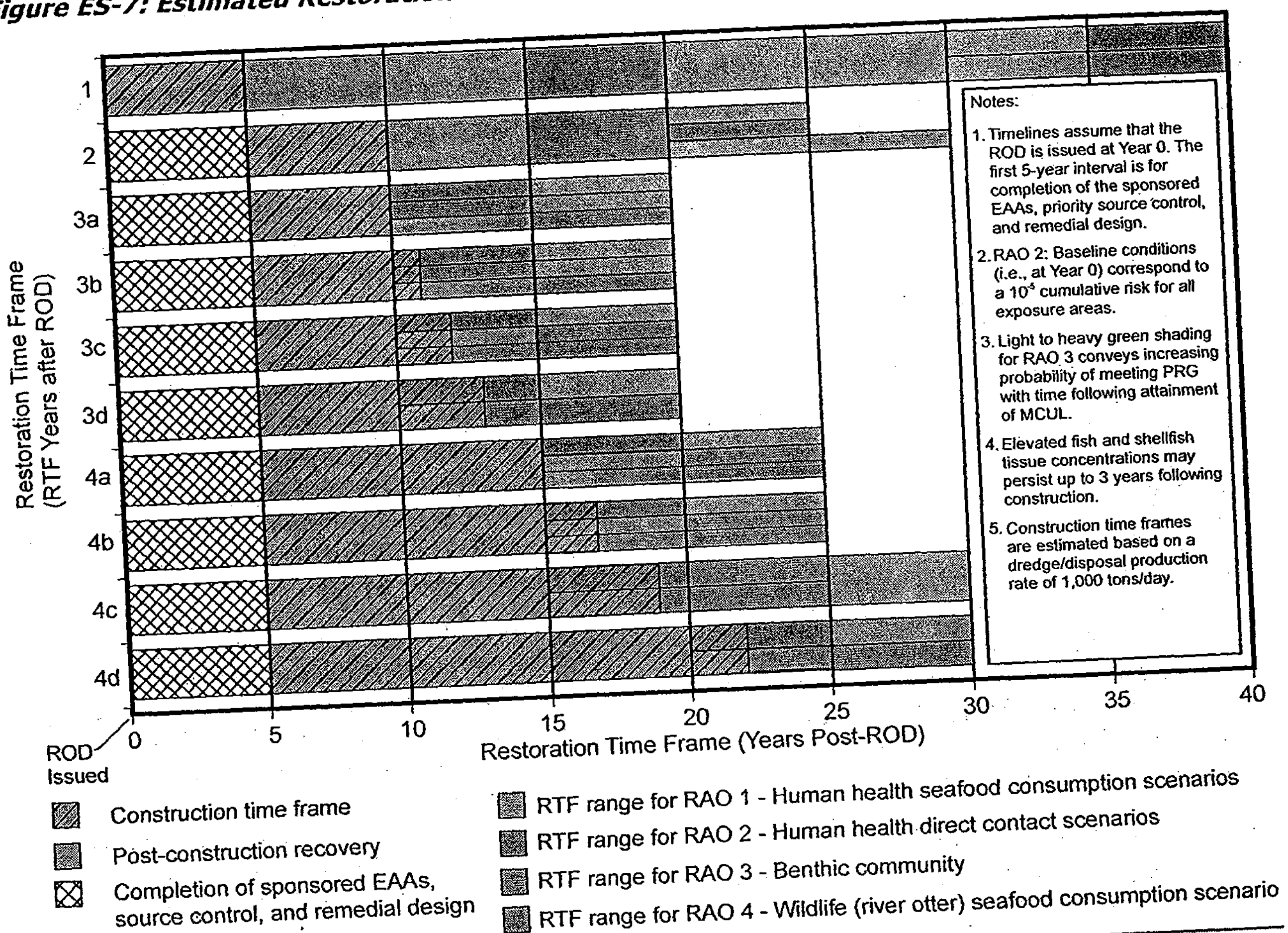
SHORT-TERM EFFECTIVENESS

Short-term effectiveness is a measure of the time required to achieve the RAOs and the risks and impacts that may occur during that implementation. The evaluation had these key results:

- Alternative 3 achieves the RAOs in the shortest time and is ranked higher than Alternative 4 as a result of its shorter construction periods and fewer construction-related impacts. Alternative 2 has a similar restoration time frame to Alternative 4, but fewer construction-related impacts. Alternative 1 has the shortest construction period with the least construction-related impacts, but requires the longest time to achieve the RAOs.

Greater sediment removal through dredging means greater permanence, but at a higher cost and over a longer period than other technologies. Also, for people and wildlife that eat resident seafood from the LDW, risks will likely remain high throughout the dredging period under any alternative. Consumption advisories can help manage these increased risks to people, but not wildlife.

Figure ES-7: Estimated Restoration Time Frames of the Remedial Alternatives



- Figure ES-7 shows the estimated restoration time frames for achieving the RAOs. The restoration time frame includes the time to complete the EAAs and design and implement the active remediation components of a remedial alternative, and the recovery time associated with MNR. The Alternative 3 series is projected to achieve all RAOs in 15 to 20 years. Alternatives 4a and 4b are projected to achieve all the RAOs in 20 to 25 years and Alternatives 2, 4c, and 4d are projected to achieve all the RAOs in 25 to 30 years. Alternative 1 may require 40 years to achieve all the RAOs because it would have to rely only on natural recovery processes for all areas outside the sponsored EAAs.
- Short-term construction-related impacts (environmental, worker, and community) increase proportionately with the area affected by the cleanup and the amount of dredging included in an alternative. Alternatives with a containment emphasis have fewer short-term impacts (and those impacts have a shorter duration) compared to the alternatives with a dredging emphasis. This relationship holds for each of the key short-term impacts evaluated in this analysis, including mobilizing chemicals into fish and shellfish tissue, habitat disturbance, equipment and vehicle emissions, traffic, consumption of landfill capacity, and worker protection.

- For people and wildlife that eat resident seafood from the LDW, risks will be elevated throughout the period of dredging under each alternative. Consumption advisories can help manage these increased risks to people but not wildlife. The duration of these short-term risks would be greatest under Alternative 4d and least for Alternative 1 and affect the restoration time frames for those RAOs.
- For all alternatives, the construction sequencing affects how much risk is reduced during and after the construction period. Cleanup of the most contaminated SMAs during the earliest phases is expected to achieve faster progress toward achieving the RAOs. Sequencing becomes progressively more important as the extent and duration of active remediation increase.
- Alternatives 3a and 3b rank highest when considering the time to achieve RAOs and construction-related impacts. Alternatives 3c and 3d rank the second highest, and Alternatives 4a, 4b, and 2 are ranked in the middle. Alternative 2 has a longer restoration time frame than 4a and 4b but fewer construction-related impacts. Alternatives 4c and 4d are ranked lower due to their longer restoration time frame and higher construction-related impacts. Alternative 1 is ranked similarly to Alternatives 4c and 4d because it has the longest restoration time frame.

IMPLEMENTABILITY

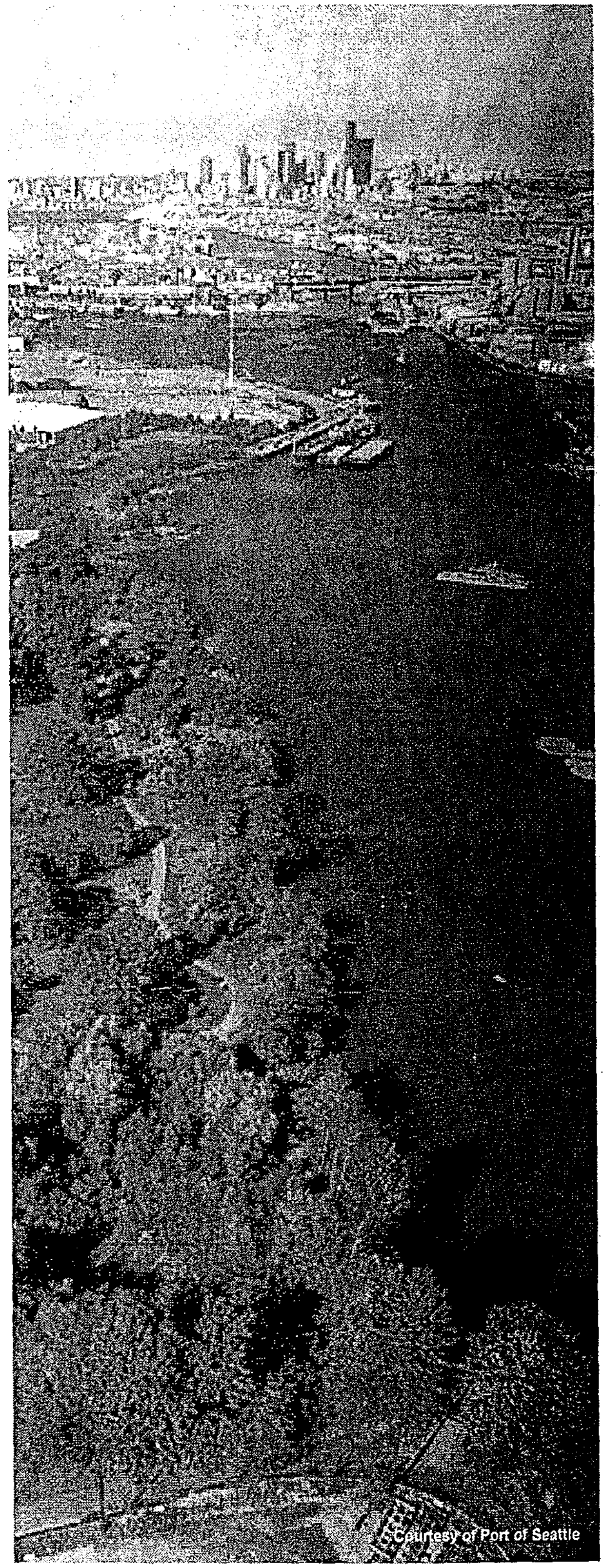
This criterion considers both the technical and administrative ability to implement each alternative. Each of the alternatives involves various combinations of technologies that have been successfully implemented at numerous sites in the Puget Sound region and throughout the country. The required equipment and appropriately skilled personnel are readily available and coordination of the activities among agencies can be achieved. Based on the comparative analysis:

- Alternative 1 is ranked high because some of the required approvals have already been obtained and the removal actions have either been completed or are expected to be initiated soon.
- Alternative 2 is ranked lower than other alternatives under this criterion because of the administrative complexity associated with getting approval for a contained aquatic disposal site in the LDW.
- Alternatives 3a and 3b rank high (similar to Alternative 1) because the emphasis on containment and smaller active footprints is expected to pose fewer technical and administrative challenges than comparable alternatives that emphasize removal or larger active footprints. The larger active footprints of Alternatives 3c and 3d are ranked lower than Alternatives 3a and 3b.
- As the RALs decrease in the Alternative 4 series, the active remediation footprint also increases, thereby raising the potential for technical problems and administrative delays (e.g., water quality monitoring, protection of fish migration windows, coordination with vessel traffic). Therefore, subalternatives 4b, 4c, and 4d rank lower than subalternative 4a. Project sequencing is an important consideration from a recontamination perspective. The larger dredging alternatives (4b, 4c, and 4d) are more difficult to sequence in a specific order, because of the difficulties in coordinating multiple remediation projects and source control actions, and associated programmatic difficulties.
- Alternative 4d has the lowest ranking (along with Alternative 2) as it may be less implementable than the other alternatives because the treatment (soil washing) technology would be subject to additional permitting requirements and greater administrative complexity if located off-site. Significant administrative concerns are also associated with the end-use of any treated sediments.

COST

In terms of cost, the comparative analysis reached these conclusions:

- The alternatives differ significantly in costs. Alternative 2 has the next lowest cost after Alternative 1, whereas Alternative 4d has the highest cost, at approximately three times more than Alternative 2.
- Alternatives with a containment focus (Alternative 3 series) have significantly lower costs than the corresponding alternatives that rely on dredging for active remediation (Alternative 4 series). Alternatives 3a and 3b have similar costs to Alternative 2 and are cost-effective because they achieve the RAOs in a similar time frame to Alternatives 3c and 3d.


Courtesy of Port of Seattle

Expected Outcomes and Uncertainties

Given that the alternatives are estimated to require one to two decades to implement and even longer to achieve cleanup goals, the cleanup actions will likely need to be adapted to new information as it becomes available. The alternatives address this uncertainty by including the expectation that long-term monitoring and contingency actions will be a necessary part of any alternative selected. The FS analyses lead to the following predictions (and uncertainties in these predictions will need to be considered in the decision-making process):

- Alternatives 2 through 4 are expected to significantly reduce seafood consumption risks after they are implemented. However, seafood consumption risks (to humans and wildlife) can be expected to increase for the duration of construction as a result of the disturbance of contaminated sediments. The alternatives vary substantially in their estimated construction periods.
- For any alternative, following construction, natural recovery, and achievement of the RAOs, anthropogenic background concentrations of chemicals will remain in sediment and in fish and shellfish tissue. The LDW sediments are expected to equilibrate to an anthropogenic background concentration reflecting the influx of upstream sediments and other urban inputs. For this reason, seafood consumption advisories may remain in effect in the LDW, no matter which alternative is selected.
- Alternatives 2 through 4 are expected to make significant progress toward achieving the RAOs immediately after construction. Using conservative assumptions, it is highly likely that all of the RAOs will be fully achieved in a period of 20 to 30 years for Alternatives 2 through 4. Alternative 3 achieves the RAOs in the shortest time when compared to all the other alternatives.
- Long-term monitoring and source control measures will be necessary regardless of the remedial alternative selected.
- Interim goals can be set based on these expectations and the alternatives can be adapted as new information is developed, both during the design phase, during construction, and during the execution of the long-term monitoring plan.

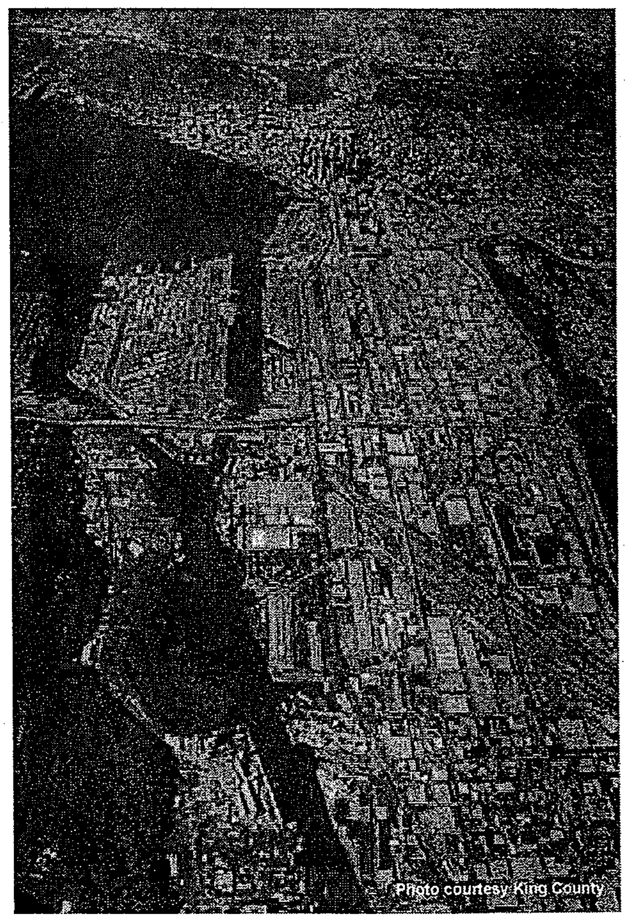


Photo courtesy King County

Conclusions and Recommendations

Beyond the CERCLA and MTCA frameworks for evaluating alternatives in an FS, a substantial body of research and guidance has been developed to address cleanup of contaminated sediment sites. Agencies recognize that sediment sites are complex, difficult to predict, and often require an integrated approach for success. In response to these challenges and lessons learned from other projects, EPA developed 11 sediment risk management principles. These 11 guiding principles were also considered in developing the recommendations presented in the FS regarding the most effective approach to cleanup. A recommended approach to project phasing is presented in Section 11 and incorporates these guiding principles. Key considerations include:

- Controlling sources of contaminants will be critical to the long-term success of any remedial action taken in the LDW. Ecology is implementing a source control program that will ultimately reduce sources of contaminants entering the LDW.[3]
- The greatest reduction in LDW-wide chemical concentrations will result from managing the previously identified EAAs and other identified hot spots. Interestingly, while all areas of known contamination in the LDW could be remediated through active remediation projects (requiring more than 20 years), such an extensive cleanup will take almost as long as it should take much of the LDW to recover naturally following removal of sediment from the most highly contaminated areas.
- Elevated chemical concentrations in seafood tissue during and immediately following dredging operations are well documented, and extensive dredging can also have adverse short-term impacts on the community, workers, and the environment as a result of the extended construction period. Some of these short-term impacts can be decreased by relying on non-dredging technologies with shorter construction durations, such as capping, ENR, and MNR.
- The added environmental, economic, and social costs of implementing alternatives with more extensive dredging should be weighed against the incremental benefits that can be achieved by dredging.
- Considering the uncertainties in predicting future conditions in such a complex system as the LDW, various adaptive management approaches should be included in the cleanup decision.

Risk Management Principles Recommended for Contaminated Sediment Sites

1. Control sources early.
2. Involve the community early and often.
3. Coordinate with states, local governments, Indian tribes, and natural resource trustees.
4. Develop and refine a conceptual site model that considers sediment stability.
5. Use an iterative approach in a risk-based framework.
6. Carefully evaluate the assumptions and uncertainties associated with site characterization data and site models.
7. Select site-specific, project-specific, and sediment-specific risk management approaches that will achieve risk-based goals.
8. Ensure that sediment cleanup levels are clearly tied to risk management goals.
9. Maximize the effectiveness of institutional controls and recognize their limitations.
10. Design remedies to minimize short-term risks while achieving long-term protection.
11. Monitor during and after sediment remediation to assess and document remedy effectiveness.

Source: EPA (2002)

[3] Final evaluation of source control status may occur before construction of the selected remedial alternative.

For Discussion: An Adaptive Management Approach

Many factors need to be weighed during the selection of a remedial alternative for the LDW. At this time, there is insufficient information to adequately evaluate the CERCLA modifying criteria of state, tribal, and community acceptance. That analysis will be integrated into the record of decision for the LDW based on input received during the development of the Final FS and proposed plan for the LDW.

Based on the CERCLA and MTCA evaluation criteria, the national guidance for contaminated sediment remediation, and the extensive comparative analysis of alternatives, the remedial alternative selected for the LDW should involve a carefully crafted approach that concentrates on actively cleaning up the most contaminated areas first, evaluating the monitoring results, and then continuing active cleanup as needed to achieve the RAOs within a reasonable time frame. This approach is made after considering:

- The inherent uncertainties in predicting the restoration time frames for any alternative.
- The certainty that a long time frame will be necessary to implement the alternatives with the greatest amount of dredging, combined with the greater short-term impacts of those alternatives.
- The conceptual site model and empirical data, which indicate that the LDW is a net depositional environment and suggest that many SMAs will have already achieved the RAOs by the time any sequenced cleanup addresses those areas.
- Experiences at other complex sediment sites that point to the necessity of using adaptive management strategies, as recommended by EPA guidance, the National Academy of Sciences, and other independent, scientific peer reviews of sediment sites throughout the country.
- The substantial public and private funding required for any of the alternatives reviewed in this FS.

The approach should focus on: cleaning up the most contaminated areas first to reduce risks the fastest, assessing the progress of natural recovery, learning from each incremental cleanup experience, and adjusting further actions based on the newest data and lessons learned.

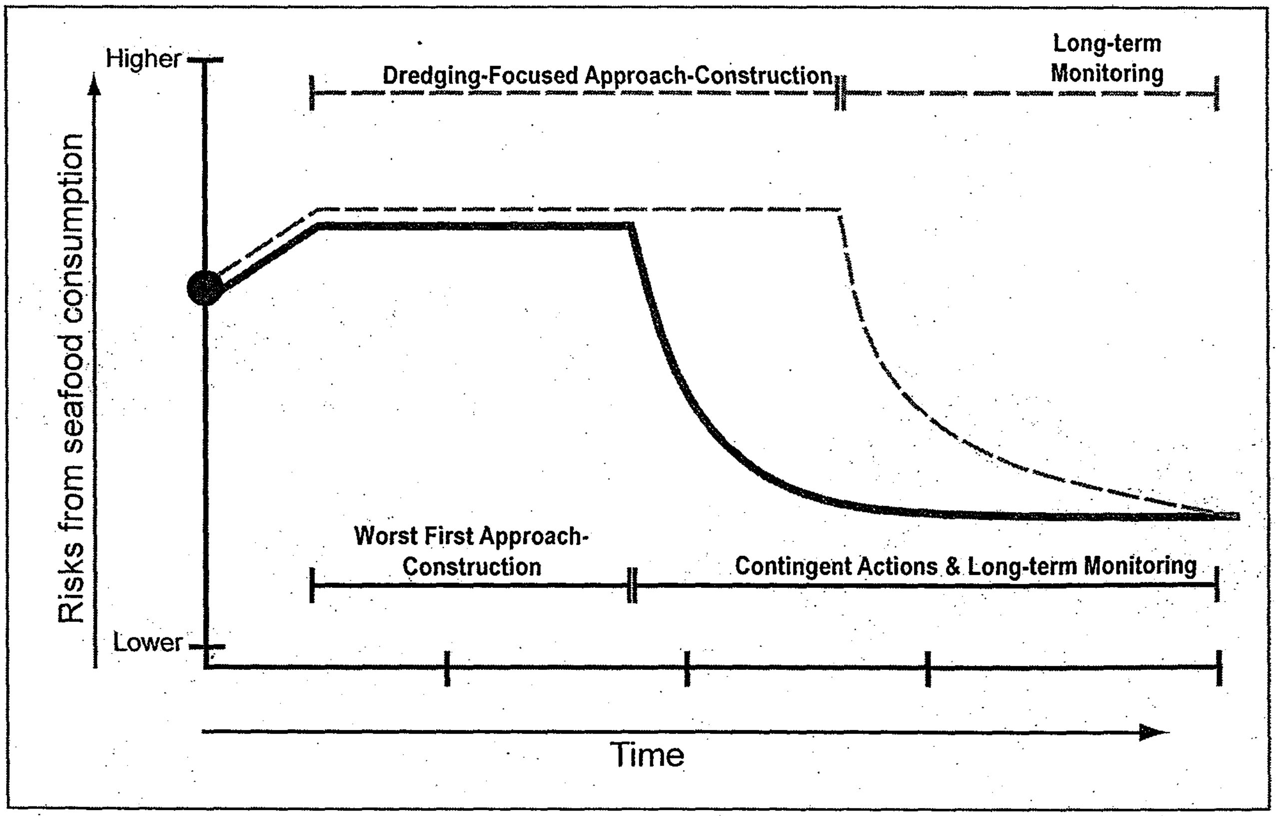
The approach assumes that project sequencing will start with active remediation of the most contaminated areas, with subsequent management/remediation of the less contaminated areas as necessary to achieve the RAOs. Intermittent monitoring, as embedded in the long-term performance monitoring plan, will provide valuable information regarding the progressive recovery of the system prior to remedy completion. Hence, the long-term performance monitoring results will be used to guide and craft adaptive management contingency actions, as needed, to achieve the RAOs.

Because Alternatives 3 and 4 both include subalternatives a through d, each subset fully captures and embeds the previous subalternative's actions along with the actions identified to achieve the lower RALs. This provides a "continuum" of actions. By linking this continuum of actions with the overall management plan to progressively remediate the most contaminated SMAs first (i.e., "worst first") and then combining it with ongoing natural sediment recovery processes, this combination introduces the possibility for significant flexibility in the implementation of cleanup in the LDW.

The most contaminated SMAs have the greatest influence on spatially-weighted average concentrations of the risk-driver chemicals. The approach of first remediating hot spots is expected to achieve the greatest reduction in the LDW-wide spatially-weighted average concentrations and risks. Each successive cleanup action, continuing with the "next worst" area of remaining sediment, results in the quickest and most effective incremental risk reduction.

Simultaneously, the input of Green/Duwamish River sediment and its deposition throughout the entire LDW is predicted to result in continued natural recovery processes after sources have been adequately controlled. LDW-wide trends show that many areas of the LDW are recovering naturally. As the areas with the highest chemical concentrations are actively remediated, natural recovery will likely continue in the areas with lower chemical concentrations not designated for active management. Under this scenario, by the time a phased active remediation would be scheduled for these less contaminated areas, natural recovery is predicted to have already lowered concentrations in these areas to the point that they will either have already have achieved the RAOs or would clearly achieve them within a reasonable restoration time frame. A carefully orchestrated sequence of remedies and monitoring will determine when enough active remediation has been completed to achieve the RAOs. Figure ES-8 illustrates these concepts.

Figure ES-8: Effect of Cleanup Approaches on Seafood Risks



Project phasing is an important tool for achieving goals and minimizing impacts and costs. For all alternatives, construction sequencing affects how rapidly risk is reduced during and after construction. Cleanup of the most contaminated areas during the earliest phases – "Worst First" – makes the fastest progress toward cleanup goals.

Next Steps

This draft FS provides the basis for obtaining input from many interested parties. EPA, Ecology, and LDWG intend to solicit input from a broad range of stakeholders and incorporate this input into the next draft of this FS. The second draft of the FS will be available in early 2010 for additional public input and agency review and the FS will then be finalized. EPA and Ecology will then issue a proposed plan that identifies a preferred remedial alternative for the LDW. Formal public comment will be received on the proposed plan. After public comments on the proposed plan are received and evaluated, the agencies will select the final remedial alternative and publish the decision in their respective decision documents.


Photo courtesy King County


Photo courtesy City of Seattle


Photo courtesy Windward Environmental

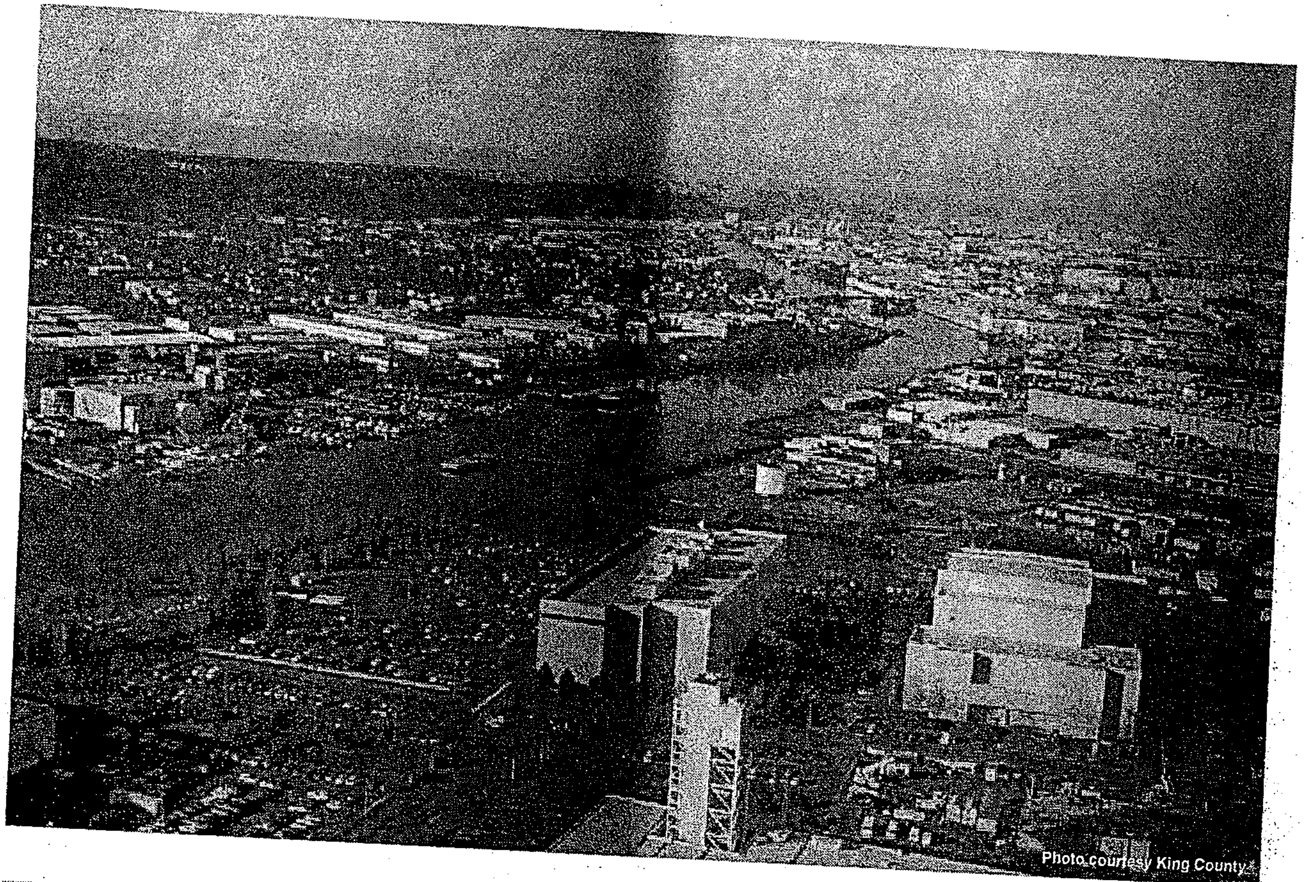
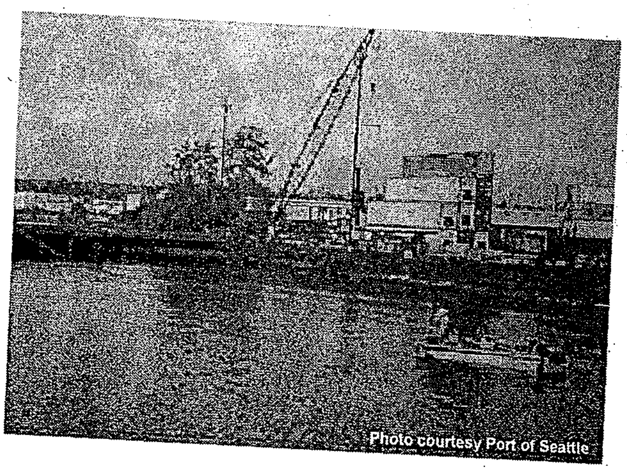


Photo courtesy King County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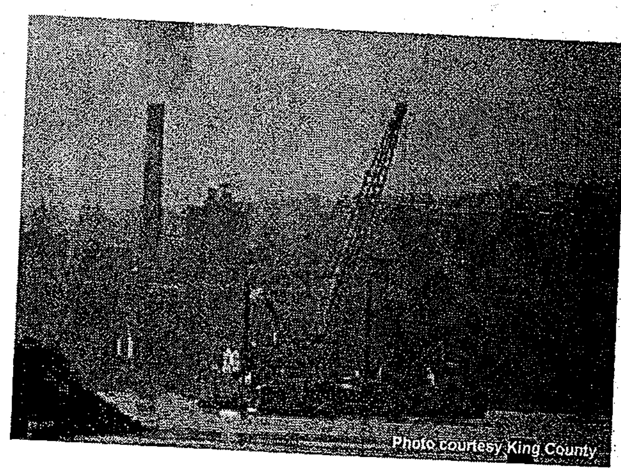
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Lower Duwamish Waterway Group

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