Lower Duwamish Waterway

Site Description

The Duwamish River, located in Washington State, extends from the City of Auburn to Elliot Bay. It originates at the confluence of the Green and Black Rivers, flows northeast for approximately 12 miles, and divides at the southern end of Harbor Island (in Seattle) to form the East and West Waterways around Harbor Island, which then discharge into Elliot Bay. The Lower Duwamish Waterway Site is a 5-mile stretch of the Duwamish River, which ends immediately upstream of the East and West Waterways around Harbor Island. This waterway is a federal navigation channel maintained by the U.S. Army Corps of Engineers. Note that the East and West Waterways are operable units within the Harbor Island Superfund Site (Project ID 10-03).

Site History

In 1997, King County's Department of Natural Resources performed a combined sewer overflow (CSO) water-quality assessment for the Duwamish River and Elliott Bay; the results concluded that estuary conditions pose potentially unacceptable risks to human health and the environment (U. S. Environmental Protection Agency [EPA], 2007a). This same year, the Boeing Company (Boeing) collected 88 surface sediment samples to evaluate potential chemical releases to the Duwamish Waterway attributable to Boeing facilities. These results indicated that there were polychlorinated biphenyls (PCBs), mercury and semivolatile organic compounds (SVOCs) in the surface sediment (EPA, 2007a).

Further sampling was conducted at the site in August and September 1998. EPA consultants collected 312 surface and 35 subsurface sediment samples from the Lower Duwamish Waterway. These results documented polynuclear aromatic hydrocarbons (PAHs), phthalates, PCBs and inorganic compounds in both surface and subsurface sediments (EPA, 2007a).

On December 20, 2000, EPA and the Washington State Department of Ecology (WA DOE) signed an Administrative Order on Consent (AOC) with the City of Seattle (the City), King County, Port of Seattle and Boeing to investigate the nature and extent of contamination in Lower Duwamish Waterway sediments. Under the AOC, the parties are required to collect information, evaluate potential risks to human health and the environment, recommend areas that warrant early cleanup action, conduct any necessary additional sampling, and prepare a final investigation report and an evaluation of options (Phase 1 Remedial Investigation Report) for long-term cleanup (EPA, 2007a).

In 2001, EPA and WA DOE signed a memorandum of agreement which stated that EPA will manage and lead the remedial investigation (RI) of waterway sediments and WA DOE will manage and lead source control efforts to protect sediment quality (EPA, 2007a).

Potential Responsible Parties

The Port of Seattle, the City, and Boeing have been identified as the potentially responsible parties (PRPs) for this site.

Threats and Contaminants

The constituents of concern (COCs) in the Lower Duwamish Waterway are arsenic, copper, lead, mercury, tributyltin, PAHs and PCBs. PCBs, arsenic, PAHs and dioxins and furans pose a risk to human health from exposure to chemicals in Lower Duwamish Waterway sediments and seafood. Direct contact with sediments during commercial netfishing, clamming or beach play in the waterway and consumption of seafood from the waterway were identified as primary exposure pathways.

Cleanup Approach

The purpose of the Phase I RI, which was completed in 2003, was to assess the human health risks and ecological risks associated with the Lower Duwamish Waterway. In this phase, the parties compiled data from past studies of the waterway and prepared a *Phase I RI Report*, which provided a preliminary assessment of human health and ecological risks based on existing data (EPA, 2007a).

In January 2004, WA DOE issued the *Final Source Control Strategy for the Lower Duwamish Waterway* (EPA, 2007a), which presented the following information:

- Description of the process of source control, roles of various regulators responsible for providing source control and methods that WA DOE will use to track and document the progress of source control.

- Physical extent of the source area for the site is approximately 32 square miles, and includes all types of urban land use, including interstate highways and airports, which reflect much of Seattle's industrial and commercial history.

The objective of the Phase II RI was to collect and evaluate data necessary to support the RI/Feasibility Study and future remedial decisions for the site. The Phase II RI was conducted in February 2007 and included the collection of additional fish, shellfish and benthic invertebrate tissue samples; collection of sediment samples; and performance of toxicity tests.

The *Lower Duwamish Waterway Remedial Investigation Report Results of the Phase II RI* was released for public review and comment on November 5, 2007. The key findings include (Windward Environmental LLC., 2007):

- Majority of the sediment contamination in the Lower Duwamish comes from historical releases; the majority of the highest levels of chemicals in sediment are detected at depth.

- High concentrations of PCBs were detected in surface sediments in localized areas.

- Most of the human health risk is from PCBs, arsenic, PAHs, and dioxins and furans.

- The majority of new cleaner sediment entering the Lower Duwamish originates from the Green River; the new sediment is burying the existing impacted sediment. Chemical concentrations in surface sediment are reduced by approximately 50% every 5 to 10 years from the transport of the cleaner sediment.

- The risk-based goals for direct sediment contact for total PCBs were higher than both the natural background concentration and the range of urban background concentrations.

The Phase II RI data were used to revise the human health and ecological risk assessments that were established during Phase I. The conclusions of the Phase I and Phase II draft risk assessments are that COCs would pose an unacceptable risk to humans consuming large amounts of resident fish and shellfish, and that ecological risks to fish and wildlife were relatively low, with the exception of risks to river otter from PCBs (EPA, 2007a). EPA and WA DOE will use this information to determine the long-term cleanup actions necessary in the waterway to protect both human health and the environment. The Washington Department of Health has implemented institutional controls, such as posting signs along the river advising people not to eat resident fish and shellfish (EPA, 2007a).

Seven Areas Designated For Early Cleanup Actions

In addition to providing the initial human health and ecological risk assessments, the Phase I RI identified seven areas for early cleanup actions; each area is known as an Early Action Area (EAA) (EPA, 2007a). These areas include:

- Duwamish/Diagonal Waterway CSO and storm drain, EAA 1.
- Trotsky, located on the west side of the waterway (at about river mile 2.2), EAA 2.
- Slip 4, EAA 3.
- Boeing Plant 2, EAA 4.
- Terminal 117 (Malarkey), EAA 5
- South of Boeing Plant 2 (at about river mile 3.8), EAA 6.
- Norfolk CSO, EAA 7.

As of the end of 2007, cleanup activities have been completed at the Duwamish/Diagonal Waterway (EAA 1) and Norfolk CSO (EAA 7) (EPA, 2003).

Duwamish/Diagonal Waterway (EAA 1)

From November 2003 to March 2004, King County completed a 7-acre sediment remediation project at the King County Duwamish CSO outfall and the City of Seattle Diagonal Way CSO/Storm Drain (SD) outfall (Duwamish/Diagonal CSO/SD) site on the Duwamish River in Seattle, Washington (EchoChem, 2005). This area is on the east side of the Duwamish River, upstream of Harbor Island and immediately downstream of Kellogg Island in the lower portion of the Duwamish River. It is within the south industrial section of Seattle (EPA, 2004).

The original site extends about 750 feet along the shoreline upstream and downstream of the Duwamish/Diagonal Waterway outfalls (Area A); it is about 260 feet wide. The addition to the site extends about 500 feet along the shoreline upstream and downstream of the former Diagonal Avenue Treatment Plant outfall and the Diagonal Avenue South storm drain outfall (Area B). This area is about 160 feet wide and does not touch the shoreline.

The objective of the Duwamish/Diagonal CSO/SD sediment remediation project was to remove sediment from a 5-acre rectangle (Area A) and a 2-acre rectangle (Area B). Area A was the original proposed cleanup area designed to address chemicals associated with discharges from the Duwamish/Diagonal CSO/SD and to remediate about 5 acres of the highest bis(2-ethylhexyl)phthalate (BEHP) values in surface sediments. Area B addresses a historic chemical “hot spot” associated with discharges from a historic sewage treatment plant. High PCB values in these sediments represented a significant risk of recontamination to cleanup in Area A if sediments in Area B were dredged at a later time. The cleanup action for Areas A and B involved first dredging sufficient contaminated sediment from both cleanup areas to make room for a layer of cap material. Then the remaining contaminated sediments within each cleanup area were covered with a minimum of 3 feet of capping material to isolate the remaining chemicals from the environment and return the site to approximately the bottom elevations that existed prior to dredging (EcoChem, 2005).

In 2003, Miller Contracting Inc. of Bellingham, Washington, was selected as the prime contractor. J.E. McAmis Industries of Chico, California, was selected as the subcontractor responsible for dredging these two areas (EcoChem, 2005).

“Rabanco Regional Disposal Company (Rabanco) of Seattle, Washington was the contractor selected as the contractor for disposing dredged materials. Rabanco had a separate agreement with Wilder Construction Company of Everett, Washington, to operate an offloading facility at the Port of Seattle’s Terminal 25. Sediment delivered to that facility would be offloaded from the barge, placed in lined railroad cars, and transported to Rabanco’s Roosevelt Landfill in Klickitat County, Washington” (EcoChem, 2005).

“The contractor mobilized a derrick (*Crystal Gale*), tugs *(MV Norton Bay* and *MV Loren M)*, split hull barges *(Sand Island and Swan Island)*, and a hydrographic survey vessel to the site. The *Crystal Gale* is 142 feet long by 58 feet wide with a 12-foot draft. It is equipped with an American 12-210 crawler crane with a 10 cubic yards (cy) clamshell bucket. The derrick is equipped with a differential global positioning system (DGPS) with an antenna on the tip of the boom over the bucket. WinOps® software was used to allow the operator to know where the horizontal position of the bucket was relative to the dredge plan at any given time. The vertical position of the dredge bucket was determined by foot markings on the cable and an electronic tide gauge that updated every 5 minutes. Two upstream and two downstream anchors were placed outside the dredge area, and winches on the corners of the dredge barge were used to change position upstream and downstream. The small tug (*MV Loren M)* periodically moved anchors inshore and offshore so the dredge barge could move inshore or offshore. Occasionally, the dredge had to be moved inshore to allow river traffic to pass. Dredged sediment was placed in the two split hull barges (1,700 cy capacity each) and taken to the offloading facility for offloading, transport, and disposal. Water overflow pipes on the split hull barges were covered with three layers of filter fabric, which allowed some dewatering at the dredge site and no overflow at the offloading site. Some excess water was pumped from barges to holding tanks either on the barge or at the offloading facility" (EcoChem, 2005).

During the dredging, King County monitored the water quality and collected post-dredge confirmation sediment samples. Turbidity did exceed acceptable levels periodically during dredging, and the following steps were taken to address this: reducing the rate of dredging and the rate of movement through the water, not overfilling the bucket, and using a different bucket (EcoChem, 2005). For example, an 18-cy rock bucket without digging teeth was used to try to reduce turbidity; however, this bucket still resulted in higher than acceptable turbidity values. Consequently, the 10-cy clamshell digging bucket was used for the duration of the dredging, which reduced turbidity to acceptable levels (EcoChem, 2005).

Capping Activities

Capping began after all dredging activities were complete and elevations were confirmed by post-dredge surveys. The remaining sediments within each cleanup area were covered with a minimum of 3 feet of capping material to isolate the remaining sediments from the environment and return the site to approximately the bottom elevations that existed prior to dredging. Capping material was obtained from Canadian quarries and transported to the site by flat deck haul barges. Base cap and habitat mix materials were obtained from Lehigh Northwest – Producer's Pit in Victoria, British Columbia (BC) and the quarry spall and riprap were obtained from Pitt River Quarries in Coquitlam, BC. The capping material was placed using a Hitachi 1800 excavator with a clamshell bucket. Base cap material was initially placed throughout Area B and approximately half of Area A. The logistics of ordering and obtaining the required quantities of the different capping materials from the two different quarries resulted in placement of materials at different locations in the site as the materials were available. Approximately 75,232 cy of capping material was placed over Area A and Area B; approximately 53,162 cy of base cap material, 12,043 cy of habitat mix, 3,686 cy quarry spall, and 6,341 cy of rip rap.

Water Quality and Sediment Sampling Analysis

Water quality was monitored in accordance with the approved *Water Quality Monitoring Sampling and Analysis Plan* (KCDNRP, 2003). Sampling occurred two times each day when dredging operations occurred during both tidal events. One sampling event was during the flood tide and one during the ebb tide. Field measurements were taken at each sampling location either just prior to or just after grab samples were collected for chemical analysis. A Hydrolab MiniSonde® was used to collect field data, including surface water temperature, pH, turbidity, specific conductance, salinity and dissolved oxygen. Water grab samples were collected using two 10 liter Niskin bottles hung on a hydro wire. The samples were collected 90 cm above the bottom and 60 cm below the surface at each location (EcoChem, 2005).

The water samples selected for chemical analysis each day were those that were collected when the highest turbidity conditions were observed based on field turbidity measurements. These samples were analyzed for total suspended solids, salinity, turbidity, mercury, PAHs, phthalates, and PCBs in accordance with the monitoring plan. Only the laboratory turbidity values were used for official comparison to water quality standards (EcoChem, 2005).

The Sediment Monitoring and Sampling Analysis Plan (KCDNRP, 2003) required sediment sampling beyond the site boundary to document changes in chemical concentrations of surface sediments due to dredging. Twelve monitoring stations were established beyond the site boundary; they were sampled before and after the project was implemented to document potential changes in chemical concentrations in sediment. The stations were located upstream, downstream, inshore, and offshore and were approximately 50 to 150 feet from the dredge prism. Ten individual grab samples were collected at each station and were combined into one composite sample. All samples were submitted to the King County Environmental Laboratory for analysis of sediment characterization (PCBs, base/neutral/acids, chlorinated pesticides, mercury, metals, total organic carbon [TOC], total solids and grain size) (EcoChem, 2005).

Sediment samples collected at the 12 stations in October 2003 exceeded the sediment quality standard (SQS) or cleanup screening levels (CSL), specified in Washington's Sediment Management Standards (SMS), for one or more of the 5 chemicals (PCBs, BEHP, benzyl butyl phthalate [BBP], 1,4 dichlorobenzene, mercury, cadmium and silver). CSLs represent sediment concentrations above which there is an increased likelihood, but not a certainty, for adverse effects to benthic invertebrates. The following is a summary of CSLs for chemicals measured in the Lower Duwamish Waterway sediments (Windward Environmental, LLC. 2003):

- 1,4 dichlorobenzene – 9.0 mg/kg organic carbon (OC)
- BBP – 64 mg/kg OC
- BEHP – 78 mg/kg OC
- Cadmium – 6.7 mg/kg dry weight (dw)
- Mercury – 0.59 mg/kg dw
- PCB – 65 mg/kg OC
- Silver – 6.1 mg/kg dw

The following are the results from the samples collected before and after implementing the sediment remediation project as stated in the *Duwamish/Diagonal CSO/SD Sediment Remediation Project Closure Report* (EcoChem, 2005):

- For PCBs, all 12 stations exceeded SMS before construction with 9 greater then SQS and 3 greater then CSL. After construction, 11 stations exceeded SMS with 2 greater then SQS and 9 greater then CSL, which is a net increase of 6 stations exceeding the CSL. The maximum increase occurred at two stations, which increased to over 2 times the CSL and 3 times the CSL. The greatest increase in PCB dry weight concentrations was detected at 4 stations near Area B, concentrations increased 2,309 ppb (from 341 to 2,650 ppb), 2,100 ppb (from 1,290 to 3,160), 943 ppb (from 327 to 1270), and 702 ppb (from 427 to 1,130). The greatest increase in PCB concentrations detected near Area A at three stations were 631 ppb (from 103 to 733), 381 ppb (from 263 to 644), and 292 ppb (from 373 to 666).

- Five of the eight stations within the 50 foot site boundary had a reduction in PCB values after construction. This reduction may be due to the transport of capping sand beyond the site boundary.

- For BEHP, 9 stations exceeded SMS before construction with 5 greater than SQS and 4 greater than CSL. After construction, 11 stations exceeded SMS with 2 greater than the SQS and 9 greater than the CSL for a net increase of 5 stations greater than the CSL and 2 stations greater than the SMS. For BBP, one station exceeded the SQS before construction and this increased to 8 stations after construction, but no stations exceeded the CSL.

- For mercury, 4 stations initially exceeded SMS (2 greater than the SQS and 2 greater than the CSL), but in the samples collected after the project was implemented, these all dropped below SMS and one different station exceeded the CSL.

- For cadmium, silver and 1,4 dichlorobenzene, only one station initially exceeded SMS for each chemical (1 greater than the SQS for first compound and 1 greater than the CSL for the last two compounds), but in the after samples this dropped to no stations above the SMS.

Confirmation testing of the chemical levels on surfaces of cleanup Areas A and B began in the summer of 2004, approximately two months after the completion of the project; and is scheduled to continue for 10 years or until 2014. There are five surface sediment monitoring stations in Area A and three stations in Area B, all located on the cap surface. The results of the June 2004 baseline (Year 0) sampling event are as follows (EcoChem, 2005):

- Six of the surface grab stations are located in areas covered with habitat mix, making it difficult to collect samples. The other two stations were located in areas covered with gravel; the samples had to be sieved due to the gravel size.

- *Area A* – One station in Area A had the lowest concentration for both PCB (34 ppb) and BEHP (1.7 ppb). The highest BEHP values occurred in two stations located in Area A near the Diagonal Way CSO/SD outfall pipe, 442 and 324 ppb. The highest value of PCB in Area A was 46.7 ppb. The two lowest PCB values detected (18.5 and 20 ppb) were in Area A

Area B – The lowest value of BEHP of 89 ppb occurred in Area B. The highest values of PCBs (120 and 82 ppb) occurred in Area B. The lowest PCB value in Area B was 30.8 ppb.

Trotsky, West Side of the Waterway (at about River Mile 2.2) (EAA 2)

This area is located on the western bank of the Lower Duwamish Waterway, just south of the First Avenue St. bridge in King County, Washington. EAA 2 consists of a small inlet, approximately 80 feet wide at its mouth and tapering to a narrow stream at its head. It was identified as an area requiring sediment cleanup based on work conducted for the Lower Duwamish Waterway Superfund Site. The following chemicals are potential contaminants of concern at EAA 2: lead, mercury, PCBs, phthalates and zinc.

WA DOE is the lead for source control for EAA 2; its drainage basin outlines the area where sources need to be controlled. The routes for constituents to EAA 2 sediments include: direct discharges via piped outfalls, bank erosion from adjacent properties, surface runoff from adjacent properties, groundwater discharge, air deposition, and spills directly to the inlet. WA DOE developed a Source Control Action Plan for EAA 2 which describes what source control actions are necessary. As part of the Source Control Action Plan, WA DOE hired a contractor to put together a *Summary of Existing Information and Data Gaps Report*. In May 2007, WA DOE performed sampling to address some of the data gaps identified in the *Summary of Existing Information Data Gaps Report*. Investigation activities included sampling and analysis of subsurface soil, groundwater, seep water, stormwater outfall sediment and water, and intertidal sediment. Sampling results are presented in the *Lower Duwamish Waterway Early Action Area 2 Data Report, Additional Site Characterization Activities, July 2007*. The additional site characterization activities included sampling and analysis of subsurface soil, groundwater, seep water, stormwater outfall sediment and water, and Intertidal sediment. All the samples were analyzed for metals (arsenic, chromium, lead, mercury and zinc), PCBs, pesticides, SVOCs and TOC. In addition some of the soil, sediment and groundwater samples were analyzed for total petroleum hydrocarbons – diesel (NWTPH-Dx) and total petroleum hydrocarbons – gasoline (NWTPH-Gx).

Split spoon samples were collected from upland soil borings and analyzed. The samples were compared to the soil-to-sediment screening level, based on saturated soil conditions and sediment management standards cleanup screening level (SL-CSL-Sat). All the soil borings exceeded the SL-CSL-Sat screening levels for metals and PCBs; three out of seven samples exceeded the screening levels for SVOCs and total petroleum hydrocarbons. Sediment samples were collected on the south side of slip 1 near the Trotsky property. Samples were collected from the upper four inches of the sediment and analyzed. Two of the five sediment samples collected exceeded the screening levels in 34 of the 45 constituents they were analyzed for. All the sediment samples exceeded the screening levels for PCBs and pesticides.

One sediment sample was collected from the Second Avenue South storm drain outfall, the sample was analyzed and exceeded the screening level for PCBs, pesticides, and three of the 29 SVOCs.

Groundwater samples were collected from three monitoring wells upland from the inlet. Analyses detected exceedances in all the constituents in one of the wells. In the remaining wells, metals and PCBs primarily exceeded the criteria.

Two seeps were sampled from within the Intertidal zone on the south side of the inlet near the Trotsky property; arsenic, mercury and PCBs exceeded screening levels.

Slip 4 (EAA 3)

This area was studied by the City and King County with EPA oversight. The sediments in this area primarily contain PCBs. Cleanup options were presented to the EPA in December 2005, with public comment on the selected cleanup option occurring in early 2006. In May 2006 through an Action Memorandum, the EPA approved the non-time-critical removal action which selected the remedy for the site; a combination of removing sediments and placing clean sand and gravel over remaining contamination (EPA, 2006). In October 2006, the City and King County submitted the draft 60% design document for review by the EPA (EPA, 2007c). In February 2007, the City and King County submitted the draft 100% design document for review by EPA (EPA, 2007d).

Cleanup was scheduled to occur in fall 2007, but has been delayed due to uncertainties on whether sources of PCB contamination to Slip 4 (Boeing Plant 2) have been adequately controlled (EPA, 2007a).

Boeing Plant 2 (EAA 4)

Sediment samples were collected in March 2007 by EPA; results of this sampling effort are not yet available. Samples were collected within the central part of the Duwamish Waterway to determine the western extent of the Boeing Plant 2 early action cleanup. A Memorandum of Agreement (MOA) between Boeing and Jorgensen Forge was signed on December 6, 2007. The MOA assigns joint responsibility to Boeing and Jorgensen for the cleanup of a portion of the sediments along the southern boundary of Boeing Plant 2 (EPA, 2007e).

Terminal 117 (Malarkey), EAA 5

Early cleanup for this area was pursued under EPA Superfund oversight (EPA, 2007a). Terminal 117 was investigated by the Port of Seattle and the City to determine the extent of impacted soil. In July 2005, EPA selected a cleanup option that involved removing PCB-containing soil and replacing it with clean fill. Following this decision, however, high concentrations of PCBs in soils were discovered in the upland area. To address these high PCB concentrations, EPA completed a time-critical removal action (TCRA) in October 2006. The TCRA identified three areas within the 3 acre site and a 5- to 60 foot wide area adjacent to the shoreline that required removal of soil due to high levels of PCBs. Two of the upland areas had a removal action level of 25 ppm, in the third upland area and the shoreline area the top two feet of soils were removed (RETEC Group, Inc., 2007). An interim asphalt cap was constructed in the four soil removal areas after clean backfill and identifier filter fabric were placed and compacted to the existing grade. The remaining upland soils and sediments are anticipated to be remediated in 2008 (EPA, 2007a). The total cost associated with the TCRA activities incurred in complying the EPA’s order was approximately $2.6 million. The cost included the direct field construction costs and other costs related to the TCRA (RETEC Group, Inc., 2007).

Post-Cleanup Sediment Monitoring for Terminal 117

Long-term sediment, seep and groundwater monitoring are being conducted to determine if the TCRA cleanup has addressed the PCB-impacted sediments, and to determine if sediments continue to be affected. If PCBs from the upland soils continue to impact the sediments, follow-up source control actions will be implemented.

The first semi-annual Operation and Maintenance Report was developed; it is not yet publicly available, but is expected to be released in early 2008. The report discusses the long-term monitoring for Terminal 117. The roads within the site were sampled before and after the sediment removal and the data are included in the report. Several areas of the site have been covered with asphalt; there may not be any "post-asphalt" samples from those locations (EPA, 2007b).

South of Boeing Plant 2 (EAA 6)

EAA 6 is south of Boeing Plant 2, the site is located at river mile 3.8 and is known as Former Slip 5. EAA 6 is Boeing property located on both sides of the waterway; on the west side the property includes a Boeing facility and a greenbelt with a walking path, on the east side of the waterway the property is divided between Boeing/Thompson and Boeing/Isaacson.

Sediments from Area 6 were sampled during two investigations in 1997 and 1998. Samples were collected from Boeing property east of the navigation channel adjacent to the Isaacson and Thompson properties and just offshore of a storm drain outfall. There were several CSL or ML exceedances; PAH and BEHP exceeded the CSL in this area.

As of January 2008, WA DOE is developing the Existing Information and Data Gaps Report for the site.

Norfolk CSO (EAA 7)

In 1999, King County completed a 1-acre cleanup at the Norfolk CSO outfall site (EPA, 2004). Mechanical dredging was performed by General Construction Company and Foss Environmental Services. A mechanical clamshell dredge was used to remove sediments and to place backfill. The dredge consisted of an American 9260 125-ton crawler crane equipped with a 4-cy bucket mounted to a 164-by-50 foot barge. Dredging was performed in three different phases, the area identified as the “likely hot spot” by King County was removed first and isolated in 50 cy quantities and samples were submitted to King County Environmental Laboratory for PCB analysis. All sediments with PCB concentration greater than 45 ppm dw were sent to the Subtitle C landfill in Arlington, Oregon operated by Chemical Waste Management of the Northwest. Sediments with a PCB concentration lower than 45 ppm were sent to the Subtitle D Olympic View landfill in Bremerton, Washington. After the completion of the hot spot dredging the remaining sediment was dredged, it did not require isolation or chemical testing. The total volume dredged is approximately 1,850 cy from the hot spot area and 2,200 cy from the remaining sediment dredging area. Confirmation testing was performed and dredging continued until either there were no exceedances (less than 45 ppm) or until slope stability was met. The dredged area was backfilled with clean backfill taken from a section of the river downstream (KCDNRP, 1999). Post-removal monitoring was conducted for 5 years as part of the EPA 5-Year Review.

The post-removal monitoring at the Norfolk CSO was conducted to evaluate possible recontamination of the backfill sediment as a result of continuing CSO discharges, and to evaluate the effectiveness of source-control measures that were implemented. For each of the first 3 years, eight samples were collected from four locations in the top 2 and 10 centimeters (cm) of sediment and analyzed for percent solids TOC, 13 priority pollutant metals (12 priority pollutant metals for year 2 and year 3), base neutral acids, and PCBs. The results for years 1 through 3 can be found in the *Lower Duwamish Waterway Early Action Area 7 Final Summary of Existing Information and Identification of Data Gaps Report* (WA DOE, 2007).

Year 1 Results (2000):

- Percent solids ranged from 76.9 to 77.6%.
- TOC ranged from 1,210 to 3,180 milligrams per kilogram (mg/kg) dw.
- All metals were below their respective SQS chemical criteria.
- PCBs were not detected above the method detection limits, but the method detection limits for three samples (ranging from 13 to 18 mg/kg OC) exceeded the SQS of 12 mg/kg OC.
- Dibenzofuran was not detected above the detection limits; in three samples the method detection limit (ranging from 20 to 29 mg/kg OC) exceeded the SQS of 15 mg/kg OC.
- The following analytes were all detected below their respective method detection limits and below their SQS criteria: benzoic acid, benzyl alcohol, 2-methylphenol, 4-methylphenol, pentachlorophenol and phenol.

Year 2 Results (2001):

- Percent solids ranged from 52.7 to 74.4%.

- TOC concentrations ranged from 2,770 to 15,600 mg/kg dw.

- For metals, arsenic, cadmium and silver were detected below their respective detection limits and below their respective SQS (57, 5.1, and 410 mg/kg dw) and CSLs (93, 6.7, and 960 mg/kg dw). Concentrations of all the other metals were at levels reported to be typical of natural, area-wide concentrations.

- PCBs were detected in all eight samples, four of which (concentrations ranging from 18.6 to 677 mg/kg OC) exceeded the SQS (12 mg/kg OC) and CSL (65 mg/kg OC).

- High molecular weight PAHs were all below their SQS and CSL criteria.

- Dibenzofuran was not detected above the detection limits, which ranged from 1.7 to 6.8 mg/kg OC, below the SQS and CSL criteria of 15 and 58 mg/kg OC, respectively.

Year 3 Results (2002):

- Percent solids ranged from 47.4 to 84.2%.

- TOC ranged from 980 to 26,200 mg/kg dw.

- Cadmium and silver were not detected in any samples. The detection limits were below their respective SQS values of 5.1 and 6.1 mg/kg dw. All other metal concentrations are at levels reported to be typical of natural area-wide concentrations and were below SQS chemical criteria.

- PCBs were detected in six samples with concentrations ranging from 3.61 to 30.4 mg/kg OC. The highest concentration (30.4 mg/kg OC) exceeded the SQS (12 mg/kg OC).

- Dibenzofuran was not detected above the detection limits, which ranged from 1.2 to 18 mg/kg OC. The SQS and CSL criteria are 15 and 58 mg/kg OC, respectively.

In July 2002, WA DOE conducted a study to determine if any PCB-impacted sediment remained after the initial 1999 cleanup activities that could be transported via eroded soil to the clean backfill sediment cap. WA DOE collected 22 sediment samples from 21 sample stations from the inshore area between the Norfolk CSO/SD outfall and the Boeing south storm drain outfall. These samples were analyzed for TOC, percent solids, grain size, and PCBs as Aroclors. TOC ranged from 0.4 to 4.62%. Total PCB concentrations, based on detected Aroclors, ranged from 0.6 to 330 mg/kg OC. The total PCB concentrations in six of these samples exceeded the SQS of 12 mg/kg OC, and of these, three exceeded the CSL of 65 mg/kg OC (WA DOE, 2007).

As a result of the study conducted in July 2002, Boeing removed approximately 60 cy of PCB-contaminated sediments in the area near the south storm drain outfall in 2003. As part of the confirmatory sampling, 18 confirmation sediment samples were collected in October 2003 and analyzed for PCBs as Aroclors and TOC. Results for TOC ranged from 0.18% to 2.20%. Total PCB concentrations ranged from non-detect to 2,190 mg/kg OC and exceeded the SQS (12 mg/kg OC) in four samples (61 to 2,190 mg/kg OC). Boeing concluded that most of the sediment containing total PCBs above the SQS was removed, except for one small area of sediment containing total PCBs above the CSL of 65 mg/kg OC (WA DOE, 2007).

Boeing conducted additional sampling in Areas A and B in 2004 and 2005. In both years, four surface sediment samples were collected and analyzed for total PCBs and TOC.

2004 Results: PCB concentrations ranged from non-detect to 27 micrograms per kilogram (µg/kg) dw. TOC concentrations ranged from 0.128% to 0.242%. The results for all samples were below the SQS for PCBs. In December 2004, two solids samples were collected from the south storm drain at manhole locations both downstream and upstream of a combined sediment trap/oil-water separator; they were analyzed for PCBs, TOC, and percent solids. TOC results were 13.8 and 19.7%, respectively. Total PCB results were 7,100 µg/kg dw for the sample collected from downstream of the sediment trap/oil-water separator, and 20,000 µg/kg dw for the sample collected from upstream of the sediment trap/oil-water separator. Each of these PCB concentrations exceeded the lowest apparent effects threshold (LAET) (130 µg/kg dw) and the second lowest apparent effects threshold (2LAET) (1,000 µg/kg dw) values (WA DOE, 2007).

2005 Results: TOC concentrations ranged from 0.53 to 1.56%, and PCB concentrations ranged from non-detect to 353 µg/kg dw (S1-05). In one sample the TOC normalized concentration was 22.6 mg/kg OC and the PCB concentration exceeded the SQS (12 mg/kg OC) and LAET (130 µg/kg dw), but was below the CSL (65 mg/kg OC) and 2LAET (1,000 µg/kg dw). Total PCB results for the three other samples were below the detection limits of 31 and 32 µg/kg dw, below the LAET value and corresponding to TOC-normalized values of 2.1 mg/kg OC and 5.8 mg/kg OC, below the SQS. In November 2005, two solids samples were collected from the south storm drain located downstream and upstream of a sediment trap/oil-water separator and were analyzed for PCBs, TOC and percent solids. TOC results ranged from 6.09 to 22.70%. Total PCB results ranged from 12,600 µg/kg dw (downstream) to 61,500 µg/kg dw (upstream). Additionally, two samples of accumulated solids were collected from the sediment trap/oil-water separator. Total PCBs concentrations were 15,100 and 15,800 µg/kg dw. Concentrations of the storm drain solids and accumulated solids exceeded the LAET (130 µg/kg dw) and 2LAET (1,000 µg/kg dw) (WA DOE, 2007).

Future Activities

The EAA are expected to be completed and a cleanup plan for sediment remaining in the waterway is scheduled to be finalized by 2008 (Lower Duwamish Waterway Group, 2007).

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