Pre-Assessment Screen – Lower Duwamish River

ELLIOTT BAY TRUSTEE COUNCIL, DECEMBER 2, 2009

I. INTRODUCTION, AUTHORITIES, AND DELEGATIONS

Pursuant to the authority of section 107(f) of the Federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended, 42 U.S.C. section 9607(f), and other applicable Federal and state laws, designated authorities may act on behalf of the public as natural resource trustees to pursue claims for natural resource damages for injury to, destruction of, or loss of natural resources resulting from the release of hazardous substances to the environment. Claims may be pursued against parties that have been identified as responsible for releasing hazardous substances to the environment. Under CERCLA, sums recovered by trustees as damages shall be used only to restore, replace, or acquire the equivalent of such natural resources.

The purpose of a preassessment screen is to provide a review of readily available information on hazardous substance releases and the potential impacts of those releases on natural resources under the trusteeship of Federal, tribal and state authorities. The review should determine whether there is a reasonable probability of making a successful claim against parties responsible for releasing hazardous substances to the environment. A preassessment screen also documents the trustees' determination that further investigation and assessment efforts are warranted.

This preassessment screen addresses potential claims for natural resource damages for injury to, destruction of, or loss of natural resources resulting from the release of hazardous substances to the Lower Duwamish River (LDR). It was prepared in accordance with the preassessment screen provisions of the Federal regulations for Natural Resource Damage Assessments under CERCLA, 43 CFR Part 11, Subpart B, sections 11.23 through 11.25.

The LDR is an approximate 7 mile segment of the lower river extending from the vicinity of North Winds Weir to the mouth at Elliott Bay. The segment includes the Harbor Island Superfund site (added to the National Priorities List (NPL) in 1983), the Lockheed West Seattle Superfund site (added to the NPL in 2007), and the Lower Duwamish Waterway Superfund site (added to the NPL in 2001). The LDR is more fully described in Section II below. The natural resource trustees for the LDR who have participated in the preparation of this preassessment screen include the Secretary of the United States Department of Commerce, acting through the National Oceanic and Atmospheric Administration (NOAA), the Secretary of the United States Department of the Interior (DOI), acting through the U.S. Fish and Wildlife Service, the Director of the State of Washington Department of Ecology (ECY), the Muckleshoot Indian Tribe, and the Suquamish Tribe.

A review of readily available information documenting releases of polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), metals, semivolatile organic compounds, organotins, and pesticides to the LDR; the presence of these hazardous substances in the sediments at levels exceeding Washington State Sediment Management Standards (SMS) (WAC 173-204); and the effects of these releases on natural resources for which Federal and state agencies and Indian tribes may assert trusteeship under section 107(f) of CERCLA, ensures that there is a reasonable probability of making a successful claim against an identified potentially responsible party for natural resource damages with respect to these releases. Specifically, the Trustees have determined that:

(1) A release of a hazardous substance has occurred;

(2) Natural resources for which the trustees may assert trusteeship under CERCLA have been or are likely to have been adversely affected by the release;

(3) The quantity and concentration of the released hazardous substance is sufficient to potentially cause injury to natural resources;

(4) Data sufficient to pursue an assessment are readily available or likely to be obtained at a reasonable cost; and

(5) Response actions, if any, carried out or planned do not or will not sufficiently remedy the injury to natural resources without further action.

II. INFORMATION ON THE LDR

A. Description of the Affected Environment

The LDR is an approximate 7 mile segment of the Duwamish River extending from the vicinity of North Winds Weir to the mouth at Elliott Bay. The segment includes the Lower Duwamish Waterway Superfund site and the Harbor Island Superfund site. Several sites within the area are being cleaned up by the Environmental Protection Agency (EPA) and ECY under the Resource Conservation and Recovery Act and Model Toxics Control Act.

Lower Duwamish River

The Duwamish River (Figure 1) is a heavily traveled and industrialized river that is located south of Seattle, Washington. From its point of origin at the confluence of the Green and Black rivers near Tukwila, WA, the river flows approximately 11 miles northwest toward Harbor Island. At Harbor Island, the river diverges to form the East and West waterways before discharging into Elliott Bay. An area of approximately 483 square miles drains into the Duwamish River/Green River system. Dredging and filling activities over the past century have significantly changed the original course of the river. The U.S. Army Corps of Engineers maintains a navigation channel in the lower

Duwamish, beginning at the upper turning basin -- Turning Basin #3. The shoreline of the LDR is characterized by constructed bulkheads; manmade structures, including piers, wharves, and buildings extending over the water; and banks covered in riprap or other fill materials.

Areas adjacent to the LDR have been developed primarily for industrial and commercial operations. For example, cargo handling and storage, as well as manufacturing operations, including the manufacture of boats, concrete and other stone material, paper, metals, and airplane parts, are prevalent along the lower reaches of the river. The Duwamish also serves as a point of discharge for numerous storm drains (SD) and combined sewer overflows (CSO).

Stream flow of the LDR averages about 1,500 to 1,800 cubic feet per second (cfs) and ranges from 200 cfs to 12,000 cfs. The river largely is regulated by the Howard-Hanson dam located upstream of the Green and Black rivers. Peak discharges generally occur during the winter rains, with secondary peaks during spring snowmelt. The lowest flow rates occur during the late summer and fall.

Tidal effects throughout the LDR create estuarine stratification, forming a "saltwater wedge" in which the surface water is generally fresh or brackish while the bottom layers are more saline. The upstream extent of this saltwater wedge has been found as far down channel as the 16th Avenue South Bridge; however, during low flows, the saltwater wedge often extends well upstream of the LDR.

Sediment composition varies throughout the LDR. According to historical surface sediment data, sediment in subtidal areas near bridges and in areas along the shore adjacent to CSO and SD discharges and riprap tend to be coarser sediments. Conversely, sediments in the remnant mudflats, along slopes of side channels and within parts of the navigation channel tend to be finer-grained sediments.

The Duwamish estuary is an important habitat for more than 50 fish species, including chum, Chinook, pink, and coho salmon and steelhead. Three salmon hatcheries within the Green/Duwamish River system release approximately 10 million juvenile salmon each year, and the river and its tributaries support a natural salmon run of an equal or larger amount. The LDR supports recreational, subsistence, ceremonial, and commercial fishing. Intertidal habitats in the LDR are small, usually less than one acre in size, except for Kellogg Island which is the largest contiguous intertidal habitat remaining in the river. Nonetheless, the LDR and surrounding habitat also support more than 80 species of birds and nine species of mammals.

Harbor Island

Harbor Island covers about 350 acres in an industrial area of Seattle. Harbor Island begins where the Duwamish River diverges into the East and West Waterways and empties into Elliott Bay. The island consists largely of artificial fill and overlies former tidal flats of the Duwamish River delta.

Construction of the island began between 1903 and 1905 when the East and West waterways and the main navigational channel of the Duwamish River were dredged. Since 1905, land use on Harbor Island has been predominantly commercial and industrial, with major activities including ocean and rail transport operations, bulk fuel

storage and transfer, secondary lead smelting, lead fabrications, shipbuilding, and metal plating. Warehouses, laboratories, office buildings, and a marina also are located on the island.

In 1937, a secondary lead smelter was constructed near the center of Harbor Island. In 1982, EPA identified a significant volume of lead-contaminated soil coupled with elevated levels of other hazardous pollutants at the smelter. Concurrently, monitoring recorded high levels of suspended lead particles. Following concern that run-off from the Island's soil contributed to elevated lead levels in nearby surface water and ground water, the site was placed on the NPL as a Superfund site. The Harbor Island Superfund site covers about 400 acres.

Biological Resources

Historically, the Green/Duwamish River basin was heavily forested with evergreen coniferous trees and an understory of various shrubs, ferns, and herbs. In the lower valley, emergent wetland vegetation was interspersed with forested riparian (alder, willow, cottonwood) and patches of swamp with cedar and spruce. The Duwamish River meandered through an extensive estuarine zone where freshwater marsh transitioned into brackish and salt marsh with extensive mudflats. The estuary, marshy floodplain, and forested basin were utilized by many species of migratory and resident waterfowl, songbirds, and raptors, large and small mammals, amphibians, and reptiles (King County, 2005).

Fish species that were historically present in the basin included Chinook, coho, sockeye, pink and chum salmon, steelhead and sea-run cutthroat trout, Dolly Varden and bull trout, resident rainbow and cutthroat trout, and other resident fish (US ACOE 2000). In 2005, a winter study of salmonid presence and use in the LDR collected a total of 39 different species of fish, including anadromous, estuarine, marine and freshwater species (US ACOE 2005). Significant numbers of Chinook, coho and chum salmon and steelhead trout are released from state and tribal hatcheries.

Currently, the lower Green/Duwamish River basin is highly urbanized along most of the river corridor, particularly in the lower 12 miles. Upstream of the LDR, extensive levees line the river protecting residential, commercial, and industrial properties adjacent to the river. Small patches of red alder, black cottonwood, big-leaf maple, and willow grow along the riverbank, which is typically confined between flood control levees. More commonly, Himalayan blackberry and various grass species dominate the channel bank vegetation. Swallows, sparrows, coyote, raccoon, and river otter inhabit these remnant habitats.

An estimated 330,000 birds winter in Puget Sound, and several million shorebirds and other water birds stop here during migration. Puget Sound is nesting habitat for an estimated 33,000 seabirds and South Puget Sound provides for approximately 30% of the total midwinter waterfowl use of Washington's coastal areas (US DOI, Fish and Wildlife Service, 1982). Nearly 100 bird species have been observed in the LDR including

migrating shorebirds, loons, grebes, alcids, geese, surface feeding and diving ducks, raptors, kingfishers, gulls, and terns (Cordell *et al.* 1999; Elliott Bay/Duwamish Restoration Program (EBDRP) 2000; US DOI, Fish and Wildlife Service 2006). Two recently de-listed migratory bird species under the Federal Endangered Species Act (ESA): peregrine falcon (*Falco peregrinus*) and bald eagle (*Haliaeetus leucocephalus*) are known to forage or spend time in the Elliott Bay/Duwamish River system.

Several nesting areas have been identified in the vicinity of Harbor Island in the Elliott Bay area. They include the glaucous-winged gull (*Larus glaucescens*) colony near Pier 30 of the East Duwamish Waterway (US DOI, Fish and Wildlife Service, 1989) and cavity-nesting pigeon guillemots (*Cepphus columba*) found historically in the West Duwamish Waterway under the P/S Freight Dock and Terminal Five in 1994 (personal communication from Mary Mahaffy, U.S. fish and Wildlife Service to Jeff Krausmann, U.S. fish and Wildlife Service, 1996). Great blue heron (*Ardea herodias*) have nested in the bluffs of West Seattle just west of the Duwamish estuary since the 1940s (US Department of Commerce (US DOC), NOAA, 1985), but abandoned these colonies in 1999 (US DOI, Fish and Wildlife Service, 2002). Since 2003, osprey (*Pandion haliaetus*) have begun nesting along the LDR from the confluence of the Green River to Harbor Island and Elliott Bay. Kellogg Island, located immediately upstream of Harbor Island, provides nesting and roosting habitat for a number of migratory and resident avian species including neotropical songbirds, raptors and other waterfowl. Kellogg Island has also provided habitat for uncommon nesters to Western Washington such as the Northern oriole (*Icterus galbula bullockii*), gadwall (*Anas strepera*) and spotted sandpiper (*Actitis macularia*) (Port of Seattle, 1979).

Federally Listed Species

Federally listed threatened salmonid species under the ESA that are known to occur or may be found in the vicinity of the LDR include Coastal-Puget Sound Bull Trout, Puget Sound Chinook salmon, and Puget Sound steelhead (WDFW, 2008). Other federally listed species that may occur within the area include Stellar sea lion, humpback whale, southern resident killer whale, leatherneck sea turtle, and marbled murrelet. Federal Species of Concern include bald eagle and peregrine falcon. In addition, the LDR has been included in the area designated as critical habitat for Puget Sound Chinook salmon (September 2005). Critical habitat for Puget Sound steelhead, which occur in this area, is under development (US DOC, NOAA, http://www.nwr.noaa.gov/ESA-Salmon Listings/). The State of Washington has listed Orca and humpback whales and leatherback sea turtles as endangered species. The state lists Steller sea lions as threatened species, and bald eagle, peregrine falcon, purple martin (*Carpodacus purpureus*), coho and chum salmon, as species of concern.

Chinook Salmon

Puget Sound stocks of Chinook salmon (*Oncorhynchus tshawytscha*) are listed as a threatened species. The species occurs in the Green/Duwamish basin from the river mouth up to the Tacoma diversion dam. Designated critical habitat for Puget Sound Chinook salmon within the areainclude freshwater rearing sites, freshwater migration corridor, and estuarine and nearshore marine areas with appropriate environmental

conditions.

Bull Trout
Coastal-Puget Sound bull trout (*Salvelinus confluentus*) are listed as a threatened species. Puget Sound populations include both resident and migratory forms. The LDR is part of the Puget Sound Management Unit for bull trout. Historically, bull trout were found in abundance in the middle Green River basin. Currently no bull trout stock is recognized in the Duwamish/Green River. However, anadromous bull trout regularly visit the lower Duwamish downstream of river mile 5.8 (King County 2003).

Steelhead
Puget Sound steelhead (*Oncorhynchus mykiss*) was listed as a threatened species on May 11, 2007. The distinct population segment includes all naturally-spawned anadromous winter-run and summer-run steelhead populations in streams in the river basins of the Strait of Juan de Fuca, Puget Sound, and Hood Canal, Washington, bounded to the west by the Elwha River (inclusive) and to the north by the Nooksack River and Dakota Creek (inclusive), as well as the Green River natural and Hamma Hamma winter-run steelhead hatchery stocks (US DOC, NOAA, 2007). Winter Steelhead enter the Duwamish River from November to May and spawn in the upper Green River and its tributaries. In addition to the wild stock, hatchery produced summer and winter steelhead also occur in the watershed (King County, 2003). No critical habitat has yet been designated for Puget Sound steelhead, although their requirements would be similar to that for Chinook salmon.

Stellar Sea Lion
Stellar sea lions are listed as threatened, but only rarely occur in Puget Sound south of Admiralty Inlet (Yates, 1988). There are no known areas of critical habitat for Stellar sea lion within the LDR.

Humpback Whale
Humpback whales are listed as threatened, but have only rarely been seen in Puget Sound. No critical habitat for humpback whales is present within the LDR.

Leatherback Sea Turtle
Leatherback sea turtles are listed as threatened, but there have been no sightings within Puget Sound and no critical habitat is present within the LDR.

Marbled Murrelet
Marbled murrelets are listed as threatened. Murrelets feed on fish and invertebrates usually within two miles of shore. They nest in stands of mature and old growth forest. The marbled murrelet typically forages for prey during the day and visits its nest site in the canopy of old-growth forests at dawn or dusk. No critical habitat for marbled murrelet is present within the LDR

1. The time, quantity, duration, and frequency of the releases and discharges.

Portions of the following were excerpted from the Draft Remedial Investigation Report, Lower Duwamish Waterway Group. November 5, 2007.

The LDR receives contaminant inputs from industrial activities and other sources. Since the early 1900s, oil and hazardous substances were discharges as a result of current and historical industrial and municipal activities. Facilities released materials through permitted and non-permitted discharges, including but not limited to spills during cargo transfer and refueling, stormwater runoff through contaminated soils at upland facilities, and discharge of contaminated groundwater.

The LDR, including the East and West Waterways and Harbor Island, were developed in the early 1900s through dredging, filling, and channelization. Filling mudflats and wetlands created land available for development. With the onset of World War I, shipyards, airplane manufacturing, food processing, and cold storage industries became important along the LDR (Sato 1997). Lumber storage and milling yards, metal fabrication, and equipment manufacturing were also common (Sato 1997; Ecology 2006a). The Boeing Plant 2 produced B-17 and B-29 bombers during World War II. The War also resulted in an increased need for shipyards and maintenance docks for the US Navy. Several ship-building, salvaging, and maintenance companies were located on Harbor Island. Construction and cement companies, slaughterhouses, meat-packing facilities, and a cannery were located along the LDR in the 1930s and 1940s (Foster 1945). Lumber production, including the use of pole treating and wood preserving processes; metal working facilities, machine shops, shipyards, cement and asphalt companies, manufacturing facilities, lime and concrete plants, and chemical manufacturing (including paint, glue, resin, and wood preservatives) were also established along the LDR at this time. Industrial development resulted in an increased need for waste disposal, and many unregulated dumping sites were created.

In the 1950s and 1960s, metal working facilities along the LDR included metal manufacturers and recyclers, galvanization plants, and foundries. Steel, tin, aluminum, titanium, nickel, and lead (at the Harbor Island smelter) were all used in various metal-working industries. With an increase in demand for fuel products, several petroleum storage facilities and storage tank farms were established on Harbor Island. By the 1980s, much of the land adjacent to the LDR was occupied by industry. Aviation industries and Port operations including cargo storage and transport continued to expand during this time. Harbor Island was still used largely for shipyard activities and petroleum storage. Other metal-working industries remained on Harbor Island and along the rest of the LDR during this time period (Sweet Edwards 1985). Wood preserving, chemical processing (including used oil and antifreeze), and other types of manufacturing continued throughout the 1980s. Industry to the south of Harbor Island near Kellogg Island was primarily related to cement and gypsum manufacturing and included several waste disposal sites.

The Henderson-E Marginal Way S system collected stormwater runoff and municipal/ industrial wastewater from approximately 5,900 acres on the east side of the LDR and conveyed flow to the Diagonal Avenue wastewater treatment plant (WWTP). The Diagonal Avenue WWTP operated from 1938 until approximately 1969 when the plant was closed and flows were diverted to the West Point Wastewater Treatment Plant. In 1958, the total population served by the Diagonal Avenue WWTP was about 30,000 and the West Seattle system served an area of about 1,950 acres located along the west side of the river (Brown and Caldwell 1958). At that time, none of the raw sewage and stormwater flow from this system was treated and seven raw sewage outfalls discharged to the LDR.

The principal source of organic waste to the LDR was raw sewage that originated from industrial facilities and residential areas along the LDR (Foster 1945). This type of waste was usually routed through the City's sewer system into the Diagonal Avenue WWTP; however, many of the industrial properties along the LDR were too low in elevation for effective use of the gravity fed sewer lines and raw waste streams in these locations were either stored temporarily in open ponds or discharged untreated to the LDR (Brown and Caldwell 1958).

By the late 1950s, industries were required to obtain a wastewater discharge permit from the Pollution Control Commission for management of their industrial and raw sewage waste streams. At that time, 150 industries had industrial discharge permits. A survey conducted in 1957 indicated that industrial waste streams that discharged directly into the LDR without pre-treatment could potentially reach a volume of about 33,900 gallons per day (gpd) (Brown and Caldwell 1958). The majority of this industrial waste (63%) was associated with metal-related industries. The study indicated that the wastes from metal-plating industries were particularly hazardous and required separate pretreatment. The same survey identified a total of 14 industries that discharged industrial wastewater (at a rate of approximately 2,500 gpd) into networks that would be processed through the Diagonal Avenue WWTP . Industrial discharges that passed through the Diagonal Avenue WWTP originated from adhesives and chemical plants, metal plating facilities, beverage bottling operations, cement handling and production, compressed gas operations, food canning, sawmill and wood-working related industries, steel plants, and truck manufacturing operations (Brown and Caldwell 1958). In 1962, Metro assumed operation of the Diagonal Avenue WWTP until its closure in 1969, when the Elliott Bay Interceptor (EBI) was brought on-line and flow was diverted to the West Point WWTP, which discharges treated wastewater to Puget Sound.

Many of the industries that were present along the LDR in the past are still in operation today. Currently aviation facilities used for the construction, maintenance, and operation of aircraft, Port-owned and privately owned terminals used for cargo shipping and receiving, motor vehicle and marine vessel maintenance, cement production, manufacturing plants, and various other industries all operate along the LDR.

2. The name of the hazardous substances.

Hazardous substances released to the LDR include, but are not limited to, the following chemicals: polychlorinated biphenyls (PCBs), dioxins, polycyclic aromatic hydrocarbons (PAHs), metals (arsenic, cadmium, chromium, copper, lead, mercury, silver, and zinc), chlorobenzenes, phthalates, phenols, hexachlorobutadiene, organochlorine pesticides (DDT and degradation products), and antifouling agents such as tributyltin (TBT).

3. The history of the current and past use of the site identified as the source of the discharges of oil and releases of hazardous substances.

Portions of the following were excerpted from the Draft Remedial Investigation Report, Lower Duwamish Waterway Group. November 5, 2007.

The LDR is maintained as a federal navigation channel by the US Army Corps of Engineers and the corridor is one of Seattle's primary industrial areas. Current land use, zoning requirements, and land ownership within this corridor are consistent with the characteristics of an active industrial waterway. The shoreline along the majority of the LDR has been developed for industrial and commercial operations. Common shoreline features include constructed bulkheads, piers, wharves, sheet piling walls, buildings that extend over the water, and steeply sloped banks armored with riprap or other fill material. Despite the highly modified river habitat, the LDR is home to diverse communities of fish, birds, mammals, and invertebrate species. The LDR supports considerable commercial navigation, but is also used for various recreational activities such as boating, kayaking, fishing, and beach play. The LDR is also the site of the Muckleshoot Indian Tribe's commercial fishery for salmon. The Suquamish Tribe actively manages its fisheries within the LDR upriver to the Spokane Street Bridge.

In the course of the development of the area, industrial practices and waste streams have contributed chemicals to the LDR. In many cases, chemicals and other wastes were discharged directly to the river or disposed of on upland properties without sufficient containment (Foster 1945; Seattle-King County Department of Public Health 1984). Wastes were transported to the LDR directly through storm drainage systems, as a component of the discharge from sanitary sewer systems, through atmospheric deposition, or direct disposal along the shoreline. Sanitary sewer systems serviced large industrial areas along the LDR.

Historically, many industrial facilities used unlined, open-air waste ponds for pretreatment of slurries and other waste water (Sweet Edwards 1985; Foster 1945). Often the ponds and lagoons were located along the LDR shoreline and contained chemicals that could enter area soil and/or groundwater and eventually enter the LDR. Waste slurries derived from routine maintenance and cleaning of tanks and equipment were often dumped directly into the LDR or into wastewater ponds on a daily to yearly basis, depending on the industry (Foster 1945).

Several lumber yards were located along the LDR in the past, particularly at the upstream reach of the LDR near the Upper Turning Basin. Wastes associated with lumber processing included creosote used in pole dipping, and arsenic and sulfate salts of copper

and zinc used to preserve logs. Creosote is known to contain PAHs. Other wood preservatives and resins may have contained TBT (EPA 2003).

Historically, oil and fuel were discharged to the LDR from industrial activities including ship-building and repair facilities, ship salvaging companies, brick manufacturing, machine shops, pole treating facilities, and hydraulic equipment manufacturing (Foster 1945). In the past, oily wastes were observed seeping from facilities located along the LDR shoreline (Sweet Edwards 1985). Additional historical sources of petroleum wastes included storage, transport, and use of fuel at aviation, railway, motor vehicle, and fuel storage and tank farm facilities. These may have reached the LDR through direct discharge (spills, dumping and transport through storm drain networks) and through indirect discharge (migration through soil or groundwater). Recycled or waste oils sometimes contained PCBs from electrical or hydraulic equipment and other sources of PCBs or from mixing or cross-contamination with PCB oil (ATSDR 2000). Recycling of these oils often resulted in oil spills (Sweet Edwards 1985).

Significant uses of PCBs included its use as a dielectric fluid in transformers and as a component of hydraulic oils. Releases to the environment associated with both of these uses have been well documented. PCBs have also been used in many other products, such as capacitors, heat transfer systems, inks and carbonless copy paper, the ballasts of some fluorescent light fixtures and paints. PCB contamination along the LDR has also been documented in connection with the waste oil used as fuel in asphalt manufacturing (Ecology 2005a; Windward et al. 2005a), as well as associated with caulking and sealant materials used on pavement and asphalt.

Industrial waste discharges originating from manufacturing and metalworking companies often contained a variety of chemicals. Acidic solutions were among the most widely reported chemical releases associated with these industries (Sweet Edwards 1985; Foster 1945). Other wastes included metal scraps, sodium borate, cyanide, and zinc salts (Foster 1945). Chromium, copper, cadmium, and nickel are associated with electroplating (Sweet Edwards 1985).

The evolution of wastewater permit programs required industrial properties along the waterway to upgrade their systems and interconnect with the interceptor line. Starting in 1969, large portions of the public and private sewer lines were connected into the Elliott Bay Interceptor line, and subsequent system overflows were eventually limited to the current County and City CSO locations. Some connections required complex infrastructure improvements; thus, raw sewage was discharged for several years after 1969, including through the Henderson/E Marginal Way S system. The raw sewage outfall (Fox sewer line) into Slip 4 continued to discharge until 1976 (City of Seattle 1998).

In 1974, a spill occurred at the GSA dock when a transformer was dropped and cracked while being loaded onto a barge in Slip 1, resulting in the release of approximately 980 L (260 gal.) of high-concentration PCB dielectric fluid (primarily Aroclor 1242) into the LDR (EPA 1975). Two separate dredging operations were conducted to address the

sediment contamination that resulted from the spill. An initial cleanup by EPA in 1974 was estimated to recover approximately 300 L (80 gal.) of PCBs. A second dredging attempt by EPA and the USACE in 1976 was required to recover PCBs that had spread throughout Slip 1 and into the channel, in part because of a 20-yr flood that occurred in the winter of 1975-1976. The second cleanup involved hydraulic dredging of sediments containing PCBs in the northwest corner of Slip 1. About 38 million L (10 million gal.) of PCB-contaminated slurry was piped to settling lagoons on the Chiyoda Property (formerly the Diagonal Avenue WWTP property and currently the location of the Port of Seattle's T-108). Most of the slurry was deposited in one of the lagoons located closest to the LDW, while the second lagoon received overflow water from the first lagoon. Water pumped from the lagoons was filtered through a sand and charcoal filter to remove suspended particles and PCBs before discharging to the LDR.

Two other known significant historical spills were documented in the Washington State Pollution Control Commission (WPCC) Progress reports between 1945 and 1957 (Dexter et al. 1985). The Duwamish Manufacturing Company reportedly spilled 5,000 gal. of crude oil from a valve left open on a tank (the exact date and location of the spill is unknown). The site was subsequently cleaned, but most of the leaking oil had already entered the LDR. Another reported incident occurred at the Duwamish/Diagonal Avenue S SD. A large amount of oil (quantity not reported) was found entering the LDR from the SD. The oil had come from the Union Pacific Railroad roundhouse where drained oil had overflowed from a sump, which was intended to prevent the oil from reaching the sewer (WPCC, as cited in Dexter et al. 1985).

4. Relevant operations occurring at or near the site.

Much of the sediment contamination in the LDR is believed to be the result of historical sources. Many of these historical sources, including direct discharges of municipal and industrial wastewater, have largely been controlled through compliance with modern regulatory requirements, improved business practices, elimination of product use, or cleanups of industrial property. Many of the direct discharges have been diverted to the sanitary sewer system and are now treated at the West Point wastewater treatment plant. Inspection and compliance programs are in place to monitor and control the handling and disposal of manufacturing wastes produced by industrial operations along the LDR. In addition, the chemical loading from stormwater and combined sewer overflows (CSOs) has been greatly reduced by permit programs that require the monitoring and control of discharges that could otherwise enter the LDR. Potential ongoing sources include stormwater runoff, CSOs, industrial wastewater discharges, deposition from uncontrolled or partially controlled air emissions (from motor vehicles and the burning of wood and fossil fuels), illicit discharges and spills, groundwater transport of contaminants, erosion of contaminated bank material, and upstream contributions from the Green River.

Historical and current land use practices in the Green/Duwamish River watershed provide the potential for chemicals to enter the river upstream of the LDR. These potential upstream sources include pesticide and fertilizer runoff from agricultural operations; chemicals from various sources, including but not limited to roadways, industrial and

commercial facilities, and surface water runoff from mining operations; chemicals deposited by atmospheric deposition, and contaminated sediment from logging and sawmill operations and urban development throughout the watershed.

5. Additional oil or hazardous substances potentially discharged or released from the site.

There are over 100 storm drains, combined sewer overflows (CSOs), and other miscellaneous outfalls that discharge into the LDR, resulting in releases of a variety of chemicals over the past 90 years. Contamination has resulted from spills and leaks from industrial facilities, industrial operations, waste disposal practices, surface water runoff, storm drain discharge, groundwater discharge, erosion of contaminated soils, atmospheric deposition of industrial air emissions, and combined sewer overflows. Raw sewage has been released through CSOs when waste water treatment plants exceeded capacity during periods of heavy rain, when runoff from roads, parking lots, and lawns enters the waste stream. Spills of petroleum hydrocarbon products into the LDR have been documented over the years. There are several sites along the LDR where petroleum hydrocarbons and volatile and semi-volatile organic compounds occur in the groundwater, the result of leaking underground storage tanks or on-site spills. Surface sediment samples from within the LDR area were analyzed for dioxins and furans from 23 locations as part of the Remedial Investigation (Windward 2005b) and from 24 locations as part of the EPA Site Inspection (Weston 1999a). At least one dioxin or furan congener was detected in every sample, with individual congener concentrations ranging from 0.0730 to 241,000 ng/kg dw. Chlordane was identified as a contaminant of concern in the LDR in a Public Health Assessment published by the Agency for Toxic Substances and Disease Registry (ATSDR 2003). Results of a trend monitoring program conducted in Washington rivers found the chlorinated pesticides Dieldrin, Endosulfan, and Lindane; and the flame retardant polybrominated diphenyl ether in the LDR. (Washington Department of Ecology 2009).

6. Potentially responsible parties.

Sediment contamination within the LDR was evaluated using sediment contamination data from studies conducted from 1991 to 2005 for 29 pollutants of concern, including but not limited to PAHs, PCBs, metals, chlorobenzenes, phthalates, and phenols (metals data from a 1985 Elliott Bay sediment survey were used to extend coverage of the East Waterway).

Tax parcel data were obtained to identify potential contributors of contamination to the LDR. All parcels of land adjacent to the LDR and all non-residential properties between the main roadways (East Marginal Way and West Marginal Way) parallel to the LDR were considered for analysis. In addition, parcels for the King County International Airport and Boeing Field were included as they are known to drain directly to the LDR. While sites further inland contribute to contaminant loads in LDR sediments, their effects are assumed to be captured through storm drains (SDs) and combined sewer overflows (CSOs) in the drainage basin. The discharges from these drains were taken into consideration as a potential source of substances of concern (SOCs) separate from the

adjacent tax parcels. The SDs and CSOs considered are based on those identified and mapped during the Elliott Bay Estuary Program (Tetra Tech, 1988). Residential parcels were not included in the analysis, largely because releases of SOCs from residential properties are expected to be low and generally captured through evaluating contributions from CSOs and storm drains.

Publicly available site-specific data were reviewed, including information about the types and amounts of substances used or stored on site; wastewater, soil, groundwater and other sampling data; reports of spills and releases; permit data; and similar documentation of contaminant use and/or releases on site. Most of these data were obtained from files maintained at the Washington Department of Ecology (ECY) and at U.S. EPA Region 10 offices in Seattle, Washington.

Because sites identified for this evaluation border or drain directly to the LDR, it is reasonable to assume the existence of a potential viable pathway for contaminant transport at every site. Files were reviewed for evidence of on-site activities that could be a source of one or more contaminants or result in the release of substances that mobilized or otherwise exacerbated the release of one or more contaminants to the LDR. Files were also reviewed for evidence that one or more contaminants were present in site wastewater/discharges, soil, surface water and/or groundwater. Information used to make this determination included records of National Pollution Discharge Elimination System (NPDES) violations, surface water contamination, ground water contamination, and soil or sediment contamination.

Based on data from EPA and ECY files, it is apparent that specific parcels along the LDR are known to have stored, used and/or released SOCs. Some SOCs are known to be common contaminants of SDs or CSOs. Some stretches of the LDR are broadly contaminated with an SOC potentially attributable to a large number of parcels. Overall, the approach reflects the common sense notion that discrete, elevated concentrations of contaminants found in sediments bordering a site on which activities took place that used those contaminants should be attributed to that site.

B. Damages Excluded from Liability under CERCLA

Title 43 CFR Part 11.24(b) notes certain damages are excluded from liability under CERCLA, such as damages resulting from a discharge or release that was specifically identified as an irreversible and irretrievable commitment of natural resources in an environmental assessment, damages from a release that occurred wholly before enactment of CERCLA, or damages resulting from other federally-permitted activities as those defined in Section 101(10) of CERCLA. In the LDR, a significant number of releases have occurred that have the potential to cause or continue to cause injury and damages that are not excluded from liability under CERCLA. There are significant historical releases that occurred in the LDR prior to any permitting under environmental laws, and these contaminants continue to be present in the LDR and are potentially causing both injury and damage to this date. No environmental impact statement or similar environmental analysis has ever identified an irretrievable or irreversible

commitment of natural resources[1] at this site. Moreover, continuing non-permitted releases still occur and are also potential sources resulting in injury to natural resources and natural resource damages.

Aside from discharges permitted under the NPDES, there are no other known concerns relative to 43 CFR Part 11.24(b) warranting exclusion from liability under CERCLA, the Oil Pollution Act, or the Clean Water Act. Any injuries that may have resulted exclusively from specific NPDES releases, or other releases found to be under exclusion during the remedial investigations or injury assessments, will not be considered further during the damage assessment. At this time the natural resource trustees are not aware of any other possible defenses or exclusions of liability under applicable laws that would preclude initiating a natural resource damage assessment.

III. PRELIMINARY IDENTIFICATION OF RESOURCES AT RISK

A. Preliminary identification of pathways

Contaminants from specific sources identified previously are primarily introduced into the LDR through point and non-point discharges, from spills, and to a lesser degree from aerial deposition and soil erosion. The primary media for transport of contaminants and exposure to organisms are surface water, groundwater, sediment, and tissue (i.e., from consumption of contaminated prey items or food chain transfer). Surface water flow over upland areas erodes soil or collects material from impermeable surfaces and transports contaminants from urban or industrial areas in the dissolved or particulate phase to the LDR. Precipitation infiltrates upland soils and can leach contaminants from soils as it percolates to the water table and flows along the top of impermeable layers or alongside discharge pipes before entering the LDR as seeps above the waterline or as transition zone water below the waterline. Groundwater discharge at seeps or in the transition zone provides a pathway for contaminants to reach aquatic organisms through direct contact and ingestion of surface water, particulates, and prey items. Contaminated bedload sediment, or suspended sediment and particulates, are transported via river flow and tidal action from local sources and deposited, resuspended, and redeposited within the LDR.

The primary exposure pathways of a contaminant from media to receptors are via contaminants that accumulate in the sediments. The organisms that live in and on the sediments and that are exposed to sediment contamination, form the base of the food web upon which most of the fish, birds, and other wildlife that use the LDR environment depend. As illustrated by the food web diagram in Figure 2, contamination of the sediments affects nearly all aspects of the LDR ecosystem. Contaminants have been found in tissues of benthic invertebrates and fish in the LDR area.

[1] Irretrievable or irreversible commitment of natural resources refers to impacts that cannot be recovered or reversed. The losses are permanent.

B. Exposed Areas

Contaminated sediments occur in an approximate 7 mile reach from upstream of Turning Basin #3 to the mouth of the Duwamish River at Elliott Bay. For the majority of the 29 contaminants assessed, the reach can be characterized as having localized areas with relatively high chemical concentrations separated by larger areas with lower chemical concentrations. For contaminants such as PAHs, their distribution is widespread, covering the majority of the waterway.

C. Exposed Water Estimates

The entire LDR from the Duwamish River mouth to a point upstream of Turning Basin #3 has been exposed to contaminants. The area includes approximately 7 miles of river and associated nearshore habitat.

D. Estimates of Concentrations

Sediment chemistry data sets were selected to obtain the best representation of the spatial extent of contamination and maximum areal coverage of the LDR. A protocol was developed for reviewing qualified data and addressing multiple samples from the same station. Contaminant concentrations were evaluated based on threshold concentrations (Table 1) developed for the Hylebos Waterway in Commencement Bay (US DOC, NOAA 2002). These threshold concentrations represent contaminant levels at which a reduction in ecological service occurs. Scientific literature, technical data, applicable regulatory standards, etc. were reviewed to determine the effects of varying sediment concentrations of these substances on key species or species groups. A series of concentration levels were established for each contaminant, expressed as a percent reduction in ecological services. These were based on the observation that as concentrations of hazardous substances increase, both the number of species adversely affected and the severity of effects also increases.

The sediment chemistry data sets used in the analysis are listed in Table 2. Surface samples (predominately 0 – 15 cm) were used and pre-remediation data were selected from certain studies (e.g. 1995 Norfolk CSO Sediment Cleanup Study). Comparison of sediment contaminant concentrations with threshold concentrations indicates at least a 5% service loss[2] for all 29 contaminants evaluated; up to a 15 – 20% service loss for contaminants such as arsenic, copper, mercury, tributyltin, phthalates, and phenol; and up to a 40 – 60% loss for PCBs and PAHs.

Hazard quotients, based on a range of effects data, including no-observed-adverse-effect levels (NOAELs) and lowest-observed-adverse-effect levels (LOAELs) were used to evaluate tissue samples collected for the Lower Duwamish Waterway superfund site Remedial Investigation. Substances of concern were defined as chemicals with LOAEL-

[2] Service means the functions performed by a natural resource for the benefit of another natural resource or the public. They may be classified as ecological services (provision of food, protection from predation, nesting habitat, etc.) and human services (fishing, hunting, nature photography, education, etc.)

based Hazard Quotients greater than or equal to one, which indicates a potential for adverse effects. Chemicals that were identified as SOCs for at least one fish and wildlife species included PCBs, cadmium, chromium, copper, lead, and mercury (Lower Duwamish Waterway Group 2007). A review of selected tissue sample data sets collected between 1992 and 2005 (80% collected in 2004 and 2005 as part of the Remedial Investigation) shows that PCBs were present in most of the samples. In general, mean concentrations in whole-body fish were highest in English sole and shiner surfperch (ranging from 1,000 to 3,900 µg/kg ww in English sole and 457 to 4,300 µg/kg in shiner surfperch) (Lower Duwamish Waterway Group 2007). These concentrations are above the toxicity reference values used for evaluation using the critical tissue-residue approach in the Lower Duwamish Waterway Baseline Ecological Risk Assessment.

In a 2005 Health Consultation, the Washington Department of Health (WDOH 2005) recommended that no resident fish (e.g. English sole, starry flounder, perch) or crab be eaten from the LDR due to PCB contamination. They also recommended that consumption of shellfish from the LDR should be avoided due to chemical and biological contamination. The WDOH further recommended that the Washington Department of Fish and Wildlife restrict or actively discourage fishing for the resident species identified in the advisory to support protecting public health.

E. Potentially Affected Resources

Because of the central role that sediments and the sediment based biological community play in the LDR, the Trustees decided to evaluate the potential loss of natural resources in terms of affected habitat, rather than numbers of individual species impacted. Juvenile Chinook salmon and English sole were used as representative species to assess the value of habitat to fish. Four bird assemblages, representing the variety of bird species occurring in the area, were used to assess the value of habitat to birds. Although the various fish species in the LDR display a variety of life history requirements, juvenile Chinook salmon and English sole have feeding modes, behavioral characteristics, and habitat requirements that sufficiently overlap those of other species to consider them appropriate surrogates. The four bird assemblages are grouped as a function of their foraging behavior and include both resident and migratory species. The bird assemblages use similar habitat as juvenile Chinook salmon, and are linked through their food webs, so habitat value for birds is linked to habitat value for juvenile salmon. Existing habitats in the LDR were classified and given a value that represents the ecological services these habitats provide to the representative species.

To evaluate the impact of contaminated sediments on these natural resources, the Trustees began with the assumption that habitats contaminated to the point that they cause harm to species that use them provide less ecological services than do uncontaminated habitats. Scientific literature, technical data, and applicable regulatory standards were reviewed to determine how varying concentrations of different contaminants in sediment affect key species. The Trustees judged contamination to be injurious when the concentration of the contaminants in the sediments was sufficient to result in an adverse effect to identified species. The adverse effects range from subcellular alterations to mortality. As concentrations of contaminants in sediment

increase, the severity of the impacts also increases, as does the number of species adversely affected. From this information, the Trustees developed a series of concentration threshold levels for each contaminant, and assigned to each threshold an increasing percent reduction in ecological services.

As noted in Section III. D. above, concentrations of individual contaminants in certain areas of the LDR sediments are at levels that result in anywhere from 5 to 60% loss of ecological services[3]. Some of these contaminants occur in near-shore and intertidal areas, habitats that are critical to the species represented by juvenile Chinook salmon, English sole, and bird assemblages. Many of these habitats are affected by multiple contaminants, compounding the service loss.

The natural resources and natural resource services affected or potentially affected from releases or discharges of contaminants in the LDR include, but are not limited to:

- Anadromous and resident fishes
- Migratory birds, including osprey, bald eagle, mergansers and other waterfowl, great blue heron, shorebirds, belted kingfisher, and other species
- Aquatic-dependent mammals such as mink and river otter and species they depend on as prey items
- Shellfish
- Aquatic invertebrates
- Threatened species
- Habitat for trust resources, including food, shelter, breeding, foraging, and rearing areas, and other factors essential for survival
- Lost human use

IV. Preassessment Screen Criteria

As indicated earlier, title 43 CFR Part 11.23(e) notes the five criteria that must be met before proceeding past the preassessment phase to a full natural resource damage assessment. The criteria and corresponding conclusions based on this preassessment screen are as follows:

[3] Ecological services are the physical, chemical, or biological functions that one natural resource provides for another. Examples include provision of food, protection from predation, and nesting habitat, among others.

1) **A discharge of oil or release of hazardous substance has occurred.** Releases of appreciable quantities of petroleum compounds, organochlorine pesticides, PCBs, volatile and semi-volatile organic compounds, solvents, metals, and other materials listed in this preliminary assessment are documented for the Harbor Island and Lower Duwamish Waterway Superfund sites, and have been released over a long period of time.

2) **Natural resources for which a State or Federal agency or Indian Tribe may assert trusteeship under CERCLA have been or are likely to have been adversely affected by the discharge or release.** Natural resources over which the State and Federal agencies and Indian Tribes may assert trusteeship have been and are likely to continue to be adversely impacted. Existing field data indicate that hazardous substance concentrations in sediment and tissue spatially coincide or are elevated near areas with known releases from industrial facilities or other documented sources.

3) **The quantity and concentration of the discharged oil or released hazardous substances is sufficient to potentially cause injury to those natural resources.** Sediment samples from the LDR contain hazardous materials at concentrations that exceed concentrations associated with injury in sediment, water, fish, birds, and other natural resources.

4) **Data sufficient to pursue an assessment are readily available or likely to be obtained at reasonable cost**. Data currently exist from the LDR that will be helpful and cost effective to use to further assess injury of natural resources. Additional studies will be needed to better quantify injury and service losses for some resources, but these data can be obtained at reasonable costs. The expected costs of resource restoration will exceed the costs of preparing the assessment.

5) Response actions from Superfund remedial activities carried out or planned do not or will not sufficiently remedy the injury to natural resources without further action. The trustees expect the remedial actions at the Lower Duwamish Waterway and Harbor Island Superfund sites will, to a certain extent, minimize or eliminate exposure to hazardous substances. The full extent of such impact cannot be assessed until the remedial action is selected by EPA. However, even at this stage it is evident that the direction of the remedial investigation/feasibility study is not toward full restoration of likely injuries, and will not address lost services of resources which have been ongoing since the enactment of CERCLA. Thus, additional restoration, replacement, and rehabilitation of natural resources will ultimately be necessary.

References

ATSDR. 2000. Toxicological profile for polychlorinated biphenyls (PCBs): chemical and physical information [online]. Agency for Toxic Substances and Disease Registry, Atlanta, GA. Updated 5/25/01. Available from: http://www.atsdr.cdc.gov/toxprofiles/tp17.pdf. *As cited in* Lower Duwamish Waterway Group. Draft Remedial Investigation. November 5, 2007.

ATSDR. 2003. Public Health Assessment – Lower Duwamish Waterway, Seattle, King County, WA. Prepared by Washington State Department of Health Under a Cooperative Agreement with the ATSDR. September 30, 2003. http://www.atsdr.cdc.gov/HAC/PHA/lowerduwamish/ldw_toc.html

Brown and Caldwell. 1958. Metropolitan Seattle sewerage and drainage survey: A report for the City of Seattle, King County and the State of Washington on the collection, treatment and disposal of sewage and the collection and disposal of storm water in the metropolitan Seattle area. Brown and Caldwell Consulting Engineers, Seattle, WA. *As cited in* Lower Duwamish Waterway Group. Draft Remedial Investigation. November 5, 2007.

City of Seattle. 1998. Elliott Bay/Duwamish source control project: Final report. City of Seattle Public Utilities, Seattle, WA. *As cited in* Lower Duwamish Waterway Group. Draft Remedial Investigation. November 5, 2007.

Cordell, J.R., L.M. Tear, K. Jensen and H.A. Higgens. 1999. Duwamish River Coastal America Restoration and Reference Sites: Results from 1997 Monitoring Studies, FRI-UW-9903. University of Washington, Seattle, 1999. *As cited in* Lower Duwamish River NRDA Programmatic Restoration Plan & Programmatic Environmental Impact Statement.

Dexter RN, Goldstein LS, Chapman PM, Quinlan EA. 1985. Temporal trends in selected environmental parameters monitored in Puget Sound. NOAA technical memorandum NOS OMA 19. National Ocean Service, National Oceanic and Atmospheric Administration, Rockville, MD. *As cited in* Lower Duwamish Waterway Group. Draft Remedial Investigation. November 5, 2007.

Ecology. 2005a. Lower Duwamish Waterway source control action plan for the Terminal 117 early action cleanup. Washington Department of Ecology, Northwest Regional Office, Bellevue, WA. *As cited in* Lower Duwamish Waterway Group. Draft Remedial Investigation. November 5, 2007.

Ecology. 2006a. Lower Duwamish Waterway source control action plan for the Slip 4 early action area. No. 06-09-046. Washington Department of Ecology, Northwest Regional Office, Toxics Cleanup Program, Bellevue, WA. *As cited in* Lower Duwamish Waterway Group. Draft Remedial Investigation. November 5, 2007.

Elliott Bay/Duwamish Restoration Program (EBDRP). Intertidal habitat projects monitoring program. Panel Publication 23, U.S. Fish and Wildlife Service, Western Washington Fish and Wildlife Office, Lacey, Washington, 2000. *As cited in* Lower Duwamish River NRDA Programmatic Restoration Plan & Programmatic Environmental Impact Statement.

EPA. 1975. Methods for acute toxicity tests with fish, macroinvertebrates, and amphibians. EPA-660/3-75-009. As cited in LeBlanc 1980. US Environmental Protection Agency, Washington, DC. *As cited in* Lower Duwamish Waterway Group. Draft Remedial Investigation. November 5, 2007.

EPA. 2003. Ambient aquatic life water quality criteria for tributyltin (TBT) - final. EPA 822-R-03-031. US Environmental Protection Agency, Washington, DC. *As cited in* Lower Duwamish Waterway Group. Draft Remedial Investigation. November 5, 2007.

Foster RF. 1945. Sources of pollution in the Duwamish-Green River drainage area. December 6, 1945. *As cited in* Lower Duwamish Waterway Group. Draft Remedial Investigation. November 5, 2007.

King County, Washington. Programmatic Biological Effects Analysis- King County River Management Program, by A. Johnson, K. Macdonald and P. Trotter. Seattle, 2003. *As cited in* Lower Duwamish River NRDA Programmatic Restoration Plan & Programmatic Environmental Impact Statement.

King County Department of Natural Resources and Parks. Historical Aquatic Habitats in the Green and Duwamish River Valleys and the Elliott Bay Nearshore, King County, Washington, by Brian Collins and Amir Sheikh. Seattle, 2005. *As cited in* Lower Duwamish River NRDA Programmatic Restoration Plan & Programmatic Environmental Impact Statement.

Lower Duwamish Waterway Group. Port of Seattle/City of Seattle/King County/The Boeing Company. Draft Remedial Investigation. November 5, 2007

Port of Seattle. Terminal 107 Environmental Studies: Wildlife Study, by D.J. Canning, S.G. Herman and G.B. Shea. Seattle, 1979. *As cited in* Lower Duwamish River NRDA Programmatic Restoration Plan & Programmatic Environmental Impact Statement.

Sato M. 1997. The price of taming a river: the decline of Puget Sound's Green/Duwamish Waterway. The Mountaineers, Seattle, WA. *As cited in* Lower Duwamish Waterway Group. Draft Remedial Investigation. November 5, 2007.

Seattle-King County Department of Public Health. 1984. Abandoned landfill study in the city of Seattle. Seattle-King County Department of Public Health, Seattle, WA. *As cited in* Lower Duwamish Waterway Group. Draft Remedial Investigation. November 5, 2007.

Sweet Edwards. 1985. Duwamish ground water study. Prepared for Municipality of Metropolitan Seattle. Sweet, Edwards and Associates, Inc. and Harper-Owes Company, Seattle, WA. *As cited in* Lower Duwamish Waterway Group. Draft Remedial Investigation. November 5, 2007.

Tetra Tech, Inc. Elliott Bay Action Program: Evaluation of Potential Contaminant Sources, TC-3338-23, Puget Sound Estuary Program, Prepared for U.S. Environmental Protection Agency, Region X, 1988.

U.S. Army Corps of Engineers, Seattle District. Green/Duwamish River Basin Ecosystem Restoration Study, King County, Washington, Final Feasibility Report, Seattle, 2000. *As cited in* Lower Duwamish River NRDA Programmatic Restoration Plan & Programmatic Environmental Impact Statement.

U.S. Army Corps of Engineers, Seattle District. Salmonid Presence and Habitat Use in the Lower Duwamish River, Winter 2004/2005. Seattle, 2005. *As cited in* Lower Duwamish River NRDA Programmatic Restoration Plan & Programmatic Environmental Impact Statement.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. Biology of Puget Sound Marine Mammals and Marine Birds: Population Health and Evidence of Pollution Effects, by J.S. Calambokidis, J. Speich, G. H. Peard, J. C. Steiger, D. M. Frye and L. J. Lowenstine. NOAA Technical Memorandum. Rockville, Maryland, 1985. *As cited in* Lower Duwamish River NRDA Programmatic Restoration Plan & Programmatic Environmental Impact Statement.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. Hylebos Waterway Natural Resource Damage Settlement Proposal Report. Public Review Draft, March 14, 2002.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration. Endangered and Threatened Species: Final Listing Determination for Puget Sound Steelhead. Federal Register 7, No. 91. (May 11, 2007). *As cited in* Lower Duwamish River NRDA Programmatic Restoration Plan & Programmatic Environmental Impact Statement.

U.S. Department of Interior. Fish and Wildlife Service. Regional Resource Plan. Region 1. Portland, Oregon, 1982. *As cited in* Lower Duwamish River NRDA Programmatic Restoration Plan & Programmatic Environmental Impact Statement.

U.S. Department of Interior. Fish and Wildlife Service. Catalog of Washington Seabird Colonies, by S. Speich and T. Wahl. U.S. Fish and Wildlife Service Biological Report 88(6), 1989. *As cited in* Lower Duwamish River NRDA Programmatic Restoration Plan & Programmatic Environmental Impact Statement.

U.S. Department of the Interior. Fish and Wildlife Service. Preliminary Environmental Assessment of Dioxin-like Chlorobiphenyls in Great Blue Herons of the Lower Duwamish Waterway in Seattle, WA. May 2002. *As cited in* Lower Duwamish River NRDA Programmatic Restoration Plan & Programmatic Environmental Impact Statement.

U.S. Department of Interior. Fish and Wildlife Service. Elliott Bay/Duwamish Restoration Program: Intertidal Habitat Projects Monitoring Report, 2005. Lacey, Washington, 2006. *As cited in* Lower Duwamish River NRDA Programmatic Restoration Plan & Programmatic Environmental Impact Statement.

WDFW (Washington Department of Fish and Wildlife), December, 2008. http://wdfw.wa.gov/recovery.htm *As cited in* Lower Duwamish River NRDA Programmatic Restoration Plan & Programmatic Environmental Impact Statement.

Washington Dept. of Health. 2005. Lower Duwamish Waterway Site: Updated Fish Consumption Advisory and Evaluation of Marine Tissue Collected from the Lower Duwamish Waterway in August and September 2004. Seattle, Washington. Prepared under a cooperative agreement with the Agency for Toxic Substances and Disease Registry.

Washington State Dept. of Ecology. 2009. Trends Monitoring for Chlorinated Pesticides, PCBs, and PBDEs, in Washington Rivers and Lakes, 2007. Washington State Toxics Monitoring Program. Publication 09-03-013. http://www.ecy.wa.gov/pubs/0903013.pdf

Weston. 1999a. Site inspection report, Lower Duwamish River (RK 2.5-11.5), Seattle, Washington. Vol. 1-Report and appendices. Prepared for US Environmental Protection Agency, Region 10. Roy F. Weston, Inc., Seattle, WA. *As cited in* Lower Duwamish Waterway Group. Draft Remedial Investigation. November 5, 2007.

Windward, DOF, Onsite. 2005a. Lower Duwamish Waterway Superfund site, Terminal 117 early action area. Terminal 117 engineering evaluation/cost analysis. Prepared for the Port of Seattle. Windward Environmental LLC, Dalton,
Olmsted & Fuglevand, Inc., and Onsite Enterprises, Inc., Seattle, WA. *As cited in* Lower Duwamish Waterway Group. Draft Remedial Investigation. November 5, 2007.

Windward. 2005b. Lower Duwamish Waterway remedial investigation. Data report: Round 2 surface sediment sampling for chemical analyses and toxicity testing. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA. *As cited in* Lower Duwamish Waterway Group. Draft Remedial Investigation. November 5, 2007.

Yates, S. 1988. Marine Mammals of Puget Sound, the San Juans and the Strait of Georgia. The Globe Pequot Press, Old Saybrook, CT. *As cited in* Lower Duwamish River NRDA Programmatic Restoration Plan & Programmatic Environmental Impact Statement.

Figure 1. Map of Lower Duwamish River.

Figure 2 . Example Food Web for Lower Duwamish River (modified from "Commencement Bay Phase 1 Damage Assessment").

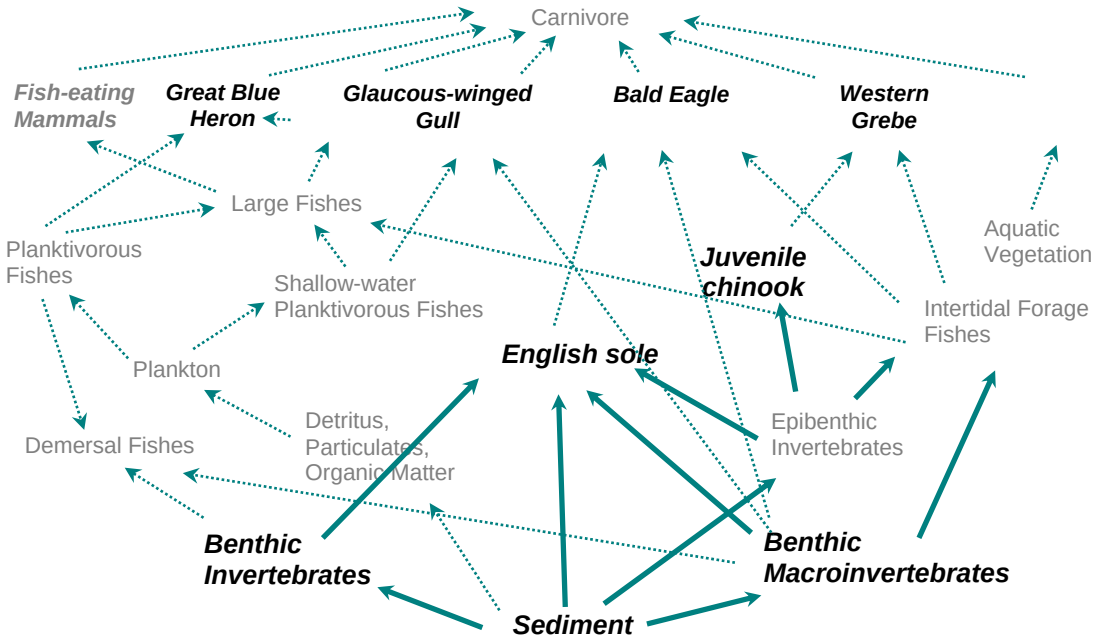

Table 1
LOWER DUWAMISH RIVER THRESHOLD
SEDIMENT CONCENTRATIONS FOR FOOTPRINT MAPS

Substance of Concern	Symbol	Units	Low	Med	High	Very High
PAHs (total)		ppm dw	1	5	50	250
PCBs		ppm dw	0.113	2.5	30	90
Metals						
Arsenic	AS	ppm dw	57	130	500	700
Cadmium	CD	ppm dw	5.1	14		
Chromium	CR	ppm dw	100	1200		
Copper	CU	ppm dw	390	1300		
Lead	PB	ppm dw	450	1200		
Mercury	HG	ppb dw	410	1300	2100	2300
Silver	AG	ppm dw	3.3	8.4		
Zinc	ZN	ppm dw	410	530	1600	3800
Tributyltin	TBT	ppb dw	220	1000		
Chlorobenzenes						
1,2-dichlorobenzene	ODCB	ppb dw	35	150		
1,4-dichlorobenzene	PDCB	ppb dw	110	120		
1,2,4-trichlorobenzene	TCB	ppb dw	31	64		
Hexachlorobenzene	HCB	ppb dw	22	230		
Phthalates						
bis (2-Ethylhexyl) phthalate	BEPH	ppb dw	1300	8500		
Butylbenzyl phthalate	BBPH	ppb dw	63	970		
Di-n-butyl phthalate	DnBPH	ppb dw	50	5100		
Di-n-octyl phthalate	DOPH	ppb dw	100	6200		
diethylphthalate	DEPH	ppb dw	50	1200		
dimethylphthalate	DMPH	ppb dw	71	1400		
Phenols						
4-methyl phenol	MP4	ppb dw	670	3600		
2,4-dimethyl phenol	DMP	ppb dw	29	77		
Pentachlorophenol	PCP	ppb dw	160	690		
Phenol	PNL	ppb dw	420	1200		
Hexachlorobutadiene	HCBD	ppb dw	11	270		
DDTs						
DDD		ppb dw	16	68	540	3000
DDE		ppb dw	9	62	3100	4600
DDT		ppb dw	19	34	270	3000

Units: ppm = Parts per million
ppb = Parts per billion
dw = Dry weight

Table 2. Sediment chemistry sampling events used in assessment of contamination in Lower Duwamish River.
1985 - 03 Lockheed Shipyard #2 1991 EPA Harbor Island RI 1995 Boeing Plant 2 Phase 2A 1995 Harbor Island Supplemental Remedial Investigation 1995 Norfolk CSO Sediment Cleanup Study 1996 Boeing Plant 2 Phase 2B 1996 Duwamish/Diagonal Cleanup 1997 Boeing Duwamish Waterway Phase 1 1997 King County Duwamish WQ Sediment 1998 EPA Lower Duwamish River 1998 NMFS Duwamish Waterway Characterization 1998 NS&T Central Puget Sound 2000 James Hardie Outfall 2003 - 04 Duwamish / Diagonal Dredge Monitoring 2003-04 Terminal 117 Early Action 2004 Boeing Plant 2 DSOA Upriver Area 1 2004 Rhone-Poulenc 2005 LDWRI-Surface Sediment Round 1 2005 LDWRI-Surface Sediment Round 2 2004 LDG Slip 4 early action 2004 LDWRI-Benthic 2004 Jorgensen August 2004 Boyer Towing 2006 Kenworth/PACCAR RI 2006 LDWRI-Surface Sediment Round 3
* 1985 EPA Elliott Bay Sediment Survey * 1995 King County Chelan CSO Base/NPDES * 1995 King County Connecticut CSO/NPDES
* metals were selected from these data and used to extend coverage in the East Waterway