FINAL

Remedial Investigation Report

Tongue Point Multi-Sites Project

Former Tongue Point Naval Air Station

Astoria, Oregon

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Executive Summary

The Seattle District, United States Army Corps of Engineers (USACE) is conducting investigation and remediation activities at the Former Tongue Point Naval Air Station (NAS), located in Astoria, Oregon under the authorities of the Defense Environmental Restoration Program for Formerly Used Defense Sites (DERP-FUDS), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, 42 United States Code [U.S.C.], Section 9601 et seq., as amended), and regulatory requirements of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR], Section 300). The remedial investigation phase of this work was conducted following the scope and approach developed collaboratively with the Oregon Department of Environmental Quality (ODEQ) and the United States Fish and Wildlife Service (USFWS) as presented in the *Final Management Plan* (MP) (CDM 2008a) and the *Final Quality Assurance Project Plan* (QAPP) (CDM 2008b).

The Former Tongue Point NAS is located at river mile 18 on the Columbia River (Cathlamet Bay) off Old Highway 30 and is within the city limits of Astoria, Oregon. The project is referred to as the Tongue Point Multi-Sites (TPMS) Project because multiple decision units (DUs) are located within the study area of the Former Tongue Point NAS. These DUs comprise six terrestrial release areas and three aquatic areas. These subareas were identified to include all areas thought to have been sources (terrestrial) or to have been affected by releases from these sources (aquatic) associated with DoD era activities from 1941 to 1962.

RI Objectives and Approach

Objectives of the RI were to characterize the nature and extent of chemical concentrations by media, to characterize human health and ecological risks and to provide data and other information to support the feasibility study. Conclusions of the Remedial Investigation (RI) include recommendations for identifying areas within DUs that require response action and preliminary remedial action objectives (RAOs) to support evaluation of remedial alternatives.

The RI addressed sources and releases from Department of Defense (DoD) era activity on a DU basis. Each of the six terrestrial and three aquatic DUs was investigated separately as one of the "multi-sites" in the TPMS project.

RI Objectives

Specific objectives of this RI are:

- Characterize possible impacts in environmental media to identify possible sources of chemicals in upland DUs and in near-shore aquatic DU.
- Determine if the Tongue Point Landfill interim removal action is protective of the aquatic environment offshore of the landfill.

- Perform baseline human health and ecological risk assessments.
- Identify DUs within the Study Area that may require remedial actions.
- Develop preliminary RAOs.

Study Area Investigation

To address RI objectives, fieldwork was conducted from 8 September to 10 October 2008. The six upland/terrestrial DU were identified as possible source areas while the aquatic DUs could have received chemicals released from these sources. Characterization at each DU involved sampling and analyzing the following media:

- Aboveground Storage Tank (AST) Fuel Storage Area – Surface soil, subsurface soil, and groundwater
- Underground Storage Tank (UST) Site Number (No.) 1 – Subsurface soil, soil gas, groundwater, light nonaqueous phase liquid (LNAPL), near-shore surface water, and near-shore sediment
- Refueling Pit 3 – Subsurface soil, soil gas, ambient air, groundwater, near-shore surface water, and near-shore sediment
- UST Site No. 4 – Surface and subsurface soil
- Incinerator Building – not sampled during this RI. Evaluations used data collected by USACE in 2007
- Fire Training Area – Subsurface soil, soil gas, groundwater, LNAPL, near-shore surface water, and near-shore sediment
- Aquatic - North of Pier 8 –Surface sediment, surface water, and fish/clam tissue
- Aquatic - Finger Piers – Surface sediment, surface water, fish/clam tissue and sediment cores
- Aquatic - Near Landfill –Surface sediment, surface water, and fish/clam tissue

DoD era activity involved storage and use of fuels for ships and seaplanes, and source areas and releases were characterized for petroleum hydrocarbons. However, analyte lists were broadened to include other organic and inorganic constituents to ensure appropriate characterization of possible releases from other activities, including handling of electrical transformers, pesticide application, and training at the former fire training area.

Physical Characteristics and Land Use of the Study Area

The Study Area comprises approximately 230 acres, with 85 acres located on shore and 145 acres located off shore. The terrestrial portion of the Study Area is situated within the flat-lying area on the banks of Cathlamet Bay and is bordered by upland

areas to the southwest, Tongue Point to the north, and Mill Creek to the south. The aquatic portion lies in and around a group of eight finger piers that extend into the Bay. These finger piers date from DoD operations after 1946.

The northern portion of the Study Area (Tongue Point itself) is restricted access and is managed by the USFWS as the Tongue Point Eagle Sanctuary. The portion of the Study Area between Tongue Point and south to Hangar 2 was a center of DoD activity and is currently the Tongue Point Job Corps Center. The portion of the Study Area between Hangar 2 and Pier 1 was used historically by the Navy and is currently owned by Washington North Tongue Point. This area is used as a multi-use transportation logistics and intermodal facility. The southernmost portion of the Study Area is currently owned by the Oregon Department of State Lands (ODSL) and includes the former Fire Training Area DU. A portion of the Fire Training Area DU is covered by dredge materials that were placed in 2001 long after cessation of DoD activities. Outside and south of the Study Area, but still on ODSL property, is the Tongue Point Landfill. The landfill contains waste from previous removal actions at the TPMS and is being addressed under a separate response action. No residences exist on Washington North or ODSL properties.

Groundwater at TPMS occurs at a depth of approximately 5 to 8 feet (ft) below ground surface (bgs) in fill and alluvium. The hydraulic conductivity of the shallow aquifer is 1 to 20 feet/day. Groundwater is not used as a drinking water source and is not likely to be used for drinking water in the future because of limited yields and availability of a high-quality municipal supply.

Water depth of the Aquatic DUs is 10 to 12 feet deep and sediments in the aquatic DUs consist of 5 to 20 feet of silt and sandy silt underlain by sand. Sediment accumulation at the Finger Piers DU was 1.5 to 3.2 feet over the 13.4-year period, or 1.3 to 2.9 inches per year. Approximately 8 feet of sediment has accumulated since the cessation of DoD activities in 1962.

RI Results

Results of the remedial investigations were interpreted separately for each of the nine DUs.

Nature and Extent

Significant findings by media for each DU are summarized, with a focus on selected chemicals that were identified based upon their potential to impact results of human health and/or ecological risk assessments. In the risk assessments, formal screening of detected chemicals identifies chemicals of potential concern (COPC) for human health and chemicals of potential ecological concern (CPEC).

AST Fuel Storage Area

Lead was the only constituent selected for further evaluation of extent in surface soil; petroleum hydrocarbons did not exceed DU-specific total petroleum hydrocarbon (TPH) screening levels. When in use, aviation gas (AVGAS) was stored in the ASTs.

AVGAS contains tetraethyl lead (TEL), which has a half-life of a few weeks in surface soil, and degrades leaving residual inorganic lead. Lead concentrations in soil were below human health screening criteria and it was not selected for further evaluation of extent of impacts on this basis. However, because concentrations of lead in AST surface soil were the maximum values in the Study Area, and owing to its bioaccumulative properties, lead was further evaluated for ecological effects. The only chemical selected for evaluation of extent of impacts in AST groundwater was arsenic, which is discussed and mapped for groundwater at all DUs. The highest concentration of arsenic in groundwater is greater than its comparison criteria of 0.038 µg/L.

UST Site No. 1

No chemicals were identified at concentrations expected to influence risk management and no chemicals were further evaluated for extent of impacts in soil at the UST Site No.1 DU. However, benzene was identified for further evaluation of extent of impacts in soil gas. Benzene was found in areas upgradient and proximal to two USTs that were closed-in-place.

Gasoline-range petroleum hydrocarbons (TPH-G) and diesel-range petroleum hydrocarbons (TPH-D) were detected in groundwater above the DU-specific TPH screening levels. Carcinogenic polycyclic aromatic hydrocarbon (PAHs) and arsenic are also identified for further evaluation of extent of impacts in groundwater. Historically, MW-06 at UST Site No. 1 has had LNAPL; 1.72 feet of LNAPL was observed at MW-06 during the September 2008 investigation.

Arsenic was identified for further evaluation of extent of impacts in surface water, and total dichlorodiphenyltrichloroethane (DDT), carcinogenic PAHs, and mercury were identified for further evaluation of extent of impacts in near shore sediment. Most chemical detections and maximum concentrations were reported immediately downgradient of the former tank cavity. However, these constituents would not have been released from the former USTs. These USTs were used for fuel storage.

Refueling Pit 3

No chemicals were identified for further evaluation of impacts in soils at Refueling Pit 3 DU. Only 2-propanol and 4-ethyltoluene were detected in soil gas. Applicable screening criteria are not available for either chemical and they were retained for evaluation in the risk assessment.

TPH-G was identified for further evaluation of extent of impacts in groundwater. Trichloroethene (TCE) was also identified for further evaluation of extent of impacts, although the only detection was in an upgradient well. As with other DU, arsenic was identified for further evaluation of extent of impacts, although all detections were below its maximum contaminant level (MCL).

Arsenic is also identified for evaluation of extent of impacts in surface water, and carcinogenic PAHs, polychlorinated biphenyl (PCB), total DDT, and mercury were

identified similarly for sediment. These chemicals would not have been released from Refueling Pit 3, which was used for AVGAS during the era of DoD activity.

UST Site No. 4

Carcinogenic PAHs (cPAHs) were identified for additional evaluation of extent of impacts in soil. Petroleum hydrocarbons did not exceed TPH screening levels. Groundwater was not encountered in the investigation at this DU.

Incinerator Building

Carcinogenic PAHs and chlorinated dioxins/furans (as 2,3,7,8-TCDD equivalents (TEQ)) were identified for additional evaluation of extent of impacts in soil. Groundwater was not investigated at this DU.

Fire Training Area

TPH-D and arsenic were identified for additional evaluation of extent of impacts in soil. No volatile organic compounds (VOC) in soil gas were identified for additional evaluation of extent of impacts, but 2-hexanone, 2-propanol, 4-ethyltoluene, and ethanol were retained for further qualitative evaluation in the HHRA due to lack of applicable screening criteria.

TPH-G, benzene, 1,2,4-trimethylbenzene, and vinyl chloride, were identified as VOC for additional evaluation of extent of impacts in groundwater. Dioxins/furans 2,3,7,8-TCDD TEQ, naphthalene, cPAHs as benzo(a)pyrene (BaP) equivalents, arsenic, iron, and manganese, were identified for additional evaluation of extent of impacts in groundwater.

Arsenic was identified for additional evaluation of extent of impacts in surface water. Carcinogenic PAHs, total DDT, total PCBs, lead, and mercury were identified for additional evaluation of extent of impacts in sediments. Detailed documentation of the DoD activities at this DU was not available. Therefore, the investigation determined that some uncertainty exists whether chemicals reported from off shore of the DU are related to ongoing releases from former activities at the DU, or may likely be related to the nearby stormwater discharge.

Aquatic - North of Pier 8

Arsenic was the only chemical selected for additional evaluation of extent of impacts in surface water in the Aquatic - North of Pier 8 DU. Carcinogenic PAHs, arsenic and mercury were identified for further evaluation of extent of impacts in sediment.

Chemicals detected in clam tissue include fluoranthene, pyrene, total DDT, dioxins/furans, arsenic, chromium, lead, mercury, and selenium. Arsenic, chromium, lead, and selenium were identified for further evaluation of extent of impacts. Note that chromium was included because of lack of applicable criteria.

Several chemicals were detected in forage fish tissue including fluoranthene, pyrene, total DDT, alpha-chlordane, dieldrin, hexachlorobenzene, arsenic, chromium, lead, mercury, and selenium. Only total DDT, chromium, lead, selenium, and mercury

were retained for further evaluation of extent of impacts. Chromium was selected due to lack of applicable screening criteria.

Several chemicals were detected in fillets from surrogate fish species used to represent game fish, including total DDT, arsenic, chromium, lead, mercury, and selenium. Chromium, lead, mercury, and selenium were retained for additional evaluation of extent of impacts. Chromium was selected due to lack of applicable screening criteria.

Aquatic - Finger Piers

Arsenic was the only constituent identified for additional evaluation of extent of impacts for surface water. In sediment, cPAHs, total PCBs, and mercury were identified for additional evaluation of extent of impacts in sediments.

Several chemicals were detected in the clam tissue including total DDT, dieldrin, arsenic, chromium, lead, mercury, and selenium. Chromium, lead, and selenium were retained for further evaluation of extent of impacts. Chromium was selected due to lack of applicable screening criteria.

Chemicals detected in forage fish tissue include fluoranthene, pyrene, total DDT, dieldrin, dioxins/furans (as 2,3,7,8-TCDD TEQ), arsenic, chromium, lead, mercury, and selenium. Chromium, lead, mercury, and selenium were retained for further evaluation of extent of impacts. Chromium was selected due to lack of applicable screening criteria.

Several chemicals were detected in fillets from surrogate fish species used to represent game fish, including: total DDT, dioxins/furans (as 2,3,7,8-TCDD TEQ), arsenic, chromium, lead, mercury, and selenium. Chromium, mercury, and selenium were retained for further evaluation of extent of impacts, and, chromium was included because of the lack of applicable screening criteria.

Aquatic - Near Landfill

Arsenic was the only constituent identified for additional evaluation of extent of impacts in surface water. Carcinogenic PAHs, total PCBs, dioxins/furans, as 2,3,7,8-TCDD TEQ, and mercury were all identified for additional evaluation of extent of impacts in surface sediments.

Several chemicals were detected in clam tissue, including: fluoranthene, pyrene, total DDT, dieldrin, dioxins/furans (as 2,3,7,8-TCDD TEQ), arsenic, chromium, lead, mercury, and selenium. Chromium, lead, mercury, and selenium were retained for additional evaluation of extent of impacts. Note that chromium was included for additional evaluation of extent of impacts because of the lack of applicable screening criteria.

Chemicals detected in forage fish tissue include fluoranthene, pyrene, total DDT, alpha-chlordane, dieldrin, hexachlorobenzene, arsenic, chromium, lead, mercury, and selenium. Chromium, lead, mercury, and selenium were retained for additional

evaluation of extent of impacts, and chromium was selected due to lack of applicable screening criteria.

Several chemicals were detected in fillets from surrogate fish species used to represent game fish, including: total DDT, dioxins/furans (as 2,3,7,8-TCDD TEQ), arsenic, chromium, lead, mercury, and selenium. Chromium, lead, mercury, and selenium were retained for additional evaluation of extent of impacts, and chromium was included because of the lack of applicable screening criteria.

Near-Shore Surface Sediments

One objective of the RI was to evaluate near-shore sediments adjacent to the Tongue Point landfill to evaluate if the landfill was a continuing source after completion of containment and removal action in 2006. Comparisons of 2008 RI data to historical data collected before 2006 were used to evaluate whether or not the landfill was a continuing source. Comparisons between these data sets concluded that 2008 post-removal concentrations are less than historical values before the removal action. In addition, 2008 data showed similar mean concentrations of TCDD TEQ in the 2008 Near Landfill DU sediments as those from the Aquatic-Reference Area. The evaluation conclusively demonstrated that sediments nearshore at the landfill, and in the Finger Pier DU, show no indication of a possible current or continuing source of dioxins/furans or other contaminates associated with past DoD acitivity. Moreover, no available data suggest that current dioxin/furan levels near the landfill are different from those concentrations in upgradient sediments.

Fate and Transport Processes

Fate and transport processes, are discussed separately for upland (terrestrial) and aquatic DUs.

Upland Decision Units

Important fate and transport mechanisms for terrestrial DUs are adsorption and biodegradation, with volatilization playing a role for the light hydrocarbons (TPH-G and benzene, toluene, ethylbenzene, and xylenes (BTEX) compounds) and possibly chlorinated VOC in groundwater at the former Fire Training Area DU. Petroleum hydrocarbons, mainly constituents of AVGAS, diesel fuels and oil that are resistant to (or not subject to) biodegradation and that tend to adsorb to soil are still found at upland source areas. In addition, other chemicals or chemicals groups, including cPAHs, dioxins/furans, and lead, are resistant to (or do not) biodegrade and tend to be immobile in soil. Some of these constituents are found in soils in upland source areas.

Other soil components, which are more mobile or biodegradable, are not as prevalent in the soil, or are not detectable. Where LNAPL remains (UST Site No. 1 and Fire Training Area), aqueous concentrations of diesel-related components tend to be higher in groundwater. An anaerobic condition where LNAPL is present limits biodegradation of hydrocarbons.

Aquatic Decision Units

Fate and transport offshore of TPMS is controlled by sediment deposition. The location of the site strongly favors deposition and significant scouring seldom occurs, if ever. Active sedimentation buries sediments quickly to depths below the biotic zone and effectively removes them from the aquatic habitat. Concentrations of AVGAS, diesel fuel components and metals are higher in buried sediments when compared to the Reference Area surface sediments.

Further, deposition of fine-grained sediment high in organic carbon content absorbs organic chemicals and reduces their bioavailability. Reducing conditions in buried sediments preserves PAHs and hydrocarbons because biodegradation of these chemicals is primarily oxidative.

Conclusions of the Risk Assessments

Results and conclusions for the human health and ecological risk assessments – human health risk assessment (HHRA) and baseline ecological risk assessment (BERA), respectively -- are similar for upland DUs and for aquatic DUs. Thus, the discussion for both assessments is organized by these groups of DU.

Human Health Risk Assessment

The HHRA provides a quantitative estimate of cancer risk and health hazard associated with COPCs at the Study Area under current and future anticipated land-use conditions. Methods and procedures followed are consistent with current ODEQ and United States Environmental Protection Agency (EPA) guidance for HHRAs.

Following DoD's CERCLA authorities for environmental restoration of FUDS properties, petroleum is not being addressed in the HTRW program but will be addressed in the CON/HTRW program. The State of Oregon does not exclude petroleum hydrocarbons, and petroleum hydrocarbons were addressed per ODEQ risk assessment guidance. The distinction between CERCLA and ODEQ evaluations was honored in the risk characterization section of the HHRA.

Upland Decision Units

Considering all scenarios evaluated for current land use, upper-range excess cancer risk estimates do not exceed the ODEQ threshold for excess lifetime cancer risk (ELCR) of 1×10^{-5} for exposure to multiple carcinogens and thus all estimates fall within or below the EPA target cancer risk range of 10^{-4} to 10^{-6}. Carcinogenic COPCs are arsenic, carcinogenic PAH as B(a)P equivalents, and dioxins/furans as TEQ in soil; arsenic, cPAH, dioxin/furan TEQ, TCE and vinyl chloride in GW; and benzene, 1,3-butadiene, chloroform and PCE in soil gas. COPCs varied among the upland decision units.

In addition, all noncancer hazard indices (HI) are below the ODEQ and EPA threshold of 1. Depending on decision unit and medium, COPCs quantitatively evaluated for noncancer effects include As, Mn, dioxins/furans as TEQ, TPH-G, TPH-D, and trimethylbenzenes. Results support the conclusion that COPCs identified in

soil and groundwater at AST, UST Site No. 1, Refueling Pit 3, UST Site No.4, Incinerator Building and Fire Training Area DUs are not likely to cause adverse health effects for any human receptors that currently use upland areas of the TPMS.

Considering all scenarios evaluated for future land-use, calculated upper-range excess cancer risks exceed ODEQ threshold for ELCR of 1×10^{-5} and are within the EPA target cancer risk range of 10^{-4} to 10^{-6}, for consumption of groundwater as drinking water at UST Site No. 1 (future resident 1×10^{-4}), Refueling Pit 3 (future worker 3×10^{-5}), and Fire Training Area (future worker 7×10^{-5}) DUs. Noncancer HIs exceed the ODEQ and EPA threshold HI of 1 for future indoor workers at UST Site No. 1 and Refueling Pit 3 DUs, and for future residents at UST Site No. 1 DU.

Carcinogenic risks at UST Site No. 1 and Refueling Pit 3 DUs are attributed almost entirely to arsenic in groundwater, which appears to be present only at background levels. However, arsenic is reported only at concentrations below state and federal drinking water standards. Since future potable use of groundwater is unlikely and arsenic does not appear to be related to past DoD activities, risks and hazards associated with groundwater consumption do not appear to be DoD related and are largely hypothetical.

Carcinogenic risk of 3×10^{-5} at the Fire Training Area DU from consumption of groundwater (future worker) is attributed to vinyl chloride. This risk exceeds the ODEQ threshold and is within the EPA target cancer risk range of 10^{-4} to 10^{-6}. Vinyl chloride is likely related at least in part to past DoD activity from degradation of chlorinated solvents, tetrachloroethene (PCE) and TCE, used during fire training exercises. Arsenic is a contributor to total carcinogenic risk, but appears to be present only at background concentrations. Total carcinogenic risk, including arsenic and vinyl chloride in groundwater is 7×10^{-5}.

At UST Site No. 1 and Refueling Pit 3, non-cancer hazards exceed the ODEQ threshold of 1 for gasoline and diesel range petroleum hydrocarbons in groundwater. These constituents are likely to be DoD related. Small contributions to non-cancer hazards are made by arsenic and manganese, but both of these inorganic constituents are likely to be associated with background rather than historical DoD activities. As previously mentioned, future potable use of groundwater at TPMS is unlikely.

Aquatic Decision Units

For current and future land-use scenarios, upper-bound excess cancer risks for recreational users other than anglers are below or within the EPA target risk range of 10^{-6} to 10^{-4}. In addition, all HIs for recreational user scenarios are below 1. Recreational users of the shoreline at TPMS are unlikely to experience significant exposure.

Possible cancer risks for anglers for North of Pier 8 and Near Landfill DUs are at the upper end of the EPA target risk range and the cancer risk estimate for the Finger Piers DU is slightly higher. These cancer risks are almost entirely due to consumption of fish, as opposed to direct contact with sediment and surface water. Similarly,

ingestion of fish tissue is the basis for the noncancer HI that exceeds the regulatory threshold of 1 at the Finger Piers DU.

Risks from exposure to arsenic in fish tissue make up the majority of the total excess cancer risk: 78% at the Near Landfill, 85% at Finger Piers, and 96% at North of Pier 8. Risks from dioxins/furans make up the rest of the estimated cancer risk. Arsenic and dioxins/furans are also noncancer hazard drivers at the Finger Piers. Arsenic was not detected in soils or sediments at concentrations above regional background levels.

Quantitative risk estimates are uncertain because appropriate target species for anglers could not be collected, and sculpin were used as a surrogate. The multiple lines of evidence approach, however, indicates that sculpin data can be used in comparative fashion, along with other available data, to support conclusions concerning risks from fish consumption.

Multiple Lines of Evidence

A multiple lines of evidence approach was used to evaluate chemical concentrations in fish tissue and sediments in the aquatic DUs. Arsenic and 2,3,7,8-TCDD TEQ were subject to this more detailed analysis.

First, mean arsenic concentrations in sediment are at or below the regional default background concentration of 7 milligrams per kilogram (mg/kg). Arsenic does not appear to be related to historical or ongoing releases from DoD-era upland sources.

Second, the mean concentration of 2,3,7,8-TCDD TEQ in surface sediment, is higher at the Reference Area than at the Near Landfill DU, and dioxin/furan concentrations present in surface sediment at the Near Landfill DU are significantly lower than historical levels.

Third, concentrations of 2,3,7,8-TCDD and 2,3,7,8-TCDF in fish fillets collected from Tongue Point are similar to those collected from other nearby sites along the Columbia River and lower than regional values, i.e., upriver in Cathlamet Bay and upriver portions of Lewis and Clark National Wildlife Refuge (NWR).

These lines of evidence demonstrate that arsenic and dioxins/furans in surface sediment and fish tissues at the aquatic DUs most likely reflect ambient concentrations in the lower Columbia River Basin and are not related to releases from the landfill or past DoD activities.

Baseline Ecological Risk Assessment

The results of the BERA are summarized by DU and describe risk estimates by media type and ecological receptor group.

Upland Decision Units

Upland DUs are discussed in groups below because of similarities in results of the assessment.

Incinerator Building, Refueling Pit 3, UST Site No. 1, UST Site No. 4 - The Incinerator Building, Refueling Pit 3, UST Site No. 1, and UST Site No. 4 DUs provide little or no suitable habitat for ecological receptors. No action based on potential for ecological exposure is recommended for these DU.

AST Fuel Storage Area

Maximum detected concentrations of TPH-D and oil-range petroleum hydrocarbons (TPH-O), as evaluated under ODEQ guidance, exceeded screening levels. However, the localized presence of petroleum does not represent significant threat to ecological receptors. Soils at the AST Fuel Storage Area contain lead at concentrations exceeding conservative thresholds for plant toxicity and for individual omnivorous birds, but not for populations of avian receptors or small mammal populations.

Aquatic Decision Units

Petroleum hydrocarbons were detected in sediment samples from the Aquatic DUs and in near-shore discrete samples. As assessed under ODEQ guidance, sediment-associated ecological receptors are unlikely to be exposed to harmful concentrations of petroleum hydrocarbons.

Conclusions for other CPECs are:

- Several CPECs in sediment are associated with hazard quotients (HQ) exceeding 1.0 (based on protection of benthic invertebrates), but no HQ exceeds 5 and in most cases DU HQs are similar to the Reference Area HQs.
- Barium in surface water at all locations (including the Reference Area) is associated with HQs exceeding 1.0, but elevated HQs are not likely to be site related. Further, estimates are subject to considerable uncertainty because of sparse ecotoxicity data.
- Total DDT concentrations in sediments for the Aquatic DUs and Reference Areas are associated with HQs slightly exceeding 1.0 for individual small piscivorous avian receptors (represented by belted kingfisher). All other HQs remain below 1.0.
- Mercury concentrations in sediments for the Aquatic DUs and Reference Areas are associated with one or more HQs exceeding 1.0 for piscivorous birds. In all cases, the HQs for the Near Landfill DU slightly exceed HQs for the Reference Area; the North of Pier 8 and Finger Pier DU HQs are slightly below HQs for the Reference Area.
- PCBs were not detected above tissue-residue reporting limits in whole body fish and soft tissue clams taken from any of the aquatic DUs, but were reported in sediments in some near shore sediment samples. Using a sediment effects threshold (SET) for juvenile salmon from the literature as a reference point, the highest average Aroclor 1254 concentration would not be sufficient to cause harm to salmonid fish populations and individuals.

The ecological risk assessment (ERA) concludes that ecological risks identified are minor and unlikely to be related to past DoD activity and do not appear to be

different from risks associated with chemicals in sediments in other parts of Cathlamet Bay or other locations in the Lower Columbia River.

Conclusions

Existing conditions are protective of current and future human receptors within the Study Area. The only DoD related risks or hazards identified were associated with future use of groundwater as drinking water at the Fire Training Area. Such use does not seem at all likely in the foreseeable future.

For future indoor workers at the Fire Training Area DU, vinyl chloride-related cancer risk from consumption of groundwater is 3×10^{-5} and exceeds the ODEQ ELCR. Vinyl chloride is likely to be related to past DoD activity from use of chlorinated solvents, such as PCE and TCE, during fire training exercises. Total risk from consumption of groundwater at the Fire Training Area is 7×10^{-5}, with arsenic being the other major contributor. Arsenic is likely present only at background concentrations. Although this risk is below the upper bound of the EPA target cancer risk range of 10^{-4} to 10^{-6}, concentrations of vinyl chloride documented at the Fire Training Area DU exceed EPA and ODEQ regulatory criteria (MCLs) of 2 ug/L for future use of groundwater. Given a cancer risk above 1×10^{-5} and the exceedance of the MCL for vinyl chloride, concentrations of vinyl chloride could restrict potable use of groundwater in the future.

Evaluations of the aquatic DUs concludes that study area sediments nearshore at the landfill, and in the Finger Pier DU show no indication of a possible current or continuing source of dioxins/furans or other contaminates associated with past DoD activity.

The presence of LNAPL at limited locations within the UST Site No. 1 and Fire Training Area DUs does not present a quantifiable human health or ecological risk. Although the investigation data show that the transport pathway is not complete for migration of LNAPL to surface water and sediment in Cathlamet Bay, the possibility exists for future migration to result from extreme precipitation or tidal events. Therefore, petroleum hydrocarbons as LNAPL represent a source and potential future threat to surface water and sediment.

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Acronyms and Abbreviations

%	percent
%D	percent difference
µg/kg	microgram per kilogram
µg/L	microgram per liter
µg/m^3	microgram per cubic meter
µm	micrometer
°C	degree Celsius
ABS	absolute value
A/E	Agricultural/Engineering
Ag	silver
API	American Petroleum Institute
ARARs	applicable or relevant, and appropriate requirements
As	arsenic
AST	aboveground storage tank
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
ATL	acceptable tissue level
atm-m^3/mol	atmosphere cubic meter per mole
AVGAS	aviation gasoline
Ba	barium
B(a)P	benzo(a)pyrene
bgs	below ground surface
BAF	bioaccumulation factor
BCF	bioconcentration factor
BSAF	biota-sediment accumulation factor
BERA	baseline ecological risk assessment
BHC	hexachlorocyclohexane
BML	below mud line
BOR	Bureau of Reclamation
BTEX	benzene, toluene, ethylbenzene, and xylenes
CalEPA	California EPA
CARS	Consolidated Automotive Research Services, Inc.
Cd	cadmium
CDD	chlorinated dioxin
CDF	chlorinated dibenzofuran
CDM	CDM Federal Programs Corporation
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm	centimeter
cm/s	centimeter per second
cm^2	square centimeter
cm/s^2	centimeter per square second
cm^2/s	square centimeter per second
cm^3/cm^2/s	cubic centimeter per square centimeter per second
COI	chemical of interest in the ODEQ screening process for HRA

COC	chemical of concern
COPC	chemical of potential concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CPEC	chemical of potential ecological concern
Cr	chromium
Cresmont	Cresmont Capital Products
CSEM	conceptual site exposure model
CSM	conceptual site model
CTE	central tendency exposure
CTL	critical tissue level
Cu	copper
DCA	dichloroethane
DCE	dichloroethene
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DERP	Defense Environmental Restoration Program
DERP-FUDS	Defense Environmental Restoration Program for Formerly Used Defense Sites
DI	daily intake
dioxin/furan	chlorodibenzo-p-dioxin and chlorodibenzo-p-furan
DO	dissolved oxygen
DoD	Department of Defense
DOI	United States Department of Interior
DOL	United States Department of Labor
DPT	direct push technology
DQI	data quality indicator
DQO	data quality objective
DSMOA	Department of Defense and State Memorandum of Agreement
DU	decision unit
DUAR	data usability and assessment review
EBV	ecological benchmark value
EC	exposure concentration
ECD	electron capture detector
ED	ethylene dibromide
EPA	United States Environmental Protection Agency
EPC	exposure point concentration
EPH	extractable petroleum hydrocarbon
ERA	ecological risk assessment
ESU	evolutionarily significant unit
FP	Finger Pier
FR	Federal Regulation
FS	feasibility study
ft	ft
FUDS	Formerly Used Defense Sites
GC	gas chromatography
g/cm-s	gram per centimeter per second

g/cm^2–s	gram per square centimeter per second
$g/cm\text{-}s^2$	gram per centimeter per square second
g/cm^3	gram per cubic centimeter
gpm	gallons per minute
GSA	Government Services Administration
H_A	alternative hypothesis
HCB	hexachlorobenzene
HCID	hydrocarbon identification
Hg	mercury
HHRA	human health risk assessment
HI	hazard index
H_o	null hypothesis
HPAH	high molecular weight polycyclic aromatic hydrocarbon
HQ	hazard quotient
ICP	inductively coupled plasma
ID	identification
IS	incremental sampling
IRIS	Integrated Risk Information System
IUR	inhalation unit risk
J&E	Johnson and Ettinger model
kg	kilogram
kHz	kilohertz
K-M	Kaplan-Meier
K_{OC}	organic-carbon partition coefficient
K_{OW}	octanol-water partition coefficient
K_{sp}	solubility product constant
LCRS	Lower Columbia River Study
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
L/kg	liters per kilogram
LNAPL	light nonaqueous phase liquid
LPAH	low molecular weight polycyclic aromatic hydrocarbon
LRI	limited remedial investigation
M	molar concentration
m^2	square meter
m^2/g	square meter per gram
MARAD	Maritime Administration
MCL	maximum contaminant level
MDL	method detection limit
MERTS	Marine and Environmental Research and Training Station
mg/kg	milligram per kilogram
mg/kg-day	milligram per kilogram per day
mg/L	milligram per liter
MLLW	mean lower low water
mmHg	millimeters mercury
MMRP	Military Munitions Response Program
Mn	manganese

MOGAS	automotive gasoline
MP	management plan
MRL	minimal risk level
m/s	meter per second
MS	matrix spike
MSD	matrix spike duplicate
MTBE	methyl tert butyl ether
NAD 27	North American Datum of 1927
NAS	Naval Air Station
NAPL	nonaqueous phase liquid
Navy	Department of the Navy
NCEA	National Center for Environmental Assessment
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NES	Northwest EnviroService
NESCAUM	Northeast States for Coordinated Air Use Management
ng/kg	nanogram per kilogram
ng/L	nanogram per liter
NGVD 29	National Geodetic Vertical Datum of 1929
Ni	nickel
NMFS	National Marine Fisheries Services
No.	number
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no-observed-adverse-effect level
NWTPH-Gx	Northwest Total Petroleum Hydrocarbon Method-gasoline range organics
OAR	Oregon Administrative Rule
OC	organic carbon
ODEQ	Oregon Department of Environmental Quality
ODSL	Oregon Department of State Lands
OHWM	ordinary high water mark
ORC	oxygen release compound
ORNHIC	Oregon Natural Heritage Information Center
OSWER	Office of Solid Waste and Emergency Response
OVM	organic vapor monitor
PAH	polycyclic aromatic hydrocarbon
PARCCS	precision, accuracy, representativeness, comparability, completeness, and sensitivity
Pb	lead
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PCP	pentachlorophenol
PeCDD	pentachlorodibenzo-p-dioxin
PeCDF	pentachlorodibenzofuran
PEF	particulate emission factor
Pegasus	Pegasus Environmental Management Services, Inc.
pg/g	picograms per gram

PHH	planar halogenated hydrocarbon
PID	photoionization detector
PND	Peratrovich, Nottingham and Drage, Inc.
ppm	parts per million
PPRTV	provisional peer reviewed toxicity values
ppt	parts per thousand
PRG	preliminary remediation goal
PVC	polyvinyl chloride
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RAOs	remedial action objectives
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
REL	reference exposure level
RfC	reference concentration
RfD	reference dose
RI	remedial investigation
RME	reasonable maximum exposure
RPD	relative percent difference
RSD	relative standard deviation
RSET	Regional Sediment Evaluation Team
RSL	regional screening level
SARA	1986 Superfund Amendments and Reauthorization Act
Sb	antimony
Se	selenium
SET	sediment effects threshold
SF	screening factor
SFF	site foraging factor
SI	site inspection
SIM	selected ion monitoring
SL	screening level
SLVs	screening level values
SOP	standard operating procedure
SOW	statement of work
SQL	sample quantitation limit
STSC	Superfund Technical Support Center
SVOC	semi-volatile organic compound
T&E	threatened and endangered
TAL	target analyte list
TBT	tributyltin
2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
2,3,7,8-TCDF	2,3,7,8-tetrachlorodibenzofuran
TCE	trichloroethene
TDS	total dissolved solids
TEF	toxicity equivalence factor
TEQ	toxicity equivalent

TM	technical memorandum
TOC	total organic carbon
TPH	total petroleum hydrocarbon
TPH-D	diesel-range petroleum hydrocarbons
TPH-G	gasoline-range petroleum hydrocarbons
TPH-O	oil-range petroleum hydrocarbons
TPMS	Tongue Point Multi-Sites Project
TPNIP	Tongue Point Navigation Improvements Project
TRPH	total recoverable petroleum hydrocarbons
TRV	toxicity reference value
UCL	upper confidence limit
URS	URS Corporation
U.S.	United States
USACE	United States Army Corps of Engineers
U.S.C.	United States Code
USCS	Unified Soil Classification System
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UST	underground storage tank
UV	ultraviolet
Va	vanadium
VC	vinyl chloride
VDEQ	Virginia Department of Environmental Quality
VF	volatilization factor
VOC	volatile organic compound
V_P	vapor pressure
VPH	volatile petroleum hydrocarbon
WAC	Washington Administrative Code
WHO	World Health Organization
WMW	Wilcoxon-Mann-Whitney
Zn	zinc
cm^2	square centimeter
g	gram
L	liter
m^3	cubic meter
mg	milligram
ng	nanogram
µg	microgram

Section 1
Introduction

The Seattle District United States Army Corps of Engineers (USACE) is conducting investigation and remediation activities at the Former Tongue Point Naval Air Station (NAS), located in Astoria, Oregon. These response actions are conducted with the authorities of the Defense Environmental Restoration Program for Formerly Used Defense Sites (DERP-FUDS) within the USACE program for response actions addressing hazardous, toxic, and radioactive waste (HTRW) and containerized (CON)/HTRW releases. These programs follow requirements and regulations of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, 42 United States Code [U.S.C.], Section 9601 et seq., as amended), and regulatory requirements of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR], Section 300).

CDM Federal Programs Corporation (CDM) performed the remedial investigation (RI) for the Multi-Sites Project through contract number W912DW-06-D-1002 Delivery Order 008 with USACE. The investigation was conducted following the scope and approach developed collaboratively with the Oregon Department of Environmental Quality (ODEQ) and the United States Fish and Wildlife Service (USFWS) as presented in the *Final Management Plan* (MP) (CDM 2008a) and the *Final Quality Assurance Project Plan* (QAPP) (CDM 2008b).

The Former Tongue Point NAS is located at river mile 18 on the Columbia River (Cathlamet Bay) off Old Highway 30 and is within the city limits of Astoria, Oregon. **Figure 1-1** shows the project vicinity, as inset map, and maps features with property ownership boundaries. The project and study area are referred to as the Multi-Sites Project because multiple decision units (DUs) are within the study area of the Former Tongue Point NAS. The DUs comprise six terrestrial release areas and three aquatic areas. These subareas are identified because each may be affected by past practices or releases, and each are represented by a data set and will have individual remedial decisions through subsequent steps of the CERCLA process. During the investigation phase, the DUs do not have distinct boundaries, but have a geographic extent approximated by the limits of sample points. As needed for remedial decisions and quantifying remedial alternatives, the boundaries could be specified in the feasibility study phase. The DUs are shown on **Figure 1-2** and are as follows:

- Aboveground Storage Tank (AST) Fuel Storage Area
- Underground Storage Tank (UST) Site Number (No.) 1
- Refueling Pit 3
- UST Site No. 4
- Incinerator Building

- Fire Training Area
- Aquatic area north of pier 8 off shore from UST Site No. 1 (or Aquatic - North of Pier 8)
- Aquatic area associated with the finger piers (or Aquatic - Finger Piers)
- Aquatic area east of Tongue Point associated with the former landfill (or Aquatic - Near Landfill)

Two other possible source areas, the Munitions Storage Area and the Machine Gun Range, have been moved into the Military Munitions Response Program (MMRP) and are no longer part of the current Multi-Sites Project. These MMRP areas are being investigated by the USACE and initial documents are completed (USACE 2007).

The USACE is working collaboratively with the ODEQ to meet the regulatory requirements of this investigation and associated cleanup activities. ODEQ is the lead regulatory agency and USACE is the lead federal agency. ODEQ is providing oversight and consultation with DoD throughout the investigation, evaluation of site risks, in support of the USACE's selection of remedial or corrective actions. The United States Environmental Protection Agency (EPA) is not involved with remedial decisions for the Tongue Point study area.

1.1 Purpose and Objectives of the RI Report

RI activities were designed after conclusions and recommendations of the MP were addressed and refined (CDM 2008a). The QAPP functioned as the work plan for this investigation and was developed collaboratively with the USACE, the ODEQ, and the USFWS (CDM 2008b). The RI fieldwork was conducted from 8 September through 10 October 2008.

The purpose of this RI report is to present and evaluate data collected during RI activities to support remedial decisions and achieve closure for the specific decision units within the study area. To achieve that purpose, the RI objectives are to:

- Characterize possible impacts in environmental media to identify possible sources of chemicals in upland areas and in near-shore water areas.
- Determine if the Tongue Point Landfill removal action is protective of the aquatic environment, off shore and downstream of landfill.
- Perform baseline human health and screening level ecological risk assessments and, if warranted by evaluation of the screening level risk assessment, conduct a baseline ecological risk assessment.
- Identify sites within the study area that require remedial actions. If DUs pose no threat to possible receptors, recommend site closure.

1.2 Scope of the RI

As a part of developing the QAPP, planning and scoping meetings were held to develop an overall approach to meet the objective for closing the nine DUs previously described (see **Figure 1-2**). These initial meetings were held in August and September 2007 to define the overall scope and goals of the RI. The QAPP identifies the procedures and methods for collecting data necessary to support remedial decisions for the nine DUs.

On November 7 and 8, 2007, a kick-off meeting was held at the Tongue Point Job Corps Facility with stakeholders to receive their input for the scope and goals of the RI. Stakeholders for the Former Tongue Point NAS include USACE, ODEQ, Job Corps (Department of Labor), Washington North Tongue Point, and USFWS (who were not available to attend the kick-off meeting). The USACE prepared the MP for the Multi-Sites Project in February 2008, and distributed it to the stakeholders. The MP outlined the project objectives, scope, and general approach to the Multi-Sites Project. The draft MP was discussed in detail with the stakeholders in a meeting held on March 12, 2008, and was finalized based on responses received during the meeting and subsequent discussions. The project-specific QAPP describes the methods and quality procedures for the RI to collect the information necessary to assess the human health and ecological risks posed by chemicals released and detected at the terrestrial DUs. The information collected and evaluations performed are to support the goal of obtaining closure of the individual FUDS sites within the DUs.

Based on the previous investigations within the study area, the QAPP set the focus on addressing the release of petroleum hydrocarbons (and associated degradation byproducts) as the principal threat to human and ecological receptors in the AST Fuel Storage Area, UST Site No. 1, and UST Site No. 4 DUs. Therefore, the chemicals analyzed in each of these DUs were limited to petroleum-related compounds.

Activities that were performed in each DU in support of meeting the RI objectives are as follows:

- *AST Fuel Storage Area* – Nine composite surface and nine discrete subsurface soil samples and one groundwater sample were collected and analyzed for compounds associated with petroleum hydrocarbon contamination.

- *UST Site No. 1* – Five discrete subsurface soil samples, six soil gas samples, eight groundwater samples, and two near-shore surface water and sediment samples were collected and analyzed for compounds associated with petroleum hydrocarbon contamination. One light nonaqueous phase liquid (LNAPL) sample was collected and analyzed for characterization of the product.

- *Refueling Pit 3* – Four discrete subsurface soil samples, six soil gas samples, two ambient air samples, nine groundwater samples, and two near-shore surface water and sediment samples were collected and analyzed for compounds associated with contamination by petroleum hydrocarbons and volatile organic compounds (VOCs).

- *UST Site No. 4* – Nine discrete surface and three discrete subsurface soil samples were collected and analyzed for compounds associated with petroleum hydrocarbon contamination.

- *Incinerator Building* – No samples were collected from this DU during this RI; see **Section 3.1.5**.

- *Fire Training Area* – Fifteen discrete subsurface soil samples, seven soil gas samples, 17 groundwater samples, and two near-shore surface water and sediment samples were collected and analyzed for compounds associated with contamination by petroleum hydrocarbons and VOCs. One LNAPL sample was collected and analyzed for characterization of the product.

- *Aquatic - North of Pier 8* – Seven incremental multiple sampling (IS) surface sediment samples, one offshore surface water sample, and three discrete tissue samples were collected and analyzed for compounds associated with upland source areas (i.e., petroleum hydrocarbons).

- *Aquatic - Finger Piers* – Seven IS surface sediment samples, three discrete sediment samples from cores, two offshore surface water samples, and three discrete tissue samples were collected and analyzed for compounds associated with upland source areas (i.e., petroleum hydrocarbons and VOCs).

- *Aquatic - Near Landfill* – Seven IS surface sediment samples, one offshore surface water sample, and three discrete tissue samples were collected and analyzed for compounds associated with upland source areas (i.e., petroleum hydrocarbons and VOCs).

These RI activities supplement soil, groundwater, sediment, and tissue data collected during previous investigations (summarized in **Section 1.4.3**) and provide new soil, soil gas, ambient air, groundwater, sediment, surface water, and tissue data. The data collected were used as follows:

- Soil data were used to assess and delineate possible source areas and to support the baseline human health risk assessment.

- Soil gas and ambient data were used as the source term in the Johnson and Ettinger (J&E) model for estimating migration of VOCs to indoor air to support human health risk evaluations.

- Groundwater data were used to identify the extent of impacts, to support fate and transport evaluations, to support the baseline HHRA, and to identify remedial alternatives.

- Sediment and surface water data were used to support fate and transport evaluations and to characterize the possible impacts of the "downgradient" environment by possible upland source areas.

- Tissue data were used to support the baseline human health and ecological risk assessments.

1.3 Regulatory Framework

The Department of Defense (DoD) Defense Environmental Restoration Program (DERP) evaluates threats to human health and the environment arising from releases of contamination from hazardous substances and pollutants and accomplishes cleanups at Formerly Used Defense Sites (FUDS). CERCLA and the National Contingency Plan (NCP) apply to most DERP activities in accordance with § 9601-9675 of CERCLA.

Environmental restoration and cleanup at properties within the FUDS program are implemented following specific policy (USACE 2004) that complies with the Department of Defense (DoD) Defense Environmental Restoration Program (DERP) guidance (DoD 2012), CERCLA (42 USC § 9601 *et seq.*, as amended by the 1986 Superfund Amendments and Reauthorization Act, SARA), and other regulatory authorities such as the Resource Conservation and Recovery Act (RCRA Subtitle I requirements of 40 CFR 280 and applicable State requirements).

DoD activities for environmental restoration of FUDS properties follow the CERCLA framework based on DERP authority. Releases of hazardous substances (defined in § 9620 of CERCLA) are addressed within DoD's CERCLA authority. Petroleum, oil, and lubricants (POL) are excluded from the CERCLA definition of hazardous substances, but may constitute pollutants or contaminants, and be addressed as RCRA corrective actions within DERP's Containerized Hazardous, Toxic, and Radioactive Waste Projects (CON/HTRW) response actions. Releases of lead-based paint and asbestos containing may be addressed in certain situations such as during building demolition and debris removal or as an incidental response to cleanup of CERCLA hazardous substances.

DoD implements CERCLA responses that identify and incorporate applicable standards, thereby satisfying its RCRA obligations along with its CERCLA obligations. The substantive provisions of the ODEQ environmental cleanup process per the State's RCRA authority (Oregon Administrative Rules [OAR] 340-122-0205 through 340-122-0360) for petroleum release sites are applicable standards per RCRA, although they are not applicable or relevant and appropriate requirements (ARARs) within a CERCLA decision process.

The Former Tongue Point NAS study area has progressed through the preliminary assessment/site inspection (SI) phase, and an interim removal phase for several of the DU's. The present RI will lead to risk management decisions associated with a feasibility study (FS). Risk management decisions will be based on the site history, previous response actions, and comparisons to chemical and risk based regulatory criteria that are identified in this RI. The FS will identify and evaluate remedial alternatives to achieve risk-based goals, and identify preliminary ARARs to determine compliance with environmental laws.

The USACE (on behalf of DoD) and ODEQ have signed a Department of Defense and State Memorandum of Agreement (DSMOA). The DSMOA program was established to engage state regulators to expedite environmental restoration and environmental compliance at DoD installations, including FUDS. The DSMOA allows the state of Oregon to be reimbursed for DSMOA-eligible services at the Former Tongue Point NAS. ODEQ is providing oversight and consultation with DoD throughout the investigation, evaluation of site risks, and selection of remedial or corrective actions.

1.4 Study Area Background

The following subsections provide an overview of the former land use, transition of property ownership, and current land use of the study area. The regulatory framework, previous investigations, and cleanup actions will be discussed.

1.4.1 Study Area Description

The Former Tongue Point NAS is located on the eastern side of Tongue Point on U.S. Highway 30 in Clatsop County, Oregon, Township 8 North, Range 9 West, Sections 2 and 11, Willamette Meridian (See **Figure 1-3**). Latitude and longitude measured at a benchmark at UST Site No. 1 are: latitude: 46°12′18.79″; longitude: 123°45′41.77″. The study area is within a rural area on the tidelands near the mouth of the Columbia River.

The Former Tongue Point NAS encompasses approximately 840 acres of a peninsula on the south shore of the Columbia River estuary, approximately 3 miles east of Astoria, Oregon. The peninsula was created by hydrofilling Tongue Neck, a tidal isthmus connecting the river shore to a small offshore island. For the purposes of this investigation, the landward boundary of the Study Area (most of the western boundary) is defined by the Portland and Western Railroad (from Mill Creek north to Hanger 3) and Tongue Point Road (from Hanger 3 north to the Boiler House). From the Boiler House north, the western boundary of the Study Area is the Columbia River. The main channel of the Columbia River bounds the Former Tongue Point NAS on the north. Cathlamet Bay bounds the Study Area east of the Finger Piers, and Mill Creek is the southern boundary south of the former landfill. The exception to this definition of the Study Area boundaries is that the Incinerator Building, located just west of the Portland and Western Railroad west of Pier 2, is considered within the Study Area.

Eight reinforced concrete finger piers are situated on the east side of the hydrofilled area on Cathlamet Bay. The piers are approximately 30 to 50 feet wide and 1,100 to 1,500 feet long. They are numbered one through eight from south to north. The piers are spaced approximately 520 feet apart, with the exception of Piers 7 and 8, which are approximately 290 feet apart. The wharf between Piers 6 and 8, constructed of treated wood, is 700 feet long and 25 feet wide. The piers accommodate more than 19,000 linear feet of berthing space (Aosved 1992). In addition to the finger piers, concrete ramps extend into the river about midway between Piers 3 and 4 and on the south side of Pier 7.

Property ownership within and near the Multi-Sites Project study area is illustrated on **Figure 1-1** and listed as follows:

- USFWS, as part of the Lewis and Clark NWR – this property includes the AST Fuel Storage Area.
- U.S. Department of Labor (DOL), Tongue Point Job Corps Center – this property includes UST Site No. 1, a portion of the aquatic area north of the finger piers and off shore of UST Site No. 1, Refueling Pit 3, UST Site No. 4, and the Incinerator Building.
- Washington-North Tongue Point (WNTP), a subdivision of Washington Development Company – this property includes the north and eastern portions of the Fire Training Area.
- ODSL – this property includes the Former Landfill and the aquatic areas east of the Former Landfill and east of the finger piers, the southern and western portion of the Fire Training Area, and the stockpiled dredge materials from Pier 4.

The adjacent property owner is the U.S. Coast Guard buoy depot.

1.4.2 Study Area History

Originally, Tongue Point was a small island in the Columbia River. In January 1921, approximately 395 acres of land, including all tidelands, wharfage, and riparian rights, were deeded from Clatsop County to the United States, which placed the property under the control of the Department of the Navy (Navy). The Navy continued to acquire acreage until the base consisted of approximately 840 acres in 1948. The DoD era activity is considered to coincide with active occupation of shore facilities from 1941 through 1962 as described below.

The property was originally used by the Navy in 1924 as a submarine and destroyer base. Use was limited to the uplands area and some tidelands, but the property was essentially dormant until dredging and filling began in 1939. In 1939, the Navy began converting the base to an NAS for seaplanes. This conversion required additional construction along the waterfront areas of eastern Cathlamet Bay. Between 1939 and 1941, the subtidal lands south of Tongue Point Island were hydraulically filled with sediment from offshore dredging operations. The hydrofilled area extended from Tongue Point Island south nearly to the mouth of Mill Creek and east to the shore of the Columbia River. Thus, Tongue Point became a peninsula. Nearly all of the hydraulically filled area was paved. Hydrofilling enlarged the NAS to approximately 550 acres. After additional property was deeded from Clatsop County to the federal government, the former NAS encompassed approximately 840 acres.

Use by DoD from 1941 through 1946 was as a Naval Seaplane Base. Seaplane hangars, AVGAS refueling systems, and repair and maintenance facilities were constructed on the hydrofilled portion of the NAS. Construction to support naval air operations was completed in 1942 and seaplanes (PBY Catalina) arrived in early 1943.

Concrete ramps were built to allow seaplanes access to the river. A large ordnance storage area was constructed on Tongue Point. To meet the needs of the base population, living quarters, an athletic field, a medical dispensary, a powerhouse, a sewage treatment plant, a fire training area, sludge burn pits, pipelines, tanks, and a waste incinerator were built on the hydrofilled and upland portions of the site. Although refueling of diesel submarines and ships from Pier 8 was reported before 1941, there was no record of UST installation before 1941.

In 1946, naval air operations ceased and the base became a fleet facility for the Columbia River Group of the Pacific Reserve Fleet though 1962. To accommodate the reserve fleet, the river was dredged and eight concrete finger piers were constructed. Activities at the base included handling of electrical transformers, pesticide application, ship deactivation, preservation of deactivated ships, ship overhauls, and reactivation of deactivated ships. Wastes, construction debris, waste fuel, and sandblasting grit generated during the mothballing of these ships were disposed of at the landfill located on the southern end of the property, currently owned by ODSL. Mothballing typically involved the following activities:

- Grinding and stripping of old paint from the hull, superstructure, etc.
- Application of several coats of paint.
- Removal of diesel fuel, bunker oil, and motor oil from engines.
- Application of light protective oil on and inside engines.
- Application of a sealant to outer surfaces.

In January 1962, the Navy deactivated the facility and the property was subsequently transferred to the Government Services Administration (GSA) later that year. At that time, the former NAS occupied 840 acres and consisted of approximately 320 structures. The property boundaries included the Tongue Point Village housing area (also known as Blue Ridge) and Navy Heights, currently referred to as the Emerald Heights housing area.

In 1965, the Tongue Point Village was sold by GSA to a private owner. The remaining property was formally transferred to the DOL in 1971. Subsequent property transfers include acquisition of the southern portion of the former NAS by the ODSL in 1980 (45 acres of the former NAS south of the Job Corps Center property); the transfer of Emerald Heights housing area from DOL to the State of Oregon and subsequently to the County of Clatsop in January 1990; and the transfer of 70 acres that comprise the northern portion of Tongue Point to the USFWS to add to the Lewis and Clark NWR.

Several activities involving the fueling systems were conducted after the DoD property was transferred to the GSA. In the 1970s, the ASTs that were used to store AVGAS at the AST Fuel Storage Area were decommissioned. In late 1988, after Job Corps Center personnel noticed fuel leaking into the Columbia River, RIs of USTs

were initiated by the U.S. Department of the Interior's (DOI's) Bureau of Reclamation (BOR) at eight sites around the Job Corps Center. Based on this initial investigation, on August 22, 1990, UST Site No. 1 was placed on the Federal Agency Hazardous Waste Compliance Docket (Federal Facility Identifier [FFID] No. OR-2161630643).

The USACE began oversight in 1990 under the purview of DERP-FUDS. Under the direction of the USACE, all of the USTs and the entire pipeline were pumped and cleaned in 1990, and UST Site Nos. 1 through 8 were decommissioned in 1992. Tanks and piping connected with these UST sites were used to store and transfer AVGAS, diesel fuel, and gasoline, with limited amounts of Bunker C fuel.

In support of the site inspection phase and the limited remedial investigation for sediment, the USACE installed seven monitoring wells in March through April of 1994 (USACE 1997). These wells were designated the Finger Pier (FP) wells and numbered FP-1 through FP-7 and located along the shoreline between Finger Piers 1 to 6. The objective was to obtain a quantitative indication of possible soil contaminants and of contaminated groundwater migrating from upland of the Finger Piers into the sediments adjacent to the Finger Piers. During the installation of these wells, soil samples were collected and analyzed by EPA method 6000/7000 for Priority Pollutant Metals (10 metals), EPA Method 8080 for PCBs and Pesticides, EPA Method 8260 for Volatile Organics, EPA 8270 for Semi-Volatile Organics, and EPA Method 8015 COE Modification for Identification and Quantification of Petroleum Hydrocarbons. To evaluate groundwater, quarterly groundwater sampling were completed in May, August, and November 1994, and February 1995 at the seven monitoring wells. Chemical analyses of these samples consisted of the same analytical tests as for the above mentioned soil samples. The available analytical results are in **Appendix D-1**.

In April 1994, the ODEQ issued a letter to the USACE stating that no additional characterization work on UST Site Nos. 2, 3, 5, 6, 7, and 8 and Refueling Pit Nos. 1, 2, and 4 through 13 was required and these sites could be closed under Oregon's soil matrix cleanup rules. Additional characterization work has been ongoing since 1994 on UST Site Nos. 1 and 4 and Refueling Pit 3 toward the goal of closing these sites as well. Quarterly monitoring of groundwater for petroleum constituents at UST Site No. 1 began in September 2002. Fourteen rounds of groundwater samples were collected at UST Site 1 through September 2006. An initial soil investigation was conducted at UST Site No. 4 in 2000. Four quarters of groundwater data were collected at Refueling Pit 3 in 2001.

In February 2006, the USACE removed a portion of the fuel pipeline and conducted an SI at the DOL Job Corps Center. Approximately 200 feet of the pipeline was excavated and removed from an area designated for construction of a new cafeteria for the Job Corps Center. A visual inspection showed that the pipe and its coating were intact and in good condition. Soil samples were collected every 20 feet along the length of the pipeline and analyzed for petroleum constituents. Detected concentrations in soil were all less than Oregon soil matrix cleanup levels and were

not indicative of a release of AVGAS. Investigation work focusing on the remaining fuel piping and pipeline has not been undertaken.

1.4.3 Summary of Previous Investigations and Cleanup Actions

This section summarizes earlier investigation and cleanup actions associated with known source areas that are part of the Multi-Sites Project. A list of the primary investigations conducted in the Study Area is included next. Secondary, or minor, investigations are not included in this list, but are summarized in the subsections that follow.

- USACE. 1994a. Draft Land Utilization History, Tongue Point Former Naval Air Station, Astoria. Seattle District. Seattle, Washington.
- USACE. 1994b, 1995, 1996, 1997. Miscellaneous groundwater sampling reports for UST Site 1.
- Woodward Clyde. 1998. Former Tongue Point Naval Air Station, Finger Pier Sediments, Limited Remedial Investigation. Prepared for USACE, Seattle District. July 9, 1998.
- URS Greiner Woodward Clyde. 1999a. Limited Remedial Investigation Phase II Landfill Site, Former Tongue Point Naval Air Station, Astoria, Oregon. Prepared for USACE, Seattle District. March 5, 1999.
- USACE. 1999a. Underground Storage Tank Site #4, Corrective Action Report, Former Tongue Point Naval Air Station, Clatsop County, Oregon. Seattle District. July 1999.
- USACE. 1999b. Refueling Pit #3 Site, Corrective Action Report, Former Tongue Point Naval Air Station, Clatsop County, Oregon. Seattle District. July 1999.
- URS Greiner Woodward Clyde. 2000a. Sediment Report Addendum 4 to Limited Remedial Investigation, Field Data Acquisition and Analysis, Former Tongue Point Naval Air Station, Astoria, Oregon. Prepared for USACE, Seattle District. December 2000.
- URS Greiner Woodward Clyde. 2000b. Engineering Study Report, Underground Storage Tanks Site No. 1, Former Tongue Point Naval Air Station, Astoria, Oregon. Prepared for USACE, Seattle District. May 2000.
- USACE. 2000. Field Report Investigation, Underground Storage Tank Site #1.
- URS Corporation (URS). 2005. *Geophysics Reconnaissance Survey Results, Tongue Point Multi-Sites Project.* Prepared for USACE, Seattle District. February 7, 2006.

1.4.3.1 AST Fuel Storage Area

Originally, the ASTs contained AVGAS to support seaplane-training operations during World War II. The AST Fuel Storage Area is located on the northern portion

of Tongue Point (**Figure 1-2**) at an elevation of approximately 92 feet mean lower low water (MLLW). The storage area is the northernmost DU addressed in this RI. The AST Fuel Storage Area is situated topographically above the rest of the study area. The area is situated on land currently owned by the USFWS and is part of the Tongue Point Eagle Sanctuary, which is heavily forested and largely undeveloped (except for historical military structures).

The preliminary assessment and SI (Weston 1993) reported that four 75,000-gallon ASTs historically occupied the AST Fuel Storage Area and that the tanks were removed in the 1970s. At the time of removal, the structural integrity of the tanks was reportedly good and the tanks still contained some petroleum. Underground piping historically connected the ASTs to UST Site No. 1 through the Fuel Pipeline, which remains in place in the area of the ASTs, beneath the Tongue Point Street housing area, into the area of UST Site No. 1 and beyond (See **Figure 1-2**). The tanks are reported to have been constructed on foundations consisting of concrete rings and sand purposefully soaked with oil to prevent corrosion. The basis for the historical information is a 1992 interview with T. Thompson, former Job Corps Center operations manager (Weston 1993).

During the preliminary assessment and site inspection, a site visit to the AST Fuel Storage Area was made, but no samples were collected in this area and no further investigation was conducted. At the time of the site visit, the four concrete pads were located and appeared to have a sandy cover (Weston 1993).

The USFWS conducted its own investigation of possible soil contamination on the Lewis and Clark NWR that included a portion of the AST Fuel Storage Area. As part of the investigation, soil samples were collected near the pump house and from one of the AST bases and were submitted for analyses for PAHs (Buck and Materna 2007). Although several PAH compounds were detected at concentrations above ODEQ guidelines, the extent of contamination was not delineated.

Further investigations were not conducted in this area until November 2005, when a geophysical survey was conducted in the area (URS 2005). The focus of the geophysical survey was to locate and mark subsurface fuel piping throughout the site; however, some additional observations were made at the AST Fuel Storage Area at the time of the geophysical survey. These observations are as follows:

- A pump house remains at the AST Fuel Storage Area. Pumps are no longer present; however, the pipeline, manifold, and isolation valves are still present. Inside the pump house, the Main Fuel Pipeline protrudes from the ground and branches into four separate pipelines. These four pipelines connect the pump house to the four historical ASTs. One additional pipe is configured as an overhead fill immediately outside the pump house.

- Cut pipe sections were observed at ground surface for three of the four pipes at the former AST locations. Investigation of the ground surface at one of the former AST

locations confirmed that large-diameter concrete foundation rings were used to support the tanks. The diameter of the rings was not directly measured, but they are expected to have a 28-feet diameter based on historical drawings. The ring observed was approximately 2 feet wide by 1 foot thick. The area within the ring appeared to be filled with approximately 1 foot of oily sand, covered with forest detritus and limited vegetation.

The former NAS as-built drawings depicted additional pipelines that connected each of the ASTs. These additional lines do not connect to the pump house and may have functioned as return lines or overflow lines for the ASTs. One set of these additional lines was identified in the field during the geophysical survey.

1.4.3.2 UST Site No. 1

A multitude of activities occurred at UST Site No. 1 spanning more than 16 years, including initial investigative work, tank and contents removal, soil sampling, well installations and groundwater monitoring, soil contaminant delineation, and removal actions. The following paragraphs present a detailed chronological history of the activities related to UST Site No. 1.

Before 1950, all UST Site No. 1 fuel tanks were used for storage of AVGAS for Navy seaplane use. They were converted to diesel fuel storage in 1950 after the aircraft refueling system was deactivated. Former UST Site No. 1 is located in the northeast portion of the Job Corps Center along Cathlamet Bay (see **Figure 1-1**). The site formerly consisted of six 25,000-gallon fuel tanks buried in fill, which consisted primarily of fine-grained sand with minor amounts of silt and clay that was dredged from the Columbia River. The USTs may have been placed partially within the less permeable clay that has been encountered at 8 to 10 feet bgs beneath the sand fill (RZA-AGRA 1992). The USTs were located 7 feet bgs, approximately 1 to 3 feet below the water table, and covered by a concrete slab. The tanks were serviced by two 4-inch pipes and a 1-inch pipe entering the valve pit located approximately 15 feet south of the tanks. In addition, a 6-inch pipe ran from the valve pit to a drain in the seawall along the Columbia River.

In late 1988, after Job Corps Center personnel observed "fuel leaking into the Columbia River" (they most likely observed fuel sheen on water in Cathlamet Bay), preliminary SIs of USTs, including those at UST Site No. 1, were initiated by the DOI's BOR (ODEQ 1994). The investigations involved sampling of UST contents and bulkhead drains, and limited soil sampling. Temporary groundwater monitoring wells were installed in the soil borings. Field screening, as well as laboratory analysis, indicated that the six USTs at Site No. 1 contained a diesel fuel/water mixture. Elevated levels of gasoline and toluene were identified in soil borings. Liquid samples from bulkhead drains indicated the presence of gasoline contamination at the groundwater interface along the seawall. Although there was some question of analytical data integrity because of sampling techniques and excessive sample holding times, the BOR concluded that soil and groundwater were contaminated near UST Site No. 1 and along the abandoned 6-inch AVGAS pipeline running southward.

The BOR recommended pumping out the contents of all USTs and pipelines, and conducting additional investigation to better define the lateral and vertical extent of contamination (BOR 1989). Based on the August 1990 BOR investigation report, UST Site No. 1 was placed on the Federal Agency Hazardous Waste Compliance Docket (FFID No. OR-2161630643).

The USACE began oversight in 1990 under purview of the DERP-FUDS. Under the direction of the USACE, the contents of all six UST Site No. 1 tanks and associated piping were removed by Northwest EnviroService (NES) in August 1990. At this time, the tanks themselves were not removed. As before, analysis indicated the presence of diesel (diesels No. 1 and 2) mixed with water (Weston 1993).

In 1991, the USACE drilled and sampled five soil borings, and groundwater monitoring wells MW-01 through MW-05 were installed as part of a UST decommissioning investigation for the entire former Tongue Point NAS. Analyses of soil samples indicated oil and diesel contamination and groundwater samples indicated the presence of diesel (RZA-AGRA 1992).

Decommissioning of all six tanks at UST Site No. 1 was performed in April 1992 under the direction of the USACE (Pegasus Environmental Management Services, Inc. [Pegasus] 1992). The four easternmost tanks (Tanks 1 through 4) were over-excavated and removed. The two westernmost tanks (Tanks 5 and 6) were filled with concrete slurry and decommissioned in place because of their close proximity to a Job Corps Center building and concrete-covered patio area. LNAPL was reportedly observed throughout the excavation upon removal of the tanks and was skimmed from the surface and removed. Monitoring wells MW-02 and MW-03 were abandoned during the tank removal because they were within the excavation footprint. A total of 1,302 cubic yards of contaminated soil adjacent to and beneath Tanks 1 through 4 were removed as part of the decommissioning task. Three 18-inch diameter product recovery wells (EW-01 through EW-03) were installed for possible future groundwater/LNAPL recovery and the excavation was backfilled with clean fill.

A series of quarterly rounds of groundwater monitoring began in December 1993 to determine how UST Site No. 1 tanks, associated piping removal, and contaminated soil and LNAPL removal had affected local groundwater contaminant concentrations. Groundwater samples were collected from six wells (EW-01, EW-02, EW-03, MW-01, MW-04, and MW-05) and analyzed for total recoverable petroleum hydrocarbons (TRPH), PAHs, and VOCs. Low concentrations of xylenes or PAHs or both were detected in at least one sample; however, no analytes were detected at concentrations greater than 1993 ODEQ groundwater cleanup levels (URS Greiner Woodward Clyde 2000b). Based on results from the initial groundwater sampling rounds and no observed LNAPL in the recovery wells, the three recovery wells (EW-1 through EW-3) were abandoned in March 1994. Two new wells (MW-06 and MW-07) were installed downgradient (east) of the UST excavation footprint. Petroleum-contaminated soils were found during installation of these two wells and petroleum-contaminated groundwater was encountered during well development.

Subsequent quarterly monitoring continued until July 1997, using various combinations of wells MW-01, MW-04, MW-05, MW-06, and MW-07. Samples were analyzed for TRPH, TPH-G, TPH-D, and PAHs. In general, results for samples collected from wells upgradient of the USTs (MW-01 and MW-05) showed no impact or low levels of petroleum hydrocarbons. These wells were not sampled in all monitoring rounds. The last sample collected from well MW-04, located downgradient of Tanks 5 and 6, showed TPH-D and heavy oil-range petroleum hydrocarbon contamination. MW-04 was subsequently abandoned in May 1994 because the well was physically damaged and bentonite contamination was reported.

Results of samples from downgradient wells MW-06 and MW-07 showed varying concentrations of TPHs in all monitoring rounds, including the first round in May 1994. Low concentrations of TPH-G (C10 to C12) were detected in groundwater samples from both wells, along with higher concentrations of TPH-D. A review of the available chromatograms from the TPH-D and TPH-G analyses suggested that the gasoline range contamination does not show a gasoline pattern. These hydrocarbons were interpreted to be the lighter end of a diesel fuel signature (URS Greiner Woodward Clyde 2000b).

During 1994 to 1997 groundwater monitoring, field personnel detected varying amounts of free product when sampling MW-06 and MW-07. Well MW-07 was reported as having LNAPL ranging from none to a light sheen, and MW-06 was found to have LNAPL ranging from a noticeable sheen to up to 10 inches of product (USACE 1994b, 1995, 1996, 1997).

In March 1998, the USFWS collected shoreline sediment samples east of UST Site No. 1 in Cathlamet Bay. At low tide, two surface grab samples were collected for the analysis of PAHs and other organic compounds. One sample was collected from the upper shoreline among riprap, and another was collected from the lower shoreline on the tidal mudflat. Analytical results indicated low PAH values; 469 micrograms per kilogram (µg/kg) and 113 µg/kg for the riprap and mudflat samples, respectively (Buck 1999). As part of a limited RI (LRI) of former Tongue Point NAS Finger Pier sediments (Woodward Clyde 1998), sampling and chemical analysis were performed for sediments from 20 background locations within Cathlamet Bay, including locations off shore east of UST Site No. 1 near Pier 8. Five of the 20 samples had detectable PAH concentrations, ranging from 52 to 348 µg/kg (Woodward Clyde 1998).

In May 1999, the USACE conducted a direct-push soil investigation at UST Site No. 1 to better characterize the vertical and horizontal extent of diesel-containing LNAPL contamination and to characterize the geology and hydrostratigraphy of this site. The investigation concluded LNAPL was present in limited to low-permeability fill above the alluvium, generally no deeper than 20 feet bgs. LNAPL was observed to be constrained to an area north of First Street and east of the Job Corps Center buildings, and possibly by basalt bedrock on the northeast boundary of the study area. Based on LNAPL presence and the heterogeneous but consistently low-permeability nature of

the soils in which it was found, the LNAPL was concluded to occur in isolated and nonmobile pockets. Extraction methods were determined to be an ineffective remediation tool for LNAPL recovery. A recommendation was made to investigate the cost and feasibility of excavating the remaining LNAPL-containing soil to the extent practicable (USACE 2000).

The USACE performed an analysis of remedial alternatives in 2000. In situ treatment using bioslurping (combined LNAPL, groundwater, and air extraction, separation, and treatment) was chosen as the preferred remedial alternative for UST Site No. 1 (URS Greiner Woodward Clyde 2000b). The analysis, however, did not consider over-excavation of LNAPL-containing soil as on option, because the building adjacent to UST Site No. 1 was to remain in place and remediation for clean closure was a primary objective.

In July 2001, the USACE conducted a second UST Site No. 1 soil over-excavation encompassing a slightly larger footprint than the original tank and soil removal operation of 1992 (Remtech 2001). This time 1,715 cubic yards of soil was removed from the excavation, including 1,100 cubic yards of contaminated soil. Before backfilling with clean fill, 3,000 pounds of oxygen release compound (ORC) was worked into the saturated soil at the base of the excavation (about 12 feet bgs) to accelerate in situ biodegradation of remaining petroleum contamination. The expected effective lifespan of the ORC at UST Site No. 1 was about 1 year. One existing well was decommissioned (MW-07) and three new wells (MW-08, MW-09, and MW-10) were installed within the excavation footprint to monitor the progress of the biodegradation. To facilitate the ongoing groundwater monitoring activities, polyvinyl chloride (PVC) bladder pumps with Teflon® bladders and Teflon®-lined tubing were dedicated to monitoring wells MW-05, MW-08, MW-09, and MW-10. Teflon-lined 1/4–inch polyethylene tubing was dedicated to monitoring well MW-06 to permit sample collection using a peristaltic pump, since a bladder pump would be fouled by the significant free product seen in this well.

Quarterly groundwater monitoring of wells MW-05, MW-06, MW-08, MW-09, and MW-10 was conducted from December 2002 to September 2006. Water level measurements were recorded during this same period at these wells and at MW-01. LNAPL continued to be observed in well MW-06, as well as a sheen observed in MW-08.

A low tide, nighttime shoreline inspection using an ultraviolet (UV) lamp failed to detect LNAPL or petroleum sheen emanating from seeps downgradient of UST Site No. 1 (Marsh 2008). Observations were made by Mr. Loren Garner of ODEQ during November 13 and 14, 2008 (Garner 2008). Approximately 10.1 inches of rain were observed during the first 2 weeks of November. The day before the observed sheen, Astoria, Oregon, received 3.48 inches of precipitation. Extreme winter tides occurred during the observation. On November 13, a high tide of 10.3 feet MLLW at 12:23 p.m. and a low tide of –1.5 feet MLLW at 7:35 p.m. were recorded at the National Oceanic and Atmospheric Administration (NOAA) Tongue Point/Astoria tidal station. A

heavy sheen was observed at 3:00 p.m. and continued for at least 30 minutes. Noticeable petroleum odors were perceived. On November 14 at 3:00 p.m., during a similar tide cycle, a heavier sheen and odor were observed. The sheen was visible for about 50 yards downstream along the shoreline.

1.4.3.3 Refueling Pit No. 3

Refueling Pit 3 is located on the Job Corps Center property approximately 35 feet south of the southeast corner of Hangar 1, as shown on **Figure 1-1**. The hangar is currently used as a recreation/education center and is on the lowland portion of the facility. The area was and still is covered with concrete pavement approximately 12 to 18 inches thick extending to the seawall that is approximately 110 feet to the east. The refueling pit was part of an aircraft fueling system installed in 1941 and operated until 1946. Prior to removal, the pit protruded 6 to 7 inches above the surrounding grade. It was 3.5 feet wide by 9 feet long and contained a fueling hose reel, strainer, meter, associated piping, and a light.

In March 1992, the USACE removed fueling equipment and a portion of a concrete vault from Refueling Pit 3 (Pegasus 1992). Soil samples at the time of the removal revealed the presence of gasoline-contaminated soil approximately 4 feet bgs. After removal of the fueling equipment, the pit was covered with a 12-inch concrete pad. Gasoline contamination in soil was present at 560 mg/kg and xylenes up to 42 mg/kg.

On July 21 and 22, 1997, the USACE conducted push probe sampling at 12 locations to screen soil and groundwater at the subject site and aid in the selection of monitoring well placement. All 12 locations were prepared by cutting an 8-inch diameter concrete core through the 8- to 10-inch-thick pavement overlying the sample locations. One location was abandoned upon encountering an old metal pipe at 1.5 feet bgs. The pipe was confirmed in 2006 by a geophysical survey to be the main fuel oil pipeline. Groundwater was measured at 5.5 feet bgs in most sampling locations, with only minor fluctuation between the two field sampling days. Soil and groundwater samples were collected for analysis of benzene, toluene, ethylbenzene, and total xylenes by EPA Method 8021, TPH-G by Northwest Total Petroleum Hydrocarbon Method-gasoline range organics (NWTPH-Gx), and total lead by EPA Method 7421. The maximum soil contamination measured was 1,160 mg/kg gasoline, 89 mg/kg ethylbenzene, and 12 mg/kg benzene. The maximum water contamination measured was TPH-G up to 67 milligrams per liter (mg/L), benzene up to 9.9 mg/L ethylbenzene up to 7.9 mg/L, and lead up to 5.8 micrograms per liter (µg/L) (USACE 1999b).

In October 1997, the USACE Seattle District project geologist directed the installation of five shallow monitoring wells and the drilling of two exploratory soil borings using a hollow-stem auger drill rig. Strong contaminant odor was detected in drill cuttings and the development water of wells MW-01, MW-02, MW-04, and MW-05, but no free product was observed in the cuttings of any of the wells or soil borings (USACE

1999b). No contaminant odors were detected in the soil or development water of MW-03.

TPH-G was detected in soil at concentrations ranging from 19.5 to 1,070 mg/kg. Lead concentrations ranged from 11.9 to 43.1 mg/kg. The maximum benzene concentration was 9.8 mg/kg in soil. Toluene, ethylbenzene, and xylenes were all below ODEQ soil cleanup criteria.

The first round of groundwater sampling at the Refueling Pit 3 site was conducted by the USACE Seattle District sampling team using portable submersible pumps during November 1997. Samples were collected and analyzed for BTEX by EPA Method 8021, TPH-G by NWTPH-Gx, TPH-D by NWTPH-Dx, and total lead and dissolved lead by EPA Method 7421. TPH-G was quantified up to 4.0 mg/L, TPH-O were quantified up to 0.044 mg/L, and heavy fuel oil-range petroleum hydrocarbons were quantified up to 0.632 mg/L. Concentrations of 150 µg/L benzene, 820 µg/L ethylbenzene, and 4.0 µg/L xylenes were detected in MW-04 and 26 µg/L total lead and 4.0 µg/L dissolved lead were detected in MW-02. Fuel odor (but no free product) was detected in many of the monitoring wells.

The second round of groundwater sampling at the Refueling Pit 3 site was conducted in April 1998. Samples were collected and analyzed for BTEX compounds, TPH-G, TPH-D, methane, total and dissolved lead, nitrate, nitrite, chloride, and sulfate. TPH-G was quantified at 4.8 mg/L and TPH-D was quantified at 1.48 mg/L in MW-04. Monitoring well MW-04 contained the following compounds above analytical reporting limits: 120 µg/L benzene, 780 µg/L ethylbenzene, 9 µg/L xylenes, 34.1 mg/L sulfate, 6.8 mg/L chloride, and 4,400 µg/L methane. Monitoring well MW-02 contained total lead (but no dissolved lead) at a concentration of 5 µg/L. Monitoring well MW-01 contained the following compounds above analytical reporting limits: 11.4 mg/L sulfate, 7.0 mg/L chloride, and 2,900 µg/L methane.

In addition to sampling monitoring wells MW-01 through MW-05, one monitoring well (FP-01) installed during the Finger Pier LRI was sampled because it was downgradient of Refueling Pit 3. Additionally, heavy oil-range petroleum hydrocarbons have been historically detected in this monitoring well (Woodward Clyde 1998). The maximum concentrations detected from FP-01 were TPH-G at 0.58 mg/L, non-purgeable hydrocarbons as gasoline at 4.8 mg/L, heavy fuel oil at 0.632 mg/L, non-purgeable hydrocarbons as diesel at 1.48 mg/L, benzene at 150 µg/L, ethylbenzene at 820 µg/L, and lead at 26 µg/L. This well was abandoned because of bentonite contamination sometime after the April 1998 sampling event. Four quarters of groundwater monitoring was conducted by the USACE at the Refueling Pit 3 DU in 2001.

The most recent groundwater sampling event was completed in October 2007. The following monitoring wells in Refueling Pit 3 were sampled: MW-01, MW-02, MW-03, MW-04, and MW-05. The analytical results, when compared with ODEQ residential risk-based concentrations (RBCs), indicated exceedances for benzene (0.45 µg/L in

MW-04), TCE (1.5 µg/L in MW-03), and vinyl chloride (VC) (0.08 µg/L in MW-02 and 0.13 µg/L in MW-03). Previous analytical results not published by the USACE are included as **Appendix D**.

1.4.3.4 UST Site No. 4

UST Site No. 4 is located on a vegetated hillside (estimated as an approximately 30 percent (%) slope [TMC Environmental 1993]) approximately 120 feet south (measured to the former UST location) of Staff Housing Building L (see **Figure 1-2**) southwest of Hangar 2. Housing is currently used by Job Corps Center employees.

Native soils at UST Site No. 4 have been described as approximately 3.5 feet of red-brown to yellow-brown sandy clay soil overlying thinly bedded, fine-grained siltstone and sandstone bedrock (TMC Environmental 1993). Both an older fill (from UST installation) and a younger fill (placed following UST removal) are present at UST Site No. 4.

Two 25,000-gallon USTs (Tank UST-1 and Tank UST-2) have been documented in this area and reportedly stored AVGAS (Weston 1993). Historical drawings show that up to six additional USTs were planned for this area, but historical records and investigations confirmed that these tanks were never installed. Piping from UST Site No. 4 runs west to a remote fill vault at Tongue Point Road (one 4-inch diameter pipe) and east to the Main Fuel Pipeline beneath the waterfront portion of the subject site (two pipes [one 4-inch diameter and one 6-inch diameter]). In addition to the two USTs, fixtures included a below-ground concrete vault containing a complex assemblage of tanks, pipes, valves, and filters for a hydraulic (water-driven) pump and distribution system (TMC Environmental 1993). These ancillary fixtures are often referred to as the "filter and valve pits" and were located north of the two USTs.

The contents of the USTs and piping were removed in 1990 (Weston 1993). The USTs were subsequently decommissioned in 1992 (TMC Environmental 1993). Approximately 7,430 gallons of a fuel/water mixture and three drums of sludge were removed from the USTs during decommissioning. Piping, valves, and filters inside the valve pits were removed during decommissioning. The tank saddles were removed from the concrete hold-down slab and approximately one third of the northwest corner of the slab itself was removed. The concrete slab was observed to extend south beyond the limits of the excavation.

During decommissioning activities, an exploratory pit was excavated at the eastern edge of the concrete hold-down slab to examine soil types and assess the presence or absence of groundwater. Base course gravel was observed immediately beneath the concrete slab and bedrock was observed 1 to 2 feet below the concrete slab. Groundwater was not observed (TMC Environmental 1993).

Tank UST-1 was rust pitted, but no rust-through or other leakage points were observed. Tank UST-2 had an 8-foot-long crack along an improperly welded seam. Indications of leakage from piping in the filter and valve pit were observed. Soils

containing petroleum hydrocarbons were confirmed and removed during decommissioning. Approximately 930 cubic yards of contaminated soil were removed and disposed of, with maximum TPH concentrations in the disposed soil of 216 mg/kg TPH-G and 237 mg/kg TPH-O. Contaminated soils are known to remain in place below the concrete slab and to the southeast, east, and north of the excavation perimeter. The presence of the concrete slab and unstable hill slopes precluded additional excavation.

Following over-excavation of the accessible contaminated soil, five confirmation soil samples were collected using a hand auger at the base of the perimeter of the excavation. Detectable TPH concentrations in these samples (EPA Method 418.1) ranged from 16 to 45 mg/kg. One of the two soil samples collected from below areas of known leakage observed in the valve pit piping contained TPH at 31 mg/kg. The confirmation samples were not analyzed for TPH-G because early hydrocarbon identification (HCID) analysis results indicated the presence of only TPH-O. HCID results received later indicated the presence of TPH-G as well, and the UST removal report recommended additional investigation that included analysis for TPH-G (TMC Environmental 1993). ODEQ indicated that closure of UST Site No. 4 might be possible if data were obtained that demonstrated a limited extent of remaining petroleum in soil (ODEQ 1994).

Additional investigation of UST Site No. 4 was conducted by USACE in 1997 using a 4-wheel-drive backhoe (USACE 1999a). During this investigation, USACE collected soil samples from nine test pits in and around the UST removal excavation. Samples from within the limits of the UST excavation were collected from the bottom of the test pit, in native material, rather than from backfill material. A 16-foot deep north-south trench was excavated to verify the location of the concrete slab. This investigation found that petroleum hydrocarbons (as TPH-G) remained in the soil at locations southeast of the UST excavation at concentrations ranging from 330 to 1,700 mg/kg. Some seepage was noted in three of the nine test pits but "significant groundwater" was not found (USACE 1999a). Based on this investigation, USACE published a corrective action report that recommended no further action for UST Site No. 4.

In a 1999 response to the corrective action report, ODEQ did not concur with the no further action recommendation for UST Site No. 4 (ODEQ 1999). ODEQ requested additional investigation work to characterize the lateral extent of petroleum hydrocarbons in soil east of the UST excavation. ODEQ requested that groundwater be sampled at the source and downgradient from the UST excavation. Although not discussed by ODEQ, the quality of fill used to backfill the UST was not thoroughly documented in previous studies, leaving the potential for residual petroleum hydrocarbons in surface and subsurface soil in the cavity. In addition, the TPH-G soil concentrations exceed the RBCs for ODEQ residential exposures.

1.4.3.5 Incinerator Building

The Incinerator Building is a small, short-stacked brick structure located in the southern portion of the study area, west of Pier 2 and west of the Portland and Western Railroad tracks (see **Figure 1-2**). The structure has approximate dimensions of 10 feet wide by 25 feet long and is positioned adjacent to the stepp slope in a heavy forested and thick brushy area. Historical maps label the incinerator "Refuse and Garbage Incinerator." The incinerator was constructed by the Navy to burn confidential papers, but it was never used by the Job Corps Center (Weston 1993). This information is based on a 1992 interview with T. Thompson, former Job Corps Center operations manager. A later USACE document reports that the incinerator served as a refuse and garbage burner in which sludge from the drying beds of the local sewage treatment facility may have been burned (USACE 1994a).

To characterize the ash, one residual ash sample was collected from inside the incinerator (Weston 1993). The sample was analyzed for target analyte list (TAL) metals, and the results were interpreted to conclude that the incinerator was not used to burn munitions.

No investigation of the incinerator area had been performed since 1993 until the surface soil and ash sampling effort in October 2007. For this sampling activity, one ash sample was collected from inside the chimney and several surface soil samples were collected in a grid pattern around the incinerator structure. The sampling was accomplished to look for near-field evidence of contamination including ash and stack deposition. The direction of the wind was not of concern given the confining nature of the forest and adjacent slope. The unvalidated analytical results of the ash sample indicated the presence of various PAHs, PCBs, and dioxin/furan compounds. In addition, 4-nitrotoluene and various metals were detected. These analytical results were used as the basis for selecting the suite of chemicals for analyses of the surface soil samples. Five soil IS were analyzed for metals, semi-volatile organic compounds (SVOCs), PAHs, PCBs, and dioxins and furans. Soil and ash analytical results are discussed in more detail in **Sections 3** and **4**.

1.4.3.6 Fire Training Area

A review of historical documents determined the Fire Training Area DU was formerly used for fire training exercises and was a public works storage yard (USACE 1994a). The former public works storage yard had warehouse buildings a railroad spur. The former fire training structures were located northeast of the storage area and included two steel oil-storage tanks and one steel tank specifically used for fire training. Records show the fire training structures were built in 1947. Details of the previous investigations follow.

The USACE Seattle District installed seven monitoring wells (FP-1 through FP-7) along the eastern shoreline near Finger Piers 1 through 6 (USACE 1997). The wells were installed in 1994 and sampled in 1994 and 1995 to monitor groundwater in support of the Finger Piers Sediment LRI (Woodward Clyde 1998). As related to the Fire Training Area DU, the wells FP-5, FP-6, and FP-7 are located near piers 1 and 2

(see **Figure 1-4**) and are discussed for background information. Groundwater samples from FP-5, FP-6, and FP-7 were collected four times; in May, August, November 1994, and February 1995 and analyzed for VOCs, TPH, chlorinated pesticides/PCBs, and metals (Woodward Clyde 1998). The soil sample collected during well installation of FP-6 in March 1994 had vinyl chloride at 16 µg/kg. When FP-6 was first sampled in May 1994, vinyl chloride was detected at a concentration of 53 µg/L. The maximum vinyl chloride concentration in FP-6 was 56 µg/L in August 1994. Groundwater samples from wells FP-5 that is 500 feet north and FP-7 that is 500 feet south of FP-6, were nondetect for vinyl chloride. Vinyl chloride concentrations in the four groundwater samples from well FP-6 ranged from 41 to 56 µg/L. The compound cis-1,2-dichloroethene (cis-1,2-DCE) was detected in a groundwater sample from well FP-6 at a maximum of 0.8 µg/L during the November 1994 sampling event.

During the 1995 Phase II Landfill Site LRI, groundwater screening samples were collected and analyzed by a mobile laboratory for target VOCs to determine the location of new monitoring wells (URS Greiner Woodward Clyde 1999a). As part of this screening, thirty-three HydroPunch® borings were completed at the Former Public Works Storage Yard, which is now the Fire Training Area DU and near the northern boundary of the former Landfill (See **Figure 1-4**). In addition to the planned target VOCs (1,1-dichloroethene [DCE], cis-1,2-DCE, trans-1,2-DCE, TCE, PCE, and VC), the screening samples were analyzed for methane as an indicator of landfill gases. Dissolved methane may also be an indicator of active biodegradation. Vinyl chloride was the most commonly detected VOC, with a maximum detection (36 µg/L) in sample HGW-1 at the northeast corner of the former Fire Training Area. Other detections of vinyl chloride were southwest and southeast of sample HGW-1. Results were nondetect for all analyzed VOCs, including vinyl chloride, in groundwater samples collected from the southern and western portions of the Fire Training Area DU (see Figure 1-4). These data showed that the source area of vinyl chloride and distribution of vinyl chloride in groundwater was constrained within the northern and eastern portion of the Fire Training Area DU.

The results of the groundwater screening samples led to the installation of five wells in what is now the Fire Training Area DU: MW-18S, MW-18D, MW-19, MW-21, and MW-22. Monitoring well pair MW-18S/MW-18D was installed near the highest detection of vinyl chloride, or likely source area, near sample HGW-1. Monitoring well MW-19 was installed approximately 100 feet southeast of the highest detection of vinyl chloride near sample HGW-30. Monitoring well MW-21 was installed at the western margins of the vinyl chloride groundwater plume near screening sample HGW-5. Monitoring well MW-22 was installed at the southern margins of the vinyl chloride groundwater plume south of sample HGW-7.

During installation of these wells, two soil samples were collected from each boring; one at a shallow depth and one at the water table. Soil samples were analyzed for VOCs, SVOCs, TPH-G, TPH-D, PCBs, chlorinated pesticides, herbicides, and metals. Samples collected from the water table depths had the highest detections of VC. One

shallow sample (5 ft bgs.) collected from soil boring MW-19 had 11 petroleum-related VOCs detected at concentrations up to 7,600 µg/kg (1,2,4-trimethylbenzene). Vinyl chloride was detected in the soil samples collected from the water table at concentrations up to 34 µg/kg (MW-22). The shallow soil sample collected from soil boring MW-19 had higher concentrations of SVOCs than the deeper water table sample. SVOCs were detected in all of the soil boring samples with the most commonly detected being bis(2-ethylhexyl)phthalate and perylene. No pesticides or herbicides were detected in the soil boring samples. Aroclor 1254 was detected in four samples collected at the water table at concentrations ranging from 24 µg/kg (MW-21) to 100 µg/kg (MW-18S and MW-22). TPH was detected in every soil sample collected from the soil borings. The highest concentrations were observed in the shallow and water table samples from soil boring MW-19 at depths of 5 feet and 15 feet bgs. The petroleum in the soil samples from MW-19 was identified as partially weathered or non-weathered diesel fuel and lubricant/hydraulic/dielectric/pump fluid/motor oil-range hydrocarbons (URS Greiner Woodward Clyde 1999a).

Wells MW-17, MW-18S, MW-18D, MW-19, MW-21, and MW-22 (installed in 1995 as part of the LRI of the Former Landfill) and FP-6 were sampled for VOCs in multiple sampling events in 1995 and 1996. Vinyl chloride was identified in five of the six wells and again in FP-6. Only MW-21 was nondetect for vinyl chloride. The highest concentrations were found in MW-18D at between 26 and 67 µg/L. In the three groundwater samples from FP-6 collected from November 1995 to May 1996, the vinyl chloride concentration decreased to range between 25 and 30 µg/L from the maximum of 56 µg/L in the August 1994 sampling event. Maximum vinyl chloride concentrations in the other wells were 0.5 µg/L (MW-17), 2.1 µg/L (MW-18S), 13 µg/L (MW-19), and 17 µg/L (MW-22). The two highest concentrations of cis-1,2-DCE were detected in MW-22 at concentrations of 28 and 42 µg/L in February and August 1996. All other reported concentrations of this compound were at least one order of magnitude lower. The condition of wells FP-05, FP-06, and FP-07 could not be observed during the 2008 field activities, but are reported to have been abandoned. Wells MW-18S, MW-21, and MW-22 are not readily accessible because of placement of a dredged materials stockpile in 2001. The horizontal position of existing wells was surveyed in December 2005 in conjunction with the geophysics work performed along the pipeline layout. The top casing elevation was surveyed at MW-18D and MW-19.

Groundwater sampling was completed on October 26, 2007, for Fire Training Area wells MW-17 and MW-18D. The analytical results, when compared with ODEQ residential RBCs, indicated exceedances for benzene (1.2 µg/L in MW-18D) and vinyl chloride (0.61 µg/L in MW-18D). Well MW-19 was not sampled in October 2007 because of the presence of 0.7 feet of petroleum product as light non-aqueous phase liquid (LNAPL).

During a site visit conducted on 7 May 2008, wells MW-17, MW-18D, MW-19, and MW-22 were located, but wells MW-18S and MW-21 were not found. Further reconnaissance efforts to locate these wells were made during the field investigation

after equipment was used to clear brush and allow better access. See **Sections 3.3.2.2** and **3.3.6.2**.

Although much of the shoreline was inaccessible, an effort to find seeps in accessible areas was made. No seeps were observed.

1.4.3.7 Aquatic Areas Surrounding Finger Piers

Consolidated Automotive Research Services, Inc. (CARS), a tenant on the ODSL-owned portion of the site, initiated plans to develop the wharf and Piers 4 and 5 for automobile importing in 1990 (ODEQ 1998d). CARS submitted a permit to dredge 920,000 cubic yards of material on both sides of Piers 4 and 5. Sediment sampling and analyses, as part of the permit process taken, were summarized by CARS, although no actual laboratory reports or data were provided (Woodward Clyde 1998). Eighteen 20-foot samples were taken from the areas surrounding Piers 4 and 5. Samples were composited by 5-foot depth intervals and by core location. Samples were analyzed for metals, VOCs, SVOCs, PCBs, and pesticides. The highest concentration of analytes was detected at a depth of 4 to 8 feet. The highest metal and SVOC detections were found in the composite sample from the east end of Pier 4 (Woodward Clyde 1998).

Cresmont Capital Products (Cresmont), a tenant of the WNTP, received a permit to dredge 650,000 cubic yards from the finger piers area surrounding Piers 4 and 5 in February 1998 from the USACE. Because of difficulties in obtaining an ODEQ Section 401 Water Quality Certificate, the dredge area was revised to include approximately 40,000 cubic yards from around Pier 4. Cresmont completed this phase of dredging in March 2001. The dredge spoils were temporarily stored on the WNTP facility. Three composite samples of the dredge spoils were collected and analyzed in preparation for relocating the dredge spoils to an upland location (the Fire Training Area) by Peratrovich, Nottingham and Drage, Inc. (PND). Two composite samples were taken from areas within the pile that generally represented dredge spoils from the north and south sides of the pier. Sample SS2 represents the north side, and sample SS1 is from the south side of the pier. PND noted that dredged area on the north side of Pier 4 is equivalent to the sample locations FCF18 and FCF20, and FCF16 represents the area dredged on the south side (samples collected in May 1995 and results reported in the Finger Pier Sediment LRI, Woodward-Clyde 1998). The third composite sample (SS3) consisted of three grab samples taken from the area of concern portion of the stockpile (equivalent to sample FCF16), and then composited on site. All three samples were analyzed for priority pollutant metals, PCBs, pesticides, SVOCs, PAHs, tributyltin (TBT), and total organic carbon (TOC). Analytical results were compared to the screening levels (SL) identified in *Dredged Material Evaluation Framework, Lower Columbia River Management Area* (USACE 2009). The analytical results for all samples were below the screening level value (SLV) for all parameters except the combined value of 4,4′-DDT, 4,4′-dichlorodiphenyldichloroethylene (DDE), and 4,4′-dichlorodiphenyldichloroethane (DDD) in SS1, which was slightly above the SLV. Analytical results for total DDx at location SS1 was 8.1 µg/kg and exceed the SLV of 6.9 µg/kg. The sample from the area of concern (SS3), and on the south side of Pier 4, was below the SL. PND concluded that the findings of this sampling event indicated

that the dredge spoils were suitable for the planned unconfined upland disposal (PND 2001).

In May 1995, sediment core samples and grab samples were collected a part of the LRI focusing on sediments in the finger pier area (Woodward-Clyde 1998). This investigation involved sampling and chemical analysis of sediment samples from background locale and locations surrounding the finger piers (see **Figure 1-5**). All sediment samples were analyzed for SVOCs, chlorinated pesticides/PCBs, metals, petroleum hydrocarbons, TOC, grain size distribution, and interstitial salinity. Surface sediment samples were analyzed for VOCs and TBT.

Twenty surface samples, taken from the upper 10 centimeters (cm) of sediment, were collected throughout Cathlamet Bay. These 20 surface sediment samples were collected upriver of the finger piers and were used to characterize background sediment chemistry for this investigation. Surface sediment samples and sediment cores were collected at 32 locations in and around the Tongue Point finger piers area. Surface samples were collected because groundwater was identified as a possible pathway for transport of contaminants from DoD-related activities on the upland portion of the study area to the sediments near the finger piers. The LRI included surface sediment sampling in order to obtain information relevant to the release of contaminants from the sediments to environmental receptors. The 0-10 cm interval was selected for sampling because it is commonly considered the biologically active zone of the sediment profile.

Seventy-five composite samples and nine discretionary samples were collected from the sediment cores. The cores were divided into two or three composite core samples, with each interval representing a period of land ownership occupation. This proportional sampling scheme was based on bathymetric surveys conducted in 1956 and 1994. These surveys demonstrated that annual sediment accumulation rates had been relatively consistent. An ash layer, assumed to be from the 1980 Mt. St. Helens eruption, was used as a chronostratigraphic indicator. Historical land ownership was divided into three periods: DoD (1947–1962), Job Corps/GSA tenants (1962–1980), and Job Corps/OSDL tenants (1980–1998). The lower third of the sediment core represented the sediments that accumulated during DoD's use of the finger piers as the Tongue Point NAS. The middle third represented the Job Corps/GSA period and the upper third represented the Job Corps/OSDL period of occupation.

Twenty-nine of the sediment cores showed two distinct sediment horizons: an upper, dark black or gray-black, organic-rich silt and a lower horizon of gray, fine- to medium-grain sand with alternating layers of silt. The finer-grained silt horizon appears to have been deposited after the area was dredged for infilling of Tongue Neck in 1947. The coarser-grained sand layer was present before dredging. In core FCF16, sand blast grit was observed within the silt horizon.

Because sediment quality standards had not been established by ODEQ (Woodward-Clyde, 1998), the Marine Sediment Quality Standards established by the Washington

Department of Ecology in Washington Administrative Code (WAC) 173-204-320 were used. The metals in the finger piers sediment samples that exceeded the background sediment concentrations were sodium, silver, and mercury. Metals did not exceed the marine sediment screening criteria. High molecular weight PAH (HPAHs) frequently exceeded their respective background threshold values. One low molecular weight PAH (LPAH), phenanthrene, was detected in all of the surface samples. Heavily weathered TPH-D and TPH-O were detected in most of the surface samples. Four pesticides (4,4'-DDD, 4,4'-DDE, 4,4'-DDT, and hexachlorobenzene) were detected in four surface samples, and PCBs were not detected. Three VOCs were detected in the surface samples at concentrations less than 12 µg/L. The most prevalent VOC was 1,1-dichloroethane (DCA), which was detected in five samples. TBT was not commercially available at the time of DoD's use of the Tongue Point site, so any TBT found in sediments in this DU must be attributed to post-DoD activities. TBT was detected in all 32 surface grab samples.

Metal exceedances were more frequent in the lower third of the cores than in the upper two-thirds. Mercury and zinc exceedances were seen in six of the lower third cores. LPAH maximum concentrations occurred at cores FCF16, FCF24, and FCF25. HPAH maximum concentrations were focused near shore near Piers 6 and 7, and near Pier 1. All of the maximums were observed in the middle of the three layers. Most samples from both the upper and lower intervals contained TPH-D and TPH-O at concentrations exceeding background threshold values. The average concentration of TPH-D was significantly higher in samples from the lower third of each core than from the upper two-thirds. TPH-D concentrations were higher near shore. 4,4'-DDD and 4,4'-DDE were detected in half of the core samples. Two PCBs, Aroclor 1254 and 1248, were detected. Seven VOCs were detected in the upper two-thirds of the cores. Each VOC was detected in one sample only. TBT was detected in nine composite samples collected from the upper two-thirds of the sediment cores.

The following observations and conclusions from the LRI (Woodward Clyde 1998) investigation are summarized:

- The upper one-third of the sediment cores had lower concentrations of chemical compounds than the middle and lower thirds. Concentrations of inorganics and SVOCs were less than the sediment screening criteria, and TPHD exceeded the background threshold value. Analytical results of samples in the 0- to 10 centimeter portion had the lowest concentrations and represent the biologically active zone where potential exposure to ecological receptors could occur. Overall, the data for the upper one-third of the sediment cores showed no threat to human health or the environment and no evidence of impacts from DoD era activity.

- Variability in sedimentation rates over time could account for the similarity between the middle and lower third concentrations. If sedimentation rates were greater during the DoD era, then the relatively higher concentrations in the middle and lower thirds compared to the upper third might be mostly attributed to DoD activities. Based on the average sedimentation rates after 1980 for individual cores, determined from the Mount St. Helen's ash depth, 22 of the 29 cores with ash layers experienced higher

average sedimentation rates before 1980 than after the Mount St. Helens eruption. The maximum pre-1980 sedimentation rate was calculated to be 4.2 inches per year at FCF30. As described in **Section 2.4.4**, it is unlikely that a more accurate representation of the DoD-era sediments based on the ash layer would result in significant changes to the analytical or statistical results.

- The lower one-third of the sediment cores collected during the LRI corresponded to the approximate period of DoD activities at Tongue Point. Samples collected from this lower interval often exceeded the background threshold values for metals, PAHs, and TPH-D, but only a few samples had exceedances of sediment screening criteria for mercury, zinc, and bis(2-ethylhexyl)phthalate.

- Chemical concentrations in the middle third of sediment cores were similar to chemical concentrations in the lower third of sediment cores. Review of the chemical data for samples collected from the sediments overlying the DoD-era sediments (i.e., the middle third samples collected from 11 cores) suggests that DoD activities may not have been the sole source for the chemicals found in the lower third of the sediments. Hydrofilling and finger pier construction may have created a depositional environment for fine-grained materials from localities upstream of the Columbia River. This depositional environment could have persisted after DoD activities ceased, allowing fine-grained sediments with elevated chemical concentrations to accumulate from upriver.

- An alternative explanation for the similar chemical concentrations in the lower and middle thirds of the sediment cores collected at Tongue Point is that both DoD and post-DoD activities had similar annual loading rates for the observed constituents. This explanation is not as well supported by the limited available information on site history, which indicates that the scale of the water-based activities during the 1962–1980 period was lower than during the DoD era. It is possible that land-based sources increased after DoD left the site, contributing to the observed concentrations in the post DoD-era sediments.

1.4.3.8 Aquatic Area Off Shore of Former Tongue Point Landfill

The Tongue Point Navigation Improvements Project (TPNIP) involved dredging the navigation channel and the turning basin adjacent to the Tongue Point Finger Piers (Siipola et al. 1993). Before the dredging, sediment core samples were collected and analyzed to evaluate the suitability of the dredged material for ocean disposal (Siipola et al. 1993). Twenty-five sediment samples were collected in 1988 from five stations in the navigation channel east of the finger piers. The cores were combined into two composite samples and analyzed for 65 PAHs, 19 pesticides, five PCBs, eight metals, TPH, and TOC. Total PAH concentrations were 1,013 mg/kg and 1,059 mg/kg for the two composite samples. No PCB Aroclors were detected. PCB detection limits were, however, four times higher than the detection limits specified for the Tongue Point Finger Piers LRI. The pesticide DDD was estimated at 1.9 to 2.4 µg/kg in the two composite samples (Siipola et al. 1993). Cadmium, lead, and zinc were reported at concentrations greater than ODEQ background values of soil and sediment (ODEQ

2002). The maximum concentration of oil and grease was 57.6 mg/kg and the maximum concentration of petroleum hydrocarbons was 23 mg/kg.

Four solid-phase bioassays tests were performed. Only one static bioassay test showed statistically significant differences in survival between control samples and Tongue Point composite sediment samples. Chemicals were selected for the evaluation based on their bioaccumulation properties and the magnitude of their detected concentrations. A significant enhancement of 4,4′-DDD was observed in clam tissues at an average concentration of 8.0 µg/kg. The U.S. Food and Drug Administration's allowable limit for 4,4′-DDD is 5,000 µg/kg. No other chemicals were bioaccumulated (Siipola et al. 1993). The dredged area and the offshore disposal site were monitored after dredging. The USACE concluded that the Tongue Point dredging and disposal caused no significant contamination, toxicity, or bioaccumulation impacts at either Tongue Point or the disposal site (Siipola et al. 1993). Within two weeks after completion of dredging, surface sediment samples were collected in Cathlamet Bay, adjacent to the finger piers, and upstream from the dredging site. These samples were analyzed for grain size, metals, PAHs, PCBs, pesticides, and TOC. PAHs or PCBs were not detected. The pesticide 4,4′-DDD was detected at a concentration of 3.0 µg/kg at one location.

In August 1990, another round of post-dredging samples was collected from six locations in Cathlamet Bay during the CARS investigation mentioned previously for the Finger Piers area (summarized in the 1998 Woodward-Clyde report). The surface sediment samples were analyzed for grain size, metals, PAHs, pesticides, PCBs, and TOC. PCBs were not detected above the analytical reporting limit. The pesticides Lindane and methoxychlor were detected in one sample at 3.4 µg/kg and 4.7 µg/kg, respectively. The detection limits for PAHs were significantly lower than those for PAHs in surface sediments collected at the same sampling locations in 1989. Although PAHs were detected at these lower detection limits, the concentrations did not exceed the detection limits of the 1989 sampling event.

In 1992, the USACE conducted an LRI at the Tongue Point Landfill (Shapiro 1993). The investigation included sediment sampling at eight locations south of Pier 1. The samples were analyzed for VOCs, SVOCs, PCBs, pesticides, and metals. Seven of the samples were collected within 50 feet of the landfill shoreline. The eighth sample was a background sample collected from Cathlamet Bay, approximately 600 feet east of the landfill and 1,000 feet south of Pier 1. Low concentrations of VOCs (acetone and 2-butanone) and SVOCs (phenols, PAHs, phthalate, and benzoic acid) were present in the seven shoreline sediment samples. Only one SVOC, bis(2-ethylhexyl)phthalate, was detected above the reporting limit and background concentration. All other reported SVOC concentrations were estimated below the detection limit (Shapiro 1993). One PCB, Aroclor 1254, and one pesticide, 4,4′-DDD, were detected at concentrations of 3,900 µg/kg and 53 µg/kg, respectively. Most metal detections were elevated above the background station in at least one sediment sample. The greatest exceedances included copper, lead, manganese, mercury, and zinc, which were detected at concentrations approximately 3 to 37 times the background sample

concentrations. Significant concentrations of TPH were detected in sediment samples taken from the margins of the landfill (Shapiro 1993). VOCs, SVOCs, PCBs, and pesticides were not detected in the background sediment sample.

In May of 1997, sediment samples were collected as part of an investigation in the intertidal zone and offshore areas to assess the potential for contaminants migrating from the landfill. The results of this investigation were reported in the LRI of the Landfill Site report (URS Greiner Woodward-Clyde 1999a). Sixty surface sediment samples were taken from the mud flat (near the Mill Creek outlet) and off shore (north of outlet) adjacent to the landfill. Three of the northern near-shore samples (sample ID not designated in report text) exceeded screening criteria for copper and zinc. SVOCs and pesticides were not detected above screening criteria. PCBs were detected in four samples above SLs. Three samples (FGS-142, FGS-152, and FGS-159) had dioxin concentrations that exceeded levels reported in the *Lower Columbia River Study* (LCRS) (TetraTech 1995). Dioxins were detected in four samples collected in the mudflat above the concentrations reported in the LCRS.

Further sampling was conducted in 1999 and reported as an addendum to the Tongue Point LRI, Phase II, Landfill Site (URS Greiner Woodward Clyde 2002a,b). The purpose of the sediment sampling was to delineate the extent of chemicals and to determine the required extent of sediment excavation within the near-shore area as part of the design for an interim action at the Tongue Point Landfill. The near-shore area was defined as the area within the oil-absorbent boom and the area southeast and outside of the boom. Sampling data were intended to delineate the horizontal extent of the contaminated sediment in the near-shore area southeast of the boom and the vertical extent of the contaminated sediment both within the boom and southeast of the boom. This sampling effort was designed to eliminate the need for confirmation sampling during the pending interim action, a planned excavation.

The sediment samples were collected from 19 locations within or adjacent to the existing oil adsorbent boom (99SC01 through 99SC19) and 8 locations southeast of the boom (99SC20 through 99SC27). Among the 162 possible depth-interval samples, 150 sediment samples were recovered. Samples were collected with a hand auger, with borings completed to 6 feet bgs. Each sample was assigned a number consisting of the sample point number (i.e., 99SC01) followed by the depth designator "A" through "F", with A indicative of the interval from 0 to 1 foot bgs.

Samples were analyzed for TPH-D using the NWTPH-Dx method. TPH-D was detected in 33 of 76 analyzed samples, with a maximum concentration of 33,000 mg/kg in sample 99SC20A. The TPH concentrations in the A samples (or ground surface to 1 foot bgs) ranged from nondetect (99SC27A) to 33,000 mg/kg (99SC20A). The TPH concentrations in the B samples ranged from nondetect (in 9 of the 27 sample locations) to 4,800 mg/kg (99SC16B). The TPH concentrations in the C samples ranged from nondetect (in 17 of the 27 sample locations) to 3,600 mg/kg (99SC16C). TPH was detected in five of the six D samples with a maximum of 3,600 mg/kg (99SC16D). TPH was detected in four of the six E samples with a maximum of

2,200 mg/kg (99SC01E). The TPH concentrations in the two F samples, 99SC01F and 99SC16F, were 420 mg/kg and 970 mg/kg, respectively. TPH concentrations generally decreased with increasing depth.

All samples were analyzed for 23 metals. Each metal was detected in one or more of the sediment samples analyzed. Metals concentrations varied widely between sample points, with a wide variance in concentrations of chromium, copper, lead, and mercury. Chromium concentrations ranged from 13.9 mg/kg (99SC20C) to 103 mg/kg (99SC15B); copper concentrations ranged from 7.5 mg/kg (99SC20C) to 2,640 mg/kg (99SC01B). Lead concentrations ranged from nondetect (99SC01B, 99SC01C, 99SC14B, and 99SC15C) to 779 mg/kg (99SC16C) and mercury concentrations ranged from nondetect (99SC20C and 99SC23C) to 3.1 mg/kg (99SC16C). The concentrations of metals decreased with increasing depth.

After completion of the TPH and metals analyses, 35 samples were analyzed for PCB Aroclors, pesticides, and SVOCs. PCBs were detected in 28 of the 35 samples analyzed, with a maximum concentration of 3,050 µg/kg (99SC16B). Aroclors 1260, 1254, and 1248 were the only PCB Aroclors identified. The same samples were analyzed for the pesticides 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT. Pesticides were detected in 27 of the 35 samples analyzed. The pesticide 4,4′-DDD was detected in 24 samples at concentrations ranging from 0.9 µg/kg (99SC21B) to 350 µg/kg (99SC20A) and 4,4′-DDE was detected in 26 samples at concentrations ranging from 0.89 µg/kg (99SC21B and 22C) to 210 µg/kg (99SC19C and 20A). The pesticide 4,4′-DDT was not detected in any of the samples analyzed. At least one SVOC was detected in 31 of the 35 samples analyzed. The most frequently detected SVOCs were pyrene, fluoranthene, and chrysene, occurring in 29, 27, and 25 samples, respectively. At sample points where more than one sample was analyzed, the SVOC concentrations exhibited a decrease with increasing depth, except sample 99SC01D, where the concentrations were higher than those detected in sample 99SC01B.

After completion of the PCBs, pesticides, and SVOCs analyses, 15 samples were selected for analysis of dioxins/furans to obtain sufficient information for the development of a reliable correlation with other contaminant concentrations. Dioxins/furans were detected in all samples analyzed except sample 99SC25B. The only dioxin that has an identified SL is 2,3,7,8-tetrachlorodibenzo-p-dioxin(2,3,7,8-TCDD). Concentrations of 2,3,7,8-TCDD ranged from a J-flagged 0.31 picograms per gram (pg/g) (99SC02B) to 16.8 pg/g (99SC17B).

As part of the non-time-critical removal action for the Tongue Point Landfill, performed from November 2003 to June 2006, soil and sediment were excavated from the eastern edge of the landfill (TN & Associates 2007). Other components of the removal action included installation of a cap, a barrier wall, and a free product recovery system. Maintenance and operation of the landfill remedial systems are ongoing. Reports regarding the status of this remedial action are provided to ODEQ. The operation and function of the TPMS Landfill early action will be documented and

the decision process for the landfill site will proceed parallel with the FS, to permit a combined Record of Decision.

1.5 Report Organization

This RI report summarizes the field activities and the findings of the investigation conducted in support of the Multi-Sites Project, Former Tongue Point NAS. This document presents the human health and ecological risk assessments, the initial identification of potential preliminary ARARs, with a summary and conclusions of findings. This document is divided into the following sections:

Section 1	Introduction
Section 2	Study Area Physical Setting
Section 3	Study Area Investigation
Section 4	Nature and Extent of Contamination
Section 5	Fate and Transport
Section 6	Human Health Risk Assessment
Section 7	Baseline Ecological Risk Assessment
Section 8	Conclusions
Section 9	References

Appendix A, Boring Logs, contains all the boring logs completed for all soil microwells completed during this investigation and contains the sediment coring logs for the sediment Vibracores completed in the Aquatic - Finger Piers DU.

Appendix B, Photographic Log, contains a photographic log of selected photographs that illustrate the various activities completed during the investigation.

Appendix C, Field Sampling Forms, contains copies of all applicable Field Sampling Forms completed during the RI.

Appendix D1, Tabulated analytical results for groundwater from previous USACE investigations that have not been published, and were used to help characterize the Study Area. **Appendix D2**, statistical comparison of selected historic data for surface sediment samples to 2008 RI data.

Appendix E, Tabulated analytical results from this RI presented by decision unit and matrix.

Appendix F, Data Usability Assessment Report.

Appendix G, Technical Memorandum – Sedimentation Rates, presents an evaluation sedimentation rates and sediment depositional patterns. Includes bathymetric maps from 1995 and 2008.

Appendix H, Technical Memorandum – Rising Head Permeability Tests, presents the results of the slug tests performed in the Refueling Pit 3 DU.

Appendix I, Analytical Laboratory Reports, includes all the analytical reports prepared by the contract laboratories.

Appendix J, Data Validation Reports, contains the data validation reports prepared by the independent data validating subcontractor and used in the data usability assessment of **Appendix F**.

Appendix K, Land and Bathymetric Survey Reports, contains the maps and figures prepared by the surveying subcontractor.

Appendix L, Human Health Risk Assessment Evaluations, including the data tables and statistical calculations and Pro UCL outputs.

Appendix M, Ecological Risk Assessment Evaluations, including the data tables for screening and selection of chemicals, and the food web models.

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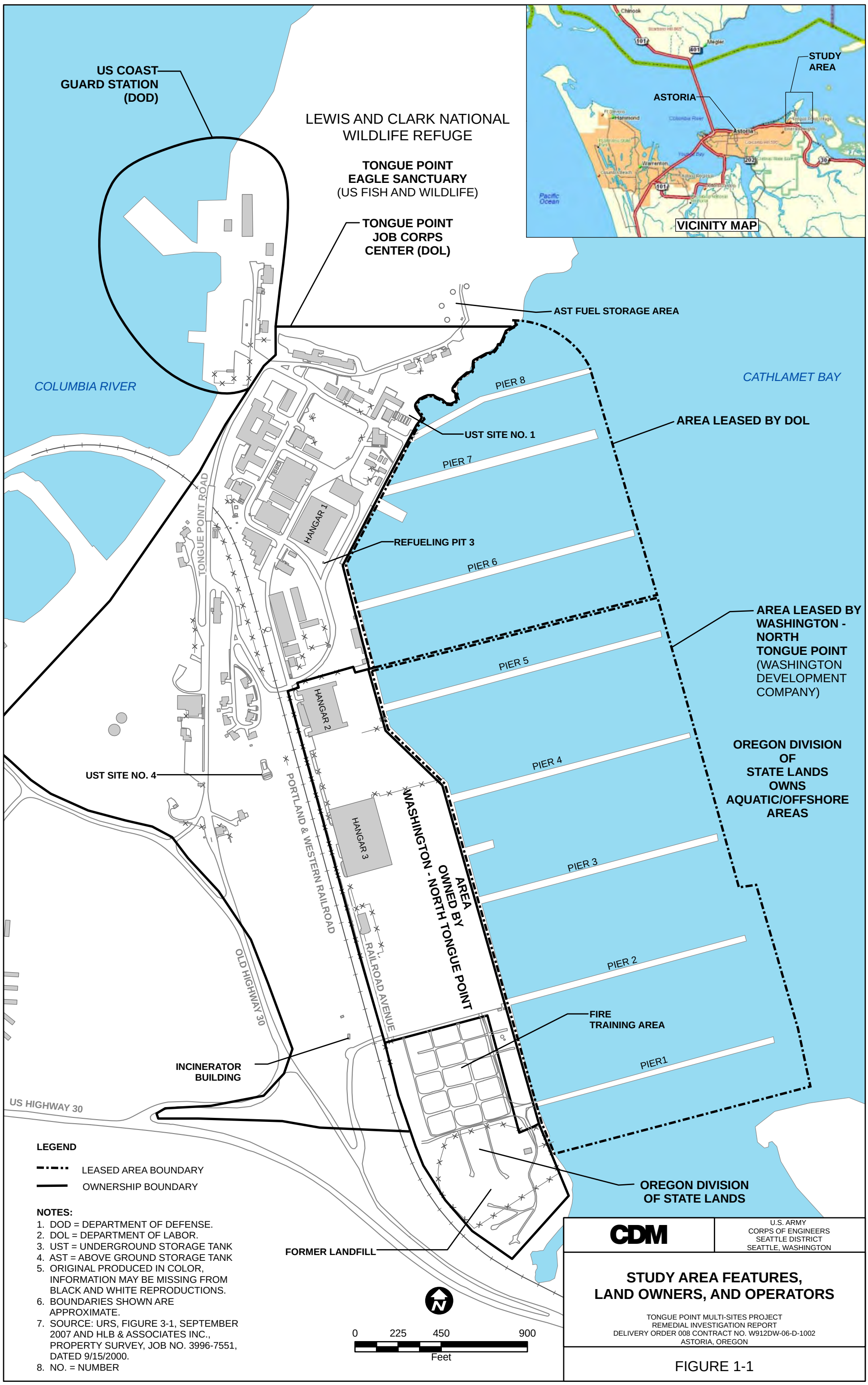
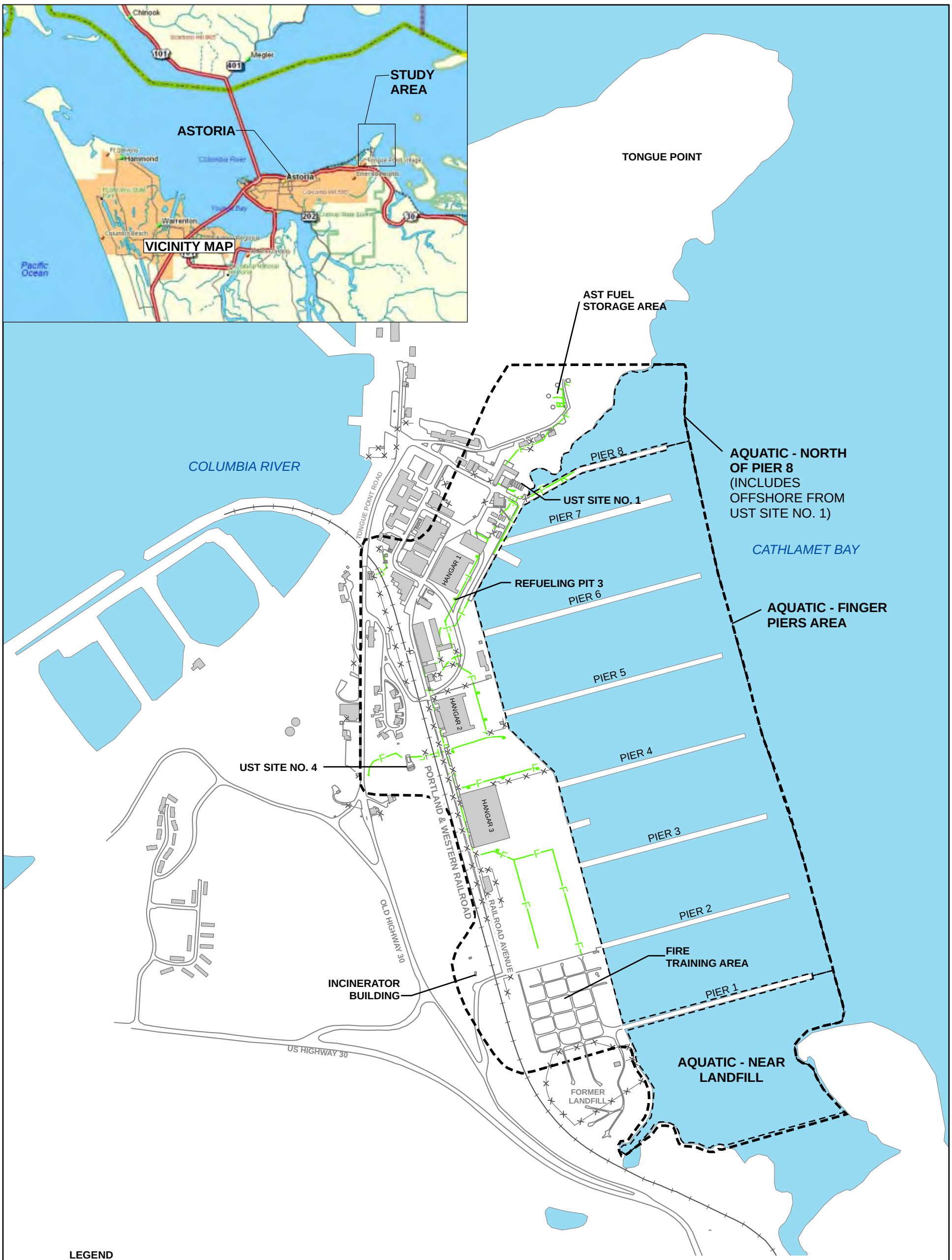

US COAST GUARD STATION (DOD)
LEWIS AND CLARK NATIONAL WILDLIFE REFUGE
TONGUE POINT EAGLE SANCTUARY (US FISH AND WILDLIFE)
TONGUE POINT JOB CORPS CENTER (DOL)
STUDY AREA
ASTORIA
VICINITY MAP
Chinook
Megler
Hammond
Warrenton
Astoria
Pacific Ocean
AST FUEL STORAGE AREA
COLUMBIA RIVER
CATHLAMET BAY
PIER 8
PIER 7
PIER 6
PIER 5
PIER 4
PIER 3
PIER 2
PIER1
UST SITE NO. 1
AREA LEASED BY DOL
HANGAR 1
HANGAR 2
HANGAR 3
REFUELING PIT 3
TONGUE POINT ROAD
AREA LEASED BY WASHINGTON - NORTH TONGUE POINT (WASHINGTON DEVELOPMENT COMPANY)
OREGON DIVISION OF STATE LANDS OWNS AQUATIC/OFFSHORE AREAS
UST SITE NO. 4
PORTLAND & WESTERN RAILROAD
AREA OWNED BY WASHINGTON - NORTH TONGUE POINT
RAILROAD AVENUE
OLD HIGHWAY 30
FIRE TRAINING AREA
INCINERATOR BUILDING
US HIGHWAY 30
OREGON DIVISION OF STATE LANDS
FORMER LANDFILL
LEGEND
LEASED AREA BOUNDARY
OWNERSHIP BOUNDARY
NOTES:
1. DOD = DEPARTMENT OF DEFENSE.
2. DOL = DEPARTMENT OF LABOR.
3. UST = UNDERGROUND STORAGE TANK
4. AST = ABOVE GROUND STORAGE TANK
5. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
6. BOUNDARIES SHOWN ARE APPROXIMATE.
7. SOURCE: URS, FIGURE 3-1, SEPTEMBER 2007 AND HLB & ASSOCIATES INC., PROPERTY SURVEY, JOB NO. 3996-7551, DATED 9/15/2000.
8. NO. = NUMBER
0 225 450 900
Feet
CDM
U.S. ARMY CORPS OF ENGINEERS SEATTLE DISTRICT SEATTLE, WASHINGTON
STUDY AREA FEATURES, LAND OWNERS, AND OPERATORS
TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON
FIGURE 1-1



LEGEND

- APPROXIMATE BOUNDARY OF AQUATIC DECISION UNITS
- APPROXIMATE BOUNDARY OF STUDY AREA
- FENCE
- RAILROAD
- FUEL PIPELINE

NOTES:

1. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
2. BASE MAP FILES FROM URS (FIGURE 1-2) SEPTEMBER 2007.
3. AST = ABOVE GROUND STORAGE TANK.
4. UST = UNDERGROUND STORAGE TANK.
5. US = UNITED STATES
6. NO. = NUMBER

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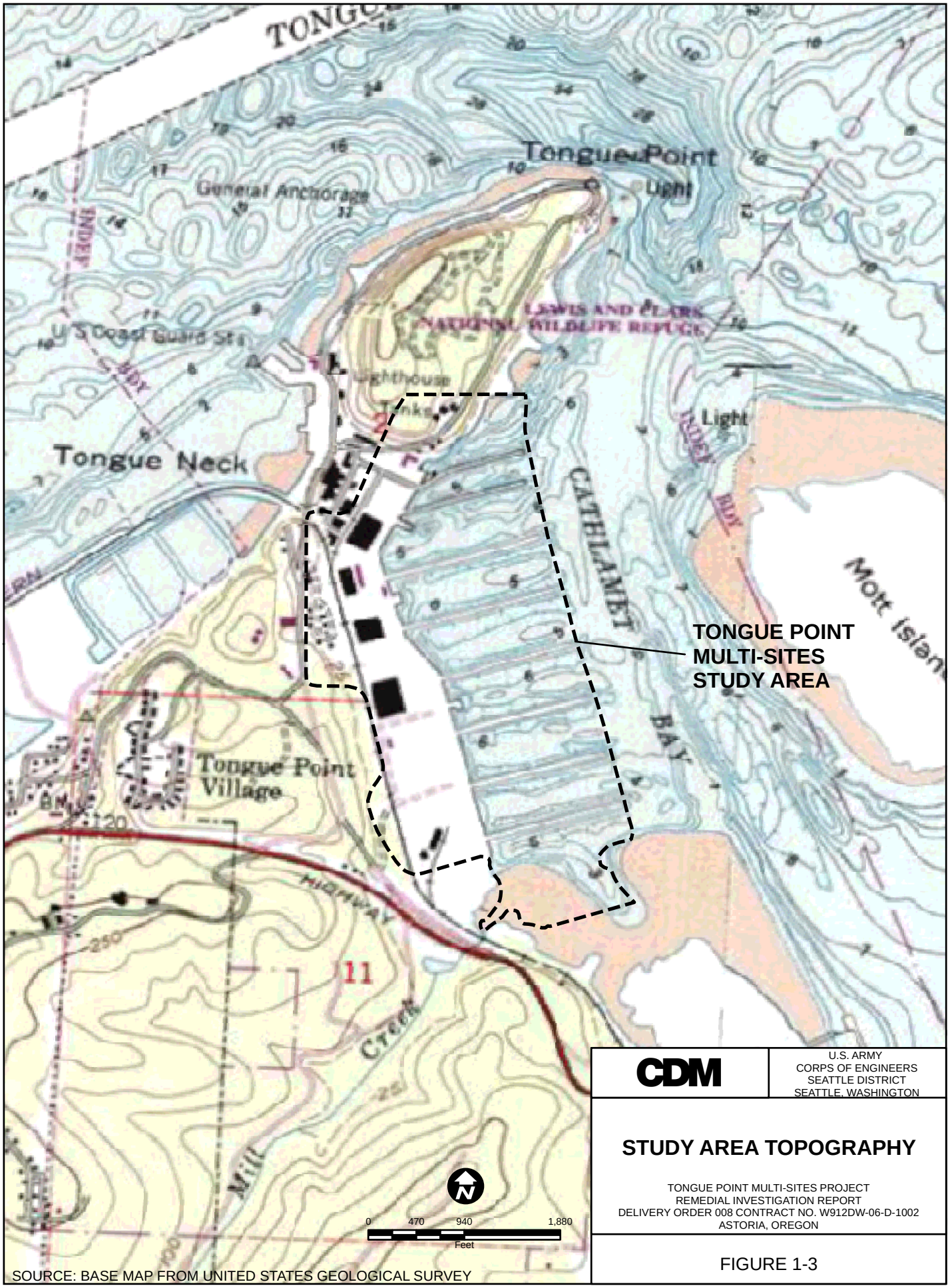
SEATTLE, WASHINGTON

DECISION UNITS WITHIN THE STUDY AREA

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 1-2



SOURCE: BASE MAP FROM UNITED STATES GEOLOGICAL SURVEY

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STUDY AREA TOPOGRAPHY

TONGUE POINT MULTI-SITES PROJECT
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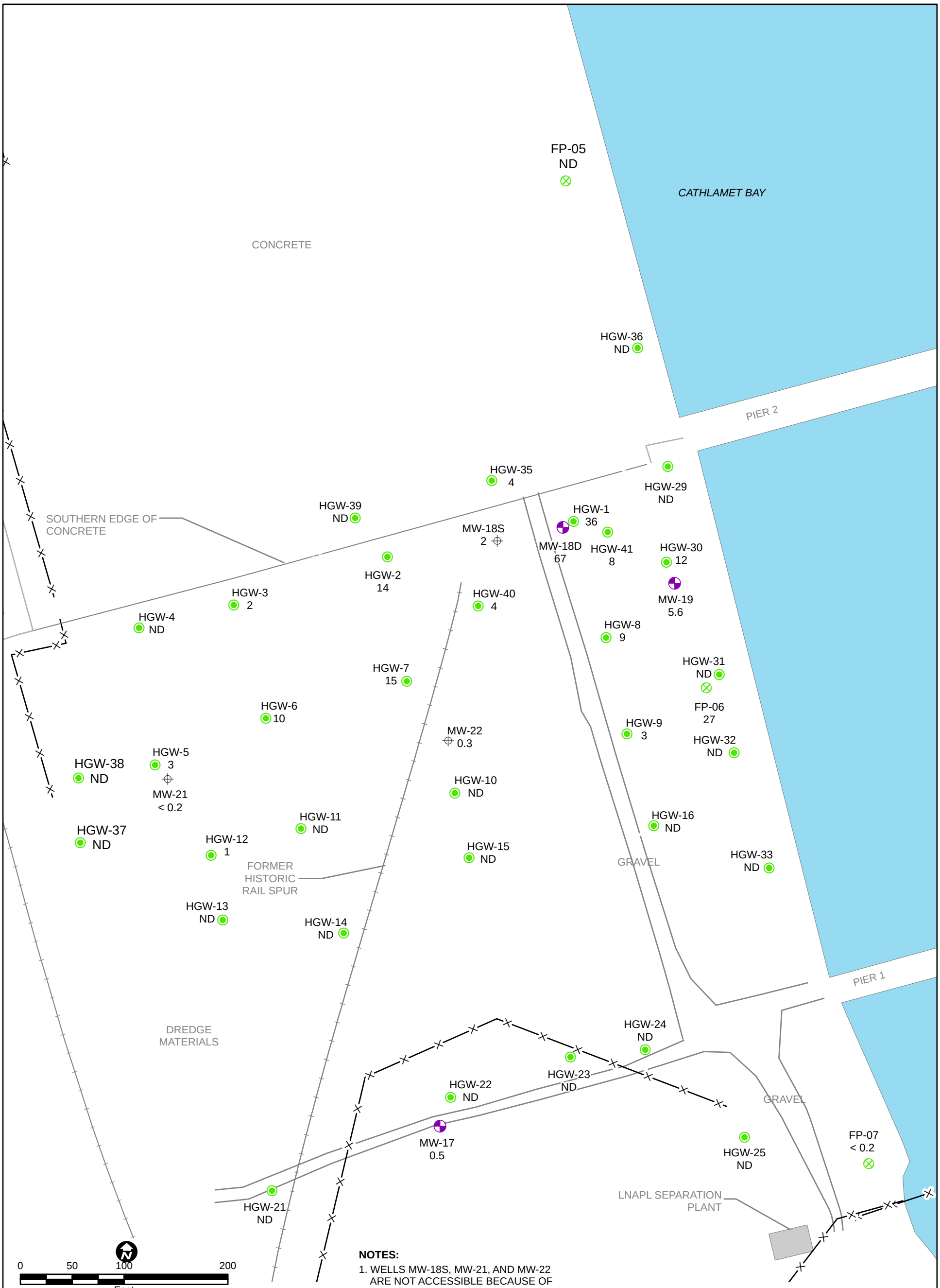
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 1-3



LEGEND

- EXISTING WELL AND ANALYTICAL RESULTS FOR VINYL CHLORIDE IN GROUNDWATER SAMPLES FROM NOVEMBER 1995
- INACCESSIBLE WELL AND ANALYTICAL RESULTS FOR VINYL CHLORIDE IN GROUNDWATER SAMPLES FROM NOVEMBER 1995
- ABANDONED WELL AND ANALYTICAL RESULTS FOR VINYL CHLORIDE IN GROUNDWATER SAMPLES FROM NOVEMBER 1995
- HYDROPUNCH GROUNDWATER SAMPLE LOCATION AND ANALYTICAL RESULTS FOR VINYL CHLORIDE IN GROUNDWATER SAMPLES FROM SEPTEMBER 1995, FOR FIELD SCREENING USING ON-SITE GAS CHROMATOGRAPH EQUIPMENT

NOTES:

1. WELLS MW-18S, MW-21, AND MW-22 ARE NOT ACCESSIBLE BECAUSE OF DREDGE SPOIL PILES PLACED IN 2001
2. DREDGE SPOIL AREA HISTORICALLY USED AS A PUBLIC WORKS STORAGE YARD AND HAD SEVERAL WAREHOUSE BUILDINGS.
3. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
4. BASE MAP DATA: URS, FIGURE 3-7, SEPTEMBER 2007.
5. DPT = DIRECT PUSH TECHNOLOGY
6. µg/L = MICROGRAMS PER LITER
7. LNAPL = LIGHT NON-AQUEOUS PHASE LIQUID
8. ND = NOT DETECTED AT LIMIT OF 1U µg/L
9. ANALYTICAL RESULTS WERE FROM THE TONGUE POINT LANDFILL LIMITED RI - URS GREINER WOODWARD CLYDE, 1999a.

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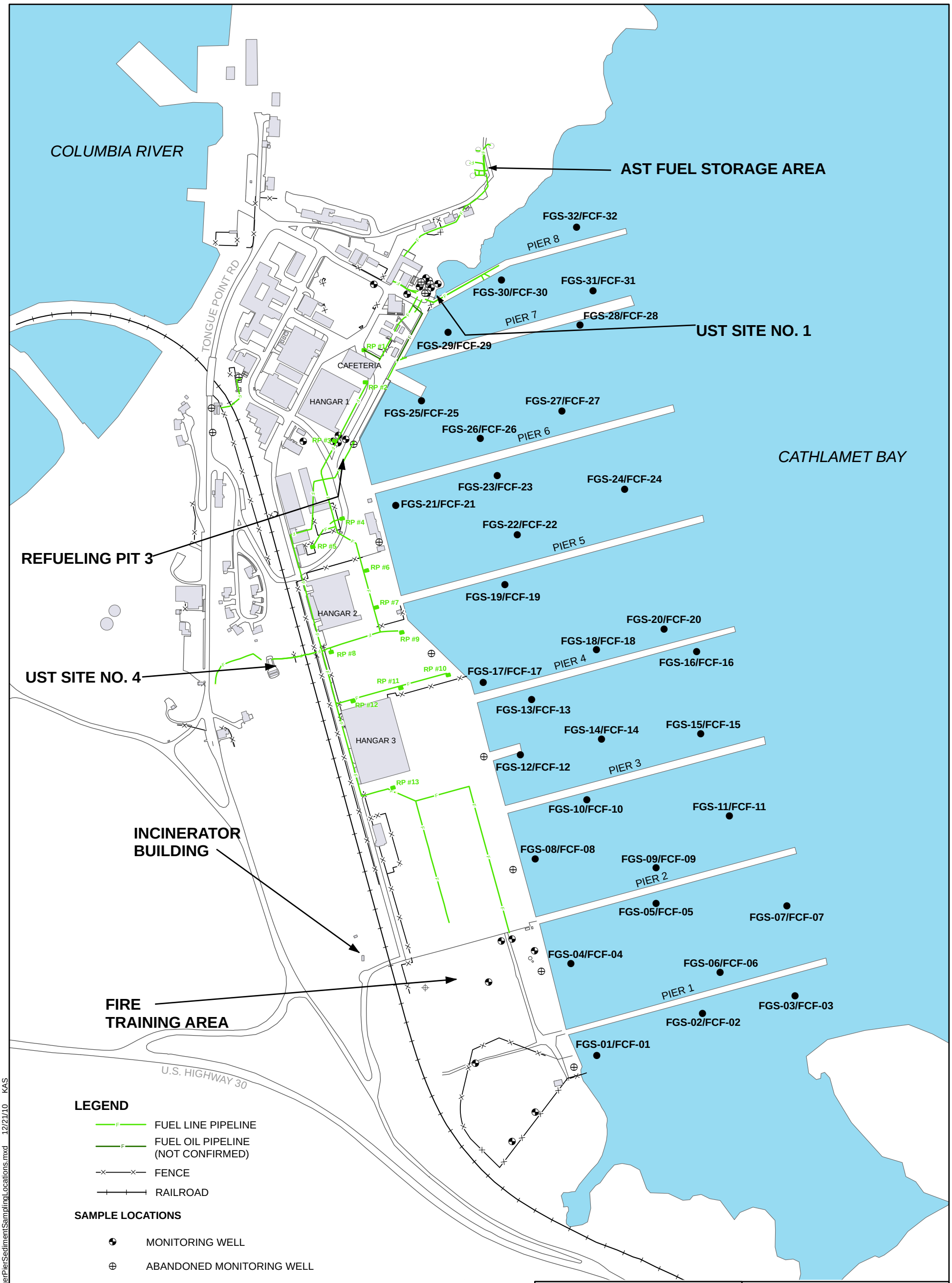
Historic Fire Training Area Groundwater Sampling Locations and Vinyl Chloride Concentrations in Groundwater

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 1-4



NOTES:

1. ORIGINAL PRODUCED IN COLOR INFORMATION MAY BE MISSING FROM BLACK AND WHITE PRODUCTIONS.
2. SOURCE: URS, FIGURE 3-5, SEPTEMBER 2007.
3. FINGER PIER SEDIMENT SAMPLING SOURCE: WOODWARD-CLYDE, FIGURE 2-2, JULY 9, 1998.

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SEATTLE, WASHINGTON

HISTORICAL FINGER PIERS SEDIMENT SAMPLING LOCATIONS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 1-5

K:\GIS\WC_Projects\Tounge_Point_Remediation\Figure1-4_FingerPierSedimentSamplingLocations.mxd 12/21/10 KAS

Section 2
Study Area Physical Setting

This section includes brief summaries of the physical characteristics of the Study Area and surrounding region, where applicable. The data presented are necessary to define potential transport pathways and receptor populations. Most of the data (i.e., geology, hydrogeology, existing populations, and so on) presented were collected during the field planning and investigation, but climate, land use, and additional ecological information was obtained from previous investigations and local data clearinghouses, when necessary.

2.1 Climate

The data obtained for the climate of the Study Area were obtained from the Western Regional Climate Center for the Astoria Regional Airport in Astoria, Oregon. This weather station is approximately 6.5 miles west of the Study Area. Generally, the climate of the surrounding region is marine temperate, which is characterized by mild, rainy winters and cool summers with temperatures ranging from 25°F to 90°F.

Average monthly precipitation in Astoria ranges from 1.16 to 10.40 inches for the 30-year monthly normal period of 1971 to 2000. The highest amount of rainfall occurs between October and May, with the heaviest rain events occurring between November and February. Although rain during the summer months is uncommon, fog occurs frequently.

There is a seasonal wind pattern in the area. Between May and September, the wind comes out of the west-southwest to west-northwest. Between September and May, the wind direction is more variable, with wind coming from two opposite directions: 1) west-southwest to west-northwest and 2) east to east-northeast. Annually, wind speeds average 7.7 miles per hour. Maximum wind gusts are highest during the winter months of November through February.

2.2 Land Use

Property ownership is shown on **Figure 1-1,** and the following sections describe land use within the Study Area from the north to south.

The northern portion of the Study Area, consisting of land on Tongue Point, is managed by the USFWS; it is forested and largely undeveloped (except for former DoD-era munitions bunkers and the machine gun rifle range). Tongue Point is designated as the Tongue Point Eagle Sanctuary, and is the downstream boundary of the Lewis and Clark NWR (Topinka 2005). Current land use on this portion of the site is wildlife management, habitat protection, and wildlife observation (USFWS 2006). The USFWS does not permit residential use in this area.

The central portion of the Study Area, or the area between Tongue Point and Hangar 2, is currently used by the Tongue Point Job Corps Center as a vocational training center. Facilities include classrooms, workshops, cafeterias, recreation centers, and dormitories. The Job Corps Center has been operated by the DOL since 1965 and currently occupies 48 buildings, formerly constructed by the Navy, which are situated on 120 of the 278 acres currently owned by the DOL. Most Job Corps Center employees and all students live onsite in residences and dormitories.

The portion of the site between Hangar 2 and Pier 1 is owned by WNTP. WNTP is developing the property at Tongue Point (28 acres owned on shore and 50 acres leased off shore) into a multi-use transportation logistics and intermodal facility, with facilities for vessel operations and moorage. This marine industrial facility provides berthage, storage, hangar, warehouse, and office rental space for marine, industrial, and light manufacturing companies (Washington North Tongue Point 2006). There are no residents living in this area.

The southern portion of the Study Area is owned by the ODSL. The northwestern portion of the Fire Training Area is covered by a large dredge materials pile. The dredging activity surrounding Pier 4 that created dredge spoils took place in 2001; therefore, the dredge spoil pile was emplaced post-DoD occupation of the Study Area and was not investigated during this RI. The ODSL also owns the land containing the former Tongue Point Landfill south of the Fire Training Area. The landfill is being addressed under a separate response action. There are no residents living in the area south of Hangar 2.

Though not part of the Multi-Sites Project area, a U.S. Coast Guard facility occupies 10 acres of property on the west side of Tongue Neck adjoining the Tongue Point Job Corps Center. The facility consists of nine buildings and a pier. The facility is the base for the Aids to Navigation Team Astoria unit. This unit maintains navigational aids, including buoys and lighthouses, over an area of responsibility extending from Cape Flattery, Washington, to Cape Mears, Oregon, and 150 miles of the Columbia River. This facility has been a buoy tender port since 1939, and a navigational light has been present at Tongue Point since 1876 (U.S. Coast Guard 2006). Up to nine active duty personnel live on site (U.S. Coast Guard 2003).

2.3 Topography

The topography of the Study Area and surrounding lands is shown in the U.S. Geological Survey (USGS) 7.5 minute topographic quadrangle of Astoria, which is provided in **Figure 1-3.** The total Study Area comprises 227 acres, with 82 acres located onshore and 145 acres located off shore. The terrestrial portion of the Study Area is situated within the flat-lying area situated on the banks of the Columbia River and Cathlamet Bay and is bordered by upland areas to the southwest, the prominent Tongue Point to the north, and Mill Creek to the south. The aquatic portion lies within Cathlamet Bay immediately surrounding the finger piers.

Tongue Point was originally a small island in the Columbia River west of Astoria, Oregon. Between 1939 and 1941, the subtidal lands south of Tongue Point Island were hydraulically filled with sediment from offshore dredging operations. The hydrofilled area extended from Tongue Point Island south nearly to the mouth of Mill Creek and east to the shore of the Columbia River, creating the current topographic expression of Tongue Point, which is now a peninsula. Mill Creek is the primary drainage for the upland areas south and southwest of the Study Area. Mill Creek flows in a northeast direction and discharges into Cathlamet Bay. Mill Creek is flanked by prominent northeast-trending ridges.

The majority of structures and paved areas within the Study Area are located along the Cathlamet Bay waterfront, which is situated at an approximate elevation of 15 feet above MLLW. Topography throughout this waterfront area is relatively flat from Pier 8 south to Pier 2. From Pier 2 south, ground surface elevation increases to approximately 25 feet above MLLW because of the pile of dredge material on the northwest portion of the Fire Training Area DU and the former Tongue Point Landfill located to the south. West of the waterfront area, ground surface rises to approximately 150 feet above MLLW at the northern terminus of a northeast trending ridge, located west of the Study Area. In the north, ground surface rises steeply to the peak of Tongue Point, at a high point of 280 feet above MLLW. The following bullets describe the topography of the terrestrial DUs.

- The AST Fuel Storage Area is located on the eastern flank of Tongue Point at an elevation of approximately 92 feet above MLLW. The ground surface slopes steeply southeast toward the Columbia River. This DU encompasses approximately 0.34 acres.

- UST Site No. 1 is situated adjacent to the bank of the Columbia River at an elevation of approximately 16 feet above MLLW. Topography is relatively flat above the former UST cavity, with a steep bank east and northeast of the former cavity created by the bulkhead along the Columbia River. This DU encompasses approximately 0.46 acres.

- Refueling Pit 3 is located along the paved waterfront area south of Hangar 1 at an elevation of approximately 16 feet above MLLW. The pavement has a slight gradient directed southeast toward Cathlamet Bay. This DU encompasses approximately 0.84 acres.

- UST Site No. 4 is located in the upland slope, west of the waterfront area at an elevation of approximately 30 feet above MLLW. The ground surface slopes steeply east of the former UST cavity to the former Portland & Western Railroad line below the slope and toward waterfront near Hangar 2. This DU encompasses approximately 0.16 acres.

- The Incinerator Building is located in a forested region of the upland area, northwest of the former Fire Training Area. The elevation is approximately 25 feet above MLLW and ground surface slopes slightly to the northeast, toward Cathlamet Bay. This heavily wooded DU encompasses approximately 0.27 acres.

- The Fire Training Area consists of a flat concrete paved area in the northern portion of the DU, and the southern portion is unpaved. As mentioned previously, the western portion of the DU is covered by dredge spoils. The stockpile of dredged material is not being addressed by this RI. The elevation of the northern paved area is approximately 12 feet above MLLW with a slight gradient directed northeast to Cathlamet Bay. The surface elevation in the dredge spoils area ranges from 24 feet above MLLW to 11 feet above MLLW with a general topographic slope northeast toward Cathlamet Bay. This DU encompasses approximately 5.5 acres.

2.4 Geology and Hydrogeology

The following sections describe the geology and hydrogeology of the TPMS area.

2.4.1 Geologic Setting

Tongue Point is located in the Astoria structural basin (Astoria Basin) within the Coast Range physiographic province. The bedrock within the Astoria Basin consists of Miocene marine deposits of the Astoria Formation. The lithology of this formation comprises primarily fossiliferous siltstone and claystone (Shapiro 1993). The Astoria Formation is estimated to be 2,000 feet thick in the vicinity of the Study Area (USACE 1999b). Columbia River flood basalts, of similar age to the Astoria Formation, are present in the vicinity. An outcrop of Columbia River basalt creates the prominent "point" of Tongue Point. Recent alluvium consisting of floodplain and estuarine deposits of the Columbia River and tributaries is present throughout the Astoria Basin. The alluvium comprises clay, silt, sand, and gravel (Walsh 1987).

The only fault mapped in the vicinity is a northeast-trending fault located south of the Study Area along the drainage course of Mill Creek (Walsh 1987).

2.4.2 Study Area Geology and Hydrogeology

Most of the buildings and paved areas in the waterfront portion of the Study Area were constructed on unconsolidated fill from material dredged from the Columbia River. Native surface soils are exposed in some of the upland areas and have been identified as the Templeton Ecola Silt Loam. Bedrock geologic units mapped in the Study Area include marine siltstone and claystone of the Youngs Bay member and the Cannon Beach member of the Astoria Formation (Walsh 1987). The maximum depth explored during this investigation was 30 feet bgs in the Fire Training Area.

Groundwater occurs at the Study Area under unconfined conditions within fill and alluvium, which overlies low permeability bedrock that acts as an aquitard. The groundwater is not used as a drinking water source and is not likely to be used for drinking water in the future because the water-bearing zones have limited yield, and there is an existing supplied-water infrastructure.

Three terrestrial cross sections and one aquatic cross section were prepared using lithologic data from this investigation and previous investigations. The locations of the cross-section lines are shown on **Figure 2-1**. Study Area geology as presented in

the geologic cross sections A – A′, B – B′, and C – C′ (shown on **Figures 2-2, 2-3,** and **2-4**, respectively) is based on the borings of this field investigation. Boring logs included in **Appendix A** contain detailed lithologic descriptions and temporary well designs, when applicable. The following sections present a summary of the geology and hydrogeology of each DU based on current and prior subsurface investigations of the Study Area. Physical property testing (i.e., grains size analysis, porosity, and so on) for the vadose zone soils is presented in **Section 3.4**.

2.4.2.1 AST Fuel Storage Area

A surficial layer of fill underlies the AST Fuel Storage Area from ground surface to approximately 6 feet bgs. Colluvium extends below the fill to depths ranging from 17 feet bgs to greater than 20 feet bgs (maximum depth explored). Alluvium underlies the colluvium to depths of at least 20 feet bgs. The fill includes a wide variety of soil types, including silt, silty sand, and poorly graded sand with minor gravel and organic material. The colluvium consists of brown silt with minor quantities of clay and silty sand. Weathered basalt fragments are present within the colluvium. Alluvium was observed only at the deepest boring (AST-10) and consists of interbedded gray silt and poorly graded sand.

Groundwater was encountered only at the AST Fuel Storage Area with the alluvial unit, under unconfined conditions. The depth to groundwater at boring AST-10 was 15 feet bgs during the September 2008 investigation. The depth to the confining bedrock surface and the thickness of the water bearing alluvium at the AST Fuel Storage Area are not known. Based on similar lithology, the hydraulic conductivity of the water-bearing alluvium at the AST Fuel Storage Area is expected to be similar to that reported for alluvium in other areas of the Study Area, K = 0.1 to 1 feet/day (USACE 1999b). The groundwater flow direction and hydraulic gradient could not be determined because groundwater was encountered only at a single boring adjacent to the pump house (see **Figure 3-2**); however, groundwater flow is expected to follow the topography and flow east toward the Columbia River.

2.4.2.2 UST Site No. 1

The geology of UST Site No. 1 is summarized in geologic cross section A–A′, shown on **Figure 2-2**. Fill underlies the ground surface at UST Site No. 1 to depths of up to 12 feet bgs. Alluvium underlies the fill and extends to depths of 20 feet bgs to up to 40 feet bgs (USACE 2000). Bedrock of the Astoria Formation underlies the alluvium. The fill includes material placed during the initial development of the submarine and destroyer base in 1921, more recent hydraulically placed fill from dredge spoils, and the backfill of the 2001 remedial excavation. Fill comprises a variety of soil types, including silt, clay, silty sand, poorly graded sand, and occasional gravel. Alluvium consists of interbedded gray silt and poorly graded sand and silty sand. Bedrock was not observed to the maximum depth explored (20 feet bgs); however, based on the submarine and destroyer base construction borings, bedrock is present at depths of 20 to 40 feet bgs and comprises claystone of the Astoria Formation (USACE 2000).

Groundwater at UST Site No. 1 occurs under unconfined conditions within fill and the alluvium. During fieldwork in September 2008, the depth to groundwater ranged from 5 to 9 feet bgs. Assuming that bedrock occurs at depths between 20 and 40 feet bgs, the minimum saturated thickness of the shallow aquifer is between 10 and 30 feet bgs. Aquifer testing has not been conducted at UST Site No. 1. However, based on similar lithology, the hydraulic conductivity of the shallow aquifer at UST Site No. 1 is expected to be similar to the range (K = 1 to 20 feet/day) determined by the hydraulic conductivity test performed at the Refueling Pit 3 DU.

A groundwater elevation contour map for UST Site No. 1, based on September 2008 groundwater level measurements, is presented in **Figure 2-5.** The groundwater contours indicate mounding of groundwater centered on the former remedial excavation with radial groundwater flow to the northeast, east, and southeast, with a very steep hydraulic gradient toward Cathlamet Bay. The hydraulic gradient during September 2008 at the edge of the groundwater mound ranged from 0.07 to 0.18 feet/foot. The groundwater mounding is attributed to increased recharge through the landscaped area at the former UST Site No. 1 excavation site and the permeability contrast between the excavation backfill and the surrounding fill and alluvium. Seasonal fluctuations in groundwater levels range from 2 to 6 feet bgs based on quarterly groundwater monitoring data collected by the USACE between 2002 and 2006. The shallow aquifer is influenced by tidal effects, and previous studies have reported as much as 6 feet of tidal influence to groundwater levels at UST Site No. 1 (URS Greiner Woodward Clyde 2000b).

2.4.2.3 Refueling Pit 3

The geology of Refueling Pit 3 is summarized in geologic cross section B–B′, shown on **Figure 2-3**. Fill underlies the ground surface to depths of approximately 15 feet bgs. Alluvium underlies the fill and extends to depths of up to 21 feet bgs (USACE 1999b). Bedrock of the Astoria Formation underlies the alluvium. The Navy placed the fill in 1921 during the site's initial development as a submarine and destroyer base. The fill consists of interlayered gray and brown silty sand and silt, with occasional gravel and wood debris. Alluvium consists of gray, poorly graded sand. Bedrock was not observed to the maximum depth that was explored during the September 2008 investigation (20 feet bgs). However, based on the submarine destroyer base construction borings, the bedrock surface is present at depths of 18 to 21 feet bgs and the bedrock consists of siltstone and mudstone of the Astoria Formation (USACE 1999b).

Groundwater at Refueling Pit 3 occurs under unconfined conditions within the fill and the alluvium. During the September 2008 investigation, the depth to groundwater ranged from 7 to 8 feet bgs. The saturated thickness represented by the slug test data ranges from 10 to 14 feet. The average linear groundwater velocity is estimated at 1.5 feet/day in the area between Refueling Pit 3 and the Columbia River. The hydraulic conductivity measured at RFP-Refueling Pit 3 ranges from K= 15 to 20 feet/day for wells screened across fill. The slug test conducted at well MW-03, which is a well screened across both fill and alluvium, indicates a lower hydraulic

conductivity of approximately 1 foot/day (refer to **Appendix H** for hydraulic calculations). The lower hydraulic conductivity observed in the well that partially penetrates alluvium is consistent with aquifer testing results performed by previous investigators (USACE 1999b). The Astoria Formation bedrock has been previously reported to act as an aquitard to the overlying water-bearing zone based on the reported relatively low hydraulic conductivity of the formation (USACE 2000). Laboratory based hydraulic conductivity (Kv) determinations of the Astoria Formation bedrock indicate that the hydraulic conductivity ranges from $K = 3 \times 10^{-5}$ to 6×10^{-5} feet/day (USACE 1999a).

A groundwater elevation contour map for Refueling Pit 3, based on September 2008 groundwater level measurements, is presented in **Figure 2-6.** The contours indicate that groundwater flows southeast toward Cathlamet Bay. The hydraulic gradient for the September 2008 measurements ranges from 0.003 to 0.015 feet/foot, increasing in the direction of the bay. Seasonal fluctuations in groundwater levels are expected to be about 2 to 4 feet based on data collected from the aquifer at the nearby UST Site No. 1. Groundwater levels at Refueling Pit 3 are expected to be tidally influenced based on previous investigations of the shallow aquifer at UST Site No. 1 and the Fire Training Area (URS Greiner Woodward Clyde 2000b).

2.4.2.4 UST Site No. 4

Fill underlies UST Site No. 4 from ground surface to depths of up to 15.5 feet bgs. The fill is underlain by 2 feet of native soil or colluvium, which is underlain by the weathered siltstone bedrock of the Astoria Formation. The fill includes material that was placed during the 1992 UST decommissioning excavation and older fill that was placed during the original development of the site. The UST excavation backfill consists of yellow-brown to gray, poorly graded sand and silty sand; the older fill consists of gray silt and silty sand with occasional gravel and construction debris. Concrete was encountered at boring UST4-03 at depth of 14.5 feet bgs, and previous investigations reported the presence of a concrete slab at 14 feet bgs within the older fill (USACE 1999a). The native soil (or colluvium) is a dark brown to yellow-brown clay and is most likely derived from the weathered bedrock, which consists of yellow-brown to brown, stiff to hard silt.

Groundwater was not encountered to the total depth explored (20 feet bgs) during this investigation. Previous investigators have reported the occurrence of isolated perched groundwater in fill at UST Site No. 4 at depths ranging from 10 to 14 feet bgs; however, it is likely that the occurrence of perched groundwater is limited to the permeable backfill that was placed in historical excavations that cut into the Astoria Formation bedrock (USACE 1999a). The flow of perched groundwater from these historical bedrock excavations could only occur if the perched groundwater completely filled and "overtopped" the historical excavation. If this occurred, then it is likely that the perched groundwater would flow along the soil-bedrock interface, down-slope to the northeast, toward the drainage ditch at the bottom of the slope.

2.4.2.5 Incinerator Building

No subsurface data were collected at the Incinerator Building during this investigation.

2.4.2.6 Fire Training Area

The geology of the Fire Training Area is summarized in geologic cross section C–C′, shown on **Figure 2-4**. Fill underlies the ground surface at the Fire Training Area to depths of approximately 17 feet bgs. Alluvium underlies the fill and extends to depths up to 22 to 32 feet bgs (or to the maximum depth explored at this DU). Bedrock of the Astoria Formation underlies the alluvium. The fill includes mounds of dredge spoils overlying older hydraulic fill that was placed as part of early site development. Fill consists predominantly of yellow-brown, poorly graded sand with minor silt and silty sand layers. Alluvium is gray, poorly graded sand interbedded with silty sand and silt. Bedrock consists of brown claystone. As shown in cross section C–C′, the bedrock surface dips eastward; as a result, the alluvium thickens toward the east.

Groundwater at the Fire Training Area has unconfined conditions within fill and the alluvium. During the September 2008 investigation, the depth to groundwater ranged from 5 to 15 feet bgs, with the deeper depths being within the dredged stockpile area (see **Figure 2-4**). The saturated thickness ranges from 12 to 20 feet, with the greatest saturated thickness near the banks of the Columbia River. Aquifer testing has not been conducted at the Former Fire Training Area; however, based on similar lithology, the hydraulic conductivity of the unconfined water bearing zone is expected to be similar to that determined for fill and alluvium at Refueling Pit 3, which ranges from K = 1 to 20 feet/day.

From the field measurements and laboratory analyses tabulated in **Table 2-1**, groundwater geochemistry is characterized by anaerobic conditions. Specifically, the characteristics are represented by the measured dissolved oxygen (DO) concentrations ranging from 0.17 to 0.4 mg/L and oxidation/reduction potential (ORP) values ranging from -63.5 to -129.6 millivolts (mV). Methane concentrations, in samples from three locations, ranging from 1,000 J to 21,000 µg/L are another indicator of anaerobic conditions and that biodegradation of chlorinated ethenes may be occurring and creating the vinyl chloride plume (see **Figure 2-1**). See **Section 5.3.2** for further discussion.

A groundwater elevation contour map for the Former Fire Training Area, based on September 2008 groundwater level measurements, is presented in **Figure 2-7.** The contours indicate that groundwater flows east toward Cathlamet Bay. The approximate hydraulic gradient measurement is I = 0.0075 feet/foot. Based on previous investigations, groundwater levels are expected to be tidally influenced (URS Greiner Woodward Clyde 2000b). The average linear groundwater velocity is estimated at 0.8 foot/day. Calculations for this estimate are provided in **Appendix H.**

2.4.3 Groundwater Yield

The estimated yield for wells screened in the unconfined water-bearing zone ranges from a minimum of 0.3 gallons per minute (gpm) to a maximum of 9.4 gpm. This estimate is based on an unconfined saturated thickness ranging from 10 to 14 feet, hydraulic conductivities ranging from 1 to 20 feet/day, and assumes an 80% efficient 16-inch diameter well screened across the entire saturated thickness. A data summary for the hydraulic conductivity evaluation conducted at Refueling Pit 3 is shown on **Figure 2-8**. The complete evaluation of the hydraulic conductivity analysis and an explanation of the calculations are provided in **Appendix H.** This estimate is based on the slug test results and thickness observed at Refueling Pit 3. Based on similar hydrogeologic characteristics, a similar range in well yields is expected for wells throughout the Study Area.

2.4.4 Sediments

Sediment characteristics for the aquatic DUs (including the Finger Piers, Near Landfill, and North of Pier 8) are summarized in the following sections. A detailed description of the sediment stratigraphy and annual sedimentation rate is provided in **Appendix G**.

2.4.4.1 Stratigraphy

The sediment stratigraphy for the Finger Piers, Near Landfill, and Pier 8 areas is summarized in **Figure 2-9**, showing a sediment core cross section. The information presented on this figure comprises locations sampled during this investigation and sediment cores collect during the *Finger Pier Sediments, Limited Remedial Investigation* (Woodward Clyde 1998). The sediment stratigraphy consists of a thick sequence of silt and sandy silt underlain by sand. The silt unit ranges from 5 to 20 feet in thickness. The silt is dark gray to black, of low to moderate plasticity, generally firm in consistency, and with a high organic content. Trace quantities of wood fragments, shells, and invertebrates are present in the upper 3 feet of sediment. The underlying sand unit is at least 10 feet thick (Woodward Clyde 1998). The sand is gray to dark gray, poorly graded, fine grained, and medium dense to dense. As indicated on **Figure 2-9**, a thin gray to light gray clay layer, which was interpreted as the volcanic ash deposited during the 1980 eruption of Mount St. Helens, was observed at depths of approximately 2 feet below mud line (BML) in two of the sediment cores (FP-13 and FP-13A) collected during this investigation. The same clay layer was observed in most of the historical sediment cores collected during the *Finger Pier Sediments, Limited Remedial Investigation* (Woodward Clyde 1998).

The upper silt unit is believed to be sediment deposited after the initial development of the destroyer and submarine base and construction of the Finger Piers (Woodward Clyde 1998). The underlying sand represents sediment deposited in a higher energy environment before development. Infilling of the bay and construction of the Finger Piers slowed river flow velocities, resulting in a lower energy depositional environment and increased silt deposition.

2.4.4.2 Bathymetry

The results of the bathymetric survey conducted 4 to 5 September 2008 for the Finger Piers, Near Landfill, and North of Pier 8 DUs are shown as a bathymetric contour map, which is included as **Figure 3-1.** The survey notes and details are in **Appendix K**. The depth of water relative to MLLW ranges from 5 feet deep near mudflats surrounding the former Tongue Point Landfill to 28 feet deep surrounding Pier 4. Two prominent bathymetric features are present: (1) a depression of the river bottom around Pier 4, and (2) a northeast-trending steep-sided channel on the north side of Pier 7. The remaining area around the finger piers is relatively flat. A short distance beyond the east end of the piers, the river bottom drops off steeply, to depths exceeding 30 feet below MLLW, in the John Day Channel (NOAA 2009).

The depression around Pier 4 resulted from dredging activities performed in 2001 (PND 2001). Based on the depth of marker units in the sediment cores, the total dredging depth of the 2001 dredging event was approximately 8.7 feet below MLLW. The channel along the north side of Pier 7 may represent a former erosional feature along the south side of the former Tongue Point Island, which existed before the infilling of the bay. Alternatively, this feature may be evidence of a historical dredging event.

2.4.4.3 Sedimentation Rates

The estimated sediment accumulation ranged from approximately 1.1 to 4.6 feet over the 13.4-year period between the 1995 and 2008 bathymetric surveys. The least sediment accumulation occurred at the south end of the DU, south of Pier 1, and the greatest sediment accumulation occurred within the steep-sided channel north of Pier 7. Sediment accumulation over the remainder of the Finger Piers DU was more uniform, ranging from 1.5 to 3.2 feet over the 13.4-year period. This is equivalent to a sedimentation rate of 1.3 to 2.9 inches per year. Therefore, based on the 1995 and 2008 bathymetric surveys of the Finger Piers area, the average sedimentation rate was estimated at 2.1 inches per year. Based on this sedimentation rate, approximately 8.1 feet of sediment has accumulated since the cessation of DoD-related activities in 1962.

2.4.4.4 Physical Properties of Sediment

Archived sediment collected from the aquatic Reference Area and the Aquatic-Near Landfill DU were composited and submitted for grain size analysis by ASTM D4464M. The predominant grain size in soil collected from the Reference Area was fine sand and was classified as silty sand, using the Unified Soil Classification System (USCS). The predominant grain size in soil collected from the Near Landfill DU was silt. **Table 2-2** presents a summary of the grain size analysis.

2.4.5 Physical Properties of Soil

Samples of representative soil types (poorly graded sand with silt, silty sand, and silt) were collected from the UST Site No. 1, Refueling Pit 3, and Fire Training Area DUs and submitted for laboratory analysis to determine the *in-situ* soil properties of the vadose zone. The following tests were performed:

- Bulk density by American Society for Testing and Materials (ASTM) D2937
- Grain density by ASTM D854
- Moisture content by ASTM D2216
- Grain size distribution by ASTM C136, ASTM D42, and ASTM D422/D4464
- Air permeability by the American Petroleum Institute (API) Method RP-40
- TOC by Plumb (1981)

The predominant grain size in soil collected from UST Site No. 1 was fine sand and the soil was classified as silty sand, using the USCS classification system. The predominant grain size in soil collected from Refueling Pit 3 was clay and was classified as silty clay. The Fire Training Area DU soils were classified as silty sand, with fine sand being the dominant grain size. **Table 2-3** presents a summary of the physical properties of the vadose zone soil samples.

2.5 Surface Water Hydrology

The Columbia River is the primary surface water feature at the Study Area. The Study Area is located approximately 12 miles upstream of the mouth of the Columbia River in Cathlamet Bay, which is considered a lower energy slackwater environment (URS Greiner Woodward Clyde 2000a). The Columbia River is influenced by tidal fluctuations and the release schedule of upstream Bonneville Dam. The magnitude of the tidal fluctuation at the Study Area is 7 to 8 feet, based on tidal information from the NOAA gauge at the Tongue Point U.S. Coast Guard Station (URS Greiner Woodward Clyde 2000a).

As shown on **Figure 1-3**, Mill Creek discharges to Cathlamet Bay just south of the Study Area and provides drainage for the upland areas southwest of the Study Area. Stormwater runoff at the Study Area flows into stormwater inlets and is then conveyed via storm drains to discharge points at the edge of the Columbia River. An unlined drainage ditch runs along the west side of the railroad tracks along the west boundary of the Study Area and provides drainage for upland areas and the western portion of the Study Area. The drainage ditch discharges to the Columbia River at the mouth of Mill Creek.

2.6 Biota

The following sections summarize the ecologies of the terrestrial and aquatic environments as they relate to the DUs within the Study Area. Species observed during the initial site visit (May 2008) and during the investigation (September 2008) are listed in **Table 2-4**.

The Study Area is located within the lower Columbia River estuary ecosystem. Potential habitats within 2 miles of the Study Area include the open water habitat of

Cathlamet Bay; upland conifer forest at the tip of Tongue Point; and upland/riparian forest on Mott and Lois Islands within the Lewis and Clark NWR and on the Tongue Point Peninsula. In addition, there are emergent wetlands, intertidal flats, and subtidal areas associated with Mill Creek and the John Day River. Mill Creek enters Cathlamet Bay near the south end of the landfill. The John Day River enters Cathlamet Bay approximately 1.5 miles southeast of the Study Area. Mill Creek drains generally to the northeast, emptying into an emergent marsh wetland located southeast of the Study Area.

2.6.1 Aquatic Environment

The Study Area is located in the lower portion of the Tidal-Fluvial Zone (Simenstad et al. 1990) of the Columbia River estuary, adjacent to the Lewis and Clark NWR. This zone of the estuary is characterized by the dominance of freshwater inputs from the Columbia River. Salinities near the Study Area vary widely, both seasonally and over individual tidal cycles. In shallow subtidal areas, such as those adjacent to the aquatic decision units, bottom salinities range from 0.0 parts per thousand (ppt) at low tide (Emmett et al. 1984) to 15 ppt during high tide and low river flow conditions (Ingles 1989). Salinities in the navigation channels off Tongue Point (i.e., Tongue Point Channel, North Channel, and so on) are considerably higher, due to the intrusion of the salt wedge up the channel, and range from 20 to 25 ppt during low Columbia River flow conditions (Fox *et al*. 1984; NOAA 2009).

Aquatic habitat within Cathlamet Bay (see **Figure 1-3** for the area of Cathlamet Bay) is predominantly shallow, subtidal habitat dominated by fine sediments. Benthic invertebrate sampling was conducted at approximately 2-week intervals between April 18 and September 14, 1984, in the Maritime Administration (MARAD) basin less than 1 mile east-southeast of the Study Area (Emmett et al. 1986). This basin is located in Cathlamet Bay south-southeast of Mott Island and north-northwest of Lois Island; the Aquatic - Reference Area is located within this basin. A total of 26 taxa were collected during the sampling interval. Total numbers of organisms averaged from 64,696 per square meter (m^2) during June and July to 231,392 per m^2 during August and September. These numbers were relatively high when compared to other shallow subtidal areas sampled in the tidal-fluvial zone of the Columbia River during the same period.

The presence of relatively high densities of benthic invertebrates around Cathlamet Bay creates an important feeding area for fish and other higher-order predators (Ingles 1989). Fish sampling in Cathlamet Bay has been conducted using bottom trawls, beach seines, and gill nets. Trawling was conducted monthly in the Tongue Point navigational channel north of Tongue Point for a period of 24 months and monthly in the John Day Channel off the mouth of the John Day River from March through September (Emmett et al. 1984; McCabe 1987; NOAA 2009). Seining was conducted over a 2-year period at sites around the MARAD basin (Olhausen 1980; Cates 1983). Gill nets were set at the end of and along the south side of Pier 1 and in the MARAD basin (Ingles 1989).

Sturgeon larvae and fry do not tolerate salinities greater than 11 ppt and, therefore, they would not be expected to be present in the vicinity of the Study Area. Shad densities appear to be highest in the winter, but 1- and 2-year-old shad are present in the estuary year-round. Although the area is essentially fresh, marine fish such as Pacific tomcod, Northern anchovy, Pacific herring, and shiner perch are present during low-flow periods. Adult herring can be abundant at the entrance to Tongue Point. Other species that may be present year-round include longfin smelt, peamouth, large-scale sucker, and starry flounder. One starry flounder was caught during surface sediment sampling in the Aquatic - Finger Piers DU, but was thrown back because it was under the size limit.

Juvenile salmonids are present throughout the year, with highest densities in the spring. Juvenile fall Chinook numbers peak in late summer closer to the main channel. Although they are present in the MARAD basin, their numbers do not approach those found near the main channel (McCabe 1987; Smith 1981). Fall Chinook born the same year were by far the most abundant. This is to be expected, as they frequent shallow water.

Fish collected from the Tongue Point area (Ingles 1989) contained concentrations of PCBs and the pesticide DDE that were above the EPA guidelines set for protection of aquatic resources. In particular, PCB residues were similar to dietary concentrations shown to cause reproductive problems in mink (Ingles 1989).

2.6.2 Terrestrial Environment

The following information is based on a limited literature search, which includes various reports before 1991, as listed in **Section 6**.

Terrestrial habitats within the Study Area include the upland conifer forest at the tip of Tongue Point, upland/riparian forest on the Tongue Point peninsula, and emergent wetlands, flats, and subtidal areas along Mill Creek.

The upland/riparian forests are characterized by red alder in the more recently cleared areas and black cottonwood trees in the upland/wetland mixed habitats. Other overstory trees include Douglas fir, Sitka spruce, and western hemlock. Several black cottonwood trees and conifers are large enough to provide perching sites for raptors such as bald eagles. Understory vegetation includes many native species such as red elderberry, salmonberry, and thimbleberry, with the herbaceous species including sword fern as well as lady fern and horsetail in the wetter areas. Himalayan blackberry, an invasive non-native plant, occurs in dense stands where the ground has been disturbed. Wetland areas may be dominated by reed canary grass.

Mill Creek drains generally to the northeast, emptying into an emergent marsh wetland located approximately 750 feet south of the Fire Training Area. Wetlands at or near the site are riverine-tidal emergent marsh dominated by narrow-leafed graminoid species, including sedges *(Carex),* cattails *(Typha),* and rushes *(Scirpus, Juncus).* Aquatic macrophytes are present as patchy areas on shallower mudflats.

Aquatic habitat at the Study Area includes intertidal and subtidal mudflats and subtidal channel (URS Greiner Woodward Clyde 2000a).

Wildlife species known to occur in the vicinity of the Study Area are shorebirds that use the flats and marsh areas for foraging and nesting, as well as migrating, breeding, and overwintering waterfowl, including mallard, northern pintail, American widgeon, green-winged teal, scaup species, canvasback, mergansers, grebes, and wood ducks, among others. Great blue heron have been observed foraging on the tidal flats. Songbirds and neotropical migrants use the diversity of habitats for breeding, nesting, foraging, and migration. These include woodpeckers, swallows, American crow, black-capped chickadees, Bewick's wren, golden-crowned kinglets, and various warblers. These birds often are found within forested or scrub/shrub habitats. Mammals observed within the Study Area include black-tailed deer, raccoons, and opossums. River otters and nutria may frequent the Study Area but were not observed during this investigation.

2.6.3 Special Status Species

The National Marine Fisheries Service (NMFS) listed the Snake River sockeye salmon evolutionarily significant unit (ESU) as a federally endangered species in November 1991 (56 Federal Regulation [FR] 58619). Since this first listing, a number of both salmon and steelhead trout ESUs in the Columbia River basin have been identified for federal protection under the Endangered Species Act. In April 1992, the NMFS listed the Snake River spring/summer and fall Chinook ESUs as threatened species (57 CFR 14653). In August 1997, the NMFS listed the upper Columbia River steelhead ESU as endangered and the Snake River basin steelhead trout ESU as threatened (62 CFR 43937). The lower Columbia River steelhead ESU was listed as a threatened species in March 1998 (63 CFR 13347). On March 10, 1998, the NMFS issued a proposed rule to list the middle Columbia River steelhead ESU and the upper Willamette River steelhead ESU as threatened species (63 CFR 11797). Both of these ESUs were listed in March 1999 (64 CFR 14517 and 64 CFR 14513). In addition, in March 1999 the Lower Columbia River and the upper Willamette River Chinook salmon ESUs were listed as threatened species, and the upper Columbia River spring-run Chinook salmon ESU was listed as an endangered species (64 CFR 14308). In a separate ruling in March 1999, the Columbia River chum salmon ESU was listed as a threatened species (64 CFR 14508). The southwestern Washington/Columbia River coastal cutthroat trout was proposed for listing as a threatened species in April 1999 (64 CFR 16397). In November 1999, the Columbia River bull trout was listed as a threatened species by the USFWS (64 CFR 58909). The USFWS has sole jurisdiction of the threatened southwestern Washington/Columbia River coastal cutthroat trout and the Columbia River bull trout. The critical habitat for the bull trout was revised and the final listing for habitat was published 18 October 2010 in 50CFR Part 17 docket FWS-R1-ES-2009-0085. http://federalregister.gov/a/2010-25028 .

Critical habitat has been designated for Snake River sockeye salmon, Snake River spring/summer Chinook salmon, Snake River fall Chinook salmon, lower Columbia River Chinook salmon, upper Willamette River Chinook salmon, upper Columbia

River spring-run Chinook salmon, Columbia River chum salmon, upper Columbia River steelhead, lower Columbia River steelhead, Snake River basin steelhead, upper Willamette River steelhead, and middle Columbia River steelhead (58 CFR 68543 and 65 CFR 7764). Critical habitat has not been proposed for the southwestern Washington/Columbia River cutthroat trout (proposed for threatened status) and the Columbia River bull trout (threatened status). The critical habitat designations for the listed species include the lower Columbia River estuary near the Study Area.

Critical habitat within this reach of the Columbia River consists of the water, river bottom, and adjacent riparian zone. Shallow water habitat in the Columbia River is generally considered a particularly sensitive component of critical habitat because many juvenile anadromous salmonids use shallow water habitat for feeding, cover, and resting areas during their downstream migration. Although there is no formal published definition of shallow water habitat, it is generally being defined as waters between the ordinary high water mark (OHWM) and 20 feet below MLLW. The adjacent riparian zone has been defined for the Snake River sockeye ESU and the Snake River spring/summer and fall Chinook ESUs to include the area within a horizontal distance of 300 feet from the OHWM. The adjacent riparian zone for the remainder of the listed ESUs is defined on a functional rather than quantitative basis. Shallow subtidal habitat in the vicinity of the Study Area is rich in food organisms utilized by juvenile salmonids. Juvenile Chinook salmon have been shown to occur in relatively large numbers near the mouths of Mill Creek and the John Day River (Oregon Natural Heritage Information Center [ORNHIC] 2009). Sockeye salmon were not found in any of the fish samples collected by the NMFS in the mid-1980s. However, it is possible that Snake River sockeye salmon could occur in the main Columbia River channel east and northeast of the Study Area.

Cathlamet Bay and the Columbia River estuary serve as important foraging and wintering grounds for migrating birds. Migratory birds are protected by the Migratory Bird Treaty Act. During the winter months, flocks of migratory birds and waterfowl are a common sight throughout the area because they are attracted to productive foraging areas in the near-shore environments in the vicinity of the Study Area. For example, peregrine falcons (*Falco peregrinus*) (formerly listed as federally endangered) are known to use the vicinity surrounding the Study Area and during migration may overwinter within the Columbia River estuary. In the past, individual peregrine falcons have been observed foraging and perching within the Study Area (ORNHIC 2009). Peregrines feed on waterfowl, which are abundant within the estuary, concentrating in large numbers within the intertidal flats and marsh habitats.

Of the species observed at the Study Area (see **Table 2-4**), only three were federal or state listed species. These include the bald eagle (state threatened); bufflehead (state sensitive species), and crayfish (state-currently stable). Although no longer a federally listed species, bald eagles are protected by the Bald and Golden Eagle Protection Act, which provides protection for these eagle species and their habitats. Crayfish of unidentified species were also observed; although some species in the region are species of concern, populations of most are considered currently stable.

Individual eagles were observed near the outlet of Mill Creek and flying over the Tongue Point area. Bufflehead were seen in the mudflat area, in the open water north of the finger piers area, and in and around the finger piers. Crayfish were seen near the shorelines, as well as at the base of some of the finger piers.

Table 2-1
Groundwater Results for Monitored Natural Attenuation Parameters
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical/Parameter	Sample Location (Sample ID)		
	FTA-04 (06110)	FTA-09 (06106)	MW-18D (06100)
Dissolved Oxygen (DO) (mg/L)	0.40	0.17	0.31
Oxidation/ Reduction Potential (ORP) (mV)	-63.5	-87.6	-129.8
Total Alkalinty, as $CaCO_3$ (µg/L)	190,000	326,000	355,000
Total Dissolved Solids (µg/L)	270,000	NA	NA
Total Sulfide (µg/L)	1,000 U	1,000 U	1,000 U
Nitrate (µg/L)	100 U	100 U	100 U
Nitrite (µg/L)	100	172	100 U
Chloride (µg/L)	13,300	48,200	42,600
Sulfate (µg/L)	2,340	162,000	753
Iron (µg/L)	8,490	35,300	18,700
Manganese (µg/L)	1,170	2,930	1,760
Methane (µg/L)	7,400	1,000 J	21,000
Ethane (µg/L)	2 J	1.3 J	32
Ethene (µg/L)	9.4 J	2 U	2 U

Notes:

ID - identification
mg/L - milligram per liter
mV - millivolt
CaCO3 - calcium carbonate
µg/L - microgram per liter

Table 2-2
Sediment Physical Properties
Tongue Point Multi-Sites Project, Astoria, Oregon

Decision Unit Being Modeled	Sample Being Used for Characterization	Grain Size Analysis ASTM D4464M			
		Particle Size Distribution			Unified Soil Classification System (ASTM D2487)
	Sample ID	Description	Retained on Sieve Number	Weight Percent	
Aquatic - Near Landfill	09303, 09304, 09305	Gravel	4	0.00	Silt (ML)
		C. Sand	10	0.01	
		M. Sand	40	0.63	
		F. Sand	200	9.81	
		Silt	>0.005 mm	77.64	
		Clay	<0.005 mm	14.91	
Aquatic - Reference Area	10300, 10304, 10306	Gravel	4	0.00	Silty Sand (SM)
		C. Sand	10	0.00	
		M. Sand	40	0.21	
		F. Sand	200	65.77	
		Silt	>0.005 mm	32.09	
		Clay	<0.005 mm	1.93	
Aquatic - Reference Area	10302, 10305	Gravel	4	0.00	Silty Sand (SM)
		C. Sand	10	0.00	
		M. Sand	40	0.59	
		F. Sand	200	60.63	
		Silt	>0.005 mm	34.79	
		Clay	<0.005 mm	3.99	

Notes:

ASTM = American Society for Testing and Materials
C. = course
F. = fine
ID = identification
M. = medium
mm = millimeters

Table 2-3
Soil Physical Properties
Tongue Point Multi-Sites Project, Astoria, Oregon

Sample ID	Boring ID	Depth Range of Sample (feet bgs)	Grain Size Analysis ASTM D4464M: Particle Size Distribution (wt %)		Mean Grain Size Description (Trask)	Unified Soil Classification System (ASTM D2487)	Specific Gravity (at 20 °C) ASTM D854	TOC mg/kg Walkley-Black	Dry Bulk Density (grams/cm^3) ASTM D2937	Moisture Content (wt %) ASTM D2216	Air Permeability (millidarcies) API RP-40
UST Site No. 1											
02417	UST1-4	2.3 - 2.9	Gravel C. Sand M. Sand F. Sand Silt Clay	0.00 0.00 6.90 67.77 16.40 8.93	Fine Sand	Silty Sand (SM)	2.60	710	1.38	12.4	4688
Refueling Pit 3											
03418	RFP3-3	3.0 - 3.5	Gravel C. Sand M. Sand F. Sand Silt Clay	0.00 0.00 0.00 0.00 48.27 51.73	Silt	Silty Clay (CL)	2.47	4750	1.22	33.6	184
Fire Training Area											
06406	FTA-2	3.0 - 3.5	Gravel C. Sand M. Sand F. Sand Silt Clay	0.00 0.00 1.78 87.34 8.74 2.14	Fine Sand	Poorly Graded Sand with Silt (SP-SM)	2.66	270	1.42	20.1	4355
06417	FTA-5	12.5 - 13	Gravel C. Sand M. Sand F. Sand Silt Clay	0.00 0.00 18.11 44.83 27.96 9.11	Fine Sand	Silty Sand (SM)	2.66	1450	1.47	21.1	827

Notes:

°C = degrees Celsius
API = American Petroelum Institute
ASTM = American Society for Testing and Materials
bgs = below ground surface
cm^3 = cubic centimeters
ID = identification
mg/kg = milligram per kilogram
No. = number
TOC = total organic content
UST = undergound storage tank
wt % = weight percent
% = percent

Table 2-4
Wildlife Species Identified During Initial Site Visit (May 6-7, 2008)
Tongue Point Multi-Sites Project, Astoria, Oregon

Species	Genus Species [1]	State Status [2]	Field Notes	Year-round or Migratory
Birds				
American crow	*Corvus brachyrhynchos*			Year-round
American goldfinch	*Carduelis tristis*		Observed in the field habitat west of the Landfill.	Year-round
American robin	*Turdus migratorius*		Many individuals seen.	Year-round
American wigeon	*Anas americana*		A pair observed along with individuals. All feeding in the mudflat area offshore of the Landfill during low tide.	Migratory
Bald eagle	*Haliaeetus leucocephalus*	ST	Observed roosting above the Mill Creek outlet and adjacent to Landfill and flying over the Tongue Point Eagle Sanctuary.	Year-round
Barn swallow	*Hirundo rustica*			Migratory
Belted kingfisher	*Ceryle alcyon*			Year-round
Bufflehead	*Bucephala albeola*	SSS		Migratory
California gull	*Larus californicus*			Migratory
Canada goose	*Branta canadensis*		Some pairs had young with them.	Year-round
Caspian tern	*Sterna caspia*		Many seen with fish and loafing on Piers 2 and 3 with signs of use apparent at Pier 1. Sometimes in groups of up to 150 individuals. Terns were displaying courtship behavior. Many terns feeding in the waters near the finger piers and the mudflat area east of Pier 1 and offshore of the Landfill.	Migratory
Common loon	*Gavia immer*		Seen in and around Finger Piers 1, 2, and 3.	Migratory
Common raven	*Corvus corax*			Year-round
Common yellowthroat	*Geothlypis trichas*			Migratory
Dowitchers	*Limnodromus sp.*			Migratory
Double crested cormorant	*Phalacrocorax auritis*			Year-round
Dunlin	*Calidris alpina*		Flocks from approximately 40 to 100s of individuals were seen feeding in the mudflat area offshore of the Landfill. Many of the group were in breeding plumage.	Migratory
European starling	*Sturnus vulgaris*			Year-round
Gadwall	*Anas strepera*		A pair observed feeding in the mudflat area offshore of the Landfill during low tide.	Migratory
Golden-crowned sparrow	*Zonotrichia atricaopilla*		Observed in the field habitat west of the Landfill.	Migratory
Great blue heron	*Ardea herodias*			Year-round
Greater scaup	*Aythya marila*		Many rafts seen. Also feeding along the mudflat area offshore of the Landfill during low tide.	Migratory
Green-winged teal	*Anas crecca*		A pair observed feeding along the mudflat area offshore of the Landfill during low tide.	Year-round
House finch	*Carpodacus mexicanus*			Year-round
House wren	*Troglodytes aedon*			Migratory
Killdeer	*Charadrius vociferus*		Pair seen and nesting behavior observed in the Landfill.	Year-round
Lazuli bunting	*Passerina amoena*			Migratory
Lesser scaup	*Aythya affinis*		Seen in rafts in Cathlamet Bay and around the finger piers, especially Piers 6, 7, and 8.	Migratory
Mallard	*Anas platyryhnchos*		Many pairs of mallards observed.	Year-round
Northern shoveler	*Anas clypeata*		Seen feeding adjacent the mudflat area offshore of the Landfill during low tide.	Year-round
Osprey	*Pandion haliaetus*		Osprey pair active in the area with their nest on the channel marker north of Pier 1.	Migratory
Red-tailed hawk	*Buteo jamaicensis*			Year-round
Red-winged blackbird	*Agelaius phoeniceus*		Flocks seen.	Year-round
Ring-billed gull	*Larus delawarensis*			Year-round
Rock pigeon	*Columba livia*			Year-round
Song sparrow	*Melospiza melodia*			Year-round
Tree swallow	*Tachycineta bicolor*			Migratory
Vaux's swift	*Chaetura vauxi*			Migratory
Western gull	*Larus occidentalis*			Year-round
Western scrub-jay	*Aphelocoma californica*			Year-round
White-crowned sparrow	*Zonotrichia leucophrys*		Observed in the field habitat west of the Landfill.	Year-round
Wilson's warbler	*Wilsonia pusilla*			Migratory

Table 2-4 (continued)
Wildlife Species Identified During Initial Site Visit (May 6-7, 2008)
Tongue Point Multi-Sites Project, Astoria, Oregon

Species	Genus Species [1]	State Status [2]	Field Notes	Year-round or Migratory
Other Wildlife				
Asiatic clam	*Corbicula sp.*		Sampled for biota tissue analysis.	Year-round
Black-tailed (mule) deer	*Odocoileus hemionus*			Year-round
Brush rabbit	*Sylvilagus bachmani*			Year-round
Coyote	*Canis latrans*			Year-round
Crayfish	Uncertain	CS	Presumptive identification (*Oronectes neglectus* , *Procambarus clarkii* , or *Pacifastacus sp*).	Year-round
Feral cats	*Felis sp.*			Year-round
Harbor seal	*Phoca vitulina*			Year-round
House mouse	*Mus musculus*			Year-round
Mountain lion	*Felis concolor*		Reported by Job Corps Center staff.	Year-round
Northern raccoon	*Procyon lotor*			Year-round
Northern river otter	*Lontra canadensis*			Year-round
Nutria	*Myocastor coypus*			Year-round
Pacific chorus (tree) frog	*Pseudacris (Hyla) regilla*			Year-round
Prickly sculpin	*Cottus asper*		Sampled for biota tissue analysis.	Year-round
Sea lion	*Uncertain*		Presumptive identification (*Zalophus californianus* or *Eumetopias jubatus*).	
Striped skunk	*Mephitis mephitis*		Seen as a roadkill in the area.	Year-round
Three-spined stickleback	*Gasterosteus aculeatus*		Sampled for biota tissue analysis.	Year-round
Virginia opossum	*Didelphis virginiana*			Year-round

Notes:

[1] Latin genus species names are in accordance with the Chandler *et al.* 2001 (birds), Bowers *et al.* 2007 (mammals) and Behler and King 1979 (reptiles and amphibian).

[2] State Status are State Threatened (ST), State Sensitive Species (SSS), and Currently Stable (CS) from Oregon Department of Fish and Wildlife 2009.

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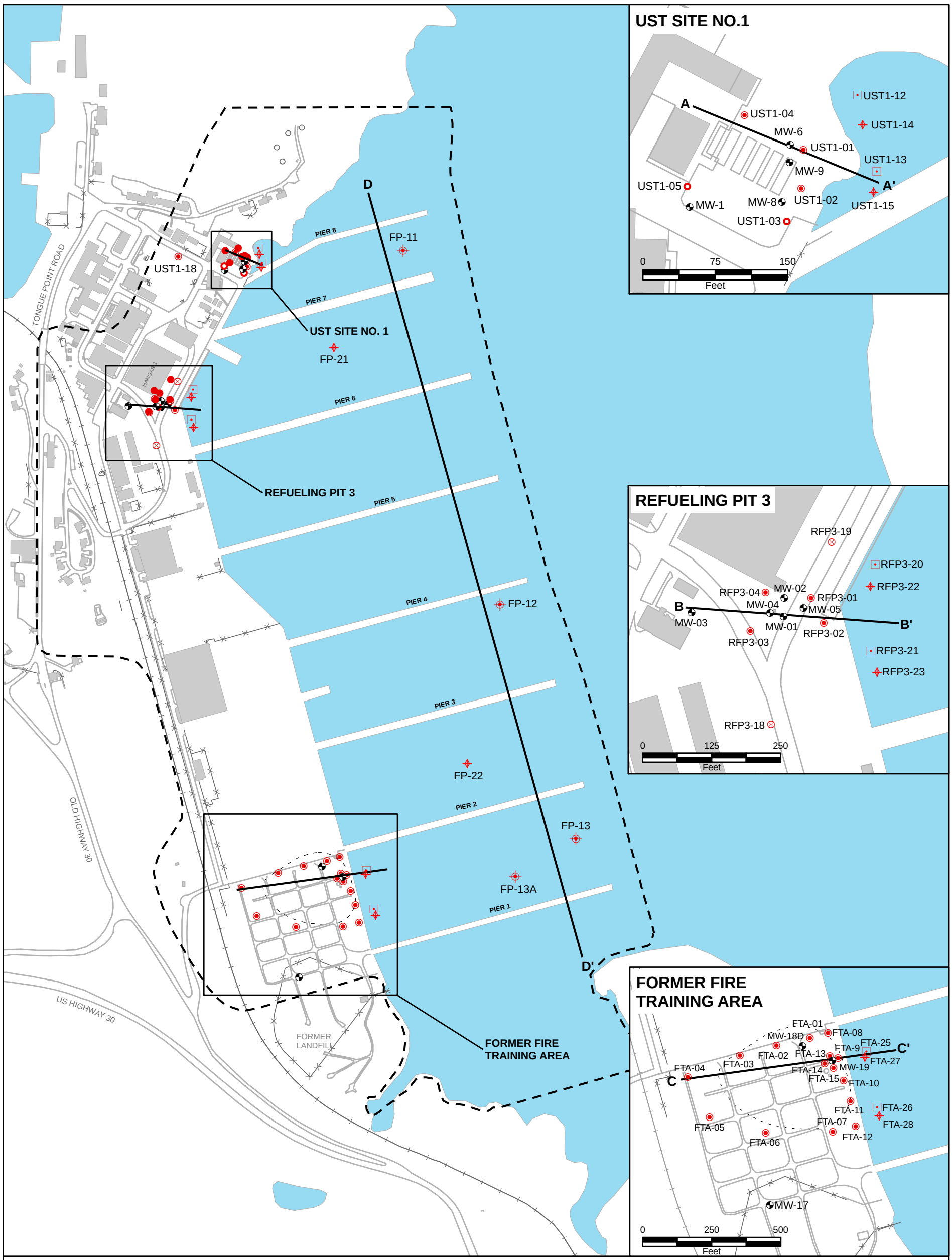


LEGEND

- AMBIENT AIR LOCATION
- DPT BORING/MICROWELL
- EXISTING MONITORING WELL
- DPT BORING
- SEDIMENT CORE LOCATIONS
- SURFACE WATER SAMPLE LOCATION
- NEARSHORE SEDIMENT CORE SAMPLE
- CROSS SECTION LINES
- FENCE
- RAILROAD
- HISTORIC VINYL CHLORIDE PLUME
- STUDY AREA BOUNDARY

NOTES:

1. BASE MAP FILES FROM URS (FIGURE 1-2) SEPTEMBER 2007.
2. DPT = DIRECT PUSH TECHNOLOGY
3. UST = UNDERGROUND STORAGE TANK
4. US = UNITED STATES
5. NO. = NUMBER
6. URS = URS CORPORATION

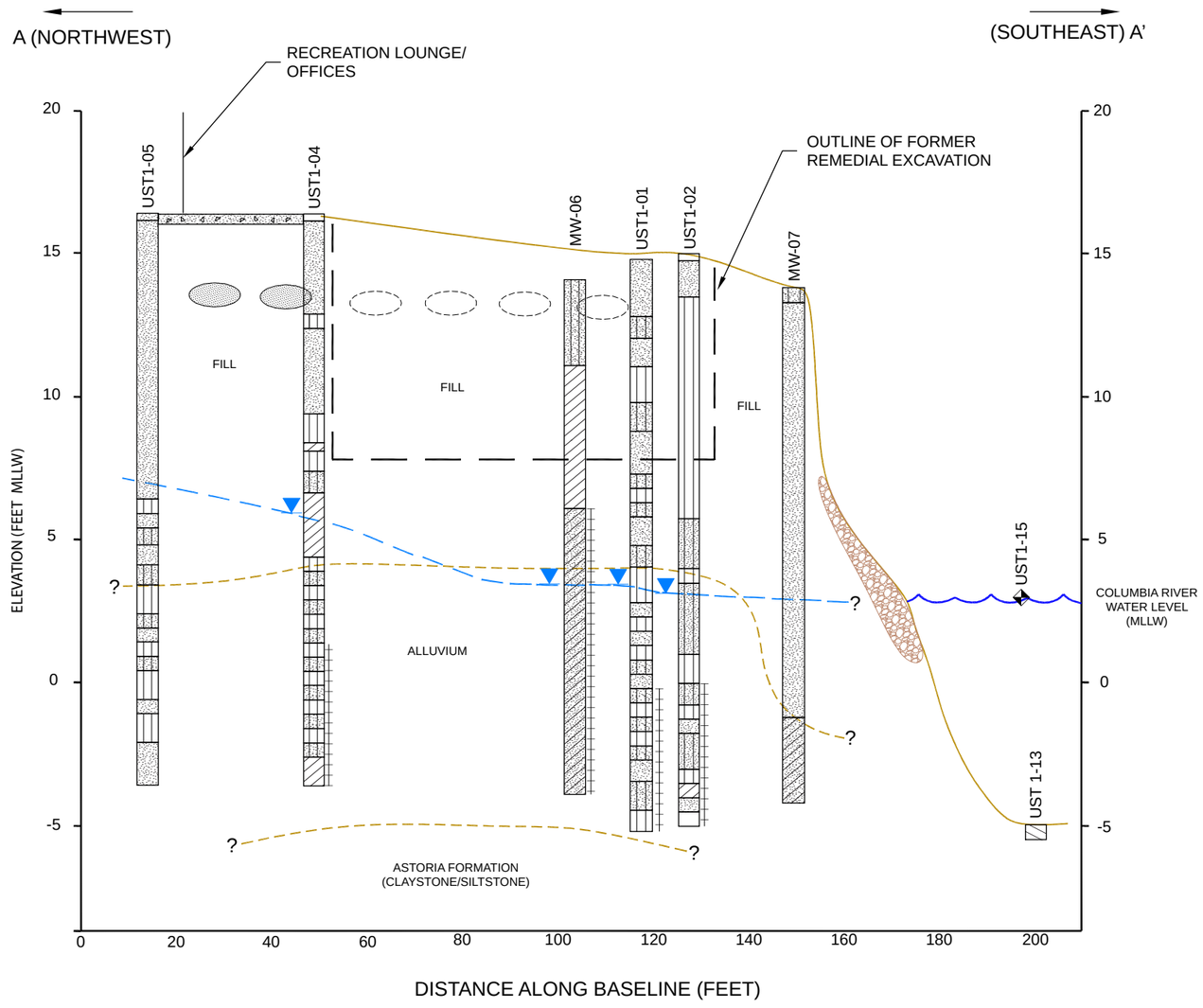
CDM

U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

CROSS SECTIONS BASE MAP

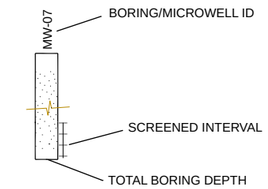
TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 2-1



HORIZONTAL SCALE: 1" = 30'
VERTICAL SCALE: 1" = 5'

LEGEND



- SURFACE WATER SAMPLE LOCATION
- SURFACE SEDIMENT SAMPLE LOCATION
- GROUNDWATER ELEVATION, SEPTEMBER 2008
- RIP-RAP SHORE LINE
- CONCRETE
- ? INFERRED
- UST (CLOSED IN PLACE)
- UST (REMOVED)
- MLLW MEAN LOWER LOW WATER
- UST UNDERGROUND STORAGE TANK

LITHOLOGIC LEGEND

- SP POORLY GRADED SAND; SAND-GRAVEL MIXTURES, WITH LITTLE TO NO FINES
- SM SILT; SILT, CLAY, SAND MIXTURES, MAY CONTAIN TRACE ORGANICS, WOOD, PLANT OR SHELL DEBRIS
- ML SILTY SAND; SAND, GRAVEL MIXTURES, MINOR FINES
- CL CLAY; CLAY, SILT, SAND MIXTURES, MAY CONTAIN TRACE ORGANICS, WOOD, PLANT OR SHELL DEBRIS
- SC CLAYEY SAND; SAND, CLAY, GRAVEL MIXTURES

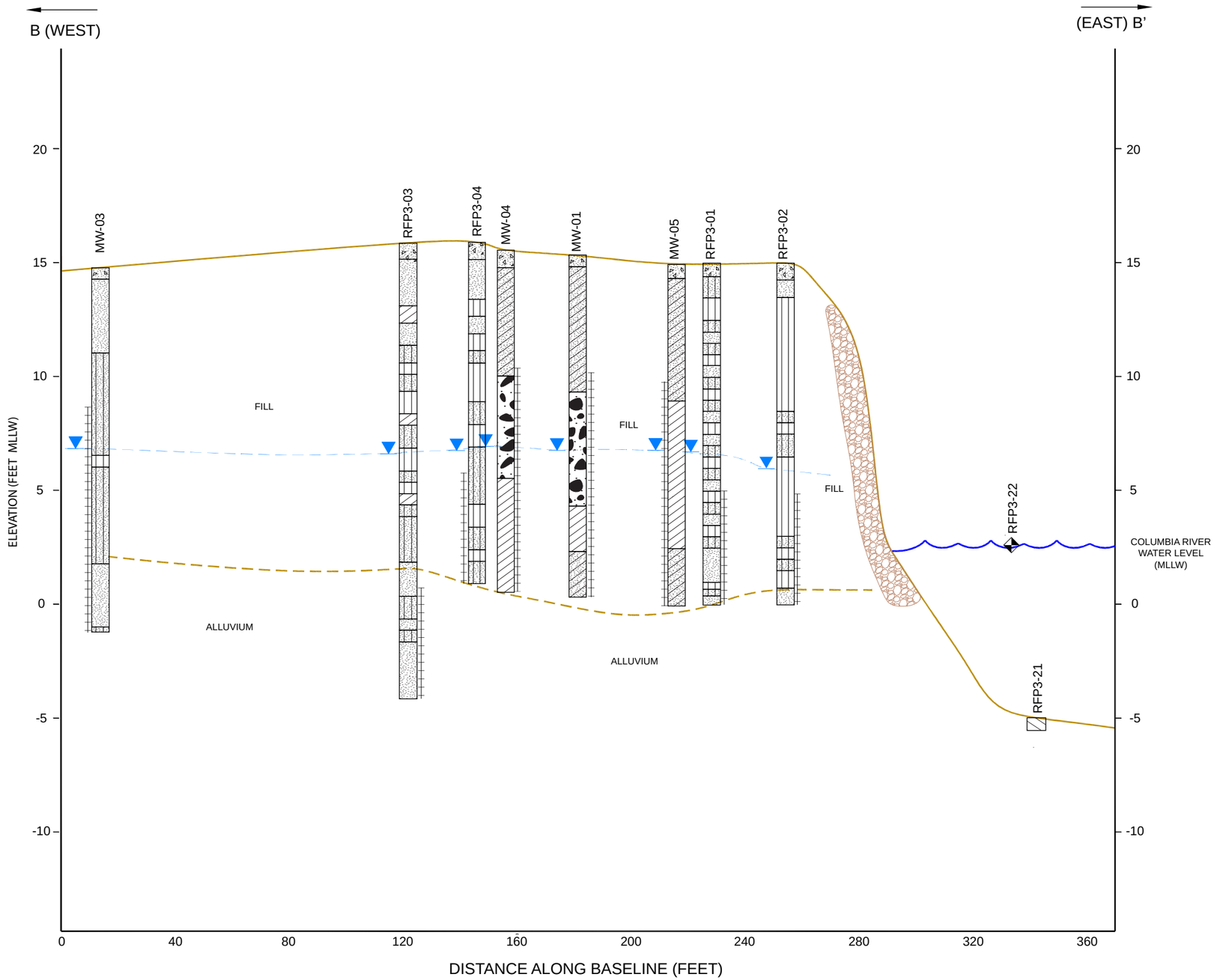
CDM

U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

GEOLOGIC CROSS SECTION A-A'
UST SITE NO. 1

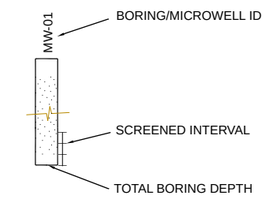
TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 2-2



HORIZONTAL SCALE: 1" = 40'
VERTICAL SCALE: 1" = 5'

LEGEND



SURFACE WATER SAMPLE LOCATION

SURFACE SEDIMENT SAMPLE LOCATION

GROUNDWATER ELEVATION, SEPTEMBER 2008

RIP-RAP SHORE LINE

CONCRETE - TYPICALLY 18"

MLLW MEAN LOWER LOW WATER

LITHOLOGIC LEGEND

GP POORLY GRADED GRAVEL; GRAVEL-SAND MIXTURES, WITH LITTLE TO NO FINES

SP POORLY GRADED SAND; SAND-GRAVEL MIXTURES, WITH LITTLE TO NO FINES

SM SILT; SILT, CLAY, SAND MIXTURES, MAY CONTAIN TRACE ORGANICS, WOOD, PLANT OR SHELL DEBRIS

ML SILTY SAND; SAND, GRAVEL MIXTURES, MINOR FINES

CL CLAY; CLAY, SILT, SAND MIXTURES, MAY CONTAIN TRACE ORGANICS, WOOD, PLANT OR SHELL DEBRIS

SC CLAYEY SAND; SAND, CLAY, GRAVEL MIXTURES

CDM

U.S. ARMY
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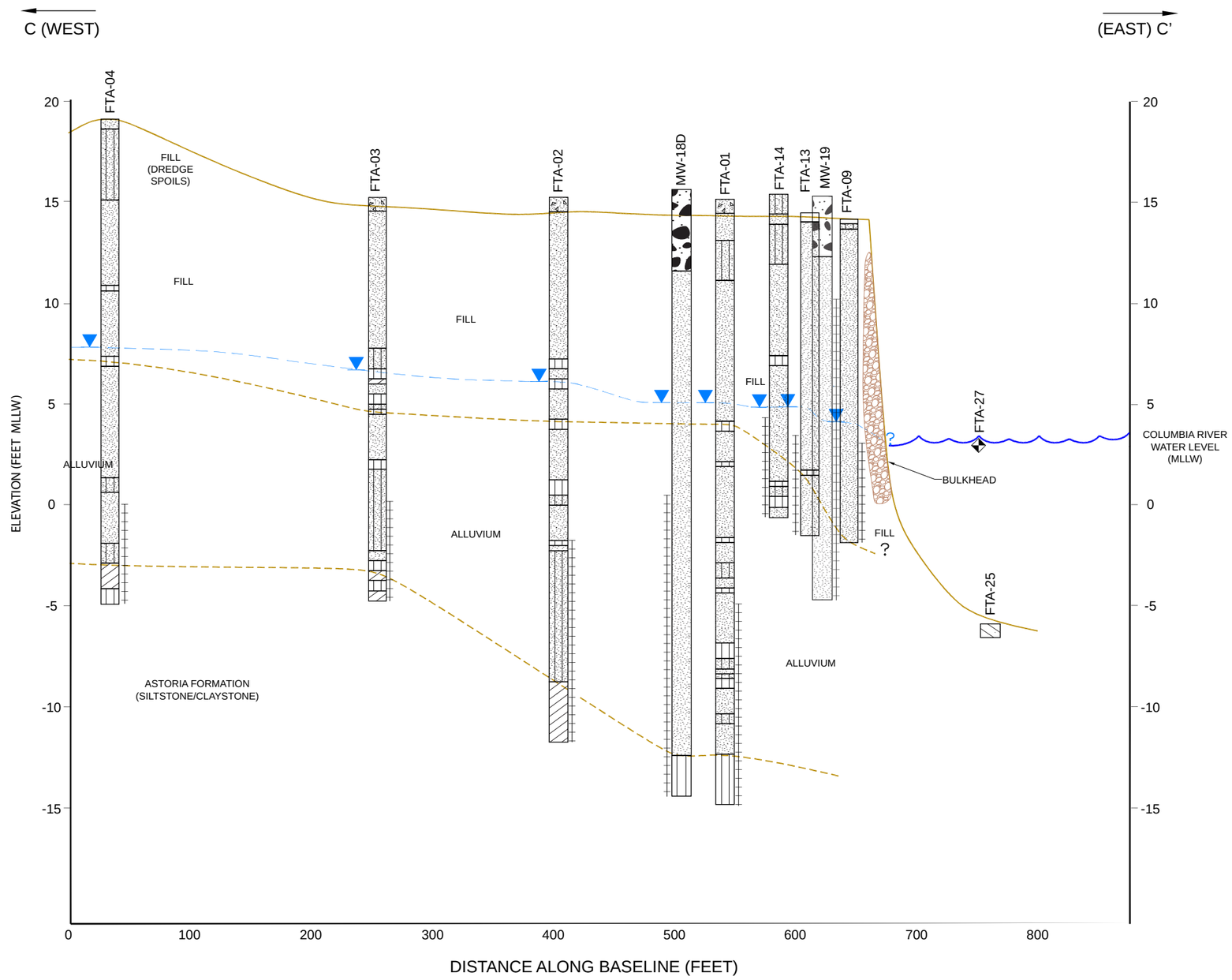
SEATTLE DISTRICT
SEATTLE, WASHINGTON

GEOLOGIC CROSS SECTION B-B'
REFUELING PIT 3

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 2-3



HORIZONTAL SCALE: 1" = 100'

VERTICAL SCALE: 1" = 6'

LEGEND

MW-01 — BORING/MICROWELL ID

SCREENED INTERVAL

TOTAL BORING DEPTH

SURFACE WATER SAMPLE LOCATION

SURFACE SEDIMENT SAMPLE LOCATION

GROUNDWATER ELEVATION, SEPTEMBER 2008

RIP-RAP SHORE LINE

CONCRETE

? INFERRED

MLLW MEAN LOWER LOW WATER

LITHOLOGIC LEGEND

GP POORLY GRADED GRAVEL; GRAVEL-SAND MIXTURES, WITH LITTLE TO NO FINES

SP POORLY GRADED SAND; SAND-GRAVEL MIXTURES, WITH LITTLE TO NO FINES

SM SILT; SILT, CLAY, SAND MIXTURES, MAY CONTAIN TRACE ORGANICS, WOOD, PLANT OR SHELL DEBRIS

ML SILTY SAND; SAND, GRAVEL MIXTURES, MINOR FINES

CL CLAY; CLAY, SILT, SAND MIXTURES, MAY CONTAIN TRACE ORGANICS, WOOD, PLANT OR SHELL DEBRIS

SC CLAYEY SAND; SAND, CLAY, GRAVEL MIXTURES

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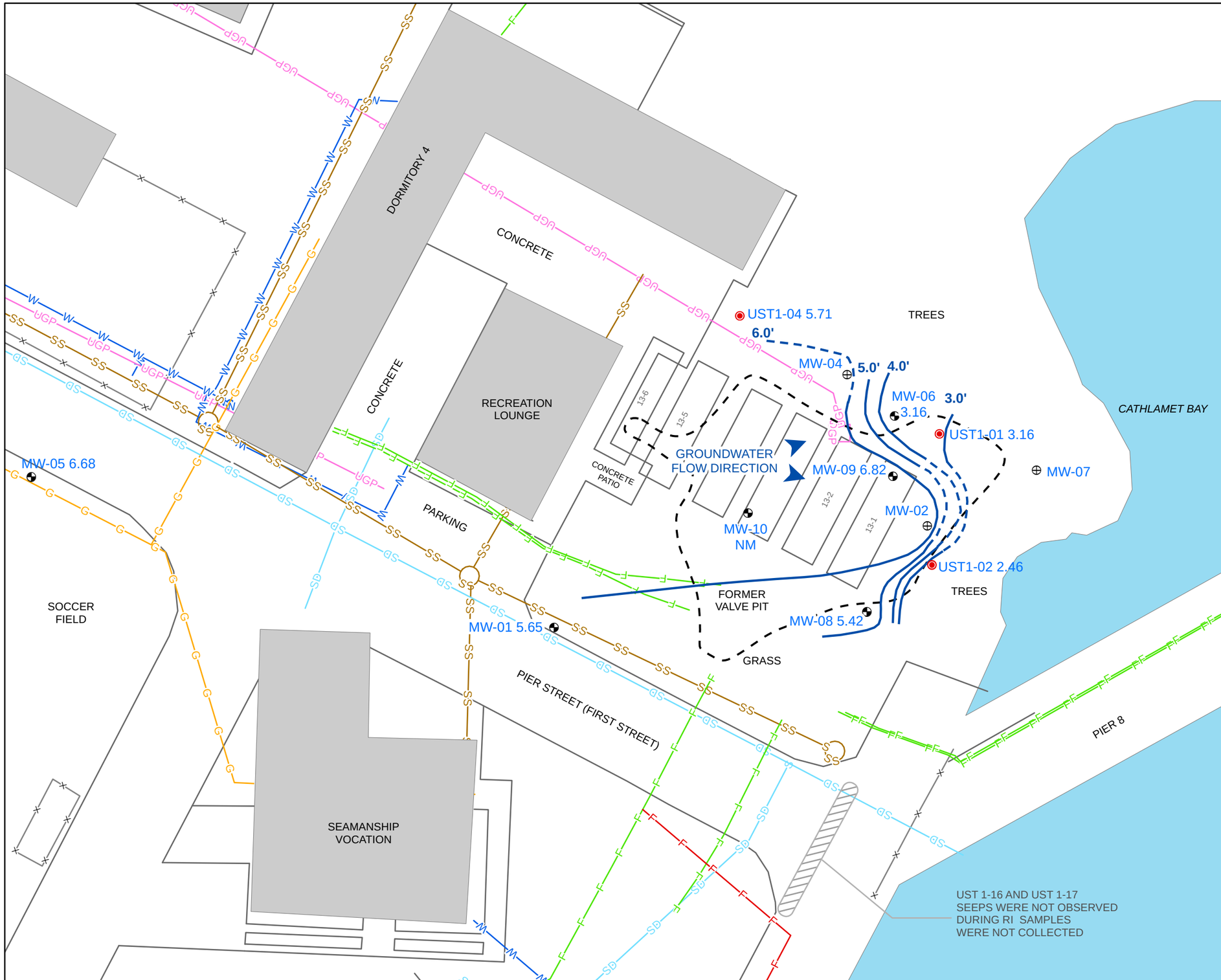
GEOLOGIC CROSS SECTION C-C'
FIRE TRAINING AREA

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 2-4



LEGEND

- EXISTING MONITORING WELL
- ABANDONED MONITORING WELL
- DPT BORING/MICROWELL
- APPROXIMATE EXTENT OF JULY 2001 EXCAVATION
- 6.0' GROUNDWATER ELEVATION CONTOUR (FT MLLW), DASHED WHERE ELEVATION WAS ESTIMATED
- FENCE
- F FUEL LINE FROM GEOPHISICAL SURVEY
- F FUEL LINE NOT CONFIRMED BY GEOPHYSICAL SURVEY
- UST1-02 2.46 WELL IDENTIFICATION AND GROUNDWATER ELEVATION (FT MLLW)

UTILITIES

- G GAS
- UGP UNDERGROUND POWER
- SS SANITARY SEWER
- S STEAM
- SD STORM DRAIN
- W WATER

NOTES

1. GROUNDWATER ELEVATION CONTOURS ARE BASED ON MEASUREMENTS COLLECTED FROM SEPTEMBER 22 THROUGH 26, 2008 AND DO NOT REPRESENT A SINGLE SNAPSHOT IN TIME; HOWEVER, THEY DO REFLECT STATIC CONDITIONS MEASURED IN THE WELL.
2. FREE PRODUCT OBSERVED IN MW-06 AND GROUNDWATER ELEVATION CORRECTED FOR FREE PRODUCT THICKNESS.
3. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
4. BASE MAP FILES FROM URS (FIGURE 3-2) SEPTEMBER 2007.
5. DPT = DIRECT PUSH TECHNOLOGY
6. UST = UNDERGROUND STORAGE TANK
7. MLLW = MEAN LOWER LOW WATER
8. FT = FEET
9. RI = REMEDIAL INVESTIGATION
10. NM = NOT MEASURED; UNABLE TO LOCATE

0 15 30 60
Feet

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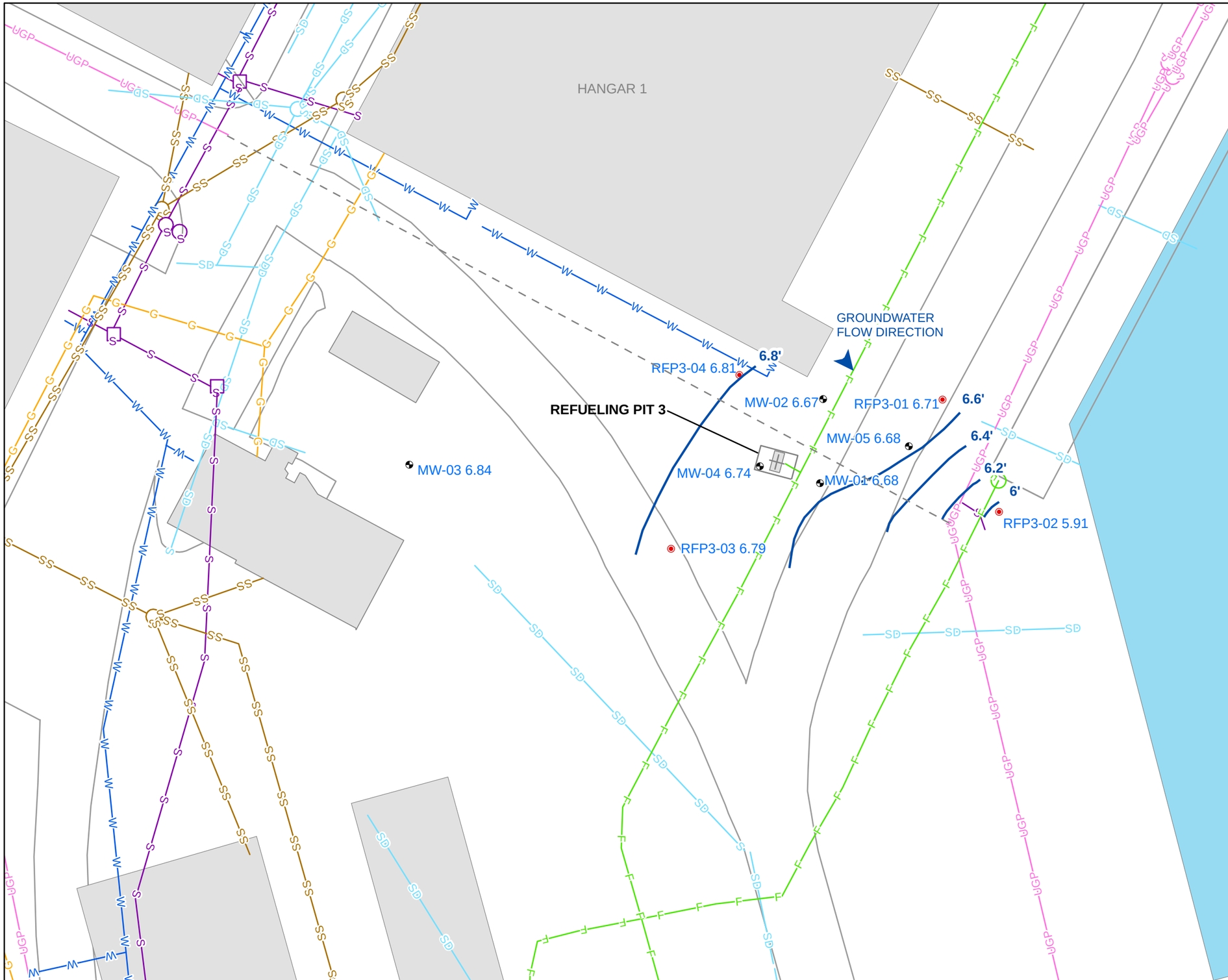
UST SITE NO. 1
GROUNDWATER CONTOUR MAP

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 2-5



LEGEND

- DPT BORING/MICROWELL
- EXISTING MONITORING WELL
- 6.2' GROUNDWATER ELEVATION CONTOUR (FT MLLW)
- FUEL LINE FROM GEOPHYSICAL SURVEY
- FUEL LINE NOT CONFIRMED BY GEOPHYSICAL SURVEY
- RFP3-02 5.91 WELL IDENTIFICATION AND GROUNDWATER ELEVATION (FT MLLW)

UTILITIES

- GAS
- UNDERGROUND POWER
- SANITARY SEWER
- STEAM
- STORM DRAIN
- WATER

NOTES:

1. GROUNDWATER ELEVATION CONTOURS ARE BASED ON MEASUREMENTS COLLECTED FROM SEPTEMBER 22 THROUGH 26, 2008 AND DO NOT REPRESENT A SINGLE SNAPSHOT IN TIME; HOWEVER, THEY DO REFLECT STATIC CONDITIONS MEASURED IN THE WELL.
2. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
3. BASE MAP FILES FROM URS (FIGURE 3-4) SEPTEMBER 2007.
4. APPROXIMATE LIMITS OF PIT REMOVAL EXCAVATION INDICATED BY CONCRETE PATCH.
5. DPT = DIRECT PUSH TECHNOLOGY
6. MLLW = MEAN LOWER LOW WATER
7. FT = FEET

0 20 40 80
Feet

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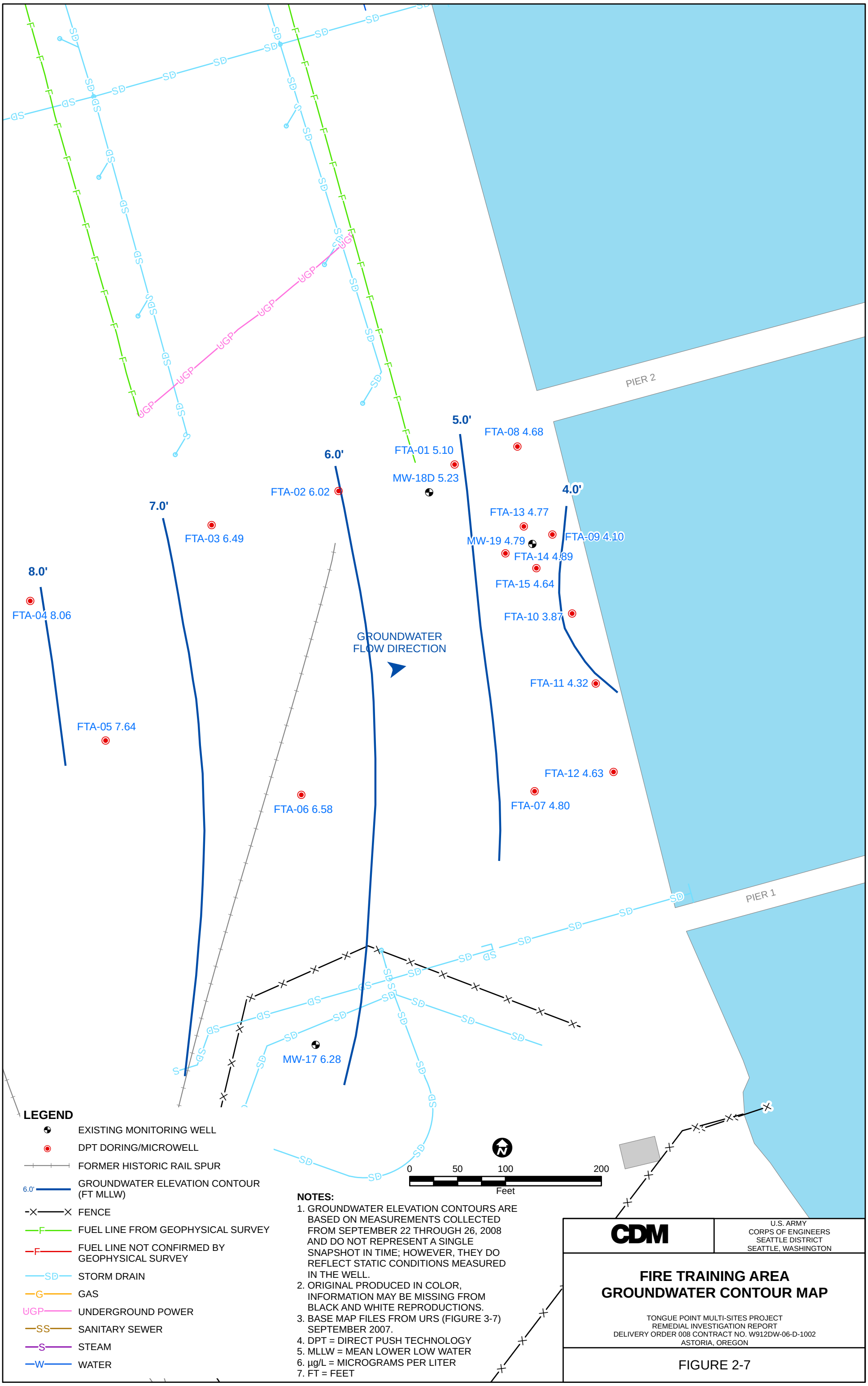
REFUELING PIT 3 GROUNDWATER CONTOUR MAP

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 2-6


PIER 2
PIER 1
5.0'
FTA-08 4.68
FTA-01 5.10
6.0'
MW-18D 5.23
FTA-02 6.02
4.0'
7.0'
FTA-13 4.77
FTA-03 6.49
MW-19 4.79
FTA-09 4.10
FTA-14 4.89
8.0'
FTA-15 4.64
FTA-04 8.06
FTA-10 3.87
GROUNDWATER
FLOW DIRECTION
FTA-11 4.32
FTA-05 7.64
FTA-12 4.63
FTA-06 6.58
FTA-07 4.80
MW-17 6.28
0
50
100
200
Feet
LEGEND
EXISTING MONITORING WELL
DPT DORING/MICROWELL
FORMER HISTORIC RAIL SPUR
6.0'
GROUNDWATER ELEVATION CONTOUR (FT MLLW)
FENCE
FUEL LINE FROM GEOPHYSICAL SURVEY
FUEL LINE NOT CONFIRMED BY GEOPHYSICAL SURVEY
STORM DRAIN
GAS
UGP
UNDERGROUND POWER
SANITARY SEWER
STEAM
WATER
NOTES:
1. GROUNDWATER ELEVATION CONTOURS ARE BASED ON MEASUREMENTS COLLECTED FROM SEPTEMBER 22 THROUGH 26, 2008 AND DO NOT REPRESENT A SINGLE SNAPSHOT IN TIME; HOWEVER, THEY DO REFLECT STATIC CONDITIONS MEASURED IN THE WELL.
2. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
3. BASE MAP FILES FROM URS (FIGURE 3-7) SEPTEMBER 2007.
4. DPT = DIRECT PUSH TECHNOLOGY
5. MLLW = MEAN LOWER LOW WATER
6. µg/L = MICROGRAMS PER LITER
7. FT = FEET
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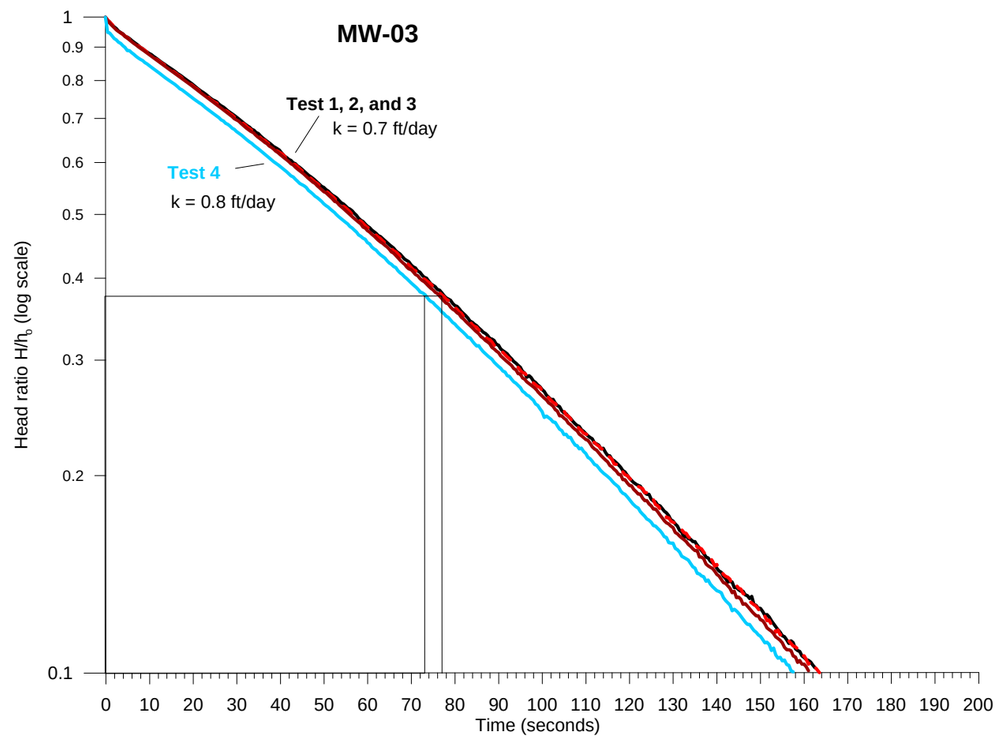
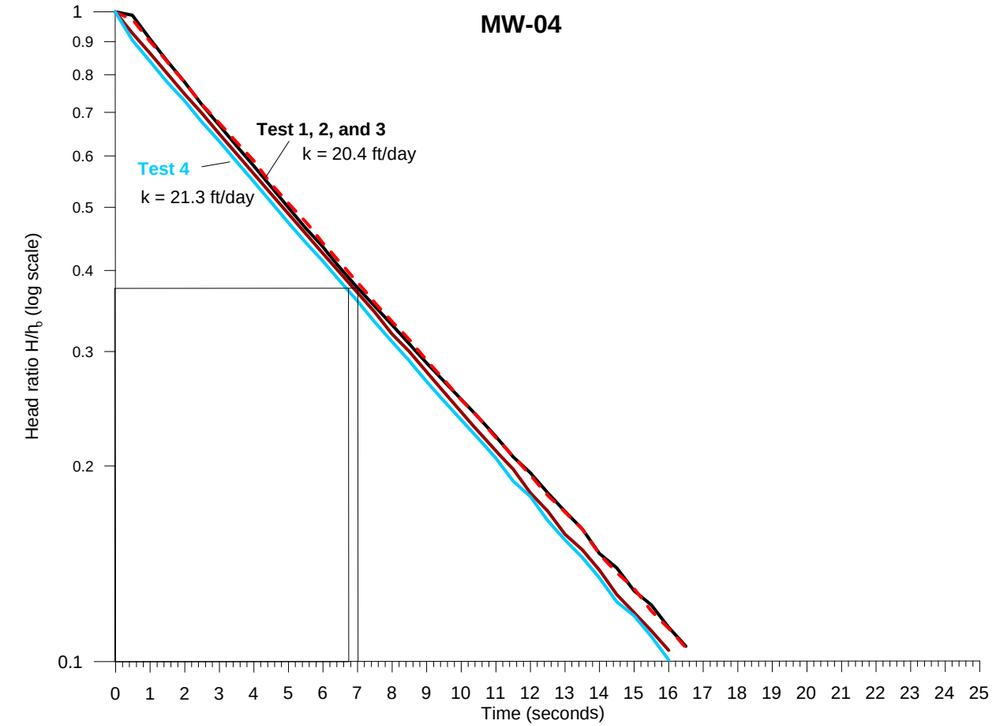
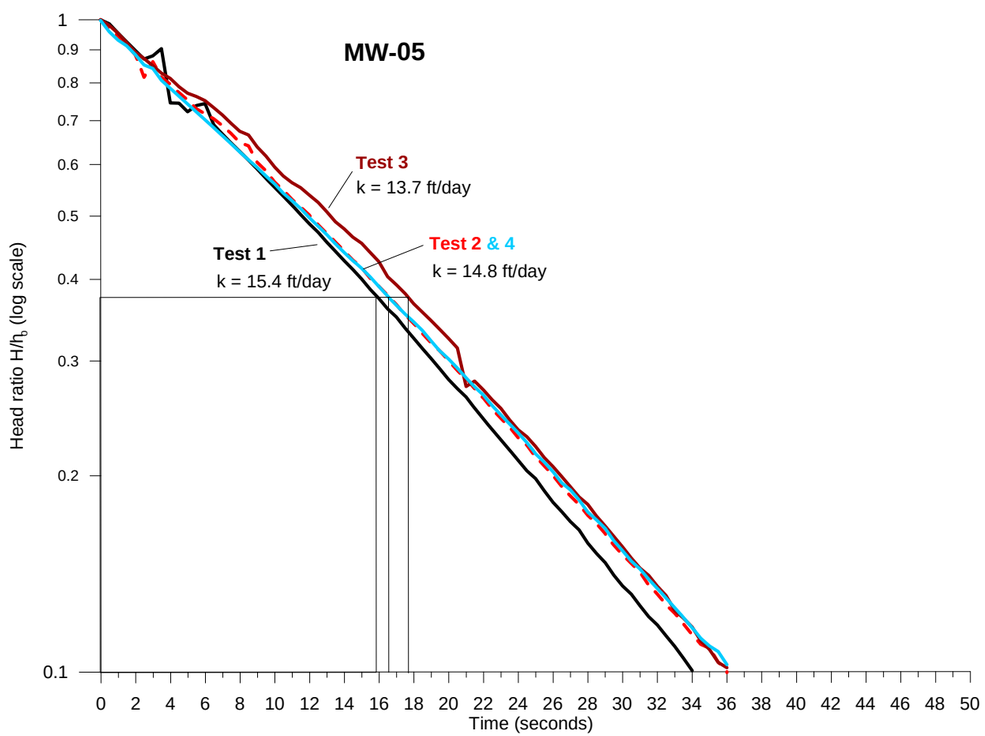
FIRE TRAINING AREA
GROUNDWATER CONTOUR MAP
TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON
FIGURE 2-7







Tongue Point Slug Test Results - Hydraulic Conductivity (ft/day)

Test Number	MW-03	MW-04	MW-05
Test 1	0.8	20.4	15.4
Test 2	0.8	20.4	14.8
Test 3	0.8	20.4	13.7
Test 4	0.7	21.3	14.8

Hvorslev Equation(1)

$K = r^2 \ln(L/R) / 2LT_o$

Where:

K = hydraulic conductivity
r = the radius of the well casing
R = the radius of the well screen
L = the length of the well screen
T_o = the time it takes for the water level to rise or fall to 37 percent of the initial change (see figures)

(1) Fetter, 2001; pages 193-197

Notes:
ft = feet
H = Measured head
h_O = Measure head after slug deployment (at time 0)

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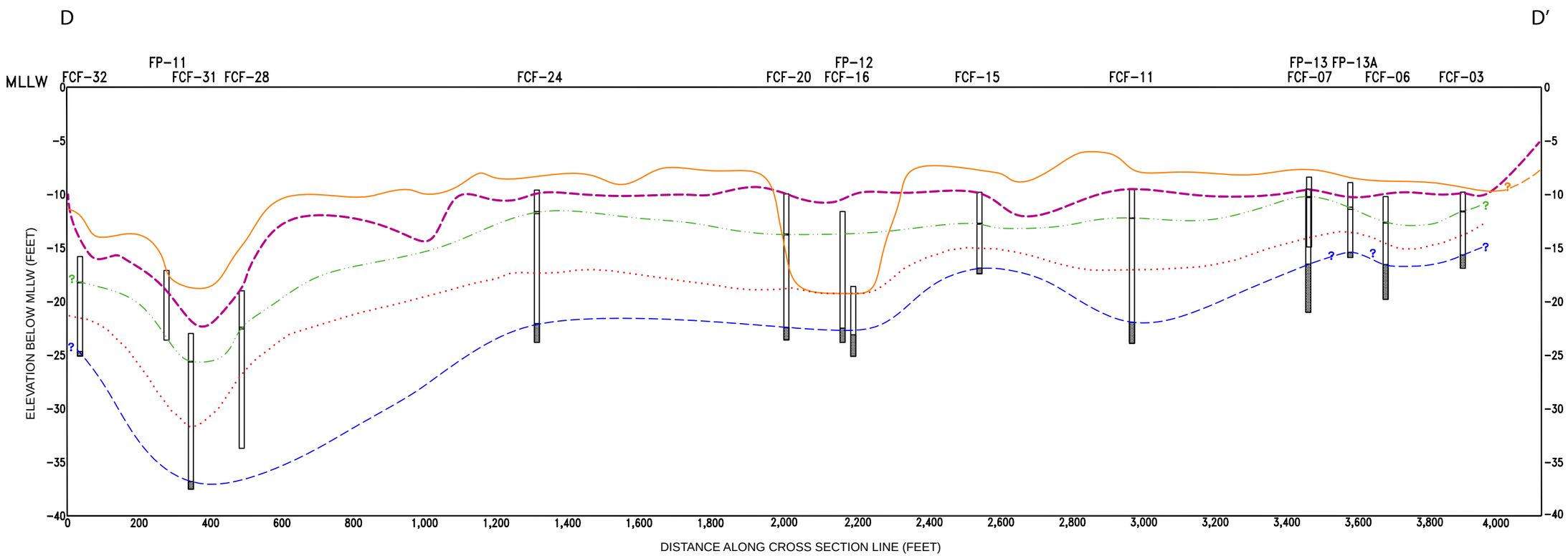
SLUG TEST RESULTS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 2-8



LEGEND

- 2008 SEDIMENT SURFACE
- 1995 SEDIMENT SURFACE
- 1980 SEDIMENT SURFACE (MT. ST. HELENS ASH)
- 1962 SEDIMENT SURFACE (SEDIMENTATION RATE BASED)
- 1947 SEDIMENT SURFACE (TOP OF SAND)
- MLLW MEAN LOWER LOW WATER
- ? INFERRED

NOTES

HORIZONTAL SCALE: 1" = 300'
VERTICAL SCALE: 1" = 10'
1995 SEDIMENT CORE LOGS AND BATHYMETRY DATA FROM WOODWARD-CLYDE, 1995, "FINGER PIERS SEDIMENT LIMITED REMEDIAL INVESTIGATION."
2008 SEDIMENT CORE LOGS AND BATHYMETRY DATA FROM CDM TONGUE POINT MULTI-SITES PROJECT REMEDIAL INVESTIGATION.

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SEDIMENT CORE CROSS SECTION D-D'
AQUATIC DECISION UNITS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 2-9

Section 3
Study Area Investigation

This section presents a brief description of data quality objectives (DQOs) for the RI, the methods of the investigation, and deviations from the QAPP (CDM 2008b). A summary of quality assurance (QA)/quality control (QC) activities conducted, as part of this investigation, is included. This includes a brief narrative of the data verification, validation, and usability review, and a summary of the review results.

Based on the previous investigations within the Study Area, the QAPP set the focus on addressing the release of petroleum hydrocarbons (and associated degradation byproducts) as the principal threat to human and ecological receptors in the AST Fuel Storage Area, UST Site No. 1, and UST Site No. 4 DUs. Therefore, the chemicals analyzed in each of these DUs were limited to petroleum-related compounds. Previously unreported data from previous environmental investigations conducted by the USACE at Refueling Pit 3, Incinerator Building, and Fire Training Area DUs have been combined with analytical data collected during this RI to develop a complete description of environmental conditions and to evaluate potential threats to receptor populations at these DUs. Relevant analytical data collected during previous investigations that are used in the RI are included in **Appendix D**. A complete set of analytical data collected for this RI is presented in **Appendix E**. A discussion of the RI data sets for each medium is provided in **Section 4**.

3.1 Data Quality Objectives

DQOs were identified in the Final MP and further modified in the Final QAPP (CDM 2008a,b). The DQOs were first developed by evaluating the existing data and determining what additional data were necessary to characterize the study area and to develop a conceptual site model (CSM). This RI obtained additional data to achieve the following objectives:

- Define source areas of contamination.
- Evaluate potential pathways of contaminant migration.
- Identify potential receptors and associated exposure pathways.

The DQOs developed for each DU of the study area are briefly summarized in the sections that follow. A more detailed description of the DQOs is presented in Section 2 of the QAPP (CDM 2008b).

3.1.1 AST Fuel Storage Area

A summary of the DQO discussion for the AST Fuel Storage Area is presented here.

3.1.1.1 AST Fuel Storage Area Objective

The objective for the AST Fuel Storage Area was to assess the nature and extent of petroleum-related compounds in soil and groundwater beneath and surrounding the AST foundations and the pump house. This was done to determine (or validate the assumptions of the CSM specifically as it pertains to) the fate and transport of chemicals that may be a threat to potential ecological receptors.

3.1.1.2 AST Fuel Storage Area Data Gaps

Petroleum had been documented in oiled sand placed at the ground surface as part of the AST foundation; however, the lateral and vertical extent of petroleum in soil had not been delineated. The presence or absence of petroleum in the soil surrounding the AST foundations, and near the pump house, had not been established. The presence or absence of petroleum in groundwater at and downgradient of the AST Fuel Storage Area had not been investigated. The direction of groundwater flow in this area had not been determined.

3.1.1.3 AST Fuel Storage Area Performance Objectives

The performance objectives for the AST Fuel Storage Area are as follows:

- Reporting limits for the soil and groundwater analytical results should be equal to or less than ecologically based SLs to the extent practicable. The lateral and vertical extent of chemicals in soil should be identified to allow for the analysis of the potential transport pathways.
- Soil exploration and sampling provide data to support a CSM of the soil and bedrock profile at the AST Fuel Storage Area. Temporary borings completed throughout the DU were used to determine the occurrence of groundwater.
- Groundwater sampling provides data to support a presence or absence determination of petroleum in groundwater at the AST Fuel Storage Area. If groundwater contamination is present, data will be used to assess the potential transport pathway of groundwater to surface water.
- Water level data (with vertical survey control) from the three microwells must be collected with sufficient accuracy (to the nearest 0.01 foot) to estimate the groundwater flow direction.

3.1.1.4 AST Fuel Storage Area Decision Rules

The decision rules for the AST Fuel Storage Area are the following:

- If the data meets the quality parameters discussed in **Section 3.8**, the data will be used to evaluate the nature and extent of chemicals. Additionally, chemical data will be used to determine the potential transport of chemicals downgradient to support human health risk evaluations and estimate the risk to potential terrestrial ecological receptors.

- If analytical results are less than RBCs, the data will be used only to evaluate the nature and extent of chemicals and will not be used in the risk assessments.

3.1.2 UST Site No. 1

A summary of the DQO discussion for UST Site No. 1 is presented here.

3.1.2.1 UST Site No. 1 Sampling Objectives

The sampling objectives for UST Site No. 1 were to define the nature and extent of LNAPL and chemicals in soil, soil gas, groundwater, surface water, and near-shore sediment due to fuel leakage/spillage from the tanks and associated piping. Data will be used to support human health risk evaluations and to evaluate ecological risks posed to downgradient aquatic receptors by conditions at UST Site No. 1.

3.1.2.2 UST Site No. 1 Data Gaps

Petroleum hydrocarbons were reported in subsurface soil and as LNAPL on groundwater at UST Site No. 1. The lateral extent of LNAPL and petroleum-related chemicals in soil, soil gas, and groundwater had not been delineated to allow for the evaluation of potential impacts to human health and ecological receptors. Although there were limited subsurface soil and groundwater data, there were no soil gas data. In addition, surface water and near-shore sediment had not been sampled before this RI.

The presence, extent, and the chemical/physical properties of LNAPL in the vicinity of MW-06 needed to be identified to support evaluations for recovery and remedy selection. In addition, there were no current geochemical property data to define the conditions for natural attenuation of VOCs in groundwater.

3.1.2.3 UST Site No. 1 Performance Objectives

The performance objectives for UST Site No. 1 are the following:

- Set analytical reporting limits generally equal to or less than the applicable screening criteria for human and ecological receptors to the extent practicable.
- Select soil sample locations to delineate the lateral extent of petroleum in soil at concentrations greater than applicable screening criteria.
- Assess the presence or absence of petroleum (dissolved phase and LNAPL) in soil and groundwater and evaluate the potential for petroleum-related chemicals to migrate to offshore surface water and sediment.
- Assess the presence or absence of petroleum hydrocarbons in soil gas near the dormitory and other previously identified LNAPL source areas.
- Assess the presence or absence of petroleum hydrocarbons in near-shore sediment and surface water.

3.1.2.4 UST Site No. 1 Decision Rules

The decision rules for UST Site No. 1 are the following:

- If the data meets the quality parameters discussed in **Section 3.8**, the data will be used in the risk evaluations.
- If data quality does not meet these requirements, then, to the extent practical, data will be used to delineate lateral extent of impacts to soil, near-shore sediment, soil gas, and groundwater, and to recommend additional analysis of soil, soil gas, and groundwater, to meet risk assessment objectives.

3.1.3 Refueling Pit 3

A summary of the DQO discussion for Refueling Pit 3 is presented next.

3.1.3.1 Refueling Pit 3 Sampling Objectives

The sampling objectives for Refueling Pit 3 were the following:

- Identify the nature and extent of petroleum-related compounds in soil, soil gas, near-shore sediment, and groundwater to support human health risk and risk evaluations of potential aquatic ecological receptors, to identify potential source areas, and to support identification and evaluation of remedial technologies.
- Confirm groundwater flow direction and gradient to assess the potential groundwater to surface water transport pathway and whether there is potential for groundwater flow to transport VOCs to areas beneath Hangar 1.
- Verify the absence (or presence) of dissolved phase and LNAPL to support potential transport pathways and remedial recommendations.
- Collect geochemical data to characterize groundwater to support future identification evaluation of remedial technologies for soil, soil gas, and groundwater. Collect soil physical property data to support modeling of vapor intrusion from soil gas to indoor air into Hangar 1.

3.1.3.2 Refueling Pit 3 Data Gaps

The five existing wells sampled in October 2007 indicated the presence of VOCs in groundwater, but did not delimit the nature and extent of VOCs. Historical data are greater than 10 years old and do not represent current conditions. Historical water level measurements were not sufficient to evaluate the current groundwater gradient. Groundwater geochemical data were last measured in 1998. Therefore, existing data do not represent current geochemical and hydrogeological conditions.

The existing soil analytical results did not delineate the extent of VOCs and petroleum hydrocarbons in soil and soil gas. No data existed for soil gas, and soil property data required for evaluating soil vapor migration were limited. Additionally, nearby aquatic surface water and near-shore sediment data did not exist to evaluate potential

impacts of petroleum hydrocarbon compounds and VOCs to aquatic ecological receptors.

3.1.3.3 Refueling Pit 3 Performance Objectives

The performance objectives for Refueling Pit 3 are as follows:

- Analytical reporting limits should generally be equal to or less than the applicable screening criteria for human and ecological receptors to the extent practicable.
- Water level data (with vertical survey control) must be collected with sufficient accuracy (to the nearest 0.01 foot) and coverage to determine the groundwater flow direction. Slug testing (or other field methods) data must be sufficient to estimate aquifer properties.
- Field and laboratory analytical data must meet standards and reporting limits necessary to evaluate natural attenuation conditions.

3.1.3.4 Refueling Pit 3 Decision Rules

The decision rules for Refueling Pit 3 are the following:

- If field screening of soil and groundwater samples from the first four direct push technology (DPT) locations indicate low concentrations at the margins of the affected area, then the area will be considered delineated for the purposes of meeting RI objectives. Step-out DPT locations would be installed if evidence of contamination were found during field screening.
- If the data meets the quality parameters discussed in **Section 3.8**, the data will be used in the risk evaluations. If results do not meet all criteria specified in the QAPP, then to the extent practical, data will be used to delineate the lateral extent of impacts to soil, near-shore sediment, soil gas, and groundwater, and recommend additional analysis of soil gas and groundwater, to meet risk assessment objectives.
- If possible, the water level measurements collected downgradient from the potential source areas will be evaluated. If water level measurements can be collected between the fuel pit (a possible source area) and the surface water, then no further groundwater measurement locations are needed. If field evaluation of measurements indicate that a downgradient water level data point has not been identified, mobilize DPT to place one additional temporary well in the most likely downgradient direction.
- If LNAPL is not present, no future measurements are necessary. If LNAPL is found, further monitoring of LNAPL in existing wells and evaluation of LNAPL recovery is recommended.

3.1.4 UST Site No. 4

A summary of the DQO discussion is presented here for UST Site No. 4.

3.1.4.1 UST Site No. 4 Sampling Objectives

The sampling objectives for UST Site No. 4 were the following:

- Identify the nature and extent of petroleum-related chemicals in soil and groundwater (if present) to support human health and ecological risk evaluations. Use analytical data to identify a potential source area, and support identification and evaluation of remedial technologies.
- Identify the potential presence of groundwater in the UST "basin" excavation, and if present, evaluate whether this groundwater is confined to the excavation or is part of a local perched water-bearing zone that potentially leads to downgradient receptors.
- Identify and evaluate potential threats to terrestrial ecological receptors based on findings for chemicals in shallow soil (less than 2 feet bgs).

3.1.4.2 UST Site No. 4 Data Gaps

Petroleum compounds at concentrations greater than criteria have been documented in subsurface soil at UST Site No. 4. The horizontal and vertical extent of petroleum in soil had not been delineated. The presence or absence of petroleum in groundwater at, and downgradient of, the UST excavation had not been investigated. The nature of groundwater movement in this area had not been documented in sufficient detail to verify the CSM or to support the risk evaluations if needed.

3.1.4.3 UST Site No. 4 Performance Objective

The performance objectives for UST Site No. 4 are the following:

- Analytical reporting limits should generally be less than or equal to applicable screening criteria to the extent practicable.
- Soil sampling locations will be used to delineate the extent of contamination and verify the physical conceptual site model of topsoil over bedrock outside the limits of the previous remedial excavation.
- Groundwater sampling locations will provide data to support a presence or absence determination of petroleum in groundwater at the UST excavation area and at representative downgradient locations.

3.1.4.4 UST Site No. 4 Decision Rules

The decision rules for UST Site No. 4 are the following:

- If analytical results for petroleum-related compounds in soil or groundwater are less than residential RBCs, consider the lateral extent delineated, with no further evaluations needed.
- If analytical results of soil samples exceed RBCs, proceed with human and ecological risk evaluations.

3.1.5 Incinerator Building

A summary of the DQO discussion for the Incinerator Building is presented next.

3.1.5.1 Incinerator Objectives

The objectives for the Incinerator Building were the following:

- Assess the nature and extent of ash-related chemicals in surface soil to support evaluations of human health risk and ecological effects, using the ash and soil sample analytical results from the October 2007 sampling event.
- Estimate the volume of residual ash inside the Incinerator Building to support future evaluations of remedial alternatives.
- Obtain local or regional inorganic background concentrations for comparison of 2007 surface soil and ash chemical concentrations to background levels to support human health and terrestrial ecological risk evaluations.

3.1.5.2 Incinerator Building Data Gaps

No data gaps were anticipated. USACE will provide chemistry data for surface soil adjacent to and near the Incinerator Building that were collected in October 2007. These data were used in human health and ecological risk assessments.

3.1.5.3 Incinerator Building Performance Objectives

The performance objective for the Incinerator Building is to achieve analytical reporting limits should generally be less than or equal to applicable screening criteria to the extent practicable.

Background values for soil as determined by ODEQ were found to be sufficient for characterization of the inorganics during the human health and ecological scoping, screening, and selection of COPCs technical memoranda (CDM 2009a,b). A discussion of the background and reference criteria used in this RI is included in **Section 4.1**.

3.1.5.4 Incinerator Building Decision Rules

The decision rules for the Incinerator Building are the following:

- If the surface soil data meet the quality parameters discussed in **Section 3.8**, the data will be used in the risk evaluations. If data quality does not meet these requirements, then, to the extent practical, data will be used to delineate lateral extent of impacts to surface soil, and additional analysis of soil will be recommended to meet risk assessment objectives.
- If regional background soil chemical data are found to be insufficient, then a recommendation may be made to collect up to three background soil samples at a reference location to be determined for analysis of inorganics.

- Determine if a release of CERCLA hazardous substances has occurred at the site. The evaluation of whether a release has occurred will be made using soil data collected in October 2007 compared to regulatory criteria (see **Section 4.3.5**).

3.1.6 Fire Training Area

A summary of the DQO discussion for the Fire Training Area follows.

3.1.6.1 Fire Training Area Sampling Objectives

The sampling objectives for the Fire Training Area were to:

- Identify the nature and extent of VOCs and LNAPL in groundwater, soil, soil gas, and near-shore sediments to support human health and ecological risk evaluations, identify potential source areas, and support identification and evaluation of remedial technologies.
- Confirm groundwater flow direction and gradient to evaluate the groundwater to surface water pathway.
- Analyze groundwater samples for geochemical parameters to characterize groundwater to support identification of and future evaluation of groundwater remedial technologies for both dissolved-phase VOCs and LNAPL.
- If present, sample LNAPL and analyze chemical and physical properties to support evaluation of remedial technologies.
- Collect and analyze soil samples for physical properties to support modeling of vapor migration from soil gas to indoor air.

3.1.6.2 Fire Training Area Data Gaps

Concentrations of vinyl chloride dissolved in groundwater have been documented historically in monitoring wells located between Piers 1 and 2. Previous groundwater data from nearby wells (last sampled in 1996) reported VOCs, but these data are more than 10 years old and do not represent current concentrations or the extent of VOCs. Two wells (MW-17 and MW-18D) sampled in October 2007 indicated detections of VOCs in groundwater, and one well (MW-19) had measurable LNAPL. Although these data indicate a release, the data did not identify a source area and did not delineate the extent of VOCs in groundwater. However, based on historical groundwater data and the analytical results from the October 2007 groundwater samples, the extent of contamination along the southern boundary of the Fire Training Area has been adequately delineated and required no further investigation (URS Greiner Woodward Clyde 1999).

The presence, extent, and chemical/physical properties of LNAPL near MW-19 needed to be identified to support evaluations for recovery and remedy selection. In addition, no current groundwater elevations were available to determine

groundwater flow directions, and there were no current geochemical property data to define the conditions for natural attenuation of VOCs in groundwater.

Previous soil data (17 samples) indicate soil has been affected by VOCs, but the source areas have not been identified and there was no delineation of the extent of VOCs in soil. In addition, data did not exist for soil gas, and there were no data for the physical properties of soil to support modeling of the migration of soil gas.

Nearby aquatic surface water and near-shore sediment data did not exist to evaluate the potential impact of petroleum hydrocarbon compounds and VOC plumes on sediment and groundwater.

3.1.6.3 Fire Training Area Performance Objective

The performance objectives for the Fire Training Area are:

- Use analytical reporting limits that are generally equal to or less than applicable criteria, to the extent practicable, to support human health and ecological risk evaluations.
- Complete a topographic survey of reference point elevations with sufficient accuracy for site conditions, typically to the nearest 0.1 foot. Collect water level data with 0.01-foot precision to determine groundwater flow direction.
- Ensure that data meets performance parameters specified in the QAPP as necessary to evaluate groundwater geochemistry and soil physical properties.

3.1.6.4 Fire Training Area Decision Rules

The decision rules for the Fire Training Area are the following:

- If chemical concentrations in groundwater are less than RBCs, no further evaluations are needed. If results are greater than RBCs, delimit the lateral extent of groundwater contamination with the data, and perform site-specific risk assessments.
- If groundwater data are sufficient to estimate gradient and support evaluation of the groundwater to surface water pathway, then use these data to estimate transport to surface water in support of risk evaluations. If groundwater elevations are not sufficient to determine gradients, recommend that additional (seasonal) water level measurements be collected from existing wells.
- If sufficient type and quantity of data collected support evaluation of remedial technologies, then use the data for preliminary identification and evaluation of potential remedial technologies. If not, recommend collection of supplemental data from the existing monitoring wells to better support the preliminary evaluations of remedial technologies.

3.1.7 Aquatic – Finger Piers Area

A summary of the DQO discussion for the aquatic areas surrounding the finger piers follows.

3.1.7.1 Aquatic – Finger Piers Sampling Objective

The sampling objectives for the Aquatic - Finger Piers Area were the following:

- Collect surface sediment chemistry data and compare them with the background reference data set to support evaluations of ecological effects and human health risks associated with sediments near the finger piers.
- Evaluate the rate of sediment accumulation/deposition for assessing sediment transport/burial, to evaluate potential for future dredging, and assess potential for natural recovery as a component of a final remedy.
- Collect surface water chemical data to assess surface water human health and ecological exposure pathways.
- Collect selected biota tissue chemistry data to assess bioavailability and potential impacts to benthic fauna and to assess human health (consumption) and ecological exposure pathways (both direct and food-web exposures).
- Identify a suitable reference location for Columbia River surface sediments to represent background sediment data for surface sediments between the finger piers. This reference location will be used for background sediment data for surface sediments adjacent to the landfill and the aquatic area north of the finger piers described below.

3.1.7.2 Aquatic – Finger Piers Area Data Gaps

Current surface sediment chemistry data for both the finger piers and a reference area were not available. The previous 1998 investigation collected adequate sediment core chemical data, but there was no tie-in to existing bathymetry or sediment stratigraphy or to the potential source areas at specific sites. The previous hydrographic survey is more than 10 years old and does not represent the current surface elevation of sediment in Cathlamet Bay and the Finger Piers area. The previous investigation determined an average rate of sedimentation of 1.87 inches per year. There were no current data for surface water and tissue chemistry for the Finger Piers area.

3.1.7.3 Aquatic – Finger Piers Area Performance Objective

The performance objectives for the Aquatic - Fingers Pier Area are the following:

- Achieve analytical reporting limits less than or equal to applicable sediment SLs and generic RBCs, to the extent practicable, for protection of human health and ecological receptors.

- Achieve analytical reporting limits less than or equal to ODEQ aquatic surface water quality criteria or EPA NAWQC for consumption of water and organism, to the extent practicable, for protection of human health and ecological receptors.

- Achieve analytical reporting limits less than or equal to applicable tissue concentrations, to the extent practicable, for protection of human health and ecological receptors.

3.1.7.4 Aquatic – Finger Piers Area Decision Rules

The decision rules for the Aquatic - Finger Piers Area are the following:

- Compare sediment data to sediment SLs and reference sediment analytical data set. If data are greater than these two criteria, recommend further analysis of selected (archived) discrete, near-shore samples to delineate potential sources. If highly bioaccumulative chemicals are found to occur in surface sediments at elevated concentrations (relative to background or reference), additional biota sampling may be warranted to assess impacts to upper trophic level fish, birds, and mammals.

- In consideration of potential future uses that may require dredging, sediment chemistry will be evaluated chemical by chemical, to determine the most appropriate handling of dredged materials. Chemical quality data for the deeper sediments will be compared to the limits as described in the *Regional Sediment Evaluation Team (RSET) Dredged Material Evaluation Framework* for freshwater procedures (USACE 2009). See Section 3.7 for deviations. For assessing risks to benthic invertebrates, accepted and approved local or regional toxicity valueswill be used.

- Compare tissue data to applicable regulatory threshold data. If highly bioaccumulative chemicals are found to occur in tissue (i.e., clams) samples at elevated concentrations (relative to background or reference), then additional biota sampling may be warranted to assess impacts to upper trophic level fish, birds, and mammals.

- Compare surface water data to applicable regulatory threshold data. If highly bioaccumulative chemicals are found to occur in surface water at elevated concentrations (relative to background or reference), additional surface water sampling may be warranted to assess impacts.

3.1.8 Aquatic – Near Landfill

A summary of the DQO discussion for the Aquatic - Near Landfill DU is presented next.

3.1.8.1 Aquatic – Near Landfill Sampling Objective

The sampling objectives for the Aquatic - Near Landfill DU were the following:

- Collect surface sediment chemistry data to compare with reference data to determine if there is residual contamination after the landfill, removal action completed in 2006.

- Collect surface water chemical data to evaluate human health and ecological risk pathways.
- Collect selected biota tissue chemistry data to assess bioavailability and potential impact to benthic fauna and assess whether human health (consumption) and ecological risk pathways (both direct and food-web exposures) are significant.

3.1.8.2 Aquatic – Near Landfill Data Gaps

Current surface sediment analytical data for both the area near the landfill and a reference area were not available. The sediment data collected during the 2000 study (URS Greiner Woodward Clyde 2000a) are from just outside of the landfill before the removal action. There were no current data for surface water chemistry for the aquatic area near the landfill. Tissue samples from clams were collected from three locations near the shore of the landfill in September 1998. No current tissue data were available.

3.1.8.3 Aquatic – Near Landfill Performance Objective

The performance objectives for the Aquatic - Near Landfill DU are the following:

- Achieve analytical reporting limits less than or equal to applicable sediment RBCs, to the extent practicable, for protection of human health and ecological receptors.
- Achieve analytical reporting limits less than or equal to applicable aquatic surface water MCLs and relevant RBCs, to the extent practicable, for protection of human health and ecological receptors.
- Achieve analytical reporting limits less than or equal to applicable tissue threshold values, to the extent practicable, for protection of human health and ecological receptors.

3.1.8.4 Aquatic – Near Landfill Decision Rules

The decision rules for the Aquatic - Near Landfill DU are the following:

- Compare sediment data to sediment SLs and reference sediment analytical data set. If data are higher than these two criteria, recommend further analysis of selected (archived) discrete near-shore samples to delineate potential sources. If highly bioaccumulative chemicals are found to occur in sediments at elevated concentrations (relative to background or reference), additional biota sampling may be warranted to assess impacts to upper trophic level fish, birds, and mammals.
- Compare tissue data to applicable regulatory threshold data. If bioaccumulative chemicals are found to occur in biota tissue (i.e., clams) samples at concentrations greater than those in samples from reference locations, additional biota sampling may be warranted to assess impacts to upper trophic level fish, birds, and mammals.

- Compare surface water data to applicable regulatory threshold data. If highly bioaccumulative chemicals are found to occur in surface water at elevated concentrations (relative to background or reference), additional surface water sampling may be warranted to assess impacts.

3.1.9 Aquatic – North of Pier 8

A summary of the DQO discussion for the aquatic area north of Pier 8 is presented next.

3.1.9.1 Aquatic - North of Pier 8 Sampling Objectives

The sampling objectives for the Aquatic - North of Pier 8 DU were the following:

- Collect surface sediment chemistry data to compare with reference data set to determine if chemicals associated with UST Site No. 1, AST Fuel Storage Area, or the aquatic areas have been transported to sediments North of Pier 8.

- Collect surface water chemical data to assess whether surface water human health and ecological risk pathways are significant.

- Collect selected biota tissue chemistry data to assess bioavailability and potential impact to benthic fauna and to assess whether human health (consumption) and ecological risk pathways (both direct and food-web exposures) are significant.

3.1.9.2 Aquatic - North of Pier 8 Data Gaps

The performance objectives for the Aquatic - North of Pier 8 area are the following:

- Achieve analytical reporting limits less than or equal to applicable sediment SLs and generic RBCs, to the extent practicable, for protection of human health and ecological receptors.

- Achieve analytical reporting limits less than or equal to applicable aquatic surface water MCLs and generic RBCs, to the extent practicable, for protection of human health and ecological receptors.

- Achieve analytical reporting limits less than or equal to applicable tissue concentrations, to the extent practicable, for protection of human health and ecological receptors.

3.1.9.3 Aquatic - North of Pier 8 Decision Rules

The decision rules for the Aquatic - North of Pier 8 area are the following:

- Compare sediment data to sediment SLs and reference data. If data are greater than these two criteria, recommend further analysis of selected (archived) discrete near-shore samples to delineate potential sources. If highly bioaccumulative chemicals are found to occur in sediments at elevated concentrations (relative to background or

reference), additional biota sampling may be warranted to assess impacts to upper trophic level fish, birds, and mammals.

- Compare tissue data to applicable regulatory threshold data. If highly bioaccumulative chemicals are found to occur in biota tissue (i.e., clams) samples at elevated concentrations (relative to background or reference), additional biota sampling may be warranted to assess impacts to upper trophic level fish, birds, and mammals.

- Compare surface water data to applicable regulatory threshold data. If highly bioaccumulative chemicals are found to occur in surface water at elevated concentrations (relative to background or reference), additional surface water sampling may be warranted to assess impacts.

3.2 Bathymetric and Land Surveys

A bathymetric survey was completed in all aquatic DUs. The primary objectives of the bathymetric survey were to:

- Determine the surface differences from earlier surveys.

- Determine the rates of sedimentation.

- Aid in the establishment of the final target depths of the three sediment cores completed in the Aquatic – Finger Piers Area.

After the completion of all sampling activities within the upland DUs, a State of Oregon Licensed Surveyor (or Engineer) performed a land survey of all sampling points for position and elevation relative to mean sea level. The terrestrial locations were surveyed 30 September to 3 October 2008 and notes are provided in **Appendix K**. Additional location information obtained included ring foundations of ASTs, perimeter of dredge sediment stockpiles, corners of buildings adjacent to DUs, and the edge of concrete foundations at the Fire Training Area.

3.2.1 Bathymetric Survey

A bathymetric survey was completed by CLE Engineering on September 4 and 5, 2008, off shore of the Finger Pier and Landfill DUs in Cathlamet Bay. The purpose of the survey was to determine the surface differences from earlier, mid-1990s surveys and the rates of sedimentation. The information obtained was used to determine the possibility of natural recovery should future dredging expose deeper sediments of Navy-era deposition. The survey information was used to determine the final depths of the three sediment cores that were advanced in the Aquatic - Finger Piers Area to correlate the cores with sediment cores collected in 1998. The results of the survey, shown as bathymetric contours, are shown on **Figure 3-1**.

The bathymetric survey conformed to the USACE 2002, EM 1110-2-1003 Hydrographic Surveying Manual accuracy standards for Class 1 surveys, procedure specifications for bathymetry, and specifications contained herein.

- A navigation line spacing interval of 100 feet for data collected was determined on site for optimum beam coverage and overlap to meet the accuracy and resolution required and to ensure that no gap in coverage exists. Cross-line checks were run, because they are required for all Class 1 surveys. Procedures and tolerances conformed to criteria prescribed in EM 1110-2-1003.

- The hydrographic survey vessel conformed to the U.S. Coast Guard requirements for passenger-carrying vessels of its size. An operator possessing a valid U.S. Coast Guard license to pilot passenger-carrying vessels was present on the vessel during all sounding operations.

- Each sounding for depth was accomplished by a fully integrated and automated hydrographic data acquisition system using a single-beam echo sounder that (1) is capable of speed-of-sound correction adjustments and has a frequency operating capability of 200 kilohertz (kHz) +/-20 with a manufacturer's stated accuracy of 0.03 meters (0.1 foot) or less, and (2) has motion sensor capability with a manufacturer's stated compensation accuracy of +/-0.05 degrees or less for vessel pitch and roll and the greater of 5 cm or 5% for heave.

- Bar checks and calibration were performed at the intervals specified in EM 1110-2-1003 for Class 1 surveys. Calibrations and checks were taken at 5-foot intervals to the maximum working depth of the Study Area and are shown on the depth record (see **Appendix K**).

All survey files were edited to eliminate extraneous data and display an accurate representation of the area of interest. Data with a quality index of less than three and depths below or above known parameters were eliminated. The thinning interval did not exceed 10 feet. Surveying was completed with a Trimble DSM digital GPS system and referenced using World Geodetic System of 1984 (WGS 84) units as longitude (northings) and latitude (eastings) as recorded in **Table 3-8**. Vertical positions are referenced to National Geodetic Vertical Datum of 1929 (NGVD 29). Survey references and deliverables are included in **Appendix K**.

3.2.2 Land Survey

On September 30 through October 3, 2008, under the supervision of a State of Oregon Registered Engineer, the survey was completed for the DPT boring locations, soil vapor sampling locations, and temporary microwell locations to record position and elevation relative to mean sea level. Horizontal and vertical measurements are accurate to +/-0.01 foot. Surveying was completed with a Trimble DSM digital GPS system and referenced using World Geodetic System of 1984 (WGS 84) units as longitude (northings) and latitude (eastings) as recorded in **Table 3-8**. Final horizontal positions were projected to the Oregon State Plane Coordinate System

North American Datum of 1927 (NAD 27). Final vertical positions were projected to the National Geodetic Vertical Datum of 1929 (NGVD 29). The U.S. Survey Foot was the unit of measurement used. Field staff followed the procedures outlined in the CDM Topographic Survey Standard Operating Procedures (SOP) provided in **Appendix C** of the QAPP (CDM 2008b).

The USACE was provided a 3-D MicroStation V8 DGN digital file and hard copy of the survey. All horizontal and vertical control monuments were used, and their location, designation, description, and northing, easting, and elevation values were clearly defined in the mapping. For the terrestrial results were projected to the Oregon State Plan Coordinate System as noted above. Map scales are 1 inch = 40 feet. Survey references and hard copy deliverables are in **Appendix K**. All mapping sheets contain, but are not limited to, the following information:

- Survey date
- Project name
- North arrow
- Bar scale
- Coordinate grid tics
- Contact number
- Survey firm
- Surveyor's certification and seal

Additional pertinent land features surveyed are as follows:

- Ring foundations of ASTs removed from the AST Fuel Storage Area
- Perimeter of dredge sediment stockpiles in the Fire Training Area
- Corners of buildings adjacent to study areas (e.g., corners of Hangars 1 and 3, corners of storage shed near UST Site No. 4)
- Edge of concrete foundations at Fire Training Area

3.3 Terrestrial Investigations

Six terrestrial DUs are included in the Multi-Site Project because they may potentially be source areas. Five upland DUs were investigated as part of this RI to characterize potential impacts in environmental media and to identify potential releases of hazardous substances. From north to south, these areas are the AST Fuel Storage Area, UST Site No. 1, Refueling Pit 3, UST Site No. 4, and the Fire Training Area. One

upland DU, the Incinerator Building, was not investigated as a part of this RI. Data collected in 2007, under the supervision of the USACE, will be used to characterize this DU.

A list of DU-specific VOCs was planned to customize analyses for specific constituents at a DU. A "short-list" of VOCs was to be performed on all soil and groundwater samples collected from areas that have historically been impacted only by petroleum hydrocarbons (i.e. AST Fuel Storage Area, UST Site No. 1, and UST Site No. 4). The short-list of VOCs are those compounds that are associated with petroleum hydrocarbons. The "long-list" of VOCs includes the halogenated compounds. The long-list of VOCs was requested at the upland DUs where these compounds were considered to be related to past DoD practices as evident from past investigations (i.e. Refueling Pit 3 and Fire Training Area). For the terrestrial samples, analyses type by DU, location and sample identification number are tabulated as follows; Table 3-1 soil analyses; Table 3-2 has all groundwater analyses listed by DU, Table 3-3 lists LNAPL analyses; Table 3-4 lists soil gas and ambient air analyses. The aquatic sample analyses are listed on Table 3-5 for Sediment, Table 3-6 for surface water, and Table 3-7 for tissue analyses.

3.3.1 AST Fuel Storage Area

The analyses conducted for each media at each sampling location at the AST Fuel Storage Area are shown in **Tables 3-1** and **3-2**. Sampling locations are shown on **Figure 3-2**. Surface soil conditions at the AST Fuel Storage Area were assessed by the collection of nine 3-point composite surface soil samples. Subsurface soil conditions were assessed by the completion of three DPT borings and the collection of three soil samples in each boring. Groundwater conditions were assessed by the collection of one groundwater sample from a temporary microwell adjacent to the pump house.

3.3.1.1 Soil Sampling

To assess the nature and extent of petroleum hydrocarbons (and associated compounds) in oiled soil inside and outside of the AST foundation rings and adjacent to the pump house, nine 3-point composite surface soil samples were collected. One 3-point composite surface soil sample was collected from oiled sand within each of the four AST foundation rings. These samples are identified as AST-01 through AST-04 in **Table 3-1** and on **Figure 3-2**. One 3-point composite surface sample was collected from the oiled sand just outside each of the four AST foundation rings. These samples are identified as AST-05 through AST-08 in **Table 3-1** and on **Figure 3-2**. One 3-point composite surface soil sample, identified as AST-09, was collected from around the pump house near a potential release area to assess the presence or absence of petroleum contamination.

Subsurface conditions downgradient of the ASTs were assessed for the potential migration of petroleum hydrocarbons via groundwater. Three soil borings, AST-10, AST-11, and AST-12, were advanced using DPT techniques. Locations for the three DPT borings are shown on **Figure 3-2** and described as follows:

- AST-10 was located approximately 5 feet north of the pump house.
- AST-11 was located on the gravel road approximately 20 feet east of the foundation ring wall for AST Ring No. 12-2.
- AST-12 was located in the gravel road and approximately 60 feet northeast of the pump house.

Three soil samples were collected from each boring. One soil sample was collected from the 1 to 3 feet bgs interval; the second soil sample was collected at the interval containing the strongest field evidence of petroleum hydrocarbons; and the third soil sample was collected at the first depth interval where no field evidence of petroleum hydrocarbons was observed. The soil/bedrock contact was not encountered in any of these borings. For the exact sample depths, see **Table 3-1** and the boring logs in **Appendix A.**

Soil samples were analyzed for TPH-G, TPH-D, TPH-O, VOCs, PAHs, and total lead as shown in **Table 3-1**. Field test results for one soil sample from boring AST-01 showed concentrations of petroleum hydrocarbons and was submitted for analysis of extractable petroleum hydrocarbons (EPH) and volatile petroleum hydrocarbons (VPH) to identify the hydrocarbon fractions for potential use in calculating a site-specific soil cleanup level using the ODEQ model (ODEQ 2003).

3.3.1.2 Groundwater Sampling

Subsurface conditions were assessed for potential migration of petroleum hydrocarbons topographically downgradient of the ASTs. Three soil borings, AST-10, AST-11, and AST-12, were advanced using DPT techniques. Locations for the three DPT borings are shown on **Figure 3-2** and described in the previous section.

Groundwater was encountered in only one (AST-10) of the DPT borings. A temporary microwell was installed to collect a groundwater sample. The microwell construction details are shown in **Table 3-9**. The groundwater sample was collected using low-flow sampling techniques. The groundwater sample was analyzed for TPH-G, TPH-D, TPH-O, VOCs, PAHs, and total metals as shown in **Table 3-2**. Information obtained from the analytical sample results was used to determine if petroleum hydrocarbons have migrated downgradient of the ASTs. The groundwater flow direction could not be determined in the AST area, because groundwater was only encountered in one of the three locations. The temporary microwell was removed after groundwater sampling and within 72 hours of installation.

3.3.2 UST Site No.1

The analyses conducted for each media at each sampling location at UST Site No. 1 are shown in **Tables 3-1** through **3-6**. Sampling locations are shown on **Figures 3-3** and **3-4**.

3.3.2.1 Soil Sampling

Five soil borings, UST1-01 through UST1-05, were advanced using DPT to evaluate soil and groundwater quality associated with the UST excavation. Sample locations UST1-01 through UST1-05 were located in areas not previously investigated to determine if soil, groundwater, or both pose a threat to human health. The locations of these five DPT borings are shown on **Figure 3-3** and are described as follows:

- UST1-01 was located within the northwestern portion of the UST excavation and approximately 15 feet east of MW-06. LNAPL has been observed on the groundwater at MW-06.
- UST1-02 was located approximately 2 feet east and hydraulically downgradient of the UST excavation.
- UST1-03 was located south of the UST excavation, approximately 19 feet south of MW-08. Historically, sheen had been observed on groundwater at MW-08.
- UST1-04 was located northeastern of the UST excavation, adjacent to Dormitory 4. Soil and groundwater near the eastern end of the UST excavation has not been previously investigated.
- The planned location for UST1-05 shown in the QAPP was near the west end of the UST excavation, approximately 20 feet southeast of the Recreation Lounge building's south corner. UST1-05 was relocated because the tree and a planter box prohibited access by the drilling equipment. The location sampled was approximately 11 feet southeast of the Recreation Lounge Building and approximately 50 feet southwest of the UST excavation. Soil near the western end of the UST excavation has not been previously investigated.

Each of the five borings was advanced to approximately 20 feet bgs. One soil sample was collected from each boring, either from an area within the vadose zone exhibiting the strongest field evidence of contamination (i.e., elevated organic vapor meter [OVM] with a photoionization detector [PID] readings or discoloration) or just above the groundwater interface, if no field evidence of contamination was identified. For the exact sample depths, see **Table 3-1** and the boring logs included as **Appendix A.**

Field screening indicated the absence of VOCs; therefore, the extent of VOCs and petroleum hydrocarbons was considered delineated and the soil boring exploration program was completed. Soils were screened in the field using an Organic Vapor Monitor OVM_ PID and tested in the field using a Sitelab Ultra Violet Fluorescence (UVF)-3100 Analyzer and field extraction kit. One split sample was collected from location UST1-01 and analyzed by the Sitelab UVF-3100 Analyzer. For verification and confirmation purposes, the sample was sent to the contract laboratory for analysis.

Soil samples were analyzed for TPH-G, TPH-D, TPH-O, VOCs, PAHs, and total lead as shown in **Table 3-1**. Two soil samples from UST1-01 and UST1-03 containing field evidence of contamination were submitted for analysis of EPH/VPH to determine the composition of the product at the site for potential use in calculating a site-specific soil cleanup level using the ODEQ model (ODEQ 2003).

3.3.2.2 Groundwater Sampling

To assess the concentrations of petroleum hydrocarbons (and associated compounds) in groundwater downgradient of the UST excavation and adjacent to Dormitory 4, microwells were installed in borings UST1-01, UST1-02, and UST1-04. The microwells were screened from 12 to 17 feet bgs. Groundwater samples were collected from existing monitoring wells MW-01, MW-06, MW-08, MW-09, and MW-10 using low-flow sampling techniques. Groundwater samples from monitoring wells were analyzed for TPH-G, TPH-D, TPH-O, VOCs, PAHs, TOC, total and dissolved metals as shown on **Table 3-2.** Dedicated tubing was located within MW-06 to facilitate the collection of a groundwater sample below the LNAPL. Wells MW-02, MW-04, and MW-07 were previously abandoned as described in Section 1.4.3.2. The existing monitoring well and microwell construction details are shown in **Table 3-9**. Groundwater samples were collected from each of the microwells using low-flow sampling techniques. Groundwater samples from microwells were analyzed for TPH-G, TPH-D, TPH-O, VOCs, PAHs, TOC, and total metals as shown on **Table 3-2.** The temporary microwells were removed after groundwater sampling and within 72 hours of installation.

Originally, the sampling activity planned in the QAPP was to collect two water samples from seeps at UST Site No. 1 under Pier 8 to determine if petroleum-impacted groundwater in this area is a risk to human and ecological receptors in Cathlamet Bay. The presence of seeps was inspected on August 26, September 12, September 18, and October 1, 2008. Groundwater seeps were not observed during RI field activities and thus could not be sampled. The potential need for seep sampling will be evaluated using the groundwater data collected during the RI.

3.3.2.3 LNAPL Sampling

The existing wells MW-01 and MW-06 were checked for the presence of LNAPL before sampling using an interface probe. LNAPL was not detected in monitoring well MW-01, and 1.72 feet of free product was detected in MW-06. Monitoring wells MW-08, MW-09, and MW-10 contained dedicated bladder pumps and the interface probe could not fit into the sounding port. As shown in **Table 3-3**, an LNAPL sample was collected from MW-06 to analyze the composition of the product beneath the site for use in identifying remedial alternatives.

3.3.2.4 Soil Gas Sampling

To support evaluations of indoor air exposure through vapor intrusion and to determine if soil vapor extraction may be a component of the final remedy, soil gas samples were collected from UST Site No. 1. A total of six soil gas samples (UST1-06

through UST1-11) were collected as identified on **Table 3-4**. Two of the soil gas samples were collected adjacent to Dormitory 4, one adjacent to the Recreation Lounge, and three from the potential source area in the vicinity of MW-06 as shown on **Figure 3-3**. All of the soil gas samples were submitted for analyses of VOCs by EPA Method TO-15, oxygen, and carbon dioxide by ASTM 1945-96 Method 3. At the two soil gas probes located adjacent to Dormitory 4 (UST1-06 and UST1-07 on **Figure 3-3**), samples were collected for analysis of SVOCs by EPA Method TO-17. To provide site-specific soil parameters for vapor intrusion modeling, a representative vadose zone soil sample was collected from boring UST1-04 and analyzed for bulk density, grain density, total porosity, moisture content, grain size distribution, air permeability, and TOC, as indicated in **Table 3-1**.

3.3.2.5 Near-Shore Sediment Sampling

To assess the potential transport pathway for migration of chemicals from UST Site No. 1 soil and groundwater to sediments, two near-shore sediment surface samples (UST1-12 and UST1-13) were collected and analyzed for TPH-D, TPH-O, TPH-G, VOCs, SVOCs (including PAHs), pesticides (including hexachlorobenzene), inorganics, TOC, total volatile solids, total sulfide, ammonia, and percent solids, as shown in **Table 3-5**. The sediment samples were collected as part of the sampling effort for the Aquatic - North of Pier 8 DU and not during the upland investigation of UST Site No. 1. The sampling locations are shown on the UST Site No. 1 (Eastern Area) on **Figure 3-3**.

3.3.2.6 Near-Shore Surface Water Sampling

To assess the potential transport pathway for migration of chemicals from UST Site No. 1 soil and groundwater to surface water, two near-shore surface water samples (UST1-14 and UST1-15) were collected and analyzed for the similar suite of analytes, as the near-shore sediment samples. Analytes included TPH-D, TPH-O, TPH-G, VOCs, PAHs, total and dissolved inorganics and ammonia (see **Table 3-6**). The surface water samples were collected as part of the sampling effort for the Aquatic - North of Pier 8 DU and not during the upland investigation of UST Site No. 1. High-volume water sampling methods were used to collect samples for analysis of organic compounds. The high volume water sampling method was used to concentrate trace levels of particulate-bound and dissolved-phase chemicals from a large volume of water for analysis by standard analytical methods. The high volume surface water sampling method was used to collect samples for analysis of PAHs, PCBs, organochlorine pesticides, and dioxin/furans, if these particular analyses were required in a decision unit. Surface water grab samples were collected at each location by diverting water from the PUF column in order to collect samples for analysis of gasoline- and diesel-range petroleum hydrocarbons, VOCs, total and dissolved metals, and ammonia. The sampling locations are shown on the UST Site No. 1 (Eastern Area) on **Figure 3-3**.

3.3.3 Refueling Pit 3

The analyses to be conducted for each media at each sampling location at Refueling Pit 3 are shown in **Tables 3-1** and **3-2** and **Tables 3-4** through **3-6**. Sampling locations are shown on **Figure 3-5**. Subsurface conditions at Refueling Pit 3 were assessed by advancing four DPT borings (with the installation of four microwells), sampling five existing monitoring wells, collecting seven soil gas samples, and collecting two ambient air samples.

3.3.3.1 Soil Sampling

Four borings, identified as RFP3-01, RFP3-02, RFP3-03, and RFP3-04, were advanced around the refueling pit as shown on **Figure 3-5**. Boring RFP3-02 was advanced adjacent to the approximate location of abandoned monitoring well FP-01. The four borings were advanced to a depth of 15 feet bgs. Refusal was encountered in boring RFP3-02 three times before boring completion at the target termination depth of 15 feet bgs. Refusal was attributed to the presence of large rocks or other debris. Soils were field screened for the presence of contamination using the OVM-PID. One sample was collected from each boring from soil exhibiting the strongest field evidence of contamination, or just above the groundwater interface, if no field evidence of contamination was observed. For the exact sample depths, see **Table 3-1** and the boring logs included as **Appendix A.**

Soils were screened in the field using an OVM-PID and analyzed in the field using a Sitelab UVF-3100 Analyzer. One split sample from RFP3-02 was collected from one sample analyzed by the Sitelab UVF-3100 Analyzer and sent to a laboratory for analysis for verification and confirmation purposes. Soil samples were submitted for analysis of TPH-G, TPH-D, TPH-O, VOCs, PAHs, and total lead as shown in **Table 3-1**. One soil sample from boring RFP3-01 contained field evidence of contamination and was submitted for analysis of EPH/VPH to determine the composition of the product at the site for potential use in calculating a site-specific soil cleanup level using the ODEQ model (ODEQ 2003).

As specified in the QAPP (CDM 2008b), up to four additional borings (identified as RFP3-05, RFP3-06, RFP3-07, and RFP3-08) may have been advanced using DPT methods to further define the extent and magnitude of contamination in soil or groundwater. Soil samples collected from borings RFP3-01 through RFP3-04, and analyzed using the Sitelab UVF-3100 Analyzer, indicated that concentrations of TPH-G or TPH-D did not exceed ODEQ RBCs (for human health soil ingestion, dermal contact, and inhalation residential pathway); therefore, the extent of VOCs and petroleum hydrocarbons was considered delineated and the soil boring exploration program was completed. The ODEQ RBC for TPH-G is 720 parts per million (ppm) and the ODEQ RBC for TPH-D is 3,900 ppm.

3.3.3.2 Groundwater Sampling

Temporary microwells were installed in the four borings to collect groundwater samples. The microwells were screened from 7 to 12 feet bgs. Groundwater samples

from all wells were collected using low-flow sampling techniques. Temporary microwells were removed after groundwater sampling and within 72 hours of installation. Existing well and microwell construction details are in **Table 3-9**.

Groundwater samples collected from all microwells and existing wells MW-01 through MW-05 were submitted for analysis of TPH-G, TPH-D, TPH-O, VOCs, PAHs, TOC, and total metals. As shown in **Table 3-2**, samples from 12 location (11 wells plus UST1-18) were analayzed for total and dissolved inorganics. Other groundwater samples from microwells were analyzed for total inorganics. In addition, groundwater samples collected from existing groundwater wells MW-01 through MW-05 were analyzed for the natural attenuation parameters methane, ethane, and ethene, nitrate, nitrite, sulfate, chloride, total sulfide, and alkalinity. Before purging and sampling, the existing monitoring wells were checked for LNAPL using an oil/water interface probe. A measurable thickness of LNAPL was not detected in any of the wells. No indications of LNAPL were observed in the four microwells or the five existing wells.

3.3.3.3 Ambient Air and Soil Gas Sampling

To assess VOCs migration through the subsurface and affect to Hangar 1 indoor air quality, soil gas samples were collected from locations outside of Hangar 1. Three soil gas samples (RFP3-13, RFP3-15, and RFP3-17) were collected around the perimeter of Hangar 1; one soil gas sample (RFP3-16) was collected at a location near Refueling Pit 3, and two soil gas samples (RFP3-11 and RFP3-12) were collocated with the DPT soil and groundwater borings located nearest Hangar 1. Soil gas sample locations are shown on **Figure 3-5**. Soil collected adjacent to Hangar 1 did not indicate the presence of LNAPL, and soil samples collected from this area and tested in the field using a Sitelab UVF-3100 Analyzer did not indicate high concentrations of petroleum hydrocarbons, so it was not necessary to collect a sub-slab soil gas sample, RFP3-14, inside Hangar 1. To evaluate background concentrations of VOCs, two ambient air samples were collected at locations upwind and downwind of Refueling Pit 3. All soil gas and ambient air samples were analyzed for VOCs by EPA Method TO-15 and oxygen and carbon dioxide by ASTM 1945-96 Method 3 as indicated in **Table 3-4**. To provide site-specific soil parameters for vapor intrusion modeling, a representative vadose zone soil sample was collected from borings RFP3-03 and RFP3-04 and analyzed for bulk density, grain density, total porosity, moisture content, grain size distribution, air permeability, and total organic carbon as indicated in **Table 3-1**.

3.3.3.4 Near-Shore Sediment Sampling

To assess the pathway for migration of chemicals from Refueling Pit 3 soil and groundwater to sediments, two near-shore surface sediment samples were collected between Finger Piers 6 and 7. Sediment samples were analyzed for TPH-D, TPH-O, TPH-G, VOCs, SVOCs, metals, organochlorine pesticides, PCBs, total volatile solids, percent solids, total sulfides, ammonia, and TOC as shown in **Table 3-5**. The sediment samples were collected as part of the sampling effort for the Aquatic - Finger Piers DU (see discussion in **Section 3.6.1**), and not during the upland

investigation of Refueling Pit 3. The sampling locations are shown on both the Refueling Pit 3 figure (**Figure 3-5**) and the Aquatic - Finger Piers figure (**Figure 3-9**).

3.3.3.5 Near-Shore Surface Water Sampling

To assess the potential transport pathway for migration of chemicals from Refueling Pit 3 soil and groundwater to the aquatic environment, two surface water samples were collected between Finger Piers 6 and 7. Surface water samples were analyzed for TPH-D, TPH-O, TPH-G, VOCs, PAHs, metals, and TOC as shown in **Table 3-6**. As stated previously, the surface water samples were collected as part of the sampling effort for the Aquatic - Finger Piers DU and not during the upland investigation of Refueling Pit 3. High-volume water sampling methods were used to collect samples for analysis of organic compounds. The high volume water sampling method was used to concentrate trace levels of particulate-bound and dissolved-phase chemicals from a large volume of water for analysis by standard analytical methods. The high volume surface water sampling method was used to collect samples for analysis of PAHs, PCBs, organochlorine pesticides, and dioxin/furans, if these particular analyses were required in a decision unit. Surface water grab samples were collected at each location by diverting water from the PUF column in order to collect samples for analysis of gasoline- and diesel-range petroleum hydrocarbons, VOCs, total and dissolved metals, and ammonia. The sampling locations are shown on both the Refueling Pit 3 (**Figure 3-5**) and the Aquatic - Finger Piers figures (**Figure 3-9**).

3.3.4 UST Site No. 4

The analyses conducted at each sampling location at UST Site No. 4 are shown in **Table 3-1**. Sampling locations are shown on **Figure 3-6**. Subsurface conditions at UST Site No. 4 were assessed by advancing three DPT borings and three hand-augured borings, and excavating two test pits.

3.3.4.1 Soil Sampling

Two DPT borings, identified as UST4-01 and UST4-03, were advanced within the UST excavation limits, as shown on **Figure 3-6**, to determine if soil within the excavation has been recontaminated. Boring UST4-01 was advanced to a depth of 16 feet bgs and UST4-03 was advanced to 20 feet bgs. An 18-inch thick concrete slab, used to support the tanks, was encountered during drilling at approximately 15 feet bgs in boring UST4-03. An additional DPT boring, identified as UST4-02, was advanced adjacent to the concrete slab to an approximate depth of 20 feet bgs to determine if soil adjacent to the former USTs had been affected by a release of petroleum hydrocarbons. Soils were field screened for the presence of contamination using visual observations and an OVM-PID. Soil samples from each boring were field-tested using a Sitelab UVF-3100 Analyzer to aid in selection of samples for laboratory analyses and to supplement the data for delimiting the vertical extent of petroleum hydrocarbon contamination.

Two soil samples were collected from each DPT boring to assess the nature and extent of chemicals present after the remedial excavation at UST Site No. 4. The first sample

was collected from soil within 0 to 1 foot bgs and the second sample was collected from soil exhibiting the strongest field evidence of petroleum hydrocarbons or just above the groundwater interface, if no evidence of petroleum was present. If no field evidence of contamination was observed, and no groundwater was encountered, then the second sample was collected from the base of the boring. For the sample depths, see **Table 3-1** and the boring logs in **Appendix A.**

Three borings, identified as UST4-04, UST4-05, and UST4-06, were hand-augured to confirm the shallow soil profile (less than 4 feet deep) over siltstone bedrock outside of the UST excavation limits. These boring locations are shown on **Figure 3-6** and are located south of the UST excavation. UST4-04 was located approximately 12 feet south of the UST excavation. UST4-05 and UST4-06 were located approximately 9 feet and 18 feet, respectively, south of the UST excavation. Soils were field screened to determine the presence of contamination. Two soil samples were collected from each hand auger boring. The first sample was collected from 0 to 1 foot bgs and the second from 2 to 3 feet bgs.

All soil samples were analyzed for TPH-G, TPH-D, TPH-O, VOCs, PAHs, and total lead as shown in **Table 3-1**. One soil sample from boring UST4-04 contained field evidence of petroleum by the UVF 3100 method, and was submitted for analysis of EPH/VPH to identify the composition petroleum fractions for use in calculating a site-specific soil SL using the ODEQ model (ODEQ 2003). Because soil samples collected at UST Site 4 are biased by source area release, the risk assessment for this site will have some high bias as discussed in Section 6.5.6.1.

3.3.4.2 Groundwater Sampling

Before the DPT portion of the UST Site No. 4 investigation, two hand-dug test pits, UST4-07 and UST4-08, were manually excavated to approximately 2 feet bgs, along the fuel pipeline. The objective of the test pit excavations was to determine if groundwater in the UST excavation is localized "perched" water or a more widespread water-bearing zone that could affect topographically downgradient media and receptors. UST4-07 and UST4-08 were located approximately 80 feet and 120 feet east of the UST excavation, respectively. Groundwater "seeps" were not encountered in either of the two test pits.

Groundwater was not encountered in borings UST4-01 and UST4-02. A perched zone of groundwater was encountered in boring UST4-03, and a temporary microwell was installed in the boring in an attempt to obtain a groundwater sample. This was part of a larger effort to evaluate whether this groundwater is confined to the excavation or is part of a local perched water-bearing zone that may lead to topographically downgradient receptors. Because groundwater did not accumulate, the temporary microwell was removed 24 hours after installation and a groundwater sample was not collected.

3.3.5 Incinerator Building

As planned, no additional sampling activities were conducted during this RI. The most recent investigation of the Incinerator Building, which included ash and surface soil sampling, was performed by the USACE in October 2007. The following description of sampling and analyses is for the activity performed in October 2007 preceding the field activity for this RI. See Section 1.4.3.5 for description and previous investigation at the Incinerator Building.

3.3.5.1 Ash Sampling

One primary ash sample (0710INCASH01) and one field duplicate were collected during the October 2007 sampling activity. The sampling was accomplished to look for near-field evidence of contamination including ash and stack deposition. The direction of the wind was not of concern given the confining nature of the forest and adjacent slope. Sampling of the ash consisted of compositing eight discrete ash samples from locations that were selected to represent the lateral and vertical extent of the ash pile that remained in the burn box. Two aliquots of ash of sufficient volume to fill all required sample containers were removed and composited a second time for the primary sample and field duplicate. The ash sample was analyzed for SVOCs (including PAHs), PCBs, dioxins/furans, nitroaromatics/nitroamines, and metals as described in the *Preliminary Draft Work Plan for Site Investigation Through Design, Tongue Point Multi-Sites Project, Former Tongue Point Naval Air Station, Astoria, Oregon* and in the field notes from this investigation (URS 2006, 2007).

3.3.5.2 Soil Sampling

During the 2007 sampling event, a 144 by 144 feet grid with 24-foot spacing (see **Figure 3-7**) was positioned to surround the Incinerator Building. Thirty-six surface soil samples were collected and composited. Five sample aliquots (0710INCS01 through 0710INCS05) were collected from the composite. Based upon the detected concentrations of dioxins/furans in the ash sample, the surface soil samples were analyzed for the same analytical suite as the ash sample: SVOCs (including PAHs), PCBs, dioxins/furans, nitroaromatics/nitroamines, and metals.

3.3.6 Fire Training Area

The analyses to be conducted for each media at each sampling location at the Fire Training Area are shown in **Tables 3-1** through **3-6**. Sampling locations are shown on **Figure 3-8**. Subsurface conditions at the Fire Training Area were assessed by advancing 15 DPT borings, sampling three existing monitoring wells, and collecting seven soil gas samples.

3.3.6.1 Soil Sampling

Fifteen soil borings, identified as FTA-01 through FTA-15, were advanced using DPT technology to identify the nature and extent of VOCs and LNAPL in soil and groundwater at the Fire Training Area. Surface soil samples were not collected because the surface consists of the dredged spoils materials that are unrelated to the DoD activity at the Fire Training Area. Borings FTA-01 through FTA-15 were located

in areas previously not investigated to support human health and ecological risk evaluations, identify source areas, and support identification and evaluation of remedial technologies.

The approximate locations of the 15 completed DPT borings are shown on **Figure 3-8** and are described here:

- FTA-01 through FTA-07 were located along the perimeter and within the dredged soil stockpile.
- FTA-08 through FTA-12 were located just upland of the bulkhead along the shoreline, between Finger Piers 1 and 2.
- FTA-13 through FTA-15 were located around monitoring well MW-19, approximately 20 feet north, west, and south of MW-19, respectively.

Borings FTA-01 through FTA-08, FTA-10 through FTA-12, and FTA-15 were advanced to 30 feet bgs, or until bedrock was encountered; borings FTA-09, FTA-13, and FTA-14 were advanced to 15 feet bgs. One soil sample was collected from each boring. Samples were collected from soil exhibiting the strongest field evidence of contamination using the OVM-PID, or just above the groundwater interface if no field evidence of contamination was present. For the exact sample depths, see **Table 3-1** and the boring logs included as **Appendix A.**

All soil samples were analyzed for TPH-G, TPH-D, TPH-O, VOCs, PAHs, TOC, and metals. In addition, soil samples from FTA-13 through FTA-15 were analyzed for dioxins/furans, organochlorine pesticides, and PCBs. One soil sample containing field evidence of petroleum hydrocarbon contamination from boring FTA-15 was submitted for analysis of EPH/VPH to determine the composition of the product at the site for use in calculating a site-specific SL using the ODEQ model (ODEQ 2003). Soil sample analyses are shown in **Table 3-1**.

3.3.6.2 Groundwater Sampling

Temporary microwells were installed within FTA-01 through FTA-15 to assess groundwater quality and support analysis of the groundwater flow direction. Screen intervals of the microwells installed in borings FTA-01 through FTA-15 are listed in **Table 3-9**. In addition, groundwater samples were collected from two existing wells (MW-17 and MW-18D). Wells were checked for the presence of LNAPL before sampling using an oil/water interface probe. During RI field activities, several reconnaissance efforts were made to locate well MW-22 and other existing wells, to document their locations and their conditions. The surface casing extension for MW-22 was located but the well casing was inaccessible. The well is surrounded by an outer casing of PVC pipe, which appears to have been installed before the placement of the dredge materials as a way to mark the location of the well. The efforts to locate MW-18S and MW-21 were unsuccessful. Existing monitoring well construction details are listed in **Table 3-9**.

Field water level measurements were collected within the microwells and existing wells to within 0.01-foot precision to determine the groundwater flow direction and gradient. Temporary microwells were removed after groundwater sampling and within 72 hours of installation. Groundwater samples were collected from each of the existing monitoring wells and microwells using low-flow sampling techniques. All groundwater samples were analyzed for TPH-G, TPH-D, TPH-O, VOCs, PAHs, TOC, and total inorganics. As shown in **Table 3-2**, samples from 12 locations (11 wells and UST1-18) were analyzed for total and dissolved inorganics, and other groundwater samples from microwells were analyzed for total inorganics. The presentation of all analytical results in Appendix E has a separate table for each DU showing results of dissolved analyses. In addition, groundwater samples from selected microwells were analyzed for organochlorine pesticides, PCBs, and dioxins/furans. Additionally, groundwater samples from wells FTA-04, FTA-09, and MW-18D were analyzed for the following monitored natural attenuation parameters: methane, ethane, and ethene, nitrate, nitrite, sulfate, chloride, sulfide, TDS, and alkalinity. Groundwater sample analyses are shown in **Table 3-2**.

3.3.6.3 LNAPL Sampling

Approximately 1.35 feet of LNAPL was measured in monitoring well MW-19. As shown in **Table 3-3**, an LNAPL sample was collected from this well for analysis of the product located beneath the site. Borings FTA-13 through FTA-15 were advanced around MW-19 to delineate the extent of LNAPL present at the Fire Training Area. FTA-09, which was advanced along the bulkhead of Cathlamet Bay, will be used to delineate the extent of LNAPL because it is located hydraulically downgradient of MW-19.

3.3.6.4 Soil Gas Sampling

Soil gas samples were collected from seven DPT soil gas probes that were advanced adjacent to the seven DPT borings located around and within the dredged sediments stockpile. The soil gas probe locations are shown on **Figure 3-8**. The soil gas probes were installed to determine soil gas concentrations around and within the stockpile area. Soil gas samples were submitted for analysis of VOCs by EPA Method TO-15 and oxygen and carbon dioxide by ASTM 1945-96 as indicated in **Table 3-4**. To provide site-specific soil parameters for vapor intrusion modeling, representative vadose zone soil samples were collected from borings FTA-02, FTA-04, and FTA-05 and analyzed for bulk density, grain density, moisture content, grain size distribution, air permeability, and TOC as indicated in **Table 3-1**.

3.3.6.5 Near-Shore Sediment Sampling

To assess the impact of petroleum hydrocarbons and VOCs released at the Fire Training Area on aquatic sediment, two near-shore sediment core samples were collected between Finger Piers 1 and 2. The sediment samples were analyzed for TPH-D, TPH-O, TPH-G, VOCs, SVOCs, organochlorine pesticides, hexachlorobenzene, PCB Aroclors, and metals as shown in **Table 3-5**. The sediment samples were collected as part of the sampling effort for the Aquatic - Finger Piers DU

and not during the upland investigation of the Fire Training Area. The sampling locations are shown on both the Fire Training Area (**Figure 3-8)** and the Aquatic - Finger Piers Area figures (**Figure 3-9**).

3.3.6.6 Near-Shore Surface Water Sampling

To assess the impact of petroleum hydrocarbons and VOCs released at the Fire Training Area on surface water, two near-shore surface water samples were collected between Finger Piers 1 and 2. The surface water samples were analyzed for TPH-D, TPH-O, TPH-G, VOCs, SVOCs, organochlorine pesticides, and metals as shown in **Table 3-6**. As stated previously, the surface water samples were collected as part of the sampling effort for the Aquatic - Finger Piers DU and not during the upland investigation of the Fire Training Area. High-volume water sampling methods were used to collect samples for analysis of organic compounds. The high volume water sampling method was used to concentrate trace levels of particulate-bound and dissolved-phase chemicals from a large volume of water for analysis by standard analytical methods. The high volume surface water sampling method was used to collect samples for analysis of PAHs, PCBs, organochlorine pesticides, and dioxin/furans, if these particular analyses were required in a decision unit. Surface water grab samples were collected at each location by diverting water from the PUF column in order to collect samples for analysis of gasoline- and diesel-range petroleum hydrocarbons, VOCs, total and dissolved metals, and ammonia. The sampling locations are shown on both the Fire Training Area (**Figure 3-8)** and the Aquatic - Finger Piers Area figures (**Figure 3-9**).

3.3.7 Groundwater Reference Area

To assess background concentrations of inorganics constituents in groundwater, a DPT boring (identified as UST1-18 in the field) was advanced near MW-05 in the soccer field west of UST Site No. 1 and a temporary microwell was installed to collect a groundwater sample. The location of the temporary microwell is shown on **Figure 3-4** and construction details are shown in **Table 3-9**. This area was selected based on the historical analytical results from MW-05, which indicate the area has not been affected by releases. The groundwater sample was analyzed for TPH-G, TPH-D, TPH-O, VOCs, PAHs, TOC, total and dissolved metals, nitrate, nitrite, chloride, sulfate, and TDS as shown in **Table 3-2.** The location and sample results are considered "reference" because the results confirmed the absence of impacts by anthropogenic chemicals and activity.

3.4 Groundwater Hydraulic Conductivity Testing

Slug tests were performed on 10 and 11 September 2008 at Refueling Pit 3, in MW-03, MW-04, and MW-05, to determine hydraulic conductivity to support assessment of the groundwater flow direction and gradient (see **Appendix H**). A data summary for the hydraulic conductivity evaluation conducted at Refueling Pit 3 is shown on **Figure 2-8**. This information is used to assess the groundwater to surface water ecological exposure pathway and whether groundwater transports VOCs to areas beneath Hangar 1. As part of planning these tests and determining well locations,

water level data collected from October 2007 were initially used. Water level data collected from the newly installed microwells and existing wells were combined to evaluate the hydrogeologic framework at Refueling Pit 3. Field water level measurements were collected, along with vertical survey control within 0.01 foot, to ensure groundwater flow was understood.

Based on the slug test results and thickness observed at Refueling Pit 3, estimated yield for wells screened in the unconfined water-bearing zone ranges from a minimum of 0.3 gallons per minute (gpm) to a maximum of 9.4 gpm. This estimate is based on an unconfined saturated thickness ranging from 10 to 14 feet, hydraulic conductivities ranging from 1 to 20 feet/day, and assumes an 80 percent efficient 16-inch diameter well screened across the entire saturated thickness. The complete evaluation of the hydraulic conductivity analysis and an explanation of the calculations are provided in **Appendix H.** Based on similar hydrogeologic characteristics, a similar range in well yields is expected for wells throughout the Study Area.

3.5 UVF-3100A Field Tests

To delimit the approximate vertical extent of petroleum hydrocarbons in soil borings and to identify the functionality of field tests for future remedial decisions, 69 depth-discrete soil samples from various depths and location at each of the five terrestrial DUs were analyzed using siteLAB's® UVF Analytical Test Kit UVF-3100A (UVF-3100A). The soil samples were selected following the rationale in the project QAPP (CDM 2008b) and based upon observations and readings on the OVM/PID (see **Section 3.3**).

The UVF tests were conducted in the field office for the gasoline TPH-G) and diesel range hydrocarbons (TPH-D). The UVF field test conducted on soil samples from each of the five upland source areas have results tabulated for TPH-G and TPH-D in **Tables 3-10a** and **3-10b**.

For comparison and confirmation of the UVF results, split samples from seven locations representing three DUs, were analyzed by the laboratory using methods NWTPH-Dx and NWTPH-Gx. Analytical laboratory data compared to UVF-3100A data are tabulated in **Table 3-10c**.

Because the UVF field test is performed on a different sample volume than that for laboratory analyses, measuring concentrations of TPH-D and TPH-G is dependent on the homogeneity of the sample matrix. Additionally, sample volumes were not homogenized before extraction because of the volatility of TPH-G. All of these factors may produce errors that cause false positive and false negative results.

As shown in **Table 3-10c**, of the seven UVF-3100A field test results for TPH-D compared to split analytical results, two (29 percent) had concentrations detected by the field test method for which the laboratory results were equal to or less than the SQL (non detects). The UVF results were of the same order of magnitude as the

laboratory SQL. One had a concentration of 5 mg/kg detected by UVF-3100A and non-detection at 5.6U mg/kg in the laboratory analysis. The other sample has a result of 32.1 mg/kg in the UVF 3100A analysis and a laboratory result of 30U mg/kg. Five of the seven split samples had UVF-3100A results less than lab concentrations. TPH-D was detected by both methods in five of the seven split samples. In three of these five split samples, the UVF-3100A results were an order of magnitude less than their corresponding laboratory results. In this instance, these three UVF-3100A results are considered false negatives. For the remaining two sample sets, a result of 6.3 mg/kg by UVF-3100A compares to a laboratory result of 11 mg/kg and a UVF result of 154.9 mg/kg compares to a laboratory result of 18J mg/kg.

For statistical comparison of the UVF-3100A and laboratory data, a linear regression of the natural log (*ln*) of the diesel-range results was completed (see **Table 3-10c)**. The best-fit line has a square of the correlation coefficient *r* (R^2) of 0.48. Poor correlation may be attributed one or more of the following scenarios:

- Different samples aliquots are used (5 grams for the UVF-3100A analysis versus 10 grams for the laboratory analysis, unless screening indicates high levels).
- The samples analyzed by the laboratory were taken through a more rigorous extraction process than the UVF-3100A samples, which were simply shaken in methanol.
- Samples were collected at different DUs where the nature of petroleum varies with age and origin.

The results of these samples suggest that at relatively low concentrations of TPH-D (<50 mg/kg), heterogeneity plays a larger role than at higher concentrations of TPH-D (>50 mg/kg), where the extraction method and heterogeneity play roles that are more significant.

Of the seven UVF-3100A test results for TPH-G, none of the samples had concentrations greater than split sample results by laboratory analyses. Only two samples yielded false negative errors, or had test results less than analytical results. For five of the seven TPH-G analyses, UVF-3100A test results were nondetect, but had reporting limits less than the laboratory SQL.

TPH-G is volatile and losses can occur when exposed to air. The 5-gram aliquot for the UVF-3100A analysis was weighed on weighing paper on an open-air balance. The 5-gram aliquot for the laboratory analysis was collected by U.S. EPA Method 5035, which uses a syringe to transfer soil from insitu directly into a 40-mL vial with methanol preservative. Sample aliquots for the laboratory analyses were immersed in the methanol extraction fluid for several days because of the time required for delivery to the lab and log-in procedures before analysis, while sample aliquots for the UVF-3100A analyses were performed in the field within one to two days of collection. A longer extraction period can extract more TPH-G over time when concentrations are higher. Additionally, a more thorough homogenization of the sample aliquot in the methanol was likely performed at the laboratory.

If the UVF-3100A results were used for screening purposes, the values would be compared to the ODEQ RBC for TPH-G of 720 mg/kg and the ODEQ RBC for TPH-D of 3,900 mg/kg. For screening decisions using the human health criteria, the UVF results compared to laboratory results are useful and produce no false negative errors. That is, when the UVF results show concentrations greater than criteria, the laboratory analyses show results greater than the 3,900 mg/kg criteria. In addition, relative to the criteria, there are no false positive errors. That is, when the UVF results indicate a concentration less than the criteria, the laboratory results are less than criteria.

Overall, based on the poor correlation of UVF-3100A results to analytical results, the UVF-3100A data should not be used to characterize the nature or extent of possible petroleum contamination. However, the use of UVF tests do show a potentially useful for indicating concentrations greater than or less than a threshold criteria, such as the human health criteria discussed above.

3.6 Aquatic Investigations

Three aquatic DUs (North of Pier 8, Finger Piers Area, and Near Landfill) proximal to the terrestrial DUs within the near-shore environment of Cathlamet Bay were investigated during this RI (see **Figure 1-2**). These aquatic DUs may have been impacted by releases from upland source areas. The environmental conditions within these DUs were assessed by collecting surface sediment samples using the IS approach, invertebrate, fish tissue samples and high volume surface water and grab samples. Sample locations for sediment, surface water, and clams were accessed from a boat and locations were recorded by a global positioning system (GPS) device when collecting samples. Invertebrate or Asian clam (*Corbicula*) tissue was collected to support food web modeling in the ecological risk assessment (see **Section 7**). The clam tissue sample matrix is designated as "TC" in **Appendix F**. Forage fish, or whole body fish, consisting of juvenile prickly sculpin (*Cottus asper*) and three-spined stickleback (*Gasterosteus aculeatus*) tissue was collected to support food web modeling. The forage fish tissue sample matrix is designated as "TM" in **Appendix F**. Fillets of prickly sculpin (*Cottus asper*) were used to support the human health risk assessment (see **Section 6**). The fish fillet tissue sample matrix is designated as "TF" in **Appendix F**.

An IS approach was used to evaluate chemical concentrations in sediments in the aquatic Study Area. IS was designed to develop an estimate of mean concentrations of chemical constituents in surface sediments in the aquatic DUs to meet the project data objectives and decision logic. Selection of IS was made because a dataset of discrete samples is likely to have a positively skewed distribution. Discrete sample results typically have higher variance than IS results. A low number of discrete samples will tend to underestimate the true (population) mean because the likelihood of sampling small areas with greater levels of contamination within a DU will be small (i.e., distributional heterogeneity within the DU will not have been adequately addressed).

The IS method improves reliability and defensibility of sampling data to estimate mean concentrations by reducing their variability compared to conventional discrete sampling strategies. The data distribution for IS replicate samples tends to be normally distributed because data are replicate estimates of the mean concentration. In contrast, discrete samples represent the underlying population of concentrations within an exposure unit, and tend to be more variable and positively skewed. In addition, levels of statistical confidence and decision uncertainty that would require a large number of discrete analyses are obtained with a few incremental multiple samples.

The aquatic investigations for this RI was planned (CDM 2008a and 2008b) with a focus on the objective of collecting sediment data to support risk evaluations and thus sought an economical approach to allow a reliable estimate of mean concentrations throughout the aquatic areas. With the understanding that risk characterization relies on estimates of exposure point concentrations, EPA guidance (EPA 1989a) provides the following explanation estimates, "Because of the uncertainty associated with any estimate of exposure concentration, the upper confidence limit (i.e., the 95 percent upper confidence limit) on the arithmetic average will be used for this variable [*the exposure point concentration*]. If there is great variability in measured or modeled concentration values (such as when too few samples are taken or when model inputs are uncertain), the upper confidence limit on the average concentration will be high, and conceivably could be above the maximum detected or modeled value. In these cases, the maximum detected or modeled value should be used to estimate exposure concentrations. This could be regarded by some as too conservative an estimate, but given the uncertainty in the data in these situations, this approach is regarded as reasonable." One means to avoid the problem of excessively high estimates for the 95 percent upper confidence limit on the mean is to collect and analyze large numbers of samples. This approach reduces the influence of right-skewed data sets on estimates of the mean, and hence reduces the size of the confidence interval about the mean. While technically sound, this option is expensive in the field, in the laboratory, for data validation and evaluation and for management of data in risk assessments. Another approach that can provide robust estimates of the mean is IMS. This approach allows large numbers of samples to be collected, thus minimizing the influence of right-skewed distributions, but eliminates the added cost and effort required to analyze large numbers of samples and manage large amounts of data. By compositing large numbers of subsamples collected within an exposure unit, extremes in right-skew are appropriately averaged, and few analyses of the composite are then required to obtain a useful estimate of the mean for use as an exposure point concentration. Thus, IS is a reliable way to obtain a defensible estimate of the mean, avoid difficulties associated with high estimates for confidence intervals about the mean, and maintain reasonable analytical and data management costs.

During the 2008 sampling event, IS was used to collect 28 surface grab samples from each of the four aquatic decision units. Each of the samples was homogenized into one container from which seven representative aliquots were removed and submitted for laboratory analyses. The upstream reference location is the fourth decision unit

from which sediment was collected using the IS approach and is used as the basis for comparison to analytical results of sediments from three Study Area aquatic decision units. Portions of sediments samples from all aquatic decision units were frozen for possible later analysis. The analytical results of IS samples for each decision unit represent the entire decision unit.

Three to seven aliquots of IS samples from the Reference Area and Near Landfill decision units were analyzed for dioxins and the remaining IS samples were frozen for possible later analysis. The strategy for evaluation of these samples was to compare the Reference Area and Near Landfill DU dioxin levels. If there was no indication of concentrations found in Near Landfill decision unit sediments differed from those in Reference sediments, then no further dioxin/furan analysis of surface sediments from the Finger Pier DU would be necessary. Conversely, any evidence of a release from the landfill to surface sediments would trigger analysis of the IS samples from the Finger Pier and North of Pier 8 DUs.

The following species (listed by preference) were considered the likely upper trophic level fish encountered within the aquatic DUs: shiner perch, Pacific herring, prickly sculpin, and starry flounder. Prickly sculpin was the only species caught in the aquatic DUs. This species was less desirable than shiner perch and Pacific herring, from a risk assessment standpoint; because (1) they are not targeted by anglers and (2) they have a low fat content that may reduce accumulation of organic bioaccumulative chemicals. The lack of other upper level trophic species (excluding salmonids) was also documented by the USGS. In a study of 2,3,7,8-TCDD TEQs in large estuaries along the west coast, benthic fish samples were collected along the Columbia River estuary, with two tissue sampling locales being northwest of Tongue Point (USGS 2003). Pacific staghorn sculpin were predominantly caught in the near-shore, shallow water environments along the Columbia River estuary (USGS 2003).

An appropriate upriver location was collaboratively chosen by the USACE and ODEQ personnel during the September 2008 field investigation and will be used as an aquatic reference location. The environmental conditions of the aquatic reference location were assessed by collecting offshore surface sediment and surface water samples and by collecting invertebrate and fish tissue samples.

3.6.1 Aquatic – Finger Piers Area

The analyses to be conducted for each media at each sampling location in the Aquatic – Finger Piers DU are shown in **Tables 3-5** through **3-7**. Sampling locations are shown on **Figure 3-9**. Environmental conditions in aquatic areas surrounding the finger piers were assessed by collecting near-shore and offshore surface sediment samples, advancing sediment cores, collecting near-shore and offshore surface water samples, and collecting IS tissue samples.

3.6.1.1 Sediment Sampling

Twenty-eight sediment samples, using the IS approach, were collected to provide data to determine ecological effects and human health risks in the aquatic environment

surrounding the finger piers. Three sediment cores were collected to determine the rate of sediment accumulation for assessing sediment transport/burial, to evaluate the issues related to future dredging, and to assess the potential for natural recovery as a remedial component. Details of the sampling method (used in all aquatic areas) are described in the next paragraph.

Using the IS approach, 28 surface sediment grab samples were collected between Piers 1 through 8. All of the samples were homogenized into one container, from which seven representative composite samples (FP-01 through FP-07) were submitted for analyses. The resulting IS data set represents the Finger Piers Area surface sediments as a whole. As shown in **Table 3-5**, analyses included TPH-D, TPH-O, SVOCs, PAHs (by selected ion monitoring [SIM]), metals, TBT, pesticides, PCBs, total volatile solids, TOC, percent solids, total sulfides, ammonia, and hexachlorobenzene. TPH-G and VOC analyses were performed on three discrete near-shore samples (MIS-33, MIS-51, and MIS-53) collected during the IS process, not from composite IS samples because of the loss of volatile compounds during homogenization. Seven discrete near-shore sediment samples (MIS-33, MIS-37, MIS-40, MIS-42, MIS-46, MIS-51, and MIS-53) collected during the IS process were set aside as archived samples for use in delineating upland source areas and correlating to the near-shore sediment samples collected for Refueling Pit 3 and the Fire Training Area. The decision process regarding the disposition of archived sediments is discussed in **Section 4.3.8.4**.

A bathymetric survey was completed in the aquatic DUs to measure general sediment surface elevations throughout Cathlamet Bay and precise surface elevations around the Finger Piers Area. The results of this survey are shown on **Figure 3-1**. To tie in current bathymetry and sediment stratigraphy with the 1998 sediment core data, three sediment core samples (FP-11, FP-12, and FP-13) were collected to a depth correlating with the previous 1998 sediment samples. The location of the sediment cores is shown on **Figure 3-9** and core logs are included in Appendix A. Based on preliminary data from the bathymetric survey, the cores were extended to depths ranging between 63.6 and 74.5 inches BML. Core FP-11 was extended to 67 inches, or below the projected depth of the Mt. St. Helens ash marker bed. It was anticipated that the Mt. St. Helens ash layer would have been encountered at 63.6 inches BML. Core FP-12 was advanced to 74.5 inches BML to extend below a sand/black silt contact, which was expected at 32.4 inches BML. Core FP-13 was advanced to 68 inches BML to extend below the Mt. St. Helens ash layer, which was expected at 42 inches BML. The length of the recovered core was the total extended length minus 6 inches that was lost during removal of the core nose. Each of these three sediment cores was logged and described following the USCS.

Surface sediment samples were collected from near-shore areas adjacent to Refueling Pit 3 and the Fire Training Area to assess the impacts to sediment and surface water from chemicals released from these upland source areas. These near-shore sediment samples and surface water samples were collected during the Finger Piers DU sampling effort, not during the upland subsurface investigations, and the analyses tables are therefore collocated with the Aquatic - Finger Piers analyses tables instead

of those for the Refueling Pit 3 and Fire Training Area. The locations for the near-shore samples are shown on **Figure 3-5** (Refueling Pit 3), **Figure 3-8** (Fire Training Area), and **Figure 3-9** (Aquatic - Finger Piers Area).

3.6.1.2 Surface Water Sampling

Two surface water samples were collected to provide surface water analytical data to assess whether surface water human health and ecological risk pathways are significant for the Finger Piers Area. The two surface water samples were collected at the locations shown on **Figure 3-9**. As shown in **Table 3-6**, analyses performed included TPH-G, TPH-D, TPH-O, VOCs, PAHs, metals, organochlorine pesticides, ammonia, and TOC. One sample was analyzed for total suspended solids. High-volume water sampling methods were used to collect samples for analysis of organic compounds. The high volume water sampling method was used to concentrate trace levels of particulate-bound and dissolved-phase chemicals from a large volume of water for analysis by standard analytical methods. The high volume surface water sampling method was used to collect samples for analysis of PAHs, PCBs, organochlorine pesticides, and dioxin/furans, if these particular analyses were required in a decision unit. Surface water grab samples were collected at each location by diverting water from the PUF column in order to collect samples for analysis of gasoline- and diesel-range petroleum hydrocarbons, VOCs, total and dissolved metals, and ammonia.

3.6.1.3 Tissue Sampling

Initially, in the QAPP (CDM 2008b), it was proposed that 28 selected benthic biota tissue samples, using an IS sampling approach, and one fish tissue sample were to be collected to provide chemistry data to assess bioavailability and impacts to benthic fauna and to assess whether human health (consumption) and ecological risk pathways (both direct and food-web exposures) are significant in the Finger Piers Area. Tissue samples of clams were to be collected concurrently in the 28 IS sediment sampling areas between Piers 1 through 8 and composited to yield seven replicate samples for analyses. Once sampling was under way, however, it became apparent that it would not be possible to collect sufficient volume of clam soft tissue for seven replicate samples. This was due to the scarcity and small size of the clams collected using the Power Van Veen sampler. Another contributing factor was that the number of replicate samples from each DU had been reduced to a single sample per area because of the limited sampling budget and timeframe allotted. A significantly smaller volume of soft tissue was recovered in the Aquatic - Finger Piers Area. As shown in **Table 3-7**, sufficient tissue sample volume was collected to perform the following analyses: SVOCs, metals, organochlorine pesticides, PCB Aroclors, dioxins /furans, TBT, and percent lipids.

Two separate methods were employed for the collection of fish tissue samples. The preferred target species, shiner perch (*Cymatogaster aggregata*), was not collected in the Finger Piers Area, so an alternative target species was selected. Prickly sculpin (*Cottus asper*) tissue (skin-on fillet) was collected using hooks and line, yielding one

sample for analysis to support the human health risk assessment. Additionally, three-spined stickleback (*Gasterosteus aculeatus*) and small (<5 inches) prickly sculpin were collected in minnow traps. The traps were placed on the north and south sides of Pier 4. The small fish (both taxa) were submitted to the laboratory for whole-body composite analysis to support the ecological risk assessment.

3.6.2 Aquatic – Near Landfill

The analyses to be conducted for each media at each sampling location in the Aquatic – Near Landfill are shown in **Tables 3-5** through **3-7**. Sampling locations are shown on **Figure 3-10**. Environmental conditions in aquatic areas off shore of the landfill were assessed by collecting near-shore and offshore surface sediment samples and surface water samples and by collecting IS tissue samples.

3.6.2.1 Sediment Sampling

Using the IS approach, 28 surface sediment grab samples from the area east of the landfill were collected and composited, from which seven representative samples were collected for analyses (LF-01 through LF-07). The resulting IS data set represents the Landfill Area sediments as a whole. As shown in **Table 3-5,** analyses included TPH-D, TPH-O, SVOCs, PAHs (by SIM), metals, organochlorine pesticides, PCB Aroclors, dioxins and furans, total volatile solids, TOC, percent solids, total sulfides, and ammonia. TPH-G, VOC, and pentachlorophenol (PCP) analyses were performed on three near-shore discrete samples (MIS-57, MIS-65, and MIS-72) collected as part of the IS process, not on composite IS samples, because of the loss of volatile compounds during the compositing process. For use in delineating upland source areas, seven discrete near-shore samples (MIS-57, MIS-61, MIS-65, MIS-69, MIS-72, MIS-80, and MIS-84) were set aside as archived samples. The same reference location for the Finger Piers DU surface sediments was used for the Landfill DU sediments. The decision process regarding the disposition of archived sediments is discussed in **Section 4.3.8.4**.

3.6.2.2 Surface Water Sampling

One surface water sample, LF-11, was collected at a location between the landfill and the mouth of Mill Creek as shown on **Figure 3-10**. As shown in **Table 3-6**, analyses conducted include TPH-D, TPH-O, TPH-G, VOCs, PAHs, metals, organochlorine pesticides, PCBs, dioxins and furans, ammonia, and total suspended solids. High-volume water sampling methods were used to collect samples for analysis of organic compounds. The high volume water sampling method was used to concentrate trace levels of particulate-bound and dissolved-phase chemicals from a large volume of water for analysis by standard analytical methods. The high volume surface water sampling method was used to collect samples for analysis of PAHs, PCBs, organochlorine pesticides, and dioxin/furans, if these particular analyses were required in a decision unit. Surface water grab samples were collected at each location by diverting water from the PUF column in order to collect samples for analysis of gasoline- and diesel-range petroleum hydrocarbons, VOCs, total and dissolved metals, and ammonia.

3.6.2.3 Tissue Sampling

As stated in the previous section, concurrent to IS sediment sampling, tissue samples of *Corbicula* (Asian clam) were collected from each IS sampling location in the reference area. In addition, prickly sculpin (*Cottus asper*) tissue (skin-on fillet) was collected using hooks and line, yielding one sample for analysis from the reference area. Additionally, three-spined stickleback (*Gasterosteus aculeatus*) and one small (<5 inches) prickly sculpin were collected in minnow traps. The traps were placed on the south side of Pier 1. The small fish caught in the minnow traps were submitted to the laboratory for whole-body analysis to support the ecological risk assessment. Tissue analyses included the following compounds: select SVOCs, metals, TBT, organochlorine pesticides, PCB Aroclors, dioxins and furans, and percent lipids, as shown in **Table 3-7**.

3.6.3 Aquatic – North of Pier 8

The analyses to be conducted for each media at each sampling location in the Aquatic - North of Pier 8 are shown in **Tables 3-5** through **3-7**. Sampling locations are shown on **Figure 3-11**. Environmental conditions in aquatic areas off shore of the AST Fuel Storage Area and UST Site No. 1 were assessed by collecting near-shore and offshore surface sediment samples and water samples and by collecting IS tissue samples.

3.6.3.1 Sediment Sampling

Using the IS sampling approach described, 28 surface sediment grab samples from the area east of UST Site No. 1 and areas north of Finger Pier 8 were collected and composited, from which seven representative samples were collected for analyses (NTP-01 through NTP-07). The resulting IS data set represents the Aquatic - North of Pier 8 area sediments as a whole. As shown on **Table 3-5**, analyses conducted included TPH-D, TPH-O, SVOCs, PAHs (by SIM), metals, total volatile solids, TOC, percent solids, total sulfides, and ammonia. TPH-G, VOC, and PCP analyses were performed on three near-shore discrete samples (MIS-01, MIS-07, and MIS-21), not on composite IS samples, because of the loss of volatile compounds during the compositing process. For use in delineating upland source areas, seven discrete near-shore samples (MIS-01, MIS-04, MIS-07, MIS-16, MIS-21, MIS-22, and MIS-23) were set aside as archived samples. The same reference location for the Finger Piers surface sediments was used for the Aquatic - North of Pier 8 sediments. The decision process regarding the disposition of archived sediments is discussed in **Section 4.3.8.4.**

Table 3-5 shows the analyses conducted on near-shore sediment samples collected adjacent to UST Site No. 1 within the Aquatic - North of Pier 8 DU. Two near shore sediment samples (UST1-22 and UST1-23) were collected during the Aquatic - North of Pier 8 DU sampling effort, not during the upland subsurface investigation of UST Site No. 1. The collection locations of the near shore samples are shown on **Figure 3-3**.

3.6.3.2 Surface Water Sampling

One surface water sample, NTP-11, was collected at the location shown on **Figure 3-11**. Analyses conducted include TPH-D, TPH-O, TPH-G, VOCs, PAHs, metals, ammonia, organochlorine pesticides, and total suspended solids.

Table 3-6 shows the analyses conducted on surface water samples collected from near-shore areas adjacent to UST Site No. 1 within the Aquatic - North of Pier 8 DU. Two near-shore surface water samples (UST1-14 and UST1-15) were collected during the Aquatic - North of Pier 8 DU sampling effort, not during the upland subsurface investigation of UST Site No. 1. High-volume water sampling methods were used to collect samples for analysis of organic compounds. The high volume water sampling method was used to concentrate trace levels of particulate-bound and dissolved-phase chemicals from a large volume of water for analysis by standard analytical methods. The high volume surface water sampling method was used to collect samples for analysis of PAHs, PCBs, organochlorine pesticides, and dioxin/furans, if these particular analyses were required in a decision unit. Surface water grab samples were collected at each location by diverting water from the PUF column in order to collect samples for analysis of gasoline- and diesel-range petroleum hydrocarbons, VOCs, total and dissolved metals, and ammonia. The collection locations of the near-shore samples are shown on **Figure 3-3**.

3.6.3.3 Tissue Sampling

Concurrent to IS sediment sampling, tissue samples of *Corbicula* (Asian clam) were collected from each IS sampling location in the reference location. In addition, prickly sculpin (*Cottus asper*) tissue (skin-on fillet) were collected using hooks and line, yielding one sample for analysis from the reference area. Additionally, three-spined stickleback (*Gasterosteus aculeatus*) and small (<5 inches) prickly sculpin were collected in minnow traps. The traps were placed on the north side of Pier 8 near UST Site No. 1. The small fish caught in the minnow traps were submitted to the laboratory for whole-body composite analysis to support the ecological risk assessment. As shown on **Table 3-7**, tissue analyses included select SVOCs, metals, TBT, organochlorine pesticides, PCBs, dioxins and furans, and percent lipids.

3.6.4 Aquatic – Reference Area

The analyses to be conducted for each media at each sampling location in the Aquatic – Reference Area are shown in **Tables 3-5 through 3-7**. Sampling locations are shown on **Figure 3-12**. Environmental conditions upriver of the aquatic DU were assessed by collecting offshore surface sediment and surface water samples and by collecting MI tissue samples.

3.6.4.1 Sediment Sampling

Using the IS sampling approach, 28 surface sediment samples were collected from a reference location using the same collection methods and analyzed for the same suite of constituents identified for the near-shore surface sediment samples. Initially, two potential reference area sampling locations were sited immediately adjacent to each

other in an aquatic area just south of the Aquatic - Near Landfill DU. On September 22, 2008, the selected reference area IS sampling locations were established by the aquatic field team following a sediment grain-size analysis conducted by the field team, with USACE and ODEQ representatives present. In addition, grain size analyses were conducted on surface sediment grabs from the Aquatic - Finger Piers DU and the Aquatic - Near Landfill DU. It was determined that all locations had sufficiently similar sediment grain sizes; therefore, either of the two reference areas could be used. To ensure comparability, the IS locations within the Reference Area were chosen so that they were similar to the other DUs for criteria that included MLLW depth, distance from shore, distance between IS sampling points, velocity of river current, and sediment characteristics. Upon evaluation of the two reference areas for these criteria, it was determined that to achieve sufficient spacing between IS sampling points (similar to the spacing in the Aquatic - Near Landfill DU and Aquatic - North of Finger Pier 8 DU), both of the reference areas would be combined into one Aquatic - Reference Area.

Upon selection of the Reference Area, 28 IS surface sediment samples were collected to yield seven composite samples for analysis (REF01 through REF-07). The following analyses were performed on the seven composite samples: TPH-D, TPH-O, SVOCs, PAHs (by SIM), metals, organochlorine pesticides, hexachlorobenzene, PCB Aroclors, total volatile solids, TOC, percent solids, total sulfide, and ammonia. Additionally, TPH-G, VOC, and PCP analyses were performed on three near-shore discrete samples (MIS-86, MIS-90, and MIS-98) collected as part of the IS process, not on composite IS samples, because of the loss of volatile compounds during the compositing process. Seven discrete near-shore sediment samples (MIS-85, MIS-86, MIS-87, MIS-89, MIS-90, MIS-98, and MIS-100) collected during the IS process were set aside as archived samples for use in delineating upriver source areas not associated with historical Study Area activities. The decision process regarding the disposition of archived sediments is discussed in Section 4.3.8.4.

3.6.4.2 Surface Water Sampling

One surface water sample, REF-13, was collected at the location shown on **Figure 3-12**. Surface water analyses included TPH-G, TPH-D, TPH-O, VOCs, PAHs (by SIM), dioxins and furans, metals, organochlorine pesticides, PCB Aroclors, total suspended solids, and ammonia. High-volume water sampling methods were used to collect samples for analysis of organic compounds. The high volume water sampling method was used to concentrate trace levels of particulate-bound and dissolved-phase chemicals from a large volume of water for analysis by standard analytical methods. The high volume surface water sampling method was used to collect samples for analysis of PAHs, PCBs, organochlorine pesticides, and dioxin/furans, if these particular analyses were required in a decision unit. Surface water grab samples were collected at each location by diverting water from the PUF column in order to collect samples for analysis of gasoline- and diesel-range petroleum hydrocarbons, VOCs, total and dissolved metals, and ammonia. **Table 3-6** shows the analyses conducted on the surface water sample collected from the Reference Area.

3.6.4.3 Tissue Sampling

As stated previously, concurrent to IS sediment sampling, tissue samples of *Corbicula* (Asian clam) were collected from each IS sampling location in the reference location. In addition, prickly sculpin (*Cottus asper*) tissue (skin-on fillet) was collected using hooks and line, yielding one sample for analysis from the reference area. Additionally, three-spined stickleback (*Gasterosteus aculeatus*) and small (<5 inches) prickly sculpin (*Cottus asper*) were collected in minnow traps. The traps were set off of the Marine and Environmental Research and Training Station (MERTS) dock operated by Clatsop Community College (under license from the USACE) located in the reference area. The small fish caught in the minnow traps were submitted to the laboratory for whole-body composite analysis to support the ecological risk assessment. As shown on **Table 3-7**, the following tissue analyses were conducted: select SVOCs, dioxins and furans, metals, TBT, organochlorine pesticides, PCB Aroclors, and percent lipids.

3.7 Deviations from QAPP

This section summarizes the deviations from the QAPP that occurred during this remedial investigation (CDM 2008b). These deviations did not affect the DQOs outlined during the initial planning stages of this RI.

- Groundwater samples (UST4-7 and UST4-8) were not collected from hand-dug test pits at UST Site No. 4 because groundwater was not encountered. Additionally, groundwater was not encountered in borings UST4-1 and UST4-2. A perched zone of groundwater was encountered in boring UST4-3, and a temporary microwell was installed in the boring in an attempt to obtain a groundwater sample. The temporary microwell was removed 24 hours after installation because of the lack of significant groundwater accumulation; therefore, a groundwater sample was not collected.

- A groundwater field duplicate sample was not collected from Refueling Pit 3 because of miscommunication within the field team. To facilitate QC evaluations and report on a DU basis, at least one groundwater sample field duplicate was to be collected from each of the five upland DUs (i.e., the AST Fuel Storage Area, UST Site No. 1, Refueling Pit 3, UST Site No. 4, and the Fire Training Area). Overall, the total number of groundwater samples collected during this RI is 35, and four field groundwater duplicates were collected. This is an 11% field duplicate sampling rate, which exceeded the 5% minimum.

- At least one soil sample field duplicate was to be collected from each of the five upland DUs (i.e., the AST Fuel Storage Area, UST Site No. 1, Refueling Pit 3, UST Site No. 4, and the Fire Training Area) to facilitate QC evaluations and reporting on a DU basis. Soil field duplicates were not collected from the AST Fuel Storage Area. The total number of soil samples collected during this RI was 55, and six field duplicate soil samples were collected. This is approximately an 11% field duplicate sampling rate, which exceeded the 5% minimum specified in the QAPP.

- Groundwater seep samples (UST1-16 and UST1-17) were not collected from the bulkhead below Pier 8 because seeps were not observed over the 4-week course of this investigation. The area was inspected on August 26, September 12, September 18, and October 1, 2008, for the presence of seeps. The need for seep sampling will be evaluated using the groundwater data collected during the RI.

- Near-shore sediment sample identifications (IDs) were in error on the original QAPP tables. RFP3-13 and RFP3-14 were identified as soil gas samples and near-shore sediment samples. The near-shore sediment samples were renamed RFP3-20 and RFP3-21 to remain consistent with soil gas labeling nomenclature.

- Chemical quality data for the deeper sediment samples from core locations FP-11, FP-12, and FP-13, were not evaluated by comparison to the limits as described in the *Regional Sediment Evaluation Team (RSET) Dredged Material Evaluation Framework* for freshwater procedures (USACE 2009). Such comparison was not compatible with the CERCLA-based remedial investigation and reporting. Each core sample had chemical analyses performed on a composite from approximately 0 to 3 foot of the core and the analytical results are in Appendix E. These data can be used for future dredging and disposal evaluations if needed.

- Soil gas sample RFP3-14 (Hangar 1 sub-slab sample) was not collected. Soil samples collected outside and adjacent to the building did not contain any visible LNAPL. Additionally, the adjacent soil gas probes did not exhibit elevated OVM-PID readings. If any of the conditions stated previously were found to exist, the USACE and the Job Corps Center facility managers would have been contacted for access into Hangar 1.

- During the field sampling, the specified number of soil samples for EPH/VPH analyses specified in the QAPP were not collected from each of the five upland DUs. During the field investigation, only one EPH/VPH soil sample was collected from the AST Fuel Storage Area and the Fire Training Area and two samples were collected at UST Site No. 1. A request was sent to the laboratory to perform EPH/VPH analyses on one soil sample from both Refueling Pit 3 and UST Site No. 4 once this deviation was made apparent. The analyses were performed after the 14-day holding time required for EPH/VPH analysis and the detected analytical results were validated, (see **Section 3.8.3.2)** with a "J" or "UJ" qualifier and used in the evaluations.

- The near-shore sediment samples from the three upland DUs (UST Site No. 1, Refueling Pit 3, and Fire Training Area) could not be collected using a manual hand auger. Because of limited accessibility and safety concerns using the hand auguring method, the Field Team Leader and the Project Manager determined that samples were to be collected while aboard the subcontractor's work vessel using the Power Van Veen Sampler.

- Because of sampling error, only three of the eight planned split samples were collected and tested using a Sitelab UVF-3100 Analyzer and field extraction kit from the 61 total

(including duplicates) soil samples submitted for analyses. The samples tested are summarized as follows:

- AST Fuel Storage Area - Two split samples were required and none was collected.
- UST Site No. 1 – One split sample was required and was collected.
- Refueling Pit 3 – Two split samples were required and only one was collected.
- UST Site No. 4 – One split sample was required and none was collected.
- Fire Training Area – Two split samples were required and only one was collected.

- For statistical reasons, up to 10% of the field, tested samples using the analyzer were to be duplicated by laboratory analysis; only 4% of the duplicates were completed.

- Initially, tissue samples of *Corbicula* (Asian clam) were to be collected concurrently with the IS sediment sampling in each Aquatic DU and composited to yield seven samples for analyses. However, once sampling was under way, it became apparent that it would not be possible to collect a sufficient volume of clam soft tissue for seven replicate samples. The relative scarcity and small size of the clams collected using the Power Van Veen Sampler, as well as the limited sampling budget and timeframe, required that the number of replicate samples from each DU be reduced to a single sample per area. In addition, a significantly smaller volume of soft tissue was recovered in the Aquatic - Finger Piers DU.

- As specified in the QAPP, PCP was to be analyzed on all seven replicate IS sediment samples from all four Aquatic DUs and on all near-shore sediment samples collected as part of the UST Site No. 1, Refueling Pit 3, and Fire Training Area DUs. Although PCP is considered a standard 8270 compound, the reporting limit is 100 µg/kg. The ODEQ Marine Screening Level is 17 µg/kg. Additionally, PCP is not recovered by the PAH SIM method because the extract for this analysis goes through a silica gel clean-up. During this silica gel clean-up, all phenol compounds are lost. The laboratory's solution was to analyze PCP using EPA Method 8151, or as part of the herbicide analysis, where the phenol would be derivatized to lose the polarity and then analyzed by gas chromatography (GC)/electron capture detector (ECD). This will provide a reporting limit of 1 µg/kg. Because of the additional costs created by using this analytical method, PCP analysis was requested on eight archived MIS sediment samples that were close to shore, as shown in **Table 3-5**. The project chemist decided that PCP would be expected to adsorb onto the sediment and would not be required for surface water analysis.

- Hexachlorobenzene (HCB) is a standard EPA Method 8270 compound with a reporting limit of 20 µg/kg. A lower reporting limit was desired because the ODEQ Marine Screening Value is 6 µg/kg. It was clarified with Columbia Analytical that the HCB could be analyzed with the pesticides to produce a reporting limit of 1 µg/kg. HCB was shown as a required analysis for the surface waters off shore of UST Site No. 1, but

not for the near-shore sediments. This was considered an error in the QAPP. It did not make sense to analyze the surface water for contaminants that were not analyzed for in the sediments, because the bulk of the contaminant would be expected in the sediment, with the primary concern being the partitioning of the contaminant between the sediment and the surface water. Ultimately, organochlorine pesticides, including HCB, are not contaminants of concern at UST Site No. 1; therefore, the surface water pesticide analyses were withdrawn.

- In the UST Site No. 4 DU, three DPT borings were to be drilled to the buried concrete slab (approximately 15 feet bgs) within the excavation area that was backfilled after tank removal. DPT boring UST4-2 was drilled to 20 feet bgs outside the excavation to determine if soil beneath the concrete slab had been affected by a release of petroleum hydrocarbons.

3.8 Data Quality

QA objectives and details regarding data management, verification, and validation were provided in the QAPP (CDM 2008b). Analytical laboratory services were procured in 2008 following a pre-qualification process that certified through signed declarations, that the laboratories were in full compliance with the Department of Defense Quality Systems Manual Environmental Laboratories (DQSM) Version 3, dated January 2006, were accredited by the National Environmental Laboratory Accreditation Conference (NELAC), and had current year National Environmental Laboratory Accreditation Program certifications for the specific analyses to be performed. The USACE project chemist received and reviewed the national and state certificates.

This section details the QA/QC activities conducted, describes the data verification, validation, and data usability review, and summarizes the review results. The field QA program was designed in accordance with the *EPA Guidance for the Data Quality Objectives Process* (EPA 2006c) and *EPA Requirements for Quality Assurance Project Plans* (EPA 2001a).

Measurement data were regularly evaluated and documented to quantitatively assess data quality, monitor consistency with DQOs, and ascertain limitations of the data based on the data validation results. Data verification included checking that results were input correctly from laboratory data printouts using an Automated Data Review program to the laboratory report and to the electronic data deliverable. The subsections that follow describe the methods of review and verification.

3.8.1 Sample QA/QC Activities

Field QC samples such as matrix spike (MS)/matrix spike duplicates (MSDs), field duplicates, rinsate blanks, and trip blanks were collected to determine the quality of the field data. The following QC samples were collected:

- Seven trip blank samples

- Twenty-one equipment rinsate samples
- Nineteen MS/MSD samples
- Two ambient air samples
- Fifteen field duplicates
- Seventeen reference samples

Reference samples were samples collected from one terrestrial location for comparison to groundwater and one aquatic location upgradient of Cathlamet Bay Both of these locations were chosen with similar environments, but were believed to be outside the area affected by historical site activities. Equipment rinsate samples were collected once per week per sampling technique that used non dedicated sampling equipment. A temperature blank was included with each shipment of samples. A trip blank was included with shipments that included samples for VOC analysis.

All field QA/QC objectives were accomplished using appropriate sampling techniques and collection of field duplicates, equipment rinsate samples, and trip blanks.

The analytical laboratory's QA program was accomplished by the laboratory implementing specific QC checks, method blanks, surrogate spikes, sample custody tracking, sample preservation, adherence to holding times; laboratory control samples (LCSs), MS/MSDs, internal standards, calibration recoveries, and serial dilutions.

3.8.2 Validation and Verification Methods

The independent data validation was performed in accordance with *EPA Contract Laboratory Program National Functional Guidelines for Inorganic and Organic Review* (EPA 2004c, 2008c).

The data validation strategy required during the RI is 10% Level IV and 90% Level III. This is a standard validation strategy and equates to all (100%) of the analytical results have the Level III validation and of those, there are 10% that were selected for Level IV validation. For this project, more than 10% of the data was validated at Level IV to achieve validation of samples representing the various conditions and areas of concern throughout the Study Area. For this RI, approximately 24% of the data was subjected to a Level IV validation and the remaining 76% of the data was validated per Level III procedures. The 24% portion of the data set for Level IV validation included both environmental and QC samples; 100% of the dioxin and furan data was subjected to Level IV validation.

Where specific guidance was not available, the data were evaluated in a conservative manner consistent with industry standards using professional experience and

judgment. The analyses were validated using the following documents, as applicable to each method:

- EPA, Contract Laboratory Program National Functional Guidelines for Superfund Organic Method Data Review, October 2008c.
- EPA, SW 846, Test Methods for Evaluating Solid Waste, revisions through Final Update IV, Third Edition, January 2008.
- EPA, Contract Laboratory Program National Functional Guidelines for Inorganic Data Review, October 2004c.
- EPA, Guidance on Systematic Planning Using the DQO Process, February 2006c.
- American Public Health Association, Standard Methods for the Examination of Water and Wastewater, 21st Edition, September 2005.
- Washington State Department of Ecology, Analytical Methods for Petroleum Hydrocarbons, June 1997.

The data validation narratives indicate that the sample analyses generally met the QC criteria cited in the methods and appropriate validation guidance documents. Results associated with QC outliers were appropriately qualified by data validators.

3.8.3 Data Usability and Assessment Review

The purpose of the data usability and assessment review (DUAR) is to evaluate the data collected and determine whether they meet the DQOs outlined in the QAPP. QA objectives for measuring data are expressed in terms of precision, accuracy, representativeness, comparability, completeness, and sensitivity (PARCCS). The QA objectives provide a mechanism for ongoing control and evaluating and measuring data quality throughout the project. Descriptions of the PARCCS criteria are provided next along with summaries of the DUAR results. The complete DUAR is included as **Appendix F**.

3.8.3.1 Precision

Precision is a quantitative term that estimates the reproducibility of a set of replicate measurements under a given set of conditions. It is defined as a measurement of mutual agreement between measurements of the same property and is expressed in terms of relative percent difference (RPD) between duplicate determinations.

RPD is calculated as follows:

$$RPD = \text{absolute value } [(C1 - C2) / \{(C1 + C2)/2)\}] \times 100\%$$

where: *C1 = Concentration of primary sample*
C2 = Concentration of duplicate sample

The analytical precision for the reported data was determined by review of organic MS/MSD and inorganic laboratory duplicate results. Field and analytical precision was determined from the review of the field duplicate results. The sample results were compared based on their RPD.

In comparing sample duplicates, when the concentration of an analyte approaches the reporting limit, the RPD may be high relative to the absolute concentrations reported. Where the duplicate concentrations reported are within five times the reporting limit, the absolute value (ABS) of the difference between the two values is calculated and used as a measure of precision. The ABS criterion is dependent on the reporting limit. When the field duplicate sample RPD exceeds the QC limit, and the concentrations are within five times the reporting limit, the ABS QC limit is the reporting limit.

The field duplicate samples were collected in the same manner as the original samples but were collected in separate, individual containers, given separate sample identifiers, and treated as individual samples by the laboratory.

Some analytical RPDs were outside criteria. The data validators qualified the data as required by validation guidelines. **Appendix F** describes the data validation observations and qualifiers by data quality indicators (DQI) type in more detail.

3.8.3.2 Accuracy

Accuracy is the degree of agreement of a measurement with an accepted reference or true value, and is a measure of the bias in a system. Accuracy of the data was assessed by comparing LCS recovery, MS recovery, calibration recovery, internal standard checks, and surrogate recoveries, and by performing serial dilution checks during metals analyses. Accuracy is expressed as a percent recovery, which was calculated by:

$$PercentRecovery = \frac{(TotalAnalyteFound - AnalyteOriginallyPresent) \times 100}{AnalyteAdded}$$

Analytical accuracy for the entire data collection activity is difficult to measure because several sources of error exist. Errors can be introduced by any of the following:

- Sampling procedure
- Field contamination
- Sample preservation and handling
- Sample matrix
- Sample preparation
- Analytical techniques

Accuracy is maintained by adhering to EPA methods, approved field, and analytical standard operating procedures (SOPs). The independent third-party data validators reviewed the laboratories' data for accuracy, through examining the reported surrogates, internal standards, calibrations, MS/MSD recoveries, LCS/laboratory control sample duplicate (LCSD) recoveries, serial dilutions, and inductively coupled plasma (ICP) interference check standards. Recoveries outside criteria are summarized next. The data validators qualified the data as required by the validation guidance. Specific details are documented in the DUAR in **Appendix F.**

Below is a summary of the findings that affect the usability of the data:

- Percent differences (%Ds) and relative standard deviation (RSDs) for calibration results were outside of criteria for several PCB Aroclors and PAH compounds. These compounds were qualified in all samples associated with these QC analyses as estimated (J/UJ).

- Surrogate recoveries were above or below criteria for several pesticides, SVOC, VOC, PCB Aroclors, PAH, and TPH-G. In addition to the analyses that were qualified as estimated (J/UJ) based on surrogate recoveries, the samples 07311 and 07313 contained nondetect semi-volatile results that were rejected (R) due to low surrogate recoveries.

- MS/MSD recoveries were outside of criteria for several dioxin and furan, SVOC, VOC, pesticide, PAH, TPH-D, VPH, EPH, dissolved gas compounds, and metal analytes. These compounds were qualified as estimated (J/UJ) in all samples associated with these QC analyses.

- LCS/LCSD recoveries were outside of criteria for several dioxin and furan, SVOC, pesticide, PAH, TPH-D, TO-15 VOC compounds, and metal analytes. In addition to the analyses that were qualified as estimated (J/UJ) based on LCS recoveries, the following samples contain nondetect semi-volatile results that were rejected (R) due to low LCS recoveries: 08800, 09800, 06805, 06806, 08803, and 01101.

Sample preservation and handling is also evaluated during the validation process. In one instance, a delivery delay resulted in the samples scheduled to be delivered to the laboratory on Saturday being delivered to the laboratory Monday afternoon. Although this sample group (SDG 081310) arrived within the allowable holding time for the analyses, the cooler temperature criterion was not met. This lead to the following actions being taken during data validation: for SDG 081310, seven soil samples from the Fire Training Area, 06426, 06428, 06431, 06434, 06437, 06440, and 06444 SVOC by SIM analysis, and PAH results were estimated (J/UJ), and detected volatile results were qualified as estimated J. The non-detect VOC results were rejected (R). The high temperature in the cooler, 20.6 degrees Celsius, exceeded the six degrees Celsius criteria limit and could have resulted in VOC loses from some or all samples.

In other instances, laboratory delays with handling coolers caused holding times to be exceeded for the following:

- Nitrate and nitrite for sample 03800 (equipment rinsate water from Refueling Pit 3)
- Ammonia for samples 02300, 02301, 07307, 07308, 07309, 07310, 07311, 07312, and 07313 (two near shore sediment samples from UST Site No. 1 and seven IS sediment replicates from Aquatic-North of Pier 8 DU)
- Sulfide for sample 08301(FP-13 sediment core sample from Aquatic-Finger Piers DU)
- TPH-Dx and TPH-Ox for samples 04401, 04403, 04417, and 06601 (three soil samples from UST Site No. 4 and near shore surface water sample [FTA-28] from Fire Training Area DU)
- TPH-Gx for sample 03802 (equipment rinsate water from Refueling Pit 3)
- Aromatic and aliphatic hydrocarbons (VPH & EPH) for samples 03410 and 04400 (one soil sample from Refueling Pit 3 [field duplicate of RFP3-01] and one soil sample from UST Site No. 4 [UST4-04])
- PAH by 8270C-SIM analysis for samples 02104, 02105, 02106, 02107, and 03105 (three groundwater samples and field duplicate from UST Site No. 1 [UST1-01, UST1-02, and UST1-04] and one soil sample from Refueling Pit 3 [RFP3-03])

Analytical results from the above samples were qualified as estimated J/UJ in most cases. Non-detect results for aromatic and aliphatic hydrocarbons by VPH method results were qualified as rejected (R) in samples 03410 and 04400 due to exceeded holding time criteria. Longer holding times could result in degradation or other loses of some hydrocarbon constituents.

The effect of data that were rejected due to holding time exceedances is assessed as part of the completeness evaluation in Section 6.4 of the DUAR (**Appendix F)**. There were sufficient samples and analytical results to support the project objectives.

Blank Contamination

Equipment rinsate blanks are used to evaluate the presence of contaminants on sampling equipment following decontamination and the potential for cross contamination during sample collection. Rinsate source blanks are used to determine the presence of contaminants in the reagent-grade source water used to prepare equipment rinsate blanks. Ambient air blanks provide information on the ambient levels of site chemicals. Trip blanks travel with the samples from the field to the laboratory for analysis to evaluate the potential for sample cross contamination. Laboratory method blanks are analyzed to indicate possible contamination introduced during the laboratory analytical procedure. Sample results were subsequently validated to a minimum of a Level 3 data validation that included method blank evaluation. All instances of blank contamination were appropriately identified and qualified according to the validation requirements specified in the project QAPP (CDM 2008b) and the DQSM requirements. Appendix J contains the

validation narratives detailing the findings of the validators. Additional details related to sample analysis can be found in the laboratory data reports located in Appendix I. The following is a brief summary of the findings.

Various dioxins and furans, SVOCs, PAHs, NWTPH hydrocarbons, EPH and VPH hydrocarbons, TO-15 compounds, and metal analytes were detected at low concentrations in the laboratory method blanks. **Appendix F** Attachment 1contains a summary of samples associated with laboratory method blank contamination. Sample results were qualified as nondetect (U), and, if applicable, the sample concentration was raised to the reporting limit.

Some sample results for zinc, nickel, Lindane, benzene, and naphthalene were qualified by the validators as nondetect (U) because of contamination in associated equipment blanks.

3.8.3.3 Representativeness

Representativeness is a qualitative term that expresses the degree to which the sample data accurately and precisely represent the environmental conditions corresponding to the location and depth interval of sample collection. Requirements and procedures for sample collection are designed to maximize sample representativeness.

Representativeness and comparability are achieved by using EPA-approved sampling procedures, analytical methodologies, and written SOPs, as presented in the QAPP (CDM 2008b). This and future sampling events should yield results representative of environmental conditions at the time of sampling.

Representativeness can be monitored by reviewing field documentation or by performing field audits, or both. For this project, a detailed review was completed for the field logbooks, chain of custody forms, field data collection forms, and laboratory sample confirmation logs and data validation packages. Appropriate laboratory QA/QC requirements were described in the QAPP (CDM 2008b) and laboratory statements of work (SOWs) to ensure that the laboratory analytical results were representative of true field conditions. Representativeness is discussed in **Section 6**, as part of human health and ecological risk assessments.

Field sampling accuracy was attained through strict adherence to the approved final QAPP and MP and by using EPA-approved analytical methods for sample analyses (CDM 2008a,b). Based on this, the data should represent as near as possible the actual field conditions at the time of sampling.

Representativeness has met the applicable requirements for the fieldwork and laboratory analyses. Deviations to the planned sampling activity were minimal and did not compromise the ability of the data to represent conditions within the Study Area. Therefore, the data collected are suitable for a representative characterization of the Study Area.

3.8.3.4 Comparability

Comparability is a qualitative term that expresses the confidence with which a data set can be compared with another. Strict adherence to standard sample collection procedures, analytical detection limits, and analytical methods ensures that data from like samples and sample conditions are comparable. This comparability is independent of laboratory personnel, data reviewers, or sampling personnel. Comparability criteria are met for the project if, based on data review, the sample collection and analytical procedures are determined to have been followed, or defined to show that variations did not affect the values reported.

To ensure comparability of data generated for the site, standard sample collection procedures and EPA-approved analytical methods were followed. Using such procedures and methods enables the current data to be comparable with the previous data sets generated with similar methods.

3.8.3.5 Completeness

Completeness of the field program is defined as the percentage of samples planned for collection as listed in the final work plan versus the actual samples collected during the field program (see equation A).

Completeness for acceptable data is defined as the percentage of acceptable data obtained that is judged to be valid versus the total quantity of data generated (see equation B.) Acceptable data include both data that passes all the QC criteria (unqualified data) and data that may not pass all of the QC criteria but had appropriate corrective actions taken (qualified but useable data).

A. $$\%\mathbf{Completeness} = \mathbf{Cx}\frac{\mathbf{100}}{\mathbf{n}}$$

where: C = actual number of samples collected
n = total number of samples planned

B. $$\%\mathbf{Completeness} = \mathbf{Vx}\frac{\mathbf{100}}{\mathbf{n'}}$$

where: V = number of measurements judged valid
n' = total number of measurements made

The overall completeness goal for this project was 90% for all validated project data. The completeness level achieved during the RI field program for the actual number of samples collected and analyses performed versus the total number of samples planned for the different media is as follows: 89% for groundwater samples; 102% for soil samples; 102% of surface water; 86% of surface sediment; 102% of tissue; and 129% for soil gas samples. A tabulated list of samples collected and parameters analyzed versus samples planned is included in **Appendix F**.

The planned number of groundwater samples was not collected because groundwater was not encountered at several of the soil boring locations. The percentage of sediment samples was not achieved because the analytical method for PCP was changed to obtain a lower limit of detection. The change in analytical method greatly affected the cost for analyses, so fewer samples were collected. Although 100% of the data planned for collection was not achieved for each media, data usability objectives were not affected because critical samples for assisting in project decisions were collected.

The completeness for acceptable data was 98.5% for the number of measurements judged to be valid versus the total number of measurements made. The data reported that are not qualified as rejected are suitable for their intended use as stated in the QAPP (CDM 2008b). The achievement of the completeness goal for usable data provides sufficient data to support the risk evaluations for project decisions.

3.8.3.6 Sensitivity

Sensitivity is related to the ability to compare analytical results with project-specific chemical concentration levels of interest, such as delineation levels, screening levels, or action levels. Analytical quantitation limits for the various sample analytes should be below the level of interest to allow an effective comparison or use of the analytical results.

Detection Limits

Each analytical method used during the RI was chosen because it has a reporting limit at or below the level of concern. For each analyte, the QAPP provided a reporting limit as the goal, or target value, that the laboratory was to achieve to provide analytical results at or below regulatory comparison criteria (CDM 2008b).

The target reporting limit is equal to or greater than the method detection limit (MDL). The reporting limits are set above MDLs to allow for sample matrix interferences and to minimize false positives. Development of the MDL is described by EPA in 40 CFR part 136, Appendix B as "the minimum concentration of a substance that can be measured and reported with a 99% confidence that the analyte concentration is greater than zero…." Generated by statistical analysis of multiple analyses of a low-level standard, MDLs represent the best fundamental measurement of instrument sensitivity and the basis for establishing reporting limits.

The reporting limits identified in the planning phase are a compromise between analytical sensitivity and precision. Setting low reporting limits can lead to poorly defensible data due to false positive (Type I) and/or false negative (Type II) errors, whereas elevated reporting limits can hamper site characterization and interpretation of results. Laboratory determinations of MDLs are performed on atypical samples (i.e., distilled water), leading to idealized limits. Confidence in detection limits increases with instrument signal level above the MDL, and higher limits mean better precision.

Laboratory results are reported according to rules that provide established certainty of detection at specific sample quantitation limits (SQL). The result for an analyte is flagged with a "U" if that analyte was not detected (i.e., was not present at a concentration above a stated limit). The associated numerical value is the SQL (or limit of quantitation), which is greater than the MDL (or the limits of detection). The SQL can vary depending upon equipment calibration and quality procedures specific to the analyses. The SQL may be adjusted for sample characteristics such as dilutions, percent moisture, and laboratory judgment. If an analyte is present at a concentration between the MDL and the SQL, the analytical result is flagged with a "J," indicating an estimated quantity. In some instances, the data validators may qualify the nondetected SQL result as an estimated concentration (UJ), which reflects decreased certainty in the SQL value.

Although the reporting limits of some analyte groups (i.e., SVOCs) are set high to avoid Type I and Type II errors, these limits provide a conservative picture of the nature and extent of the chemical being measured. Accordingly, quantitative evaluations begin with the SQL for analytes reported as not present rather than at the MDL.

Appendix F contains an evaluation of all nondetect results as compared to reporting limits, as cited in the QAPP (CDM 2008b), and either EPA or ODEQ comparison criteria. This evaluation provides information on the number of samples in which a given analyte was reported as not present at concentrations exceeding reporting limits or regulatory comparison criteria. The range of SQLs at which a given analyte was reported as not present is provided. The SQL analysis tables are separated by DU and matrix. It is important to note that compounds detected at concentrations between the SQL and the MDL would be reported down to the laboratory MDL and qualified as estimated, as described previously. The SQL analysis presented in **Appendix F** is summarized by DU and by media:

AST Fuel Storage Area

Soil - The SQLs for 28 compounds exceeded QAPP reporting limits, generally due to percent solids or presence of high concentrations of other compounds that elevated SQLs for a particular sample. The SQLs were sufficient to meet human health risk assessment (HHRA) and ecological risk assessment (ERA) criteria.

Groundwater - The SQLs for five compounds exceeded QAPP reporting limits. The SQLs for six compounds exceeded HHRA criteria. No ERA criteria were associated with groundwater matrix.

UST Site No. 1

Soil - The SQLs for 27 compounds exceeded QAPP reporting limit generally due to percent solids adjustments or the presence of high concentrations of other compounds that elevated SQLs for that particular sample. The SQLs for one compound exceeded HHRA criteria and one compound exceeded its respective ERA criteria.

Soil Gas - The SQLs for 59 compounds exceeded QAPP reporting limits. Generally, limited soil gas volume elevated the SQLs in certain samples. The SQLs for 14 compounds exceeded HHRA criteria. No ERA criteria were associated with soil gas matrix.

Groundwater - The SQLs for six compounds exceeded QAPP reporting limits; these same exceedances exceeded HHRA criteria. No ERA criteria were associated with groundwater matrix at this DU.

Surface Water - The SQLs for six compounds exceeded QAPP reporting limits. The SQLs for five compounds exceeded HHRA criteria, and SQLs were sufficient to meet all ERA criteria.

Sediment - The SQLs for 14 compounds exceeded QAPP reporting limits because of percent solids adjustments or the presence of high concentrations of other compounds that elevated SQLs for that particular sample. The SQLs for three compounds exceeded HHRA criteria and for 26 compounds exceeded ERA criteria.

Refueling Pit 3

Soil - The SQLs for 32 compounds exceeded QAPP reporting limits because of percent solids adjustments or the presence of high concentrations of other compounds that required dilutions that elevated all SQLs for that particular sample. The SQLs were sufficient to meet all HHRA and ERA criteria.

Soil Gas - The SQLs for 58 compounds exceeded QAPP reporting limits. Generally, limited soil gas volume elevated the SQLs in certain samples. The SQLs for 28 compounds exceeded HHRA criteria. No ERA criteria were assigned to the soil gas matrix.

Ambient Air - The SQLs for one compound exceeded the QAPP reporting limit. No HHRA and ERA criteria were associated with ambient air matrix.

Groundwater - The SQLs for 10 compounds exceeded QAPP reporting limits and HHRA criteria. No ERA criteria were associated with the groundwater matrix.

Surface Water - The SQLs for six compounds exceeded QAPP reporting limits. The SQLs for 10 compounds exceeded HHRA criteria; SQLs were sufficient to meet ERA criteria.

Sediment - The SQLs for 10 compounds exceeded QAPP reporting limits, generally because of percent solids adjustments or the presence of high concentrations of other compounds, which elevated SQLs for that particular sample. The SQLs for two compound exceeded HHRA criteria and the SQLs for 21 compounds exceeded ERA criteria.

UST Site No. 4

Soil - The SQLs for 33 compounds exceeded QAPP reporting limits because of percent solids adjustments or the presence of high concentrations of other compounds that required dilutions that elevated all SQLs for that particular sample. The SQLs were sufficient to meet all HHRA, while and one compounded exceeded the ERA criterion.

Fire Training Area

Soil - The SQLs for 55 compounds exceeded QAPP reporting limits because of percent solids adjustments or the presence of high concentrations of other compounds, which required dilutions that elevated all SQLs for that particular sample. The SQLs for two compounds exceeded HHRA criteria; the SQLs for three compounds exceeded ERA criteria.

Soil Gas - The SQLs for 53 compounds exceeded QAPP reporting limits. Generally, limited soil gas volume elevated the SQLs in certain samples. SQLs for eight compounds exceeded HHRA criteria, and ERA criteria were not assigned to the soil gas matrix.

Groundwater - The SQLs for nine compounds exceeded QAPP reporting limits. SQLs for 29 compounds exceeded HHRA criteria. No ERA criteria were assigned to the groundwater matrix.

Surface Water - The SQLs for five compounds exceeded QAPP reporting limits. The SQLs for 10 compounds exceeded HHRA criteria; SQLs were sufficient to meet all ERA criteria.

Sediment - The SQLs for 12 compounds exceeded QAPP reporting limits because of percent solids adjustments or the presence of high concentrations of other compounds that required dilutions, which elevated all SQLs for that particular sample. The SQLs for three compounds exceeded HHRA criteria and SQLs for 22 compounds exceeded ERA criteria.

Aquatic - Finger Piers Area

Sediment - The SQLs for 14 compounds exceeded QAPP reporting limits because of percent solids adjustments or the presence of high concentrations of other compounds that elevated SQLs for that particular sample. The SQLs for three compounds exceeded HHRA criteria and SQLs for 24 compounds exceeded ERA criteria.

Surface Water - The SQLs for six compounds exceeded QAPP reporting limits. The SQLs for 10 compounds exceeded HHRA criteria; SQLs were sufficient to meet all ERA criteria.

Tissue - The SQLs for 18 compounds exceeded QAPP reporting limit criteria because of low sample volume. Table 6-1ab of Appendix F lists the compounds that have SQLs exceeding the QAPP reporting limits; 16 of these compounds are dioxin congeners. As cited in **Section 6.2.1.2** since greater than ten percent of the dioxin

congener concentrations are below the SQLs the Kaplan-Meier (K-M) method was used to estimate the TEQ and to calculate exposure point concentrations.

Aquatic - Near Landfill

Sediment - The SQLs for 43 compounds exceeded QAPP reporting limits because of percent solids adjustments or the presence of high concentrations of other compounds that required dilutions which, elevated all SQLs for that particular sample. The SQLs for 17 compounds exceeded HHRA criteria; SQLs for 31 compounds exceeded ERA criteria.

Surface Water - The SQLs for six compounds exceeded QAPP reporting limits. The SQLs for 28 compounds exceeded HHRA criteria; SQLs were sufficient to meet all ERA criteria.

Tissue - The SQLs for 43 compounds exceeded QAPP reporting limits, generally because of low sample volume. Table 6-1x of Appendix F lists the compounds that have SQLs exceeding the QAPP reporting limits; 41 of these compounds are dioxin congeners. As cited in Section 6.2.1.2 since greater than ten percent of the dioxin congener concentrations are below the SQLs the K-M method was used to estimate the TEQ and to calculate exposure point concentrations.

Aquatic - North of Pier 8

Sediment - The SQLs for seven compounds exceeded QAPP reporting limits because of percent solids adjustments or the presence of high concentrations of other compounds, which required dilutions that elevated all SQLs for that particular sample. The SQLs were sufficient to meet all HHRA criteria; SQLs for 13 compounds exceeded ERA criteria.

Surface Water - The SQLs for five compounds exceeded QAPP reporting limits. The SQLs for 10 compounds exceeded HHRA criteria; SQLs were sufficient to meet all ERA criteria.

Tissue - The SQLs for 49 compounds exceeded QAPP reporting limits because of low sample volume. Table 6-1v of Appendix F lists the compounds that have SQLs exceeding the QAPP reporting limits; 46 of these compounds are dioxin congeners. As cited in Section 6.2.1.2 since greater than ten percent of the dioxin congener concentrations are below the SQLs the K-M method was used to estimate the TEQ and to calculate exposure point concentrations.

Aquatic – Reference Area

Sediment - The SQLs for 15 compounds exceeded QAPP reporting limits because of percent solids adjustments or the presence of high concentrations of other compounds that elevated SQLs for that particular sample. The SQLs for 12 compounds exceeded HHRA criteria; SQLs for five compounds exceeded ERA criteria.

Surface water - The SQLs for nine compounds exceeded QAPP reporting limits. The SQLs for 28 compounds exceeded HHRA criteria. No ERA criteria were assigned to surface water matrix.

Tissue - The SQLs for 50 compounds exceeded QAPP reporting limits because of low sample volume. Table 6-1ad of Appendix F lists the compounds that have SQLs exceeding the QAPP reporting limits; 49 of these compounds are dioxin congeners. As cited in Section 6.2.1.2 since greater than ten percent of the dioxin congener concentrations are below the SQLs the K-M method was used to estimate the TEQ and to calculate exposure point concentrations.

A sufficient number of samples achieved SQLs conforming to project goals and objectives. Sediment samples had relatively high percent moisture content, between 45% and 65% in most cases. This contributed to SQLs greater than the planned QAPP RLs and greater than comparison criteria, which was noted in the sediment sample results. High moisture content can also affect extraction efficiencies during SVOC, pesticide, PCB, and dioxin sample preparation. Sediment and soil samples with high organic content often cannot be concentrated down to the required volume. This has the effect of raising the SQL for a particular analytical fraction (pesticide, PCB, or SVOC).

Several soil samples contained non-target background components, which prevented adequate resolution of target compounds, resulting in SQLs greater than the planned QAPP RLs and greater than comparison criteria for such compounds as 1,2-dibromoethane (EDB) and pentachlorophenol. The lower than expected tissue sample volume caused SQLs greater than the planned QAPP RLs and greater than comparison criteria.

The effect on data usability due to various SQLs exceeding criteria is minimized since the data from non-detected results, more notable the SQL reported, is statistically vetted. For example, the Kaplan-Meier statistical method may be used for estimating exposure point concentrations in the HHRA and BERA using data sets with large numbers of non-detect results. In addition, data for individual chemicals associated with a particular medium or decision unit are considered in relation to results from that entire data set. Individual analytes reported with elevated SQLs may be shown to contribute little to site-related risks. In any event, the effect on usability from elevated SQLs is assessed within the context of the HHRA and BERA.

Additional discussion of effects from elevated SQLs are therefore included as part of the uncertainties and limitations in the RI, HHRA, or ERA reports. Details regarding the use of and uncertainty of the data are presented in **Section 6.5.6.1 and Section 6.5.6.2** of this RI report.

The data validation process evaluated the data regarding analytical quantitation limits. If sample results exceeded calibration ranges, results were qualified appropriately as estimated (J). Data validation determined the most valid analyte

result to use for samples that were reanalyzed or diluted. These results were entered into the project database and used for decision-making purposes.

Table 3-1
Soil Analyses by Decision Unit
Tongue Point Multi-Sites Project, Astoria, Oregon

				Analyses																	
Sample ID	Location	Depth of Sample (feet bgs)	Sample Collection Date and Time	PAHs (EPA Method 8270-SIM)	VOCs-*short list* (EPA Method 8260B)	VOCs-*long list* (EPA Method 8260B)	Total Pb (EPA Method 6020B)	Diesel-range and Oil-range Petroleum Hydrocarbons (NWTPH-Dx)	Gasoline-range Petroleum Hydrocarbons (NWTPH-Gx)	EPH/VPH	Total Metals (EPA Methods 6020A, 7471A)	Total Organic Carbon (EPA Method 415.1)	PCB Aroclors (EPA Method 8082)	Organochlorine Pesticides (EPA Method 8081A)	Dioxins and Furans (EPA Method 1613)	Bulk Density (ASTM 2937)	Grain Density (ASTM D854)	Moisture Content (ASTM D2216)	Grain Size Distribution (ASTM D422/D4464)	Total Organic Carbon (Plumb 1981)	Air Permeability (API RP-40)
AST Fuel Storage Area																					
01412	AST-01	0-0.5	9/10/2008 15:15	1	1		1	1	1	1											
01413	AST-05	0-0.5	9/10/2008 15:30	1	1		1	1	1												
01414	AST-02	0-0.5	9/10/2008 16:00	1	1		1	1	1												
01415	AST-06	0-0.5	9/10/2008 16:15	1	1		1	1	1												
01416	AST-03	0-0.5	9/10/2008 16:40	1	1		1	1	1												
01417	AST-07	0-0.5	9/10/2008 16:55	1	1		1	1	1												
01418	AST-04	0-0.5	9/10/2008 17:30	1	1		1	1	1												
01419	AST-08	0-0.5	9/10/2008 18:00	1	1		1	1	1												
01420	AST-09	0-0.5	9/10/2008 18:00	1	1		1	1	1												
01421	AST-10	1-3	9/15/2008 8:35	1	1		1	1	1												
01422	AST-10	10-11	9/15/2008 9:50	1	1		1	1	1												
01423	AST-10	14-15	9/15/2008 9:45	1	1		1	1	1												
01424	AST-12	1-3	9/15/2008 11:00	1	1		1	1	1												
01425	AST-12	10-11	9/15/2008 11:15	1	1		1	1	1												
01426	AST-12	19-20	9/15/2008 11:25	1	1		1	1	1												
01427	AST-11	1-3	9/15/2008 11:45	1	1		1	1	1												
01428	AST-11	10-11	9/15/2008 11:57	1	1		1	1	1												
01429	AST-11	19-20	9/15/2008 12:15	1	1		1	1	1												
UST Site No. 1																					
02400	UST1-03	5.5-6	9/12/2008 9:20	1	1		1	1	1	1											
02401	UST1-05	5.5-6	9/12/2008 10:35	1	1		1	1	1												
02406	UST1-02	5-5.6	9/13/2008 13:50	1	1		1	1	1												
02411	UST1-01	6.6-7	9/15/2008 14:50	1	1		1	1	1	1											
02412	UST1-01-FD	6.6-7	9/15/2008 14:50	1	1		1	1	1												
02413	*UST1-04*	*2.8-3*	*9/15/2008 9:57*													•	•	•	•	•	•
02414	UST1-04	6.5-7	9/15/2008 10:10	1	1		1	1	1												
02415	UST1-04-FD	6.5-7	9/15/2008 10:10	1	1		1	1	1												
02417	*UST1-04*	*2.3-2.9*	*9/16/2008 11:10*													*1*	*1*	*1*	*1*	*1*	*1*
02418	*UST1-04*	*5.2-5.5*	*9/16/2008 11:10*													•	•	•	•	•	•
Refueling Pit 3																					
03401	RFP3-03	6-7	9/16/2008 14:25	1		1	1	1	1												
03404	*RFP3-04*	*3-4*	*9/16/2008 15:20*													*1*	*1*	*1*	*1*	*1*	*1*
03405	*RFP3-04*	*5.5-6.5*	*9/16/2008 15:25*													*1*	*1*	*1*	*1*	*1*	*1*
03406	RFP3-04	4.5-5.5	9/16/2008 15:35	1		1	1	1	1												
03409	RFP3-01	7-8	9/17/2008 10:45	1		1	1	1	1												
03410	RFP3-01-FD	7-8	9/17/2008 10:45	1		1	1	1	1	1											
03416	RFP3-02	6.5-7	9/18/2008 12:35	1		1	1	1	1												
03417	*RFP3-03*	*5.5-6*	*9/16/2008 9:17*													*1*	*1*	*1*	*1*	*1*	*1*
03418	*RFP3-03*	*3-3.5*	*9/16/2008 17:45*													*1*	*1*	*1*	*1*	*1*	*1*
03419	*RFP3-02*	*3-3.5*	*9/18/2008 12:00*													•	•	•	•	•	•
UST Site No. 4																					
04400	UST4-04	0-1	9/12/2008 13:45	1	1		1	1	1	1											
04401	UST4-04	2-3	9/12/2008 14:06	1	1		1	1	1												
04402	UST4-05	0-1	9/12/2008 14:23	1	1		1	1	1												
04403	UST4-05	2-3	9/12/2008 14:32	1	1		1	1	1												
04404	UST4-06	0-1	9/12/2008 14:58	1	1		1	1	1												
04405	UST4-06	2-3	9/12/2008 14:58	1	1		1	1	1												
04407	UST4-02	0.2-0.3	9/19/2008 9:25	1	1		1	1	1												
04408	UST4-02	9-10	9/19/2008 10:00	1	1		1	1	1												
04409	UST4-02-FD	9-10	9/19/2008 10:00	1	1		1	1	1												
04412	UST4-03	0-1	9/19/2008 10:20	1	1		1	1	1												
04414	UST4-03	11-12	9/19/2008 10:45	1	1		1	1	1												
04417	UST4-01	0-1	9/22/2008 9:11	1	1		1	1	1												
04418	UST4-01	11-12	9/22/2008 9:25	1	1		1	1	1												

Table 3-1 (continued)
Soil Analyses by Decision Unit
Tongue Point Multi-Sites Project, Astoria, Oregon

				Analyses																	
Sample ID	**Location**	**Depth of Sample (feet bgs)**	**Sample Collection Date and Time**	**PAHs (EPA Method 8270-SIM)**	**VOCs-*short list* (EPA Method 8260B)**	**VOCs-*long list* (EPA Method 8260B)**	**Total Pb (EPA Method 6020B)**	**Diesel-range aand Oil-range Petroleum Hydrocarbons (NWTPH-Dx)**	**Gasoline-range Petroleum Hydrocarbons (NWTPH-Gx)**	**EPH/VPH**	**Total Metals (EPA Methods 6020A, 7471A)**	**Total Organic Carbon (EPA Method 415.1)**	**PCB Aroclors (EPA Method 8082)**	**Organochlorine Pesticides (EPA Method 8081A)**	**Dioxins and Furans (EPA Method 1613)**	**Bulk Density (ASTM 2937)**	**Grain Density (ASTM D854)**	**Moisture Content (ASTM D2216)**	**Grain Size Distribution (ASTM D422/D4464)**	**Total Organic Carbon (Plumb, 1987)**	**Air Permeability (API RP 40)**
Fire Training Area																					
06401	FTA-08	4.5-5.5	9/22/2008 10:50	1		1		1	1		1	1									
06403	FTA-01	3-4	10/2/2008 13:10	1		1		1	1		1	1									
06406	*FTA-02*	*3-3.5*	*10/2/2008 15:15*													*1*	*1*	*1*	*1*	*1*	*1*
06407	FTA-02	2.5-4	10/2/2008 15:18	1		1		1	1		1	1									
06411	FTA-03	2-3	9/23/2008 9:52	1		1		1	1		1	1									
06413	FTA-04	4.5-5.5	9/23/2008 12:15	1		1		1	1		1	1									
06416	*FTA-04*	*5.5-6*	*9/23/2008 12:15*													*1*	*1*	*1*	*1*	*1*	*1*
06417	*FTA-05*	*12.5-13*	*9/23/2008 13:50*													*1*	*1*	*1*	*1*	*1*	*1*
06418	FTA-05	13-14	9/23/2008 14:00	1		1		1	1		1	1									
06422	FTA-06	6-7	9/23/2008 15:45	1		1		1	1		1	1									
06423	FTA-06-FD	6-7	9/23/2008 15:45	1		1		1	1		1	1									
06426	FTA-07	4.5-5.5	9/24/2008 13:45	1		1		1	1		1	1									
06428	FTA-12	5-6	9/25/2008 9:40	1		1		1	1		1	1									
06431	FTA-11	5-6	9/25/2008 11:15	1		1		1	1		1	1									
06434	FTA-10	5-6	9/25/2008 12:50	1		1		1	1		1	1									
06437	FTA-09	5.5-6.5	9/25/2008 14:15	1		1		1	1		1	1									
06440	FTA-15	5.5-6.5	9/25/2008 15:15	1		1		1	1	1	1	1	1	1	1						
06444	FTA-14	5-6	9/25/2008 15:48	1		1		1	1		1	1	1	1	1						
06449	FTA-13	5-6	9/26/2008 12:45	1		1		1	1		1	1	1	1	1						
06450	FTA-13-FD	5-6	9/26/2008 12:45										1	1	1						
Totals				63	42	21	47	63	63	6	16	16	4	4	4	8	8	8	8	8	8

Notes:

Italicized samples indicate that these samples were only analyzed for soil physical properties.
1 = This symbol indicates that samples were collected for this analysis and sent to the appropriate contract laboratory.
• = This symbol indicates that samples were collected for this analysis and sent to the contract laboratory, but were put on HOLD pending other analytical results.
short list = Limited to VOCs specific to petroleum hydrocarbon contamination
long list = Limited to VOCs specific to contamination by chlorinated and non-chlorinated solvents

API = American Petroleum Institute
AST = aboveground storage tank
ASTM = American Society for Testing and Materials
bgs = below ground surface
EPA = United States Environmental Protection Agency
EPH = extractable petroleum hydrocarbons
FD = field duplicate
HCB = hexachlorobenzene
ID = identification
No. = number
PAHs = polycyclic aromatic hydrocarbons
PCB = polychlorinated biphenyls
Pb = lead
UST = underground storage tank
VOCs = volatile organic compounds
VPH = volatile petroleum hydrocarbons

Table 3-2
Groundwater Analyses by Decision Unit
Tongue Point Multi-Sites Project, Astoria, Oregon

Sample ID	Location	Sample Collection Date and Time	Analyses															
			PAHs (EPA Method 8270-SIM)	VOCs-*short list* (EPA Method 8260B)	VOCs-*long list* (EPA Method 8260B)	Diesel-range and Oil-range Petroleum Hydrocarbons (NWTPH-Dx)	Gasoline-range Petroleum Hydrocarbons (NWTPH-Gx)	Total Metals (EPA Methods 6020A, 7470A)	Dissolved Metals (EPA Methods 6020A, 7470A)	Total Organic Carbon (EPA Method 415.1)	Methane, Ethane, Ethene (EPA Method RSK-175)	Total Sulfide (EPA Method 376.1)	Nitrate, Nitrite, Sulfate, Chloride (EPA Method 300.0)	Total Dissolved Solids (EPA Method 160.1)	Alkalinity (EPA Method 310.1)	PCB Aroclors (EPA Method 8082)	Organochlorine Pesticides (EPA Method 8081A)	Dioxins and Furans (EPA Method 1613)
AST Fuel Storage Area																		
01100	AST-10	9/17/2008 10:15	1	1		1	1	1	•	1								
01101	AST-10-FD	9/17/2008 12:30	1	1		1	1	1	•	1								
UST Site No. 1																		
02100	MW-01	9/11/2008 11:00	1	1		1	1	1	1	1								
02101	MW-06	9/11/2008 13:06	1	1		1	1	1	1	1								
02102	MW-08	9/11/2008 14:15	1	1		1	1	1	1	1								
02103	MW-09	9/11/2008 15:45	1	1		1	1	1	1	1								
02104	UST1-02	9/17/2008 14:00	1	1		1	1	1	•	1								
02105	UST1-01	9/17/2008 13:30	1	1		1	1	1	•	1								
02106	UST1-01-FD	9/17/2008 13:30	1	1		1	1	1	•	1								
02107	UST1-04	9/17/2008 16:00	1	1		1	1	1	•	1								
02108	UST1-18	9/18/2008 10:30	1	1		1	1	1	1	1			1	1				
Refueling Pit 3																		
03100	MW-02	9/11/2008 17:15	1		1	1	1	1	1	1	1	1	1		1			
03101	MW-03	9/15/2008 12:30	1		1	1	1	1	1	1	1	1	1		1			
03102	MW-05	9/15/2008 15:00	1		1	1	1	1	1	1	1	1	1		1			
03103	MW-01	9/16/2008 10:10	1		1	1	1	1	1	1	1	1	1		1			
03104	MW-04	9/16/2008 12:45	1		1	1	1	1	1	1	1	1	1		1			
03105	RFP3-03	9/17/2008 18:00	1		1	1	1	1	•	1								
03106	RFP3-04	9/18/2008 12:00	1		1	1	1	1		1								
03107	RFP3-01	9/18/2008 14:30	1		1	1	1	1		1								
03108	RFP3-02	9/19/2008 12:15	1		1	1	1	1		1								
Fire Training Area																		
06100	MW-18D	9/22/2008 10:30	1		1	1	1	1	1	1	1	1	1		1	1	1	
06101	MW-17	9/22/2008 12:00	1		1	1	1	1	1	1						1	1	
06102	FTA-08	9/22/2008 14:30	1				1	1		1								
06102A	FTA-08*	9/25/2008 14:30			1	1												
06103	FTA-01	9/22/2008 16:40	1		1	1	1	1		1						1		
06104	FTA-02	9/23/2008 9:45	1		1	1	1	1		1								
06105	FTA-03	9/23/2008 13:00	1		1	1	1	1		1								
06106	FTA-04	9/23/2008 16:00	1		1	1	1	1		1	1	1	1	1	1	1		
06107	FTA-05	9/25/2008 9:40	1		1	1	1	1		1						1		
06108	FTA-06	9/24/2008 16:00	1					1		1						1	1	
06108A	FTA-06*	9/25/2008 12:15			1	1	1											
06109	FTA-07	9/25/2008 16:00	1		1	1	1	1		1								
06110	FTA-09	9/26/2008 9:15	1		1	1	1	1		1	1	1	1		1	1	1	
06111	FTA-09-FD	9/26/2008 12:15	1		1	1	1	1		1	1	1				1	1	
06112	FTA-10	9/26/2008 9:55	1		1	1	1	1		1						1		
06113	FTA-15	9/26/2008 12:00	1		1	1	1	1		1						1		1
06114	FTA-11	9/26/2008 11:40	1		1	1	1	1		1								
06115	FTA-15-FD	9/26/2008 14:00														1		
06116	FTA-12	9/26/2008 13:45	1		1	1	1	1		1						1	1	
06117	FTA-14	9/26/2008 15:30	1		1	1	1	1		1						1		1
06118	FTA-13	9/26/2008 16:00	1		1	1	1	1		1						1		1
Totals			38	11	27	38	38	38	12	38	9	9	9	2	8	14	6	3

Notes:

1 = This symbol indicates that samples were collected for this analysis and sent to the appropriate contract laboratory.
• = This symbol indicates that samples were collected for this analysis and sent to the contract laboratory, but was put on HOLD pending other analytical results.
* = The full set of analyses were not collected from these sample locations. Wells had to be resampled due to bottle breakage.
short list = Limited to VOCs specific to petroleum hydrocarbon contamination
long list = Limited to VOCs specific to contamination by chlorinated and non-chlorinated solvents

AST = aboveground storage tank
EPA = United States Environmental Protection Agency
FD = field duplicate
ID = identification
No. = number
PAHs = polycyclic aromatic hydrocarbons
PCBs = polychlorinated biphenyls
UST = underground storage tank
VOCs = volatile organic compounds

Table 3-3
LNAPL Analyses by Decision Unit
Tongue Point Multi-Sites Project, Astoria, Oregon

Sample ID	Location	Sample Collection Date and Time	Analyses				
			LNAPL Composition	Specific Gravity	Viscosity at 20 °C	VOCs (EPA Method 8260B)	Total Metals (EPA Method 6020A, 7470A, 7471A)
UST Site No. 1							
02200	MW-06	9/11/2008 12:00	1	1	1	1	1
Fire Training Area							
06200	MW-19	9/19/2008 14:40	1	1	1	1	1
Totals			2	2	2	2	2

Notes:

1 = This symbol indicates that samples were collected for this analysis and sent to the appropriate contract laboratory.

°C = degrees Celsius
EPA = United States Environmental Protection Agency
ID = identification
LNAPL = light non-aqueous phase liquid
UST = underground storage tank
VOCs = volatile organic compounds

Table 3-4
Soil Gas and Ambient Air Analyses by Decision Unit
Tongue Point Multi-Sites Project, Astoria, Oregon

Sample ID	Location	Depth of Sample (feet bgs)	Sample Collection Date and Time	Analyses		
				VOCs (EPA Method TO-15 - *canister)*	Oxygen and Carbon Dioxide (ASTM 1945-96)	SVOCs (TO-17 - *sorbent tube)*
UST Site No. 1						
02500	UST1-07	5	9/19/2008 11:15	1	1	1
02501	UST1-07-FD	5	9/19/2008 11:15	1	1	1
02502	UST1-06	5	9/19/2008 14:02	1	1	1
02503	UST1-08	5	9/19/2008 15:15	1	1	
02504	UST1-09	5	9/19/2008 16:14	1	1	
02505	UST1-10	5	9/19/2008 16:45	1	1	
02506	UST1-11	5	9/19/2008 17:32	1	1	
Refueling Pit 3						
03502	RFP3-16	5	9/2/2008 9:18	1	1	
03503	RFP3-16-FD	5	9/18/2008 12:43	1	1	
03504	RFP3-12	5	9/18/2008 13:46	1	1	
03505	RFP3-13	5	9/18/2008 14:33	1	1	
03506	RFP3-15	5	9/18/2008 15:28	1	1	
03507	RFP3-17	5	9/18/2008 16:20	1	1	
03508	RFP3-11	4	9/18/2008 17:18	1	1	
Refueling Pit 3 (Ambient Air)						
03500	RFP3-18	-5	9/18/2008 8:20	1	1	
03501	RFP3-19	-5	9/18/2008 8:25	1	1	
Fire Training Area						
06500	FTA-04G	5.5	9/25/2008 10:38	1	1	
06501	FTA-05G	12	9/25/2008 11:10	1	1	
06502	FTA-06G	8	9/25/2008 11:50	1	1	
06503	FTA-07G	4	9/25/2008 13:15	1	1	
06504	FTA-01G	3.5	9/25/2008 1:45	1	1	
06505	FTA-02G	3	9/25/2008 14:28	1	1	
06506	FTA-03G	2.5	9/25/2008 15:05	1	1	
Totals				23	23	3

Notes:

1 = This symbol indicates that samples were collected for this analysis and sent to the appropriate contract laboratory.

ASTM = American Society for Testing and Materials
bgs = below ground surface
EPA = United States Environmental Protection Agency
FD = field duplicate
ID = identification
SVOCs = semi-volatile organic compounds
UST = underground storage tank
VOCs = volatile organic compounds

Table 3-5
Sediment Analyses by Decision Unit
Tongue Point Multi-Sites Project, Astoria, Oregon

Sample ID	Location	Sample Collection Date and Time	Analyses																	
			Samples Archived?	VOCs (EPA Method 8260B)	SVOCs (EPA Method 8270C)	PAHs (EPA Method 8270-SIM)	Gasoline-range Petroleum Hydrocarbons (NWTPH-Gx)	Diesel-range and Oil-range Petroleum Hydrocarbons (NWTPH-Dx)	Total Metals (EPA Methods 6020A, 7471A)	TOC (EPA Method 415.1)	TVS (EPA Method 160.4)	% Solids (EPA Method 160.3)	Total Sulfide (EPA Method 376.1)	Ammonia (EPA Method 350.1)	Tributyltin (Krone *et al.* 1989)	PCB Aroclors (EPA Method 8082)	Organochlorine Pesticides (EPA Method 8081A)	PCP (EPA Method 8151)	HCB (EPA Method 8081A)	Dioxins and Furans (EPA Method 1613)
UST Site No. 1																				
02300	UST1-12	9/26/2008 16:10	N	1	1	1	1	1	1	1	1	1	1	1			1		1	
02301	UST1-13	9/26/2008 17:00	N	1	1	1	1	1	1	1	1	1	1	1			1		1	
Refueling Pit 3																				
03300	RFP3-21	9/24/2008 17:50	N	1	1	1		1	1	1	1	1	1	1		1	1		1	
03301	RFP3-20	9/24/2008 18:20	N	1	1	1		1	1	1	1	1	1	1		1	1		1	
Fire Training Area																				
06300	FTA-25	10/1/2008 9:12	N	1	1	1	1	1	1	1	1	1	1	1		1	1		1	
06301	FTA-26	10/1/2008 10:30	N	1	1	1	1	1	1	1	1	1	1	1		1	1		1	
06302	FTA-26-FD	10/1/2008 10:35	N	1	1	1	1	1	1	1	1	1	1	1		1	1		1	
Aquatic - Finger Piers Area																				
08300	FP-12	9/16/2008 13:03	N	1	1	1	1	1	1	1	1	1	1		1	1	1		1	
08301	FP-13	9/16/2008 15:30	N	1	1	1	1	1	1	1	1	1	1		1	1	1		1	
08302	FP-11	9/16/2008 16:38	N	1	1	1	1	1	1	1	1	1	1		1	1	1		1	
08303	MIS-53	9/22/2008 9:19	Y	1			1											1		
08304	MIS-51	9/22/2008 12:19	Y	1			1													
08305	MIS-46	9/23/2008 9:50	Y																	
08306	MIS-42	9/23/2008 10:24	Y																	
08307	MIS-33	9/24/2008 10:08	Y	1			1											1		
08308	MIS-33-FD	9/24/2008 10:10	Y	1			1											1		
08309	MIS-40	9/24/2008 11:24	Y																	
08310	MIS-37	9/24/2008 13:26	Y																	
08316	FP-01	9/25/2008 8:50	N		1	1		1	1	1	1	1	1	1	1	1	1		1	
08317	FP-02	9/25/2008 8:55	N		1	1		1	1	1	1	1	1	1	1	1	1		1	
08318	FP-03	9/25/2008 9:00	N		1	1		1	1	1	1	1	1	1	1	1	1		1	
08319	FP-04	9/25/2008 9:05	N		1	1		1	1	1	1	1	1	1	1	1	1		1	
08320	FP-05	9/25/2008 9:10	N		1	1		1	1	1	1	1	1	1	1	1	1		1	
08321	FP-06	9/25/2008 9:15	N		1	1		1	1	1	1	1	1	1	1	1	1		1	
08322	FP-07	9/25/2008 9:20	N		1	1		1	1	1	1	1	1	1	1	1	1		1	
Aquatic - Near Landfill																				
09300	MIS-57	9/17/2008 10:01	Y	1			1													
09301	MIS-65	9/17/2008 12:38	Y	1			1											1		
09302	MIS-84	9/17/2008 15:13	Y																	
09303	MIS-80	9/17/2008 16:33	Y																	
09304	MIS-61	9/17/2008 17:25	Y																	
09305	MIS-69	9/18/2008 13:59	Y															1		
09306	MIS-72	9/18/2008 15:01	Y	1			1											1		
09307	LF-01	9/19/2008 15:05	N		1	1		1	1	1	1	1	1	1		1	1			1
09308	LF-02	9/19/2008 15:10	N		1	1		1	1	1	1	1	1	1		1	1			1
09309	LF-03	9/19/2008 15:15	N		1	1		1	1	1	1	1	1	1		1	1			1
09310	LF-04	9/19/2008 15:20	N		1	1		1	1	1	1	1	1	1		1	1			1
09311	LF-05	9/19/2008 15:25	N		1	1		1	1	1	1	1	1	1		1	1			1
09312	LF-06	9/19/2008 15:30	N		1	1		1	1	1	1	1	1	1		1	1			1
09313	LF-07	9/19/2008 15:35	N		1	1		1	1	1	1	1	1	1		1	1			1
Aquatic - North of Pier 8																				
07300	MIS-21	9/25/2008 13:33	Y	1			1											1		
07301	MIS-22	9/25/2008 14:20	Y																	
07302	MIS-23	9/25/2008 15:12	Y																	
07303	MIS-16	9/25/2008 15:41	Y																	
07304	MIS-01	9/26/2008 9:51	Y	1			1													
07305	MIS-04	9/26/2008 13:08	Y																	
07306	MIS-07	9/29/2008 11:30	Y	1			1													
07307	NTP-01	9/29/2008 15:20	N		1	1		1	1	1	1	1	1	1						
07308	NTP-02	9/29/2008 15:25	N		1	1		1	1	1	1	1	1	1						
07309	NTP-03	9/29/2008 15:30	N		1	1		1	1	1	1	1	1	1						
07310	NTP-04	9/29/2008 15:35	N		1	1		1	1	1	1	1	1	1						
07311	NTP-05	9/28/2008 15:40	N		1	1		1	1	1	1	1	1	1						
07312	NTP-06	9/28/2008 15:45	N		1	1		1	1	1	1	1	1	1						
07313	NTP-07	9/29/2008 15:50	N		1	1		1	1	1	1	1	1	1						

Table 3-5 (continued)
Sediment Analyses by Decision Unit
Tongue Point Multi-Sites Project, Astoria, Oregon

Sample ID	Location	Sample Collection Date and Time	Analyses																	
			Samples Archived?	VOCs (EPA Method 8260B)	SVOCs (EPA Method 8270C)	PAHs (EPA Method 8270-SIM)	Gasoline-range Petroleum Hydrocarbons (NWTPH-Gx)	Diesel-range and Oil-range Petroleum Hydrocarbons (NWTPH-Dx)	Total Metals (EPA Methods 6020A, 7471A)	TOC (EPA Method 415.1)	TVS (EPA Method 160.4)	% Solids (EPA Method 160.3)	Total Sulfide (EPA Method 376.1)	Ammonia (EPA Method 350.1)	Tributyltin (Krone *et al.* 1989)	PCB Aroclors (EPA Method 8082)	Organochlorine Pesticides (EPA Method 8081A)	PCP (EPA Method 8151)	HCB (EPA Method 8081A)	Dioxins and Furans (EPA Method 1613)
Aquatic - Reference Area																				
10300	MIS-85	9/29/2008 14:21	Y																	
10301	MIS-86	9/29/2008 15:02	Y	1			1													
10302	MIS-87	9/29/2008 15:22	Y																	
10303	MIS-89	9/29/2008 16:24	Y																	
10304	MIS-90	9/29/2008 16:35	Y	1			1											1		
10305	MIS-98	9/30/2008 12:07	Y	1			1													
10306	MIS-100	9/30/2008 13:27	Y																	
10307	REF-01	10/1/2008 16:20	N		1	1		1	1	1	1	1	1	1		1	1		1	
10308	REF-02	10/1/2008 16:25	N		1	1		1	1	1	1	1	1	1		1	1		1	
10309	REF-03	10/1/2008 16:30	N		1	1		1	1	1	1	1	1	1		1	1		1	
10310	REF-04	10/1/2008 16:35	N		1	1		1	1	1	1	1	1	1		1	1		1	
10311	REF-05	10/1/2008 16:40	N		1	1		1	1	1	1	1	1	1		1	1		1	
10312	REF-06	10/1/2008 16:45	N		1	1		1	1	1	1	1	1	1		1	1		1	
10313	REF-07	10/1/2008 16:50	N		1	1		1	1	1	1	1	1	1		1	1		1	
Totals			--	23	38	38	21	38	38	38	38	38	38	35	10	29	31	8	24	7

Notes:

1 = This symbol indicates that samples were collected for this analysis and sent to the appropriate contract laboratory.

% = percent
EPA = United States Environmental Protection Agency
FD = field duplicate
HCB = hexachlorobenzene
ID = identification
PAHs = polycyclic aromatic hydrocarbons
PCBs = polychlorinated biphenyls
PCP = pentachlorophenol
SVOCs = semi-volatile organic compounds
TOC = total organic carbon
TVS = total volatile solids
UST = underground storage tank
VOCs = volatile organic compounds

Table 3-6
Surface Water Analyses by Decision Unit
Tongue Point Multi-Sites Project, Astoria, Oregon

Sample ID	Location	Sample Collection Date and Time	Analyses													
			Samples Archived?	PAHs (EPA Method 8270-SIM)	VOCs-*short list* (EPA Method 8260B)	VOCs-*long list* (EPA Method 8260B)	VOCs (EPA Method 8260B)	Diesel-range and Oil-range Petroleum Hydrocarbons (NWTPH-Dx)	Gasoline-range Petroleum Hydrocarbons (NWTPH-Gx)	Total Metals (EPA Methods 6020A, 7470A)	Dissolved Metals (EPA Methods 6020A, 7470A)	Ammonia (EPA Method 350.1)	Organochlorine Pesticides (EPA Method 8081A)	TSS (EPA Method 160.2)	PCB Aroclors (EPA Method 8082)	Dioxins and Furans (EPA Method 1613)
UST Site No. 1																
02600	UST1-15	10/8/2008 13:45	Y	1	1			1	1	1	1	1				
02601	UST1-14	10/8/2008 14:40	Y	1	1			1	1	1	1	1				
Refueling Pit 3																
03600	RFP3-22	10/8/2008 11:55	Y	1		1		1	1	1	1	1	1			
03601	RFP3-23	10/8/2008 12:50	Y	1		1		1	1	1	1	1	1			
Fire Training Area																
06600	FTA-27	10/8/2008 10:10	Y	1		1		1	1	1	1	1	1			
06601	FTA-28	10/8/2008 11:00	Y	1		1		1	1	1	1	1	1			
Aquatic - Finger Piers Area																
08600	FP-21	10/9/2008 10:15	Y	1			1	1	1	1	1	1	1			
08601	FP-22	10/9/2008 11:15	Y	1			1	1	1	1	1	1	1	1		
Aquatic - Near Landfill																
09600	LF-11	10/7/2008 13:40	Y	1			1	1	1	1	1	1	1	1	1	1
09601	LF-11-FD	10/7/2008 14:30	N	1			1	1	1	1	1	1	1	1	1	1
Aquatic - North of Pier 8																
07600	NTP-11	10/8/2008 15:40	Y	1			1	1	1	1	1	1	1	1		
Aquatic - Reference Area																
10600	REF-13	10/7/2008 11:30	Y	1			1	1	1	1	1	1	1	1	1	1
Totals			--	12	2	4	6	12	12	12	12	12	10	5	3	3

Notes:

1 = This symbol indicates that samples were collected for this analysis and sent to the appropriate contract laboratory.
short list = Limited to VOCs specific to petroleum hydrocarbon contamination
long list = Limited to VOCs specific to contamination by chlorinated and non-chlorinated solvents

EPA = United States Environmental Protection Agency
FD = field duplicate
HCB = hexachlorobenzene
ID = identification
PAHs = polycyclic aromatic hydrocarbons
PCB = polychlorinated biphenyls
TOC = total organic carbon
TSS = total suspended solids
UST = underground storage tank
VOCs = volatile organic compounds

Table 3-7
Tissue Analyses by Decision Unit
Tongue Point Multi-Sites Project, Astoria, Oregon

Sample ID	Sample Type	Common Name	Species	Total Individuals Collected	Sample Collection Date and Time	Analyses						
						SVOCs (EPA Method 8270C)	Total Metals (EPA Methods 6020A, 7471A)	% Lipids (Bligh and Dyer, 1959 [modified])	Tributyltin (Krone, 1981)	PCB Aroclors (EPA Method 8082)	Organochlorine Pesticides (EPA Method 8081A)	Dioxins and Furans (EPA Method 1613)
Aquatic - Finger Piers Area												
08700	Clams	Asian Clam	*Corbicula*	132	9/24/2008 15:30	1	1	1	1	1	1	1
08701	Forage Fish	Prickly Sculpin Threespine Stickleback	*Cottus asper* *Gasterosteus aculeatus*	1 62	9/23/2008 19:00	1	1	1	1	1	1	1
08702	Forage Fish-FD				9/23/2008 19:05	1	1	1	1	1	1	1
08703	Fillets	Prickly Sculpin	*Cottus asper*	9	9/24/2008 18:30	1	1	1	1	1	1	1
Aquatic - Near Landfill												
09700	Clams	Asian Clam	*Corbicula*	85	9/19/2008 16:45	1	1	1	1	1	1	1
09701	Fillets	Prickly Sculpin	*Cottus asper*	9	9/27/2008 15:40	1	1	1	1	1	1	1
09702	Forage Fish	Prickly Sculpin Threespine Stickleback	*Cottus asper* *Gasterosteus aculeatus*	6 6	9/28/2008 16:44	1	1	1	1	1	1	1
Aquatic - North of Pier 8												
07700	Clams	Asian Clam	*Corbicula*	104	9/25/2008 9:04	1	1	1	1	1	1	1
07701	Fillets	Prickly Sculpin	*Cottus asper*	7	9/26/2008 17:08	1	1	1	1	1	1	1
07702	Forage Fish	Prickly Sculpin Threespine Stickleback	*Cottus asper* *Gasterosteus aculeatus*	6 9	10/1/2008 16:15	1	1	1	1	1	1	1
Aquatic - Reference Area												
10700	Clams	Asian Clam	*Corbicula*	474	9/29/2008 14:21	1	1	1	1	1	1	1
10701	Fillets	Prickly Sculpin	*Cottus asper*	9	9/30/2008 19:10	1	1	1	1	1	1	1
10702	Forage Fish	Prickly Sculpin Threespine Stickleback	*Cottus asper* *Gasterosteus aculeatus*	1 41	9/30/2008 17:15	1	1	1	1	1	1	1
Totals						6	6	6	6	6	6	6

Notes:

1 = This symbol indicates that samples were collected for this analysis and sent to the appropriate laboratory.

% = percent
EPA = United States Environmental Protection Agency
FD = field duplicate
HCB = hexachlorobenzene
ID = identification
PCB = polychlorinated biphenyls
SVOCs = semi-volatile organic compounds

Table 3-8
Sampling Location Survey Information
Tongue Point Multi-Sites Project, Astoria, Oregon

Sample ID	Northing	Easting	Elevation (feet MSL)	Elevation (feet MLLW)
AST Fuel Storage Area				
AST-1	46.20718	-123.76100	87.727	90.927
AST-2	46.20710	-123.76127	88.499	91.699
AST-3	46.20689	-123.76151	87.652	90.852
AST-4	46.20668	-123.76137	87.494	90.694
AST-5	46.20716	-123.76095	86.476	89.676
AST-6	46.20709	-123.76121	88.916	92.116
AST-7	46.20688	-123.76143	88.408	91.608
AST-8	46.20668	-123.76130	87.773	90.973
AST-9	46.20671	-123.76104	70.242	73.442
AST-10	46.20717	-123.76100	87.722	90.922
AST-11	46.20704	-123.76110	87.396	90.596
AST-12	46.20688	-123.76101	78.116	81.316
UST Site No. 1				
UST1-MW-1	46.20511	-123.76246	12.316	15.516
UST1-MW-6	46.20530	-123.76206	10.902	14.102
UST1-MW-9	46.20525	-123.76206	10.991	14.191
UST1-MW-8	46.20513	-123.76208	11.567	14.767
UST1-1	46.20528	-123.76200	11.582	14.782
UST1-2	46.20517	-123.76201	11.768	14.968
UST1-3	46.20508	-123.76206	11.961	15.161
UST1-4	46.20537	-123.76225	13.058	16.258
UST1-5	46.20516	-123.76247	13.203	16.403
UST1-6	46.20543	-123.76220	12.834	16.034
UST1-7	46.20538	-123.76246	13.725	16.925
UST1-8	46.20522	-123.76236	13.048	16.248
UST1-9	46.20531	-123.76211	12.187	15.387
UST1-10	46.20533	-123.76206	11.479	14.679
UST1-11	46.20531	-123.76201	12.064	15.264
UST1-12	46.20527	-123.76304	--	--
UST1-13	46.20506	-123.76295	--	--
UST1-14	46.20526	-123.76294	--	--
UST1-15	46.20500	-123.76296	--	--
Refueling Pit 3				
RFP3-MW-1	46.20312	-123.76365	12.024	15.224
RFP3-MW-2	46.20321	-123.76365	11.967	15.167
RFP3-MW-3	46.20312	-123.76431	11.831	15.031
RFP3-MW-4	46.20313	-123.76375	12.063	15.263
RFP3-MW-5	46.20316	-123.76351	11.597	14.797
RFP3-1	46.20321	-123.76346	11.745	14.945
RFP3-2	46.20309	-123.76336	11.751	14.951
RFP3-3	46.20304	-123.76389	12.493	15.693
RFP3-4	46.20323	-123.76379	12.808	16.008
RFP3-11	46.20323	-123.76347	11.838	15.038
RFP3-12	46.20305	-123.76390	12.553	15.753
RFP3-13	46.20323	-123.76377	12.767	15.967
RFP3-15	46.20332	-123.76369	12.871	16.071
RFP3-16	46.20312	-123.76371	12.330	15.530
RFP3-17	46.20352	-123.76347	12.377	15.577
RFP3-18	46.20258	-123.76371	--	--
RFP3-19	46.20350	-123.76333	--	--
RFP3-20	46.20323	-123.76426	--	--
RFP3-21	46.20279	-123.76427	--	--
RFP3-22	46.20317	-123.76439	--	--
RFP3-23	46.20275	-123.76414	--	--

Table 3-8 (continued)
Sampling Location Survey Information
Tongue Point Multi-Sites Project, Astoria, Oregon

Sample ID	Northing	Easting	Elevation (feet MSL)	Elevation (feet MLLW)
UST Site No. 4				
UST4-1	46.20007	-123.76471	33.860	37.060
UST4-2	46.20010	-123.76460	31.966	35.166
UST4-3	46.20004	-123.76468	33.070	36.270
UST4-4	46.19998	-123.76481	43.331	46.531
UST4-5	46.19995	-123.76466	34.763	37.963
UST4-6	46.20002	-123.76457	32.082	35.282
UST4-7	46.20026	-123.76442	13.161	16.361
UST4-8	46.20028	-123.76426	11.836	15.036
Fire Training Area				
FTA-MW-17	46.19509	-123.76037	17.153	20.353
FTA-MW-18D	46.19668	-123.75999	15.223	18.423
FTA-1	46.19677	-123.75989	11.963	15.163
FTA-1G	46.19678	-123.75989	12.018	15.218
FTA-2	46.19668	-123.76036	12.040	15.240
FTA-2G	46.19669	-123.76036	12.048	15.248
FTA-3	46.19657	-123.76088	12.039	15.239
FTA-3G	46.19658	-123.76088	12.079	15.279
FTA-4	46.19633	-123.76161	15.901	19.101
FTA-4G	46.19632	-123.76165	15.796	18.996
FTA-5	46.19594	-123.76128	22.008	25.208
FTA-5G	46.19593	-123.76132	21.547	24.747
FTA-6	46.19581	-123.76046	21.675	24.875
FTA-6G	46.19579	-123.76048	21.233	24.433
FTA-7	46.19584	-123.75950	12.097	15.297
FTA-7G	46.19582	-123.75951	11.988	15.188
FTA 8	46.19683	-123.75963	11.481	14.681
FTA-9	46.19658	-123.75947	10.945	14.145
FTA-10	46.19636	-123.75938	11.268	14.468
FTA-11	46.19616	-123.75927	10.866	14.066
FTA-12	46.19591	-123.75918	11.544	14.744
FTA-13	46.19660	-123.75959	11.283	14.483
FTA-14	46.19652	-123.75966	12.188	15.388
FTA-15	46.19648	-123.75953	11.666	14.866
FTA-25	46.19649	-123.76032	--	--
FTA-26	46.19594	-123.76014	--	--
FTA-27	46.19643	-123.76034	--	--
FTA-28	46.19585	-123.76010	--	--

Table 3-8 (continued)
Sampling Location Survey Information
Tongue Point Multi-Sites Project, Astoria, Oregon

Sample ID	Northing	Easting	Elevation (feet MSL)	Elevation (feet MSL)
Aquatic - Finger Piers Area				
FP-11	46.20527	-123.76006	--	--
FP-12	46.20029	-123.75779	--	--
FP-13	46.19703	-123.75606	--	--
FP-13A	46.19643	-123.75725	--	--
FP-21	46.20390	-123.76141	--	--
FP-22	46.19806	-123.75835	--	--
MIS-29	46.20549	-123.76035	--	--
MIS-30	46.20548	-123.75925	--	--
MIS-31	46.20419	-123.76193	--	--
MIS-32	46.20399	-123.75933	--	--
MIS-33	46.20331	-123.76260	--	--
MIS-34	46.20313	-123.76003	--	--
MIS-35	46.20272	-123.76204	--	--
MIS-36	46.20153	-123.75850	--	--
MIS-37	46.20185	-123.76270	--	--
MIS-38	46.20243	-123.76116	--	--
MIS-39	46.20253	-123.75832	--	--
MIS-40	46.20065	-123.76147	--	--
MIS-41	46.20076	-123.75974	--	--
MIS-42	46.19976	-123.76102	--	--
MIS-43	46.19985	-123.75964	--	--
MIS-44	46.20004	-123.75868	--	--
MIS-45	46.20015	-123.75691	--	--
MIS-46	46.19861	-123.76093	--	--
MIS-47	46.19925	-123.75761	--	--
MIS-48	46.19862	-123.75689	--	--
MIS-49	46.19857	-123.75875	--	--
MIS-50	46.19750	-123.75901	--	--
MIS-51	46.19701	-123.76060	--	--
MIS-52	46.19719	-123.75813	--	--
MIS-53	46.19608	-123.76022	--	--
MIS-54	46.19751	-123.75574	--	--
MIS-55	46.19688	-123.75622	--	--
MIS-56	46.19613	-123.75743	--	--
Aquatic - Near Landfill				
LF-11	46.19497	-123.75791	--	--
MIS-57	46.19521	-123.75964	--	--
MIS-58	46.19538	-123.75901	--	--
MIS-59	46.19554	-123.75836	--	--
MIS-60	46.19574	-123.75719	--	--
MIS-61	46.19490	-123.75946	--	--
MIS-62	46.19505	-123.75886	--	--
MIS-63	46.19525	-123.75777	--	--
MIS-64	46.19566	-123.75604	--	--
MIS-65	46.19460	-123.75926	--	--
MIS-66	46.19475	-123.75876	--	--
MIS-67	46.19497	-123.75816	--	--
MIS-68	46.19515	-123.75701	--	--
MIS-69	46.19430	-123.75916	--	--
MIS-70	46.19447	-123.75868	--	--
MIS-71	46.19476	-123.75761	--	--
MIS-72	46.19394	-123.75913	--	--
MIS-73	46.19420	-123.75863	--	--
MIS-74	46.19439	-123.75802	--	--
MIS-75	46.19456	-123.75685	--	--
MIS-76	46.19500	-123.75581	--	--
MIS-77	46.19397	-123.75860	--	--
MIS-78	46.19411	-123.75740	--	--
MIS-79	46.19413	-123.75594	--	--
MIS-80	46.19359	-123.75938	--	--
MIS-81	46.19365	-123.75857	--	--
MIS-82	46.19361	-123.75798	--	--
MIS-83	46.19358	-123.75665	--	--
MIS-84	46.19325	-123.75972	--	--

Table 3-8 (continued)
Sampling Location Survey Information
Tongue Point Multi-Sites Project, Astoria, Oregon

Sample ID	Northing	Easting	Elevation (feet MSL)	Elevation (feet MSL)
Aquatic - North of Pier 8				
NTP-11	46.20580	-123.76135	--	--
MIS-01	46.20708	-123.76076	--	--
MIS-02	46.20705	-123.76044	--	--
MIS-03	46.20704	-123.75998	--	--
MIS-04	46.20666	-123.76049	--	--
MIS-05	46.20683	-123.76050	--	--
MIS-06	46.20686	-123.76008	--	--
MIS-07	46.20639	-123.76101	--	--
MIS-08	46.20653	-123.76059	--	--
MIS-09	46.20665	-123.76015	--	--
MIS-10	46.20680	-123.75965	--	--
MIS-11	46.20598	-123.76184	--	--
MIS-12	46.20612	-123.76127	--	--
MIS-13	46.20628	-123.76076	--	--
MIS-14	46.20640	-123.76026	--	--
MIS-15	46.20653	-123.75975	--	--
MIS-16	46.20574	-123.76198	--	--
MIS-17	46.20590	-123.76140	--	--
MIS-18	46.20601	-123.76091	--	--
MIS-19	46.20613	-123.76040	--	--
MIS-20	46.20622	-123.75994	--	--
MIS-21	46.20516	-123.76278	--	--
MIS-22	46.20534	-123.76230	--	--
MIS-23	46.20546	-123.76199	--	--
MIS-24	46.20565	-123.76151	--	--
MIS-25	46.20575	-123.76106	--	--
MIS-26	46.20584	-123.76053	--	--
MIS-27	46.20594	-123.76009	--	--
MIS-28	46.20603	-123.75966	--	--
Aquatic - Reference Area				
REF-13	46.19382	-123.74921	--	--
MIS-85	46.19080	-123.74734	--	--
MIS-86	46.19117	-123.74791	--	--
MIS-87	46.19135	-123.74792	--	--
MIS-88	46.19159	-123.74820	--	--
MIS-89	46.19205	-123.74856	--	--
MIS-90	46.19250	-123.74890	--	--
MIS-91	46.19130	-123.74748	--	--
MIS-92	46.19175	-123.74781	--	--
MIS-93	46.19222	-123.74808	--	--
MIS-94	46.19269	-123.74835	--	--
MIS-95	46.19310	-123.74869	--	--
MIS-96	46.19357	-123.74898	--	--
MIS-97	46.19293	-123.74918	--	--
MIS-98	46.19337	-123.74956	--	--
MIS-99	46.19380	-123.74991	--	--
MIS-100	46.19415	-123.75008	--	--
MIS-101	46.19430	-123.74961	--	--
MIS-102	46.19422	-123.74984	--	--
MIS-103	46.19400	-123.74936	--	--
MIS-104	46.19391	-123.74961	--	--
MIS-105	46.19346	-123.74930	--	--
MIS-106	46.19302	-123.74896	--	--
MIS-107	46.19260	-123.74864	--	--
MIS-108	46.19124	-123.74771	--	--
MIS-109	46.19168	-123.74800	--	--
MIS-110	46.19213	-123.74831	--	--
MIS-111	46.19075	-123.74753	--	--
MIS-112	46.19272	-123.74895	--	--

Table 3-8 (continued)
Sampling Location Survey Information
Tongue Point Multi-Sites Project, Astoria, Oregon

Sample ID	Northing	Easting	Elevation (feet MSL)	Elevation (feet MSL)
Groundwater Reference Area				
UST-1-18	46.205274	-123.76342	14.058	14.058

Notes:

Terresterial locations survey completed 30 Spetember to 3 October 2008

Horizontal are referenced using World Geodetic System of 1984 (WGS 84) and noted as Northing and Easting values in this table. Vertical positions are referenced to National Geodetic Vertical Datum of 1929 (NGVD 29).

Elevation of ground surface for surface soil sampling locations. Hydropunch temporary wells, soil gas, and existing monitoring well locations elevation of top of casing .

-- = Elevation of sample location not available; not surveyed

AST = above ground storage tank
ID = identification
MSL = mean sea level
MLLW = mean lower low water
No. = number
UST = underground storage tank

Table 3-9
Existing Monitoring Wells and Microwell Construction Details and Groundwater Elevations
Tongue Point Multi-Sites Project, Astoria, Oregon

Existing Monitoring Wells							
Monitoring Well	**Decision Unit**	**Northing**	**Easting**	**Top of Casing Elevation (feet MSL)**	**Screened Interval (feet bgs)**	**Depth to Water (feet BTOC)[3]**	**Groundwater Elevation (feet MSL)**
MW-01	UST Site No. 1	942173.08	1174085.36	12.32	3 - 13	6.67	5.65
MW-06	UST Site No. 1	942237.56	1174189.48	10.90	6.9 - 16.9	[1]	3.16
MW-08	UST Site No. 1	942177.77	1174180.94	11.57	2.5 - 12.5	[1]	5.42
MW-09	UST Site No. 1	942219.16	1174189.02	10.99	2.3 - 12.3	4.17	6.82
MW-01	Refueling Pit 3	941459.95	1173754.34	12.02	4.5 - 14.3	5.37	6.65
MW-02	Refueling Pit 3	941493.80	1173755.61	11.97	4 - 13.8	5.30	6.67
MW-03	Refueling Pit 3	941467.45	1173587.40	11.83	5 - 14.8	4.99	6.84
MW-04	Refueling Pit 3	941466.77	1173729.94	12.06	4 - 13.8	5.32	6.74
MW-05	Refueling Pit 3	941475.16	1173790.56	11.60	4.5 -14.3	4.92	6.68
MW-17	Fire Training Area	938501.64	1174465.91	17.15	10 - 25	10.87	6.28
MW-18D	Fire Training Area	939078.73	1174585.46	15.22	13.5 - 28.5	9.99	5.23
MW-19	Fire Training Area	939024.89	1174693.00	15.22	5 - 20	[1]	4.79
Microwells Installed as part of 2008 RI							
Microwell	**Decision Unit**	**Northing**	**Easting**	**Top of Casing Elevation (feet MSL)**	**Screened Interval (feet bgs)**	**Depth to Water (feet BTOC)[3]**	**Groundwater Elevation (feet MSL)**
AST-10	AST Fuel Storage Area	942753.18	1174465.81	71.31	15 - 20	7.72	63.59
UST1-1	UST Site No. 1	942232.06	1174203.19	12.06	12 - 17	8.90-11.62	3.16
UST1-2	UST Site No. 1	942192.04	1174200.86	11.77	12 - 17	9.31-10.28	2.46
UST1-4	UST Site No. 1	942268.02	1174142.17	13.06	12 - 17	7.28-7.35	5.71
UST1-18	UST Site No. 1	942243.75	1173845.60	14.06	12 - 17	7.37	6.69
RFP3-1	Refueling Pit 3	941493.65	1173804.10	11.75	7 - 12	5.04	6.71
RFP3-2	Refueling Pit 3	941448.23	1173827.03	11.75	7 - 12	5.84-10.55[2]	5.91
RFP3-3	Refueling Pit 3	941433.32	1173693.70	12.49	7 - 12	5.70	6.79
RFP3-4	Refueling Pit 3	941503.68	1173721.47	12.81	7 - 12	6.00	6.81
FTA-1	Fire Training Area	939108.50	1174613.51	11.96	15 - 25	6.86	5.10
FTA-2	Fire Training Area	939080.66	1174492.42	12.04	14.5 - 24.5	6.02	6.02
FTA-3	Fire Training Area	939044.92	1174360.10	12.04	15 - 20	5.55	6.49
FTA-4	Fire Training Area	938966.25	1174170.67	15.90	18 - 23	7.84	8.06
FTA-5	Fire Training Area	938820.45	1174249.20	22.01	22 - 32	14.37	7.64
FTA-6	Fire Training Area	938763.58	1174453.25	21.68	22 - 32	15.10	6.58
FTA-7	Fire Training Area	938767.15	1174696.64	12.10	15 - 25	7.30	4.80
FTA-8	Fire Training Area	939127.09	1174678.97	11.48	15 - 25	6.80	4.68
FTA-9	Fire Training Area	939035.27	1174715.47	10.95	10 - 15	6.85	4.10
FTA-10	Fire Training Area	938952.59	1174736.03	11.27	15 - 25	7.40	3.87
FTA-11	Fire Training Area	938879.43	1174760.53	10.87	15 - 25	6.55	4.32
FTA-12	Fire Training Area	938787.20	1174779.18	11.54	15 - 25	6.91	4.63
FTA-13	Fire Training Area	939043.49	1174685.78	11.28	10 - 15	6.51	4.77
FTA-14	Fire Training Area	939015.48	1174666.45	12.19	10 - 15	7.30	4.89
FTA-15	Fire Training Area	938999.85	1174698.77	11.67	10 - 15	7.03	4.64

Notes:

[1] LNAPL present in well. Used Gobins, 1989 "Correction of Water Elevation for Floating Product" equation to determine correct groundwater elevation.
[2] Groundwater in this portion of Refueling Pit 3 appears to be tidally influenced.
[3] Water levels for RI field investigation were measured between 15 to 26 September 2008. See Appendix C for individual locations

AST = aboveground storage tank
bgs = below ground surface
BTOC = below top of casing
LNAPL = light non-aqueous phase liquid
MSL = mean sea level
MW = monitoring well
No. = number
TOC = top of casing
UST = underground storage tank

Groundwater Measurements were collected under static conditions in the wells and microwells prior to any water quality sampling.

Table 3-10a
TPH-D Results by UVF and NWTPH-Dx by Decision Unit
Tongue Point Multi-Sites Project, Astoria, Oregon

Sample Location	Sample ID	Depth (feet bgs)	Analytical Method	Result	Unit
AST Fuel Storage Area					
AST-01	01412	0 - 0.5	NWTPH-Dx	1,400	mg/kg
AST-02	01414	0 - 0.5	NWTPH-Dx	10	mg/kg
AST-03	01416	0 - 0.5	NWTPH-Dx	62	mg/kg
AST-04	01418	0 - 0.5	NWTPH-Dx	2,400	mg/kg
AST-05	01413	0 - 0.5	NWTPH-Dx	58	mg/kg
AST-06	01415	0 - 0.5	NWTPH-Dx	32	mg/kg
AST-07	01417	0 - 0.5	NWTPH-Dx	110	mg/kg
AST-08	01419	0 - 0.5	NWTPH-Dx	71	mg/kg
AST-09	01420	0 - 0.5	NWTPH-Dx	77	mg/kg
AST-10	01421	1 - 3	NWTPH-Dx	7 U	mg/kg
	01422	10 - 11	NWTPH-Dx	40	mg/kg
	01423	14 - 15	NWTPH-Dx	1,300	mg/kg
AST-11	01427	1 - 3	NWTPH-Dx	6.8 U	mg/kg
	01428	10 - 11	NWTPH-Dx	6.5 U	mg/kg
	01429	19 - 20	NWTPH-Dx	6.4 U	mg/kg
AST-12	01424	1 - 3	NWTPH-Dx	6.3 U	mg/kg
	01425	10 - 11	NWTPH-Dx	7.6 U	mg/kg
	01426	19 - 20	NWTPH-Dx	6.3 U	mg/kg
AST-13	01400	1.8 - 2	UVF-3100	223.7	ppm
AST-14	01401	1.8 - 2	UVF-3100	1,706	ppm
AST-15	01402	1.8 - 2	UVF-3100	5,000 J	ppm
AST-16	01403	1.8 - 2	UVF-3100	42.1	ppm
AST-17	01404	1.8 - 2	UVF-3100	5,369 J	ppm
AST-18	01405	1.8 - 2	UVF-3100	590.5	ppm
AST-19	01406	1.8 - 2	UVF-3100	112.9	ppm
AST-20	01407	1.8 - 2	UVF-3100	162.2	ppm
AST-21	01408	1.8 - 2	UVF-3100	3,700	ppm
AST-22	01409	1.55 - 1.75	UVF-3100	14.4	ppm
AST-23	01410	1.8 - 2	UVF-3100	5,000 J	ppm
AST-24	01411	1.8 - 2	UVF-3100	176.1	ppm
UST Site No. 1					
UST1-01	02409	3 - 3.2	UVF-3100	29.2	ppm
	02411	6.6 - 7	NWTPH-Dx	13,000 J	mg/kg
	02412*	6.6 - 7	NWTPH-Dx	1,700 J	mg/kg
	02410	6.8 - 7	UVF-3100	4,761	ppm
UST1-02	02407	3.3 - 3.5	UVF-3100	10.1	ppm
	02408	5.4 - 5.6	UVF-3100	23.8	ppm
	02406	5 - 5.6	NWTPH-Dx	6.2 U	mg/kg
UST1-03	02402	5.5 - 5.7	UVF-3100	33.2	ppm
	02400	5.5 - 6	NWTPH-Dx	540	mg/kg
	02403	11.8 - 12	UVF-3100	163.5	ppm
UST1-04	02413	2.8 - 3	UVF-3100	48	ppm
	02414	6.5 - 7	NWTPH-Dx	5,400 J	mg/kg
	02415*	6.5 - 7	NWTPH-Dx	2,700 J	mg/kg
	02416	11.8 - 12	UVF-3100	2.3	ppm
UST1-05	02404	2.8 - 3	UVF-3100	33.9	ppm
	02405	4.8 - 5	UVF-3100	15.5	ppm
	02401	5.5 - 6	NWTPH-Dx	6.7	mg/kg

Table 3-10a (continued)
TPH-D Results by UVF and NWTPH-Dx by Decision Unit
Tongue Point Multi-Sites Project, Astoria, Oregon

Refueling Pit 3					
RFP3-01	03408	3 - 3.2	UVF-3100	88.4	ppm
	03411	7 - 7.2	UVF-3100	154.9	ppm
	03409	7 - 8	NWTPH-Dx	18 J	mg/kg
	03410*	7 - 8	NWTPH-Dx	28 J	mg/kg
RFP3-02	03413	3.5 - 3.7	UVF-3100	5.6	ppm
	03412	4 - 4.2	UVF-3100	7.2	ppm
	03414	6.5 - 6.7	UVF-3100	32.1	ppm
	03416	6.5 - 7	NWTPH-Dx	30 U	mg/kg
	03415	7.8 - 8	UVF-3100	149.7	ppm
RFP3-03	03400	4.5 - 4.7	UVF-3100	80.7	ppm
	03401	6 - 7	NWTPH-Dx	34	mg/kg
	03402	9 - 9.2	UVF-3100	169.3	ppm
RFP3-04	03403	2 - 2.2	UVF-3100	0.33	ppm
	03406	4.5 - 5.5	NWTPH-Dx	19	mg/kg
	03407	8.8 - 9	UVF-3100	16.1	ppm
UST Site No. 4					
UST4-01	04419	0 - 0.2	UVF-3100	0.97	ppm
	04417	0 - 1	NWTPH-Dx	5.1 UJ	mg/kg
	04420	11 - 11.2	UVF-3100	6.3	ppm
	04418	11 - 12	NWTPH-Dx	11	mg/kg
UST4-02	04406	0.2 - 0.4	UVF-3100	3.8	ppm
	04407	0 - 1	NWTPH-Dx	7.5	mg/kg
	04410	9 - 9.2	UVF-3100	51.5	ppm
	04408	9 - 10	NWTPH-Dx	8.5	mg/kg
	04409*	9 - 10	NWTPH-Dx	10	mg/kg
UST4-03	04411	0.2 - 0.4	UVF-3100	2.2	ppm
	04412	0 - 1	NWTPH-Dx	5.1 U	mg/kg
	04413	11 - 11.2	UVF-3100	0.2 U	ppm
	04414	11 - 12	NWTPH-Dx	6 U	mg/kg
	04415	14.5 - 14.7	UVF-3100	61.8	ppm
	04416	15.75 - 15.77	UVF-3100	372.2	ppm
UST4-04	04400	0 - 1	NWTPH-Dx	13	mg/kg
	04401	2 - 3	NWTPH-Dx	7.3 UJ	mg/kg
UST4-05	04402	0 - 1	NWTPH-Dx	7.4	mg/kg
	04403	2 - 3	NWTPH-Dx	9.6 J	mg/kg
UST4-06	04404	0 - 1	NWTPH-Dx	5.2 U	mg/kg
	04405	2 - 3	NWTPH-Dx	5.3 U	mg/kg
Fire Training Area					
FTA-01	06404	3 - 3.2	UVF-3100	85.6	ppm
	06403	3 - 4	NWTPH-Dx	34	mg/kg
	06405	4.5 - 4.7	UVF-3100	0.70	ppm
FTA-02	06407	2.5 - 4	NWTPH-Dx	5.3 U	mg/kg
	06408	3.5 - 3.7	UVF-3100	0.2 U	ppm
	06409	4 - 4.2	UVF-3100	3.5	ppm
FTA-03	06410	2 - 2.2	UVF-3100	0.2 U	ppm
	06411	2 - 3	NWTPH-Dx	6.1 U	mg/kg
	06412	3 - 3.2	UVF-3100	1.2	ppm
FTA-04	06413	4.5 - 5.5	NWTPH-Dx	6.3 U	mg/kg
	06414	5.4 - 5.6	UVF-3100	1.5	ppm
	06415	7 - 7.2	UVF-3100	0.2 U	ppm
FTA-05	06419	10 - 10.2	UVF-3100	61.1	ppm
	06418	13 - 14	NWTPH-Dx	6.8 U	mg/kg
	06420	14 - 14.2	UVF-3100	3.7	ppm

Table 3-10a (continued)
TPH-D Results by UVF and NWTPH-Dx by Decision Unit
Tongue Point Multi-Sites Project, Astoria, Oregon

Fire Training Area (continued)					
FTA-06	06421	6 - 6.2	UVF-3100	48.8	ppm
	06422	6 - 7	NWTPH-Dx	33 J	mg/kg
	06423*	6 - 7	NWTPH-Dx	61 J	mg/kg
	06424	7 - 7.2	UVF-3100	75.4	ppm
FTA-07	06425	3.8 - 4	UVF-3100	1.4	ppm
	06426	4.5 - 5.5	NWTPH-Dx	6.5 U	mg/kg
	06427	5.5 - 5.7	UVF-3100	0.79	ppm
FTA-08	06400	3 - 3.2	UVF-3100	0.2 U	ppm
	06402	4.5 - 4.7	UVF-3100	5.0	ppm
	06401	4.5 - 5.5	NWTPH-Dx	5.6 U	mg/kg
FTA-09	06437	5.5 - 6.5	NWTPH-Dx	650	mg/kg
FTA-10	06435	3 - 3.2	UVF-3100	1.6	ppm
	06434	5 - 6	NWTPH-Dx	5.4 U	mg/kg
	06436	6.5 - 7	UVF-3100	1.2	ppm
FTA-11	06431	2 - 2.2	UVF-3100	2.0	mg/kg
	06432	5 - 6	NWTPH-Dx	9.5	mg/kg
	06433	6 - 6.2	UVF-3100	19.8	ppm
FTA-12	06429	4.8 - 5	UVF-3100	8.5	ppm
	06428	5 - 6	NWTPH-Dx	5.6 U	mg/kg
	06430	6 - 6.2	UVF-3100	0.2 U	ppm
FTA-13	06446	4 - 4.2	UVF-3100	0.7	ppm
	06449	5 - 6	NWTPH-Dx	35	mg/kg
	06448	6 - 6.2	UVF-3100	8.1	ppm
	06447	4.8 - 5	UVF-3100	0.21	ppm
FTA-14	06443	4 - 4.2	UVF-3100	0.86	ppm
	06444	5 - 6	NWTPH-Dx	5.7 U	mg/kg
	06445	6 - 6.2	UVF-3100	0.48	ppm
FTA-15	06441	5.3 - 5.5	UVF-3100	383.1	ppm
	06440	5.5 - 6.5	NWTPH-Dx	22,000	mg/kg
	06442	6.5 - 6.7	UVF-3100	6.3	ppm

Notes:

* denotes the sample is a duplicate of the sample immediately preceding

TPH-D - diesel-range petroleum hydrocarbons
NWTPH-Gx - Northwest TPH Method-diesel range organics
UVF - ultraviolet fluorescence
RI - remedial investigation
FS - feasibility study
OR - Oregon
ID - identification
bgs - below ground surface
AST - above ground storage tank
UST - underground storage tank
No. - number
mg/kg - milligram per kilogram
ppm - parts per million
U - not detected at reporting limit shown
J - estimated concentration

Table 3-10b
TPH-G Results by UVF and NWTPH-Gx by Decision Unit
Tongue Point Multi-Sites Project, Astoria, Oregon

Sample Location	Sample ID	Depth (feet bgs)	Analytical Method	Result	Units
AST Fuel Storage Area					
AST-01	01412	0 0.5	NWTPH-Gx	23	mg/kg
AST-02	01414	0 - 0.5	NWTPH-Gx	14 U	mg/kg
AST-03	01416	0 - 0.5	NWTPH-Gx	7.4 U	mg/kg
AST-04	01418	0 - 0.5	NWTPH-Gx	14 U	mg/kg
AST-05	01413	0 - 0.5	NWTPH-Gx	11 U	mg/kg
AST-06	01415	0 - 0.5	NWTPH-Gx	23	mg/kg
AST-07	01417	0 - 0.5	NWTPH-Gx	12 U	mg/kg
AST-08	01419	0 - 0.5	NWTPH-Gx	45	mg/kg
AST-09	01420	0 - 0.5	NWTPH-Gx	13 U	mg/kg
AST-10	01421	1 - 3	NWTPH-Gx	15 U	mg/kg
	01422	10 - 11	NWTPH-Gx	17	mg/kg
	01423	14 - 15	NWTPH-Gx	320	mg/kg
AST-11	01427	1 - 3	NWTPH-Gx	9.3 U	mg/kg
	01428	10 - 11	NWTPH-Gx	7.2 U	mg/kg
	01429	19 - 20	NWTPH-Gx	7.6 U	mg/kg
AST-12	01424	1 - 3	NWTPH-Gx	16	mg/kg
	01425	10 - 11	NWTPH-Gx	9.6 U	mg/kg
	01426	19 - 20	NWTPH-Gx	7.5 U	mg/kg
AST-13	01400	1.8 - 2	UVF-3100	1 U	ppm
AST-14	01401	1.8 - 2	UVF-3100	55	ppm
AST-15	01402	1.8 - 2	UVF-3100	131	ppm
AST-16	01403	1.8 - 2	UVF-3100	1 U	ppm
AST-17	01404	1.8 - 2	UVF-3100	1 U	ppm
AST-18	01405	1.8 - 2	UVF-3100	1 U	ppm
AST-19	01406	5 - 5.6	UVF-3100	1 U	ppm
AST-20	01407	1.8 - 2	UVF-3100	3	ppm
AST-21	01408	1.8 - 2	UVF-3100	1 U	ppm
AST-22	01409	1.55 - 1.75	UVF-3100	1 U	ppm
AST-23	01410	1.8 - 2	UVF-3100	1 U	ppm
AST-24	01411	1.8 - 2	UVF-3100	1 U	ppm
UST Site No. 1					
UST1-01	02409	3 - 3.2	UVF-3100	1 U	ppm
	02410	6.8 - 7	UVF-3100	1 U	ppm
	02411	6.6 - 7	NWTPH-Gx	1,900	mg/kg
	02412*	6.6 - 7	NWTPH-Gx	2,200	mg/kg
UST1-02	02407	3.3 - 3.5	UVF-3100	1 U	ppm
	02406	5 - 5.6	NWTPH-Gx	8.1 U	mg/kg
	02408	5.4 - 5.6	UVF-3100	1 U	ppm
UST1-03	02400	5.5 - 6	NWTPH-Gx	930	mg/kg
	02402	5.5 - 6	UVF-3100	1 U	ppm
	02403	11.8 - 12	UVF-3100	1 U	ppm
UST1-04	02413	2.8 - 3	UVF-3100	1 U	ppm
	02414	6.5 - 7	NWTPH-Gx	500	mg/kg
	02415	6.5 - 7	NWTPH-Gx	480	mg/kg
	02416	11.8 - 12	UVF-3100	1 U	ppm
UST1-05	02404	2.8 - 3	UVF-3100	1 U	ppm
	02405	4.8 - 5	UVF-3100	1 U	ppm
	02401	5.5 - 6	NWTPH-Gx	8.9 U	mg/kg

Table 3-10b (continued)
TPH-G Results by UVF and NWTPH-Gx by Decision Unit
Tongue Point Multi-Sites Project, Astoria, Oregon

Refueling Pit 3					
RFP3-01	03409	3 - 3.2	UVF-3100	1 U	ppm
	03411	7 - 7.2	UVF-3100	1 U	ppm
	03409	7 - 8	NWTPH-Gx	8.6 UJ	mg/kg
	03410*	7 - 8	NWTPH-Gx	15 J	mg/kg
RFP3-02	03413	3.5 - 3.7	UVF-3100	1 U	ppm
	03412	4 - 4.2	UVF-3100	1 U	ppm
	03414	6.5 - 6.7	UVF-3100	1 U	ppm
	03416	6.5 - 7	NWTPH-Gx	7.3 U	mg/kg
	03415	7.8 - 8	UVF-3100	1 U	ppm
RFP3-03	03400	4.5 - 4.7	UVF-3100	1 U	ppm
	03401	6 - 7	NWTPH-Gx	9.1 U	mg/kg
	03402	9 - 9.2	UVF-3100	1 U	ppm
RFP3-04	03403	2 - 2.2	UVF-3100	1 U	ppm
	03406	4.5 - 5.5	NWTPH-Gx	28	mg/kg
	03407	8.8 - 9	UVF-3100	1.26	ppm
UST Site No. 4					
UST4-01	04417	0 - 1	NWTPH-Gx	11	mg/kg
	04419	0 - 2	UVF-3100	1 U	ppm
	04418	11 - 12	NWTPH-Gx	8.7 U	mg/kg
	04420	11 - 11.2	UVF-3100	1 U	ppm
UST4-02	04407	0 - 1	NWTPH-Gx	6.8 U	mg/kg
	04406	2 - 4	UVF-3100	1 U	ppm
	04410	9 - 9.2	UVF-3100	1.44	ppm
	04408	9 - 10	NWTPH-Gx	12 J	mg/kg
	04409*	9 - 10	NWTPH-Gx	51 J	mg/kg
UST4-03	04412	0 - 1	NWTPH-Gx	7.4 U	mg/kg
	04414	11 - 12	NWTPH-Gx	7.5 U	mg/kg
	04411	2 - 4	UVF-3100	1 U	ppm
	04413	11 - 11.2	UVF-3100	1 U	ppm
	04415	14.5 - 14.7	UVF-3100	1.78	ppm
	04416	15.75 - 15.77	UVF-3100	1 U	ppm
UST4-04	04400	0 - 1	NWTPH-Gx	75	mg/kg
	04401	2 - 3	NWTPH-Gx	14	mg/kg
UST4-05	04402	0 - 1	NWTPH-Gx	24	mg/kg
	04403	2 - 3	NWTPH-Gx	9.5 U	mg/kg
UST4-06	04404	0 - 1	NWTPH-Gx	23	mg/kg
	04405	2 - 3	NWTPH-Gx	8.8	mg/kg
Former Fire Training Area					
FTA-01	06404	3 - 3.2	UVF-3100	1 U	ppm
	06403	3 - 4	NWTPH-Gx	16	mg/kg
	06405	4.5 - 4.7	UVF-3100	1 U	ppm
FTA-02	06407	2.5 - 4	NWTPH-Gx	6.3 U	mg/kg
	06408	3.5 - 3.7	UVF-3100	1 U	ppm
	06409	4 - 4.2	UVF-3100	1 U	ppm
FTA-03	06410	2 - 2.2	UVF-3100	1 U	ppm
	06411	2 - 3	NWTPH-Gx	8.4 U	mg/kg
	06412	3 - 3.2	UVF-3100	1 U	ppm
FTA-04	06413	4.5 - 5.5	NWTPH-Gx	7.9 U	mg/kg
	06414	5.4 - 5.6	UVF-3100	1 U	ppm
	06415	7 - 7.2	UVF-3100	1 U	ppm
FTA-05	06418	13 - 14	NWTPH-Gx	8.9 U	mg/kg
	06419	10 - 10.2	UVF-3100	1 U	ppm
	06420	14 - 14.2	UVF-3100	1 U	ppm

Table 3-10b (continued)
TPH-G Results by UVF and NWTPH-Gx by Decision Unit
Tongue Point Multi-Sites Project, Astoria, Oregon

Former Fire Training Area					
FTA-06	06421	6 - 6.2	UVF-3100	1 U	ppm
	06422	6 - 7	NWTPH-Gx	8.6 U	mg/kg
	06423*	6 - 7	NWTPH-Gx	7.9 U	mg/kg
	06424	7 - 7.2	UVF-3100	1 U	ppm
FTA-07	06425	3.8 - 4	UVF-3100	1 U	ppm
	06426	4.5 - 5.5	NWTPH-Gx	8.4 U	mg/kg
	06427	5.5 - 5.7	UVF-3100	1 U	ppm
FTA-08	06400	3 - 3.2	UVF-3100	1 U	ppm
	06401	4.5 - 5.5	NWTPH-Gx	7.1 U	mg/kg
	06402	4.5 - 4.7	UVF-3100	1 U	ppm
FTA-09	06437	5.5 - 6.5	NWTPH-Gx	7.8 U	mg/kg
FTA-10	06435	3 - 3.2	UVF-3100	1 U	ppm
	06434	5 - 6	NWTPH-Gx	7.1 U	mg/kg
	06436	6.5 - 7	UVF-3100	1 U	ppm
FTA-11	06431	5 - 6	NWTPH-Gx	13 U	mg/kg
	06432	5 - 6	UVF-3100	1 U	ppm
	06433	6 - 6.2	UVF-3100	1 U	ppm
FTA-12	06428	5 - 6	NWTPH-Gx	7.5 U	mg/kg
	06429	4.8 - 5	UVF-3100	1 U	ppm
	06430	6 - 6.2	UVF-3100	1 U	ppm
FTA-13	06446	4 - 4.2	UVF-3100	1 U	ppm
	06447	4.8 - 5	UVF-3100	1 U	ppm
	06449	5 - 6	NWTPH-Gx	8.8 U	mg/kg
	06448	6 - 6.2	UVF-3100	1 U	ppm
FTA-14	06443	5 - 6	UVF-3100	1 U	ppm
	06444	5 - 6	NWTPH-Gx	9.9	mg/kg
	06445	4 - 4.2	UVF-3100	1 U	ppm
FTA-15	06442	4 - 4.2	UVF-3100	1 U	ppm
	06440	5.5 - 6.5	NWTPH-Gx	260	mg/kg
	06441	6.5 - 6.7	UVF-3100	1 U	ppm

Notes:

TPH-G - gasoline-range petroleum hydrocarbons
NWTPH-Gx - Northwest TPH Method-gasoline range organics
UVF - ultraviolet fluorescence
RI - remedial investigation
FS - feasibility study
OR - Oregon
ID - identification
bgs - below ground surface
AST - above ground storage tank
UST - underground storage tank
No. - number
mg/kg - milligram per kilogram
ppm - parts per million
U - not detected at reporting limit shown
J - estimated concentration

Table 3-10c
Comparison of UVF Field Analysis Results to Laboratory Analytical Result for Split Soil Samples
Tongue Point Multi-Sites Project, Astoria, Oregon

Sample IDs	Location IDs	Parameter	UVF Sample Depth Interval (feet bgs)	UVF Result (mg/kg)	Lab Sample Depth Interval (feet bgs)	Laboratory Result (mg/kg)	R^2
Diesel-Range Hydrocarbons							
02400 / 02402	UST1-03	Diesel Range Hydrocarbons	5.5 to 5.7	33.2	5.5 to 6.0	540	0.48
02410 / 02411	UST1-01	Diesel Range Hydrocarbons	6.8 to 7.0	4,761	6.6 to 7.0	13,000 J	
03409 / 03411	RFP3-01	Diesel Range Hydrocarbons	7.0 to 7.2	154.9	7.0 to 8.0	18 J	
03414 / 03416	RFP3-02	Diesel Range Hydrocarbons	6.5 to 6.7	32.1	6.5 to 7.0	30 U	
04418 / 04420	FTA-05	Diesel Range Hydrocarbons	11.0 to 11.2	6.3	11.0 to 12.0	11	
06401 / 06402	FTA-08	Diesel Range Hydrocarbons	4.5 to 4.7	5	4.5 to 5.5	5.6 U	
06447 / 06449	FTA-13	Diesel Range Hydrocarbons	4.8 to 5.0	0.2	5.0 to 6.0	35	
Gasoline-Range Hydrocarbons							
02400 / 02402	UST1-03	Gasoline Range Hydrocarbons	5.5 to 5.7	1 U	5.5 to 6.0	930	*Not calculated*
02410 / 02411	UST1-01	Gasoline Range Hydrocarbons	6.8 to 7.0	1 U	6.6 to 7.0	1,900	
03409 / 03411	RFP3-01	Gasoline Range Hydrocarbons	7.0 to 7.2	1 U	7.0 to 8.0	8.6 U	
03414 / 03416	RFP3-02	Gasoline Range Hydrocarbons	6.5 to 6.7	1 U	6.5 to 7.0	7.3 U	
04418 / 04420	FTA-05	Gasoline Range Hydrocarbons	11.0 to 11.2	1 U	11.0 to 12.0	8.7 U	
06401 / 06402	FTA-08	Gasoline Range Hydrocarbons	4.5 to 4.7	1 U	4.5 to 5.5	7 U	
06447 / 06449	FTA-13	Gasoline Range Hydrocarbons	4.8 to 5.0	1 U	5.0 to 6.0	8.8 U	

Notes:

UVF - ultraviolet fluorescence
RI - remedial investigation
FS - feasibility study
OR - Oregon
ID - identification

bgs - below ground surface
mg/kg - milligram per kilogram
R^2 - square of the correlation coefficient r
J - estimated concentration
U - not detected at reporting limit shown

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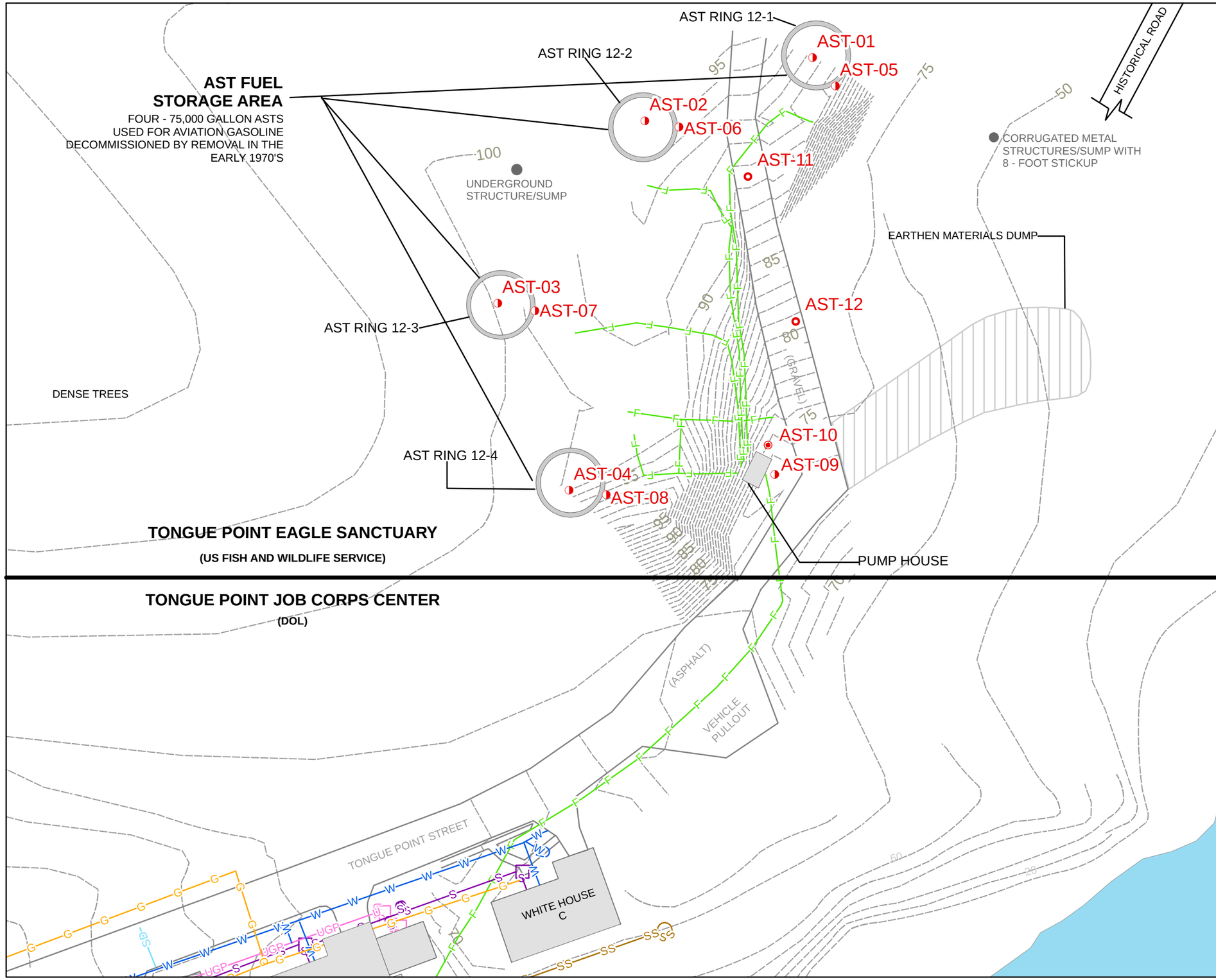
TONGUE POINT ROAD
CAFETERIA
HANGAR 1
HANGAR 2
HANGAR 3
FORMER LANDFILL
PIER 8
PIER 7
PIER 6
PIER 5
PIER 4
PIER 3
PIER 2
PIER 1
CATHLAMET BAY
0
-10
-14
-20
-12
-8
-18
-30
LEGEND
RAILROAD
FENCE
VINYL CHLORIDE PLUME
BATHYMETRIC ELEVATION MLLW (FEET)
NOTES
1. CONTOUR INTERVAL = 2 FEET
2. FIELD SURVEY OF WATER DEPTHS PERFORMED ON 4 & 5 OF SEPTEMBER 2008
3. VERTICAL CONTROL BASED ON NOAA M.L.L.W.
4. MLLW = MEAN LOWER LOW WATER
5. NOAA = NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
0 180 360 720
Feet
CDM
U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON
2008 BATHYMETRY
TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON
FIGURE 3-1



LEGEND

- DPT BORING
- DPT BORING/MICROWELL
- COMPOSITE SURFACE SAMPLE LOCATION
- FUEL LINE FROM GEOPHYSICAL SURVEY
- PROPERTY BOUNDARY (APPROXIMATE)
- TOPOGRAPHIC CONTOURS

UTILITIES

- UGP — UNDERGROUND POWER
- G — GAS
- SS — SANITARY SEWER
- S — STEAM
- SD — STORM DRAIN
- W — WATER

NOTES:

1. FOUR ABOVE GROUND STORAGE TANKS (ASTs) WERE FORMERLY LOCATED AT THE AST FUEL STORAGE AREA AS SHOWN ON THIS DRAWING.
2. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
3. BASE MAP FILES FROM URS (FIGURE 3-7) SEPTEMBER 2007.
4. HAND AUGER SAMPLES NOT SHOWN, BUT REFERENCED IN TEXT.
5. DPT = DIRECT PUSH TECHNOLOGY
6. DOL = DEPARTMENT OF LANDS
7. US = UNITED STATES

0 20 40 80
Feet

CDM

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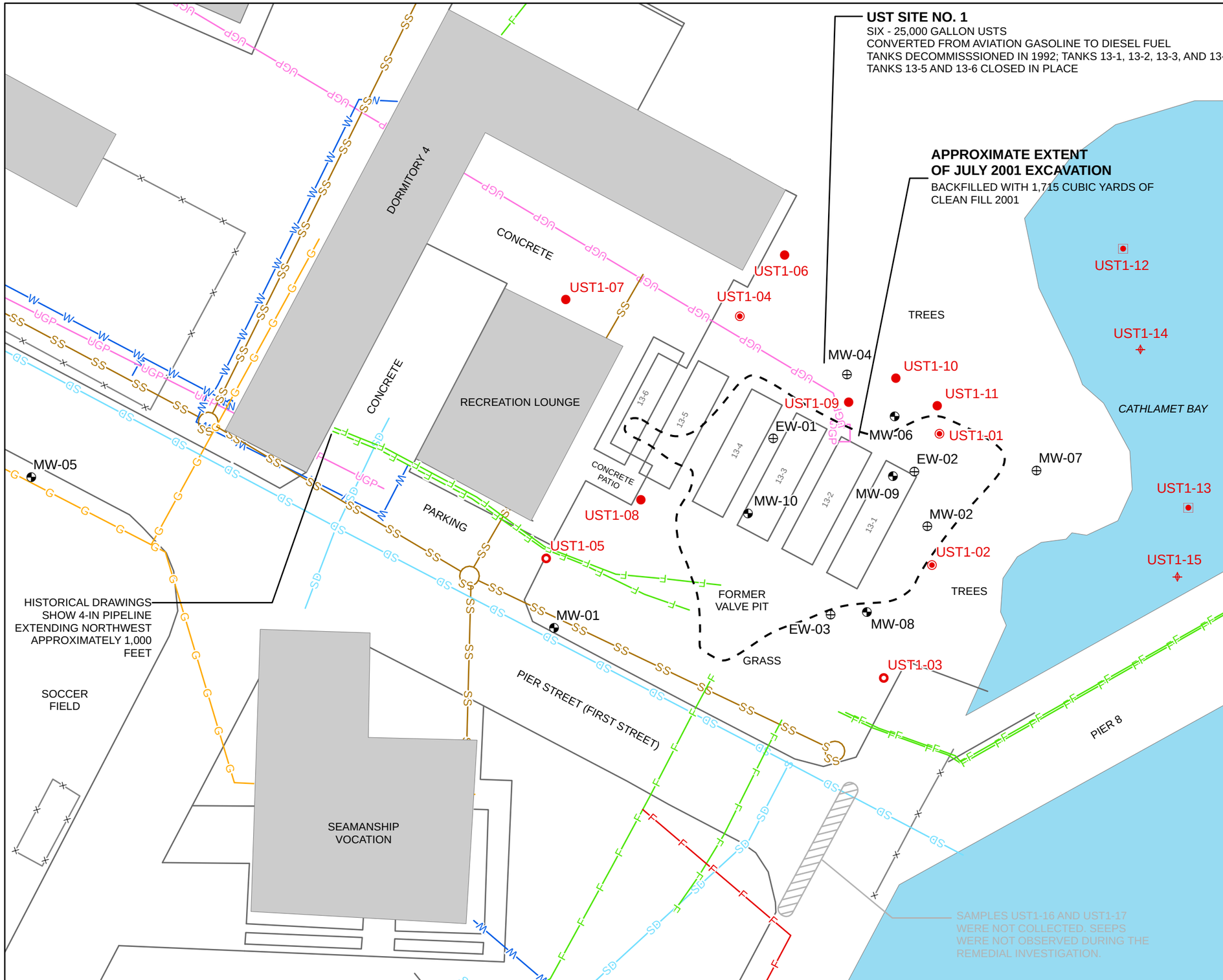
AST FUEL STORAGE AREA SAMPLING LOCATIONS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 3-2



LEGEND

- SEDIMENT CORE LOCATION
- SURFACE WATER SAMPLING LOCATION
- EXISTING MONITORING WELL
- ABANDONED MONITORING WELL
- SOIL GAS SAMPLE LOCATION
- DPT BORING/MICROWELL
- DPT BORING
- FUEL LINE FROM GEOPHISICAL SURVEY
- FUEL LINE NOT CONFIRMED BY GEOPHYSICAL SURVEY
- FENCE

UTILITIES

- GAS
- UNDERGROUND POWER
- SANITARY SEWER
- STORM DRAIN
- WATER

NOTES

1. LOCATIONS FOR ABANDONED WELLS EW-01, EW-02, EW-03 AND MW-07 HAVE NOT BEEN CONFIRMED.
2. FREE PRODUCT OBSERVED IN MW-06.
3. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
4. BASE MAP FILES FROM URS (FIGURE 3-2) SEPTEMBER 2007.
5. DPT = DIRECT PUSH TECHNOLOGY
6. UST = UNDERGROUND STORAGE TANK
7. IN = INCHES

0 15 30 60
Feet

CDM

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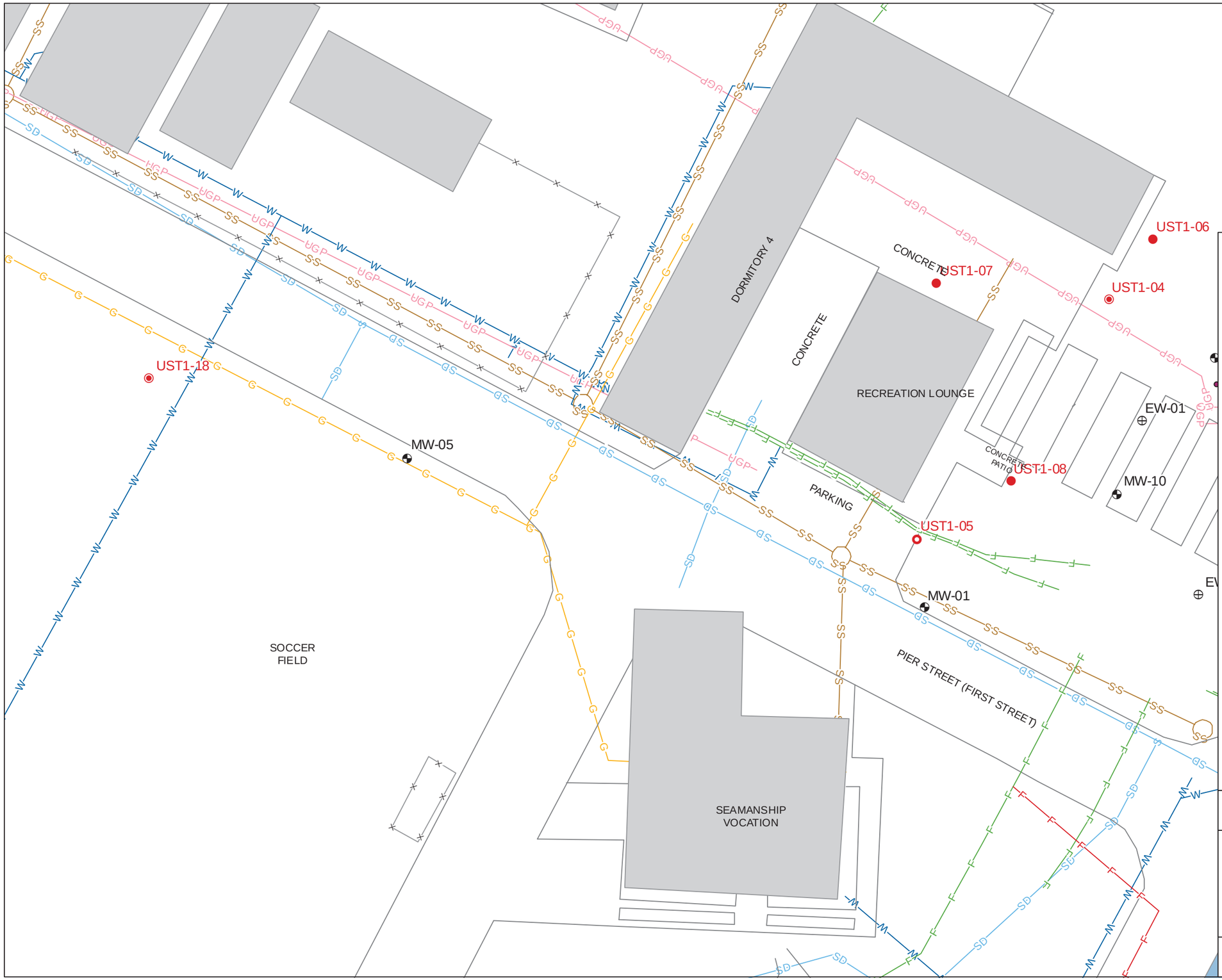
UST SITE NO. 1 (EASTERN AREA) SAMPLING LOCATIONS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 3-3



LEGEND

- EXISTING MONITORING WELL
- ABANDONED MONITORING WELL
- SOIL GAS SAMPLE LOCATION
- DPT BORING/MICROWELL
- DPT BORING
- FUEL LINE FROM GEOPHYSICAL SURVEY
- FUEL LINE NOT CONFIRMED BY GEOPHYSICAL SURVEY
- FENCE

UTILITIES

- GAS
- UNDERGROUND POWER
- SANITARY SEWER
- STORM DRAIN
- WATER

NOTES

1. ANALYTICAL RESULTS FROM SAMPLING UST1-18 NOT INCLUDED IN RISK CHARACTERIZATION.
2. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
3. BASE MAP FILES FROM URS (FIGURE 3-2) SEPTEMBER 2007.
4. DPT = DIRECT PUSH TECHNOLOGY

0 15 30 60
Feet

CDM

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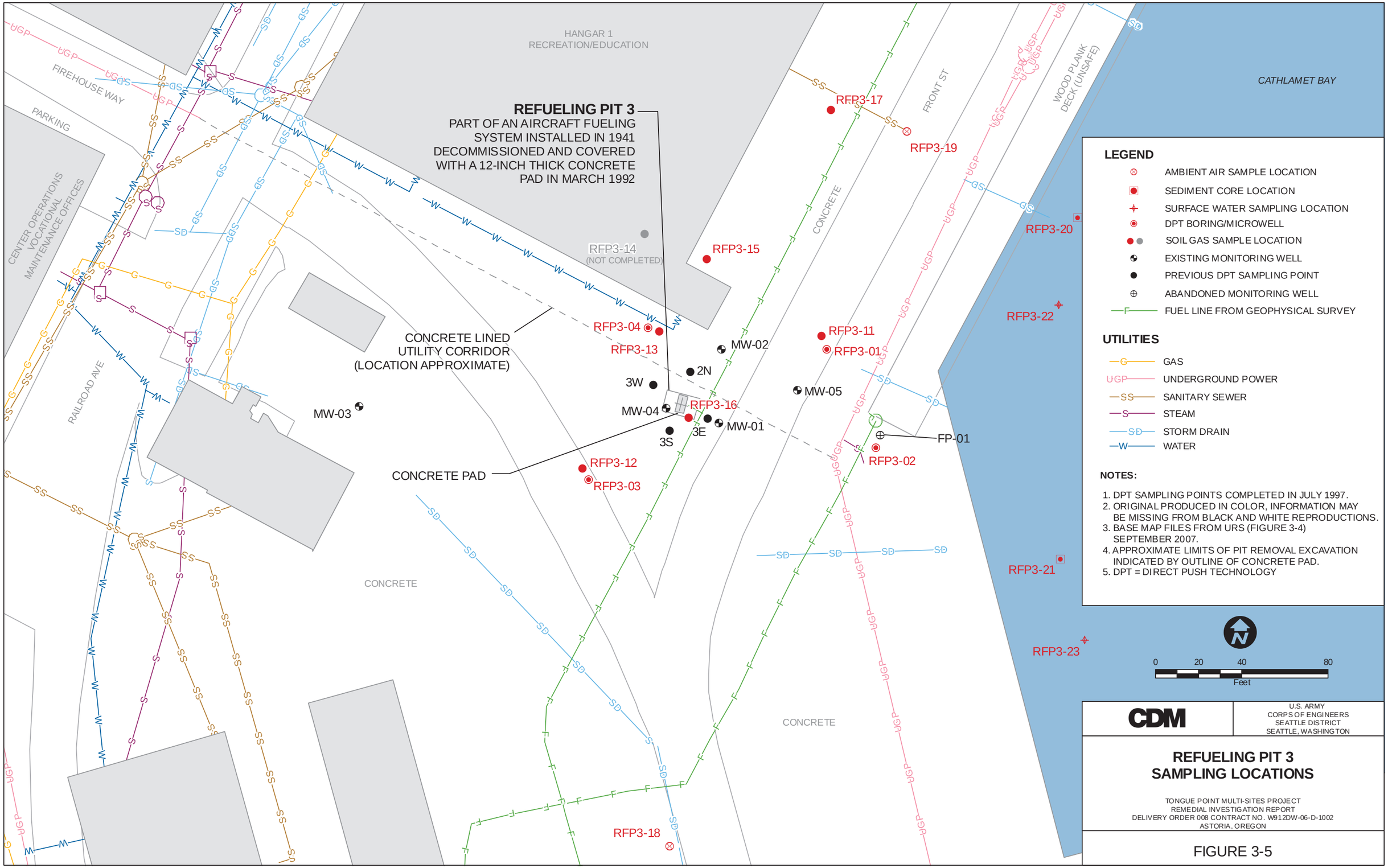
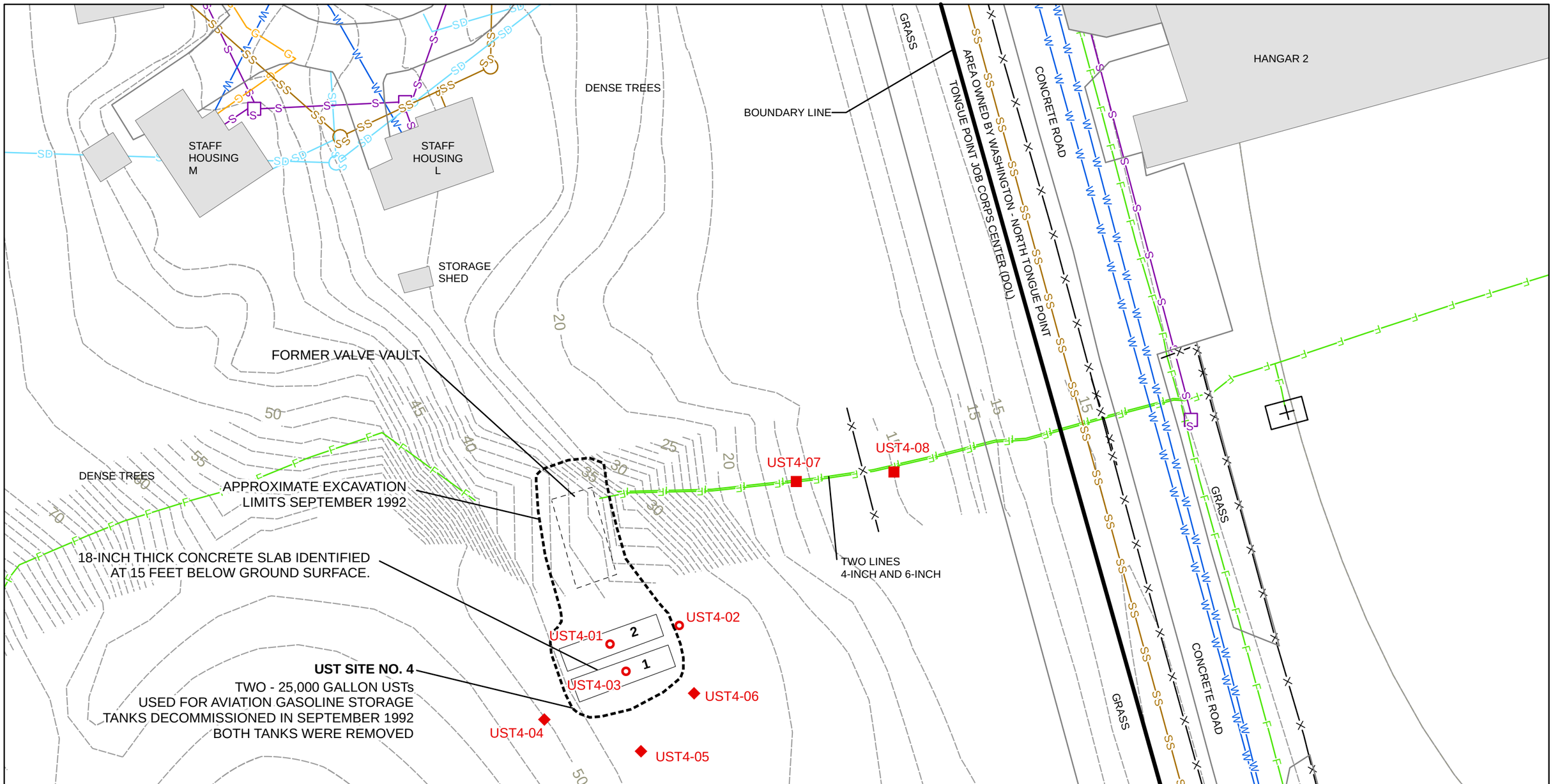
SEATTLE, WASHINGTON

UST SITE NO. 1 (WESTERN AREA) SAMPLING LOCATIONS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 3-4


HANGAR 1
RECREATION/EDUCATION
FIREHOUSE WAY
PARKING
CENTER OPERATIONS
VOCATIONAL
MAINTENANCE OFFICES
RAILROAD AVE
REFUELING PIT 3
PART OF AN AIRCRAFT FUELING SYSTEM INSTALLED IN 1941 DECOMMISSIONED AND COVERED WITH A 12-INCH THICK CONCRETE PAD IN MARCH 1992
RFP3-14
(NOT COMPLETED)
CONCRETE LINED
UTILITY CORRIDOR
(LOCATION APPROXIMATE)
CONCRETE PAD
CONCRETE
CONCRETE
FRONT ST
WOOD PLANK
DECK (UNSAFE)
CATHLAMET BAY
RFP3-17
RFP3-19
RFP3-20
RFP3-22
RFP3-21
RFP3-23
RFP3-15
RFP3-04
RFP3-13
RFP3-11
RFP3-01
RFP3-16
RFP3-12
RFP3-03
RFP3-02
RFP3-18
MW-02
MW-05
MW-03
MW-04
MW-01
2N
3W
3E
3S
FP-01
LEGEND
AMBIENT AIR SAMPLE LOCATION
SEDIMENT CORE LOCATION
SURFACE WATER SAMPLING LOCATION
DPT BORING/MICROWELL
SOIL GAS SAMPLE LOCATION
EXISTING MONITORING WELL
PREVIOUS DPT SAMPLING POINT
ABANDONED MONITORING WELL
FUEL LINE FROM GEOPHYSICAL SURVEY
UTILITIES
GAS
UNDERGROUND POWER
SANITARY SEWER
STEAM
STORM DRAIN
WATER
NOTES:
1. DPT SAMPLING POINTS COMPLETED IN JULY 1997.
2. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
3. BASE MAP FILES FROM URS (FIGURE 3-4) SEPTEMBER 2007.
4. APPROXIMATE LIMITS OF PIT REMOVAL EXCAVATION INDICATED BY OUTLINE OF CONCRETE PAD.
5. DPT = DIRECT PUSH TECHNOLOGY
N
0 20 40 80
Feet
CDM
U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON
REFUELING PIT 3
SAMPLING LOCATIONS
TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON
FIGURE 3-5



LEGEND

- DPT BORING
- HAND AUGER BORING
- TEST PIT
- PROPERTY BOUNDARY
- RAILROAD
- FENCE

UTILITIES

- GAS
- SANITARY SEWER
- STEAM
- STORM DRAIN
- WATER
- FUEL LINE FROM GEOPHYSICAL SURVEY

NOTES:

1. SIX ADDITIONAL UNDERGROUND STORAGE TANKS (USTs) MAY HAVE BEEN PRESENT HISTORICALLY; HOWEVER, THEIR PRESENCE OR REMOVAL HAS NOT BEEN CONFIRMED.
2. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
3. BASE MAP FILES FROM URS (FIGURE 3-3) SEPTEMBER 2007.
4. DPT = DIRECT PUSH TECHNOLOGY
5. DOL = DEPARTMENT OF LANDS

0 20 40 80
Feet

CDM

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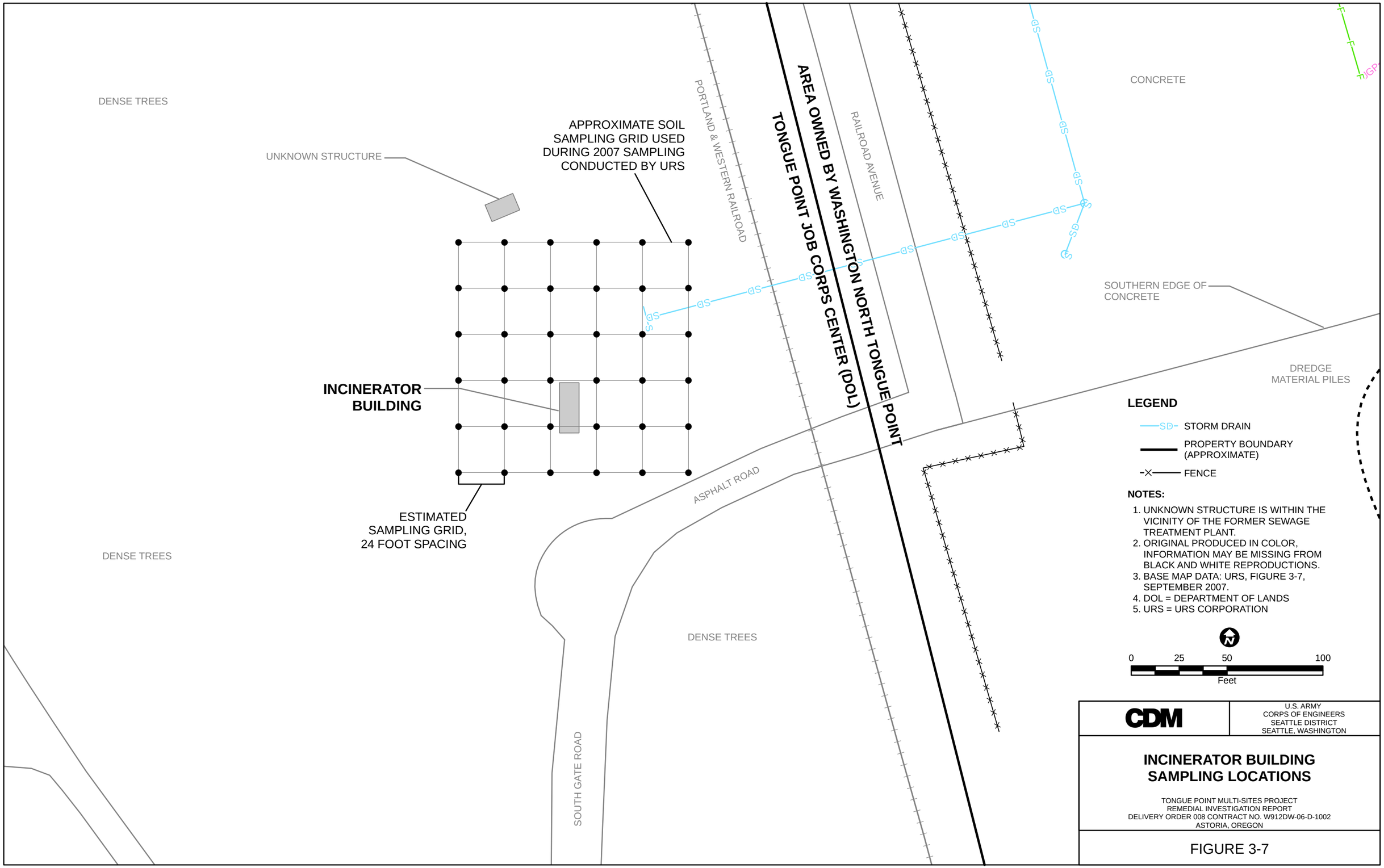
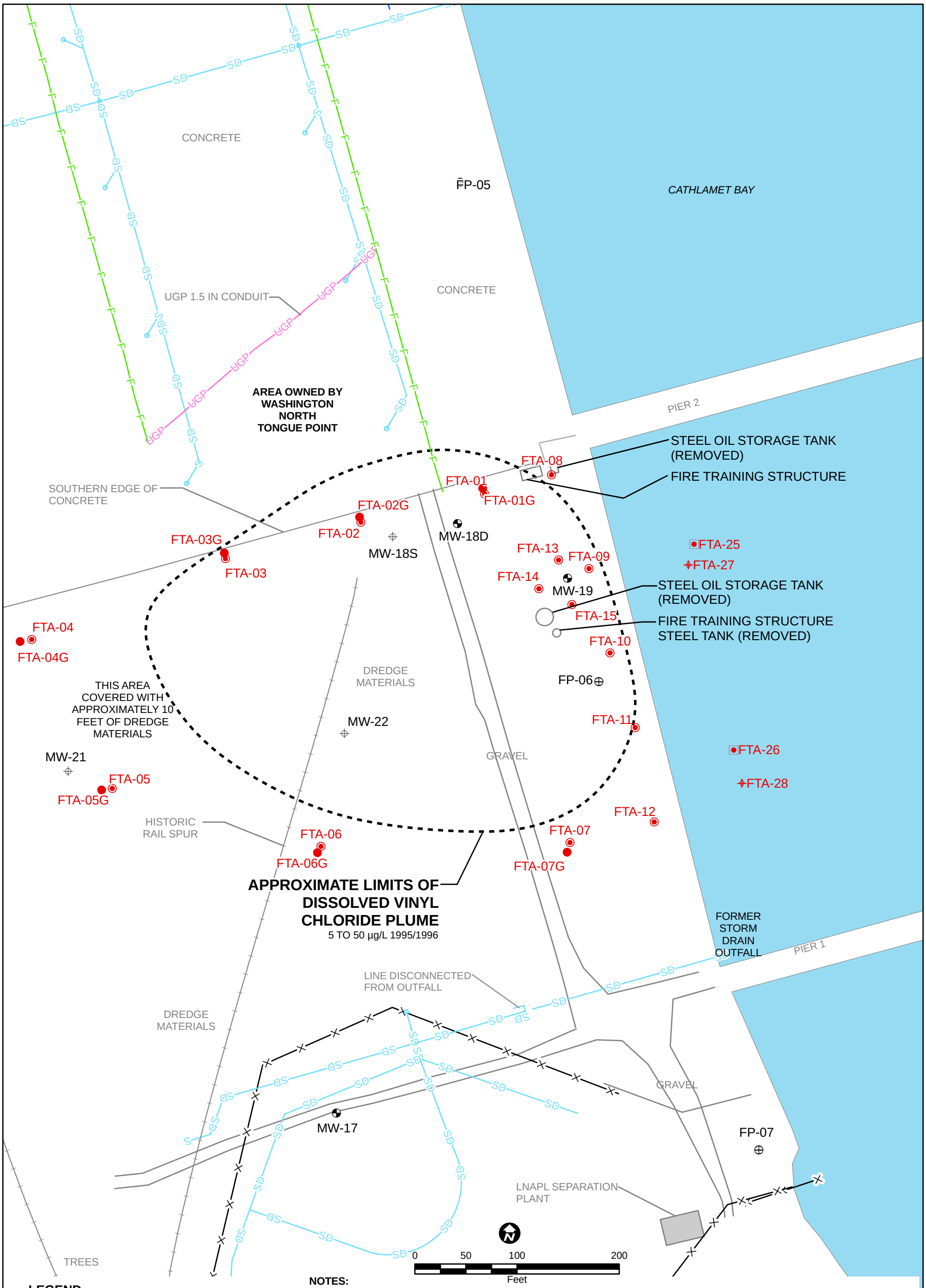
UST SITE NO. 4
SAMPLING LOCATIONS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 3-6


DENSE TREES
UNKNOWN STRUCTURE
APPROXIMATE SOIL SAMPLING GRID USED DURING 2007 SAMPLING CONDUCTED BY URS
PORTLAND & WESTERN RAILROAD
AREA OWNED BY WASHINGTON NORTH TONGUE POINT
TONGUE POINT JOB CORPS CENTER (DOL)
RAILROAD AVENUE
CONCRETE
SOUTHERN EDGE OF CONCRETE
DREDGE MATERIAL PILES
INCINERATOR BUILDING
ESTIMATED SAMPLING GRID, 24 FOOT SPACING
ASPHALT ROAD
DENSE TREES
DENSE TREES
SOUTH GATE ROAD
LEGEND
STORM DRAIN
PROPERTY BOUNDARY (APPROXIMATE)
FENCE
NOTES:
1. UNKNOWN STRUCTURE IS WITHIN THE VICINITY OF THE FORMER SEWAGE TREATMENT PLANT.
2. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
3. BASE MAP DATA: URS, FIGURE 3-7, SEPTEMBER 2007.
4. DOL = DEPARTMENT OF LANDS
5. URS = URS CORPORATION
0 25 50 100
Feet
CDM
U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON
INCINERATOR BUILDING SAMPLING LOCATIONS
TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON
FIGURE 3-7



LEGEND

- SEDIMENT CORE LOCATION
- SURFACE WATER SAMPLING LOCATION
- EXISTING MONITORING WELL
- INACCESSIBLE MONITORING WELL
- ABANDONED MONITORING WELL
- DPT DORING/MICROWELL
- SOIL GAS SAMPLE LOCATION
- PROPERTY BOUNDARY
- SD STORM DRAIN
- UGP UNDERGROUND POWER
- F FUEL LINE
- FENCE

NOTES:

1. WELLS MW-18S, MW-21, AND MW-22 ARE NOT ACCESSIBLE BECAUSE OF DREDGE SPOIL PILES.
2. DREDGE SPOIL AREA HISTORICALLY USED AS A PUBLIC WORKS STORAGE YARD AND HAD SEVERAL WAREHOUSE BUILDINGS.
3. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
4. BASE MAP DATA: URS, FIGURE 3-7, SEPTEMBER 2007.
5. DPT = DIRECT PUSH TECHNOLOGY
6. µg/L = MICROGRAMS PER LITER
7. LNAPL = LIGHT NON-AQUEOUS PHASE LIQUID
8. IN = INCH

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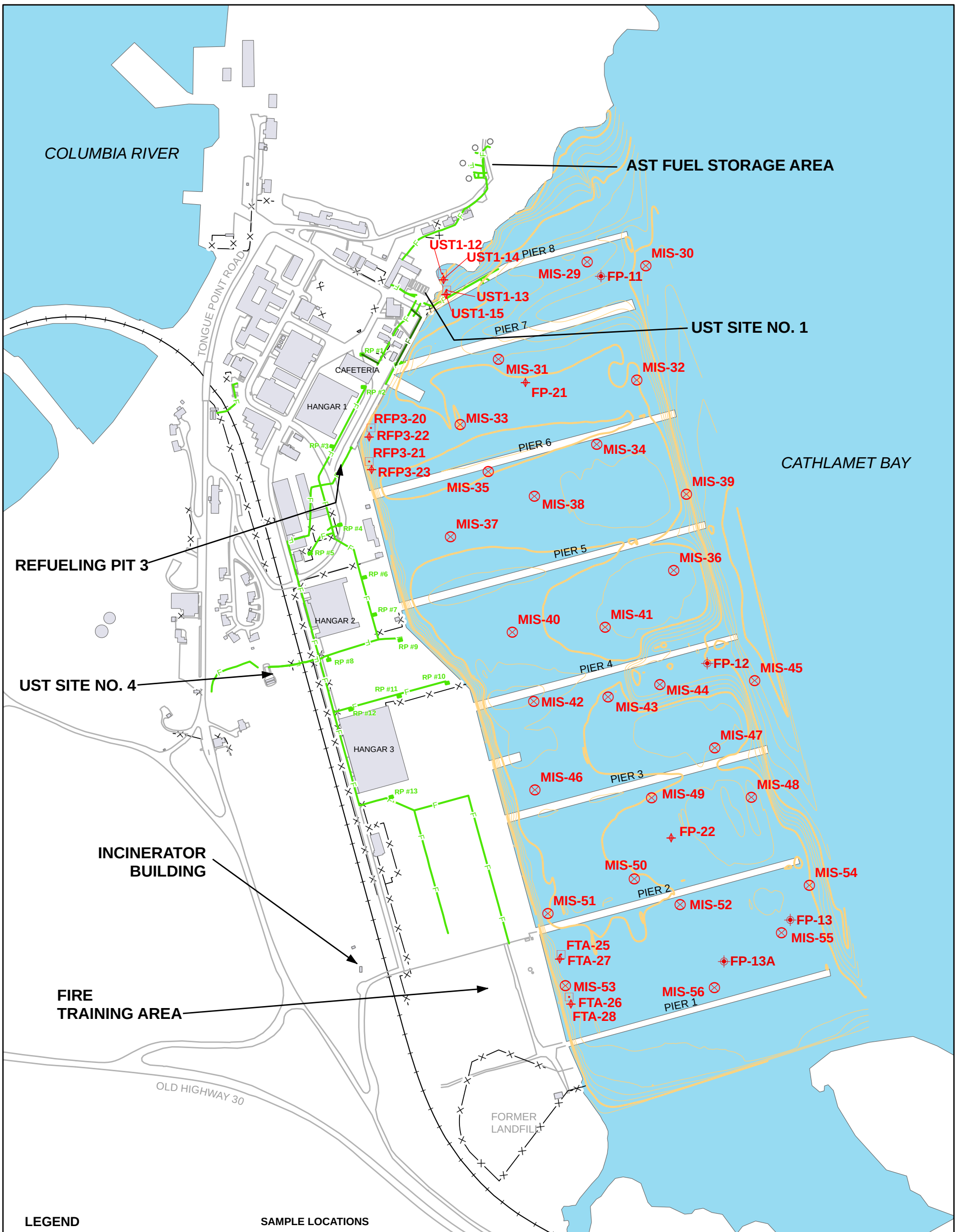
SEATTLE, WASHINGTON

FIRE TRAINING AREA SAMPLING LOCATIONS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 3-8



LEGEND

- FUEL LINE PIPELINE
- FUEL OIL PIPELINE (NOT CONFIRMED)
- FENCE
- RAILROAD

SAMPLE LOCATIONS

- NEARSHORE SEDIMENT CORE SAMPLE
- SURFACE WATER SAMPLE LOCATION AND NUMBER
- IS SURFACE SEDIMENT GRAB SAMPLE LOCATION
- SEDIMENT CORE LOCATIONS

NOTES

1. HYDROGRAPHIC SURVEY COMPLETED ON SEPTEMBER 4 AND 5, 2008.
2. BATHYMETRIC CONTOUR INTERVAL = 2 FEET
3. VERTICAL CONTROL BASED ON NOAA MLLW
4. ORIGINAL PRODUCED IN COLOR INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
5. BASE MAP DATA: URS FIGURE 3-5, SEPTEMBER 2007.
6. UST = UNDERGROUND STORAGE TANK
7. AST = ABOVE GROUND STORAGE TANK
8. NOAA = NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
9. MLLW = MEAN LOWER LOW WATER

N

0 225 450 900
Feet

CDM

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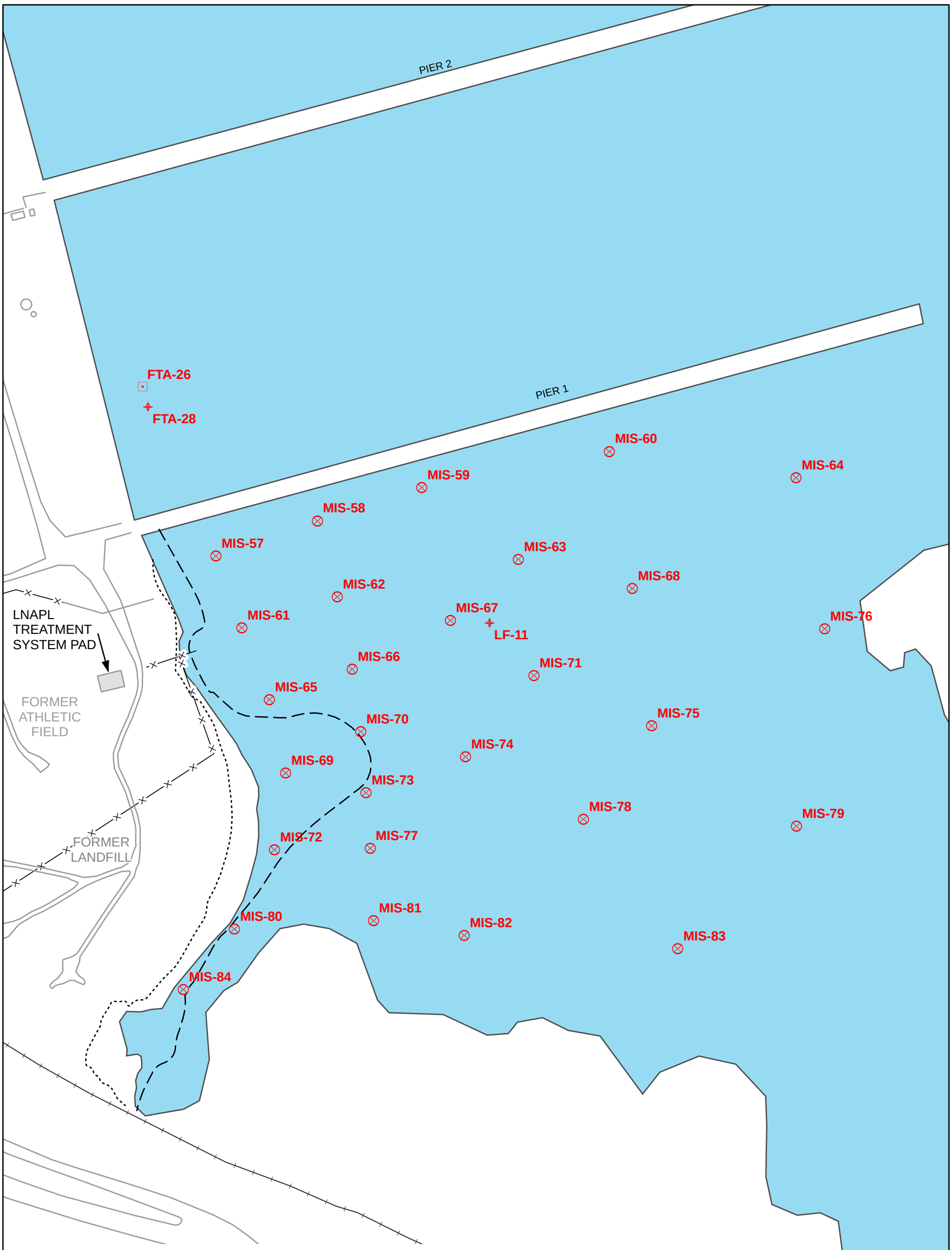
SEATTLE DISTRICT
SEATTLE, WASHINGTON

AQUATIC - FINGER PIERS AREA SAMPLING LOCATIONS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 3-9



LEGEND

- RAILROAD TRACK
- MEAN HIGHER HIGH WATER
- MEAN LOWER LOW WATER
- FENCE

SAMPLE LOCATIONS

- IMS SURFACE SEDIMENT GRAB SAMPLE LOCATIONS
- NEARSHORE SEDIMENT CORE SAMPLE
- SURFACE WATER SAMPLE LOCATION AND NUMBER

NOTES

1. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
2. BASE MAP DATA:URS; FIGURE 1-2, SEPTEMBER 2007, FIGURE 1, DECEMBER 2000 AND FIGURE 2-3, FEBRUARY 1999.
3. LNAPL = LIGHT NON-AQUEOUS PHASE LIQUID
4. IMS = INCREMENTAL MULTIPLE SAMPLING

0 75 150 300
Feet

CDM

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SEATTLE, WASHINGTON

AQUATIC - NEAR LANDFILL SAMPLING LOCATIONS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 3-10

LEWIS AND CLARK NATIONAL
WILDLIFE REFUGE

TONGUE POINT EAGLE SANCTUARY

(US FISH AND WILDLIFE SERVICE)

DENSE TREES

DENSE TREES

AST FUEL STORAGE AREA

FOUR - 75,000 GALLON ASTS
USED FOR AVIATION FUEL
DECOMISSIONED BY REMOVAL
IN THE EARLY 1970'S

AST RING 12-1

AST RING 12-2

AST RING 12-3

AST RING 12-4

PUMP HOUSE

(GRAVEL)

(ASPHALT)

TONGUE POINT STREET

B

C

STAFF HOUSING

MIS-01

MIS-02

MIS-03

MIS-05

MIS-06

MIS-10

MIS-04

MIS-09

MIS-08

MIS-15

MIS-07

MIS-14

MIS-13

MIS-20

MIS-12

MIS-19

MIS-18

MIS-28

MIS-11

MIS-17

MIS-27

NTP-11

MIS-26

MIS-16

MIS-25

MIS-24

PIER 8

MIS-23

MIS-22

MIS-21

PIER 7

LEGEND

- IMS SURFACE SEDIMENT GRAB SAMPLE LOCATION
- SURFACE WATER SAMPLE LOCATION AND NUMBER
- PROPERTY BOUNDARY (APPROXIMATE)

NOTES

1. ORIGINAL PRODUCED IN COLOR INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
2. BASE MAP DATA; URS FIGURE 3-5, SEPTEMBER 2007.
3. AST = ABOVE GROUND STORAGE TANK
4. IMS = INCREMENTAL MULTIPLE SAMPLING
5. US = UNITED STATES

N

0 50 100 200
Feet

CDM

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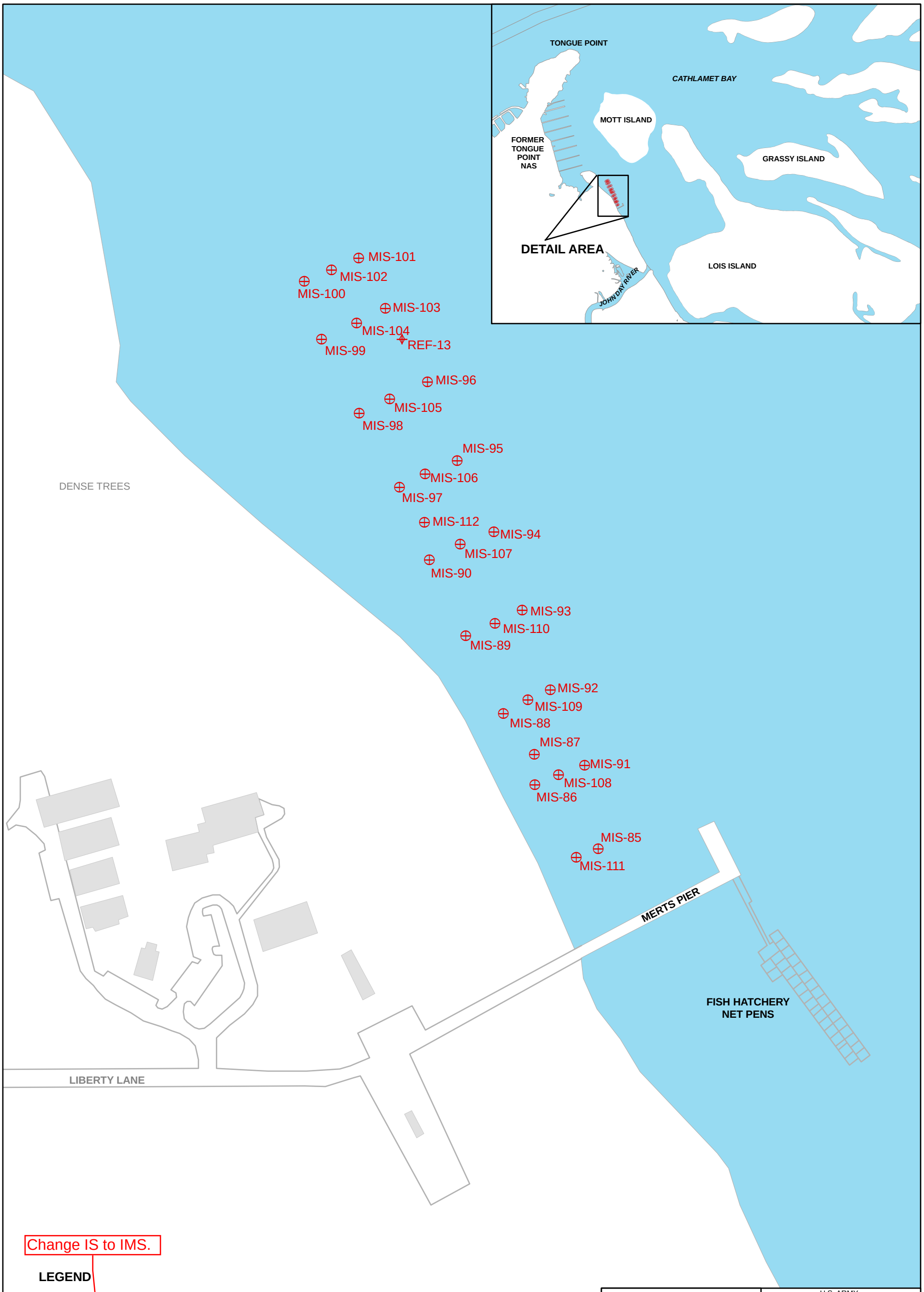
SEATTLE DISTRICT
SEATTLE, WASHINGTON

AQUATIC- NORTH OF PIER 8 SAMPLING LOCATIONS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 3-11



Change IS to IMS.

LEGEND

SURFACE WATER SAMPLE LOCATION

IS SURFACE SEDIMENT GRAB SAMPLE LOCATION

NOTE
1. BUILDINGS AND ROADS DRAWN FROM ©2009 GOOGLE™ IMAGE.
2. IMS = INCREMENTAL MULTIPLE SAMPLING
3. NAS = NAVAL AIR STATION
4. MERTS = MARINE AND ENVIRONMENTAL RESEARCH AND TRAINING STATION

200 100 0 200
Feet

CDM

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SEATTLE, WASHINGTON

AQUATIC - REFERENCE AREA SAMPLING LOCATIONS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 3-12

Section 4
Nature and Extent of Contamination

This section describes the nature and extent of chemicals detected in soil, soil gas, groundwater, surface water, sediment, and tissue for the Tongue Point Multi-Sites Project Study Area. This report focuses on data collected for the 2008 RI sampling effort; although, recent historical data from the Incinerator Building DU were used during the human health and ecological risk assessments.

This section provides the following:

- Discussion of "reference area" data collected in the Study Area to published background concentrations for the State of Oregon and the Columbia River Basin. This discussion primarily pertains to aquatic-related media (sediment, surface water, and tissue) sampled in the Aquatic – Reference Area.
- Discussion of criteria used to evaluate chemicals detected within the Study Area.
- Evaluation of the nature and extent of chemicals in sampled media by DU within the Study Area.
- Summary and discussion of the results of the RI investigation.

4.1 Background and Reference Criteria

The following subsections discuss the background criteria from Oregon and federal regulatory agencies and from other investigations in the Columbia River Basin that were used to evaluate detected chemicals in soil, surface water, and sediment in the Study Area. A summary of all the reference samples collected within the Study Area and how these reference sample results compare to regional background values are detailed below.

4.1.1 Soil Background and Reference Criteria

Reference soil samples were not collected from the Study Area. Regional background levels are listed in ODEQ's Default Background Concentrations for Metals memorandum (ODEQ 2002) for the following 12 inorganic constituents: antimony, arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, silver, selenium, and zinc (ODEQ 2002). The background levels for soil are shown in **Table 4-1a**. Following the ODEQ guidance method, these regional background soil concentrations are compared to maximum detected concentrations of lead in soil collected from the AST Fuel Storage Area, UST Site No.1, Refueling Pit 3, and UST Site No.4. Only lead concentrations were of interest at these DUs because contamination had been delimited during previous investigation to petroleum-related compounds (USACE 1999a, b; USACE 2000; and URS Grenier Woodward Clyde 2000b). All inorganic

chemicals were considered for soil collected from the Incinerator Building and Fire Training Area DUs.

4.1.2 Soil Gas Background and Reference Criteria

State or regional background values for soil gas do not exist. Two ambient air samples were collected from the Study Area. One upwind (RFP3-19) and one downwind (RFP3-18) ambient air sample were collected from the Refueling Pit 3 DU (see **Figure 3-5**). As shown in **Table 4-1b**, these two soil gas samples were analyzed for VOCs only.

4.1.3 Groundwater Background and Reference Criteria

State or regional background values for groundwater do not exist; therefore, a groundwater reference sample (UST1-18) was collected from a location of the Study Area that was not historically used during DoD's occupancy of the Study Area (see **Figure 3-4**). As shown in **Table 4-1c**, this groundwater sample was analyzed for anions, sulfide, inorganic constituents, petroleum-related VOCs, PAHs, TPH-D, TPH-O, and TPH-G (see **Table 3-2** for details).

4.1.4 Surface Water Background and Reference Criteria

Concentrations of chemicals in surface water from the Aquatic - Reference Area DU were determined using a high-volume sampling technique. The surface water sample from location REF-13 was analyzed for inorganic constituents, VOCs, SVOCs, pesticides, PCBs, dioxins and furans, TPH-D, TPH-O, and TPH-G (see **Tables 3-6** and **4-1d**). Inorganic concentrations from sample REF-13 were compared to ODEQ-suggested default background inorganic constituents in surface water (ODEQ 2002). In general, all the detected inorganic concentrations were less than ODEQ background concentrations. The remaining analytical data from this sample are provided for informational purposes only.

4.1.5 Sediment Background and Reference Criteria

Concentrations of chemicals in surface sediment from the Aquatic - Reference Area DU were determined using the IS technique. Seven sediment aliquots (REF-01, REF-02, REF-03, REF-04, REF-05, REF-06, and REF-07) were analyzed for inorganic constituents, SVOCs, PAHs, pesticides, PCBs, and TPH-D and TPH-O (see **Tables 3-5** and **4-1e**). Inorganic concentrations of these seven samples were compared to ODEQ-suggested default background inorganic constituents in sediment (ODEQ 2002). Copper, lead, and zinc concentrations in the reference samples exceed the suggested ODEQ background concentrations. The remaining analytical data are provided for informational purposes only.

4.1.6 Tissue Background and Reference Criteria

Concentrations of chemicals for use as a site-specific reference location of clam, forage fish, and game fish tissue were analyzed from the Aquatic - Reference Area DU tissue samples. Tissue samples were analyzed for bioaccumulative inorganic constituents,

pesticides, and PAHs, PCBs, and dioxins and furans (see **Tables 3-7** and **4-1f**). A comparison of regional background fish and clam tissue data to tissue data from the Study Area is included in **Section 6.1.5.2.6**.

4.2 Comparison Criteria

The following subsections discuss the comparison criteria and guidance values from state and federal regulatory agencies used to evaluate detected chemicals in soil, soil gas, groundwater, surface water, and sediment in the Study Area. These criteria were identified through collaboration with the ODEQ and USACE during preparation of the QAPP (CDM 2008b). The criteria were developed by regulatory agencies to be protective of human and ecological receptors for the specific exposure scenario and media.

As used in this RI, these criteria support the objectives of the investigation related to identifying threats to human and ecological receptors and identifying source areas in soil. Comparison of criteria to analytical results was performed to assist with mapping and discussion related to the extent of impacted media. In this discussion, human health criteria are used for comparison. Use of human health criteria provides a comprehensive comparison and identification of chemicals. Although the use of human health criteria does not focus on the subset of chemicals with predominantly an ecological effect, the detailed evaluations of ecological receptors presented in **Section 6** address chemicals with ecological effects.

DU-specific TPH screening levels were calculated using the ODEQ spreadsheet for calculating RBCs for TPH (http://www.deq.state.or.us/lq/rbdm.htm) (ODEQ 2007b) and the following DU-specific data:

- TPH fraction data analyzed for VPH and EPH fractions
- Corresponding data for BTEX, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, and naphthalene

4.2.1 Soil Criteria

One of the DQOs detailed in the QAPP was to determine the nature and extent of soil contamination to support evaluations of the CSMs. To answer this DQO, the following soil criteria, based on protection of human and ecological receptors, were considered in the evaluation of detected chemicals in soil.

Comparison criteria for soil were obtained from the listed sources and shown in hierarchical order:

- ODEQ (2008) RBCs) for soil (soil ingestion, dermal contact, and inhalation) for residential or construction worker scenario
- EPA (2008a) regional screening levels (RSLs) for residential or industrial soil

- DU-specific soil RBCs for TPH-D, TPH-O, and TPH-G for residential or construction worker scenario
- EPA Region 9 (2004a) preliminary remediation goals (PRGs) for residential or industrial soil when RSLs and RBCs are not available

4.2.2 Groundwater Criteria

Groundwater within the Study Area is not used for potable water and will not be used as a source of drinking water in the near future. Potable water is provided through existing infrastructure by the City of Astoria.

Comparison criteria for groundwater, specific to risk characterization for human health, were obtained from the following sources and shown in hierarchical order:

- ODEQ (2008) RBCs for groundwater (ingestion and inhalation from tap water) for residential scenario
- EPA (2008a) RSLs for tap water
- DU-specific RBCs for TPH-D, TPH-O, and TPH-G for tap water
- EPA Region 9 (2004a) PRGs for tap water, when RSLs and RBCs were not available

4.2.3 Soil Gas Criteria

Vapor intrusion is the major exposure pathway associated with contaminated soil gas. The comparison criteria used were obtained from the following sources and are shown in hierarchical order:

- EPA (2008a) RSLs for residential air. An attenuation factor of 200 is applied to RSLs for residential air to predict soil gas screening levels (ODEQ 2009a).
- ODEQ (2008) RBCs for air inhalation for residential scenario. An attenuation factor of 200 is applied to air RBCs to predict soil gas screening levels (ODEQ 2009a).
- EPA's Subsurface Vapor Intrusion Guidance (EPA 2002f) targets shallow soil gas concentrations and is used when RSLs and RBCs are not available. Because these concentrations are based on an attenuation factor of 10, an additional attenuation factor of 20 is applied to account for a total attenuation factor of 200 (ODEQ 2009a).

4.2.4 Surface Water Criteria

Comparison criteria for surface water were obtained from the following sources and shown in hierarchical order:

- ODEQ (2009b) water quality criteria for human health for consumption of water and organism (OAR 340-041 Tables 33A and 33B)

- National Recommended Water Quality Criteria for consumption of water and organism (EPA 2006b)
- Federal MCLs (EPA 2009c)
- ODEQ (2008) RBCs for groundwater (ingestion and inhalation from tap water) for residential scenario
- EPA (2008a) RSLs for tap water
- EPA Region 9 (2004a) PRGs for tap water when RSLs and RBCs are not available

4.2.5 Sediment Criteria

The following comparison criteria for sediment were obtained from the following sources and shown in hierarchical order:

- ODEQ (2007a) Sediment Bioaccumulation Screening Level Values for humans
- ODEQ (2008) RBCs for soil (soil ingestion, dermal contact, and inhalation) for residential scenario
- EPA (2008a) RSLs for residential soil
- EPA Region 9 (2004a) PRGs for residential soil when RSLs and RBCs were not available
- DU–specific soil RBCs for TPH-D, TPH-O, and TPH-G for residential scenario (for near shore sediment only)

4.2.6 Tissue Criteria

The ODEQ (2007a) Sediment Bioaccumulation Screening Level Values for human comparison criteria were used for tissue.

4.3 Discussion of Analytical Results

The discussion of analytical results that follows (**Section 4.3**) is based on those chemicals that were reported at concentrations greater than their SQL in one or more samples in one or more media at a specific DU. Statistical summary tables, comprising the minimum value, the maximum value, and the frequency of detection (number of results greater than SQL divided by the number of samples), are presented by media and DU in **Tables 4-2a** through **4-10c**. Applicable Study Area-specific reference and regional background values (if available for the selected media) are listed for reference in **Tables 4-1a** through **4-1f**.

Comparison criteria identified in **Sections 4.1 and 4.2**, are tabulated in **Tables 4-2a** through **4-10c** and used to identify a constituent's potential contribution to risk and the extent of affected media. Constituents selected for mapping include those related to past DoD activity, or have potential to migrate and result in adverse effects to

receptors. In addition, the bioaccumulative chemicals are mapped. For determining nature and extent in soil, surface and subsurface soil were not separately evaluated. To support risk evaluations, soil samples are subdivided by depth range; additional details are provided in **Sections 6** and **7**.

Section 4.4 summarizes chemical constituents that exceed criteria in the tables and that have significance relative to the pathways and media identified for the study area conceptual site model. Constituents summarized in Section 4.4 are further discussed for fate and transport considerations in **Section 5.**

The mapping of constituents focuses on investigation objectives (**Section 3.1**) and the potential for selected chemicals to migrate, bioaccumulate, or have adverse effect to receptors in various media. Note that the purpose of mapping was not to illustrate constituent distributions for all COPC identified in the HHRA, or all CPECs identified in the BERA. The intent is to illustrate the extent of contamination that could be site-related for a number of chemicals that will; (1) best show the extent of impacts and may, (2) be of importance for risk management.

Based on past DoD use of facilities within the Study Area, petroleum hydrocarbons and associated chemicals (e.g., PAHs and lead) at six terrestrial DUs, are mapped on **Figures 4-1**, **4-2**, **4-4**, **4-5**, **4-7**, **4-8**, **4-9**, and **4-11** to support CSM presentation in **Section 5**. To simplify the presentation of the PAH analytical data on **Figures 4-1**, **4-2**, **4-4**, **4-5**, **4-7** through **4-9**, **4-11**, **4-12**, and **4-14**, the PAHs were grouped by molecular weight or by being carcinogenic. The LPAHs are acenaphthene, acenaphthylene, anthracene, fluorene, and phenanthrene. The HPAHs are fluoranthene, pyrene, benz(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3,-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene. The carcinogenic PAHs (cPAHs) are benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-c,d)pyrene. The mapping and discussion of cPAHs uses the toxicity equivalent value (TEQ) derived in Section 6.2.1.2. The transport characteristics (i.e., Henry's law constant, K_{OC}, and K_{OW}) of PAHs roughly correlate to their molecular weights and is expanded on in **Section 5**. Chemicals detected in soil gas that did not have applicable screening criteria and may pose a risk the human health were included on **Figures 4-3**, **4-6**, and **4-10**. Chemicals that posed the greatest threat to ecological receptors and support the fate and transport discussion in Section 5 are presented on **Figures 4-12**, **4-14**, and **4-15**.

4.3.1 AST Fuel Storage Area

This section summarizes the analytical results of chemicals detected in surface and subsurface soil and groundwater present at the AST Fuel Storage Area DU.

4.3.1.1 Soil

All soil samples were analyzed for TPH, petroleum-related VOCs, PAHs, and lead, and one soil sample was analyzed for EPH and VPH (see **Table 3-1**). As shown in **Table 4-2a**, TPH-D and TPH-O were reported in 11 of 16 soil samples, with maximum

concentrations of 2,400 mg/kg and 7,300 mg/kg, respectively, detected at location AST-04. TPH-G was reported in 6 of 16 soil samples with a maximum concentration of 320 mg/kg at location AST-10. PAHs were reported in 14 of 16 soil samples, with a maximum concentration of 0.22 mg/kg (pyrene and fluoranthene) at sample location AST-06. Lead was reported in all 16 samples analyzed, with a maximum concentration of 262 mg/kg detected at sample location AST-08.

All of the nine PAHs detected in soil had maximum concentrations below comparison criteria (see **Table 4-2a**). The only inorganic chemical analyzed for in soil was lead, and the maximum detected value (262 mg/kg) exceeded the ODEQ background concentration of 17 mg/kg, but did not exceed the applicable comparison criteria level of 800 mg/kg. The concentrations of TPH-G, TPH-D, and TPH-O that were reported in the AST Fuel Storage Area did not exceed the DU-specific TPH RBCs.

Analytical results for all 18 soil samples are provided in Appendix E. As a result of risk assessment exposure considerations (see Section 6.2.2), sample results from AST-11, (19 to 20 feet bgs) and AST-12 (19 to 20 feet bgs) are excluded from the dataset used for statistical summary in Table 4-2a. Analytical results for samples from all depths at AST-11 and AST-12 are mapped on Figure 4-1. As indicated on the map and the Appendix E data tables, lead was detected at depth of 19-20 feet in AST-11 and AST-12, and in AST-12 benzo(a)pyrene was detected and used in the calculation of cPAH. All other analytes and petroleum compounds were less than the SQL (non-detected) in these two samples.

Figure 4-1 shows the soil concentrations of selected constituents at the AST Fuel Storage Area. With the exception of acenaphthene, acenaphthylene, fluorene, pentachlorophenol, and TPH-G, all maximum concentrations were detected in surface soil samples collected inside, or just outside of, the AST ring foundations.

4.3.1.2 Groundwater

Because groundwater was encountered in one of three borings, one groundwater sample (AST-10) was collected and was analyzed for TPH, petroleum-related VOCs, PAHs, and metals. The analytical results are presented in **Table 4-2b. Figure 4-4** shows the groundwater concentrations of selected constituents at the AST Fuel Storage Area. As shown in **Table 4-2b**, TPH-D was reported at an estimated concentration of 290 J µg/L. Pyrene was the only PAH reported in groundwater and was detected at an estimated concentration of 0.0096 J µg/L. Twelve of the 18 metals analyzed were reported in the groundwater sample.

The following inorganic constituents were detected above the reference criteria: barium, iron, manganese, and nickel. Arsenic was not detected above the reference criteria, but was detected at an order of magnitude (0.605 J µg/L) greater than the comparison criteria (0.038 µg/L).

4.3.2 UST Site No. 1

This section summarizes the analytical results of chemicals detected in soil, soil gas, groundwater, near-shore surface water, and surface sediment present within the UST Site No. 1 DU.

4.3.2.1 Soil

All soil samples were analyzed for TPH, petroleum-related VOCs, PAHs, and lead, and one soil sample was analyzed for EPH and VPH. **Figure 4-2** shows the soil concentrations of selected constituents at UST Site No. 1. As shown in **Table 4-3a**, TPH-D and TPH-G were reported in three of the five soil samples, with maximum concentrations of 13,000 mg/kg and 1,900 mg/kg, respectively, at location UST1-01. TPH-O was reported in one of the five soil samples, at a concentration of 18 mg/kg at location UST1-02. Two VOCs (isopropylbenzene and n-propylbenzene) were reported in three of five soil samples, with an estimated maximum concentration of 1.3 J mg/kg (n-propylbenzene) at location UST1-03. PAHs were reported in all five soil samples, with an estimated maximum concentration of 8.4 J mg/kg (phenanthrene) at location UST1-01. Lead was reported in all five subsurface soil samples, with a maximum concentration of 14.6 mg/kg at location UST1-03.

All of the ten PAH maximum concentrations were detected below comparison criteria; no consensus background criteria were identified for PAHs (see **Table 4-3a**). The only inorganic chemical analyzed for in soil was lead. None of the detected values of lead exceeded the ODEQ background concentration of 17 mg/kg or the comparison criteria value of 800 mg/kg. The concentrations of TPH-G, TPH-D, and TPH-O detected did not exceed the DU-specific TPH RBCs.

Seven of the 10 maximum detections of PAHs, plus the diesel and gasoline range hydrocarbons, were located in the soil sample collected from location UST1-01. As shown on **Figure 4-2**, UST1-01 was advanced in the former excavation northeast of Tank 13-1. UST1-01 is 15 ft east of monitoring well MW-06, a monitoring well with measurable LNAPL (see **Section 3**).

4.3.2.2 Soil Gas

Six soil gas samples were analyzed for VOCs and two soil gas samples were analyzed for SVOCs. **Figure 4-3** shows the soil gas concentrations of selected constituents at UST Site No. 1. As shown in **Table 4-3b**, 34 VOCs were reported in the soil gas samples, with maximum concentrations of 3,100 micrograms per cubic meter ($\mu g/m^3$) and 3,200 $\mu g/m^3$ for n-propylbenzene and cyclohexane, respectively. BTEX were reported at a maximum concentration of 130, 390, 54, and 250 $\mu g/m^3$, respectively. Six PAHs were detected in two samples at an estimated maximum concentration of 3.8 J $\mu g/m^3$ (naphthalene) at location UST1-07.

1,1-Difluoroethane, a tracer gas used during sampling to verify the integrity of the soil gas probe seal, was tentatively identified in one of the six samples at an estimated concentration of 1,800 NJ $\mu g/m^3$. The soil gas probe seal is considered intact as long

as the presence of the tracer gas is below 10%, i.e., 100,000 parts per million in volume or 270,143,000 µg/m^3 (NYSDOH 2006b).

As stated in **Section 4.1**, two ambient air samples were collected from Refueling Pit 3. The analytical results from these two samples serve as the reference soil gas samples collected in the Study Area. The following VOCs exceeded the reference criteria in all samples in which these compounds were detected: 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, 1,3-butadiene, 2-butanone, 2-propanol, acetone, benzene, chloroform, cyclohexane, ethanol, ethylbenzene, hexane, isopropylbenzene, n-heptane, n-propylbenzene, styrene, and tetrachloroethene. Benzene was the only chemical that exceeded the comparison criteria. The maximum detected value of 130 µg/m^3 at location UST1-08 exceeded the comparison criteria value of 62 µg/m^3.

of the detected maximum concentrations 32 of 40 were located in borings UST1-07 and UST1-08. As shown on **Figure 4-3**, UST1-07 and UST1-08 were advanced in the area upgradient and proximal to the two USTs that were closed-in-place.

4.3.2.3 Groundwater

Groundwater samples were analyzed for TPH, petroleum-related VOCs, PAHs, and metals. **Figure 4-4** shows the groundwater concentrations of selected constituents at UST Site No. 1. Measurable LNAPL was detected in well MW-06, and a sheen was observed on purged groundwater from well MW-09. TPH-D was reported in five of the seven groundwater samples with a maximum concentration of 610 µg/L in well MW-06 (see **Table 4-3c**). TPH-G was reported in two of the seven groundwater samples with a maximum concentration of 540 µg/L in well MW-06. As shown in **Table 4-3c**, VOCs were reported in three of seven groundwater samples, with a maximum concentration of 1.1 µg/L (n-propylbenzene) in monitoring well MW-06. PAHs were reported in six of the seven groundwater samples with a maximum concentration of 2.6 µg/L (fluorene) in monitoring well MW-06. Eleven of the 18 metals analyzed were reported in seven of the groundwater samples.

As stated in **Section 4.1**, one groundwater reference sample was collected in the Study Area. As shown in **Table 4-3c**, all detected TPH-D and TPH-G concentrations were greater than the reference criteria. TPH-G and TPH-D were detected above the DU-specific TPH RBCs used as comparison criteria in the two samples (MW-06 and UST1-01) in which TPH-G and TPH-D were detected. Of the three VOCs detected, only one chemical, n-propylbenzene, was detected above the reference criteria. VOC concentrations did not exceed comparison criteria. The following five PAHs exceeded the reference value in all samples in which these compounds were detected: acenaphthylene, anthracene, dibenzofuran, fluorene, and pyrene. These five PAHs were detected below comparison criteria. The calculated cPAHs TEQ exceeded the comparison criteria in the one sample (MW-09) in which they were detected. Two inorganic constituents (iron and manganese) were detected at concentrations above reference criteria in all samples in which they were detected. Both of these inorganics exceeded comparison criteria. Arsenic was detected at concentrations ranging from 0.545 J µg/L to 6.65 µg/L, which exceeded comparison criterion in all groundwater

samples. Manganese exceeded comparison criterion in four samples (UST1-04, MW-01, MW-06, and MW-09), with concentrations ranging from 919 to 1,460 µg/L.

Most of the detected maximum concentrations were located in monitoring well MW-06 and UST1-01. As shown on **Figure 4-4**, MW-06 and UST1-01 are located north and northeast of the former location of UST 13-1. Historically, MW-06 has had visible free product; free product was observed during this RI.

4.3.2.4 Near-Shore Surface Water

Near-shore surface water samples were analyzed for TPH, VOCs, PAHs, pesticides, PCBs, and metals. **Figure 4-4** shows the near-shore surface water concentrations of selected constituents at UST Site No. 1. As shown on **Table 4-3d**, eight PAHs were reported in both near-shore surface water samples, with a maximum concentration of 0.028 µg/L (phenanthrene) at location UST1-14. Five of the 18 inorganic constituents analyzed for were detected in both surface water samples.

As shown in **Table 4-3d**, the following PAHs exceeded the reference criteria in all samples in which these compounds were detected: 1-methylnaphthalene, 2,3,5-trimethylnaphthalene, 2,6-dimethylnaphthalene, 2-methylnaphthalene, acenaphthene, acenaphthylene, cPAHs, dibenzofuran, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene. All 13 PAHs were reported at concentrations below comparison criteria at both sample locations (see **Table 4-3d**). Two inorganic constituents (barium and nickel) were detected at concentrations above reference or background criteria, but the detections did not exceed comparison criteria. Arsenic was detected below background criteria, but exceeded comparison criteria. Arsenic was detected at estimated concentrations of 0.931 J µg/L and 0.939 J µg/L; the comparison criterion value is 0.018 µg/L.

4.3.2.5 Near-Shore Surface Sediment

Near-shore surface sediment samples were analyzed for TPH, VOCs, SVOCs, pesticides, PCBs, and metals. **Figure 4-2** shows the near-shore surface sediment concentrations of selected constituents at UST Site No. 1. As shown on **Table 4-3e**, TPH-D and TPH-O were reported in both of the near-shore sediment samples, with estimated maximum concentrations of 36 J mg/kg and 200 J mg/kg, respectively, at sample location UST1-13. Eight SVOCs (specifically PAHs) were reported in both of the sediment samples, with a maximum concentration of 0.088 mg/kg (fluoranthene) at location UST1-13. Total DDT was reported at location UST1-13 at a concentration of 0.0047 mg/kg. The following 13 inorganic constituents were reported in both sediment samples: antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, nickel, silver, vanadium, and zinc.

As shown on **Table 4-3e,** TPH-D, and TPH-O concentrations did not exceed the DU-specific TPH RBCs; however, the maximum concentration of TPH-D and TPH-O exceeded the reference value. The total DDT concentration at location UST1-13 was reported at a concentration (0.0047 mg/kg) above the comparison criteria concentration of 0.00033 mg/kg. The following SVOCs exceeded the reference criteria

in all samples in which these compounds were detected: acenaphthene, acenaphthylene, bis(2-ethylhexyl)phthalate, fluorene, and naphthalene. Fifteen of the 16 SVOCs were reported at concentrations below comparison criteria. cPAH TEQ exceeded comparison criteria at sample location UST1-13. Six inorganic constituents (arsenic, chromium, lead, selenium, vanadium, and zinc) were detected at concentrations above reference or background criteria in both samples. Mercury was detected at a concentration of 0.123 mg/kg in sample UST1-13. This concentration exceeded the comparison criterion value of 0.07 mg/kg.

All but three of the 34 chemical detections and maximum concentrations were reported at location UST1-13 (See Table 4-3e). As shown on **Figure 4-2**, UST1-13 is immediately downgradient of the former tank cavity. Location UST1-13 is the closest sampling point to the area where observations have been made of stormwater and groundwater drainage from the concrete bulkhead and observations of a surface sheen were made near the shore (see **Section 1.4.3.2**). The area of these samples receives aerial dispersions and stormwater discharges associated with the current industrial use of the facility. In addition, near shore sediment could receive petroleum and PAH released from the fueling of the nearby ship currently used for training at the Job Corp Center.

4.3.3 Refueling Pit 3

This section summarizes the analytical results of chemicals detected in subsurface soil, soil gas, groundwater, near-shore surface water, and near-shore surface sediment at the Refueling Pit 3 DU.

4.3.3.1 Soil

Subsurface soil samples were analyzed for TPH, VOCs, PAHs, and lead. **Figure 4-5** shows the soil concentrations of selected constituents at Refueling Pit 3. As shown in **Table 4-4a**, TPH-O was reported in all four soil samples, at a maximum concentration of 150 mg/kg. TPH-D was reported in three of the four soil samples, with a maximum concentration of 34 mg/kg at location RFP3-03. TPH-G was reported in one soil sample at a concentration of 28 mg/kg at location RFP3-04. VOCs were not reported in any of the soil samples. Nine PAHs were reported in four samples, with a maximum concentration of 0.6243 mg/kg (cPAHs) at location RFP03-03. The only inorganic chemical analyzed for in soil was lead. Lead was reported in all four soil samples, with a maximum concentration of 20.4 mg/kg at location RFP3-04.

All of the nine PAH and three TPH maximum concentrations were detected below comparison criteria; background criteria do not exist for these chemicals in soil (see **Table 4-4a**). The maximum detected value of lead (20.4 mg/kg) exceeded the ODEQ background concentration of 17 mg/kg, but did not exceed the comparison criterion value of 800 mg/kg. The concentrations of TPH-G, TPH-D, and TPH-O detected did not exceed the DU-specific TPH RBCs.

As shown in **Table 4-4a** and on **Figure 4-5**, the eight of 13 maximum detections were located in the soil sample collected from location RFP3-02. Boring RFP3-02 was advanced downgradient of Refueling Pit 3.

4.3.3.2 Soil Gas

Soil gas and ambient air samples were analyzed for VOCs. **Figure 4-6** shows the soil gas concentrations of selected constituents at Refueling Pit 3. As shown on **Table 4-4b**, 16 VOCs were reported in the soil gas samples, with an estimated maximum concentration of 100,000 J µg/m^3 reported for isopropylbenzene at sample location RFP3-16 when excluding the tracer gas (1,1-difluoroethane) concentration. BTEX were reported at a maximum concentration of 74, 1,500, 77, and 620 µg/m^3, respectively.

1,1-Difluoroethane, a tracer gas used during sampling to verify the integrity of the soil gas probe seal, was identified in four of the six samples at a maximum concentration of 1,600,000 µg/m^3. The soil gas probe seal is considered intact as long as the presence of the tracer gas is below 10%, i.e., 100,000 parts per million in volume or 270,143,000 µg/m^3 (NYSDOH 2006).

The two ambient air samples collected from Refueling Pit 3 provide reference criteria for soil gas samples collected in the Study Area. The following VOCs exceeded the reference criteria in all samples in which these compounds were detected: 1,1-difluoroethane, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, 2-butanone, 2-propanol, 4-ethyltoluene, acetone, benzene, carbon disulfide, ethylbenzene, isopropylbenzene, n-heptane, n-propylbenzene, o-xylene, toluene, and total xylenes. Detected chemicals did not exceed comparison criteria. 2-Propanol and 4-ethyltoluene do not have relevant comparison criteria and are shown on **Figure 4-6**.

Most of the detected maximum concentrations were located at sample location RFP3-13. As shown on **Figure 4-6**, RFP3-13 is located north of Refueling Pit 3 and south of the southeast corner of Hangar 1.

4.3.3.3 Groundwater

Groundwater was analyzed for TPH, VOCs, PAHs, and inorganic constituents. **Figure 4-7** shows the groundwater concentrations of selected constituents at Refueling Pit 3. LNAPL was not identified in any of the existing monitoring wells or in the temporary borings. As shown on **Table 4-4c**, TPH-G was reported in one groundwater sample, MW-04, at an estimated concentration of 3,000 J µg/L. Five VOCs were reported in five of nine groundwater samples, with a maximum concentration of 640 µg/L (isopropylbenzene) at location MW-04. Five PAHs were reported in three of the nine groundwater samples, with an estimated maximum concentration of 0.027 J µg/L (phenanthrene) at location MW-05. Thirteen of the 18 metals analyzed were reported in one or more of the nine groundwater samples analyzed.

As shown in **Table 4-4c**, TPH-G was detected at a concentration greater than the reference criterion at sample location MW-04. Of the five VOCs detected, three chemicals, ethylbenzene, isopropylbenzene, and n-propylbenzene were detected above the reference criteria. One VOC, trichloroethene, was detected in well MW-03 at a concentration of 1.8 µg/L, which exceeds the comparison criterion value of 0.029 µg/L. Naphthalene was detected in well MW-03 at a concentration of 0.022 µg/L and phenanthrene was detected in well MW-05 at an estimated concentration of 0.027 J µg/L. Both of these concentrations exceed the reference criteria for these compounds, but are below the comparison criteria. Three inorganic constituents (arsenic, barium, and calcium) were detected at concentrations above reference criteria in all samples in which they were detected. The only inorganic chemical that exceeded the comparison criterion (0.038 µg/L), arsenic, was detected at concentrations ranging from 0.792 J to 9.49 µg/L in eight of nine groundwater samples.

Table 4-4c shows that 11 of 24 maximum concentrations were located in monitoring wells MW-03 and MW-04. As shown on **Figure 4-7**, MW-03 is located upgradient of Refueling Pit 3. Detections of chlorinated VOCs (TCE and cis-1,2-DCE) in this monitoring well indicate a source area upgradient of Refueling Pit 3 possibly related to the industrial shop facility at the Job Corp Training Center. MW-04 is located within limits of the former refueling pit excavation.

4.3.3.4 Near-Shore Surface Water

Near-shore surface water samples were analyzed for TPH, VOCs, SVOCs, pesticides, PCBs, and metals. **Figure 4-7** shows the near-shore surface water concentrations of selected constituents at Refueling Pit 3. As shown in **Table 4-4d**, six SVOCs were reported in the near-shore surface water samples, with a maximum concentration of 0.0013 µg/L (phenanthrene) at location RFP3-23. Five inorganic constituents were detected in both surface water samples with a maximum concentration of 27.8 µg/L (barium) at location RFP3-22. Gamma-hexachlorocyclohexane (BHC), or Lindane, was the only pesticide detected in surface water; the maximum concentration (0.0013 µg/L) was detected at location RFP3-22.

As shown on **Table 4-4d**, the following PAHs exceeded the reference criteria in all samples in which these compounds were detected: 2,6-dimethylnaphthalene, 2-methylnaphthalene, dibenzofuran, and fluorene. All six SVOCs were reported at concentrations below comparison criteria at both sample locations. Two inorganic constituents (barium and nickel) were detected at concentrations above reference criteria, but the detections did not exceed comparison criteria. Arsenic was detected above the reference value, but below the background criterion. The estimated concentrations of arsenic (0.994 J and 0.997 J µg/L) exceed the comparison criterion value of 0.018 µg/L.

4.3.3.5 Near-Shore Surface Sediment

Near-shore surface sediment samples were analyzed for TPH, VOCs, SVOCs (including PAHs), pesticides, PCBs, and metals. **Figure 4-5** shows the near-shore surface sediment concentrations of selected constituents at Refueling Pit 3. As shown

in **Table 4-4e**, TPH-D was reported in both of the near-shore sediment samples, with a maximum concentration of 52 J mg/kg at location RFP3-21. TPH-O was reported in both samples, with an estimated maximum concentration of 410 J mg/kg at location RFP3-20. Five SVOCs (benzoic acid, bis-(2-ethylhexyl)phthalate, carbazole, dibenzofuran, and phenol) were reported in both samples, with an estimated maximum concentration of 0.14 J mg/kg (benzoic acid) at location RFP3-20. Twelve PAHs were reported in both sediment samples, with a maximum concentration of 0.24 mg/kg (fluoranthene) at location RFP3-21. Pesticides were reported in both sediment samples, with a maximum concentration of 0.0085 mg/kg (total DDT) at location RFP3-21. Total PCBs were reported in both sediment samples at concentrations ranging from 0.046 to 0.062 mg/kg. Thirteen inorganic constituents were reported in both sediment samples, with a maximum concentration of 289 mg/kg (manganese) at location RFP3-21.

As shown in **Table 4-4e,** TPH-D, and TPH-O concentrations did exceed their respective reference values, but did not exceed the DU-specific TPH RBCs. The following SVOCs and PAHs exceeded the reference criteria in all samples in which these compounds were detected: 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, benzo(e)pyrene, benzo(g,h,i)perylene, bis(2-ethylhexyl)phthalate, cPAHs, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene. With the exception of cPAHs, all SVOCs and PAHs were reported at concentrations below comparison criteria. cPAHs exceeded comparison criteria at both sediment sample locations. The total DDT concentration at both RFP3-20 and RFP3-21 exceeded the comparison criterion concentration of 0.00033 mg/kg by an order of magnitude. Total PCB concentrations in both samples exceeded the comparison criterion. The following metals exceeded the reference criteria in both sediment samples collected at Refueling Pit 3: antimony, cadmium, chromium, copper, lead, mercury, nickel, silver, vanadium, and zinc. Mercury was the only metal that exceeded the comparison criterion.

Most chemical detections and maximum concentrations were reported at location RFP3-21. As shown on **Figure 4-5**, RFP3-21 is immediately downgradient of the former refueling pit. Sample location RFP3-20 is downgradient from RFP3-21. Both sample locations are proximal to storm drain outfalls. The area of these samples receives aerial dispersion and stormwater discharges related to the current industrial use of the facility. In addition, near shore sediment could receive petroleum and PAH released from the fueling of the ship currently used for training at the Job Corp Center.

4.3.4 UST Site No. 4

This section summarizes the analytical results of chemicals detected in surface and subsurface soil present at the UST Site No. 4 DU.

4.3.4.1 Soil

Soil samples were analyzed for TPH, VOCs, PAHs, and lead. Lead was the only targeted inorganic analyte, however, one sample, UST4-01, was analyzed for the entire suite of inorganic constituents. These inorganic constituents will not be evaluated in the risk assessment included in **Section 6**. **Figure 4-8** shows the soil concentrations of selected constituents at UST Site No. 4. As shown in **Table 4-5**, TPH-D was reported in 6 of the 12 soil samples, with a maximum concentration of 13 mg/kg. TPH-O was reported in 9 of the 12 soil samples, with a maximum concentration of 120 mg/kg. TPH-G was reported in 7 of the 12 soil samples, with a maximum concentration of 75 mg/kg. All maximum TPH concentrations were reported at sample location UST4-04 (see **Figure 4-8**). Two VOCs, benzene and toluene, were reported at two separate locations (UST4-02 and UST4-04, respectively) at concentrations of 0.39 mg/kg and 0.0083 J mg/kg, respectively. Ten PAHs were reported in 9 of the 12 soil samples, with a maximum concentration of 0.022 mg/kg (pyrene) at sample location UST4-05. The only inorganic chemical analyzed for in soil was lead. Lead was reported in all 12 soil samples, with a maximum concentration of 13.5 mg/kg at location UST4-01. The analytical results for arsenic, barium, cadmium, chromium, and selenium at UST4-01 are presented in **Table 4-5** for informational purposes only.

The concentrations of TPH-G, TPH-D, and TPH-O detected did not exceed the DU-specific TPH RBCs. Benzene and toluene were detected in UST Site No. 4 soil samples; however, the maximum concentrations of these VOCs were below their respective comparison criteria. All of the 10 PAH maximum concentrations were detected below comparison criteria with the exception of cPAHs; background criteria do not exist for PAHs (see **Table 4-5**). cPAHs TEQ exceeded the comparison criteria in the all five samples in which cPAHs were detected. Lead was detected in all 12 samples, but concentrations were below both the background value and the comparison criterion.

The majority of maximum detections were located in the soil sample collected from locations UST4-01 and UST4-04. As shown on **Figure 4-8**, UST4-01 was advanced within the UST removal excavation limits at the approximate location of UST Tank 2. UST4-04 was advanced southwest of the UST removal excavation limit.

4.3.5 Incinerator Building

This section summarizes the analytical results of chemicals detected in surface soil present at the Incinerator Building DU. USACE collected surface soil samples from this DU in 2007.

4.3.5.1 Soil

Surface soil IS replicate samples were analyzed for SVOCs (including PAHs), PCBs, dioxins/furans, and inorganic constituents. As shown on **Table 4-6**, 15 SVOCs, total PCBs, dioxins/furans, and 23 inorganic chemicals were detected in surface soils collected at the Incinerator Building in 2007. PAHs were reported in the five soil

replicates with a maximum concentration of 0.087 mg/kg (cPAHs). Total PCBs were reported in all five replicates at concentrations ranging from 0.014 to 0.017 mg/kg. Dioxins/furans (reported as TEQ) was reported in five replicates at concentrations ranging from 5.627×10^{-6} to 1.751×10^{-5} mg/kg. Twenty-two inorganic constituents were detected in all five replicates; selenium was detected in four of the five replicates.

Of the 23 inorganic constituents detected, calcium, magnesium, sodium, and potassium do not warrant further evaluation because they are nontoxic, essential nutrients, or electrolytes. Of the 11 inorganic chemicals for which background data are available (antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc), the concentrations of copper, lead, mercury, and zinc exceed background levels. None of the inorganic chemical concentrations exceeded their respective comparison criteria. Carcinogenic PAHs did not exceed comparison criteria in any of the five replicates. The detected concentrations of dioxins/furans were above the comparison criteria, with the maximum detected concentration on the same order as the criterion. Total PCBs concentrations were less than the comparison criteria.

4.3.6 Fire Training Area

This section summarizes the analytical results of chemicals detected in surface and subsurface soil, soil gas, groundwater, near-shore surface water, and near-shore surface sediment present at the Fire Training Area DU.

4.3.6.1 Soil

Fifteen soil samples were analyzed for TPH, VOCs, PAHs, and inorganic constituents. Select soil samples were analyzed for dioxins/furans, pesticides, and PCBs. **Figure 4-9** shows the soil concentrations of selected constituents at the Fire Training Area. As shown in **Table 4-7a**, TPH-D and TPH-O were reported in 6 of the 15 soil samples, with maximum concentrations of 22,000 mg/kg and 3,200 mg/kg, respectively, at location FTA-15. TPH-G was reported in 2 of the 14 soil samples, with a maximum concentration of 260 mg/kg at location FTA-15. VOCs were reported in 2 of the 15 soil samples, with an estimated maximum concentration of 10 J mg/kg (1,2,4-trimethylbenzene) at location FTA-15. Eleven PAHs were reported in 5 of the 15 soil samples, with an estimated maximum concentration of 15 J mg/kg (phenanthrene) at location FTA-15. Dioxins/furans (reported as 2,3,7,8-TCDD TEQ) were reported in all of the three soil samples for which the analysis was performed, at a maximum concentration of 1.537×10^{-6} mg/kg at location FTA-15. Three pesticides were reported in one of the three samples for which the analysis were performed. Heptachlor and methoxychlor were detected at estimated concentrations of 0.0043 J mg/kg and 0.0039 J mg/kg, respectively, in sample FTA-15. Total DDT was reported in the soil sample collected from FTA-15 at a concentration of 0.0038 mg/kg. Seven of the 18 inorganic constituents analyzed were reported in 15 soil samples.

As shown on **Table 4-7a**, the TPH-D concentration in soil at location FTA-15 exceeded the DU-specific TPH RBC, but was within 10% of the criterion. The concentrations of

two inorganic constituents, cadmium and lead, were above their background values in sample FTA-06, but did not exceed the comparison criteria.

Most maximum detections were located in the soil sample collected from location FTA-15. As shown on **Figure 4-9**, FTA-15 is south of monitoring well MW-19. Historically, MW-19 has had visible free product; free product was observed during this RI.

4.3.6.2 Soil Gas

Seven soil gas samples were analyzed for VOCs. **Figure 4-10** shows the soil gas concentrations of selected constituents at the Fire Training Area. As shown on **Table 4.7b**, 39 VOCs were reported in soil gas samples, with a maximum concentration of 270 µg/m^3 (toluene) when excluding the tracer gas (1,1-difluoroethane) concentration. Chlorinated VOCs were reported in soil gas samples, with a maximum concentration of 83 µg/m^3 for PCE, 0.54 µg/m^3 for TCE, and 0.058 J µg/m^3 for vinyl chloride. BTEX were reported at maximum concentrations of 49, 270, 46, and 170 µg/m^3, respectively.

1,1-Difluoroethane, the tracer gas used during sampling to verify the integrity of the soil gas probe seal, was reported in three of the seven samples at a maximum concentration of 11,000 µg/m^3. The soil gas probe seal is considered intact as long as the presence of the tracer gas is below 10%, i.e., 100,000 parts per million in volume or 270,143,000 µg/m^3 (NYSDOH 2006b).

Two ambient air samples were collected from Refueling Pit 3 and provide reference criteria for soil gas samples collected in the Study Area. The following VOCs exceeded their respective reference values in all samples in which these compounds were detected: 1,1,1-trichloroethane, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, 1,3-butadiene, 2-butanone, 2-hexanone, 4-ethyltoluene, 4-methyl-2-pentanone, acetone, benzene, bromodichloromethane, carbon disulfide, chloroform, cis-1,2-DCE, cyclohexane, ethylbenzene, hexane, methylene chloride, n-heptane, n-propylbenzene, o-xylene, PCE, toluene, trans-1,2-DCE, TCE, and total xylenes. Chloroform was detected above its comparison criterion in three soil gas samples (FTA-02G, FTA-03G, and FTA-06G). 2-Hexanone, 2-propanol, 4-ethyltoluene, and ethanol do not have relevant comparison criteria. These four chemicals will be evaluated in **Section 6**.

Most of the detected maximum concentrations were at location FTA-03G. As shown on **Figure 4-10**, FTA-03G was advanced within the suspected source area of the vinyl chloride groundwater plume.

4.3.6.3 Groundwater

Seventeen groundwater samples were analyzed for TPH, VOCs, PAHs, and inorganic constituents. Select samples were analyzed for dioxins/furans, pesticides, and PCBs. **Figure 4-11** shows the groundwater concentrations of selected constituents at the Fire Training Area. As shown in **Table 4.7c**, TPH-D was reported in 5 of the 17 groundwater samples, with a maximum estimated concentration of 1,100 J µg/L at location FTA-09. TPH-G was reported in 2 of the 17 groundwater samples, with a

maximum concentration of 710 µg/L at location FTA-09. Ten VOCs were reported in 12 of the 17 groundwater samples, with a maximum concentration of 27 µg/L (vinyl chloride). Nine PAHs were reported in 7 of the 17 groundwater samples, with a maximum concentration of 3.1 µg/L (fluorene) at location FTA-09. Dioxins/furans (shown as TEQ) were reported in two of the three samples for which the analysis was performed, with a maximum concentration of 4.1×10^{-6} µg/L at location FTA-14. Total DDT was reported in one of the five samples for which the analysis was performed, with a concentration of 5.4×10^{-4} µg/L at location FTA-09. Thirteen of the 17 metals analyzed were detected in 17 groundwater samples analyzed.

As shown in **Table 4-7c**, TPH-D was detected in five samples at concentrations greater than the reference value and the DU-specific TPH RBC. TPH-G was detected in two samples at concentrations greater than the reference value and the DU-specific TPH RBC. Four VOCs, 1,3,5-trimethylbenzene, benzene, n-propylbenzene, and total xylenes, were detected above the reference values. Two VOCs, benzene and vinyl chloride, exceeded the screening criteria in all samples in which these chemicals were detected (see **Figure 4-11** for concentrations). Benzene exceedances were one order of magnitude greater than the comparison criterion value of 0.35 µg/L at two locations, FTA-01 and FTA-08. Vinyl chloride exceedances were one to three orders of magnitude greater than the comparison criterion value of 0.025 µg/L at 12 locations. 1,2,4-Trimethylbenzene exceeded the comparison criterion at FTA-09. Naphthalene (0.18 µg/L) exceeded the comparison criterion value of 0.14 µg/L in sample FTA-09. cPAHs TEQ exceeded the comparison criterion in sample FTA-09 by one order of magnitude. Dioxins/furans (reported as 2,3,7,8-TCDD TEQ) were reported in two of three groundwater samples for which the analysis was performed, at a maximum concentration of 4.114×10^{-6} mg/kg at location FTA-14. This 2,3,7,8-TCDD TEQ exceeded the applicable comparison criterion. Three inorganic constituents (barium, iron, and manganese) were detected at concentrations above their respective reference values in all samples in which they were detected. Arsenic was detected at concentrations ranging from 0.506 J µg/L to 15 µg/L; these concentrations exceeded comparison criterion (0.038 µg/L) in 16 of 17 groundwater samples. Iron concentrations in groundwater samples collected from FTA-05 and FTA-09 exceeded the comparison criterion value of 26,000 µg/L. Manganese concentrations exceeded the comparison criterion value of 880 µg/L in all analyzed samples.

Most of the detected maximum concentrations were located in monitoring well FTA-09. As shown on **Figure 4-11**, FTA-09 is located downgradient of MW-19. Historically, MW-19 has had visible free product; free product was observed during this RI.

4.3.6.4 Near-Shore Surface Water

Near-shore surface water samples were analyzed for TPH, VOCs, SVOCs, pesticides, PCBs, and inorganic constituents. **Figure 4-11** shows the near-shore surface water concentrations of selected constituents at the Fire Training Area. As shown in **Table 4-7d**, SVOCs were reported in both of the near-shore surface water samples, with a maximum concentration of 0.00097 µg/L (phenanthrene) at location FTA-27. One

pesticide, gamma-BHC, or Lindane, was reported in both surface water samples, with a maximum concentration of 0.0031 µg/L. Arsenic, barium, manganese, nickel, and zinc were reported in surface water samples.

As shown in **Table 4-7d**, phenanthrene exceeded the reference value at location FTA-27 (see **Figure 4-11**). Three inorganic constituents, barium, manganese, and nickel, were detected at concentrations above their respective reference values, but the detections did not exceed comparison criteria. Arsenic was detected above the reference value; additionally, the estimated concentrations of arsenic (0.951 and 0.998 J µg/L) exceed the comparison criterion value is 0.018 µg/L by an order of magnitude.

4.3.6.5 Near-Shore Surface Sediment

Near-shore surface sediment samples were analyzed for TPH-D, TPH-O, TPH-G, VOCs, SVOCs (including PAHs), pesticides, PCBs, and inorganic constituents. **Figure 4-9** shows the near-shore surface sediment concentrations of selected constituents at the Fire Training Area. As shown in **Table 4-7e**, TPH-D and TPH-O were reported in both of the near-shore sediment samples, with an estimated maximum concentration of 33 J mg/kg and 200 J mg/kg, respectively, at location FTA-26. Sixteen SVOCs were reported in the sediment samples, with a maximum concentration of 0.044 mg/kg (pyrene) at location FTA-26. Total DDT was the only pesticide reported in the sediment samples, at a maximum concentration of 0.00217 mg/kg. Total PCBs were reported in both sediment samples, with an estimated maximum concentration of 0.02 J mg/kg. Fourteen inorganic constituents were reported in both sediment samples at a maximum concentration of 359 mg/kg (manganese) at location FTA-26.

As shown in **Table 4-7e,** TPH-D, and TPH-O concentrations did exceed their respective reference values, but did not exceed the DU-specific TPH RBCs. The following SVOCs exceeded the reference criteria in all samples in which these compounds were detected: acenaphthene, acenaphthylene, anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, bis(2-ethylhexyl)phthalate, cPAHs, di-n-butylphthalate, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene. With the exception of cPAHs, all SVOCs were reported at concentrations below comparison criteria. cPAHs exceeded comparison criteria at both sediment sample locations, but detections were of the same order of magnitude as the criteria. The total DDT concentration at both FTA-26 and FTA-25 exceeded the reference and comparison criterion concentration of 0.00033 mg/kg by one order of magnitude. Total PCBs exceeded the comparison criterion in both samples by one order of magnitude at location FTA-25 and by two orders of magnitude in sample FTA-26. The following inorganic constituents exceeded their respective reference values in both sediment samples collected at the Fire Training Area: antimony, arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, vanadium, and zinc. Lead and mercury exceeded comparison criteria in both samples.

As shown in Table 4-7e, 27 of the 34 maximum concentrations were reported at location FTA-26. As shown on **Figure 4-9**, FTA-26 is located in Cathlamet Bay downgradient of DPT boring FTA-12 and north of Pier 1.

4.3.7 Aquatic - North of Pier 8

This section summarizes the analytical results of chemicals detected in surface water, surface sediment, and tissue present at the Aquatic - North of Pier 8 DU.

4.3.7.1 Surface Water

The surface water sample was analyzed for TPH, VOCs, SVOCs (including PAHs), pesticides, PCBs, and inorganic constituents. **Figure 4-14** shows the surface water concentrations of selected constituents at the aquatic DUs. One PAH (phenanthrene) was detected in surface water sample NTP-11 at a concentration of 0.00044 µg/L (see **Table 4-8a**). One pesticide, gamma-BHC, or Lindane, was reported at a concentration of 0.00086 µg/L. The following inorganic constituents were detected: arsenic, barium, manganese, and nickel.

As shown on **Table 4-8a**, three inorganic constituents (arsenic, barium, and nickel) were detected at concentrations above their respective reference values. One inorganic, arsenic, was detected at a concentration (1.04 µg/L) greater than the comparison criterion (0.018 µg/L).

4.3.7.2 Surface Sediment

Seven IS surface sediment replicate samples were analyzed for TPH-D and TPH-O, SVOCs (including PAHs), pesticides, PCBs, and inorganic constituents. Three discrete sediment samples were analyzed for VOCs and TPH-G. **Figures 4-12** and **4-13** show the sediment concentrations of selected constituents at the aquatic DUs. As seen on **Table 4-8b**, 15 SVOCs were detected in the seven replicate sediment samples with an estimated maximum concentration of 0.0466 mg/kg (cPAHs TEQ). Fourteen inorganic chemicals were detected in all seven replicates with a maximum concentration of 608 mg/kg (manganese). TPH-D and TPH-O were reported in all replicates, with estimated maximum concentrations of 16 J mg/kg and 74 J mg/kg, respectively. As shown on **Figure 4-13**, TPH-G was detected at one location, MIS-21, at an estimated concentration of 2.9 J mg/kg.

The following SVOCs were detected at concentrations greater than their respective reference values in all samples in which the chemical was detected: acenaphthene, benzo(a)pyrene, benzo(g,h,i)perylene, bis (2-ethylhexyl)phthalate, cPAHs, fluoranthene, fluorene, naphthalene, phenanthrene, phenol, and pyrene. cPAHs exceeded comparison criteria in six of the replicates, but detections were of the same order of magnitude as the criteria. The following inorganic constituents exceeded their respective reference or background values in all replicates analyzed: antimony, arsenic, cadmium, chromium, copper, lead, manganese, nickel, selenium, silver, vanadium, and zinc. Arsenic exceeded its comparison criterion in four of seven replicates and mercury exceeded its comparison criterion in three of seven replicates.

4.3.7.3 Tissue

All tissue samples collected from the North of Pier 8 DU were analyzed for PAHs, tributyltin, dioxins/furans, PCBs, and select bioaccumulative inorganic constituents and pesticides. As stated in **Section 4.1**, reference samples of the same species were collected from the Aquatic - Reference Area. The reference samples were analyzed for the same compounds required for the aquatic DUs. **Figure 4-15** shows the tissue sample concentrations of selected constituents at the aquatic DUs.

The following chemicals were detected in the clam tissue collected from the North of Pier 8 aquatic DU: fluoranthene, pyrene, total DDT, dioxins/furans, arsenic, chromium, lead, mercury, and selenium. Fluoranthene and pyrene were detected at concentrations of 0.021 mg/kg and 0.01 mg/kg, respectively. These detections exceeded their respective reference values, but did not exceed the comparison criteria. Total DDT were reported at a concentration of 0.0014 mg/kg; this concentration did not exceed the reference value or comparison criterion value. Dioxins/furans, reported as 2,3,7,8-TCDD TEQ, were reported at a concentration of 3.0×10^{-6} J mg/kg. A reference value for dioxins/furans is not available for clams; dioxin/furan congeners were not detected in clams from the Aquatic - Reference Area. The detected concentration in clams in the North of Pier 8 aquatic DU did not exceed the comparison criterion value of 6.4×10^{-6} mg/kg. Arsenic, chromium, lead, mercury, and selenium were reported at the following concentrations: 11.1 mg/kg, 2.46 mg/kg, 0.229 mg/kg, 0.062 mg/kg, and 2.7 mg/kg, respectively. Arsenic exceeded the reference value. Arsenic, lead, and selenium exceeded the comparison criteria; a comparison criterion value for chromium in tissue is not available. The arsenic and lead exceedances were of the same order of magnitude as the criteria; the selenium exceedance was two orders of magnitude greater than the comparison criterion value of 0.024 mg/kg.

The following chemicals were detected in the forage fish tissue collected from the North of Pier 8 aquatic DU: fluoranthene, pyrene, total DDT, alpha-chlordane, dieldrin, hexachlorobenzene, dioxins/furans, arsenic, chromium, lead, mercury, and selenium. Fluoranthene and pyrene were detected at estimated concentrations of 0.0021 J mg/kg and 0.0013 J mg/kg, respectively. These detections did not exceed their reference values or comparison criteria. Total DDT, alpha-chlordane, dieldrin, and hexachlorobenzene were reported at concentrations of 0.1058 mg/kg, 0.0014 mg/kg, 0.001 mg/kg, and 0.0073 mg/kg, respectively. All of these detections exceeded the reference values. Only total DDT exceeded the comparison criterion value of 0.054 mg/kg. Dioxins/furans, reported as 2,3,7,8-TCDD TEQ, were reported at a concentration of 5.9×10^{-7} mg/kg. The detected concentration in forage fish in the North of Pier 8 aquatic DU exceeded the reference value of 3.3×10^{-7} mg/kg, but did not exceed the comparison criterion. Arsenic, chromium, lead, mercury, and selenium were reported at the following concentrations: 2.09 mg/kg, 0.53 mg/kg, 0.604 mg/kg, 0.145 mg/kg, and 1.9 mg/kg, respectively. Arsenic, chromium, and lead exceeded their respective reference criteria. Lead, mercury, and selenium exceeded the comparison criteria; a comparison criterion value for chromium in tissue is not available. The lead exceedance was of the same order of magnitude as the

criterion; the mercury exceedance was one order of magnitude greater than the comparison criterion value of 0.088 mg/kg. Selenium exceeded the comparison criterion value of 0.024 mg/kg by two orders of magnitude.

The following chemicals were detected in the game fish fillets collected from the North of Pier 8 aquatic DU: total DDT, arsenic, chromium, lead, mercury, and selenium. Total DDT was reported at an estimated concentration of 0.00614 J mg/kg; this concentration did not exceed the reference value or the comparison criterion. Arsenic, chromium, lead, mercury, and selenium were reported at the following concentrations: 0.95 mg/kg, 0.66 mg/kg, 0.201 mg/kg, 0.268 mg/kg, and 2.2 mg/kg, respectively. All five of these inorganic constituents exceeded their reference criteria. Lead, mercury, and selenium exceeded the comparison criteria; a comparison criterion value for chromium in tissue is not available. The lead exceedance was of the same order of magnitude as the criterion; the mercury exceedance was one order of magnitude greater than the comparison criterion value of 0.088 mg/kg. Selenium exceeded the comparison criterion value of 0.024 mg/kg by two orders of magnitude.

4.3.8 Aquatic – Finger Piers

This section summarizes the analytical results of chemicals detected in surface water, surface sediment, and tissue present at the Aquatic - Finger Piers DU.

4.3.8.1 Surface Water

Two surface water samples were analyzed for TPH, VOCs, SVOCs (including PAHs), pesticides, PCBs, and inorganic constituents. **Figure 4-14** shows the surface water concentrations of selected constituents at the aquatic DUs. Two PAHs (fluoranthene and phenanthrene) were detected at location FP-22 at concentrations of 0.00045 µg/L and 0.00047 µg/L, respectively (see **Table 4-9a**). One pesticide, gamma-BHC, or Lindane, was reported in both samples with a maximum concentration of 0.0019 µg/L at location FP-21. The following inorganic constituents were detected in both samples: arsenic, barium, manganese, nickel, and zinc.

As shown on **Table 4-9a**, three inorganic constituents (arsenic, barium, and nickel) were detected at concentrations above the reference or background values at both locations. One inorganic, arsenic, was detected at a concentration (1.11 µg/L) at two orders of magnitude greater than the comparison criterion (0.018 µg/L).

4.3.8.2 Surface Sediment

SVOCs (including PAHs), pesticides, PCBs, TBT, and inorganic constituents. Three discrete sediment samples were analyzed for VOCs and TPH-G. **Figures 4-12** and **4-13** show the sediment concentrations of selected constituents at the aquatic DUs. As seen on **Table 4-9b**, one VOC, m,p-xylene, was detected at location MIS-53, at an estimated concentration of 0.00089 mg/kg. Eighteen SVOCs were detected in the seven replicate sediment samples with an estimated maximum concentration of 0.1100 J mg/kg (benzoic acid). TPH-O was reported in all replicates, with an estimated maximum concentration of 130 J mg/kg. TPH-D was reported in six of

seven replicates, with an estimated maximum concentration of 20 J mg/kg. As shown on **Figure 4-13**, TPH-G was detected at one location, MIS-51, at an estimated concentration of 2.5 J mg/kg. Total DDT and total PCBs were detected in all seven replicates at maximum concentrations of 0.0026 mg/kg and 0.0040 J mg/kg, respectively. Aldrin was detected in three of the seven replicates at an estimated maximum concentration of 0.0005 J mg/kg. Endosulfan sulfate and heptachlor were detected in two of the seven replicates at estimated maximum concentrations of 0.0004 J mg/kg and 0.0006 J mg/kg, respectively. Heptachlor epoxide was detected in five of seven replicates at an estimated maximum concentration of 0.0005 J mg/kg. TBT was reported in six of the seven replicates with a maximum concentration of 0.0037 mg/kg. Thirteen inorganic chemicals were detected in all seven replicates with a maximum concentration of 499 mg/kg (manganese).

As shown in **Table 4-9b**, TPH-D exceeded the reference criterion in all replicates in which it was detected, but the concentrations did not exceed the DU-specific TPH RBC. The following SVOCs were detected at concentrations greater than the reference values in all replicates in which they were detected: acenaphthene, acenaphthylene, anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, bis (2-ethylhexyl)phthalate, cPAHs, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene. Only cPAHs exceeded its respective comparison criterion. Total DDT exceeded the reference criterion and the applicable comparison criterion value of 0.00033 mg/kg in all replicates. Total PCBs were reported in all replicates at estimated concentrations greater than the reference and comparison criteria. Total PCBs were reported at estimated concentrations ranging from 0.0024 J to 0.0040 J mg/kg. The following inorganic constituents exceeded the reference values in all replicates analyzed from the Finger Piers aquatic DU: antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, vanadium, and zinc. Mercury concentrations in all seven replicated exceeded the comparison criterion.

4.3.8.3 Tissue

All tissue samples collected from the Finger Pier DU were analyzed for PCBs and select bioaccumulative inorganic constituents and pesticides. Tissue samples representing forage fish and fillets (see **Table 3-7**) were analyzed for SVOCs, TBT, and dioxins/furans; clam tissue volume was insufficient to complete these analyses (see **Section 3.6**). The species representing forage fish or whole body samples (Stickleback and Sculpin) and those for fillet (Sculpin) are described in **Section 3.6.1** and **Section 7.2.3.4**. **Figure 4-15** shows the tissue sample concentrations of selected constituents at the aquatic DUs.

As shown in **Table 4-9c**, the following chemicals were detected in the clam tissue collected from the Finger Piers aquatic DU: total DDT, dieldrin, arsenic, chromium, lead, mercury, and selenium. Total DDT was reported at a concentration of 0.0119 mg/kg; this concentration exceeded the reference value, but did not exceed the comparison criterion value of 0.054 mg/kg. Dieldrin was reported at an estimated concentration of 0.00099 J mg/kg. This detection exceeded the reference value, but did not exceed the comparison criterion value of 0.26 mg/kg. Arsenic, chromium,

lead, mercury, and selenium were reported at the following concentrations: 6.09 mg/kg, 2.52 mg/kg, 0.873 mg/kg, 0.055 mg/kg, and 3.4 mg/kg, respectively. Arsenic and selenium exceeded their respective reference values. Lead and selenium exceeded the comparison criteria; the comparison criterion value for chromium in tissue is not available. The lead exceedance was of the same order of magnitude as the criterion value; the selenium exceedance was two orders of magnitude greater than the comparison criterion value of 0.024 mg/kg.

The following chemicals were detected in the forage fish tissue collected from the Finger Piers aquatic DU: fluoranthene, pyrene, total DDT, dieldrin, dioxins/furans (as 2,3,7,8-TCDD TEQ), arsenic, chromium, lead, mercury, and selenium. As shown in **Table 4-9c,** fluoranthene and pyrene were detected at estimated concentrations of 0.0018 J mg/kg and 0.0012 J mg/kg, respectively. These detections did not exceed the reference value or the comparison criteria. Total DDT and dieldrin were reported at estimated concentrations of 0.0139 J mg/kg and 0.00061 J mg/kg, respectively. These detections did not exceed the reference value or their comparison criteria values. Dioxins/furans were reported at a concentration of 8.8×10^{-7} mg/kg. The detected concentration in forage fish in the North of Pier 8 aquatic DU exceeded the reference value of 3.3×10^{-7} mg/kg, but did not exceed the comparison criterion. Arsenic, chromium, lead, mercury, and selenium were reported at the following concentrations: 1.69 mg/kg, 0.26 J mg/kg, 0.325 mg/kg, 0.238 mg/kg, and 2.2 mg/kg, respectively. Arsenic and lead exceeded their respective reference values. Lead, mercury, and selenium exceeded the comparison criteria; a comparison criterion value for chromium in tissue is not available. The lead exceedance was of the same order of magnitude as the criterion; the mercury exceedance was one order of magnitude greater than the comparison criterion value of 0.088 mg/kg. Selenium exceeded the comparison criterion value of 0.024 mg/kg by two orders of magnitude.

As shown in **Table 4-9c,** the following chemicals were detected in the fish fillets collected from the Finger Piers aquatic DU: total DDT, dioxins/furans (as 2,3,7,8-TCDD TEQ), arsenic, chromium, lead, mercury, and selenium. Total DDT was reported at an estimated concentration of 0.00767 J mg/kg; this concentration exceeded the reference value of 0.00627 J mg/kg, but did not exceed the comparison criterion. Dioxins/furans were reported at a concentration of 2.3×10^{-6} mg/kg. A reference value for 2,3,7,8-TCDD TEQ is not available for fillets because dioxin/furan congeners were not detected in fish fillets from the Aquatic - Reference Area. The detected concentration for dioxins/furans in fillets in the Finger Piers aquatic DU did not exceed the comparison criterion value of 6.4×10^{-6} mg/kg. Arsenic, chromium, lead, mercury, and selenium were reported at the following concentrations: 1.31 mg/kg, 0.47 mg/kg, 0.101 mg/kg, 0.287 mg/kg, and 2 mg/kg, respectively. Arsenic and mercury exceeded the reference criteria. Mercury and selenium exceeded the comparison criteria; a comparison criterion value for chromium in tissue is not available. The mercury exceedance was one order of magnitude greater than the comparison criterion value of 0.088 mg/kg; selenium exceeded the comparison criterion value of 0.024 mg/kg by two orders of magnitude.

4.3.8.4 Comparison to Historical Sediment Data

An objective of the RI was to evaluate surficial sediments of the Finger Pier DU to identify if DoD related releases from the landfill are a possible current or continuing source of dioxins/furans to sediments. Data from the *Limited Remedial Investigation Phase II Landfill Site* report (URS Grenier Woodward Clyde 1999a) indicated that releases from the landfill could have occurred, and a removal action was completed in 2006 to address the possible release. Comparisons of RI data from the Aquatic-Reference Area and Aquatic-Near Landfill DU to historical data collected before the 2006 action are used to evaluate if the landfill is a potential current or continuing source of dioxins/furans to sediments. The details of that evaluation are presented in **Section 4.3.9.4** and are based upon the IS data. The conclusions that concentrations of chemicals in sediment vary insignificantly and are consistent between the Finger Piers, the Landfill DU, and Reference Area are presented in **Section 4.3.9.4** and **Section 6.5.6.2**. Based upon initial analytical results evaluated during the preparation of the risk technical memorandum in June 2009 (CDM 2009a and 2009b), the decision was made that archived sediment samples (Section 3 6.1) were not to be analyzed for supplemental analytes. To further support the sediment data evaluation based upon IS data, an evaluation of the IS design and use of data was prepared and is presented in the following paragraphs.

The IS design was intentionally focused on developing an estimate of mean concentrations of chemical constituents in surface sediments in the aquatic DUs to meet the project data objectives and decision logic. Selection of IS was made because a data set of discrete samples is likely to have a positively skewed distribution. Discrete sample results typically have higher variance than IS results. A low number of discrete samples will tend to underestimate the true (population) mean because the likelihood of sampling small areas with greater levels of contamination within a DU will be small. That is, the distributional heterogeneity within the DU will not have been adequately addressed.

The IS method improves reliability and defensibility of sampling data to estimate mean concentrations by reducing their variability compared to conventional discrete sampling strategies. The data distribution for IS replicate samples tends to be normally distributed because data are replicate estimates of the mean concentration. In contrast, discrete samples represent the underlying population of concentrations within an exposure unit, and tend to be more variable and positively skewed. In addition, levels of statistical confidence and decision uncertainty that would require a large number of discrete analyses are obtained with a few incremental samples.

If IS is applied to large DUs, the resulting data may obscure localized areas of higher concentrations. For the TPMS sample design, the DU area was carefully considered and the spatial extent of DUs was mapped before sampling. Such consideration was included in the definition of DUs for TPMS, and all parties agreed on DU definition before sampling as designed in the QAPP (CDM 2008a). In addition, the available historical data from discrete surface sediment samples from the LRI was considered, as discussed in the following paragraphs.

To validate conclusions based upon data from the IS for the Finger Piers DU a second set of surface sediment data were used. Specific surface sediment data and statistical evaluations are tabulated in **Appendix D2**. Comparison of the 1995 Finger Pier sediment data, reported in the Finger Pier Sediment LRI (Woodward-Clyde, 1998), and the 2008 IS from the Finger Piers DU, indicate that variability of several COPC in sediments is relatively low such that significant areas of higher concentrations are unlikely to exist (**Table 4-9d**). These comparisons indicate that sediment deposition from upstream of TPMS is the simplest explanation for existing surface sediment concentrations and homogeneity of these sediments at the Finger Piers. Sediments from upstream would be mixed thoroughly during transport and deposited fairly uniformly around the Finger Piers. Such sediments would be relatively homogeneous.

More specifically, the data set from 1995 contains data for many organic and inorganic chemicals that could be important for the risk assessments. Several possibly important inorganic chemicals were evaluated in the comparison to 2008 RI data. The inorganics evaluated, as shown on **Table 4-9d**, are arsenic, cadmium, chromium, copper, mercury, and zinc.

Similarly, two organic chemicals/chemical groups, were evaluated – benzo(a)pyrene (B(a)P), as a surrogate for carcinogenic PAH, and TPH-D – as possible chemical compounds related to past DoD activity in the Study Area. A third chemical, TBT was selected as an indicator of post-DoD era operations. TBT was not in use at the time the DoD used the upland areas and finger piers at the site. Dioxins/furans were not analyzed in 1995, and DDT/DDE/DDD data from this investigation were mostly non-detect and no useful comparison with 2008 RI data could be made.

Direct comparisons of means were made between the 1995 and 2008 data because sample quantity from 1995 (32) and subsample quantity for the IS for the Finger Piers DU (28) were similar, and because the samples/subsamples were collected from essentially the same areas in and around the finger piers (see **Figures 1-4** and **3-9**). These data sets should have about the same statistical power and should represent the same area of surface sediments.

Mean concentrations of inorganic COPCs in surface sediments and their standard errors did not change notably in a qualitative sense between 1995 and 2008 for what is currently defined as the Finger Piers DU (**Table 4-9d**). Variability for all constituents was relatively low in 1995. That is, ranges for all constituents were less than an order of magnitude, which is typical of ranges of background concentrations for inorganic constituents in many instances. Similar mean values in 2008 implies that variability was likely also low in 2008. This consistency and low variability over many years, and for many inorganic constituents, is consistent with the concept that sediment quality around the Finger Piers is dictated by sediments moving downstream rather than releases from upland sources. If upland areas were sources for one or a few constituents, one would expect high variability for a few constituents released from upland sources to surface sediments, and probably differences in mean concentrations

over many years as a result of differences in sampling locations and in source strength.

Similar numbers of samples/subsamples and similar coverage areas along with similar means, indicates that variability across the DU may have been about the same in both years. The 1995 data set did not identify locations or sample data with distinctly high concentrations, and, by inference, one would conclude that such locations were not represented in the IS. The IS data appear to have met their original intention of providing a robust estimate of means without missing important smaller areas with relatively high concentrations.

In further support, means for all but one inorganic constituent, mercury, were higher in 1995 data than in data from the 2008 IMS. The absolute difference in mean mercury concentrations (0.074 and 0.1 mg/kg for 1994 and 2008 data, respectively) is small and likely within the error of the estimates. Reasons for these decreases are not known, but available data seem clear in their suggestion that overall sediment quality is improving. Comparisons between 1995 and 2008 data sets provide no evidence for ongoing releases from the site in the area of the finger piers.

Finally, concentrations of three organic constituents have decreased since 1995, including concentrations of TBT, which was not used during the period of DoD operations. The observed drop in TPH-D since 1995 is particularly important, since UST Site No. 1 and Refueling Pit 3 could still be sources of diesel fuel releases. The data support the conclusion that neither site is a strong enough source to affect near-shore sediments.

The parallel reduction in concentrations of TBT, along with B(a)P and TPH-D likely reflects the general reduction in concentrations of many sediment constituents in the lower Columbia River over the last decade or so. The greater apparent reduction in TBT concentration compared to B(a)P and TPH-D is likely associated with the elimination of TBT from marine paints many years ago. Certainly, the results do not provide any indication of an ongoing release from DoD activity at the upland sources to near-shore surface sediments in the Finger Piers DU.

4.3.9 Aquatic – Near Landfill

This section summarizes the analytical results of chemicals detected in surface water, surface sediment, and tissue present at the Aquatic - Near Landfill DU.

4.3.9.1 Surface Water

One surface water sample was analyzed for TPH, VOCs, SVOCs (including PAHs), pesticides, PCBs, and inorganic constituents. **Figure 4-14** shows the surface water concentrations of selected constituents at the aquatic DUs. Two PAHs (fluoranthene and phenanthrene) were detected at location LF-11 at concentrations of 0.00047 µg/L and 0.00049 µg/L, respectively (see **Table 4-10a**). The following inorganic constituents were detected: arsenic, barium, manganese, and nickel.

As shown in **Table 4-10a**, three inorganic constituents (arsenic, barium, and nickel) were detected at concentrations above their reference values. One inorganic, arsenic, was detected at a concentration (1.02 µg/L) two orders of magnitude greater than the comparison criterion (0.018 µg/L).

4.3.9.2 Surface Sediment

Seven IS surface sediment replicate samples were analyzed for TPH-D and TPH-O, SVOCs (including PAHs), pesticides, PCBs, dioxins/furans, and inorganic constituents. Three discrete sediment samples were analyzed for VOCs and TPH-G. **Figures 4-12** and **4-13** show the sediment concentrations of selected constituents at the aquatic DUs. As seen in **Table 4-10b**, 17 SVOCs were detected in the seven replicate sediment samples, with an estimated maximum concentration of 0.56 J mg/kg (benzoic acid). TPH-D and TPH-O were reported in the seven replicates with estimated maximum concentrations of 23 J mg/kg and 140 J mg/kg, respectively. As shown on **Figure 4-13**, TPH-G was detected at one location, MIS-57, at an estimated concentration of 5.3 J mg/kg. Total DDT and total PCBs were detected in all seven replicates at maximum concentrations of 0.0022 mg/kg and 0.0043 J mg/kg, respectively. Heptachlor was detected in three of the seven replicates at an estimated maximum concentration of 0.0010 J mg/kg. Dioxins/furans, reported as 2,3,7,8-TCDD TEQ, were reported in all seven replicates, with a maximum concentration of 0.0000018 mg/kg. Thirteen inorganic chemicals were detected in all seven replicates, with a maximum concentration of 449 mg/kg (manganese).

As shown in **Table 4-10b**, TPH-D, TPH-O, and TPH-G exceeded the reference values in all replicates in which they were detected, but the concentrations did not exceed the DU-specific TPH RBCs. The following SVOCs were detected at concentrations greater than the reference values in all replicates in which these chemicals were detected: anthracene, benzo(g,h,i)perylene, bis (2-ethylhexyl)phthalate, and pyrene. With the exception of cPAHs, none of the detected SVOCs exceeded comparison criteria. cPAHs exceeded comparison criteria in five of the replicates, but detections were of the same magnitude as the criteria. As shown on **Table 4-10b**, the detected concentrations of dioxins/furans in two sediment replicates in the Near Landfill aquatic DU exceeded the reference value of 9.6×10^{-7} mg/kg. All seven replicate dioxins/furans concentrations exceeded the comparison criterion value of 9.1×10^{-9} mg/kg. Total DDT exceeded the reference value of 0.0011 mg/kg in five replicates and the applicable comparison criterion value of 0.00033 mg/kg. Total PCBs were reported in all replicates at estimated concentrations greater than the reference and comparison criteria. Total PCBs were reported at estimated concentrations ranging from 0.0035 to 0.0043 J mg/kg. The following inorganic constituents exceeded the reference values in all replicates: antimony, arsenic, cadmium, chromium, lead, mercury, nickel, silver, and zinc. With the exception of mercury, none of the sediment inorganic analytical results exceeded comparison criteria. Mercury exceeded the comparison criterion value of 0.07 mg/kg in four replicates; detections were of the same order of magnitude as the criterion.

4.3.9.3 Tissue

All tissue samples collected from this DU were analyzed for SVOCs, TBT, dioxins/furans, PCBs, and select bioaccumulative inorganic constituents and pesticides. **Figure 4-15** shows the tissue sample concentrations of selected constituents at the aquatic DUs.

As shown in **Table 4-10c**, the following chemicals were detected in the clam tissue collected from the Near Landfill aquatic DU: fluoranthene, pyrene, total DDT, dieldrin, dioxins/furans (as 2,3,7,8-TCDD TEQ), arsenic, chromium, lead, mercury, and selenium. Fluoranthene and pyrene were detected at concentrations of 0.021 mg/kg and 0.0076 mg/kg, respectively. These detections exceeded their reference values, but did not exceed the comparison criteria. Total DDT was reported at a concentration of 0.00114 mg/kg; this concentration did not exceed the reference value or the comparison criterion. Dieldrin was reported at a concentration of 0.00055 mg/kg. This detection did not exceed the reference value or the comparison criterion value. Arsenic, chromium, lead, mercury, and selenium were reported at the following concentrations: 6.13 mg/kg, 1.96 mg/kg, 0.911 mg/kg, 0.089 mg/kg, and 2.4 mg/kg, respectively. The arsenic and mercury concentrations exceeded their respective reference values. Lead, mercury, and selenium exceeded the comparison criteria; a comparison criterion value for chromium in tissue is not available. The lead and mercury exceedances were of the same order of magnitude as the criteria values; the selenium exceedance was two orders of magnitude greater than the comparison criterion value of 0.024 mg/kg.

The following chemicals were detected in the forage fish tissue collected from the Near Landfill aquatic DU: fluoranthene, pyrene, total DDT, alpha-chlordane, dieldrin, hexachlorobenzene, arsenic, chromium, lead, mercury, and selenium. As shown on **Table 4-10c,** fluoranthene was detected at a concentration of 0.008 mg/kg; pyrene was detected at an estimated concentration of 0.0039 J mg/kg. The detection of fluoranthene exceeded the reference value, but did not exceed the comparison criterion. Total DDT, alpha-chlordane, dieldrin, and hexachlorobenzene were reported at concentrations of 0.0214 mg/kg, 0.00088 mg/kg, 0.0011 mg/kg, and 0.0062 mg/kg, respectively. Dieldrin and hexachlorobenzene detections exceeded the reference values, while none of the reported concentrations exceeded the comparison criteria. Arsenic, chromium, lead, mercury, and selenium were reported at the following concentrations: 1.62 mg/kg, 0.43 mg/kg, 0.374 mg/kg, 0.37 mg/kg, and 2 mg/kg, respectively. Arsenic, lead, and mercury exceeded their respective reference values. Lead, mercury, and selenium exceeded the comparison criteria; a comparison criterion value for chromium in tissue is not available. The lead exceedance was of the same order of magnitude as the criterion; the mercury exceedance was one order of magnitude greater than the comparison criterion value of 0.088 mg/kg. Selenium exceeded the comparison criterion value of 0.024 mg/kg by two orders of magnitude.

As shown in **Table 4-10c**, the following chemicals were detected in the fish fillets collected from the Near Landfill aquatic DU: total DDT, dioxins/furans (as 2,3,7,8-TCDD TEQ), arsenic, chromium, lead, mercury, and selenium. Total DDT was

reported at an estimated concentration of 0.00489 J mg/kg; this concentration did not exceed the reference value or the comparison criterion. Dioxins/furans were reported at a concentration of 9.7 x 10^{-7} mg/kg. A reference value for dioxins/furans is not available for fillets, because dioxin/furan congeners were not detected in fish fillets from the Aquatic - Reference Area. The detected concentration in fillets in the Near Landfill aquatic DU did not exceed the comparison criterion value of 6.4 x 10^{-6}mg/kg. Arsenic, chromium, lead, mercury, and selenium were reported at the following concentrations: 0.8 mg/kg, 1.13 mg/kg, 0.124 mg/kg, 0.246 mg/kg, and 2.2 mg/kg, respectively. Chromium, mercury, and selenium exceeded their respective reference values. Lead, mercury, and selenium exceeded the comparison criteria; a comparison criterion value for chromium in tissue is not available. The lead exceedance was of the same order of magnitude as the criterion; the mercury exceedance was one order of magnitude greater than the comparison criterion value of 0.088 mg/kg. Selenium exceeded the comparison criterion value of 0.024 mg/kg by two orders of magnitude.

4.3.9.4 Comparison to Historical Landfill Sediment Data

An objective of the RI was to evaluate the surficial near shore sediments of the Landfill DU to determine if the DoD related release from the landfill are a possible current or continuing source of dioxins/furans to near-shore sediments. Data from the *Limited Remedial Investigation Phase II Landfill Site* report (URS Grenier Woodward Clyde 1999a) indicated that releases from the landfill could have occurred, and a removal action was completed in 2006 to address the possible release. Comparisons of RI data from the Aquatic-Reference Area and Aquatic-Near Landfill DU to historical data collected before the 2006 action are used to evaluate the success of the removal action. Conclusions of this comparison are used to identify whether or not the interim action at the landfill has successfully removed and contained landfill contaminants.

Data are available from near-shore surface sediment samples collected along perimeter of the landfill in 1997 (URS Greiner Woodward-Clyde 1999a). Concentrations of 2,3,7,8 TCDD ranged from 1.7x10^{-6} to 6.7x10^{-6} mg/kg, and 2,3,7,8-TCDD TEQ concentrations ranged from 1.7x10^{-5} to 1.0x10^{-4} mg/kg. In 1999, core sediment samples were collected from the landfill near-shore area at various depth intervals (URS Greiner Woodward-Clyde 2000a). Dioxins/furans were detected in all but one sample. Concentrations of 2,3,7,8-TCDD ranged from a 3.1x10^{-7} J to 1.76.x10^{-6} mg/kg, and 2,3,7,8-TCDD TEQ concentrations ranged from 1.4x10^{-7} to 1.9x10^{-4} mg/kg.

Starting in 2003, as part of the removal action for the landfill, soil and sediment were excavated from the eastern edge of the landfill. Other components of the landfill remedial action included capping, a barrier wall, and a free product recovery system to prevent migration of chemical compounds from the landfill to sediment (TN & Associates 2007). The recovery system with groundwater monitoring are ongoing actions in 2010.

The mean concentration of 2,3,7,8 TCDD found in surface sediment samples collected from the Near Landfill during the 2008 RI was 2.1E-7 mg/kg, and 2,3,7,8-TCDD TEQ mean concentrations ranged from 5.3E-8 to 1.8E-6 mg/kg in the seven analyses of the IS from the Aquatic-Near Landfill DU. These concentrations are less than historical values before the removal action. A similar mean concentration of TCDD TEQ was found in sediments from the Aquatic-Reference Area (9.6×10^{-7} mg/kg) (See **Table 6-43**). These data suggest that removal action completed in 2006 was successful and that concentrations of dioxins/furans in surface sediments do not reflect the higher concentrations found historically in sediment samples near the landfill. RI data are entirely consistent with the conclusion that TCDD TEQ in sediments near the landfill is typical for sediments elsewhere in Cathlamet Bay.

Additional analysis is provided in **Section 6.5.6.2**. In summary, **Figure 6-8** presents the dioxin/furan homolog profiles for the historical sediment samples collected in 1997 and 1999. Homolog profiles represent the distribution of total CDDs and total CDFs present in a sample (i.e., dioxin fingerprint). A homolog profile can be used to compare or distinguish differences in the types and amount of congeners present. Profiles of homolog in 1997 surface sediment and 1999 core sediment collected near the landfill, are similar when based on congener concentrations. Similar dioxin/furan homolog profiles based on RI data are found in sediments from the Near Landfill and from the Reference Area. **Figure 6-9** shows CDD-dominant homolog profiles for the sediment samples from the Near Landfill and the Reference Area. This finding further supports that dioxins/furans in surface sediment reflect typical ambient concentrations from the area, unrelated to past landfill activities.

4.3.10 Comparison of Petroleum Results to Ecological Criteria

Petroleum hydrocarbons are not designated as hazardous in CERCLA, but are considered hazardous by the RCRA standards within the State of Oregon Hazardous Substance Remedial Action Rules (OAR 340-122-0100 through 340-122-0115). Per ODEQ's, R*isk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites*, petroleum hydrocarbons are initially compared in this section to support evaluation in **Section 7** regarding whether these compounds could have ecological effects (ODEQ 2003). Because ODEQ has not adopted ecological screening values or toxicity values associated with this class of chemicals, an alternative approach is used. Washington State DOE has published screening levels for specific petroleum hydrocarbons. Therefore, the comparative evaluation uses these criteria, as "surrogate" screening level values (SLV), from the following two sources:

- Washington State Department of Ecology (Ecology) derived ecological screening levels for the protection of terrestrial plants and animals exposed to hazardous constituents in soil and are listed in WAC 173-340-7493 (Ecology 2001).

- Sediment Quality Standards/Screening Level 1 (SQS/SL1) values developed by Michelsen (2010) in the *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho.*

Comparison of detected concentrations of TPH-G, TPH-D, and TPH-O in surface soils and sediment, to its respective criteria for petroleum hydrocarbons are presented in **Tables 4-11a** and **4-11b**, respectively.

Four classes of petroleum hydrocarbons were detected in UST Site No. 4 soils. These are TPH-D, TPH-G, TPH-O, and C21-C34 aliphatics. The maximum detected concentrations of these four classes of petroleum compounds in UST Site No. 4 surface soils were 13, 75, 120, and 6.2 mg/kg, respectively. As shown in **Table 4-11a**, only TPH-O were detected at concentrations approaching (for TPH-D) or exceeding (for TPH-G) the comparison criteria.

Petroleum hydrocarbons were detected in surface soils in the AST Fuel Storage Area DU, with the highest concentrations measured as TPH-D and TPH-O. As shown in **Table 4-11a,** comparisons of detected concentrations to the soil comparison criteria indicate that maximum detected concentrations of TPH-D (2,400 mg/kg) and TPH-O (7,300 mg/kg) exceed the criteria. These exceedances will be discussed in **Section 7.7**.

Petroleum hydrocarbon concentrations detected in discrete near-shore samples and offshore surface sediment samples were compared to surrogate criteria. Maximum detected concentrations of TPH-G, TPH-D, and TPH-O from all the surface sediment sampling locations (UST Site 1, Refueling Pit 3, Fire Training Area, North of Pier 8, Finger Piers, and Near Landfill) were compared to surrogate criteria. The sediment data comparisons are in **Table 4-11b**. In all cases, the maximum detected concentrations were below the comparison criteria.

4.4 Summary of Analytical Results

The discussion and mapping of analytical results in **Sections 4.3** is based on those chemicals related to past DoD use of facilities within the Study Area and includes those chemicals with the potential to migrate, bioaccumulate, or have adverse effect to receptors in various media. For evaluations and discussions of fate and transport, these chemical constituents are refined based upon whether: (1) concentrations are greater than comparison criteria, (2) concentrations are greater than reference or background values, and (3) bioaccumulation potential is high. In addition, specific chemical groups are included in Section 5 if the constituent's concentration is greater than SQL in one or more media within a DU, and parent products or degradation by-products are present, such as the chlorinated ethenes. This refined selection of constituents is based upon the decision logic shown in **Figure 4-16**. These selected constituents are listed in Section 4.4 below by DU and matrix, and are the focus of the fate and transport discussion in **Section 5.**

AST Fuel Storage Area

- Lead in soil
- Arsenic in groundwater

UST Site No. 1

- Benzene in soil gas
- cPAHs, arsenic, manganese, TPH-D, and TPH-G in groundwater
- Arsenic in surface water
- cPAHs, total DDT, and mercury in surface sediment

Refueling Pit 3

- Trichloroethene and arsenic in groundwater
- Arsenic in surface water
- cPAHs, total DDT, total PCBs, and mercury in surface sediment

UST Site No. 4

- cPAHs and dioxins/furans in soil

Fire Training Area

- TPH-D in soil
- Chloroform and PCE in soil gas
- 1,2,4-Trimethylbenzene, benzene, vinyl chloride , cPAHs, naphthalene, dioxins/furans, arsenic, iron, manganese, TPH-D, and TPH-G in groundwater
- Arsenic in surface water
- cPAHs, total DDT, total PCBs, lead, and mercury in surface sediment

Aquatic - North of Pier 8

- Arsenic in surface water
- cPAHs, arsenic, and mercury in surface sediment
- Arsenic, lead and selenium in clam tissue
- Total DDT, lead, mercury, and selenium in forage fish
- Lead, mercury, and selenium in sculpin, as surrogates for game fish

Aquatic - Finger Piers

- Arsenic in surface water
- cPAHs, total DDT, total PCBs, and mercury in surface sediment

- Lead and selenium in clam tissue
- Lead, mercury, and selenium in forage fish
- Mercury and selenium in sculpin, as surrogates for game fish

Aquatic - Near Landfill

- Arsenic in surface water
- cPAHs, dioxins/furans, total2 DDT, total PCBs, and mercury in surface sediment
- Lead, mercury, and selenium in clam tissue
- Lead, mercury, and selenium in forage fish
- Lead, mercury, and selenium in sculpin, as surrogates for game fish

Table 4-1a
Soil Background Concentrations
Background and Reference Comparison Criteria
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	Concentration[1]	Unit
Antimony	4	mg/kg dw
Arsenic	7	mg/kg dw
Cadmium	1	mg/kg dw
Chromium	42	mg/kg dw
Copper	36	mg/kg dw
Lead	17	mg/kg dw
Mercury	0.07	mg/kg dw
Nickel	38	mg/kg dw
Silver	1	mg/kg dw
Selenium	2	mg/kg dw
Zinc	86	mg/kg dw

Notes:

mg/kg - milligram per kilogram
dw - dry weight
ODEQ - Oregon Department of Environmental Quality

(1) From Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

Table 4-1b
Soil Gas and Ambient Air
Reference Comparison Criteria
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	RFP3-18 (downgradient)	RFP3-19 (upgradient)	Unit
	Concentration		
Volatile Organic Compounds			
1,1,1-Trichloroethane	0.064 J	0.069 J	µg/m^3
1,1,2,2-Tetrachloroethane	0.22 U	0.22 U	µg/m^3
1,1,2-Trichloro-1,2,2-trifluoroethane	0.78 J	1.1 J	µg/m^3
1,1,2-Trichloroethane	0.18 U	0.18 U	µg/m^3
1,1-Dichloroethane	0.13 U	0.13 U	µg/m^3
1,1-Dichloroethene	0.065 U	0.064 U	µg/m^3
1,2,4-Trichlorobenzene	6.1 U	6 U	µg/m^3
1,2,4-Trimethylbenzene	0.25 J	0.58 J	µg/m^3
1,2-Dibromoethane	1.3 U	1.2 U	µg/m^3
1,2-Dichloro-1,1,2,2-tetrafluoroethane	1.1 U	1.1 U	µg/m^3
1,2-Dichlorobenzene	0.99 U	0.97 U	µg/m^3
1,2-Dichloroethane	0.048 J	0.052 J	µg/m^3
1,2-Dichloropropane	0.76 U	0.74 U	µg/m^3
1,3,5-Trimethylbenzene	0.81 U	0.14 J	µg/m^3
1,3-Butadiene	0.36 U	0.36 U	µg/m^3
1,3-Dichlorobenzene	0.99 U	0.97 U	µg/m^3
1,4-Dichlorobenzene	0.99 U	0.97 U	µg/m^3
1,4-Dioxane	0.59 U	0.58 U	µg/m^3
2-Butanone	1.4	0.54	µg/m^3
2-Hexanone	0.28 J	3.3 U	µg/m^3
2-Propanol	0.5 J	2 U	µg/m^3
4-Ethyltoluene	0.23 J	0.52 J	µg/m^3
4-Methyl-2-Pentanone	0.67 U	0.66 U	µg/m^3
Acetone	13	6.8 U	µg/m^3
Benzene	0.5 U	0.63	µg/m^3
Benzyl Chloride	0.85 U	0.83 U	µg/m^3
Bromodichloromethane	1.1 U	1.1 U	µg/m^3
Bromoform	1.7 U	1.7 U	µg/m^3
Bromomethane	0.5 U	0.62 U	µg/m^3
Carbon Disulfide	2.6 U	2.5 U	µg/m^3
Carbon tetrachloride	0.46 J	0.67 J	µg/m^3
Chlorobenzene	0.76 U	0.74 U	µg/m^3
Chloroethane	0.43 U	0.56	µg/m^3
Chloroform	0.8 U	0.79 U	µg/m^3
Chloromethane	1.5	1.6	µg/m^3
cis-1,2-Dichloroethene	0.13 U	0.13 U	µg/m^3
cis-1,3-Dichloropropene	0.74 U	0.73 U	µg/m^3
Cyclohexane	0.56 U	0.55 U	µg/m^3
Dibromochloromethane	1.4 U	1.4 U	µg/m^3

Table 4-1b (continued)
Soil Gas and Ambient Air
Reference Comparison Criteria
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	RFP3-18 (downgradient)	RFP3-19 (upgradient)	Unit
	Concentration		
Volatile Organic Compounds			
Dichlorodifluoromethane	2.9	2.8	µg/m^3
Difluoroethane	2.2 U	2.2 U	µg/m^3
Ethanol	2.2	1.7	µg/m^3
Ethylbenzene	0.23	0.41	µg/m^3
Hexachlorobutadiene	8.7 U	8.6 U	µg/m^3
Hexane	0.14 J	0.25 J	µg/m^3
Isopropylbenzene	0.81 U	0.79 U	µg/m^3
Methyl tert-Butyl Ether	0.59 U	0.58 U	µg/m^3
Methylene chloride	0.54 J	1.1 U	µg/m^3
n-Heptane	0.67 U	0.29 J	µg/m^3
n-Propylbenzene	0.81 U	0.17 J	µg/m^3
o-Xylene	0.15	0.27	µg/m^3
Styrene	0.7 U	0.68 U	µg/m^3
Tetrachloroethene	0.029 J	0.031 J	µg/m^3
Tetrahydrofuran	2.4 U	2.4 U	µg/m^3
Toluene	0.61	0.88	µg/m^3
Total Xylenes	0.59	1.1	µg/m^3
trans-1,2-Dichloroethene	0.65 U	0.64 U	µg/m^3
trans-1,3-Dichloropropene	0.74 U	0.73 U	µg/m^3
Trichloroethene	0.1 U	0.17 U	µg/m^3
Trichlorofluoromethane	2.7 J	2.8 J	µg/m^3
Vinyl Chloride	0.042 U	0.041 U	µg/m^3

Notes:

µg/m^3 - microgram per cubic meter
U - not detected at the reporting limit shown
J - estimated concentration

Table 4-1c
Groundwater
Reference Comparison Criteria
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	UST1-18[1]	
	Concentration	Unit
Anions		
Chloride	8750	µg/L
Nitrite - N	100 U	µg/L
Nitrate	95.2 J	µg/L
Sulfate	859	µg/L
Inorganics		
Aluminum	1000 U	µg/L
Antimony	1 U	µg/L
Arsenic	1 U	µg/L
Barium	31.9	µg/L
Beryllium	200 U	µg/L
Cadmium	2 U	µg/L
Calcium	39200	µg/L
Chromium	5 U	µg/L
Copper	2 U	µg/L
Iron	3060	µg/L
Lead	1 U	µg/L
Magnesium	20200	µg/L
Manganese	136	µg/L
Mercury	0.5 U	µg/L
Nickel	0.624 J	µg/L
Selenium	2 U	µg/L
Silver	1 U	µg/L
Thallium	1 U	µg/L
Zinc	10 U	µg/L
Volatile Organic Compounds		
Ethylbenzene	0.5 U	µg/L
N-Propylbenzene	0.5 U	µg/L
1,2-Dibromoethane	2 U	µg/L
1,2-Dichloroethane	0.5 U	µg/L
1,3,5-Trimethylbenzene	2 U	µg/L
Toluene	0.5 U	µg/L
Total Xylenes	1 U	µg/L
Benzene	0.5 U	µg/L
o-Xylene	0.5 U	µg/L
1,2,4-Trimethylbenzene	2 U	µg/L
Isopropylbenzene	2 U	µg/L

Table 4-1c (continued)
Groundwater
Reference Comparison Criteria
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	UST1-18[1]	
	Concentration	Unit
Polycyclic Aromatic Hydrocarbons		
Anthracene	0.019 U	µg/L
Pyrene	0.019 U	µg/L
Dibenzofuran	0.019 U	µg/L
Benzo(g,h,i)perylene	0.019 U	µg/L
Indeno(1,2,3-cd)pyrene	0.019 U	µg/L
Benzo(b)fluoranthene	0.019 U	µg/L
Fluoranthene	0.019 U	µg/L
Benzo(k)fluoranthene	0.019 U	µg/L
Acenaphthylene	0.019 U	µg/L
Chrysene	0.019 U	µg/L
Benzo(a)pyrene	0.019 U	µg/L
Dibenzo(a,h)anthracene	0.019 U	µg/L
Benzo(a)anthracene	0.019 U	µg/L
Acenaphthene	0.019 U	µg/L
Phenanthrene	0.019 U	µg/L
Fluorene	0.019 U	µg/L
Naphthalene	0.019 U	µg/L
Petroleum Hydrocarbons		
Diesel Range Hydrocarbons	250 UJ	µg/L
Motor Oil Range Hydrocarbons	500 U	µg/L
Gasoline Range Hydrocarbons	250 U	µg/L

Notes:

µg/L - microgram per liter
U - not detected at the reporting limit shown
J - estimated concentration
RI - remedial investigation
DoD - Department of Defense
(1) Sample collected as part of this RI from location upgradient of decision units, and in area that was not subject to DoD-era activities.

Table 4-1d
Surface Water
Background and Reference Comparison Criteria
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	ODEQ (2002)[1]	Reference Area (REF-13)[2]	Unit
	Concentration		
Inorganics			
Antimony	<1	1 U	µg/L
Arsenic	2	0.956 J	µg/L
Barium	NV	25.5	µg/L
Cadmium	<1	NA	µg/L
Chromium	1	5 U	µg/L
Copper	9	0.876 U	µg/L
Iron	NV	1000 U	µg/L
Lead	13.3	1 U	µg/L
Manganese	NV	17.7	µg/L
Mercury	<0.1	0.50 U	µg/L
Nickel	5.5	10 U	µg/L
Silver	<1	NA	µg/L
Selenium	0.2	2 U	µg/L
Zinc	38	5.12 J	µg/L
Volatile Organic Compounds			
Ethylbenzene	NV	0.5 U	µg/L
N-Propylbenzene	NV	0.5 U	µg/L
1,2-Dibromoethane	NV	2 U	µg/L
1,2-Dichloroethane	NV	0.5 U	µg/L
1,3,5-Trimethylbenzene	NV	2 U	µg/L
Toluene	NV	0.5 U	µg/L
Tetrachloroethene	NV	0.5 U	µg/L
Total Xylenes	NV	1 U	µg/L
cis-1,2-Dichloroethene	NV	0.5 U	µg/L
trans-1,2-Dichloroethene	NV	0.5 U	µg/L
Benzene	NV	0.5 U	µg/L
1,1,1-Trichloroethane	NV	0.5 U	µg/L
Vinyl Chloride	NV	0.5 U	µg/L
1,1-Dichloroethene	NV	0.5 U	µg/L
Trichloroethene	NV	0.5 U	µg/L
o-Xylene	NV	0.5 U	µg/L
1,2,4-Trimethylbenzene	NV	2 U	µg/L
Isopropylbenzene	NV	2 U	µg/L
Semi-volatile Organic Compounds			
1-Methylnaphthalene	NV	0.0004 U	µg/L
1-Methylphenanthrene	NV	0.0004 U	µg/L
2-Methylnaphthalene	NV	0.0004 U	µg/L
2,3,5-Trimethylnaphthalene	NV	0.0004 U	µg/L
2,6-Dimethylnaphthalene	NV	0.0004 U	µg/L
Acenaphthylene	NV	0.0004 U	µg/L
Acenaphthene	NV	0.0004 U	µg/L
Anthracene	NV	0.0004 U	µg/L
Benzo(a)anthracene	NV	0.0004 U	µg/L
Benzo(b)fluoranthene	NV	0.0004 U	µg/L
Benzo(k)fluoranthene	NV	0.0004 U	µg/L
Benzo(g,h,i)perylene	NV	0.0004 U	µg/L
Benzo(a)pyrene	NV	0.00051 U	µg/L
Benzo(e)pyrene	NV	0.0004 U	µg/L
Carbazole	NV	0.0004 U	µg/L
Chrysene	NV	0.0004 U	µg/L
Indeno(1,2,3-Cd)Pyrene	NV	0.0004 U	µg/L
Dibenzo(a,h)anthracene	NV	0.0004 U	µg/L
Dibenzofuran	NV	0.0004 U	µg/L
Dibenzothiophene	NV	0.0004 U	µg/L

Table 4-1d (continued)
Surface Water
Background and Reference Comparison Criteria
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	ODEQ (2002)[1]	Reference Area (REF-13)[2]	Unit
	Concentration		
Semi-volatile Organic Compounds, continued			
Fluoranthene	NV	0.00065	µg/L
Fluorene	NV	0.0004 U	µg/L
Naphthalene	NV	0.0004 UJ	µg/L
Perylene	NV	0.0004 U	µg/L
Phenanthrene	NV	0.00064	µg/L
Pyrene	NV	0.00052	µg/L
Pesticides			
4,4'-DDD	NV	0.0004 U	µg/L
4,4'-DDE	NV	0.0004 U	µg/L
4,4'-DDT	NV	0.0004 U	µg/L
Aldrin	NV	0.0004 U	µg/L
alpha Chlordane	NV	0.0004 U	µg/L
Dieldrin	NV	0.0004 U	µg/L
gamma BHC (Lindane)	NV	0.0044	µg/L
Hexachlorobenzene	NV	0.0004 U	µg/L
Mirex	NV	0.0004 U	µg/L
Polychlorinated Biphenyls			
Aroclor 1016	NV	0.002 U	µg/L
Aroclor 1221	NV	0.0022 U	µg/L
Aroclor 1232	NV	0.002 U	µg/L
Aroclor 1242	NV	0.002 U	µg/L
Aroclor 1248	NV	0.002 U	µg/L
Aroclor 1254	NV	0.002 U	µg/L
Aroclor 1260	NV	0.002 U	µg/L
Dioxins/Furans			
Total Hepta-Furans	NV	1 U	pg/L
Total Hexa-Furans	NV	1 U	pg/L
Total Penta-Furans	NV	1 U	pg/L
Total Tetra-Furans	NV	0.2 U	pg/L
Total Hexa-Dioxins	NV	1 U	pg/L
Total Hepta-Dioxins	NV	0.0519 U	pg/L
Total Pentachlorodibenzo-p-dioxin	NV	1 U	pg/L
Total Tetra-Dioxins	NV	0.2 U	pg/L
1,2,3,4,7,8-Hexachlorodibenzo-p-Dioxin	NV	1 U	pg/L
1,2,3,6,7,8-Hexachlorodibenzo-p-Dioxin	NV	1 U	pg/L
1,2,3,7,8,9-Hexachlorodibenzo-p-Dioxin	NV	1 U	pg/L
1,2,3,4,6,7,8-Heptachlorodibenzo-p-Dioxin	NV	0.0519 U	pg/L
1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin	NV	0.2934 U	pg/L
1,2,3,7,8-Pentachlorodibenzo-p-Dioxin	NV	1 U	pg/L
1,2,3,4,7,8-Hexachlorodibenzofuran	NV	1 U	pg/L
1,2,3,6,7,8-Hexachlorodibenzofuran	NV	1 U	pg/L
1,2,3,7,8,9-Hexachlorodibenzofuran	NV	1 U	pg/L
2,3,4,6,7,8-Hexachlorodibenzofuran	NV	1 U	pg/L
1,2,3,4,6,7,8-Heptachlorodibenzofuran	NV	0 U	pg/L
1,2,3,4,7,8,9-Heptachlorodibenzofuran	NV	1 U	pg/L
1,2,3,4,6,7,8,9-Octachlorodibenzofuran	NV	2 U	pg/L
2,3,4,7,8-Pentachlorodibenzofuran	NV	1 U	pg/L
1,2,3,7,8-Pentachlorodibenzofuran	NV	10 U	pg/L
2,3,7,8-Tetrachlorodibenzo-p-dioxin	NV	0.2 U	pg/L
2,3,7,8-Tetrachlorodibenzofuran	NV	0.2 U	pg/L

Table 4-1d (continued)
Surface Water
Background and Reference Comparison Criteria
Tongue Point Multi-Sites Project RI/FS
Former Tongue Point Naval Air Station, Astoria, Oregon

Chemical	ODEQ (2002)[1]	Reference Area (REF-13)[2]	Unit
	Concentration		
Petroleum Hydrocarbons			
Diesel Range Hydrocarbons	NV	250 U	µg/L
Motor Oil Range Hydrocarbons	NV	500 U	µg/L
Gasoline Range Hydrocarbons	NV	250 U	µg/L

Notes:

J - estimated concentration
U - not detected at the reporting limit shown
µg/L - microgram per liter
pg/L - picogram per liter
NV - no value
NA - nat analyzed
DDD - dichlorodiphenyldichloroethane
DDE - dichlorodiphenyldichloroethylene
DDT - dichlorodiphenyltrichloroethane
RI - remedial investigation
ODEQ - Oregon Department of Environmental Quality

(1) From Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(2) Sample collected as part of this RI from Aquatic-Reference Area (See Figure 3-12).

Table 4-1e
Sediment
Background and Reference Comparison Criteria
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	ODEQ (2002)[1]	Reference Area (REF-01 through REF-07)[2]	Unit
	Concentration		
Inorganics			
Antimony	1	0.09 J - 0.12 J	mg/kg dw
Arsenic	7.9	4.62 - 5.15	mg/kg dw
Barium	NV	80.2 - 90.9	mg/kg dw
Cadmium	<0.5	0.292 - 0.317	mg/kg dw
Chromium	30	13.5 - 15.7	mg/kg dw
Copper	12	26.1 - 31.7	mg/kg dw
Lead	2.0	7.43 - 8.18	mg/kg dw
Manganese	NV	431 - 512	mg/kg dw
Mercury	0.2	0.05 - 0.075	mg/kg dw
Nickel	20	11.9 - 13	mg/kg dw
Selenium	0.4	0.09 U - 0.05 J	mg/kg dw
Silver	0.4	0.06 - 0.09	mg/kg dw
Vanadium	NV	49.1 - 56.5	mg/kg dw
Zinc	53	60.4 - 68.8	mg/kg dw
Pesticides			
4,4'-DDD	NV	0.21 J - 0.27 J	µg/kg dw
4,4'-DDE	NV	0.44 J - 0.68 J	µg/kg dw
4,4'-DDT	NV	1.1 U - 0.41 J	µg/kg dw
Aldrin	NV	1.0 UJ - 1.1 U	µg/kg dw
alpha Chlordane	NV	1.0 UJ - 1.1 U	µg/kg dw
Chlordane	NV	25 UJ - 25 U	µg/kg dw
Camphene	NV	50 UJ - 51 U	µg/kg dw
Dieldrin	NV	1.0 UJ - 1.1 U	µg/kg dw
Endosulfan I	NV	1.0 UJ - 1.1 U	µg/kg dw
Endosulfan II	NV	1.0 UJ - 1.1 U	µg/kg dw
Endosulfan Sulfate	NV	1.0 UJ - 1.1 U	µg/kg dw
Endrin	NV	1.0 UJ - 1.1 U	µg/kg dw
gamma BHC (Lindane)	NV	1.0 UJ - 1.1 U	µg/kg dw
Heptachlor	NV	1.0 UJ - 1.1 U	µg/kg dw
Heptachlor epoxide	NV	1.0 UJ - 1.1 U	µg/kg dw
Hexachlorobenzene	NV	1.0 UJ - 0.19 J	µg/kg dw
Methoxychlor	NV	1.0 UJ - 1.1 U	µg/kg dw
Mirex	NV	1.0 UJ - 1.1 U	µg/kg dw
Polychlorinated Biphenyls			
Aroclor 1016	NV	10 U - 11 U	µg/kg dw
Aroclor 1221	NV	20 U - 21 U	µg/kg dw
Aroclor 1232	NV	10 U - 35 U	µg/kg dw
Aroclor 1242	NV	10 U - 16 U	µg/kg dw
Aroclor 1248	NV	10 U - 11 U	µg/kg dw
Aroclor 1254	NV	10 U - 11 U	µg/kg dw
Aroclor 1260	NV	10 U - 11 U	µg/kg dw

Table 4-1e (continued)
Sediment
Background and Reference Comparison Criteria
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	ODEQ (2002)[1]	Reference Area (REF-01 through REF-07)[2]	Unit
	Concentration		
Semi-volatile Organic Compounds			
1,2,4-Trichlorobenzene	NV	9.8 U - 10 U	µg/kg dw
1,2-Dichlorobenzene	NV	9.8 U - 10 U	µg/kg dw
1,3-Dichlorobenzene	NV	9.8 U - 10 U	µg/kg dw
1,4-Dichlorobenzene	NV	9.8 U - 10 U	µg/kg dw
2,4,5-Trichlorophenol	NV	9.8 UJ - 10 U	µg/kg dw
2,4,6-Trichlorophenol	NV	9.8 UJ - 10 U	µg/kg dw
2,4-Dimethylphenol	NV	49 UJ - 50 U	µg/kg dw
2-Methylphenol	NV	9.8 UJ - 10 U	µg/kg dw
4,6-Dinitro-2-Methylphenol	NV	98 UJ - 100 U	µg/kg dw
4-Methylphenol	NV	9.8 UJ - 10 U	µg/kg dw
4-Nitroaniline	NV	20 UJ- 20 U	µg/kg dw
Benzoic Acid	NV	200 UJ	µg/kg dw
Benzyl Alcohol	NV	9.8 UJ - 10 U	µg/kg dw
Bis(2-Ethylhexyl)phthalate	NV	6.4 U - 35 U	µg/kg dw
Caprolactam	NV	20 UJ	µg/kg dw
Carbazole	NV	9.8 U - 10 U	µg/kg dw
Dibenzofuran	NV	9.8 U - 10 U	µg/kg dw
Diethylphthalate	NV	9.8 U - 10 U	µg/kg dw
Dimethylphthalate	NV	9.8 U - 10 U	µg/kg dw
Di-N-Butylphthalate	NV	5.5 J - 9.4 J	µg/kg dw
Di-N-Octyl Phthalate	NV	9.8 U -10 U	µg/kg dw
Hexachlorobenzene	NV	9.8 U -10 U	µg/kg dw
Hexachlorobutadiene	NV	9.8 U -10 U	µg/kg dw
Hexachloroethane	NV	9.8 U -10 U	µg/kg dw
Nitrobenzene	NV	9.8 U -10 U	µg/kg dw
N-Nitrosodiphenylamine	NV	9.8 U -10 U	µg/kg dw
Pentachlorophenol	NV	98 UJ - 100 U	µg/kg dw
Phenol	NV	7.7 J - 12 J	µg/kg dw
Polycyclic Aromatic Hydrocarbons			
2-Methylnaphthalene	NV	0.52 J - 2.5 J	µg/kg dw
Acenaphthene	NV	0.35 J - 0.58 J	µg/kg dw
Acenaphthylene	NV	0.41 J - 0.77 J	µg/kg dw
Anthracene	NV	1.2 J - 1.9 J	µg/kg dw
Benzo(a)anthracene	NV	5.4 - 7.3	µg/kg dw
Benzo(a)pyrene	NV	7.2 - 11	µg/kg dw
Benzo(b)fluoranthene	NV	8.0 - 13	µg/kg dw
Benzo(e)pyrene	NV	6.3 - 9.3	µg/kg dw
Benzo(g,h,i)perylene	NV	7.2 - 12	µg/kg dw
Benzo(k)fluoranthene	NV	3.1 - 4.7	µg/kg dw
Chrysene	NV	8.5 - 12	µg/kg dw
Dibenzo(a,h)anthracene	NV	1.1 J - 2.0 J	µg/kg dw
Fluoranthene	NV	8.8 - 17	µg/kg dw
Fluorene	NV	0.50 J - 0.62 J	µg/kg dw
Indeno(1,2,3-Cd)Pyrene	NV	6.6 - 10	µg/kg dw
Naphthalene	NV	1.6 U - 2.5	µg/kg dw
Phenanthrene	NV	4.1 - 7.5	µg/kg dw
Pyrene	NV	11 - 18 J	µg/kg dw

Table 4-1e (continued)
Sediment
Background and Reference Comparison Criteria
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	ODEQ (2002)[1]	Reference Area (REF-01 through REF-07)[2]	Unit
	Concentration		
Petroleum Hydrocarbons			
Diesel Range Hydrocarbons	NV	7.8 J - 10 J	mg/kg dw
Oil Range Hydrocarbons	NV	44 J - 66 J	mg/kg dw

Notes:

U - not detected at the reporting limit shown
J - estimated concentration
µg/kg - microgram per kilogram
mg/kg - milligram per kilogram
dw - dry weight
NV - no value
DDD - dichlorodiphenyldichloroethane
DDE - dichlorodiphenyldichloroethylene
DDT - dichlorodiphenyltrichloroethane
RI - remedial investigation
ODEQ - Oregon Department of Environmental Quality

(1) From Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.
(2) Sample collected as part of this RI from Aquatic-Reference Area (See Figure 3-12).

Table 4-1f
Tissue
Reference Comparison Criteria
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	Fish Fillet (1)	Forage Fish (1)	Clams (1)	Unit (wet weight)
	Concentration			
Inorganics				
Arsenic	0.88	1.25	4.9	mg/kg
Lead	0.131	0.27	1.87	mg/kg
Selenium	2	2.6	3.2	mg/kg
Chromium	0.52	0.47	4.25	mg/kg
Mercury	0.205	0.303	0.066	mg/kg
Semi-volatile Organic Compounds				
Fluoranthene	5 U	5 U	6.1	ug/kg
Fluorene	1.8 U	1.7 U	1.9 U	ug/kg
Pyrene	5 U	5 U	3.9 J	ug/kg
Pesticides				
4,4'-DDT	0.77 J	1.7	0.76 J	ug/kg
4,4'-DDD	0.9 J	2.5	0.78 J	ug/kg
4,4'-DDE	4.6	18	4.6	ug/kg
Alpha-Chlordane	1 U	0.98 U	1.1 U	ug/kg
Dieldrin	1 U	0.69 J	0.63 J	ug/kg
Hexachlorobenzene	1 U	0.81 J	1.1 U	ug/kg
Tributyl Tin as TBT ion	5.5 U	2	6 U	ug/kg
Polychlorinated Biphenyls				
Aroclor 1016	10 U	11 U	11 U	ug/kg
Aroclor 1221	20 U	20 U	21 U	ug/kg
Aroclor 1232	10 U	16 U	17 U	ug/kg
Aroclor 1242	10 U	9.8 U	11 U	ug/kg
Aroclor 1248	10 U	14 U	11 U	ug/kg
Aroclor 1254	10 U	17 U	11 U	ug/kg
Aroclor 1260	10 U	9.9 U	11 U	ug/kg
Dioxin/Furan				
2,3,7,8-Tetrachlorodibenzo-p-dioxin	2.1 U	2.49 U	2.26 U	ng/kg
1,2,3,7,8,9-Hexachlorodibenzo-p-Dioxin	5.24 U	6.22 U	5.65 U	ng/kg
Total Tetra-Furans	2.1 U	0.412 J	2.26 U	ng/kg
Total Penta-Furans	2.1 U	0.651 J	2.26 U	ng/kg
1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin	0.77 U	2.06 U	4.69 U	ng/kg
Total Hexa-Dioxins	5.24 U	6.22 U	0.22 J	ng/kg
1,2,3,4,6,7,8-Heptachlorodibenzo-p-Dioxin	5.24 U	0.341 U	0.916 U	ng/kg
Total Pentachlorodibenzo-p-dioxin	2.1 U	2.49 U	2.26 U	ng/kg
Total Hepta-Dioxins	5.24 U	0.696 U	2.11 U	ng/kg
Total Hepta-Furans	5.24 U	6.22 U	0.338 J	ng/kg
1,2,3,4,6,7,8,9-Octachlorodibenzofuran	10.5 U	12.4 U	0.59 U	ng/kg
1,2,3,4,7,8-Hexachlorodibenzo-p-Dioxin	5.24 U	6.22 U	5.65 U	ng/kg
1,2,3,7,8-Pentachlorodibenzo-p-Dioxin	2.1 U	2.49 U	2.26 U	ng/kg
Total Tetra-Dioxins	2.1 U	2.49 U	2.26 U	ng/kg
2,3,7,8-Tetrachlorodibenzofuran	2.1 U	2.49 U	2.26 U	ng/kg
1,2,3,4,7,8,9-Heptachlorodibenzofuran	5.24 U	6.22 U	5.65 U	ng/kg
Total Hexa-Furans	5.24 U	6.22 U	0.264 J	ng/kg
2,3,4,7,8-Pentachlorodibenzofuran	2.1 U	0.29 J	2.65 U	ng/kg
1,2,3,7,8-Pentachlorodibenzofuran	5.24 U	0.361 J	5.65 U	ng/kg
1,2,3,6,7,8-Hexachlorodibenzofuran	5.24 U	0.197 U	5.65 U	ng/kg
1,2,3,6,7,8-Hexachlorodibenzo-p-Dioxin	5.24 U	6.22 U	5.65 U	ng/kg
2,3,4,6,7,8-Hexachlorodibenzofuran	5.24 U	6.22 U	5.65 U	ng/kg
1,2,3,4,6,7,8-Heptachlorodibenzofuran	5.24 U	6.22 U	0.172 U	ng/kg
1,2,3,4,7,8-Hexachlorodibenzofuran	5.24 U	0.239 U	0.0904 U	ng/kg
1,2,3,7,8,9-Hexachlorodibenzofuran	5.24 U	6.22 U	5.65 U	ng/kg

Notes:

J - estimated concentration
U - not detected at the reporting limit shown
µg/kg - microgram per kilogram
mg/kg - milligram per kilogram
ng/kg - nanogram per kilogram
RI - remedial investigation
DDD - dichlorodiphenyldichloroethane
DDE - dichlorodiphenyldichloroethylene
DDT - dichlorodiphenyltrichloroethane
(1) Sample collected as part of this RI from Aquatic-Reference Area (See Figure 3-12).

Table 4-4a
Soil Summary Statistics, Reference, and Comparison Criteria
Refueling Pit 3
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Background Value (1)	Comparison Criteria (2)
Polycyclic Aromatic Hydrocarbons									
83-32-9	Acenaphthene	0.0037 J	0.0038 J	mg/kg	RFP3-01	2 / 4	0.0065 - 0.0072	NV	19,000
208-96-8	Acenaphthylene (3)	0.0079	0.0079	mg/kg	RFP3-02	1 / 4	0.0065 - 0.0072	NV	19,000
120-12-7	Anthracene	0.0110	0.0110	mg/kg	RFP3-02	1 / 4	0.0065 - 0.0072	NV	93,000
191-24-2	Benzo(g,h,i)perylene (4)	0.0070	0.0250	mg/kg	RFP3-02	4 / 4	0.0065 - 0.0072	NV	6,700
-	Carcinogenic PAHs (5)	0.0393	0.6243	mg/kg	RFP3-03	4 / 4	0.0065 - 0.0072	NV	2.1
206-44-0	Fluoranthene	0.0051 J	0.0320	mg/kg	RFP3-02	4 / 4	0.0065 - 0.0072	NV	8,900
86-73-7	Fluorene	0.0043 J	0.0043 J	mg/kg	RFP3-02	1 / 4	0.0065 - 0.0072	NV	12,000
85-01-8	Phenanthrene (6)	0.0051 J	0.0100	mg/kg	RFP3-02	4 / 4	0.0065 - 0.0072	NV	8,900
129-00-0	Pyrene	0.0087	0.0390	mg/kg	RFP3-02	4 / 4	0.0065 - 0.0072	NV	6,700
Inorganics									
7439-92-1	Lead (7)	9.24	20.4	mg/kg	RFP3-04	4 / 4	2.59 - 2.88	17	800
Total Petroleum Hydrocarbons									
-	Diesel Range Hydrocarbons (8)	18 J	34	mg/kg	RFP3-03	3 / 4	6.4 - 30	NV	18,000
-	Oil Range Hydrocarbons	32	150	mg/kg	RFP3-02	4 / 4	13 - 61	NV	40,000
-	Gasoline Range Hydrocarbons (8)	28	28	mg/kg	RFP3-04	1 / 4	4.9 - 9.1	NV	18,000

Notes:

RFP - refueling pit
PAH - polycyclic aromatic hydrocarbon
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality

mg/kg - milligram per kilogram
J - estimated concentration
DU - decision unit
RBCs - risk-based concentrations

NV - no value
CAS - Chemical Abstracts Service
No. - number
RSL - regional screening level

Bold values exceed Comparison Criteria

Underlined values exceed Background Value.

(1) Background values from Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(2) Comparison criteria for soil, include ODEQ (2008) risk-based concentrations (RBCs) for soil (ingestion, dermal contact and inhalation for construction workers). EPA (2008a) regional screening levels (RSLs) for industrial soil are used for chemicals where RBCs are not available.

(3) Comparison criterion for acenaphthene is used as a surrogate for acenaphthylene.

(4) Comparison criterion for pyrene is used as a surrogate for benzo(g,h,i)perylene.

(5) Carcinogenic PAHs: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene

(6) Comparison criterion for fluoranthene is used as a surrogate for phenanthrene.

(7) Lead was the only metal analyzed in soil at Refueling Pit 3.

(8) DU-specific RBCs are developed for diesel-range petroleum hydrocarbons and gasoline-range petroleum hydrocarbons based on total petroleum hydrocarbon fraction data (ODEQ 2003).

Table 4-2b
Groundwater Summary Statistics, Reference, and Comparison Criteria
AST Fuel Storage Area
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Comparison Criteria (2)
Semi-Volatile Organic Compounds									
129-00-0	Pyrene	0.0096 J	0.0096 J	µg/L	AST-10	1 / 1	0.019 - 0.019	0.019 U	1,100
Inorganics									
7429-90-5	Aluminum	452 J	452 J	µg/L	AST-10	1 / 1	1,000 - 1,000	1,000 U	37,000
7440-38-2	Arsenic	**0.605 J**	**0.605 J**	µg/L	AST-10	1 / 1	1 - 1	1 U	0.038
7440-39-3	Barium	31.8	31.8	µg/L	AST-10	1 / 1	1 - 1	31.7	7,300
7440-70-2	Calcium	5,070	5,070	µg/L	AST-10	1 / 1	1,000 - 1,000	37,600	NV
7440-47-3	Chromium	0.574 J	0.574 J	µg/L	AST-10	1 / 1	5 - 5	5 U	110
7440-50-8	Copper	1.39 J	1.39 J	µg/L	AST-10	1 / 1	2 - 2	2 U	1,500
7439-89-6	Iron	6,410	6,410	µg/L	AST-10	1 / 1	1,000 - 1,000	2,570	26,000
7439-92-1	Lead	0.583 J	0.583 J	µg/L	AST-10	1 / 1	1 - 1	1 U	15
7439-95-4	Magnesium	2,290	2,290	µg/L	AST-10	1 / 1	1,000 - 1,000	20,300	NV
7439-96-5	Manganese	315	315	µg/L	AST-10	1 / 1	1 - 1	127	880
7440-02-0	Nickel	1.66 J	1.66 J	µg/L	AST-10	1 / 1	10 - 10	0.607	730
7440-66-6	Zinc	9.7 J	9.7 J	µg/L	AST-10	1 / 1	10 - 10	10 U	11,000
Total Petroleum Hydrocarbons									
-	Diesel Range Hydrocarbons	290 J	290 J	µg/L	AST-10	1 / 1	250 - 250	250 U	410

Notes:

AST - aboveground storage tank
NV - no value
ODEQ - Oregon Department of Environmental Quality
J - estimated concentration
µg/L - microgram per liter
No. - number
U - not detected at reporting limit shown
CAS - Chemical Abstracts Service
DU - decision unit

Bold values exceed Comparison Criteria.
Underlined values exceed Reference Value.

(1) Reference values are based on the concentrations at the upgradient monitoring well UST1-18. They are presented for information purpose only.
(2) Comparison criteria for groundwater, which are ODEQ (2008) RBCs for groundwater (ingestion and inhalation from tap water for residential properties).
EPA (2008) RSLs for tap water are used for chemicals where RBCs are not available.

Table 4-3a
Soil Summary Statistics, Reference, and Comparison Criteria
UST Site No. 1
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Background Value (1)	Comparison Criteria (2)
Volatile Organic Compounds									
98-82-8	Isopropylbenzene	0.0046 J	0.63 J	mg/kg	UST1-03	3 / 5	0.024 - 1.6	NV	24,000
103-65-1	n-Propylbenzene	0.011 J	1.3 J	mg/kg	UST1-03	3 / 5	0.024 - 1.6	NV	21,000
Polycyclic Aromatic Hydrocarbons									
91-57-6	2-Methylnaphthalene	0.092	2.9	mg/kg	UST1-01	2 / 5	0.0065 - 0.092	NV	4100
83-32-9	Acenaphthene	0.23 J	2.2 J	mg/kg	UST1-01	3 / 5	0.0065 - 0.092	NV	19,000
208-96-8	Acenaphthylene (3)	0.0034 J	0.0034 J	mg/kg	UST1-02	1 / 5	0.0061 - 0.0079	NV	19,000
120-12-7	Anthracene	0.004 J	0.004 J	mg/kg	UST1-02	1 / 5	0.0061 - 0.0079	NV	93,000
191-24-2	Benzo(g,h,i)perylene (4)	0.0063 J	0.021	mg/kg	UST1-03	4 / 5	0.0061 - 0.0079	NV	6,700
-	Carcinogenic PAHs (5)	0.011	0.13	mg/kg	UST1-04	4 / 5	0.0061 - 0.0079	NV	2.1
206-44-0	Fluoranthene	0.0048 J	0.23 J	mg/kg	UST1-01	4 / 5	0.0061 - 0.0079	NV	8,900
86-73-7	Fluorene	0.0076	6.7 J	mg/kg	UST1-01	4 / 5	0.0065 - 0.092	NV	12,000
91-20-3	Naphthalene	0.11	0.33 J	mg/kg	UST1-01	3 / 5	0.0061 - 0.0079	NV	580
85-01-8	Phenanthrene (6)	0.0055 J	8.4 J	mg/kg	UST1-01	4 / 5	0.0065 - 0.092	NV	8,900
129-00-0	Pyrene	0.0044 J	0.77 J	mg/kg	UST1-01	5 / 5	0.0061 - 0.0079	NV	6,700
Inorganics									
7439-92-1	Lead (7)	3.04	14.6	mg/kg	UST1-03	5 / 5	2.45 - 3.15	17	800
Total Petroleum Hydrocarbons									
-	Diesel Range Hydrocarbons	540	13,000	mg/kg	UST1-01	3 / 5	6.2 - 630	NV	16,000
-	Oil Range Hydrocarbons	18	18	mg/kg	UST1-02	1 / 5	12 - 1,300	NV	40,000
-	Gasoline Range Hydrocarbons	500	1,900	mg/kg	UST1-01	3 / 5	8.1 - 77	NV	16,000

Notes:

UST - underground storage tank
PAH - polycyclic aromatic hydrocarbon
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality

mg/kg - milligram per kilogram
J - estimated concentration
DU - decision unit
RBCs - risk-based concentrations

NV - no value
CAS - Chemical Abstracts Service
No. - number

Bold values exceed Comparison Criteria.

Underlined values exceed Background Value.

(1) Background values from Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(2) Comparison criteria for soil, include ODEQ (2008) risk-based concentrations (RBCs) for soil (ingestion, dermal contact and inhalation for construction workers). EPA (2008a) regional screening levels (RSLs) for industrial soil are used for chemicals where RBCs are not available.

(3) Comparison criterion for acenaphthene is used as a surrogate for acenaphthylene.

(4) Comparison criterion for pyrene is used as a surrogate for benzo(g,h,i)perylene.

(5) Carcinogenic PAHs: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

(6) Comparison criterion for fluoranthene is used as a surrogate for phenanthrene.

(7) Lead was the only metal analyzed in soil at UST Site No. 1.

Table 4-3b
Soil Gas Summary Statistics, Reference, and Comparison Criteria
UST Site No. 1
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Comparison Criteria (2)
Volatile Organic Carbons									
71-55-6	1,1,1-Trichloroethane	0.019 J	0.097 J	µg/m^3	UST1-06	3 / 6	0.16 - 200	0.064 J - 0.069 J	1,040,000
76-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane	0.76 J	0.98 J	µg/m^3	UST1-06	3 / 6	1.1 - 280	0.78 J - 1.1 J	6,200,000
75-37-6	1,1-Difluoroethane	1,800 NJ	1,800 NJ	µg/m^3	UST1-07	1 / 6	0.71 - 180	NA	8,400,000
95-63-6	1,2,4-Trimethylbenzene	1.9	330	µg/m^3	UST1-07	6 / 6	0.71 - 180	0.25 J - 0.58 J	1,460
107-06-2	1,2-Dichloroethane	0.036 J	0.94 J	µg/m^3	UST1-07	2 / 6	0.12 - 140	0.48 J - 0.52 J	18.8
108-67-8	1,3,5-Trimethylbenzene	1.3	150	µg/m^3	UST1-07	5 / 6	0.71 - 180	0.81 U - 0.14 J	1,260
106-99-0	1,3-Butadiene	0.39 J	0.39 J	µg/m^3	UST1-07	1 / 6	0.32 - 80	0.36 U	16.2
78-93-3	2-Butanone	0.61	33	µg/m^3	UST1-07	2 / 6	0.42 - 110	0.54 - 1.4	1,040,000
67-63-0	2-Propanol	2.2	32 J	µg/m^3	UST1-08	3 / 6	1.8 - 350	2 U - 0.5 J	NV
622-96-8	4-Ethyltoluene	0.11 J	220	µg/m^3	UST1-07	5 / 6	0.71 - 180	0.23 J - 0.52 J	NV
108-10-1	4-Methyl-2-pentanone	0.13 J	0.44 J	µg/m^3	UST1-06	2 / 6	0.59 - 150	0.66 U - 0.67 U	620,000
67-64-1	Acetone	12	290	µg/m^3	UST1-07	5 / 6	1.7 - 340	6.8 U - 13	6,400,000
71-43-2	Benzene	2.1	**130**	µg/m^3	UST1-08	3 / 6	0.23 - 120	0.5 U - 0.63	62
75-27-4	Bromodichloromethane	0.21 J	0.21 J	µg/m^3	UST1-11	1 / 6	0.96 - 240	1.1 U	13
74-83-9	Bromomethane	0.36 J	0.36 J	µg/m^3	UST1-09	1 / 6	0.56 - 140	0.5 U - 0.62 U	1,040
75-15-0	Carbon Disulfide	0.36 J	26	µg/m^3	UST1-06	4 / 6	2.2 - 110	2.5 U - 2.6 U	146,000
56-23-5	Carbon Tetrachloride	0.24 J	0.48 J	µg/m^3	UST1-07	2 / 6	0.91 - 230	0.46 J - 0.67 J	32
67-66-3	Chloroform	1.2	5 J	µg/m^3	UST1-10	5 / 6	0.7 - 180	0.79 U - 0.8 U	22
74-87-3	Chloromethane	0.4	1.6 J	µg/m^3	UST1-07	2 / 6	0.3 - 300	1.5 - 1.6	18,800
110-82-7	Cyclohexane	0.72 J	3,200	µg/m^3	UST1-08	2 / 6	0.5 - 120	0.55 U - 0.56 U	1,260,000
75-71-8	Dichlorodifluoromethane	0.62 J	3.3 J	µg/m^3	UST1-07	5 / 6	0.71 - 180	2.8 - 2.9	42,000
64-17-5	Ethanol	1.9	5.2 J	µg/m^3	UST1-07	4 / 6	1.4 - 270	1.7 - 2.2	NV
100-41-4	Ethylbenzene	5.3	54	µg/m^3	UST1-07	3 / 6	0.12 - 160	0.23 - 0.41	194
110-54-3	Hexane	0.15 J	250	µg/m^3	UST1-08	4 / 6	0.51 - 130	0.14 J - 0.25 J	146,000
98-82-8	Isopropylbenzene	13	2,500	µg/m^3	UST1-08	2 / 6	0.71 - 180	0.79 U - 0.81 U	84,000
142-82-5	n-Heptane (3)	1.3 J	2,100 J	µg/m^3	UST1-08	3 / 6	0.59 - 150	0.67 U - 0.29 J	1,260,000
103-65-1	n-Propylbenzene	50	3,100	µg/m^3	UST1-08	2 / 6	0.71 - 180	0.81 U - 0.17 J	200,000
95-47-6	o-Xylene	0.067 J	72	µg/m^3	UST1-07	4 / 6	0.12 - 160	0.15 - 0.27	146,000
100-42-5	Styrene	0.68	5.7 J	µg/m^3	UST1-07	2 / 6	0.61 - 150	0.68 U - 0.7 U	200,000
127-18-4	Tetrachloroethene	0.1 J	19	µg/m^3	UST1-07	4 / 6	0.2 - 240	0.029 J - 0.031 J	82
109-99-9	Tetrahydrofuran	0.3 J	1.3 J	µg/m^3	UST1-07	3 / 6	2.1 - 110	2.4 U	NV
108-88-3	Toluene	0.22	390	µg/m^3	UST1-08	6 / 6	0.11 - 140	0.61 - 0.88	1,040,000
75-69-4	Trichlorofluromethane	1.5 J	3	µg/m^3	UST1-06/UST1-09	4 / 6	0.81 - 200	2.7 J - 2.8 J	146,000
1330-20-7	Xylenes (Total)	0.047 J	250	µg/m^3	UST1-07	5 / 6	0.25 - 160	0.59 - 1.1	20,000
Semi-volatile Organic Carbons									
91-57-6	2-Methylnaphthalene	1.6 J	1.6 J	µg/m^3	UST1-07	1 / 2	1.4 - 1.4	NA	14,000
120-12-7	Anthracene	0.43 J	0.43 J	µg/m^3	UST1-07	1 / 2	1.4 - 1.4	NA	NV
206-44-0	Fluoranthene	0.58 J	0.58 J	µg/m^3	UST1-07	1 / 2	1.4 - 1.4	NA	NV
91-20-3	Naphthalene	0.9 J	3.8 J	µg/m^3	UST1-07	2 / 2	1.4 - 1.4	NA	14.4
85-01-8	Phenanthrene	3 J	3 J	µg/m^3	UST1-07	1 / 2	1.4 - 1.4	NA	NV
129-00-0	Pyrene	0.64 J	0.64 J	µg/m^3	UST1-07	1 / 2	2.8 - 2.9	NA	2,200

Notes:

UST - underground storage tank
µg/m^3 - microgram per cubic meter
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality
DU - decision unit

NJ - compound tentatively identified at an estimated concentration
U - not detected at reporting limit shown
CAS - Chemical Abstracts Service
SVOCs - semi-volatile organic compounds

NV - no value
J - estimated concentration
NA - not analyzed
No. - number

Bold values exceed Comparison Criteria.

Underlined values exceed Reference Value.

(1) Reference values are based on the concentrations at the upgradient and downgradient ambient air samples (RFP3-19 and RFP3-18) collected at Refueling Pit 3. They are presented for informational purposes only. SVOCs were not analyzed for in ambient air samples.
(2) EPA (2008) regional screening levels (RSLs) for residential air multiplied by an attenuation factor of 200 are used to derive soil gas screening levels. When EPA RSLs are not available, shallow soil gas concentrations presented in EPA's Subsurface Vapor Intrusion Guidance (2002f) are used, multiplied by an attenuation factor of 20 to account for a total attenuation factor of 200.

(3) Comparison criterion for cyclohexane is used as a surrogate for n-heptane.

Table 4-3c
Groundwater Summary Statistics, Reference, and Comparison Criteria
UST Site No. 1
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Comparison Criteria (2)
Volatile Organic Compounds									
95-63-6	1,2,4-Trimethylbenzene	0.31 J	0.31 J	µg/L	UST1-01	1 / 7	2 - 2	2 U	15
98-82-8	Isopropylbenzene	0.27 J	0.98 J	µg/L	MW-06	3 / 7	2 - 2	2 U	680
103-65-1	n-Propylbenzene	0.4 J	1.1	µg/L	MW-06	3 / 7	0.5 - 0.5	0.5 U	1,300
Polycyclic Aromatic Hydrocarbons									
83-32-9	Acenaphthene	0.018 J	1.2	µg/L	MW-06	6 / 7	0.019 - 0.02	0.019 U	2,200
208-96-8	Acenaphthylene (3)	0.058	0.18	µg/L	MW-06	4 / 7	0.019 - 0.02	0.019 U	2,200
120-12-7	Anthracene	0.099	0.12	µg/L	MW-06	2 / 7	0.019 - 0.02	0.019 U	11,000
-	Carcinogenic PAHs (4)	**0.022**	**0.022**	µg/L	MW-09	1 / 7	NA - NA	0.022	0.0029
132-64-9	Dibenzofuran (5)	0.26 J	0.65	µg/L	MW-06	3 / 7	0.019 - 0.02	0.019 U	12
206-44-0	Fluoranthene	0.015 J	0.041	µg/L	MW-06	5 / 7	0.019 - 0.02	0.019 U	1,500
86-73-7	Fluorene	0.034 J	2.6	µg/L	MW-06	5 / 7	0.019 - 0.038	0.019 U	1,500
91-20-3	Naphthalene	0.0098 J	0.01 J	µg/L	UST1-01	2 / 7	0.019 - 0.02	0.019 U	0.14
85-01-8	Phenanthrene (6)	0.015 J	0.66	µg/L	MW-08	5 / 7	0.019 - 0.02	0.019 U	1,500
129-00-0	Pyrene	0.021 J	0.095	µg/L	MW-06/MW-09	5 / 7	0.019 - 0.02	0.019 U	1,100
Inorganics									
7429-90-5	Aluminum	236 J	236 J	µg/L	UST1-01	1 / 7	1,000 - 1,000	1,000 U	37,000
7440-38-2	Arsenic	**0.545 J**	**6.65**	µg/L	MW-01	7 / 7	1 - 1	1 U	0.038
7440-39-3	Barium	14.7	121	µg/L	UST1-04	7 / 7	1 - 1	31.7	7,300
7440-70-2	Calcium	23,700	77,100	µg/L	MW-09	7 / 7	1,000 - 1,000	37,600	NV
7440-47-3	Chromium	0.645 J	0.732 J	µg/L	UST1-01	2 / 7	5 - 5	5 U	110
7439-89-6	Iron	8,730	23,400	µg/L	UST1-01	7 / 7	1,000 - 1,000	2,570	26,000
7439-92-1	Lead	0.507 J	0.704 J	µg/L	MW-06	2 / 7	1 - 1	1 U	15
7439-95-4	Magnesium	8,340	22,300	µg/L	MW-08	7 / 7	1,000 - 1,000	20,300	NV
7439-96-5	Manganese	237	**1,460**	µg/L	MW-01	7 / 7	1 - 1	127	880
7440-02-0	Nickel	0.525 J	1.58 J	µg/L	UST1-02	7 / 7	10 - 10	0.607	730
7440-66-6	Zinc	5.84 J	13.8	µg/L	UST1-02	7 / 7	10 - 10	10 U	11,000
Total Petroleum Hydrocarbons									
-	Diesel Range Hydrocarbons (7)	250	**610**	µg/L	MW-06	5 / 7	250 - 250	250 U	330
-	Gasoline Range Hydrocarbons (7)	**360**	**540**	µg/L	MW-06	2 / 7	250 - 250	250 U	330

Notes:

UST - underground storage tank
J - estimated concentration
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality

PAH - polycyclic aromatic hydrocarbon
µg/L - microgram per liter
CAS - Chemical Abstracts Service
No. - number

U - not detected at reporting limit shown
NA - not applicable
NV - no value
RBCs - risk-based concentrations

Bold values exceed Comparison Criteria.

Underlined values exceed Reference Value.

(1) Reference values are based on the concentrations at the upgradient monitoring well UST1-18. They are presented for informational purposes only.
(2) Comparison criteria for groundwater, which are ODEQ (2008) RBCs for groundwater (ingestion and inhalation from tap water for residential properties). EPA (2008a) RSLs for tap water are used for chemicals where RBCs are not available.
(3) Comparison criterion for acenaphthene is used as a surrogate for acenaphthylene.
(4) Carcinogenic PAHs: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.
(5) EPA Region 9 preliminary remediation goal (PRG) (2004) for tap water is used as the comparison criterion for dibenzofuran.
(6) Comparison criterion for fluoranthene is used as a surrogate for phenanthrene.
(7) DU-specific RBCs are developed for diesel range hydrocarbons and gasoline range hydrocarbons based on total petroleum hydrocarbon fraction data (ODEQ 2003).

Table 4-3d
Surface Water Summary Statistics, Reference, and Comparison Criteria
UST Site No. 1
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Background Value (2)	Comparison Criteria (3)
Semi-Volatile Organic Compounds										
90-12-0	1-Methylnaphthalene	0.00051	0.00053	µg/L	UST1-15	2 / 2	0.0004 - 0.0004	0.0004 U	NV	2.3
2245-38-7	2,3,5-Trimethylnaphthalene	0.0005	0.0005	µg/L	UST1-14	1 / 2	0.0004 - 0.0004	0.0004 U	NV	NV
581-42-0	2,6-Dimethylnaphthalene (4)	0.0004	0.00071	µg/L	UST1-14	2 / 2	0.0004 - 0.0004	0.0004 U	NV	150
91-57-6	2-Methylnaphthalene	0.00079	0.00088	µg/L	UST1-15	2 / 2	0.0004 - 0.0004	0.0004 U	NV	150
83-32-9	Acenaphthene	0.00043	0.00043	µg/L	UST1-14	1 / 2	0.0004 - 0.0004	0.0004 U	NV	670
208-96-8	Acenaphthylene (5)	0.00044	0.00044	µg/L	UST1-15	1 / 2	0.0004 - 0.0004	0.0004 U	NV	670
-	Carcinogenic PAHs (6)	0.00061	0.00061	µg/L	UST1-15	1 / 2	0.0004 - 0.00069	0.00052	NV	0.0038
132-64-9	Dibenzofuran	0.00082	0.00082	µg/L	UST1-14	1 / 2	0.0004 - 0.0004	0.0004 U	NV	12
206-44-0	Fluoranthene	0.00098	0.0011	µg/L	UST1-15	2 / 2	0.0004 - 0.0004	0.00065	NV	130
86-73-7	Fluorene	0.00052	0.0011	µg/L	UST1-14	2 / 2	0.0004 - 0.0004	0.0004 U	NV	1,100
91-20-3	Naphthalene	0.00058 J	0.00089 J	µg/L	UST1-15	2 / 2	0.0004 - 0.0004	0.0004 U	NV	0.14
85-01-8	Phenanthrene (7)	0.0012	0.0028	µg/L	UST1-14	2 / 2	0.0004 - 0.0004	0.00064	NV	8,300
129-00-0	Pyrene	0.00077	0.0011	µg/L	UST1-15	2 / 2	0.0004 - 0.0004	0.00052	NV	830
Inorganics										
7440-38-2	Arsenic	**0.931 J**	**0.939 J**	µg/L	UST1-14	2 / 2	1 - 1	0.938	<1	0.018
7440-39-3	Barium	26.4	27.1	µg/L	UST1-15	2 / 2	1 - 1	25.9	NV	1,000
7439-96-5	Manganese	12.3	14	µg/L	UST1-15	2 / 2	1 - 1	15.7	NV	50
7440-02-0	Nickel	1.07 J	1.22 J	µg/L	UST1-14	2 / 2	10 - 10	0.599	5.5	610
7440-66-6	Zinc	5.91 J	8.3 J	µg/L	UST1-14	2 / 2	10 - 10	6.11	38	7,400

Notes:

UST - underground storage tank
J - estimated concentration
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality
SVOC - semi-volatile organic compound

U - not detected at reporting limit shown
µg/L - microgram per liter
CAS - Chemical Abstracts Service
OAR - Oregon Administrative Record
RBCs - risk-based concentrations

PAH - polycyclic aromatic hydrocarbon
NV - no value
No. - number
RSL - regional screening level

Bold values exceed Comparison Criteria.

Underlined values exceed Reference or Background Value.

(1) Based on site-specific SVOC concentration of Aquatic Reference Area. They are presented for information purpose only.

(2) Background values from Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(3) Comparison criteria for surface water, which are State of Oregon water quality criteria for human health for consumption of water and organism (OAR 340-041 Tables 33A and 33B) (ODEQ 2009b). National Recommended Water Quality Criteria (EPA 2006b) for human health for consumption of water and organism are used when State of Oregon water quality criteria are not available. ODEQ RBCs for groundwate or EPA RSLs for tap water are used when water quality criteria are not available.

(4) Comparison criterion for 2-methylnaphthalene is used as a surrogate for 2,6-dimethylnaphthalene

(5) Comparison criterion for acenaphthene is used as a surrogate for acenaphthylene.

(6) Carcinogenic PAHs: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

(7) Comparison criterion for fluoranthene is used as a surrogate for phenanthrene.

Table 4-3e
Sediment Summary Statistics, Reference, and Comparison Criteria
UST Site No. 1
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Background Value (2)	Comparison Criteria (3)
Semi-Volatile Organic Compounds										
91-57-6	2-Methylnaphthalene	0.00049 J	0.0014 J	mg/kg	UST1-13	2 / 2	0.0025 - 0.0032	0.0009	NV	310
106-44-5	4-Methylphenol	0.0081 J	0.0081 J	mg/kg	UST1-13	1 / 2	0.0099 - 0.013	0.0098 U - 0.01 U	NV	310
83-32-9	Acenaphthene	0.0013 J	0.0013 J	mg/kg	UST1-13	1 / 2	0.0025 - 0.0032	0.0005	NV	2,900
208-96-8	Acenaphthylene (4)	0.0012 J	0.0012 J	mg/kg	UST1-13	1 / 2	0.0025 - 0.0032	0.0006	NV	2,900
120-12-7	Anthracene	0.00072 J	0.012	mg/kg	UST1-13	2 / 2	0.0025 - 0.0032	0.0016	NV	21,000
192-97-2	Benzo(e)pyrene (5)	0.0043	0.04	mg/kg	UST1-13	2 / 2	0.0025 - 0.0032	0.0073	NV	380
191-24-2	Benzo(g,h,i)perylene (5)	0.003	0.028	mg/kg	UST1-13	2 / 2	0.0025 - 0.0032	0.0088	NV	380
117-81-7	bis(2-Ethylhexyl)phthalate	0.054 J	0.054 J	mg/kg	UST1-13	1 / 2	0.099 - 0.13	0.0064 U - 0.035 U	NV	35
86-74-8	Carbazole	0.0055 J	0.0055 J	mg/kg	UST1-13	1 / 2	0.0099 - 0.013	0.0098 U - 0.01 U	NV	24
-	Carcinogenic PAHs (6)	0.0059	**0.060096**	mg/kg	UST1-13	2 / 2	NA - NA	0.0330	NV	0.015
206-44-0	Fluoranthene	0.0088	0.088	mg/kg	UST1-13	2 / 2	0.0025 - 0.0032	0.0122	NV	510
86-73-7	Fluorene	0.003 J	0.003 J	mg/kg	UST1-13	1 / 2	0.0025 - 0.0032	0.0006	NV	3,100
91-20-3	Naphthalene	0.0033 J	0.0033	mg/kg	UST1-13	1 / 2	0.0025 - 0.0032	0.0013	NV	4.6
85-01-8	Phenanthrene (7)	0.0023 J	0.031	mg/kg	UST1-13	2 / 2	0.0025 - 0.0032	0.0054	NV	510
108-95-2	Phenol	0.0061 J	0.0061 J	mg/kg	UST1-13	1 / 2	0.03 - 0.038	0.0093	NV	18,000
129-00-0	Pyrene	0.0092	0.079	mg/kg	UST1-13	2 / 2	0.0025 - 0.0032	0.0141	NV	380
Pesticides/Polychlorinated Biphenyls										
-	Total DDT (8)	**0.0047**	**0.0047**	mg/kg	UST1-13	1 / 2	NA - NA	0.0013	NV	0.00033
58-89-9	gamma-BHC (Lindane)	0.00051 J	0.00051 J	mg/kg	UST1-12	1 / 2	0.001 - 0.0013	0.001 U - 1 U	NV	0.44
Inorganics										
7440-36-0	Antimony	0.11 J	0.19 J	mg/kg	UST1-13	2 / 2	0.06 - 0.06	0.11	NV	31
7440-38-2	Arsenic	3.35	4.5	mg/kg	UST1-13	2 / 2	0.56 - 0.56	4.95	1	7
7440-39-3	Barium	28.5	92.8	mg/kg	UST1-13	2 / 2	2.2 - 2.2	85	NV	15,000
7440-43-9	Cadmium	0.118	0.508	mg/kg	UST1-13	2 / 2	0.022 - 0.023	0.30	<0.5	1
7440-47-3	Chromium (9)	18	18.4	mg/kg	UST1-12	2 / 2	2.2 - 2.2	14.83	NV	38
7440-50-8	Copper	13.3	52.5	mg/kg	UST1-13	2 / 2	2.2 - 2.2	29.47	30	3,100
7439-92-1	Lead	4.97	11.6	mg/kg	UST1-13	2 / 2	0.06 - 0.06	7.80	2	17
7439-96-5	Manganese	224	359	mg/kg	UST1-13	2 / 2	2.23 - 2.24	480	480	1,800
7439-97-6	Mercury	0.01 J	**0.123**	mg/kg	UST1-13	2 / 2	0.02 - 0.02	0.06	0.2	0.07
7440-02-0	Nickel	10.4	14.7	mg/kg	UST1-13	2 / 2	0.23 - 0.23	12.51	20	12,000
7782-49-2	Selenium	0.7 J	0.7 J	mg/kg	UST1-13	1 / 2	1.1 - 1.1	0.45	0.4	2
7440-22-4	Silver	0.04 J	0.11 J	mg/kg	UST1-13	2 / 2	0.02 - 0.02	0.07	0.4	390
7440-62-2	Vanadium	66.3	95.5	mg/kg	UST1-12	2 / 2	2.2 - 2.2	53.41	NV	390
7440-66-6	Zinc	54.4	88.5	mg/kg	UST1-13	2 / 2	2.23 - 2.24	65.53	53	23,000
Total Petroleum Hydrocarbons										
-	Diesel Range Hydrocarbons (10)	4.1 J	36 J	mg/kg	UST1-13	2 / 2	34 - 62	8.99	NV	4,800
-	Oil Range Hydrocarbons	20 J	200 J	mg/kg	UST1-13	2 / 2	140 - 250	49.71	NV	9,800

Notes:

UST - underground storage tank
PAH - polycyclic aromatic hydrocarbon
NV - no value
RBCs - risk-based concentrations

U - not detected at reporting limit shown
DDT - p,p'-dichlorodiphenyltrichloroethane
CAS - Chemical Abstracts Service
RSL - regional screening level

J - estimated concentration
mg/kg - milligram per kilogram
No. - number
DU - decision unit

Bold values exceed Comparison Criteria.

Underlined values exceed Reference or Background Value.

(1) Based on site-specific mean sediment concentrations of Aquatic Reference Area. They are presented for information purpose only.

(2) From Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(3) Comparison criteria for sediment, which are Oregon Department of Environmental Quality (ODEQ) (2007a) sediment bioaccumulation screening level values for humans when available. Otherwise they are ODEQ (2008) risk-based concentrations (RBCs) for soil (ingestion, dermal contact and inhalation for residential properties). EPA (2008a) regional screening levels (RSLs) for residential soil are used for chemicals where RBCs are not available.

(4) Comparison criterion for acenaphthene is used as a surrogate for acenaphthylene.

(5) Comparison criterion for pyrene is used as a surrogate for benzo(e)pyrene and benzo(g,h,i)perylene.

(6) Carcinogenic PAHs: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

(7) Comparison criterion for fluoaranthene is used as a surrogate for phenanthrene.

(8) Total DDT: p,p'-dichlorodiphenyldichloroethane, p,p'-dichlorodiphenyldichloroethylene, and p,p'-dichlorodiphenyltrichloroethane

(9) EPA RSL value is used as the comparison criterion for chromium.

(10) DU-specific RBCs are developed for diesel-range petroleum hydrocarbons based on total petroleum hydrocarbon fraction data (ODEQ 2003).

Table 4-4a
Soil Summary Statistics, Reference, and Comparison Criteria
Refueling Pit 3
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Background Value (1)	Comparison Criteria (2)
Polycyclic Aromatic Hydrocarbons									
83-32-9	Acenaphthene	0.0037 J	0.0038 J	mg/kg	RFP3-01	2 / 4	0.0065 - 0.0072	NV	19,000
208-96-8	Acenaphthylene (3)	0.0079	0.0079	mg/kg	RFP3-02	1 / 4	0.0065 - 0.0072	NV	19,000
120-12-7	Anthracene	0.0110	0.0110	mg/kg	RFP3-02	1 / 4	0.0065 - 0.0072	NV	93,000
191-24-2	Benzo(g,h,i)perylene (4)	0.0070	0.0250	mg/kg	RFP3-02	4 / 4	0.0065 - 0.0072	NV	6,700
-	Carcinogenic PAHs (5)	0.0393	0.6243	mg/kg	RFP3-03	4 / 4	0.0065 - 0.0072	NV	2.1
206-44-0	Fluoranthene	0.0051 J	0.0320	mg/kg	RFP3-02	4 / 4	0.0065 - 0.0072	NV	8,900
86-73-7	Fluorene	0.0043 J	0.0043 J	mg/kg	RFP3-02	1 / 4	0.0065 - 0.0072	NV	12,000
85-01-8	Phenanthrene (6)	0.0051 J	0.0100	mg/kg	RFP3-02	4 / 4	0.0065 - 0.0072	NV	8,900
129-00-0	Pyrene	0.0087	0.0390	mg/kg	RFP3-02	4 / 4	0.0065 - 0.0072	NV	6,700
Inorganics									
7439-92-1	Lead (7)	9.24	20.4	mg/kg	RFP3-04	4 / 4	2.59 - 2.88	17	800
Total Petroleum Hydrocarbons									
-	Diesel Range Hydrocarbons (8)	18 J	34	mg/kg	RFP3-03	3 / 4	6.4 - 30	NV	18,000
-	Oil Range Hydrocarbons	32	150	mg/kg	RFP3-02	4 / 4	13 - 61	NV	40,000
-	Gasoline Range Hydrocarbons (8)	28	28	mg/kg	RFP3-04	1 / 4	4.9 - 9.1	NV	18,000

Notes:

RFP - refueling pit
PAH - polycyclic aromatic hydrocarbon
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality

mg/kg - milligram per kilogram
J - estimated concentration
DU - decision unit
RBCs - risk-based concentrations

NV - no value
CAS - Chemical Abstracts Service
No. - number
RSL - regional screening level

Bold values exceed Comparison Criteria

Underlined values exceed Background Value.

(1) Background values from Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(2) Comparison criteria for soil, include ODEQ (2008) risk-based concentrations (RBCs) for soil (ingestion, dermal contact and inhalation for construction workers). EPA (2008a) regional screening levels (RSLs) for industrial soil are used for chemicals where RBCs are not available.

(3) Comparison criterion for acenaphthene is used as a surrogate for acenaphthylene.

(4) Comparison criterion for pyrene is used as a surrogate for benzo(g,h,i)perylene.

(5) Carcinogenic PAHs: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene

(6) Comparison criterion for fluoranthene is used as a surrogate for phenanthrene.

(7) Lead was the only metal analyzed in soil at Refueling Pit 3.

(8) DU-specific RBCs are developed for diesel-range petroleum hydrocarbons and gasoline-range petroleum hydrocarbons based on total petroleum hydrocarbon fraction data (ODEQ 2003).

Table 4-4b
Soil Gas Summary Statistics, Reference, and Comparison Criteria
Refueling Pit 3
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Comparison Criteria (2)
Volatile Organic Compounds									
75-37-6	1,1-Difluoroethane	16,000	1,600,000	µg/m^3	RFP3-11	4 / 6	40 - 93,000	2.2 U	42,000,000
95-63-6	1,2,4-Trimethylbenzene	130	200	µg/m^3	RFP3-13	2 / 6	18 - 42,000	0.25 J - 0.58 J	7,300
108-67-8	1,3,5-Trimethylbenzene	94	94	µg/m^3	RFP3-13	1 / 6	18 - 42,000	0.81 U - 0.14 J	6,300
78-93-3	2-Butanone	12	12	µg/m^3	RFP3-13	1 / 6	11 - 25,000	0.54 -1.4	5,200,000
67-63-0	2-Propanol	2,600	2,600	µg/m^3	RFP3-17	1 / 6	37 - 84,000	2 U - 0.5 J	NV
622-96-8	4-Ethyltoluene	120	170	µg/m^3	RFP3-13	2 / 6	18 - 42,000	0.23 J - 0.52 J	NV
67-64-1	Acetone	140	160	µg/m^3	RFP3-15	2 / 6	35 - 82,000	6.8 U - 13	32,000,000
71-43-2	Benzene	71	74	µg/m^3	RFP3-13	2 / 6	12 - 27,000	0.5 U - 0.63	310
75-15-0	Carbon Disulfide	48	670	µg/m^3	RFP3-17	3 / 6	12 - 27,000	2.5 U - 2.6 U	730,000
100-41-4	Ethylbenzene	61	77	µg/m^3	RFP3-15	2 / 6	16 - 37,000	0.23 - 0.41	970
98-82-8	Isopropylbenzene	100,000 J	100,000 J	µg/m^3	RFP3-16	1 / 6	18 - 42,000	0.79 U 0.81 U	420,000
142-82-5	n-Heptane (3)	56	56	µg/m^3	RFP3-13	1 / 6	15 - 35,000	0.67 U - 0.29 J	6,300,000
103-65-1	n-Propylbenzene	47	47	µg/m^3	RFP3-13	1 / 6	18 - 42,000	0.81 U - 0.17 J	1,000,000
95-47-6	o-Xylene	74	79	µg/m^3	RFP3-15	2 / 6	16 - 37,000	0.15 - 0.27	730,000
108-88-3	Toluene	460	1,500	µg/m^3	RFP3-17	4 / 6	14 - 32,000	0.61 - 0.88	5,200,000
1330-20-7	Xylenes (Total)	270	620	µg/m^3	RFP3-11	3 / 6	16 - 37,000	0.59 - 1.1	100,000

Notes:

RFP - refueling pit
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality
RSL - regional screening level

U - not detected at reporting limit shown
µg/m^3 - microgram per cubic meter
CAS - Chemical Abstracts Service
SVOCs - semi-volatile organic compounds

J - estimated concentration
NV - no value
No. - number
DU - decision unit

Bold values exceed Comparison Criteria.

Underlined values exceed Reference Value.

(1) Reference values are based on the concentrations at the upgradient and downgradient ambient air samples (RFP3-19 and RFP3-18) collected at Refueling Pit 3. They are presented for informational purposes only. SVOCs were not analyzed for in ambient air samples.
(2) EPA (2008) regional screening levels (RSLs) for residential air multiplied by an attenuation factor of 1,000 are used to derive soil gas screening levels. When an EPA RSL is not available, shallow soil gas concentrations presented in EPA's Subsurface Vapor Intrusion Guidance (2002f) are used, multiplied by an attenuation factor of 100 to account for a total attenuation factor of 1,000.
(3) Comparison criterion for cyclohexane is used as a surrogate for n-heptane.

Table 4-4c
Groundwater Summary Statistics, Reference, and Comparison Criteria
Refueling Pit 3
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Comparison Criteria (2)
Volatile Organic Compounds									
156-59-2	cis-1,2-Dichloroethene	0.49 J	4.6	µg/L	RFP3-MW03	4 / 9	0.5 - 0.5	NA	360
100-41-4	Ethylbenzene	0.65	0.65	µg/L	RFP3-MW04	1 / 9	0.5 - 0.5	0.5 U	1.4
98-82-8	Isopropylbenzene	0.31 J	640	µg/L	RFP3-MW04	5 / 9	2 - 200	2 U	680
103-65-1	n-Propylbenzene	0.22 J	18	µg/L	RFP3-MW04	3 / 9	0.5 - 0.5	0.5 U	1,300
79-01-6	Trichloroethene	**1.8**	**1.8**	µg/L	RFP3-MW03	1 / 9	0.5 - 0.5	NA	0.039
Polycyclic Aromatic Hydrocarbons									
83-32-9	Acenaphthene	0.014 J	0.014 J	µg/L	RFP3-02	1 / 9	0.019 - 0.02	0.019 U	2,200
206-44-0	Fluoranthene	0.012 J	0.012 J	µg/L	RFP3-02	1 / 9	0.019 - 0.02	0.019 U	1,500
91-20-3	Naphthalene	0.013 J	0.022	µg/L	RFP3-MW03	3 / 9	0.019 - 0.02	0.019 U	0.14
85-01-8	Phenanthrene (3)	0.01 J	0.027 J	µg/L	RFP3-MW05	3 / 9	0.019 - 0.02	0.019 U	1,500
129-00-0	Pyrene	0.016 J	0.016 J	µg/L	RFP3-02	1 / 9	0.019 - 0.02	0.019 U	1,100
Inorganics									
7429-90-5	Aluminum	310 J	310 J	µg/L	RFP3-03	1 / 9	1,000 - 1,000	1000 U	37,000
7440-38-2	Arsenic	**0.792 J**	**9.49**	µg/L	RFP3-MW03	8 / 9	1 - 1	1 U	0.038
7440-39-3	Barium	69.1	154	µg/L	RFP3-01	9 / 9	1 - 1	31.7	7,300
7440-70-2	Calcium	44,200	63,800	µg/L	RFP3-03	9 / 9	1,000 - 1,000	37,600	NV
7440-43-9	Cadmium	0.544 J	0.544 J	µg/L	RFP3-MW03	1 / 9	2 - 2	2 U	18
7440-47-3	Chromium (4)	0.514 J	0.696 J	µg/L	RFP3-03	2 / 9	5 - 5	5 U	110
7440-50-8	Copper	1.07 J	1.48 J	µg/L	RFP3-02	2 / 9	2 - 2	2 U	1,500
7439-89-6	Iron	431 J	5,130	µg/L	RFP3-MW04	9 / 9	1,000 - 1,000	2,570	26,000
7439-92-1	Lead	0.659 J	1.88	µg/L	RFP3-MW04	4 / 9	1 - 1	1 U	15
7439-95-4	Magnesium	13,400	33,500	µg/L	RFP3-02	9 / 9	1,000 - 1,000	20,300	NV
7439-96-5	Manganese	32.6	248	µg/L	RFP3-04	9 / 9	1 - 1	127	880
7440-02-0	Nickel	0.53 J	3.06 J	µg/L	RFP3-02	8 / 9	10 - 10	0.607	730
7440-66-6	Zinc	7.71 J	15.4	µg/L	RFP3-02	3 / 9	10 - 10	10 U	11,000
Total Petroleum Hydrocarbons									
-	Gasoline Range Hydrocarbons (5)	3,000 J	3,000 J	µg/L	RFP3-MW04	1 / 9	250 - 250	250 U	18,000

Notes:

RFP - refueling pit
U - not detected at reporting limit shown
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality
RSL - regional screening levels

J - estimated concentration
µg/L - microgram per liter
CAS - Chemical Abstracts Service
No. - number

NA - not applicable
NV - no value
DU - descision unit
RBCs - risk-based concentrations

Bold values exceed Comparison Criteria.

Underlined values exceed Reference Value.

(1) Reference values are based on the concentrations at the upgradient monitoring well UST1-18. They are presented for informational purposes only.

(2) Comparison criteria for groundwater, which are ODEQ (2008) RBCs for groundwater (ingestion and inhalation from tap water for residential properties). EPA (2008a) RSLs for tap water are used for chemicals where RBCs are not available.
(3) Comparison criterion for fluoranthene is used as a surrogate for phenanthrene.
(4) Comparison criterion for chromium VI is used as a surrogate for chromium.
(5) DU-specific RBCs are developed for gasoline range hydrocarbons based on total petroleum hydrocarbon fraction data (ODEQ 2003).

Table 4-4d
Surface Water Summary Statistics, Reference, and Comparison Criteria
Refueling Pit 3
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Background Value (2)	Comparison Criteria (3)
Semi-Volatile Organic Compounds										
581-42-0	2,6-Dimethylnaphthalene	0.00073	0.00073	µg/L	RFP3-23	1 / 2	0.0004 - 0.0004	0.0004 U	NV	150
91-57-6	2-Methylnaphthalene	0.00053	0.00053	µg/L	RFP3-23	1 / 2	0.0004 - 0.0004	0.0004 U	NV	150
132-64-9	Dibenzofuran	0.00074	0.00074	µg/L	RFP3-23	1 / 2	0.0004 - 0.0004	0.0004 U	NV	12
206-44-0	Fluoranthene	0.00048	0.00053	µg/L	RFP3-23	2 / 2	0.0004 - 0.0004	0.00065	NV	130
86-73-7	Fluorene	0.00056	0.00056	µg/L	RFP3-23	1 / 2	0.0004 - 0.0004	0.0004 U	NV	1,100
85-01-8	Phenanthrene	0.00057	0.0013	µg/L	RFP3-23	2 / 2	0.0004 - 0.0004	0.00064	NV	130
Pesticides										
58-89-9	gamma-BHC (Lindane)	0.00095	0.0013	µg/L	RFP3-22	2 / 2	0.0004 - 0.0004	0.0044	NV	0.98
Inorganics										
7440-38-2	Arsenic	**0.994 J**	**0.997 J**	µg/L	RFP3-22	2 / 2	1 - 1	0.94	<1	0.018
7440-39-3	Barium	27.4	27.8	µg/L	RFP3-22	2 / 2	1 - 1	25.9	NV	1,000
7439-96-5	Manganese	14.4	27.1	µg/L	RFP3-23	2 / 2	1 - 1	15.7	NV	50
7440-02-0	Nickel	1.28 J	1.55 J	µg/L	RFP3-22	2 / 2	10 - 10	0.60	5.5	610
7440-66-6	Zinc	5.4 J	6.91 J	µg/L	RFP3-23	2 / 2	10 - 10	6.11	38	7,400

Notes:

RFP - refueling pit
J - estimated concentration
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality
SVOC - semi-volatile organic compound

U - not detected at reporting limit shown
µg/L - microgram per liter
CAS - Chemical Abstracts Service
OAR - Oregon Administrative Record
RBCs - risk-based concentrations

PAH - polycyclic aromatic hydrocarbon
NV - no value
No. - number
RSL - risk-based screening level

Bold values exceed Comparison Criteria.

Underlined values exceed Reference or Background Value.

(1) Based on site-specific SVOC concentrations from the Aquatic Reference Area. They are presented for information purpose only.

(2) Background values from Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(3) Comparison criteria for surface water, which are State of Oregon water quality criteria for human health for consumption of water and organism (OAR 340-041 Tables 33A and 33B) (ODEQ 2009b). National Recommended Water Quality Criteria (EPA 2006b) for human health for consumption of water and organism are used when State of Oregon water quality criteria are not available. ODEQ RBCs for groundwater or EPA RSLs for tap water are used when water quality criteria are not available.

CDM

Table 4-4e
Sediment Summary Statistics, Reference, and Comparison Criteria
Refueling Pit 3
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical		Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Background Value (2)	Comparison Criteria (3)
Semi-Volatile Organic Compounds											
91-57-6	2-Methylnaphthalene		0.0017 J	0.0017 J	mg/kg	RFP3-20	2 / 2	0.0027 - 0.0032	0.0009	NV	310
83-32-9	Acenaphthene		0.0022 J	0.0055	mg/kg	RFP3-20	2 / 2	0.0027 - 0.0032	0.0005	NV	2,900
208-96-8	Acenaphthylene	(4)	0.0025 J	0.0044	mg/kg	RFP3-21	2 / 2	0.0027 - 0.0032	0.0006	NV	4,700
120-12-7	Anthracene		0.016	0.017	mg/kg	RFP3-21	2 / 2	0.0027 - 0.0032	0.0016	NV	23,000
192-97-2	Benzo(e)pyrene	(5)	0.078	0.1	mg/kg	RFP3-21	2 / 2	0.0027 - 0.0032	0.0073	NV	380
191-24-2	Benzo(g,h,i)perylene	(5)	0.053	0.074	mg/kg	RFP3-21	2 / 2	0.0027 - 0.0032	0.0088	NV	380
65-85-0	Benzoic Acid		0.14 J	0.14 J	mg/kg	RFP3-20	2 / 2	0.22 - 0.26	0.2 U - 200 U	NV	240,000
117-81-7	bis(2-Ethylhexyl)phthalate		0.063 J	0.083 J	mg/kg	RFP3-20	2 / 2	0.011 - 0.013	0.0064 U - 0.035 U	NV	35
86-74-8	Carbazole	(6)	0.0078 J	0.016	mg/kg	RFP3-21	2 / 2	0.011 - 0.013	0.0098 U - 0.01 U	NV	24
-	Carcinogenic PAHs	(7)	**0.11751**	**0.16278**	mg/kg	RFP3-21	2 / 2	NA - NA	0.0153	NV	0.015
132-64-9	Dibenzofuran	(8)	0.0025 J	0.0032 J	mg/kg	RFP3-20	2 / 2	0.011 - 0.013	0.0098 U - 0.01 U	NV	78
206-44-0	Fluoranthene		0.18	0.24	mg/kg	RFP3-21	2 / 2	0.0027 - 0.0032	0.0122	NV	510
86-73-7	Fluorene		0.0044	0.0048	mg/kg	RFP3-20	2 / 2	0.0027 - 0.0032	0.0006	NV	3,100
91-20-3	Naphthalene		0.0038	0.0041	mg/kg	RFP3-20	2 / 2	0.0027 - 0.0032	0.0013	NV	4.6
85-01-8	Phenanthrene	(9)	0.057	0.078	mg/kg	RFP3-21	2 / 2	0.0027 - 0.0032	0.0054	NV	510
108-95-2	Phenol		0.0057 J	0.01 J	mg/kg	RFP3-21	2 / 2	0.032 - 0.039	0.0093	NV	18,000
129-00-0	Pyrene		0.18	0.21	mg/kg	RFP3-21	2 / 2	0.0027 - 0.0032	0.0141	NV	380
Pesticides/Polychlorinated Biphenyls											
-	Total DDT	(10)	**0.00671**	**0.0085**	mg/kg	RFP3-21	2 / 2	NA - NA	0.0011	NV	0.00033
76-44-8	Heptachlor		0.00055 J	0.00055 J	mg/kg	RFP3-20	1 / 2	0.0013 - 0.0013	0.001 U - 0.0011 U	NV	0.11
1024-57-3	Heptachlor epoxide		0.00084 J	0.00084 J	mg/kg	RFP3-20	1 / 2	0.0013 - 0.0013	0.001 U - 0.0011 U	NV	0.053
-	Total PCBs	(11)	**0.046**	**0.062**	mg/kg	RFP3-21	2 / 2	NA - NA	10 U - 35 U	NV	0.00039
Inorganics											
7440-36-0	Antimony		0.28 J	0.39 J	mg/kg	RFP3-21	2 / 2	0.05 - 0.05	0.11	NV	31
7440-38-2	Arsenic		4.4	5.4	mg/kg	RFP3-21	2 / 2	0.5 - 0.5	4.95	1	7
7440-39-3	Barium		84.1	87.2	mg/kg	RFP3-20	2 / 2	0.05 - 0.05	85	NV	15,000
7440-43-9	Cadmium		0.579	0.73	mg/kg	RFP3-21	2 / 2	0.019 - 0.019	0.3	<0.5	1
7440-47-3	Chromium	(12)	17.6	20	mg/kg	RFP3-21	2 / 2	1.9 - 1.9	14.83	NV	38
7440-50-8	Copper		36	37.6	mg/kg	RFP3-21	2 / 2	0.1 - 0.1	29.47	30	3,100
7439-92-1	Lead		15.1	15.2	mg/kg	RFP3-20	2 / 2	0.05 - 0.05	7.8	2	17
7439-96-5	Manganese		270	289	mg/kg	RFP3-21	2 / 2	1.87 - 1.9	480	480	1,800
7439-97-6	Mercury		**0.093 J**	**0.096 J**	mg/kg	RFP3-21	2 / 2	0.016 - 0.017	0.06	0.2	0.07
7440-02-0	Nickel		15.5	15.7	mg/kg	RFP3-20	2 / 2	0.19 - 0.19	12.51	20	12,000
7440-22-4	Silver		0.14	0.27	mg/kg	RFP3-20	2 / 2	0.02 - 0.02	0.07	0.4	390
7440-62-2	Vanadium		59.3	68.3	mg/kg	RFP3-21	2 / 2	1.9 - 1.9	53.41	NV	390
7440-66-6	Zinc		87.3 J	102 J	mg/kg	RFP3-21	2 / 2	1.87 - 1.9	65.53	53	23,000

Table 4-4e (continued)
Sediment Summary Statistics, Reference, and Comparison Criteria
Refueling Pit 3
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Background Value (2)	Comparison Criteria (3)
Total Petroleum Hydrocarbons										
-	Diesel Range Hydrocarbons (13)	42 J	52 J	mg/kg	RFP3-21	2 / 2	53 - 64	8.99	NV	3,000
-	Oil Range Hydrocarbons	250 J	410	mg/kg	RFP3-20	2 / 2	220 - 260	49.71	NV	9,800

Notes:

RFP - refueling pit
PAH - polycyclic aromatic hydrocarbon
NV - no value
ODEQ - Oregon Department of Environmental Quality
PRG - preliminary remediation goal

U - not detected at reporting limit shown
DDT - p,p'-dichlorodiphenyltrichloroethane
NA - not applicable
CAS - Chemical Abstracts Service
RBCs - risk-based concentrations

J - estimated concentration
mg/kg - milligram per kilogram
DU - decision unit
No. - number
RSL - regional screening level

Bold values exceed Comparison Criteria.

Underlined values exceed Reference or Background Value.

(1) Based on site-specific mean sediment concentrations of Aquatic Reference Area. They are presented for information purpose only.

(2) From Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(3) Comparison criteria for sediment, which are Oregon Department of Environmental Quality (ODEQ) (2007a) sediment bioaccumulation screening level values for humans when available. Otherwise they are ODEQ (2008) risk-based concentrations (RBCs) for soil (ingestion, dermal contact and inhalation for residential properties). EPA (2008a) regional screening levels (RSLs) for residential soil are used for chemicals where RBCs are not available.

(4) Comparison criterion for acenaphthene is used as a surrogate for acenaphthylene.

(5) Comparison criterion for pyrene is used as a surrogate for benzo(e)pyrene and benzo(g,h,i)perylene.

(6) EPA Region 9 preliminary remediation goal (PRG) (2004a) for residential soil is used as comparison criterion for carbazole.

(7) Carcinogenic PAHs: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

(8) EPA Region 9 PRG (2004a) for tap water is used as comparison criterion for dibenzofuran.

(9) Comparison criterion for fluoranthene is used as a surrogate for phenanthrene.

(10) Total DDT: p,p'-dichlorodiphenyldichloroethane, p,p'-dichlorodiphenyldichloroethylene, and p,p'-dichlorodiphenyltrichloroethane.

(11) Total PCBs: Aroclor 1016, Aroclor 1221, Aroclor 1232, Aroclor 1242, Aroclor 1248, Aroclor 1254, and Aroclor 1260.

(12) EPA RSL value is used as the comparison criterion for chromium.

(13) DU-specific RBCs are developed for diesel range hydrocarbons based on total petroleum hydrocarbon fraction data (ODEQ 2003).

Table 4-5
Soil Summary Statistics, Reference, and Comparison Criteria
UST Site No. 4
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Background Value (1)	Comparison Criteria (2)
Volatile Organic Compounds									
71-43-2	Benzene	0.39	0.39	mg/kg	UST4-02	1 / 12	0.0054 - 0.0095	NV	7.3
108-88-3	Toluene	0.0083 J	0.0083 J	mg/kg	UST4-04	1 / 12	0.0054 - 0.0093	NV	5,800
Polycyclic Aromatic Hydrocarbons									
91-57-6	2-Methylnaphthalene	0.0031 J	0.0031 J	mg/kg	UST4-01	1 / 12	0.0061 - 0.0062	NV	310
208-96-8	Acenaphthylene (3)	0.0031 J	0.0034 J	mg/kg	UST4-01	2 / 12	0.0054 - 0.0073	NV	23,000
120-12-7	Anthracene	0.004 J	0.0056 J	mg/kg	UST4-05	3 / 12	0.0054 - 0.0073	NV	23,000
191-24-2	Benzo(g,h,i)perylene (4)	0.0074	0.01	mg/kg	UST4-02	5 / 12	0.0054 - 0.0071	NV	1,700
-	Carcinogenic PAHs (5)	**0.016**	**0.060**	mg/kg	UST4-01	5 / 12	0.0054 - 0.0073	NV	0.015
206-44-0	Fluoranthene	0.0036 J	0.021	mg/kg	UST4-05	8 / 12	0.0054 - 0.0071	NV	2,300
86-73-7	Fluorene	0.0047 J	0.0047 J	mg/kg	UST4-01	1 / 12	0.0061 - 0.0062	NV	3,100
87-86-5	Pentachlorophenol	0.014 J	0.014 J	mg/kg	UST4-01	1 / 12	0.24 - 0.25	NV	3
85-01-8	Phenanthrene (6)	0.005 J	0.015	mg/kg	UST4-05	4 / 12	0.0054 - 0.0073	NV	2,300
129-00-0	Pyrene	0.0035 J	0.022	mg/kg	UST4-05	9 / 12	0.0054 - 0.0073	NV	1,700
Inorganic Compounds									
7440-38-2	Arsenic	**5.64**	**5.64**	mg/kg	UST4-01	1 / 1	0.606 - 0.606	7	0.39
7440-39-3	Barium	94.5	94.5	mg/kg	UST4-01	1 / 1	0.606 - 0.606	NV	15,000
7440-43-9	Cadmium	0.70	0.70	mg/kg	UST4-01	1 / 1	0.606 - 0.606	1	1800
7440-47-3	Chromium (7)	17.7	17.7	mg/kg	UST4-01	1 / 1	0.606 - 0.606	42	38
7439-92-1	Lead	1.97 J	13.5	mg/kg	UST4-01	12 / 12	2.16 - 2.92	17	400
7782-49-2	Selenium	0.683 J	0.683 J	mg/kg	UST4-01	1 / 1	1.21 - 1.21	2	390
Total Petroleum Hydrocarbons									
-	Diesel Range Hydrocarbons (8)	7.4	13	mg/kg	UST4-04	6 / 12	5.1 - 7.3	NV	2,900
-	Oil Range Hydrocarbons	14	120	mg/kg	UST4-04	9 / 12	10 - 15	NV	9,800
-	Gasoline Range Hydrocarbons (8)	8.8	75	mg/kg	UST4-04	7 / 12	6.8 - 12	NV	2,900

Notes:

UST - underground storage tank
J - estimated concentration
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality

PAH - polycyclic aromatic hydrocarbon
µg/L - microgram per liter
CAS - Chemical Abstracts Service
No. - number

NA - not applicable
NV - no value
RBCs - risk-based concentrations
RSLs - regional screening levels

Bold values exceed Comparison Criteria.

Underlined values exceed Background Value.

(1) Background values from Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(2) Comparison criteria for soil, include ODEQ (2008) risk-based concentrations (RBCs) for soil (ingestion, dermal contact and inhalation for construction workers). EPA (2008a) regional screening levels (RSLs) for industrial soil are used for chemicals where RBCs are not available.

(3) Comparison criterion for acenaphthene is used as a surrogate for acenaphthylene.

(4) Comparison criterion for pyrene is used as a surrogate for benzo(g,h,i)perylene.

(5) Carcinogenic PAHs: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

(6) Comparison criterion for fluoranthene is used as a surrogate for phenanthrene.

(7) Comparison criterion for chromium VI is used as a surrogate for chromium.

(8) DU-specific RBCs are developed for diesel range hydrocarbons and gasoline range hydrocarbons based on total petroleum hydrocarbon fraction data (ODEQ 2003).

Table 4-6
Surface Soil Summary Statistics, Frequency of Detection, and Reference Screen
Incinerator Building
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Background Value (1)	Comparison Criteria (2)
Semi-Volatile Organic Compounds									
90-12-0	1-Methylnaphthalene	0.0012 J	0.02	mg/kg	0710INCS02	5 / 5	NA - NA	NV	99
91-57-6	2-Methylnaphthalene	0.0021 J	0.022	mg/kg	0710INCS02	5 / 5	NA - NA	NV	4,100
83-32-9	Acenaphthene	0.0011 J	0.0025 J	mg/kg	0710INCS03	5 / 5	NA - NA	NV	19,000
208-96-8	Acenaphthylene (3)	0.0014 J	0.0067	mg/kg	0710INCS05	5 / 5	NA - NA	NV	19,000
120-12-7	Anthracene	0.0036 J	0.0066	mg/kg	0710INCS04	5 / 5	NA - NA	NV	93,000
191-24-2	Benzo(g,h,i)perylene (4)	0.024	0.041	mg/kg	0710INCS04	5 / 5	NA - NA	NV	6,700
117-81-7	Bis(2-ethylhexyl)phthalate	0.041 J	0.069 J	mg/kg	0710INCS04	5 / 5	NA - NA	NV	1,200
-	Carcinogenic PAHs (5)	0.041	0.087	mg/kg	0710INCS04	5 / 5	NA - NA	NV	2.1
132-64-9	Dibenzofuran (6)	0.0014 J	0.0047 J	mg/kg	0710INCS02	5 / 5	NA - NA	NV	150
84-74-2	Di-n-butylphthalate	0.015 J	0.018 J	mg/kg	0710INCS05	5 / 5	NA - NA	NV	62,000
206-44-0	Fluoranthene	0.039	0.078	mg/kg	0710INCS04	5 / 5	NA - NA	NV	8,900
86-73-7	Fluorene	0.0014 J	0.0038 J	mg/kg	0710INCS05	5 / 5	NA - NA	NV	12,000
91-20-3	Naphthalene	0.0043 J	0.016	mg/kg	0710INCS02	3 / 5	NA - NA	NV	580
85-01-8	Phenanthrene (7)	0.02	0.048	mg/kg	0710INCS05	5 / 5	NA - NA	NV	8,900
129-00-0	Pyrene	0.045	0.084	mg/kg	0710INCS05	5 / 5	NA - NA	NV	6,700
Pesticides/Polychlorinated Biphenyls									
-	Total PCBs (8)	0.014	0.017	mg/kg	0710INCS03	5 / 5	NA - NA	NV	7.6
Dioxin/Furan									
-	Dioxin/Furan TEQ	**5.6E-06**	**1.8E-05**	mg/kg	0710INCS03	5 / 5	NA - NA	NV	3.9E-06
Inorganics									
7429-90-5	Aluminum	14,400	18,400	mg/kg	0710INCS04	5 / 5	NA - NA	NV	990,000
7440-36-0	Antimony	0.46 J	0.61 J	mg/kg	0710INCS03	5 / 5	NA - NA	4	410
7440-38-2	Arsenic	3.96	4.92	mg/kg	0710INCS01	5 / 5	NA - NA	7	13
7440-39-3	Barium	74.8	90.8	mg/kg	0710INCS04	5 / 5	NA - NA	NV	60,000
7440-41-7	Beryllium	0.473	0.597	mg/kg	0710INCS02	5 / 5	NA - NA	NV	610
7440-43-9	Cadmium	0.431	0.6	mg/kg	0710INCS03	5 / 5	NA - NA	1	800
7440-70-2	Calcium	2,690	2,860	mg/kg	0710INCS02	5 / 5	NA - NA	NV	NV
7440-47-3	Chromium	11.2	15.7	mg/kg	0710INCS05	5 / 5	NA - NA	42	920
7440-48-4	Cobalt	9.42	10.9	mg/kg	0710INCS01	5 / 5	NA - NA	NV	300
7440-50-8	Copper	30 J	39.4 J	mg/kg	0710INCS05	5 / 5	NA - NA	36	12,000
7439-89-6	Iron	29,700	38,100	mg/kg	0710INCS04	5 / 5	NA - NA	NV	720,000
7439-92-1	Lead	49.6	64.4	mg/kg	0710INCS01	5 / 5	NA - NA	17	800
7439-95-4	Magnesium	2420 J	3170 J	mg/kg	0710INCS04	5 / 5	NA - NA	NV	NV
7439-96-5	Manganese	524	609	mg/kg	0710INCS02	5 / 5	NA - NA	NV	7,200
7439-97-6	Mercury	0.241	0.306	mg/kg	0710INCS03	5 / 5	NA - NA	0.07	93
7440-02-0	Nickel	9.13	12.4	mg/kg	0710INCS05	5 / 5	NA - NA	38	20,000
7440-09-7	Potassium	660	888	mg/kg	0710INCS04	5 / 5	NA - NA	NV	NV
7782-49-2	Selenium	1.1 J	1.4 J	mg/kg	0710INCS02	4 / 5	NA - NA	2	5,100
7440-22-4	Silver	0.958	1.46	mg/kg	0710INCS05	5 / 5	NA - NA	1	1,500
7440-23-5	Sodium	122	172	mg/kg	0710INCS04	5 / 5	NA - NA	NV	NV
7440-28-0	Thallium	0.093	0.17	mg/kg	0710INCS01	5 / 5	NA - NA	NV	NV
7440-62-2	Vanadium	42.1	54.1	mg/kg	0710INCS04	5 / 5	NA - NA	NV	5,200
7440-66-6	Zinc	128	143	mg/kg	0710INCS04	5 / 5	NA - NA	86	310,000

Notes:

J - estimated concentration
TEQ - toxicity equivalent
PCB - polychlorinated biphenyl
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality
RSL - regional screening levels
RBC - risk-based concentration

PAH - polycyclic aromatic hydrocarbon
mg/kg - milligram per kilogram
NV - no value
NA - not available
CAS - Chemical Abstracts Service
No. - number
PRG - preliminary remediation goal

Bold values exceed Comparison Criteria.

Underlined values exceed Reference Value.

(1) Background values from Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(2) Comparison criteria for soil, include ODEQ (2008) risk-based concentrations (RBCs) for soil (ingestion, dermal contact and inhalation for construction workers). EPA (2008a) regional screening levels (RSLs) for industrial soil are used for chemicals where RBCs are not available.

(3) Comparison criterion for acenaphthene is used as a surrogate for acenaphthylene.

(4) Comparison criterion for pyrene is used as a surrogate for benzo(g,h,i)perylene.

(5) Carcinogenic PAHs: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

(6) EPA Region 9 preliminary remediation goal (PRG) (2004) for residential soil is used as comparison criterion for dibenzofuran.

(7) Comparison criterion for fluoranthene is used as a surrogate for phenanthrene.

(8) Total PCBs: Aroclor 1016, Aroclor 1221, Aroclor 1232, Aroclor 1242, Aroclor 1248, Aroclor 1254, and Aroclor 1260.

Table 4-7a
Soil Summary Statistics, Reference, and Comparison Criteria
Fire Training Area
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical		Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Comaprison Criteria (2)
Volatile Organic Compounds										
95-63-6	1,2,4-Trimethylbenzene		0.0027 J	10 J	mg/kg	FTA-15	2 / 15	0.021 - 0.04	NV	2,000
98-82-8	Isopropylbenzene		0.66 J	0.66 J	mg/kg	FTA-15	1 / 15	0.021 - 0.04	NV	24,000
103-65-1	n-Propylbenzene		1.4 J	1.4 J	mg/kg	FTA-15	1 / 15	0.021 - 0.04	NV	21,000
Polycyclic Aromatic Hydrocarbons										
91-57-6	2-Methylnaphthalene		0.0047 J	0.014	mg/kg	FTA-01	2 / 15	0.0055 - 0.11	NV	4,100
83-32-9	Acenaphthene		0.03	2.3 J	mg/kg	FTA-15	3 / 15	0.0055 - 0.0066	NV	19,000
208-96-8	Acenaphthylene	(3)	0.0048 J	0.0061 J	mg/kg	FTA-06	2 / 15	0.0055 - 0.11	NV	19,000
120-12-7	Anthracene		0.022	0.046	mg/kg	FTA-01	2 / 15	0.0055 - 0.11	NV	93,000
191-24-2	Benzo(g,h,i)perylene	(4)	0.032 J	0.22 J	mg/kg	FTA-15	4 / 15	0.0055 - 0.0066	NV	6,700
-	Carcinogenic PAHs	(5)	0.015	0.61	mg/kg	FTA-15	4 / 15	0.0055 - 0.11	NV	2.1
206-44-0	Fluoranthene		0.0033 J	1.4 J	mg/kg	FTA-15	5 / 15	0.0055 - 0.0066	NV	8,900
86-73-7	Fluorene		0.014	14 J	mg/kg	FTA-15	3 / 15	0.0055 - 0.0066	NV	12,000
91-20-3	Naphthalene		0.0058 J	0.75 J	mg/kg	FTA-15	3 / 15	0.0055 - 0.0066	NV	580
85-01-8	Phenanthrene	(6)	0.04	15 J	mg/kg	FTA-15	3 / 15	0.0055 - 0.0066	NV	8,900
129-00-0	Pyrene		0.0032 J	1.8 J	mg/kg	FTA-15	5 / 15	0.0055 - 0.0066	NV	6,700
Dioxin/Furan										
-	Dioxin/Furan TEQ		3.3E-08	1.5E-06	mg/kg	FTA-15	3 / 3	NA - NA	NV	1.30E-04
Pesticides/Polychlorinated biphenyls										
-	Total DDT	(7)	0.0038	0.0038	mg/kg	FTA-15	1 / 3	0.001 - 0.005	NV	58
76-44-8	Heptachlor		0.0043 J	0.0043 J	mg/kg	FTA-15	1 / 3	0.001 - 0.0011	NV	3.7
72-43-5	Methoxychlor		0.0039 J	0.0039 J	mg/kg	FTA-15	1 / 3	0.001 - 0.0011	NV	3,100
Inorganics										
7440-38-2	Arsenic		1.13	6.14	mg/kg	FTA-01	15 / 15	0.548 - 0.659	7	13
7440-39-3	Barium		33.2	139	mg/kg	FTA-06	15 / 15	0.548 - 0.659	NV	60,000
7440-43-9	Cadmium		0.167 J	1.31	mg/kg	FTA-06	15 / 15	0.548 - 0.659	1	800
7440-47-3	Chromium	(8)	7.43	40.8	mg/kg	FTA-06	15 / 15	0.548 - 0.659	42	920
7439-92-1	Lead		1.65 J	85.1	mg/kg	FTA-06	15 / 15	2.19 - 2.64	17	800
7782-49-2	Selenium		0.167 J	0.749 J	mg/kg	FTA-01	5 / 15	1.1 - 1.32	2	5,100
7440-22-4	Silver		0.143 J	0.212 J	mg/kg	FTA-15	2 / 15	3.29 - 3.95	1	1,500
Total Petroleum Hydrocarbons										
-	Diesel Range Hydrocarbons	(9)	9.5	**22,000**	mg/kg	FTA-15	6 / 15	5.3 - 6.8	NV	20,000
-	Oil Range Hydrocarbons		12	3,200	mg/kg	FTA-15	6 / 15	11 - 14	NV	40,000
-	Gasoline Range Hydrocarbons	(9)	16	260	mg/kg	FTA-15	2 / 15	6.3 - 13	NV	20,000

Notes:

J - estimated concentration
PAH - polycyclic aromatic hydrocarbon
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality
RSL - regional screening level

mg/kg - milligram per kilogram
TEQ - toxicity equivalent
CAS - Chemical Abstracts Service
RBCs - risk-based concentrations
DDT - dichlorodiphenyltrichloroethane

NA - not applicable
NV - no value
DU - decision unit
No. - number

Bold values exceed Comparison Criteria.

Underlined values exceed Reference Value.

(1) Background values from Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(2) Comparison criteria for soil, include ODEQ (2008) risk-based concentrations (RBCs) for soil (ingestion, dermal contact and inhalation for construction workers). EPA (2008a) regional screening levels (RSLs) for industrial soil are used for chemicals where RBCs are not available.

(3) Comparison criterion for acenaphthene is used as a surrogate for acenaphthylene.

(4) Comparison criterion for pyrene is used as a surrogate for benzo(g,h,i)perylene.

(5) Carcinogenic PAHs: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

(6) Comparison criterion for fluoranthene is used as a surrogate for phenanthrene.

(7) Total DDT: p,p'-dichlorodiphenyldichloroethane, p,p'-dichlorodiphenyldichloroethylene, and p,p'-dichlorodiphenyltrichloroethane.

(8) EPA RSL value is used as the comparison criterion for chromium.

(9) DU-specific RBCs are developed for diesel-range petroleum hydrocarbons and gasoline-range petroleum hydrocarbons based on total petroleum hydrocarbon fraction data (ODEQ 2003).

Table 4-7b
Soil Gas Summary Statistics, Reference, and Comparison Criteria
Fire Training Area
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Comparison Criteria (2)
Volatile Organic Compounds									
71-55-6	1,1,1-Trichloroethane	0.22 J	0.28 J	µg/m^3	FTA-06G	4 / 7	3.2 - 3.2	0.064 J - 0.069 J	5,200,000
76-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane	0.76 J	0.97 J	µg/m^3	FTA-03G	4 / 7	5.7 - 57	0.78 J - 1.1 J	31,000,000
75-35-4	1,1-Dichloroethene	0.013 J	0.061	µg/m^3	FTA-04G	4 / 7	1.2 - 1.2	0.064 U - 0.065 U	210,000
75-37-6	1,1-Difluoroethane	4.5	11,000	µg/m^3	FTA-07G	3 / 7	2 - 8	NA	42,000,000
95-63-6	1,2,4-Trimethylbenzene	0.72	44	µg/m^3	FTA-05G	7 / 7	0.71 - 37	0.25 J - 0.58 J	7,300
107-06-2	1,2-Dichloroethane	0.053 J	0.19 J	µg/m^3	FTA-03G	3 / 7	2.4 - 2.4	0.48 J - 0.52 J	94
108-67-8	1,3,5-Trimethylbenzene	2.4 J	20	µg/m^3	FTA-03G	6 / 7	0.71 - 0.71	0.81 U - 0.14 J	6,300
106-99-0	1,3-Butadiene	3.8	16	µg/m^3	FTA-05G	5 / 7	6.6 - 16	0.36 U	81
78-93-3	2-Butanone	3.5	12	µg/m^3	FTA-01G	5 / 7	8.8 - 22	0.54 - 1.4	5,200,000
591-78-6	2-Hexanone	0.69 J	0.89 J	µg/m^3	FTA-02G	2 / 7	2.9 - 120	3.3 U - 0.28 J	NV
67-63-0	2-Propanol	0.48 J	17 J	µg/m^3	FTA-05G	4 / 7	1.8 - 73	2 U - 0.5 J	NV
622-96-8	4-Ethyltoluene	0.31 J	41	µg/m^3	FTA-03G	7 / 7	0.71 - 37	0.23 J - 0.52 J	NV
108-10-1	4-Methyl-2-pentanone	0.95	0.95	µg/m^3	FTA-03G	1 / 7	0.59 - 30	0.66 U - 0.67 U	3,100,000
67-64-1	Acetone	24	100	µg/m^3	FTA-05G	7 / 7	1.7 - 71	6.8 U - 13	32,000,000
71-43-2	Benzene	4.1	49	µg/m^3	FTA-06G	7 / 7	0.23 - 24	0.5 U - 0.63	310
75-27-4	Bromodichloromethane	2.9	2.9	µg/m^3	FTA-03G	1 / 7	0.96 - 50	1.1 U	66
75-15-0	Carbon Disulfide	4.8 J	86	µg/m^3	FTA-05G	7 / 7	2.2 - 46	2.5 U - 2.6 U	730,000
56-23-5	Carbon Tetrachloride	0.35 J	0.64 J	µg/m^3	FTA-06G/FTA-04G	4 / 7	4.7 - 47	0.46 J - 0.67 J	160
108-90-7	Chlorobenzene	0.3 J	0.58 J	µg/m^3	FTA-03G	2 / 7	1.3 - 34	0.74 U - 0.76 U	52,000
67-66-3	Chloroform	0.98 J	**220**	µg/m^3	FTA-03G	6 / 7	36 - 36	0.79 U - 0.8 U	110
156-59-2	cis-1,2-Dichloroethene	0.21 J	0.62 J	µg/m^3	FTA-01G	3 / 7	0.12 - 30	0.13 U	35,000
110-82-7	Cyclohexane	1.6	51	µg/m^3	FTA-05G	5 / 7	0.51 - 10	0.55 U - 0.56 U	6,300,000
75-71-8	Dichlorodifluoromethane	0.94	2.4	µg/m^3	FTA-03G	3 / 7	0.71 - 37	2.8 - 2.9	210,000
64-17-5	Ethanol	1.1 J	22 J	µg/m^3	FTA-06G	2 / 7	1.4 - 56	1.7 - 2.2	NV
100-41-4	Ethylbenzene	0.94	46	µg/m^3	FTA-05G	7 / 7	0.12 - 32	0.23 - 0.41	970
110-54-3	Hexane	12	110	µg/m^3	FTA-05G	6 / 7	10 - 10	0.14 J - 0.25 J	730,000
98-82-8	Isopropylbenzene	0.42 J	3.5	µg/m^3	FTA-03G	5 / 7	3.7 - 37	0.79 U - 0.81 U	420,000
75-09-2	Methylene Chloride	6.3	6.3	µg/m^3	FTA-03G	1 / 7	21 - 21	1.1 U - 0.54 J	5,200
142-82-5	n-Heptane (3)	4.1	66	µg/m^3	FTA-06G	6 / 7	12 - 12	0.67 U - 0.29 J	6,300,000
103-65-1	n-Propylbenzene	0.46 J	10 J	µg/m^3	FTA-05G	6 / 7	3.7 - 3.7	0.81 U - 0.17 J	1,000,000
95-47-6	o-Xylene	1.1	41	µg/m^3	FTA-03G	7 / 7	0.12 - 32	0.15 - 0.27	730,000
100-42-5	Styrene	0.16 J	0.16 J	µg/m^3	FTA-04G	1 / 7	0.91 - 32	0.68 U - 0.7 U	1,000,000
127-18-4	Tetrachloroethene	0.81 J	83	µg/m^3	FTA-04G	6 / 7	50 - 50	0.029 J - 0.031 J	410
108-88-3	Toluene	6.1	270	µg/m^3	FTA-03G/FTA-05G	7 / 7	0.11 - 28	0.61 - 0.88	5,200,000
156-60-5	trans-1,2-Dichloroethene	0.78	0.78	µg/m^3	FTA-04G	1 / 7	0.59 - 12	0.64 U - 0.65 U	63,000
79-01-6	Trichloroethene	0.16 J	0.54	µg/m^3	FTA-03G	2 / 7	0.16 - 40	0.1 U - 0.17 U	27
75-69-4	Trichlorofluoromethane	1.1 J	3.2 J	µg/m^3	FTA-02G	4 / 7	4.2 - 42	2.7 J - 2.8 J	730,000
75-01-4	Vinyl Chloride	0.021 J	0.058 J	µg/m^3	FTA-06G	3 / 7	0.038 - 0.76	0.041 U - 0.042 U	170
179601-23-1	Xylenes (Total)	0.92	170	µg/m^3	FTA-03G	7 / 7	0.25 - 32	0.59 - 1.1	100,000

Notes:

RFP - refueling pit
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality
RSL - regional screening level

U - not detected at reporting limit shown
µg/m^3 - microgram per cubic meter
CAS - Chemical Abstracts Service
SVOCs - semi-volatile organic compounds

J - estimated concentration
NA - not analyzed
NV - no value

Bold values exceed Comparison Criteria.

Underlined values exceed Reference Value.

(1) Reference values are based on the concentrations at the upgradient and downgradient ambient air samples (RFP3-19 and RFP3-18) collected at Refueling Pit 3. They are presented for informational purposes only.

(2) EPA (2008a) regional screening levels (RSLs) for residential air multiplied by an attenuation factor of 1000 are used to derive soil gas screening levels. When EPA RSL is not available, shallow soil gas concentrations presented in EPA's Subsurface Vapor Intrusion Guidance (2002f) are used, multiplied by an attenuation factor of 100 to account for a total attenuation factor of 1000.
(3) Comparison criteria for cyclohexane is used as a surrogate for n-heptane.

Table 4-7c
Groundwater Summary Statistics, Reference, and Comparison Criteria
Fire Training Area
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Comparison Criteria (2)
Volatile Organic Compounds									
95-63-6	1,2,4-Trimethylbenzene	0.31 J	**19 J**	µg/L	FTA-09	3 / 17	2 - 2	2 U	15
108-67-8	1,3,5-Trimethylbenzene	3.4 J	3.4 J	µg/L	FTA-09	1 / 17	2 - 2	2 U	12
71-43-2	Benzene	**0.42 J**	**3.8**	µg/L	FTA-08	3 / 17	0.5 - 0.5	0.5 U	0.39
156-59-2	cis-1,2-Dichloroethene	0.4 J	4.3	µg/L	FTA-14	12 / 17	0.5 - 0.5	NV	360
98-82-8	Isopropylbenzene	0.84 J	1.3 J	µg/L	FTA-09	2 / 17	2 - 2	2 U	680
103-65-1	n-Propylbenzene	1.2	1.9 J	µg/L	FTA-09	2 / 17	0.5 - 0.5	0.5 U	1,300
95-47-6	o-Xylene	0.46 J	0.46 J	µg/L	FTA-09	1 / 17	0.5 - 0.5	0.5 U	1,200
156-60-5	trans-1,2-Dichloroethene	0.22 J	0.22 J	µg/L	FTA-14	1 / 17	0.5 - 0.5	NV	110
75-01-4	Vinyl Chloride	**0.35 J**	**27**	µg/L	FTA-02	12 / 17	0.5 - 0.5	NV	0.025
1330-20-7	Xylenes (total)	6.9 J	6.9 J	µg/L	FTA-09	1 / 17	1 - 1	1 U	200
Polycyclic Aromatic Hydrocarbons									
83-32-9	Acenaphthene	0.01 J	1.4	µg/L	FTA-09	6 / 17	0.019 - 0.019	0.019 U	2,200
208-96-8	Acenaphthylene (3)	0.23	0.68 J	µg/L	FTA-09	2 / 17	0.019 - 0.019	0.019 U	2,200
-	Carcinogenic PAHs (4)	**0.022**	**0.022**	µg/L	FTA-09	1 / 17	0.019 - 0.019	NV	0.0029
132-64-9	Dibenzofuran (5)	0.013 J	1.3 J	µg/L	FTA-09	5 / 17	0.019 - 0.019	0.019 U	12
206-44-0	Fluoranthene	0.0097 J	0.035	µg/L	FTA-09,FTA-15	5 / 17	0.019 - 0.094	0.019 U	1,500
86-73-7	Fluorene	0.019	3.1	µg/L	FTA-09	6 / 17	0.019 - 0.019	0.019 U	1500
91-20-3	Naphthalene	0.013 J	**0.18**	µg/L	FTA-09	6 / 17	0.019 - 0.094	0.019 U	0.14
85-01-8	Phenanthrene (6)	0.011 J	1.7	µg/L	FTA-09	7 / 17	0.019 - 0.019	0.019 U	1,500
129-00-0	Pyrene	0.011 J	0.05 J	µg/L	FTA-09	6 / 17	0.019 - 0.094	0.019 U	1,100
Dioxin/Furan									
-	Dioxin/Furan TEQ	1.1E-07	**4.1E-06**	µg/L	FTA-14	2 / 3	NA - NA	NV	3.8E-07
Pesticides/Polychlorinated biphenyls									
-	Total DDT (7)	0.00054	0.00054	µg/L	FTA-09	1 / 5	0.00062 - 0.00063	NV	0.17

Table 4-7c (continued)
Groundwater Summary Statistics, Reference, and Comparison Criteria
Fire Training Area
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Comparison Criteria (2)
Inorganics									
7429-90-5	Aluminum	323 J	326 J	µg/L	FTA-02	2 / 17	1,000 - 1,000	1,000 U	37,000
7440-36-0	Antimony	0.65 J	0.738 J	µg/L	FTA-04	2 / 17	1 - 1	1 U	15
7440-38-2	Arsenic	**0.506 J**	**15**	µg/L	FTA-04	16 / 17	1 - 1	1 U	0.038
7440-39-3	Barium	47.2	191	µg/L	FTA-06	17 / 17	1 - 1	31.7	7,300
7440-70-2	Calcium	24,700	81,200	µg/L	FTA-05	17 / 17	1,000 - 1,000	37,600	NV
7440-47-3	Chromium (8)	0.517 J	2.65 J	µg/L	FTA-05	5 / 17	5 - 5	5 U	110
7440-50-8	Copper	0.621 J	2.83	µg/L	FTA-03	6 / 17	2 - 2	2 U	1,500
7439-89-6	Iron	5,310	**70,400**	µg/L	FTA-05	17 / 17	1,000 - 1,000	2,570	26,000
7439-92-1	Lead	0.616 J	2.49	µg/L	FTA-03	6 / 17	1 - 1	1 U	15
7439-95-4	Magnesium	17,600	51,800	µg/L	FTA-05	17 / 17	1,000 - 1,000	20,300	NV
7439-96-5	Manganese	**1,110**	**5,170**	µg/L	FTA-05	17 / 17	1 - 5	127	880
7440-02-0	Nickel	0.6 J	79.7	µg/L	FTA-13	13 / 17	10 - 10	0.607	730
7440-66-6	Zinc	5.8 J	107	µg/L	FTA-13	12 / 17	10 - 10	10 U	11,000
Total Petroleum Hydrocarbons									
-	Diesel Range Hydrocarbons (9)	**250**	**1,100 J**	µg/L	FTA-09	5 / 17	250 - 250	250 U	200
-	Gasoline Range Hydrocarbons (9)	**320**	**710**	µg/L	FTA-09	2 / 17	250 - 250	250 U	200

Notes:

FTA - fire training area
U - not detected at reporting limit shown
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality
TEQ - toxicity equivalent
DDT - dichlorodiphenyltrichloroethane

J - estimated concentration
µg/L - microgram per liter
CAS - Chemical Abstracts Service
No. - number
PRG - preliminary remediation goal

NA - not applicable
NV - no value
RBCs - risk-based concentrations
DU - descision unit
RSL - regional screening levels

Bold values exceed Comparison Criteria.

Underlined values exceed Reference Value.

(1) Reference values are based on the concentrations at the upgradient monitoring well UST1-18. They are presented for informational purposes only.

(2) Comparison criteria for groundwater, which are ODEQ (2008) RBCs for groundwater (ingestion and inhalation from tap water for residential properties). EPA (2008a) RSLs for tap water are used for chemicals where RBCs are not available.
(3) Comparison criterion for acenaphthene is used as a surrogate for acenaphthylene.
(4) Carcinogenic PAHs: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, and dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene.
(5) EPA Region 9 preliminary remediation goal (PRG) (2004) for tap water is used as the comparison criterion for dibenzofuran.
(6) Comparison criterion for fluoranthene is used as a surrogate for phenanthrene.
(7) Total DDT: p,p'-dichlorodiphenyldichloroethane, p,p'-dichlorodiphenyldichloroethylene, and p,p'-dichlorodiphenyltrichloroethane.
(8) Comparison criterion for chromium VI is used as a surrogate for chromium.
(9) DU-specific RBCs are developed for diesel range and gasoline range petroleum hydrocarbons based on total petroleum hydrocarbon fraction data (ODEQ 2003).

Table 4-7d
Surface Water Summary Statistics, Reference, and Comparison Criteria
Fire Training Area
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Background Value (2)	Comparison Criteria (3)
Semi-Volatile Organic Compounds										
206-44-0	Fluoranthene	0.00041	0.00045	µg/L	FTA-28	2 / 2	0.0004 - 0.0004	0.00065	NV	130
85-01-8	Phenanthrene (4)	0.00055	0.00097	µg/L	FTA-27	2 / 2	0.0004 - 0.0004	0.00064	NV	130
Pesticides/Polychlorinated biphenyls										
58-89-9	gamma-BHC (Lindane)	0.0022	0.0031	µg/L	FTA-27	2 / 2	0.0004 - 0.0004	0.0044	NV	0.98
Inorganics										
7440-38-2	Arsenic	**0.951 J**	**0.998 J**	µg/L	FTA-28	2 / 2	1 - 1	0.938	<1	0.018
7440-39-3	Barium	26.8	27.6	µg/L	FTA-28	2 / 2	1 - 1	25.9	NV	1,000
7439-96-5	Manganese	13	15.8	µg/L	FTA-28	2 / 2	1 - 1	15.7	NV	50
7440-02-0	Nickel	0.981 J	1.32 J	µg/L	FTA-27	2 / 2	10 - 10	0.599	5.5	610
7440-66-6	Zinc	5.27 J	5.27 J	µg/L	FTA-27	1 / 2	10 - 10	6.11	38	7,400

Notes:

FTA - fire training area
J - estimated concentration
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality
SVOC - semi-volatile organic compound

U - not detected at reporting limit shown
µg/L - microgram per liter
RSL - regional screening level
OAR - Oregon Administrative Record
RBCs - risk-based concentrations

CAS - Chemical Abstracts Service
No. - number
NV - no value

Bold values exceed Comparison Criteria.

Underlined values exceed Reference or Background Value.

(1) Based on site-specific SVOC concentration of Aquatic Reference Area. They are presented for informational purposes only.

(2) Background values from Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(3) Comparison criteria for surface water, which are State of Oregon water quality criteria for human health for consumption of water and organism (OAR 340-041 Tables 33A and 33B) (ODEQ 2009b). National Recommended Water Quality Criteria (EPA 2006b) for human health for consumption of water and organism are used when State of Oregon water quality criteria are not available. ODEQ RBCs for groundwater or EPA RSLs for tap water are used when water quality criteria are not available.

(4) Comparison criterion for fluoranthene is used as a surrogate for phenanthrene.

Table 4-7e
Sediment Summary Statistics, Reference, and Comparison Criteria
Fire Training Area
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Background Value (2)	Comparison Criteria (3)
Semi-Volatile Organic Compounds										
91-57-6	2-Methylnaphthalene	0.00068 J	0.0011 J	mg/kg	FTA-26	2 / 2	0.0028 - 0.0031	0.0009	NV	310
83-32-9	Acenaphthene	0.00061 J	0.0013 J	mg/kg	FTA-26	2 / 2	0.0028 - 0.0031	0.0005	NV	4,700
208-96-8	Acenaphthylene (4)	0.00094 J	0.0014 J	mg/kg	FTA-26	2 / 2	0.0028 - 0.0031	0.0006	NV	4,700
120-12-7	Anthracene	0.0038	0.0046	mg/kg	FTA-26	2 / 2	0.0028 - 0.0031	0.0016	NV	23,000
192-97-2	Benzo(e)pyrene (5)	0.018	0.024	mg/kg	FTA-26	2 / 2	0.0028 - 0.0031	0.0073	NV	380
191-24-2	Benzo(g,h,i)perylene (5)	0.018	0.025	mg/kg	FTA-26	2 / 2	0.0028 - 0.0031	0.0088	NV	380
117-81-7	bis(2-Ethylhexyl)phthalate	0.035 J	0.035 J	mg/kg	FTA-26	1 / 2	0.13 - 0.23	0.0064 U - 0.035 U	NV	35
86-74-8	Carbazole (6)	0.0029 J	0.003 J	mg/kg	FTA-26	2 / 2	0.012 - 0.013	0.0098 U - 0.01 U	NV	24
	Carcinogenic PAHs (7)	**0.031**	**0.040**	mg/kg	FTA-26	2 / 2	NA - NA	0.0125	NV	0.015
84-74-2	Di-n-butylphthalate	0.0089 J	0.0098 J	mg/kg	FTA-25	2 / 2	0.012 - 0.013	0.0066	NV	6,100
206-44-0	Fluoranthene	0.032	0.038	mg/kg	FTA-26	2 / 2	0.0028 - 0.0031	0.0122	NV	510
86-73-7	Fluorene	0.0011 J	0.0014 J	mg/kg	FTA-26	2 / 2	0.0028 - 0.0031	0.0006	NV	3,100
91-20-3	Naphthalene	0.0021 J	0.0034	mg/kg	FTA-26	2 / 2	0.0028 - 0.0031	0.0013	NV	4.6
85-01-8	Phenanthrene (8)	0.011	0.013	mg/kg	FTA-26	2 / 2	0.0028 - 0.0031	0.0054	NV	510
108-95-2	Phenol	0.0049 J	0.0062 J	mg/kg	FTA-25	2 / 2	0.034 - 0.037	0.0093	NV	18,000
129-00-0	Pyrene	0.034	0.044	mg/kg	FTA-26	2 / 2	0.0028 - 0.0031	0.0141	NV	380
Pesticides/Polychlorinated Biphenyls										
-	Total DDT (9)	**0.00211**	**0.00217**	mg/kg	FTA-25	2 / 2	NA - NA	0.0011	NV	0.00033
-	Total PCBs (10)	**0.0069 J**	**0.02 J**	mg/kg	FTA-26	2 / 2	NA - NA	10 U - 35 U	NV	0.00039
Inorganics										
7440-36-0	Antimony	0.18 J	0.2 J	mg/kg	FTA-26	2 / 2	0.05 - 0.06	0.11	NV	31
7440-38-2	Arsenic	5.56	6.52	mg/kg	FTA-25	2 / 2	0.5 - 0.55	4.95	1	7
7440-39-3	Barium	87.1	108	mg/kg	FTA-26	2 / 2	2 - 2.2	85	NV	15,000
7440-43-9	Cadmium	0.633	0.698	mg/kg	FTA-26	2 / 2	0.02 - 0.022	0.30	<0.5	1
7440-47-3	Chromium (11)	20.3	21.6	mg/kg	FTA-26	2 / 2	2 - 2.2	14.83	NV	38
7440-50-8	Copper	53.1	57.1	mg/kg	FTA-26	2 / 2	2 - 2.2	29.47	30	3,100
7439-92-1	Lead	**17.4**	**17.8**	mg/kg	FTA-26	2 / 2	0.05 - 0.06	7.80	2	17
7439-96-5	Manganese	327	359	mg/kg	FTA-26	2 / 2	2.02 - 2.18	480	480	1,800
7439-97-6	Mercury	**0.105 J**	**0.116 J**	mg/kg	FTA-25	2 / 2	0.019 - 0.02	0.06	0.2	0.07
7440-02-0	Nickel	19.7	19.8	mg/kg	FTA-25	2 / 2	0.2 - 0.22	12.51	20	12,000
7782-49-2	Selenium	0.8 J	0.8 J	mg/kg	FTA-25	2 / 2	1 - 1.1	0.45	0.4	2
7440-22-4	Silver	0.13	0.13	mg/kg	FTA-25/FTA-26	2 / 2	0.02 - 0.02	0.070	0.4	390
7440-62-2	Vanadium	68	72.5	mg/kg	FTA-26	2 / 2	2 - 2.2	53.41	NV	390
7440-66-6	Zinc	92.4	104	mg/kg	FTA-26	2 / 2	2.02 - 2.18	65.53	53	23,000

Table 4-7e (continued)
Sediment Summary Statistics, Reference, and Comparison Criteria
Fire Training Area
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Background Value (2)	Comparison Criteria (3)
Total Petroleum Hydrocarbons										
-	Diesel Range Hydrocarbons (12)	25 J	33 J	mg/kg	FTA-26	2 / 2	56 - 61	8.99	NV	4,400
-	Oil Range Hydrocarbons	150 J	200 J	mg/kg	FTA-26	2 / 2	230 - 250	49.71	NV	9,800

Notes:

FTA - fire training area
PAH - polycyclic aromatic hydrocarbon
mg/kg - milligram per kilogram
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality
PRG - preliminary remediation goal

U - not detected at reporting limit shown
DDT - dichlorodiphenyltrichloroethane
CAS - Chemical Abstracts Service
NA - not applicable
RBCs - risk-based concentrations
DU - decision unit

J - estimated concentration
PCB - polychlorinated biphenyls
No. - number
NV - no value
RSL - regional screening level

Bold values exceed Comparison Criteria.

Underlined values exceed Reference or Background Value.

(1) Based on site-specific mean sediment concentrations of Aquatic Reference Area. They are presented for informational purposes only.

(2) From Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(3) Comparison criteria for sediment, which are ODEQ (2007a) sediment bioaccumulation screening level values for humans when available. Otherwise they are ODEQ (2008) risk-based concentrations (RBCs) for soil (ingestion, dermal contact and inhalation for residential properties). EPA (2008a) regional screening levels (RSLs) for residential soil are used for chemicals where RBCs are not available.
(4) Comparison criterion for acenaphthene is used as a surrogate for acenaphthylene.
(5) Comparison criterion for pyrene is used as a surrogate for benzo(e)pyrene and benzo(g,h,i)perylene.
(6) EPA Region 9 preliminary remediation goal (PRG) (2004) for residential soil is used as screening level for carbazole.
(7) Carcinogenic PAHs: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-c)pyrene.
(8) Comparison criterion for fluoranthene is used as a surrogate for phenanthrene.
(9) Total DDT: p,p'-dichlorodiphenyldichloroethane, p,p'-dichlorodiphenyldichloroethylene, and p,p'-dichlorodiphenyltrichloroethane.
(10) Total PCBs: Aroclor 1016, Aroclor 1221, Aroclor 1232, Aroclor 1242, Aroclor 1248, Aroclor 1254, and Aroclor 1260.
(11) EPA regional screening level (RSL) value is used as the comparison criterion for chromium.
(12) DU-specific RBCs are developed for diesel range petroleum hydrocarbons based on total petroleum hydrocarbon fraction data (ODEQ 2003).

Table 4-8a
Surface Water Summary Statistics, Reference, and Comparison Criteria
Aquatic - North of Pier 8
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Background Value (2)	Comparison Criteria (3)
Semi-volatile Organic Compounds										
85-01-8	Phenanthrene (4)	0.00044	0.00044	µg/L	NTP-11	1 / 1	0.0004 - 0.0004	0.00064	NV	130
Pesticides/Polychlorinated Biphenyls										
58-89-9	gamma-BHC (Lindane)	0.00086	0.00086	µg/L	NTP-11	1 / 1	0.0004 - 0.0004	0.00440	NV	0.98
Inorganics										
7440-38-2	Arsenic	**1.04**	**1.04**	µg/L	NTP-11	1 / 1	1 - 1	0.94	2	0.018
7440-39-3	Barium	27.1	27.1	µg/L	NTP-11	1 / 1	1 - 1	25.90	NV	1,000
7439-96-5	Manganese	15.4	15.4	µg/L	NTP-11	1 / 1	1 - 1	15.70	NV	50
7440-02-0	Nickel	1.31 J	1.31 J	µg/L	NTP-11	1 / 1	10 - 10	0.60	5.5	610

Notes:

NTP - north of pier 8
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality
SVOC - semi-volatile organic compound

µg/L - microgram per liter
CAS - Chemical Abstracts Service
OAR - Oregon Administrative Record
RBCs - risk-based concentrations

J - estimated concentration
NV - no value
No. - number
RSL - regional screening level

Bold values exceed Comparison Criteria.

Underlined values exceed Reference or Background Value.

(1) Based on site-specific SVOC concentration of Aquatic Reference Area. They are presented for informational purposes only.

(2) Background values from Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(3) Comparison criteria for surface water, which are State of Oregon water quality criteria for human health for consumption of water and organism (OAR 340-041 Tables 33A and 33B) (ODEQ 2009b). National Recommended Water Quality Criteria (EPA 2006b) for human health for consumption of water and organism are used when State of Oregon water quality criteria are not available. ODEQ RBCs for groundwater or EPA RSLs for tap water are used when water quality criteria are not available.

(4) Comparison criteria for fluoranthene is used as a surrogate for phenanthrene.

Table 4-8b
Sediment Summary Statistics, Reference, and Comparison Criteria
Aquatic - North of Pier 8
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Background Value (2)	Comparison Criteria (3)
Semi-volatile Organic Compounds										
91-57-6	2-Methylnaphthalene	0.0007 J	0.0026	mg/kg	NTP-03	7 / 7	0.0025 - 0.0025	0.0009	NV	310
83-32-9	Acenaphthene	0.0005 J	0.0009 J	mg/kg	NTP-05	7 / 7	0.0025 - 0.0025	0.0005	NV	4,700
208-96-8	Acenaphthylene (4)	0.0005 J	0.0010 J	mg/kg	NTP-01	7 / 7	0.0025 - 0.0025	0.0006	NV	4,700
120-12-7	Anthracene	0.0025 J	0.0081	mg/kg	NTP-01	7 / 7	0.0025 - 0.0025	0.0016	NV	23,000
192-97-2	Benzo(e)pyrene (5)	0.0100	0.0250	mg/kg	NTP-01	7 / 7	0.0025 - 0.0025	0.0073	NV	380
191-24-2	Benzo(g,h,i)perylene (5)	0.0089	0.0210	mg/kg	NTP-01	7 / 7	0.0025 - 0.0025	0.0088	NV	380
117-81-7	bis(2-Ethylhexyl)phthalate	0.0310 J	0.0310 J	mg/kg	NTP-04	1 / 7	0.1000 - 0.1000	0.0064 U - 0.035 U	NV	35
86-74-8	Carbazole (6)	0.0017 J	0.0033 J	mg/kg	NTP-03	7 / 7	0.0100 - 0.0100	0.0098 U - 0.01 U	NV	24
-	Carcinogenic PAHs (7)	0.0145	**0.0466**	mg/kg	NTP-01	7 / 7	NA - NA	0.0125	NV	0.015
206-44-0	Fluoranthene	0.0190 J	0.0390	mg/kg	NTP-03	7 / 7	0.0025 - 0.0025	0.0122	NV	510
86-73-7	Fluorene	0.0008 J	0.0014 J	mg/kg	NTP-02	7 / 7	0.0025 - 0.0025	0.0006	NV	3,100
91-20-3	Naphthalene	0.0022 J	0.0054	mg/kg	NTP-03	7 / 7	0.0025 - 0.0025	0.0013	NV	4.6
85-01-8	Phenanthrene (8)	0.0086	0.0160	mg/kg	NTP-03	7 / 7	0.0025 - 0.0025	0.0054	NV	510
108-95-2	Phenol	0.0350 J	0.0350 J	mg/kg	NTP-02	1 / 7	0.0300 - 0.0300	0.0093	NV	18,000
129-00-0	Pyrene	0.0180 J	0.0420	mg/kg	NTP-03	7 / 7	0.0025 - 0.0025	0.0141	NV	380
Inorganics										
7440-36-0	Antimony	0.17 J	0.37 J	mg/kg	NTP-04	7 / 7	0.05 - 0.05	0.11	NV	31
7440-38-2	Arsenic	6.83	**8.31**	mg/kg	NTP-06	7 / 7	0.48 - 0.49	4.94	1	7
7440-39-3	Barium	70.9	78.7	mg/kg	NTP-07	7 / 7	1.9 - 2	85	NV	15,000
7440-43-9	Cadmium	0.326	0.39	mg/kg	NTP-07	7 / 7	0.019 - 0.02	0.30	<0.5	1
7440-47-3	Chromium (9)	17.4	20	mg/kg	NTP-01	7 / 7	1.9 - 2	15	NV	38
7440-50-8	Copper	35.7	38.9	mg/kg	NTP-03	7 / 7	1.9 - 2	29.47	30	3,100
7439-92-1	Lead	10.2	14.7	mg/kg	NTP-02	7 / 7	0.05 - 0.05	7.79	2	17
7439-96-5	Manganese	537	608	mg/kg	NTP-01	7 / 7	1.93 - 1.98	480	480	1,800
7439-97-6	Mercury	0.056	**0.098**	mg/kg	NTP-05	7 / 7	0.019 - 0.02	0.06	0.2	0.07
7440-02-0	Nickel	13.2	15.1	mg/kg	NTP-07	7 / 7	0.19 - 0.2	12.51	20	12,000
7782-49-2	Selenium	0.5 J	0.7 J	mg/kg	NTP-06	7 / 7	1 - 1	0.45	0.4	2
7440-22-4	Silver	0.07 J	0.11 J	mg/kg	NTP-07	7 / 7	0.02 - 0.02	0.07	0.4	390
7440-62-2	Vanadium	59.6	65.6	mg/kg	NTP-02	7 / 7	1.9 - 2	53	NV	390
7440-66-6	Zinc	77.3	84.2	mg/kg	NTP-04	7 / 7	1.93 - 1.98	65.53	53	23,000

Table 4-8b (continued)
Sediment Summary Statistics, Reference, and Comparison Criteria
Aquatic - North of Pier 8
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Background Value (2)	Comparison Criteria (3)
Total Petroleum Hydrocarbons										
-	Diesel Range Hydrocarbons	11 J	16 J	mg/kg	NTP-04/NTP-05	7 / 7	44 - 45	8.99	NV	3,900
-	Gasoline Range Hydrocarbons	2.9 J	2.9 J	mg/kg	MIS-21	1 / 3	3.8 - 5.8	3.3 U - 3.7 U	NV	720
-	Oil Range Hydrocarbons	56 J	74 J	mg/kg	NTP-03/NTP-04	7 / 7	180 - 180	49.71	NV	9,800

Notes:

NTP - north of pier 8
NV - no value
EPA - U.S. Environmental Protection Agency
PAH - polycyclic aromatic hydrocarbon
PRG - preliminary remediation goal

U - not detected at reporting limit shown
NA - not applicable
CAS - Chemical Abstracts Service
ODEQ - Oregon Department of Environmental Quality
RSL - regional screening level

J - estimated concentration
mg/kg - milligram per kilogram
No. - number
RBCs - risk-based concentrations
DU - decision unit

Bold values exceed Comparison Criteria.

Underlined values exceed Reference or Background Value.

(1) Based on site-specific mean sediment concentrations of Aquatic Reference Area. They are presented for informational purposes only.

(2) From Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(3) Comparison criteria for sediment, which are Oregon Department of Environmental Quality (ODEQ) (2007a) sediment bioaccumulation screening level values for humans when available. Otherwise they are ODEQ (2008) risk-based concentrations (RBCs) for soil (ingestion, dermal contact and inhalation for residential properties). EPA (2008a) regional screening levels (RSLs) for residential soil are used for chemicals where RBCs are not available.

(4) Comparison criterion for pyrene is used as a surrogate for benzo(e)pyrene and benzo(g,h,i)perylene.

(5) EPA Region 9 preliminary remediation goal (PRG) (2004a) for residential soil is used as comparison criterion for carbazole.

(6) Carcinogenic PAHs: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

(7) Comparison crtierion for anthracene is used as a surrogate for phenanthrene.

(8) EPA (2008a) regional screening level (RSL) is used as the comparison criterion for chromium.

Table 4-8c
Tissue Summary Statistics, Reference, and Comparison Criteria
Aquatic - North of Pier 8
Tongue Point Multi-Sites Project, Astoria, Oregon

Tissue Type	CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Detection Frequency	Reference Value (1)	Comparison Criteria (2)
Clams	**Polycyclic Aromatic Hydrocarbons**							
	206-44-0	Fluoranthene	0.021	0.021	mg/kg	1 / 1	0.0061	19
	129-00-0	Pyrene	0.01	0.01	mg/kg	1 / 1	0.0039 J	1
	Pesticides							
	-	Total DDT (3)	0.0014	0.0014	mg/kg	1 / 1	0.00614 J	0.054
	Dioxin/Furan							
	-	Dioxin/Furan TEQ	3.0E-06 J	3.0E-06 J	mg/kg	1 / 1	NC	6.40E-06
	Inorganics							
	7440-38-2	Arsenic	**11.1**	**11.1**	mg/kg	1 / 1	4.9	6.6
	7440-47-3	Chromium	2.46	2.46	mg/kg	1 / 1	4.25	NV
	7439-92-1	Lead	**0.229**	**0.229**	mg/kg	1 / 1	1.87	0.12
	7439-97-6	Mercury	0.062	0.062	mg/kg	1 / 1	0.066	0.088
	7782-49-2	Selenium	**2.7**	**2.7**	mg/kg	1 / 1	3.2	0.024
Forage Fish	**Polycyclic Aromatic Hydrocarbons**							
	206-44-0	Fluoranthene	0.0021 J	0.0021 J	mg/kg	1 / 1	0.005 U	19
	129-00-0	Pyrene	0.0013 J	0.0013 J	mg/kg	1 / 1	0.005 U	1
	Pesticides							
	-	Total DDT (3)	**0.1058**	**0.1058**	mg/kg	1 / 1	0.0222	0.054
	5103-71-9	Alpha-Chlordane	0.0014	0.0014	mg/kg	1 / 1	0.00098 U	0.06
	60-57-1	Dieldrin	0.001	0.001	mg/kg	1 / 1	0.00069 J	0.26
	118-74-1	Hexachlorobenzene	0.0073	0.0073	mg/kg	1 / 1	0.00081 J	32
	Dioxin/Furan							
	-	Dioxin/Furan TEQ	5.9E-07 J	5.9E-07 J	mg/kg	1 / 1	3.2E-07 J	6.40E-06
	Inorganics							
	7440-38-2	Arsenic	2.09	2.09	mg/kg	1 / 1	1.25	6.6
	7440-47-3	Chromium	0.53	0.53	mg/kg	1 / 1	0.47	NV
	7439-92-1	Lead	**0.604**	**0.604**	mg/kg	1 / 1	0.27	0.12
	7439-97-6	Mercury	**0.145**	**0.145**	mg/kg	1 / 1	0.303	0.088
	7782-49-2	Selenium	**1.9**	**1.9**	mg/kg	1 / 1	2.6	0.024
Fish Fillet	**Pesticides**							
	-	Total DDT (3)	0.00614 J	0.00614 J	mg/kg	1 / 1	0.00627 J	0.054
	Inorganics							
	7440-38-2	Arsenic	0.95	0.95	mg/kg	1 / 1	0.88	6.6
	7440-47-3	Chromium	0.66	0.66	mg/kg	1 / 1	0.52	NV
	7439-92-1	Lead	**0.201**	**0.201**	mg/kg	1 / 1	0.131	0.12
	7439-97-6	Mercury	**0.268**	**0.268**	mg/kg	1 / 1	0.205	0.088
	7782-49-2	Selenium	**2.2**	**2.2**	mg/kg	1 / 1	2	0.024

Notes:

J - estimated concentration
CAS - Chemical Abstracts Service
mg/kg - milligram per kilogram
NC - not calculated; all results are non-detect
ODEQ - Oregon Department of Environmental Quality

U - not detected at reporting limit shown
No. - number
TEQ - toxicity equivalent
NV - no value
DDT - dichlorodiphenyltrichloroethane

Bold values exceed Comparison Criteria.

Underlined values exceed Reference Value.

(1) Reference values based on concentration of tissue samples collected from Aquatic-Reference Area. They are presented for informational purposes only.

(2) Comparison criteria from Appendix A, Table A-4 from ODEQ (2007a) Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment.
(3) Total DDT: p,p'-dichlorodiphenyldichloroethane, p,p'-dichlorodiphenyldichloroethylene, and p,p'-dichlorodiphenyltrichloroethane.

Table 4-9a
Surface Water Summary Statistics, Reference, and Comparison Criteria
Aquatic - Finger Piers Area
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Background Value (2)	Comparison Criteria (3)
Semi-volatile Organic Compounds										
206-44-0	Fluoranthene	0.00045	0.00045	µg/L	FP-22	1 / 2	0.0004 - 0.0004	0.00065	NV	130
85-01-8	Phenanthrene (4)	0.00047	0.00047	µg/L	FP-22	1 / 2	0.0004 - 0.0004	0.00064	NV	130
Pesticides/Polychlorinated Biphenyls										
58-89-9	gamma-BHC (Lindane)	0.0015	0.0019	µg/L	FP-21	2 / 2	0.0004 - 0.0004	0.0044	NV	0.98
Inorganics										
7440-36-0	Antimony	0.711 J	0.711 J	µg/L	FP-22	1 / 2	1 - 1	1 U	<1	5.6
7440-38-2	Arsenic	**1.11**	**1.17**	µg/L	FP-21	2 / 2	1 - 1	0.938	2	0.018
7440-39-3	Barium	28.8	29.4	µg/L	FP-21	2 / 2	1 - 1	25.9	NV	1,000
7439-96-5	Manganese	10.4	22.7	µg/L	FP-21	2 / 2	1 - 1	15.7	NV	50
7440-02-0	Nickel	1.6 J	2.23 J	µg/L	FP-21	2 / 2	10 - 10	0.599	5.5	610
7440-66-6	Zinc	5.41 J	8.36 J	µg/L	FP-22	2 / 2	10 - 10	6.11	38	7,400

Notes:

FP - finger piers
U - not detected at reporting limit shown
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality
SVOC - semi-volatile organic compound

µg/L - microgram per liter
CAS - Chemical Abstracts Service
OAR - Oregon Administrative Record
RBCs - risk-based concentrations

J - estimated concentration
NV - no value
No. - number
RSL - regional screening level

Bold values exceed Comparison Criteria.

Underlined values exceed Reference or Background Value.

(1) Based on site-specific SVOC concentration of Aquatic Reference Area. They are presented for informational purposes only.

(2) Background values from Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(3) Comparison criteria for surface water, which are State of Oregon water quality criteria for human health for consumption of water and organism (OAR 340-041 Tables 33A and 33B) (ODEQ 2009b). National Recommended Water Quality Criteria (EPA 2006b) for human health for consumption of water and organism are used when State of Oregon water quality criteria are not available. ODEQ RBCs for groundwater or EPA RSLs for tap water are used when water quality criteria are not available.
(4) Comparison criteria for fluoranthene is used as a surrogate for phenanthrene.

Table 4-9b
Sediment Summary Statistics, Reference, and Comparison Criteria
Aquatic - Finger Piers Area
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Background Value (2)	Comparison Criteria (3)
Volatile Organic Compounds										
108-38-3/106	m,p-Xylene	0.00089 J	0.00089 J	mg/kg	MIS-53	1 / 3	0.014 - 0.021	7.3 U - 8 U	NV	3,400
Semi-volatile Organic Compounds										
91-57-6	2-Methylnaphthalene	0.0008 J	0.0014 J	mg/kg	FP-06	7 / 7	0.0026 - 0.0027	0.0009	NV	310
106-44-5	4-Methylphenol	0.0030 J	0.0060 J	mg/kg	FP-04	2 / 7	0.011 - 0.011	0.0098 U - 0.01 U	NV	310
83-32-9	Acenaphthene	0.0009 J	0.0018 J	mg/kg	FP-01	7 / 7	0.0026 - 0.0027	0.0005	NV	4,700
208-96-8	Acenaphthylene (4)	0.0007 J	0.0010 J	mg/kg	FP-06	7 / 7	0.0026 - 0.0027	0.0006	NV	4,700
120-12-7	Anthracene	0.0021 J	0.0040	mg/kg	FP-03	7 / 7	0.0026 - 0.0027	0.0016	NV	23,000
192-97-2	Benzo(e)pyrene (5)	0.0120	0.0180	mg/kg	FP-01	7 / 7	0.0026 - 0.0027	0.0073	NV	380
191-24-2	Benzo(g,h,i)perylene (5)	0.0120	0.0180	mg/kg	FP-06	7 / 7	0.0026 - 0.0027	0.0088	NV	380
65-85-0	Benzoic Acid	0.1000 J	0.1100 J	mg/kg	FP-03	3 / 7	0.21 - 0.22	0.2 U - 200 U	NV	240,000
117-81-7	bis(2-Ethylhexyl)phthalate	0.0350 J	0.0350 J	mg/kg	FP-02	1 / 7	0.11 - 0.11	0.0064 U - 0.035 U	NV	35
86-74-8	Carbazole (6)	0.0016 J	0.0045 J	mg/kg	FP-01	7 / 7	0.011 - 0.011	0.0098 U - 0.01 U	NV	24
-	Carcinogenic PAHs (7)	**0.0203**	**0.0307**	mg/kg	FP-03	7 / 7	NA - NA	0.0153	NV	0.015
132-64-9	Dibenzofuran	0.0014 J	0.0014 J	mg/kg	FP-01	1 / 7	0.011 - 0.011	0.0098 U - 0.01 U	NV	150
206-44-0	Fluoranthene	0.0190	0.0460	mg/kg	FP-01	7 / 7	0.0026 - 0.0027	0.0122	NV	510
86-73-7	Fluorene	0.0009 J	0.0021 J	mg/kg	FP-06	7 / 7	0.0026 - 0.0027	0.0006	NV	3,100
91-20-3	Naphthalene	0.0025 J	0.0033	mg/kg	FP-06	7 / 7	0.0026 - 0.0027	0.0013	NV	4.6
85-01-8	Phenanthrene (8)	0.0087	0.0290	mg/kg	FP-01	7 / 7	0.0026 - 0.0027	0.0054	NV	510
108-95-2	Phenol	0.0040 J	0.0040 J	mg/kg	FP-07	1 / 7	0.031 - 0.032	0.0093	NV	18,000
129-00-0	Pyrene	0.0210	0.0450	mg/kg	FP-01	7 / 7	0.0026 - 0.0027	0.0141	NV	380
Pesticides/Polychlorinated Biphenyls										
-	Total DDT (9)	**0.0015**	**0.0026**	mg/kg	FP-03	7 / 7	NA - NA	0.0011	NV	0.00033
309-00-2	Aldrin	0.0002 J	0.0005 J	mg/kg	FP-05	3 / 7	0.0011 - 0.0011	0.001 U - 0.0011 U	NV	0.029
1031-07-8	Endosulfan sulfate (10)	0.0004 J	0.0004 J	mg/kg	FP-02	2 / 7	0.0011 - 0.0011	0.001 U - 0.0011 U	NV	370
76-44-8	Heptachlor	0.0006 J	0.0006 J	mg/kg	FP-02	2 / 7	0.0011 - 0.0011	0.001 U - 0.0011 U	NV	0.11
1024-57-3	Heptachlor epoxide	0.0002 J	0.0005 J	mg/kg	FP-07	5 / 7	0.0011 - 0.0011	0.001 U - 0.0011 U	NV	0.053
-	Total PCBs (11)	**0.0024 J**	**0.0040 J**	mg/kg	FP-06	7 / 7	NA - NA	10 U - 35 U	NV	0.00039
Tributyl Tin as ion										
688-73-3	Tributyltin	0.00103 J	0.0037	mg/kg	FP-04	6 / 7	0.002 - 0.0021	NA	NV	18

Table 4-9b (continued)
Sediment Summary Statistics, Reference, and Comparison Criteria
Aquatic - Finger Piers
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Background Value (2)	Comparison Criteria (3)
Inorganics										
7440-36-0	Antimony	0.17 J	0.24 J	mg/kg	FP-04	7 / 7	0.00005 - 0.00005	0.11	NV	31
7440-38-2	Arsenic	5	6.4	mg/kg	FP-01	7 / 7	0.0005 - 0.0005	4.95	1	7
7440-39-3	Barium	74.8	81.9	mg/kg	FP-02	7 / 7	0.00005 - 0.00005	85	NV	15,000
7440-43-9	Cadmium	0.396	0.433	mg/kg	FP-01	7 / 7	0.000019 - 0.000019	0.30	<0.5	1
7440-47-3	Chromium (12)	17.5	18.9	mg/kg	FP-03	7 / 7	0.0019 - 0.0019	14.83	NV	38
7440-50-8	Copper	32.4	34.3	mg/kg	FP-02	7 / 7	0.00009 - 0.0001	29.47	30	3,100
7439-92-1	Lead	9.84	10.3	mg/kg	FP-02	7 / 7	0.00005 - 0.00005	7.80	2	17
7439-96-5	Manganese	458	499	mg/kg	FP-03	7 / 7	0.00186 - 0.0019	480	480	1,800
7439-97-6	Mercury	**0.081 J**	**0.161 J**	mg/kg	FP-07	7 / 7	0.000015 - 0.000017	0.06	0.2	0.07
7440-02-0	Nickel	14.7	16	mg/kg	FP-02	7 / 7	0.00019 - 0.00019	12.51	20	12,000
7440-22-4	Silver	0.1	0.11	mg/kg	FP-07	7 / 7	0.00002 - 0.00002	0.07	0.4	390
7440-62-2	Vanadium	63.5	68.4	mg/kg	FP-03	7 / 7	0.0019 - 0.0019	53.41	NV	390
7440-66-6	Zinc	75.2 J	80 J	mg/kg	FP-06	7 / 7	0.00186 - 0.0019	65.53	53	23,000
Total Petroleum Hydrocarbons										
-	Diesel Range Hydrocarbons	14 J	20 J	mg/kg	FP-01	6 / 7	0.051 - 0.053	8.99	NV	3,900
-	Gasoline Range Hydrocarbons	2.5 J	2.5 J	mg/kg	MIS-51	1 / 3	6 - 8.2	3.3 U - 3.7 U	NV	720
-	Oil Range Hydrocarbons	21 J	130 J	mg/kg	FP-01/FP-07	7 / 7	0.21 - 0.21	49.71	NV	9,800

Table 4-9b (continued)
Sediment Summary Statistics, Reference, and Comparison Criteria
Aquatic - Finger Piers Area
Tongue Point Multi-Sites Project, Astoria, Oregon

Notes:

FP - finger piers
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality
PAH - polycyclic aromatic hydrocarbon
DU - decision unit
RBCs - risk-based concentrations

J - estimated concentration
NA - not applicable
CAS - Chemical Abstracts Service
DDT - dichlorodiphenyltrichloroethane
PRG - preliminary remediation goal

mg/kg - milligram per kilogram
NV - no value
No. - number
PCB - polychlorinated biphenyl
RSL - regional screening level

Bold values exceed Comparison Criteria.

Underlined values exceed Reference or Background Value.

(1) Based on site-specific mean sediment concentrations of Aquatic Reference Area. They are presented for informational purposes only.

(2) From Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(3) Comparison criteria for sediment, which are Oregon Department of Environmental Quality (ODEQ) (2007a) sediment bioaccumulation screening level values for humans when available. Otherwise they are ODEQ (2008) risk-based concentrations (RBCs) for soil (ingestion, dermal contact and inhalation for residential properties). EPA (2008a) regional screening levels (RSLs) for residential soil are used for chemicals where RBCs are not available.

(4) Comparison criterion for acenaphthene is used as a surrogate for acenaphthylene.

(5) Comparison criterion for pyrene is used as a surrogate for benzo(e)pyrene and benzo(g,h,i)perylene.

(6) EPA Region 9 preliminary remediation goal (PRG) (2004a) for residential soil is used as the comparison criterion for carbazole.

(7) Carcinogenic PAHs: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

(8) Comparison crtieria for fluoranthene is used as a surrogate for phenanthrene.

(9) Total DDT: p,p'-dichlorodiphenyldichloroethane, p,p'-dichlorodiphenyldichloroethylene, and p,p'-dichlorodiphenyltrichloroethane.

(10) Comparison criterion for endosulfan is used as a surrogate for endosulfan sulfate.

(11) Total PCBs: Aroclor 1016, Aroclor 1221, Aroclor 1232, Aroclor 1242, Aroclor 1248, Aroclor 1254, and Aroclor 1260.

(12) EPA RSL is used as the comparison criterion for chromium.

Table 4-9c
Tissue Summary Statistics, Reference, and Comparison Criteria
Aquatic - Finger Piers Area
Tongue Point Multi-Sites Project, Astoria, Oregon

Tissue Type	CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Detection Frequency	Reference Value (1)	Comparison Criteria (2)
Clams	**Pesticides**							
	-	Total DDT (3)	0.0119	0.0119	mg/kg	1 / 1	0.00614 J	0.054
	60-57-1	Dieldrin	0.00099 J	0.00099 J	mg/kg	1 / 1	0.00063 J	0.26
	Inorganics							
	7440-38-2	Arsenic	6.09	6.09	mg/kg	1 / 1	4.9	6.6
	7440-47-3	Chromium	2.52	2.52	mg/kg	1 / 1	4.25	NV
	7439-92-1	Lead	**0.873**	**0.873**	mg/kg	1 / 1	1.87	0.12
	7439-97-6	Mercury	0.055	0.055	mg/kg	1 / 1	0.066	0.088
	7782-49-2	Selenium	**3.4**	**3.4**	mg/kg	1 / 1	3.2	0.024
Forage Fish	**Semi-volatile Organic Compounds**							
	206-44-0	Fluoranthene	0.0018 J	0.0018 J	mg/kg	1 / 1	0.005 U	19
	129-00-0	Pyrene	0.0012 J	0.0012 J	mg/kg	1 / 1	0.005 U	1
	Pesticides							
	-	Total DDT (3)	0.0139 J	0.0139 J	mg/kg	1 / 1	0.0222	0.054
	60-57-1	Dieldrin	0.00061 J	0.00061 J	mg/kg	1 / 1	0.00069 J	0.26
	Dioxin/Furan							
	-	Dioxin/Furan TEQ	8.8E-07 J	8.8E-07 J	mg/kg	1 / 1	3.28E-07 J	6.40E-06
	Inorganics							
	7440-38-2	Arsenic	1.69	1.69	mg/kg	1 / 1	1.25	6.6
	7440-47-3	Chromium	0.26 J	0.26 J	mg/kg	1 / 1	0.47	NV
	7439-92-1	Lead	**0.325**	**0.325**	mg/kg	1 / 1	0.27	0.12
	7439-97-6	Mercury	**0.238**	**0.238**	mg/kg	1 / 1	0.303	0.088
	7782-49-2	Selenium	**2.2**	**2.2**	mg/kg	1 / 1	2.6	0.024
Fish Fillet	**Pesticides**							
	-	Total DDT (3)	0.00767 J	0.00767 J	mg/kg	1 / 1	0.00627 J	0.054
	Dioxin/Furan							
	-	Dioxin/Furan TEQ	2.3E-06 J	2.3E-06 J	mg/kg	1 / 1	NC	6.40E-06
	Inorganics							
	7440-38-2	Arsenic	1.31	1.31	mg/kg	1 / 1	0.88	6.6
	7440-47-3	Chromium	0.47	0.47	mg/kg	1 / 1	0.52	NV
	7439-92-1	Lead	0.101	0.101	mg/kg	1 / 1	0.131	0.12
	7439-97-6	Mercury	**0.287**	**0.287**	mg/kg	1 / 1	0.205	0.088
	7782-49-2	Selenium	**2**	**2**	mg/kg	1 / 1	2	0.024

Notes:

J - estimated concentration
CAS - Chemical Abstracts Service
mg/kg - milligram per kilogram
NC - not calculated; all results are non-detect
ODEQ - Oregon Department of Environmental Quality

U - not detected at reporting limit shown
No. - number
TEQ - toxicity equivalent
NV - no value
DDT - dichlorodiphenyltrichloroethane

Bold values exceed Comparison Criteria.

Underlined values exceed Reference Value.

(1) Reference values based on concentration of tissue samples collected from Aquatic-Reference Area. They are presented for informational purposes only.

(2) Comparison criteria from Appendix A, Table A-4 from ODEQ (2007a) Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment.

(3) Total DDT: p,p'-dichlorodiphenyldichloroethane, p,p'-dichlorodiphenyldichloroethylene, and p,p'-dichlorodiphenyltrichloroethane.

Table 4-9d
Statistical Comparison of 1995 and 2008 Data for the Finger Piers Decision Unit
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	1995 Data [1]				2008 Data [2]			
	Number of Samples	Mean	Standard Error	Coefficient of Variation	Number of Samples[3]	Mean	Standard Error (Synthetic)	90 % UCL of Mean (Synthetic)[4]
Arsenic	32	7.675	0.1894	0.14	1	5.34	0.1319	5.51
B(a)P	32	45.531	2.0290	0.25	1	17.7	0.789	18.7
Cadmium	32	0.740	0.0190	0.15	1	0.42	0.011	0.43
Chromium	32	24.000	0.4000	0.10	1	18.4	0.307	18.8
Copper	32	34.891	0.6954	0.11	1	33.1	0.660	34.0
Mercury	32	0.074	0.0015	0.11	1	0.099	0.002	0.101
TBT	32	57.500	2.2293	0.22	1	2.03	0.079	2.13
TPH-D	32	78.875	4.5629	0.33	1	15.3	0.884	16.4
Zinc	32	118.628	2.3187	0.11	1	78.3	1.531	80.3

Notes:

[1] Data from samples collected in 1995 and reported in the Finger Pier Sediment Limited Remedial Investigation (Woodward Clyde 1998)

[2] Data from sediment samples colleced in September 2008 for the Tongue Point Remedial Investigation (CDM 2010)

[3] One IS consisting of 28 subsamples collected from nodes of a grid. Seven aliquots of the composite were analyzed. See Section 3.5 for additonal description of sediment sampling strategy for the 2008 RI field investigation.

[4]Standard errors were calculated assuming that the coefficients of variation for 1995 and 2008 were the same. The 90% UCL of the mean for 2008 data (IS samples) was calculated assuming that means were normally distributed

B(a)P = benzo(a)pyrene
TPH-D = diesel range petroleum hydrocarbons
TBT = tributyltin
Metal and TPH-D data have units of miligram per kilogram (mg/kg) dry weight.

CDM

Table 4-10a
Surface Water Summary Statistics, Reference, and Comparison Criteria
Aquatic - Near Landfill
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Background Value (2)	Comparison Criteria (3)
Semi-Volatile Organic Compounds										
206-44-0	Fluoranthene	0.00047	0.00047	µg/L	LF-11	1 / 1	0.0004 - 0.0004	0.00065	NV	130
85-01-8	Phenanthrene (4)	0.00049	0.00049	µg/L	LF-11	1 / 1	0.0004 - 0.0004	0.00064	NV	130
Inorganics										
7440-38-2	Arsenic	**1.02**	**1.02**	µg/L	LF-11	1 / 1	1 - 1	0.94	2	0.018
7440-39-3	Barium	26.3	26.3	µg/L	LF-11	1 / 1	1 - 1	25.9	NV	1000
7439-96-5	Manganese	11.7	11.7	µg/L	LF-11	1 / 1	1 - 1	15.7	NV	50
7440-02-0	Nickel	2.55 J	2.55 J	µg/L	LF-11	1 / 1	10 - 10	0.60	5.5	610

Notes:

LF - near landfill
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality
SVOC - semi-volatile organic compound

µg/L - microgram per liter
CAS - Chemical Abstracts Service
OAR - Oregon Administrative Record
RBCs - risk-based concentrations

J - estimated concentration
NV - no value
No. - number
RSL - regional screening level

Bold values exceed Comparison Criteria.

Underlined values exceed Reference or Background Value.

(1) Based on site-specific SVOC concentration of Aquatic Reference Area. They are presented for informational purposes only.

(2) Background values from Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(3) Comparison criteria for surface water, which are State of Oregon water quality criteria for human health for consumption of water and organism (OAR 340-041 Tables 33A and 33B) (ODEQ 2009b). National Recommended Water Quality Criteria (EPA 2006b) for human health for consumption of water and organism are used when State of Oregon water quality criteria are not available. ODEQ RBCs for groundwater or EPA RSLs for tap water are used when water quality criteria are not available.

(4) Comparison criterion for fluoranthene is used as a surrogate for phenanthrene.

Table 4-10b
Sediment Summary Statistics, Reference, and Comparison Criteria
Aquatic - Near Landfill
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Background Value (2)	Comparison Criteria (3)
Semi-Volatile Organic Compounds										
91-57-6	2-Methylnaphthalene	0.00045 J	0.00086 J	mg/kg	LF-07	7 / 7	0.0024 - 0.0025	0.0009	NV	310
106-44-5	4-Methylphenol	0.0046 J	0.36	mg/kg	LF-01	7 / 7	0.0093 - 0.048	0.0098 U - 0.01 U	NV	310
83-32-9	Acenaphthene	0.0004 J	0.0024 J	mg/kg	LF-07	7 / 7	0.0024 - 0.0025	0.0005	NV	4,700
208-96-8	Acenaphthylene (4)	0.00056 J	0.0013 J	mg/kg	LF-02	7 / 7	0.0024 - 0.0025	0.0006	NV	4,700
120-12-7	Anthracene	0.0019 J	0.0046	mg/kg	LF-07	7 / 7	0.0024 - 0.0025	0.0016	NV	23,000
192-97-2	Benzo(e)pyrene (5)	0.0069	0.014	mg/kg	LF-02/LF-07	7 / 7	0.0024 - 0.0025	0.0073	NV	380
191-24-2	Benzo(g,h,i)perylene (5)	0.0067	0.015	mg/kg	LF-02	7 / 7	0.0024 - 0.0025	0.0088	NV	380
65-85-0	Benzoic Acid	0.096 J	0.56 J	mg/kg	LF-06	3 / 7	0.19 - 0.96	0.2 U - 200 U	NV	240,000
117-81-7	Bis(2-Ethylhexyl)Phthalate	0.0078 J	0.028 J	mg/kg	LF-03	7 / 7	0.19 - 0.96	0.0064 U - 0.035 U	NV	35
86-74-8	Carbazole (6)	0.0016 J	0.0024 J	mg/kg	LF-05	5 / 7	0.0093 - 0.048	0.0098 U - 0.01 U	NV	24
-	Carcinogenic PAHs (7)	0.011	**0.024**	mg/kg	LF-02	7 / 7	NA - NA	0.0153	NV	0.015
206-44-0	Fluoranthene	0.013	0.092 J	mg/kg	LF-07	7 / 7	0.0024 - 0.0025	0.0122	NV	510
86-73-7	Fluorene	0.00056 J	0.0033	mg/kg	LF-07	7 / 7	0.0024 - 0.0025	0.0006	NV	3,100
91-20-3	Naphthalene	0.0011 J	0.0017 J	mg/kg	LF-02	7 / 7	0.0024 - 0.0025	0.0013	NV	4.6
85-01-8	Phenanthrene (8)	0.005	0.055 J	mg/kg	LF-07	7 / 7	0.0024 - 0.0025	0.0054	NV	510
108-95-2	Phenol	0.0039 J	0.01 J	mg/kg	LF-02	6 / 7	0.028 - 0.15	0.0093	NV	18,000
129-00-0	Pyrene	0.015	0.073 J	mg/kg	LF-07	7 / 7	0.0024 - 0.0025	0.0141	NV	380
Dioxin/Furan										
-	Dioxin/Furan TEQ	**5.3E-08**	**1.8E-06**	mg/kg	LF-02	7 / 7	NA - NA	9.6E-07	NV	9.1E-09
Pesticides/Polychlorinated biphenyls										
-	Total DDT (9)	**0.0007**	**0.0022**	mg/kg	LF-07	7 / 7	NA - NA	0.0011	NV	0.00033
76-44-8	Heptachlor	0.0004 J	0.0010 J	mg/kg	LF-05	3 / 7	0.001 - 0.0011	0.001 U - 0.0011 U	NV	0.11
-	Total PCBs (10)	**0.0035 J**	**0.0043 J**	mg/kg	LF-02/LF-07	7 / 7	NA - NA	10 U - 35 U	NV	0.00039
Inorganics										
7440-36-0	Antimony	0.12 J	0.16 J	mg/kg	LF-01	7 / 7	0.00005 - 0.00005	0.11	NV	31
7440-38-2	Arsenic	5.2	6.1	mg/kg	LF-06	7 / 7	0.0005 - 0.0005	4.94	1	7
7440-39-3	Barium	78.8	95.9	mg/kg	LF-06	7 / 7	0.00005 - 0.00005	85	NV	15,000
7440-43-9	Cadmium	0.361	0.425	mg/kg	LF-06	7 / 7	0.00002 - 0.000022	0.30	<0.5	1
7440-47-3	Chromium (11)	15	17.8	mg/kg	LF-06	7 / 7	0.0021 - 0.0022	14.83	NV	38
7440-50-8	Copper	22.9	27.1	mg/kg	LF-06	7 / 7	0.0001 - 0.00011	29.47	30	3,100
7439-92-1	Lead	10.1	11.7	mg/kg	LF-06	7 / 7	0.00005 - 0.00005	7.79	2	17
7439-96-5	Manganese	378	449	mg/kg	LF-02	7 / 7	0.00206 - 0.00216	480	480	1,800
7439-97-6	Mercury	0.061	**0.081**	mg/kg	LF-07	7 / 7	0.000013 - 0.000017	0.06	0.2	0.07
7440-02-0	Nickel	12.9	15.3	mg/kg	LF-06	7 / 7	0.00021 - 0.00022	12.51	20	12,000
7440-22-4	Silver	0.08	0.1	mg/kg	LF-01/LF-05	7 / 7	0.00002 - 0.00002	0.07	0.4	390
7440-62-2	Vanadium	51.1	61.2	mg/kg	LF-06	7 / 7	0.0021 - 0.0022	53.41	NV	390
7440-66-6	Zinc	70.3	79.7	mg/kg	LF-06	7 / 7	0.00206 - 0.00216	65.53	53	23,000

Table 4-10b (continued)
Sediment Summary Statistics, Reference, and Comparison Criteria
Aquatic - Near Landfill
Tongue Point Multi-Sites Project, Astoria, Oregon

CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Location of Maximum Concentration	Detection Frequency	Range of Sample Quantitation Limit	Reference Value (1)	Background Value (2)	Comparison Criteria (3)
Total Petroleum Hydrocarbons										
-	Diesel Range Hydrocarbons	14 J	23 J	mg/kg	LF-01	7 / 7	0.047 - 0.049	8.99	NV	3,900
-	Gasoline Range Hydrocarbons	5.3 J	5.3 J	mg/kg	MIS-57	1 / 3	8.7 - 8.8	3.3 U - 3.7 U	NV	720
-	Oil Range Hydrocarbons	93 J	140 J	mg/kg	LF-01	7 / 7	0.19 - 0.2	49.71	NV	9,800

Notes:

LF - near landfill
EPA - U.S. Environmental Protection Agency
ODEQ - Oregon Department of Environmental Quality
PAH - polycyclic aromatic hydrocarbon
DU - decision unit
RBCs - risk-based concentrations

J - estimated concentration
NA - not applicable
CAS - Chemical Abstracts Service
DDT - dichlorodiphenyltrichloroethane
PRG - preliminary remediation goal

mg/kg - milligram per kilogram
NV - no value
No. - number
PCB - polychlorinated biphenyl
RSL - regional screening level

Bold values exceed Comparison Criteria.

Underlined values exceed Reference or Background Value.

(1) Based on site-specific mean sediment concentrations of Aquatic Reference Area. They are presented for informational purposes only.

(2) From Table 1: ODEQ Suggested Default Background Concentrations for Inorganic Contaminants in Various Environmental Media, Technical Memorandom: Default Background Concentrations for Metals, ODEQ Toxicology Workgroup, October 28, 2002.

(3) Comparison criteria for sediment, which are Oregon Department of Environmental Quality (ODEQ) (2007a) sediment bioaccumulation screening level values for humans when available. Otherwise they are ODEQ (2008) risk-based concentrations (RBCs) for soil (ingestion, dermal contact and inhalation for residential properties). EPA (2008a) regional screening levels (RSLs) for residential soil are used for chemicals where RBCs are not available.
(4) Comparison crtierion for acenaphthene is used as a surrogate for acenaphthylene.
(5) Comparison crtierion for pyrene is used as a surrogate for benzo(e)pyrene and benzo(g,h,i)perylene.
(6) EPA Region 9 preliminary remediation goal (PRG) (2004a) for residential soil is used as comparison criterion for carbazole.
(7) Carcinogenic PAHs: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.
(8) Comparison crtierion for fluoranthene is used as a surrogate for phenanthrene.
(9) Total DDT: p,p'-dichlorodiphenyldichloroethane, p,p'-dichlorodiphenyldichloroethylene, and p,p'-dichlorodiphenyltrichloroethane.
(10) Total PCBs: Aroclor 1016, Aroclor 1221, Aroclor 1232, Aroclor 1242, Aroclor 1248, Aroclor 1254, and Aroclor 1260.
(11) EPA RSL is used as the comparison criterion for chromium.

Table 4-10c
Tissue Summary Statistics, Reference, and Comparison Criteria
Aquatic - Near Landfill
Tongue Point Multi-Sites Project, Astoria, Oregon

Tissue Type	CAS No.	Chemical	Minimum Concentration	Maximum Concentration	Unit	Detection Frequency	Reference Value (1)	Comparison Criteria (2)
Clams	**Semi-volatile Organic Compounds**							
	206-44-0	Fluoranthene	0.021	0.021	mg/kg	1 / 1	0.0061	19
	129-00-0	Pyrene	0.0076	0.0076	mg/kg	1 / 1	0.0039 J	1
	Pesticides							
	-	Total DDT	0.00114	0.00114	mg/kg	1 / 1	0.00614 J	0.054
	60-57-1	Dieldrin	0.00055	0.00055	mg/kg	1 / 1	0.00063 J	0.26
	Dioxin/Furan							
	-	Dioxin/Furan TEQ (3)	3.7E-07 J	3.7E-07 J	mg/kg	1 / 1	NC	6.40E-06
	Inorganics							
	7440-38-2	Arsenic	6.13	6.13	mg/kg	1 / 1	4.9	6.6
	7440-47-3	Chromium	1.96	1.96	mg/kg	1 / 1	4.25	NV
	7439-92-1	Lead	**0.911**	**0.911**	mg/kg	1 / 1	1.87	0.12
	7439-97-6	Mercury	**0.089**	**0.089**	mg/kg	1 / 1	0.066	0.088
	7782-49-2	Selenium	**2.4**	**2.4**	mg/kg	1 / 1	3.2	0.024
Forage Fish	**Semi-volatile Organic Compounds**							
	206-44-0	Fluoranthene	0.008	0.008	mg/kg	1 / 1	0.005 U	19
	129-00-0	Pyrene	0.0039 J	0.0039 J	mg/kg	1 / 1	0.005 U	1
	Pesticides							
	-	Total DDT (3)	0.0214	0.0214	mg/kg	1 / 1	0.0222	0.054
	5103-71-9	Alpha-Chlordane	0.00088	0.00088	mg/kg	1 / 1	0.00098 U	NV
	60-57-1	Dieldrin	0.0011	0.0011	mg/kg	1 / 1	0.00069 J	0.26
	118-74-1	Hexachlorobenzene	0.0062	0.0062	mg/kg	1 / 1	0.00081 J	32
	Inorganics							
	7440-38-2	Arsenic	1.62	1.62	mg/kg	1 / 1	1.25	6.6
	7440-47-3	Chromium	0.43	0.43	mg/kg	1 / 1	0.47	NV
	7439-92-1	Lead	**0.374**	**0.374**	mg/kg	1 / 1	0.27	0.12
	7439-97-6	Mercury	**0.37**	**0.37**	mg/kg	1 / 1	0.303	0.088
	7782-49-2	Selenium	**2**	**2**	mg/kg	1 / 1	2.6	0.024
Fish Fillet	**Pesticides**							
	-	Total DDT (3)	0.00489 J	0.00489 J	mg/kg	1 / 1	0.00627 J	0.054
	Dioxin/Furan							
	-	Dioxin/Furan TEQ	9.7E-07 J	9.7E-07 J	mg/kg	1 / 1	NC	6.40E-06
	Inorganics							
	7440-38-2	Arsenic	0.8	0.8	mg/kg	1 / 1	0.88	6.6
	7440-47-3	Chromium	1.13	1.13	mg/kg	1 / 1	0.52	NV
	7439-92-1	Lead	**0.124**	**0.124**	mg/kg	1 / 1	0.131	0.12
	7439-97-6	Mercury	**0.246**	**0.246**	mg/kg	1 / 1	0.205	0.088
	7782-49-2	Selenium	**2.2**	**2.2**	mg/kg	1 / 1	2	0.024

Notes:

J - estimated concentration
CAS - Chemical Abstracts Service
mg/kg - milligram per kilogram
NC - not calculated; all results are non-detect
ODEQ - Oregon Department of Environmental Quality

U - not detected at reporting limit shown
No. - number
TEQ - toxicity equivalent
NV - no value
DDT - dichlorodiphenyltrichloroethane

Bold values exceed Comparison Criteria.

Underlined values exceed Reference Value.

(1) Reference values based on concentration of tissue samples collected from Aquatic-Reference Area. They are presented for informational purposes only.

(2) Comparison criteria from Appendix A, Table A-4 from ODEQ (2007a) Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment.
(3) Total DDT: p,p'-dichlorodiphenyldichloroethane, p,p'-dichlorodiphenyldichloroethylene, and p,p'-dichlorodiphenyltrichloroethane.

Table 4-11a
Comparison of Petroleum Hydrocarbons in Surface Soil to Surrogate Ecological SLVs
Tongue Point Multi-Sites Project, Astoria, Oregon

Petroleum Compound	Concentration in Soil Samples[1] (mg/kg)			Surrogate SLV[2] (mg/kg)	Max HQ	Max > Surrogate SLV?
	Min	Mean	Max			
AST Fuel Storage Area						
TPH-G	16.0	12.7	45.0	100	0.45	NO
TPH-D	10.0	353	2,400	200	**12**	**YES**
TPH-O	21.0	846	7,300	200	**37**	**YES**
UST Site No. 4						
TPH-G	8.8	18.6	75	100	0.75	NO
TPH-D	7.4	5.7	13.0	200	0.065	NO
TPH-O	14.0	39.5	120	200	0.60	NO

Notes:

[1] Min, Mean, Max = minimum, mean, and maximum detected concentrations in surface soil samples from Level II Screening as presented in Appendix M2 Table 3-4 (AST) and Table 3-5 (UST Site No. 4)

2 SLV Source = (Ecology 2001) Washington State Department of Ecology, Terrestrial Ecological Screening Values: Site Specific Ecological Evaluation (WAC 173-340-7493) Table 749-3 Ecological Indicator Soil Concentrations for Protection of Terresterial Plants and Animals, February 12, 2001

TPH-G = gasoline range hydrocarbons

TPH-D = diesel range hydrocarbons

TPH-O = motor oil range hydrocarbons

SLV = ecological screening value not recommended by ODEQ but an appropriate surrogate

Surrogate SLV for TPH-O = unavailable, therefore max HQ is derived using TPH-D SLV

HQ = hazard quotient, where HQ = max detect conc / SLV

HQ equal to or exceeding 1 indicates potential adverse ecological effects

HQ < 1 indicates no potential for adverse ecological effects

Petroleum Compounds associated with max HQ <1 are eliminated from further investigation

Petroleum Compounds associated with max HQ equal to or >1 are retained for further evaluation in Section 7.7

Bold font indicates HQ>1

Table 4-11b
Comparison of Petroleum Hydrocarbons in Sediment to Surrogate Ecological SLVs
Tongue Point Multi-Sites Project, Astoria, Oregon

Petroleum Compound	Sediment Concentrations[1] (mg/kg)			Recommended Sediment Quality Guidelines [2] (mg/kg)				Max HQ	Max >SQS?
				TPH-G and TPH-D		TPH-O			
	min	mean	max	SQS/SL1	CSL/SL2	SQS/SL1	CSL/SL2		
UST Site No. 1									
TPH-D	4.1	20.1	36	340	510	--	--	0.11	NO
TPH-O	20	110	200	--	--	3600	8400	0.06	NO
Refueling Pit 3									
TPH-D	42	47	52	340	510	--	--	0.15	NO
TPH-O	250	330	410	--	--	3600	8400	0.11	NO
Fire Training Area									
TPH-D	25	29	33	340	510	--	--	0.10	NO
TPH-O	150	175	200	--	--	3600	8400	0.06	NO
Aquatic - North of Pier 8									
TPH-G	2.9	2.43	2.9	340	510	--	--	0.01	NO
TPH-D	11	14	16	340	510	--	--	0.05	NO
TPH-O	56	67	74	--	--	3600	8400	0.02	NO
Aquatic - Finger Piers Area									
TPH-G	2.5	3	2.5	340	510	--	--	0.01	NO
TPH-D	14	15	20	340	510	--	--	0.06	NO
TPH-O	21	98	130	--	--	3600	8400	0.04	NO
Aquatic - Near Landfill									
TPH-G	5.3	5	5.3	340	510	--	--	0.02	NO
TPH-D	14	18	23	340	510	--	--	0.07	NO
TPH-O	93	107	140	--	--	3600	8400	0.04	NO

Notes:

[1] Min, Mean, Max = minimum, mean, and maximum detected concentrations in sediment samples from Level II Screening in Appendix M2, Table 3-7 (UST 1), Table 3-8 (RFP3), Table 3-9 (FTA), Table 3-10 (NTP), Table 3-11 (FP), Table 3-12 (LF)

[2] Surrogate SLV Source = Sediment quality guidelines from Michelsen, T. 2010. *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho* . Washington Department of Ecology,

SLV = screening level value

RFP = Refueling Pit 3

FTA = Fire Training Area .

NTP = North of Pier 8

FP = Finger Piers

LF = Near Landfill

TPH-G = gasoline range hydrocarbons

TPH-D = diesel range hydrocarbons

TPH-O = motor oil range hydrocarbons

SQS/SL1 = sediment quality screening level; not recommended by ODEQ but serves as an appropriate surrogate

SQS/SL1 for TPH-O = unavailable, therefore max HQ is derived using TPH-Residual SQS/SL1

HQ = hazard quotient, where HQ = max detect conc / SQS/SL1

HQ equal to or exceeding 1 indicates potential adverse effects

HQ < 1 indicates no potential for adverse ecological effects

Petroleum Compounds associated with max HQ <1 are eliminated from further evaluation as discussed in Section 7.7

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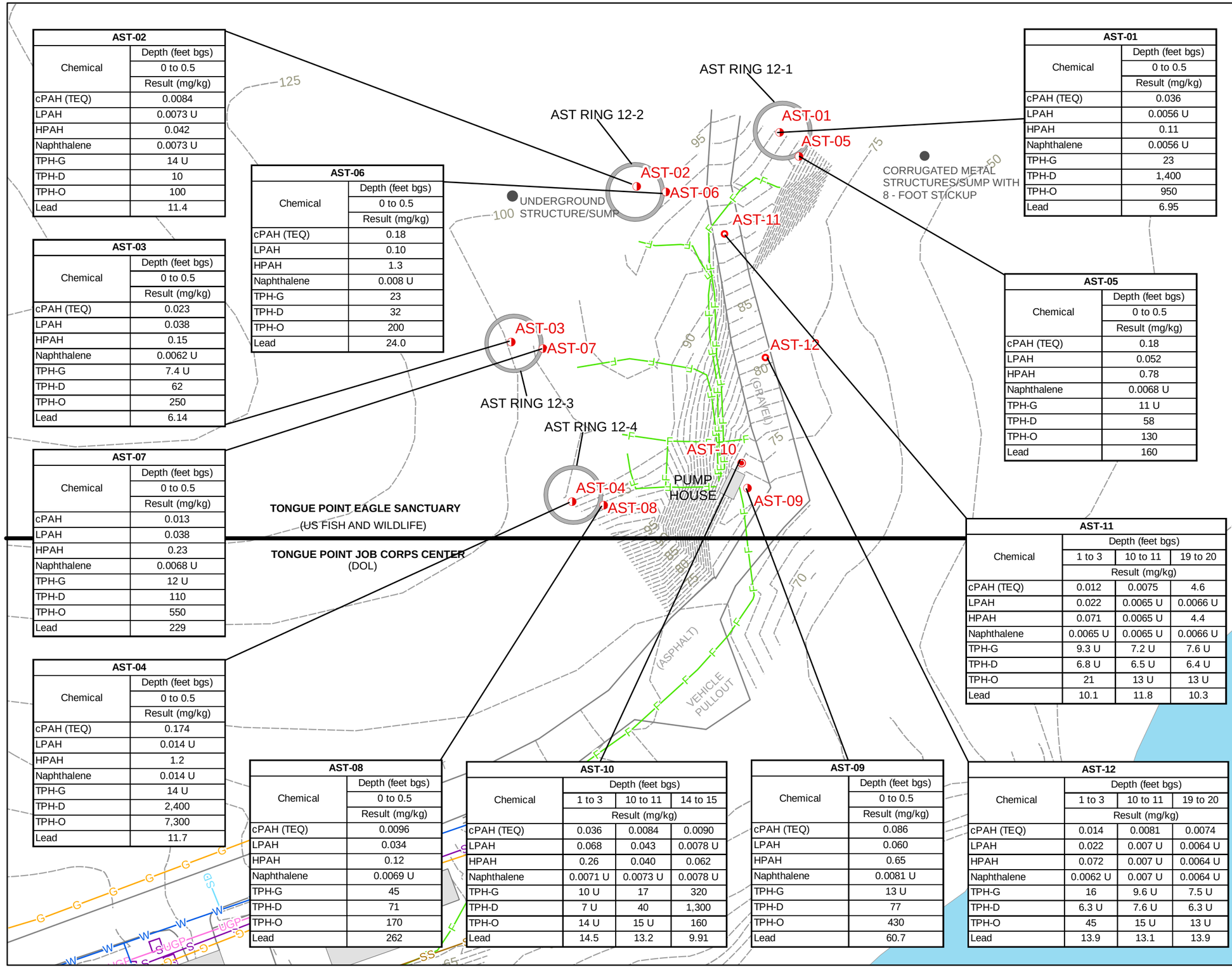


AST-02	
Chemical	Depth (feet bgs)
	0 to 0.5
	Result (mg/kg)
cPAH (TEQ)	0.0084
LPAH	0.0073 U
HPAH	0.042
Naphthalene	0.0073 U
TPH-G	14 U
TPH-D	10
TPH-O	100
Lead	11.4

AST-03	
Chemical	Depth (feet bgs)
	0 to 0.5
	Result (mg/kg)
cPAH (TEQ)	0.023
LPAH	0.038
HPAH	0.15
Naphthalene	0.0062 U
TPH-G	7.4 U
TPH-D	62
TPH-O	250
Lead	6.14

AST-07	
Chemical	Depth (feet bgs)
	0 to 0.5
	Result (mg/kg)
cPAH	0.013
LPAH	0.038
HPAH	0.23
Naphthalene	0.0068 U
TPH-G	12 U
TPH-D	110
TPH-O	550
Lead	229

AST-04	
Chemical	Depth (feet bgs)
	0 to 0.5
	Result (mg/kg)
cPAH (TEQ)	0.174
LPAH	0.014 U
HPAH	1.2
Naphthalene	0.014 U
TPH-G	14 U
TPH-D	2,400
TPH-O	7,300
Lead	11.7

AST-06	
Chemical	Depth (feet bgs)
	0 to 0.5
	Result (mg/kg)
cPAH (TEQ)	0.18
LPAH	0.10
HPAH	1.3
Naphthalene	0.008 U
TPH-G	23
TPH-D	32
TPH-O	200
Lead	24.0

AST-08	
Chemical	Depth (feet bgs)
	0 to 0.5
	Result (mg/kg)
cPAH (TEQ)	0.0096
LPAH	0.034
HPAH	0.12
Naphthalene	0.0069 U
TPH-G	45
TPH-D	71
TPH-O	170
Lead	262

AST-10			
Chemical	Depth (feet bgs)		
	1 to 3	10 to 11	14 to 15
	Result (mg/kg)		
cPAH (TEQ)	0.036	0.0084	0.0090
LPAH	0.068	0.043	0.0078 U
HPAH	0.26	0.040	0.062
Naphthalene	0.0071 U	0.0073 U	0.0078 U
TPH-G	10 U	17	320
TPH-D	7 U	40	1,300
TPH-O	14 U	15 U	160
Lead	14.5	13.2	9.91

AST-09	
Chemical	Depth (feet bgs)
	0 to 0.5
	Result (mg/kg)
cPAH (TEQ)	0.086
LPAH	0.060
HPAH	0.65
Naphthalene	0.0081 U
TPH-G	13 U
TPH-D	77
TPH-O	430
Lead	60.7

AST-01	
Chemical	Depth (feet bgs)
	0 to 0.5
	Result (mg/kg)
cPAH (TEQ)	0.036
LPAH	0.0056 U
HPAH	0.11
Naphthalene	0.0056 U
TPH-G	23
TPH-D	1,400
TPH-O	950
Lead	6.95

AST-05	
Chemical	Depth (feet bgs)
	0 to 0.5
	Result (mg/kg)
cPAH (TEQ)	0.18
LPAH	0.052
HPAH	0.78
Naphthalene	0.0068 U
TPH-G	11 U
TPH-D	58
TPH-O	130
Lead	160

AST-11			
Chemical	Depth (feet bgs)		
	1 to 3	10 to 11	19 to 20
	Result (mg/kg)		
cPAH (TEQ)	0.012	0.0075	4.6
LPAH	0.022	0.0065 U	0.0066 U
HPAH	0.071	0.0065 U	4.4
Naphthalene	0.0065 U	0.0065 U	0.0066 U
TPH-G	9.3 U	7.2 U	7.6 U
TPH-D	6.8 U	6.5 U	6.4 U
TPH-O	21	13 U	13 U
Lead	10.1	11.8	10.3

AST-12			
Chemical	Depth (feet bgs)		
	1 to 3	10 to 11	19 to 20
	Result (mg/kg)		
cPAH (TEQ)	0.014	0.0081	0.0074
LPAH	0.022	0.007 U	0.0064 U
HPAH	0.072	0.007 U	0.0064 U
Naphthalene	0.0062 U	0.007 U	0.0064 U
TPH-G	16	9.6 U	7.5 U
TPH-D	6.3 U	7.6 U	6.3 U
TPH-O	45	15 U	13 U
Lead	13.9	13.1	13.9

LEGEND

- DPT BORING
- DPT BORING/MICROWELL
- COMPOSITE SURFACE SAMPLE LOCATION
- FUEL LINE FROM GEOPHYSICAL SURVEY
- PROPERTY BOUNDARY (APPROXIMATE)
- TOPOGRAPHIC CONTOURS

UTILITIES

- UGP — UNDERGROUND POWER
- G — GAS
- SS — SANITARY SEWER
- S — STEAM
- SD — STORM DRAIN
- W — WATER

NOTES:

1. U = NOT DETECTED ABOVE THE STATED REPORTING LIMIT.
2. J = DETECTED WITH AN ESTIMATED CONCENTRATION.
3. TPH-G = GASOLINE RANGE PETROLEUM HYDROCARBONS.
4. TPH-D = DIESEL RANGE PETROLEUM HYDROCARBONS.
5. TPH-O = OIL RANGE PETROLEUM HYDROCARBONS.
6. cPAH = CARCINOGENIC POLYCYCLIC AROMATIC HYDROCARBONS. THIS INCLUDES: BENZO(A)PYRENE, BENZO(A)ANTHRACENE, BENZO(B)FLUORANTHENE, BENZO(K)FLUORANTHENE, CHRYSENE, DIBENZO(A,H)ANTHRACENE, AND INDENO(1,2,3-CD)PYRENE.
7. LPAH = LOW MOLECULAR WEIGHT POLYCYCLIC AROMATIC HYDROCARBONS. THIS INCLUDES: ACENAPHTHENE, ACENAPHTHYLENE,ANTHRACENE, FLUORENE, NAPHTHALENE, AND PHENANTHRENE.
8. HPAH = HIGH MOLECULAR WEIGHT POLYCYCLIC AROMATIC HYDROCARBONS. THIS INCLUDES: BENZO(A)PYRENE, BENZO(A)ANTHRACENE,TOTAL BENZOFLUORANTHENES, BENZO(G,H,I)PERYLENE, CHRYSENE, DIBENZO(A,H)ANTHRACENE, FLUORANTHENE, INDENO(1,2,3,-C,D)PYRENE, AND PYRENE.
9. TEQ = TOXIC EQUIVALENT; CALCULATED FOR HUMAN RECEPTORS UNLESS OTHERWISE NOTED.
10. mg/kg = MILLIGRAMS PER KILOGRAM.
11. bgs = BELOW GROUND SURFACE.
12. FOUR ABOVE GROUND STORAGE TANKS (ASTs) WERE FORMERLY LOCATED AT THE AST FUEL STORAGE AREA.
13. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
14. BASE MAP FILES FROM URS (FIGURE 3-7) SEPTEMBER 2007.
15. DOL= DEPARTMENT OF LABOR
16. US = UNITED STATES

0 25 50 100
Feet

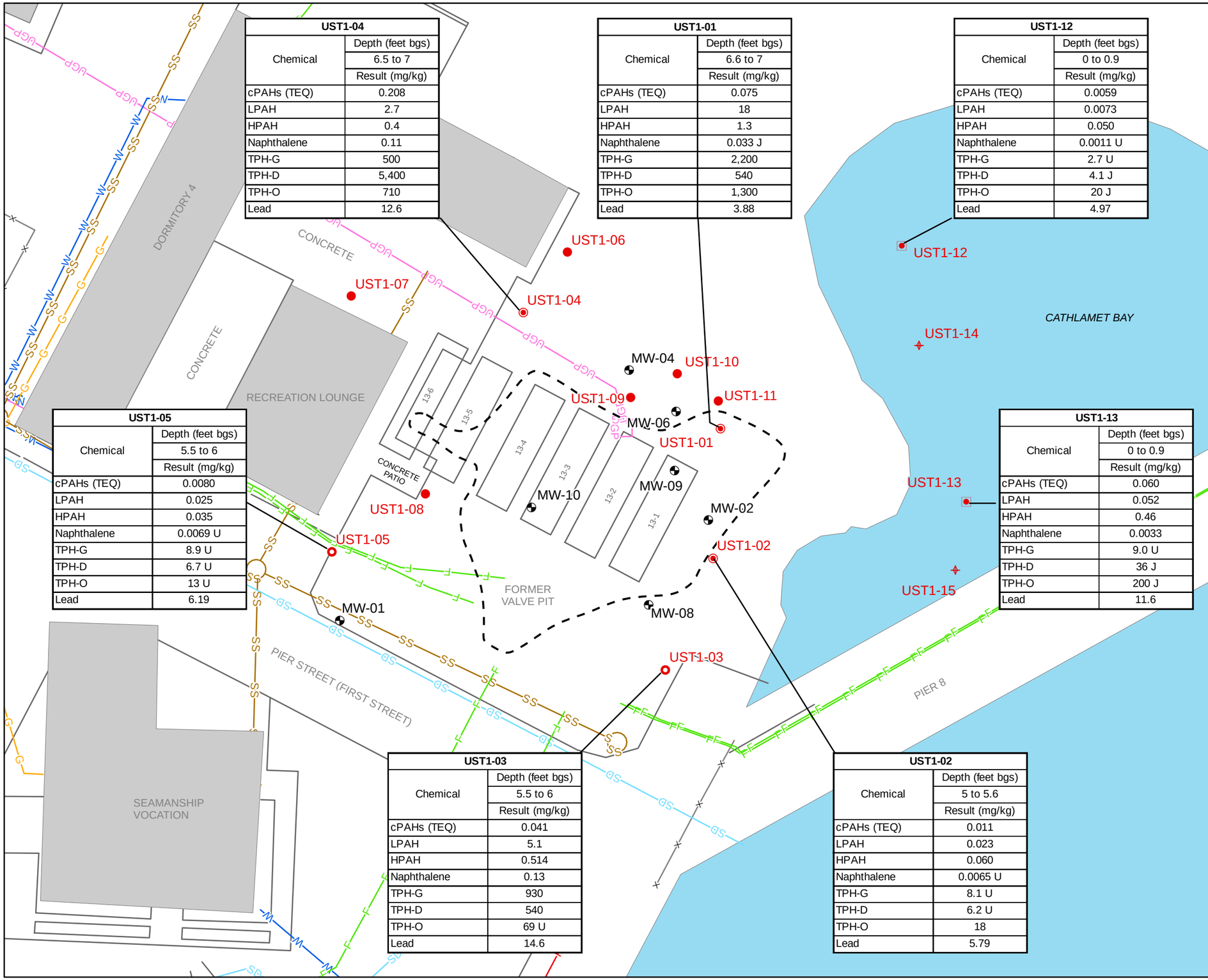
CDM

U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

AST FUEL STORAGE AREA SOIL ANALYTICAL RESULTS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 4-1



UST1-04	
Chemical	Depth (feet bgs)
	6.5 to 7
	Result (mg/kg)
cPAHs (TEQ)	0.208
LPAH	2.7
HPAH	0.4
Naphthalene	0.11
TPH-G	500
TPH-D	5,400
TPH-O	710
Lead	12.6

UST1-01	
Chemical	Depth (feet bgs)
	6.6 to 7
	Result (mg/kg)
cPAHs (TEQ)	0.075
LPAH	18
HPAH	1.3
Naphthalene	0.033 J
TPH-G	2,200
TPH-D	540
TPH-O	1,300
Lead	3.88

UST1-12	
Chemical	Depth (feet bgs)
	0 to 0.9
	Result (mg/kg)
cPAHs (TEQ)	0.0059
LPAH	0.0073
HPAH	0.050
Naphthalene	0.0011 U
TPH-G	2.7 U
TPH-D	4.1 J
TPH-O	20 J
Lead	4.97

UST1-05	
Chemical	Depth (feet bgs)
	5.5 to 6
	Result (mg/kg)
cPAHs (TEQ)	0.0080
LPAH	0.025
HPAH	0.035
Naphthalene	0.0069 U
TPH-G	8.9 U
TPH-D	6.7 U
TPH-O	13 U
Lead	6.19

UST1-13	
Chemical	Depth (feet bgs)
	0 to 0.9
	Result (mg/kg)
cPAHs (TEQ)	0.060
LPAH	0.052
HPAH	0.46
Naphthalene	0.0033
TPH-G	9.0 U
TPH-D	36 J
TPH-O	200 J
Lead	11.6

UST1-03	
Chemical	Depth (feet bgs)
	5.5 to 6
	Result (mg/kg)
cPAHs (TEQ)	0.041
LPAH	5.1
HPAH	0.514
Naphthalene	0.13
TPH-G	930
TPH-D	540
TPH-O	69 U
Lead	14.6

UST1-02	
Chemical	Depth (feet bgs)
	5 to 5.6
	Result (mg/kg)
cPAHs (TEQ)	0.011
LPAH	0.023
HPAH	0.060
Naphthalene	0.0065 U
TPH-G	8.1 U
TPH-D	6.2 U
TPH-O	18
Lead	5.79

LEGEND

- SEDIMENT CORE LOCATION
- SURFACE WATER SAMPLING LOCATION
- EXISTING MONITORING WELL
- SOIL GAS SAMPLE LOCATION
- DPT BORING/MICROWELL
- DPT BORING
- FUEL LINE FROM GEOPHISICAL SURVEY
- FUEL LINE NOT CONFIRMED BY GEOPHYSICAL SURVEY
- FENCE
- APPROXIMATE EXTENT OF JULY 2001 EXCAVATION

UTILITIES

- GAS
- UNDERGROUND POWER
- SANITARY SEWER
- STORM DRAIN
- WATER

NOTES

1. U = NOT DETECTED ABOVE THE STATED REPORTING LIMIT.
2. J = DETECTED WITH AN ESTIMATED CONCENTRATION.
3. TPH-G = GASOLINE RANGE PETROLEUM HYDROCARBONS.
4. TPH-D = DIESEL RANGE PETROLEUM HYDROCARBONS.
5. TPH-O = OIL RANGE PETROLEUM HYDROCARBONS.
6. cPAH = CARCINOGENIC POLYCYCLIC AROMATIC HYDROCARBONS. THIS INCLUDES: BENZO(A)PYRENE, BENZO(A)ANTHRACENE, BENZO(B)FLUORANTHENE, BENZO(K)FLUORANTHENE, CHRYSENE, DIBENZO(A,H)ANTHRACENE, AND INDENO(1,2,3-CD)PYRENE.
7. LPAH = LOW MOLECULAR WEIGHT POLYCYCLIC AROMATIC HYDROCARBONS. THIS INCLUDES: ACENAPHTHENE, ACENAPHTHYLENE,ANTHRACENE, FLUORENE, NAPHTHALENE, AND PHENANTHRENE.
8. HPAH = HIGH MOLECULAR WEIGHT POLYCYCLIC AROMATIC HYDROCARBONS. THIS INCLUDES: BENZO(A)PYRENE, BENZO(A)ANTHRACENE,TOTAL BENZOFLUORANTHENES, BENZO(G,H,I)PERYLENE, CHRYSENE, DIBENZO(A,H)ANTHRACENE, FLUORANTHENE, INDENO(1,2,3,-C,D)PYRENE, AND PYRENE.
9. TEQ = TOXIC EQUIVALENT; CALCULATED FOR HUMAN RECEPTORS UNLESS OTHERWISE NOTED.
10. mg/kg = MILLIGRAMS PER KILOGRAM.
11. bgs = BELOW GROUND SURFACE.
12. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
13. BASE MAP FILES FROM URS (FIGURE 3-2) SEPTEMBER 2007.

0 15 30 60
Feet

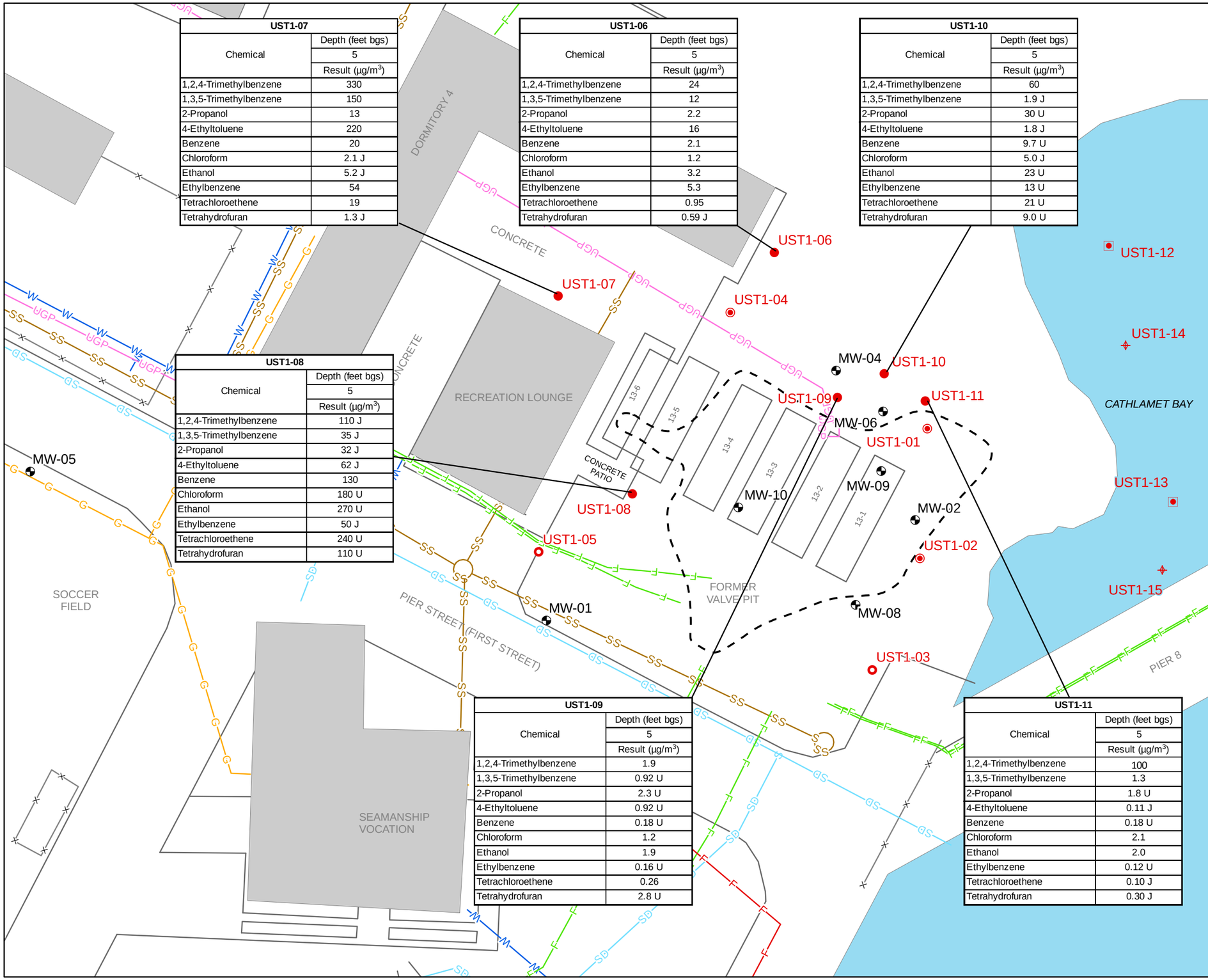
CDM

U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

UST SITE NO. 1 SOIL AND SEDIMENT ANALYTICAL RESULTS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 4-2



UST1-07	
Chemical	Depth (feet bgs)
	5
	Result (µg/m³)
1,2,4-Trimethylbenzene	330
1,3,5-Trimethylbenzene	150
2-Propanol	13
4-Ethyltoluene	220
Benzene	20
Chloroform	2.1 J
Ethanol	5.2 J
Ethylbenzene	54
Tetrachloroethene	19
Tetrahydrofuran	1.3 J

UST1-06	
Chemical	Depth (feet bgs)
	5
	Result (µg/m³)
1,2,4-Trimethylbenzene	24
1,3,5-Trimethylbenzene	12
2-Propanol	2.2
4-Ethyltoluene	16
Benzene	2.1
Chloroform	1.2
Ethanol	3.2
Ethylbenzene	5.3
Tetrachloroethene	0.95
Tetrahydrofuran	0.59 J

UST1-10	
Chemical	Depth (feet bgs)
	5
	Result (µg/m³)
1,2,4-Trimethylbenzene	60
1,3,5-Trimethylbenzene	1.9 J
2-Propanol	30 U
4-Ethyltoluene	1.8 J
Benzene	9.7 U
Chloroform	5.0 J
Ethanol	23 U
Ethylbenzene	13 U
Tetrachloroethene	21 U
Tetrahydrofuran	9.0 U

UST1-08	
Chemical	Depth (feet bgs)
	5
	Result (µg/m³)
1,2,4-Trimethylbenzene	110 J
1,3,5-Trimethylbenzene	35 J
2-Propanol	32 J
4-Ethyltoluene	62 J
Benzene	130
Chloroform	180 U
Ethanol	270 U
Ethylbenzene	50 J
Tetrachloroethene	240 U
Tetrahydrofuran	110 U

UST1-09	
Chemical	Depth (feet bgs)
	5
	Result (µg/m³)
1,2,4-Trimethylbenzene	1.9
1,3,5-Trimethylbenzene	0.92 U
2-Propanol	2.3 U
4-Ethyltoluene	0.92 U
Benzene	0.18 U
Chloroform	1.2
Ethanol	1.9
Ethylbenzene	0.16 U
Tetrachloroethene	0.26
Tetrahydrofuran	2.8 U

UST1-11	
Chemical	Depth (feet bgs)
	5
	Result (µg/m³)
1,2,4-Trimethylbenzene	100
1,3,5-Trimethylbenzene	1.3
2-Propanol	1.8 U
4-Ethyltoluene	0.11 J
Benzene	0.18 U
Chloroform	2.1
Ethanol	2.0
Ethylbenzene	0.12 U
Tetrachloroethene	0.10 J
Tetrahydrofuran	0.30 J

LEGEND

- SEDIMENT CORE LOCATION
- SURFACE WATER SAMPLING LOCATION
- EXISTING MONITORING WELL
- SOIL GAS SAMPLE LOCATION
- DPT BORING/MICROWELL
- DPT BORING
- FUEL LINE FROM GEOPHISICAL SURVEY
- FUEL LINE NOT CONFIRMED BY GEOPHYSICAL SURVEY
- FENCE
- APPROXIMATE EXTENT OF JULY 2001 EXCAVATION

UTILITIES

- GAS
- UNDERGROUND POWER
- SANITARY SEWER
- STORM DRAIN
- WATER

NOTES

1. U = NOT DETECTED ABOVE THE STATED REPORTING LIMIT.
2. J = DETECTED WITH AN ESTIMATED CONCENTRATION.
3. µg/m³ = MICROGRAMS PER CUBIC METER.
4. bgs = BELOW GROUND SURFACE.
5. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
6. BASE MAP FILES FROM URS (FIGURE 3-2) SEPTEMBER 2007.

0 15 30 60
Feet

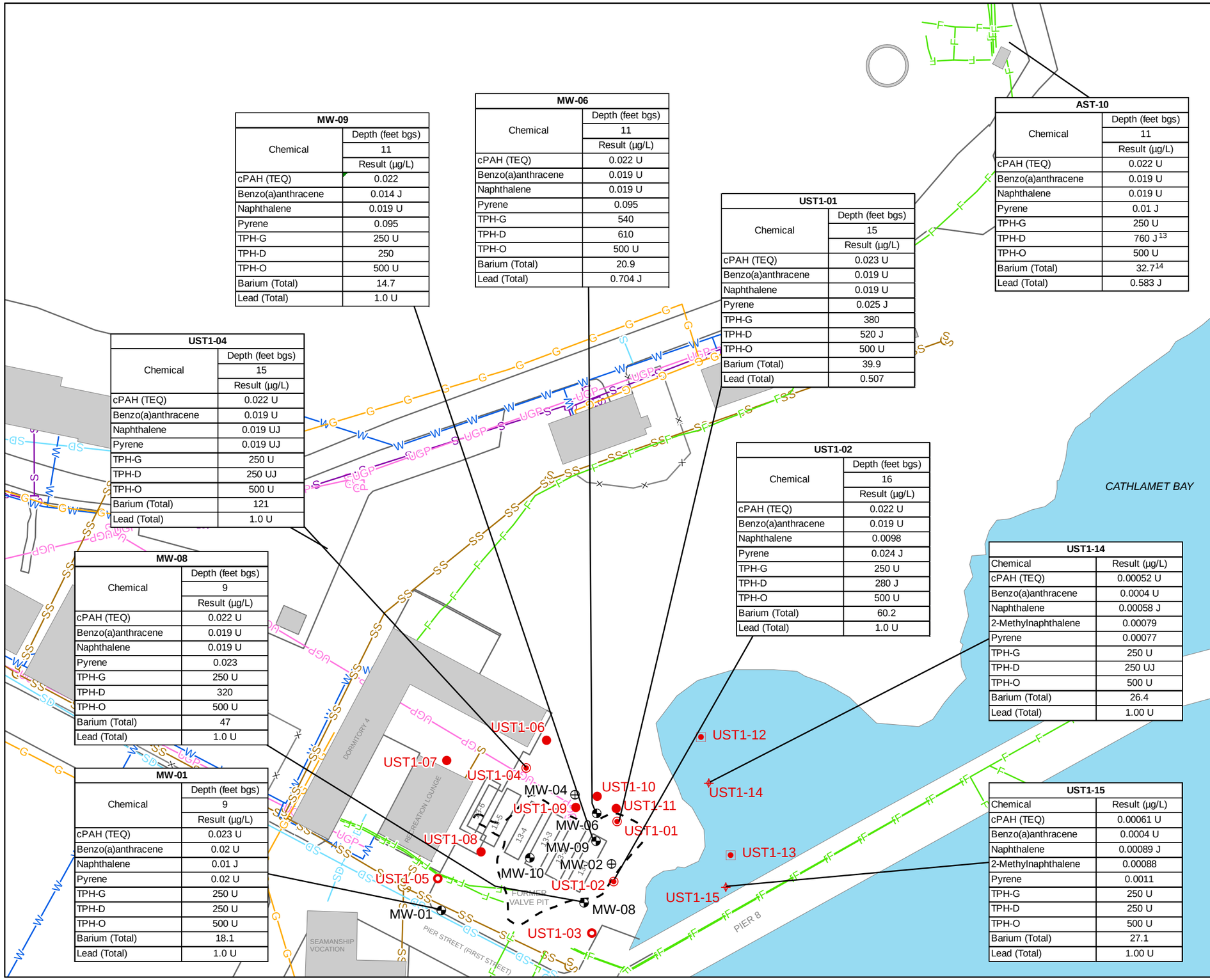
CDM

U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

UST SITE NO. 1
SOIL GAS ANALYTICAL RESULTS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 4-3



MW-09	
Chemical	Depth (feet bgs)
	11
	Result (µg/L)
cPAH (TEQ)	0.022
Benzo(a)anthracene	0.014 J
Naphthalene	0.019 U
Pyrene	0.095
TPH-G	250 U
TPH-D	250
TPH-O	500 U
Barium (Total)	14.7
Lead (Total)	1.0 U

MW-06	
Chemical	Depth (feet bgs)
	11
	Result (µg/L)
cPAH (TEQ)	0.022 U
Benzo(a)anthracene	0.019 U
Naphthalene	0.019 U
Pyrene	0.095
TPH-G	540
TPH-D	610
TPH-O	500 U
Barium (Total)	20.9
Lead (Total)	0.704 J

AST-10	
Chemical	Depth (feet bgs)
	11
	Result (µg/L)
cPAH (TEQ)	0.022 U
Benzo(a)anthracene	0.019 U
Naphthalene	0.019 U
Pyrene	0.01 J
TPH-G	250 U
TPH-D	760 J[13]
TPH-O	500 U
Barium (Total)	32.7[14]
Lead (Total)	0.583 J

UST1-01	
Chemical	Depth (feet bgs)
	15
	Result (µg/L)
cPAH (TEQ)	0.023 U
Benzo(a)anthracene	0.019 U
Naphthalene	0.019 U
Pyrene	0.025 J
TPH-G	380
TPH-D	520 J
TPH-O	500 U
Barium (Total)	39.9
Lead (Total)	0.507

UST1-04	
Chemical	Depth (feet bgs)
	15
	Result (µg/L)
cPAH (TEQ)	0.022 U
Benzo(a)anthracene	0.019 U
Naphthalene	0.019 UJ
Pyrene	0.019 UJ
TPH-G	250 U
TPH-D	250 UJ
TPH-O	500 U
Barium (Total)	121
Lead (Total)	1.0 U

UST1-02	
Chemical	Depth (feet bgs)
	16
	Result (µg/L)
cPAH (TEQ)	0.022 U
Benzo(a)anthracene	0.019 U
Naphthalene	0.0098
Pyrene	0.024 J
TPH-G	250 U
TPH-D	280 J
TPH-O	500 U
Barium (Total)	60.2
Lead (Total)	1.0 U

MW-08	
Chemical	Depth (feet bgs)
	9
	Result (µg/L)
cPAH (TEQ)	0.022 U
Benzo(a)anthracene	0.019 U
Naphthalene	0.019 U
Pyrene	0.023
TPH-G	250 U
TPH-D	320
TPH-O	500 U
Barium (Total)	47
Lead (Total)	1.0 U

UST1-14	
Chemical	Result (µg/L)
cPAH (TEQ)	0.00052 U
Benzo(a)anthracene	0.0004 U
Naphthalene	0.00058 J
2-Methylnaphthalene	0.00079
Pyrene	0.00077
TPH-G	250 U
TPH-D	250 UJ
TPH-O	500 U
Barium (Total)	26.4
Lead (Total)	1.00 U

MW-01	
Chemical	Depth (feet bgs)
	9
	Result (µg/L)
cPAH (TEQ)	0.023 U
Benzo(a)anthracene	0.02 U
Naphthalene	0.01 J
Pyrene	0.02 U
TPH-G	250 U
TPH-D	250 U
TPH-O	500 U
Barium (Total)	18.1
Lead (Total)	1.0 U

UST1-15	
Chemical	Result (µg/L)
cPAH (TEQ)	0.00061 U
Benzo(a)anthracene	0.0004 U
Naphthalene	0.00089 J
2-Methylnaphthalene	0.00088
Pyrene	0.0011
TPH-G	250 U
TPH-D	250 U
TPH-O	500 U
Barium (Total)	27.1
Lead (Total)	1.00 U

LEGEND

- SEDIMENT CORE LOCATION
- SURFACE WATER SAMPLING LOCATION
- EXISTING MONITORING WELL
- ABANDONED MONITORING WELL
- SOIL GAS SAMPLE LOCATION
- DPT BORING/MICROWELL
- DPT BORING
- COMPOSITE SURFACE SAMPLE LOCATION
- FUEL LINE FROM GEOPHISICAL SURVEY
- FUEL LINE NOT CONFIRMED BY GEOPHYSICAL SURVEY
- FENCE
- APPROXIMATE EXTENT OF JULY 2001 EXCAVATION

UTILITIES

- GAS
- UNDERGROUND POWER
- SANITARY SEWER
- STORM DRAIN
- WATER

NOTES

1. U = NOT DETECTED ABOVE THE STATED REPORTING LIMIT.
2. J = DETECTED WITH AN ESTIMATED CONCENTRATION.
3. UJ = THE ANALYTE WAS ANALYZED FOR, BUT WAS NOT DETECTED. THE REPORTED QUANTITATION LIMIT IS APPROXIMATE AND MAY BE INACCURATE OR IMPRECISE.
4. TPH-G = GASOLINE RANGE PETROLEUM HYDROCARBONS.
5. TPH-D = DIESEL RANGE PETROLEUM HYDROCARBONS.
6. TPH-O = OIL RANGE PETROLEUM HYDROCARBONS.
7. cPAH = CARCINOGENIC POLYCYCLIC AROMATIC HYDROCARBONS. THIS INCLUDES: BENZO(A)PYRENE, BENZO(A)ANTHRACENE, BENZO(B)FLUORANTHENE, BENZO(K)FLUORANTHENE, CHRYSENE, DIBENZO(A,H)ANTHRACENE, AND INDENO(1,2,3-CD)PYRENE.
8. TEQ = TOXIC EQUIVALENT; CALCULATED FOR HUMAN RECEPTORS UNLESS OTHERWISE NOTED.
9. µg/L = MICROGRAMS PER LITER.
10. bgs = BELOW GROUND SURFACE.
11. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
12. BASE MAP FILES FROM URS (FIGURE 3-2) SEPTEMBER 2007.
13. THE RESULT FOR TPH-D FOR SAMPLE LOCATION AST-10 IS FROM THE FIELD DUPLICATE. THE PARENT SAMPLE RESULT WAS 290 J.
14. THE RESULT FOR BARIUM (TOTAL) FOR SAMPLE LOCATION AST-10 IS FROM THE FIELD DUPLICATE. THE PARENT SAMPLE RESULT WAS 31.8.

0 30 60 120
Feet

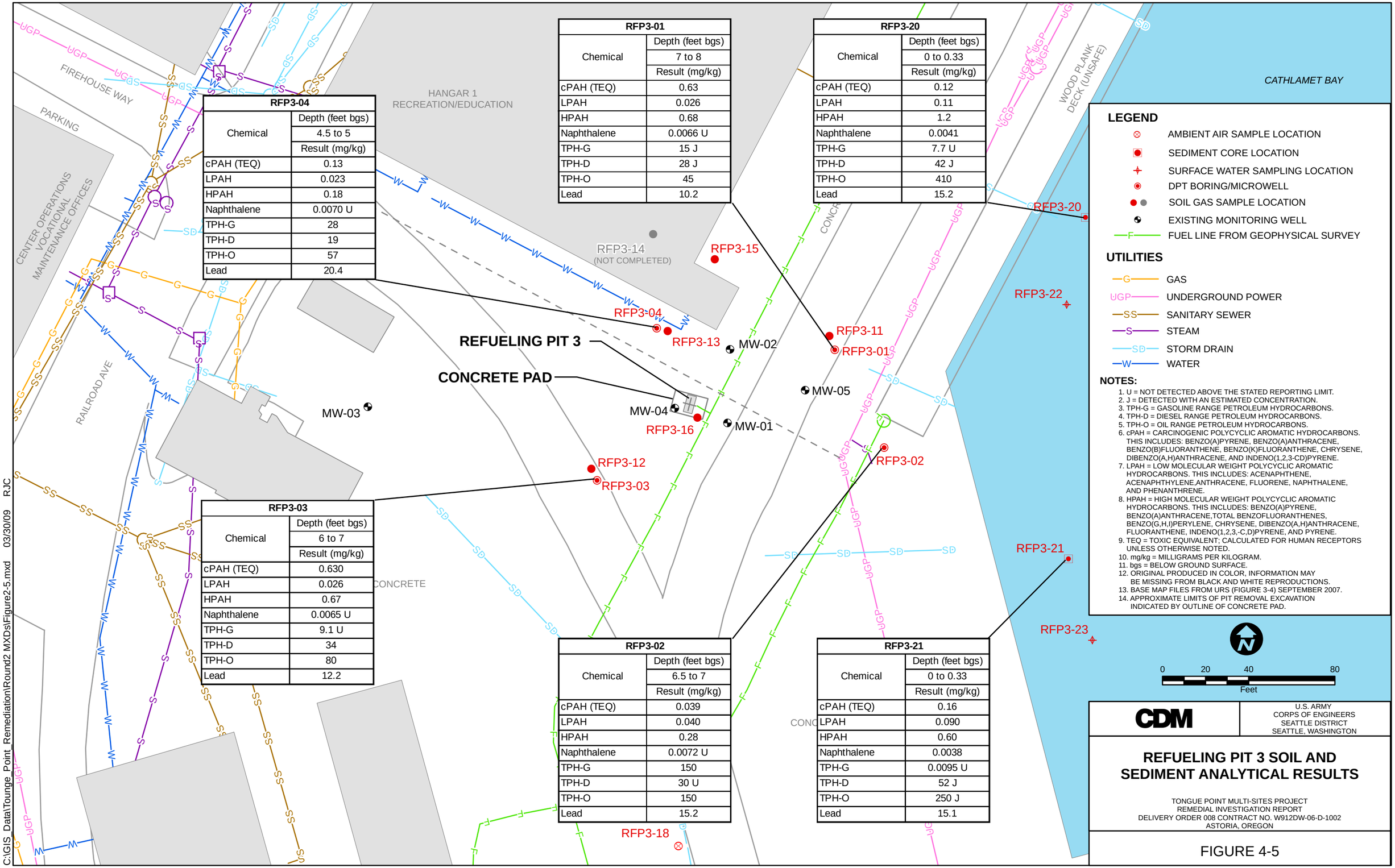
CDM

U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

UST SITE NO. 1 AND AST FUEL STORAGE AREA GROUNDWATER AND SURFACE WATER ANALYTICAL RESULTS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 4-4



RFP3-01

Chemical	Depth (feet bgs)
	7 to 8
	Result (mg/kg)
cPAH (TEQ)	0.63
LPAH	0.026
HPAH	0.68
Naphthalene	0.0066 U
TPH-G	15 J
TPH-D	28 J
TPH-O	45
Lead	10.2

RFP3-20

Chemical	Depth (feet bgs)
	0 to 0.33
	Result (mg/kg)
cPAH (TEQ)	0.12
LPAH	0.11
HPAH	1.2
Naphthalene	0.0041
TPH-G	7.7 U
TPH-D	42 J
TPH-O	410
Lead	15.2

RFP3-04

Chemical	Depth (feet bgs)
	4.5 to 5
	Result (mg/kg)
cPAH (TEQ)	0.13
LPAH	0.023
HPAH	0.18
Naphthalene	0.0070 U
TPH-G	28
TPH-D	19
TPH-O	57
Lead	20.4

RFP3-03

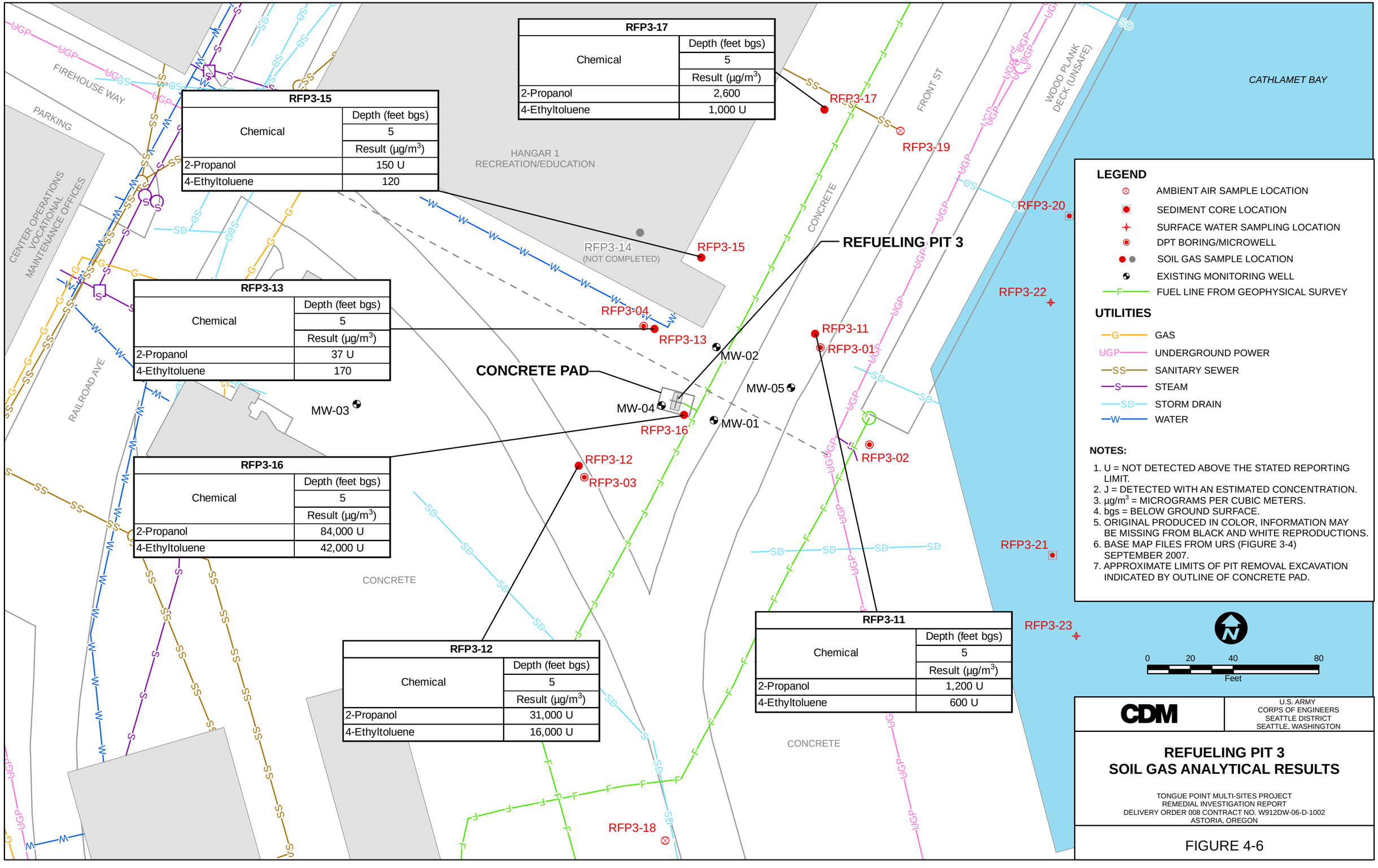
Chemical	Depth (feet bgs)
	6 to 7
	Result (mg/kg)
cPAH (TEQ)	0.630
LPAH	0.026
HPAH	0.67
Naphthalene	0.0065 U
TPH-G	9.1 U
TPH-D	34
TPH-O	80
Lead	12.2

RFP3-02

Chemical	Depth (feet bgs)
	6.5 to 7
	Result (mg/kg)
cPAH (TEQ)	0.039
LPAH	0.040
HPAH	0.28
Naphthalene	0.0072 U
TPH-G	150
TPH-D	30 U
TPH-O	150
Lead	15.2

RFP3-21

Chemical	Depth (feet bgs)
	0 to 0.33
	Result (mg/kg)
cPAH (TEQ)	0.16
LPAH	0.090
HPAH	0.60
Naphthalene	0.0038
TPH-G	0.0095 U
TPH-D	52 J
TPH-O	250 J
Lead	15.1



RFP3-17

Chemical	Depth (feet bgs) 5 Result (µg/m³)
2-Propanol	2,600
4-Ethyltoluene	1,000 U

RFP3-15

Chemical	Depth (feet bgs) 5 Result (µg/m³)
2-Propanol	150 U
4-Ethyltoluene	120

RFP3-13

Chemical	Depth (feet bgs) 5 Result (µg/m³)
2-Propanol	37 U
4-Ethyltoluene	170

RFP3-16

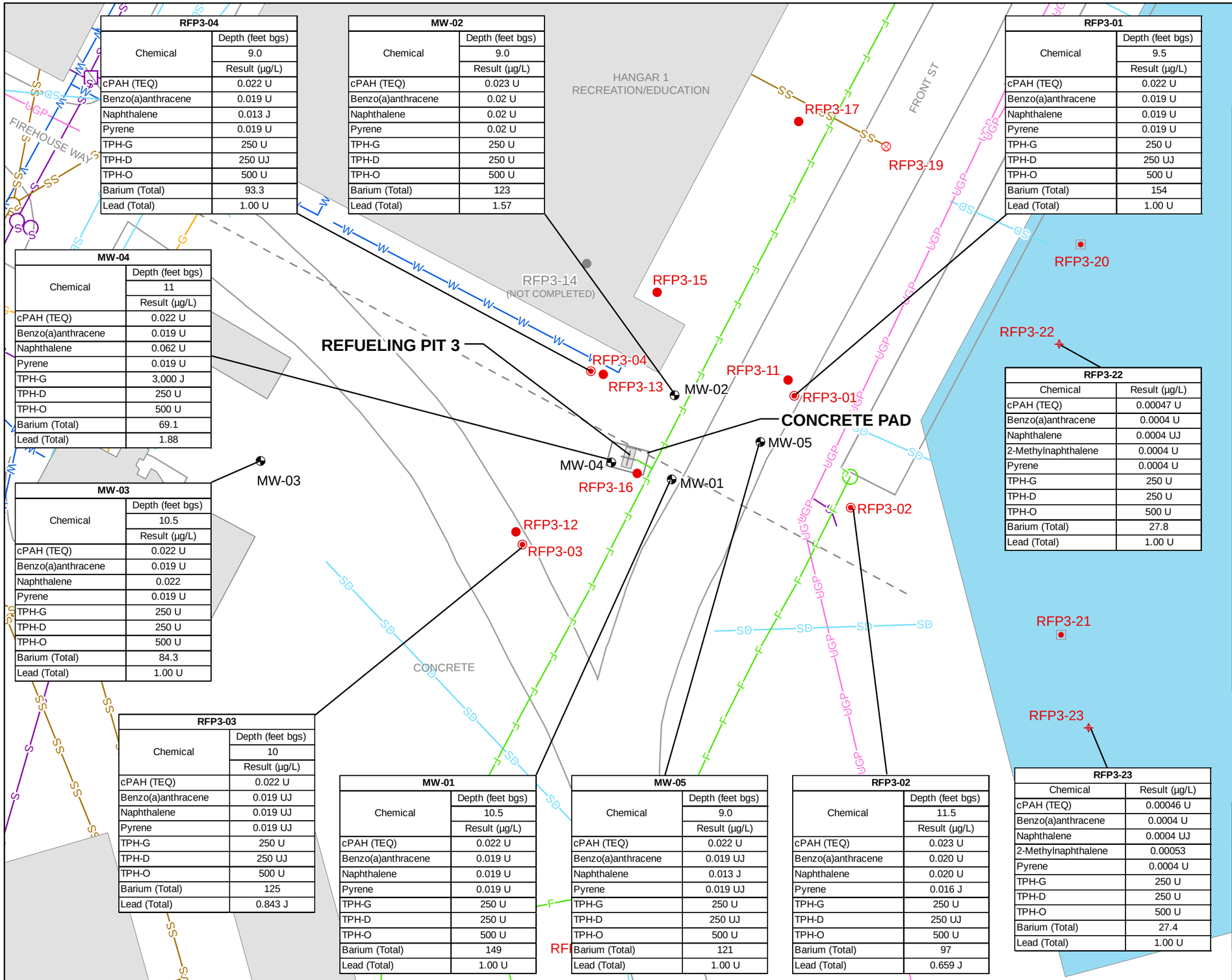
Chemical	Depth (feet bgs) 5 Result (µg/m³)
2-Propanol	84,000 U
4-Ethyltoluene	42,000 U

RFP3-12

Chemical	Depth (feet bgs) 5 Result (µg/m³)
2-Propanol	31,000 U
4-Ethyltoluene	16,000 U

RFP3-11

Chemical	Depth (feet bgs) 5 Result (µg/m³)
2-Propanol	1,200 U
4-Ethyltoluene	600 U



RFP3-04	
Chemical	Depth (feet bgs)
	9.0
	Result (µg/L)
cPAH (TEQ)	0.022 U
Benzo(a)anthracene	0.019 U
Naphthalene	0.013 J
Pyrene	0.019 U
TPH-G	250 U
TPH-D	250 UJ
TPH-O	500 U
Barium (Total)	93.3
Lead (Total)	1.00 U

MW-02	
Chemical	Depth (feet bgs)
	9.0
	Result (µg/L)
cPAH (TEQ)	0.023 U
Benzo(a)anthracene	0.02 U
Naphthalene	0.02 U
Pyrene	0.02 U
TPH-G	250 U
TPH-D	250 U
TPH-O	500 U
Barium (Total)	123
Lead (Total)	1.57

RFP3-01	
Chemical	Depth (feet bgs)
	9.5
	Result (µg/L)
cPAH (TEQ)	0.022 U
Benzo(a)anthracene	0.019 U
Naphthalene	0.019 U
Pyrene	0.019 U
TPH-G	250 U
TPH-D	250 UJ
TPH-O	500 U
Barium (Total)	154
Lead (Total)	1.00 U

MW-04	
Chemical	Depth (feet bgs)
	11
	Result (µg/L)
cPAH (TEQ)	0.022 U
Benzo(a)anthracene	0.019 U
Naphthalene	0.062 U
Pyrene	0.019 U
TPH-G	3,000 J
TPH-D	250 U
TPH-O	500 U
Barium (Total)	69.1
Lead (Total)	1.88

MW-03	
Chemical	Depth (feet bgs)
	10.5
	Result (µg/L)
cPAH (TEQ)	0.022 U
Benzo(a)anthracene	0.019 U
Naphthalene	0.022
Pyrene	0.019 U
TPH-G	250 U
TPH-D	250 U
TPH-O	500 U
Barium (Total)	84.3
Lead (Total)	1.00 U

RFP3-22	
Chemical	Result (µg/L)
cPAH (TEQ)	0.00047 U
Benzo(a)anthracene	0.0004 U
Naphthalene	0.0004 UJ
2-Methylnaphthalene	0.0004 U
Pyrene	0.0004 U
TPH-G	250 U
TPH-D	250 U
TPH-O	500 U
Barium (Total)	27.8
Lead (Total)	1.00 U

RFP3-03	
Chemical	Depth (feet bgs)
	10
	Result (µg/L)
cPAH (TEQ)	0.022 U
Benzo(a)anthracene	0.019 UJ
Naphthalene	0.019 UJ
Pyrene	0.019 UJ
TPH-G	250 U
TPH-D	250 UJ
TPH-O	500 U
Barium (Total)	125
Lead (Total)	0.843 J

MW-01	
Chemical	Depth (feet bgs)
	10.5
	Result (µg/L)
cPAH (TEQ)	0.022 U
Benzo(a)anthracene	0.019 U
Naphthalene	0.019 U
Pyrene	0.019 U
TPH-G	250 U
TPH-D	250 U
TPH-O	500 U
Barium (Total)	149
Lead (Total)	1.00 U

MW-05	
Chemical	Depth (feet bgs)
	9.0
	Result (µg/L)
cPAH (TEQ)	0.022 U
Benzo(a)anthracene	0.019 UJ
Naphthalene	0.013 J
Pyrene	0.019 UJ
TPH-G	250 U
TPH-D	250 UJ
TPH-O	500 U
Barium (Total)	121
Lead (Total)	1.00 U

RFP3-02	
Chemical	Depth (feet bgs)
	11.5
	Result (µg/L)
cPAH (TEQ)	0.023 U
Benzo(a)anthracene	0.020 U
Naphthalene	0.020 U
Pyrene	0.016 J
TPH-G	250 U
TPH-D	250 UJ
TPH-O	500 U
Barium (Total)	97
Lead (Total)	0.659 J

RFP3-23	
Chemical	Result (µg/L)
cPAH (TEQ)	0.00046 U
Benzo(a)anthracene	0.0004 U
Naphthalene	0.0004 UJ
2-Methylnaphthalene	0.00053
Pyrene	0.0004 U
TPH-G	250 U
TPH-D	250 U
TPH-O	500 U
Barium (Total)	27.4
Lead (Total)	1.00 U

LEGEND

- AMBIENT AIR SAMPLE LOCATION
- SEDIMENT CORE LOCATION
- SURFACE WATER SAMPLING LOCATION
- DPT BORING/MICROWELL
- SOIL GAS SAMPLE LOCATION
- EXISTING MONITORING WELL
- FUEL LINE FROM GEOPHYSICAL SURVEY

UTILITIES

- GAS
- UNDERGROUND POWER
- SANITARY SEWER
- STEAM
- STORM DRAIN
- WATER

NOTES:

1. U = NOT DETECTED ABOVE THE STATED REPORTING LIMIT.
2. J = DETECTED WITH AN ESTIMATED CONCENTRATION.
3. UJ = THE ANALYTE WAS ANALYZED FOR, BUT WAS NOT DETECTED. THE REPORTED QUANTITATION LIMIT IS APPROXIMATE AND MAY BE INACCURATE OR IMPRECISE.
4. TPH-G = GASOLINE RANGE PETROLEUM HYDROCARBONS.
5. TPH-D = DIESEL RANGE PETROLEUM HYDROCARBONS.
6. TPH-O = OIL RANGE PETROLEUM HYDROCARBONS.
7. cPAH = CARCINOGENIC POLYCYCLIC AROMATIC HYDROCARBONS. THIS INCLUDES: BENZO(A)PYRENE, BENZO(A)ANTHRACENE, BENZO(B)FLUORANTHENE, BENZO(K)FLUORANTHENE, CHRYSENE, DIBENZO(A,H)ANTHRACENE, AND INDENO(1,2,3-CD)PYRENE.
8. TEQ = TOXIC EQUIVALENT; CALCULATED FOR HUMAN RECPTORS UNLESS OTHERWISE NOTED.
9. µg/L = MICROGRAMS PER LITER.
10. bgs = BELOW GROUND SURFACE.
11. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
12. BASE MAP FILES FROM URS (FIGURE 3-4) SEPTEMBER 2007.
13. APPROXIMATE LIMITS OF PIT REMOVAL EXCAVATION INDICATED BY OUTLINE OF CONCRETE PAD.

0 20 40 80
Feet

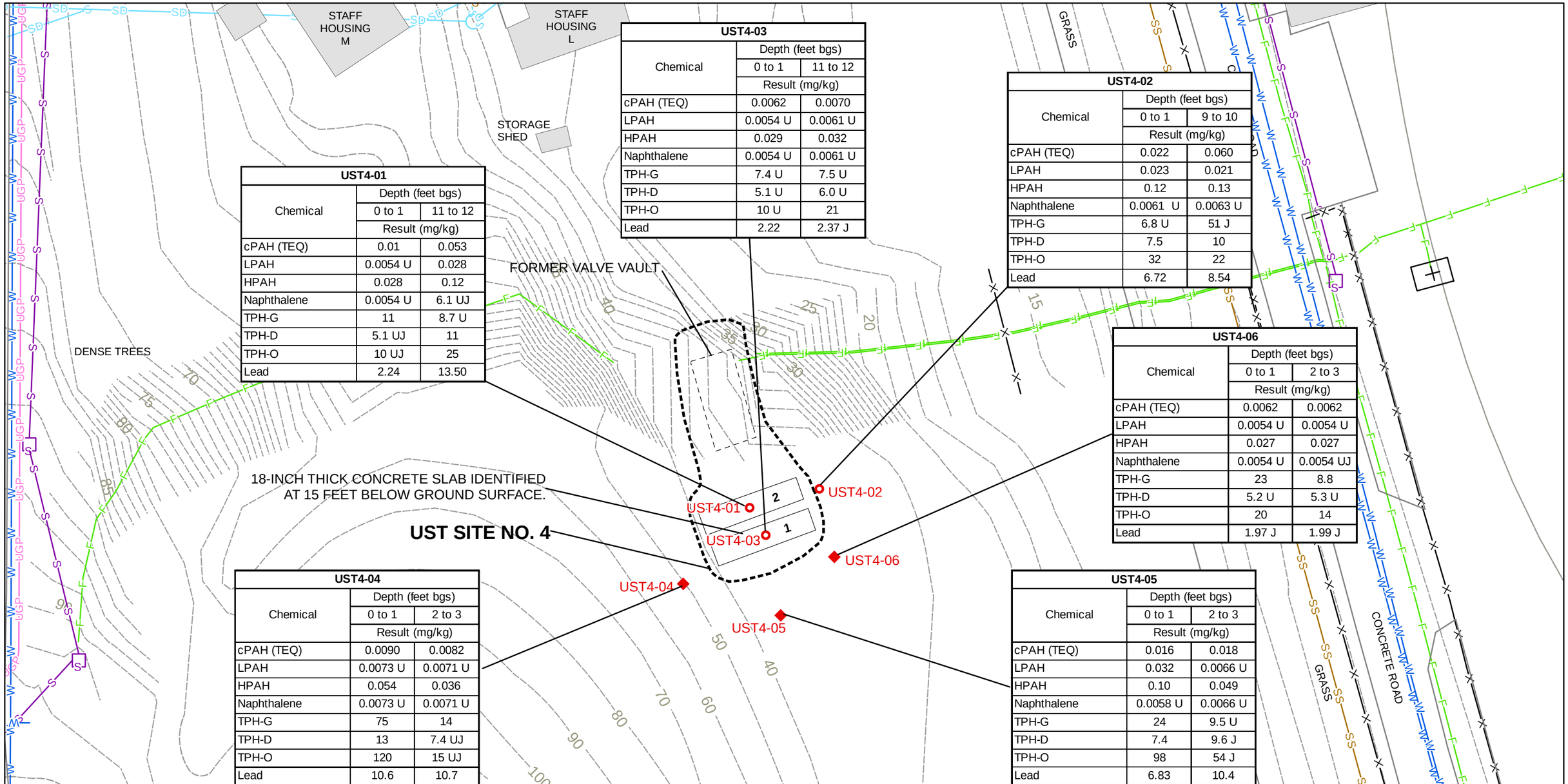
CDM

U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

REFUELING PIT 3 GROUND AND SURFACE WATER ANALYTICAL RESULTS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 4-7



UST4-01

Chemical	Depth (feet bgs) 0 to 1	11 to 12
	Result (mg/kg)	
cPAH (TEQ)	0.01	0.053
LPAH	0.0054 U	0.028
HPAH	0.028	0.12
Naphthalene	0.0054 U	6.1 UJ
TPH-G	11	8.7 U
TPH-D	5.1 UJ	11
TPH-O	10 UJ	25
Lead	2.24	13.50

UST4-03

Chemical	Depth (feet bgs) 0 to 1	11 to 12
	Result (mg/kg)	
cPAH (TEQ)	0.0062	0.0070
LPAH	0.0054 U	0.0061 U
HPAH	0.029	0.032
Naphthalene	0.0054 U	0.0061 U
TPH-G	7.4 U	7.5 U
TPH-D	5.1 U	6.0 U
TPH-O	10 U	21
Lead	2.22	2.37 J

UST4-02

Chemical	Depth (feet bgs) 0 to 1	9 to 10
	Result (mg/kg)	
cPAH (TEQ)	0.022	0.060
LPAH	0.023	0.021
HPAH	0.12	0.13
Naphthalene	0.0061 U	0.0063 U
TPH-G	6.8 U	51 J
TPH-D	7.5	10
TPH-O	32	22
Lead	6.72	8.54

UST4-06

Chemical	Depth (feet bgs) 0 to 1	2 to 3
	Result (mg/kg)	
cPAH (TEQ)	0.0062	0.0062
LPAH	0.0054 U	0.0054 U
HPAH	0.027	0.027
Naphthalene	0.0054 U	0.0054 UJ
TPH-G	23	8.8
TPH-D	5.2 U	5.3 U
TPH-O	20	14
Lead	1.97 J	1.99 J

UST4-04

Chemical	Depth (feet bgs) 0 to 1	2 to 3
	Result (mg/kg)	
cPAH (TEQ)	0.0090	0.0082
LPAH	0.0073 U	0.0071 U
HPAH	0.054	0.036
Naphthalene	0.0073 U	0.0071 U
TPH-G	75	14
TPH-D	13	7.4 UJ
TPH-O	120	15 UJ
Lead	10.6	10.7

UST4-05

Chemical	Depth (feet bgs) 0 to 1	2 to 3
	Result (mg/kg)	
cPAH (TEQ)	0.016	0.018
LPAH	0.032	0.0066 U
HPAH	0.10	0.049
Naphthalene	0.0058 U	0.0066 U
TPH-G	24	9.5 U
TPH-D	7.4	9.6 J
TPH-O	98	54 J
Lead	6.83	10.4

LEGEND

- DPT BORING
- HAND AUGER BORING
- SEPTEMBER 1992 EXCAVATION LIMITS
- RAILROAD
- FENCE

UTILITIES

- GAS
- SANITARY SEWER
- STEAM
- STORM DRAIN
- WATER
- FUEL LINE FROM GEOPHYSICAL SURVEY

NOTES:

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3. UJ = THE ANALYTE WAS ANALYZED FOR, BUT WAS NOT DETECTED. THE REPORTED QUANTITATION LIMIT IS APPROXIMATE AND MAY BE INACCURATE OR IMPRECISE.
4. TPH-G = GASOLINE RANGE PETROLEUM HYDROCARBONS.
5. TPH-D = DIESEL RANGE PETROLEUM HYDROCARBONS.
6. TPH-O = OIL RANGE PETROLEUM HYDROCARBONS.
7. cPAH = CARCINOGENIC POLYCYCLIC AROMATIC HYDROCARBONS. THIS INCLUDES: BENZO(A)PYRENE, BENZO(A)ANTHRACENE, BENZO(B)FLUORANTHENE, BENZO(K)FLUORANTHENE, CHRYSENE, DIBENZO(A,H)ANTHRACENE, AND INDENO(1,2,3-CD)PYRENE.
8. LPAH = LOW MOLECULAR WEIGHT POLYCYCLIC AROMATIC HYDROCARBONS. THIS INCLUDES: ACENAPHTHENE, ACENAPHTHYLENE,ANTHRACENE, FLUORENE, NAPHTHALENE, AND PHENANTHRENE.
9. HPAH = HIGH MOLECULAR WEIGHT POLYCYCLIC AROMATIC HYDROCARBONS. THIS INCLUDES: BENZO(A)PYRENE, BENZO(A)ANTHRACENE,TOTAL BENZOFLUORANTHENES, BENZO(G,H,I)PERYLENE, CHRYSENE, DIBENZO(A,H)ANTHRACENE, FLUORANTHENE, INDENO(1,2,3,-C,D)PYRENE, AND PYRENE.
10. TEQ = TOXIC EQUIVALENT; CALCULATED FOR HUMAN RECEPTORS UNLESS OTHERWISE NOTED.
11. mg/kg = MILLIGRAMS PER KILOGRAM.
12. bgs = BELOW GROUND SURFACE.
13. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
14. BASE MAP FILES FROM URS (FIGURE 3-3) SEPTEMBER 2007.

0 20 40 80
Feet

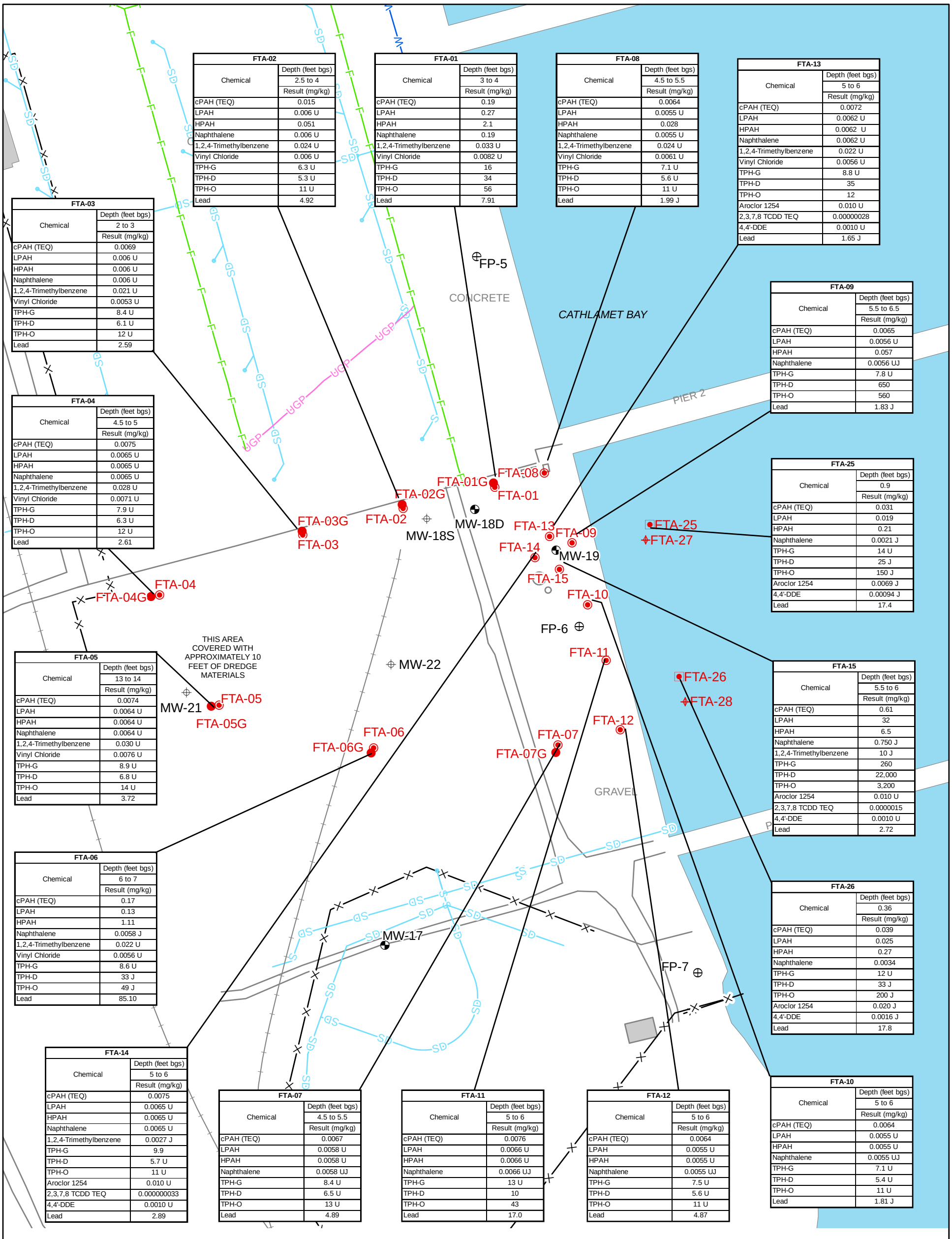
CDM

U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

UST SITE NO. 4
SOIL ANALYTICAL RESULTS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 4-8



FTA-02

Chemical	Depth (feet bgs) 2.5 to 4 Result (mg/kg)
cPAH (TEQ)	0.015
LPAH	0.006 U
HPAH	0.051
Naphthalene	0.006 U
1,2,4-Trimethylbenzene	0.024 U
Vinyl Chloride	0.006 U
TPH-G	6.3 U
TPH-D	5.3 U
TPH-O	11 U
Lead	4.92

FTA-01

Chemical	Depth (feet bgs) 3 to 4 Result (mg/kg)
cPAH (TEQ)	0.19
LPAH	0.27
HPAH	2.1
Naphthalene	0.19
1,2,4-Trimethylbenzene	0.033 U
Vinyl Chloride	0.0082 U
TPH-G	16
TPH-D	34
TPH-O	56
Lead	7.91

FTA-08

Chemical	Depth (feet bgs) 4.5 to 5.5 Result (mg/kg)
cPAH (TEQ)	0.0064
LPAH	0.0055 U
HPAH	0.028
Naphthalene	0.0055 U
1,2,4-Trimethylbenzene	0.024 U
Vinyl Chloride	0.0061 U
TPH-G	7.1 U
TPH-D	5.6 U
TPH-O	11 U
Lead	1.99 J

FTA-13

Chemical	Depth (feet bgs) 5 to 6 Result (mg/kg)
cPAH (TEQ)	0.0072
LPAH	0.0062 U
HPAH	0.0062 U
Naphthalene	0.0062 U
1,2,4-Trimethylbenzene	0.022 U
Vinyl Chloride	0.0056 U
TPH-G	8.8 U
TPH-D	35
TPH-O	12
Aroclor 1254	0.010 U
2,3,7,8 TCDD TEQ	0.00000028
4,4'-DDE	0.0010 U
Lead	1.65 J

FTA-03

Chemical	Depth (feet bgs) 2 to 3 Result (mg/kg)
cPAH (TEQ)	0.0069
LPAH	0.006 U
HPAH	0.006 U
Naphthalene	0.006 U
1,2,4-Trimethylbenzene	0.021 U
Vinyl Chloride	0.0053 U
TPH-G	8.4 U
TPH-D	6.1 U
TPH-O	12 U
Lead	2.59

FTA-09

Chemical	Depth (feet bgs) 5.5 to 6.5 Result (mg/kg)
cPAH (TEQ)	0.0065
LPAH	0.0056 U
HPAH	0.057
Naphthalene	0.0056 UJ
TPH-G	7.8 U
TPH-D	650
TPH-O	560
Lead	1.83 J

FTA-04

Chemical	Depth (feet bgs) 4.5 to 5 Result (mg/kg)
cPAH (TEQ)	0.0075
LPAH	0.0065 U
HPAH	0.0065 U
Naphthalene	0.0065 U
1,2,4-Trimethylbenzene	0.028 U
Vinyl Chloride	0.0071 U
TPH-G	7.9 U
TPH-D	6.3 U
TPH-O	12 U
Lead	2.61

FTA-25

Chemical	Depth (feet bgs) 0.9 Result (mg/kg)
cPAH (TEQ)	0.031
LPAH	0.019
HPAH	0.21
Naphthalene	0.0021 J
TPH-G	14 U
TPH-D	25 J
TPH-O	150 J
Aroclor 1254	0.0069 J
4,4'-DDE	0.00094 J
Lead	17.4

FTA-05

Chemical	Depth (feet bgs) 13 to 14 Result (mg/kg)
cPAH (TEQ)	0.0074
LPAH	0.0064 U
HPAH	0.0064 U
Naphthalene	0.0064 U
1,2,4-Trimethylbenzene	0.030 U
Vinyl Chloride	0.0076 U
TPH-G	8.9 U
TPH-D	6.8 U
TPH-O	14 U
Lead	3.72

FTA-15

Chemical	Depth (feet bgs) 5.5 to 6 Result (mg/kg)
cPAH (TEQ)	0.61
LPAH	32
HPAH	6.5
Naphthalene	0.750 J
1,2,4-Trimethylbenzene	10 J
TPH-G	260
TPH-D	22,000
TPH-O	3,200
Aroclor 1254	0.010 U
2,3,7,8 TCDD TEQ	0.0000015
4,4'-DDE	0.0010 U
Lead	2.72

FTA-06

Chemical	Depth (feet bgs) 6 to 7 Result (mg/kg)
cPAH (TEQ)	0.17
LPAH	0.13
HPAH	1.11
Naphthalene	0.0058 J
1,2,4-Trimethylbenzene	0.022 U
Vinyl Chloride	0.0056 U
TPH-G	8.6 U
TPH-D	33 J
TPH-O	49 J
Lead	85.10

FTA-26

Chemical	Depth (feet bgs) 0.36 Result (mg/kg)
cPAH (TEQ)	0.039
LPAH	0.025
HPAH	0.27
Naphthalene	0.0034
TPH-G	12 U
TPH-D	33 J
TPH-O	200 J
Aroclor 1254	0.020 J
4,4'-DDE	0.0016 J
Lead	17.8

FTA-14

Chemical	Depth (feet bgs) 5 to 6 Result (mg/kg)
cPAH (TEQ)	0.0075
LPAH	0.0065 U
HPAH	0.0065 U
Naphthalene	0.0065 U
1,2,4-Trimethylbenzene	0.0027 J
TPH-G	9.9
TPH-D	5.7 U
TPH-O	11 U
Aroclor 1254	0.010 U
2,3,7,8 TCDD TEQ	0.000000033
4,4'-DDE	0.0010 U
Lead	2.89

FTA-07

Chemical	Depth (feet bgs) 4.5 to 5.5 Result (mg/kg)
cPAH (TEQ)	0.0067
LPAH	0.0058 U
HPAH	0.0058 U
Naphthalene	0.0058 UJ
TPH-G	8.4 U
TPH-D	6.5 U
TPH-O	13 U
Lead	4.89

FTA-11

Chemical	Depth (feet bgs) 5 to 6 Result (mg/kg)
cPAH (TEQ)	0.0076
LPAH	0.0066 U
HPAH	0.0066 U
Naphthalene	0.0066 UJ
TPH-G	13 U
TPH-D	10
TPH-O	43
Lead	17.0

FTA-12

Chemical	Depth (feet bgs) 5 to 6 Result (mg/kg)
cPAH (TEQ)	0.0064
LPAH	0.0055 U
HPAH	0.0055 U
Naphthalene	0.0055 UJ
TPH-G	7.5 U
TPH-D	5.6 U
TPH-O	11 U
Lead	4.87

FTA-10

Chemical	Depth (feet bgs) 5 to 6 Result (mg/kg)
cPAH (TEQ)	0.0064
LPAH	0.0055 U
HPAH	0.0055 U
Naphthalene	0.0055 UJ
TPH-G	7.1 U
TPH-D	5.4 U
TPH-O	11 U
Lead	1.81 J

LEGEND

- SEDIMENT CORE LOCATION
- SURFACE WATER SAMPLING LOCATION
- EXISTING MONITORING WELL
- INACCESSIBLE MONITORING WELL
- ABANDONED MONITORING WELL
- DPT DORING/MICROWELL
- SOIL GAS SAMPLE LOCATION
- SD — STORM DRAIN
- UGP — UNDERGROUND POWER
- F — FUEL LINE
- FENCE

NOTES:

1. U = NOT DETECTED ABOVE THE STATED REPORTING LIMIT.
2. J = DETECTED WITH AN ESTIMATED CONCENTRATION.
3. UJ = THE ANALYTE WAS ANALYZED FOR BUT WAS NOT DETECTED. THE REPORTED QUANTITATION LIMIT IS APPROXIMATE AND MAY BE INACCURATE OR IMPRECISE.
4. BASE MAP DATA: URS, FIGURE 3-7, SEPTEMBER 2007.
5. TPH-G = GASOLINE RANGE PETROLEUM HYDROCARBONS.
6. TPH-D = DIESEL RANGE PETROLEUM HYDROCARBONS.
7. TPH-O = OIL RANGE PETROLEUM HYDROCARBONS.
8. cPAH = CARCINOGENIC POLYCYCLIC AROMATIC HYDROCARBONS. THIS INCLUDES: BENZO(A)PYRENE, BENZO(A)ANTHRACENE, BENZO(B)FLUORANTHENE, BENZO(K)FLUORANTHENE, CHRYSENE, DIBENZO(A,H)ANTHRACENE, AND INDENO(1,2,3-CD)PYRENE.
9. LPAH = LOW MOLECULAR WEIGHT POLYCYCLIC AROMATIC HYDROCARBONS. THIS INCLUDES: ACENAPHTHENE, ACENAPHTHYLENE,ANTHRACENE, FLUORENE, NAPHTHALENE, AND PHENANTHRENE.
10. HPAH = HIGH MOLECULAR WEIGHT POLYCYCLIC AROMATIC HYDROCARBONS. THIS INCLUDES: BENZO(A)PYRENE, BENZO(A)ANTHRACENE,TOTAL BENZOFLUORANTHENES, BENZO(G,H,I)PERYLENE, CHRYSENE, DIBENZO(A,H)ANTHRACENE, FLUORANTHENE, INDENO(1,2,3,-C,D)PYRENE, AND PYRENE.
11. 2,3,7,8 TCDD = 2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN
12. 4,4'-DDE = P,P'-DICHLORODIPHENYLDICHLOROETHANE
13. TEQ = TOXIC EQUIVALENT; CALCULATED FOR HUMAN RECEPTOR UNLESS OTHERWISE NOTED.
14. mg/kg = MILLIGRAMS PER KILOGRAM.
15. bgs = BELOW GROUND SURFACE.
16. DREDGE SPOIL AREA HISTORICALLY USED AS A PUBLIC WORKS STORAGE YARD AND HAD SEVERAL WAREHOUSE BUILDINGS.
17. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.

0 70 140 280
Feet

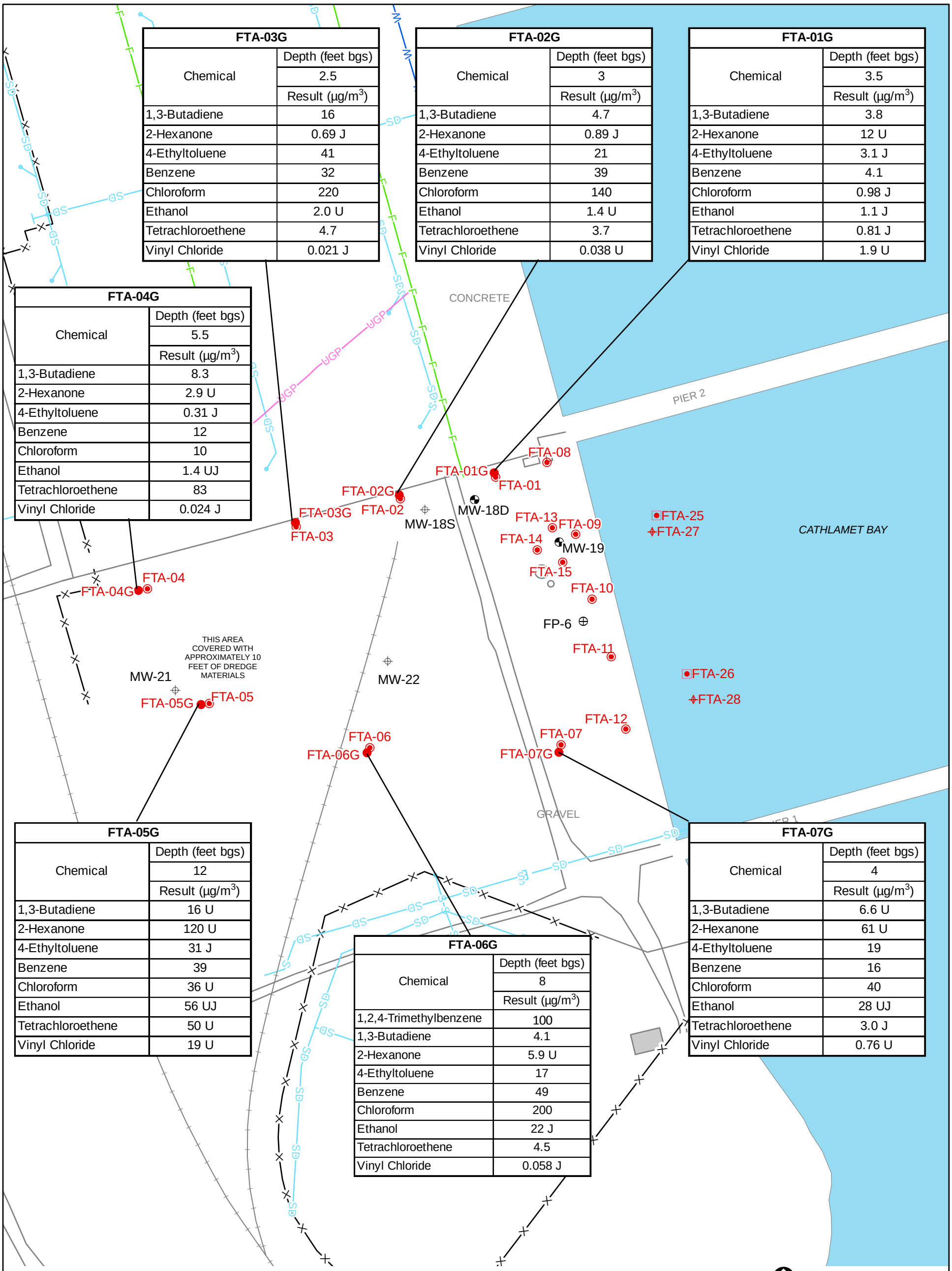
CDM

U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

FIRE TRAINING AREA SOIL AND SEDIMENT ANALYTICAL RESULTS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 4-9



FTA-03G	
Chemical	Depth (feet bgs)
	2.5
	Result (µg/m^3)
1,3-Butadiene	16
2-Hexanone	0.69 J
4-Ethyltoluene	41
Benzene	32
Chloroform	220
Ethanol	2.0 U
Tetrachloroethene	4.7
Vinyl Chloride	0.021 J

FTA-02G	
Chemical	Depth (feet bgs)
	3
	Result (µg/m^3)
1,3-Butadiene	4.7
2-Hexanone	0.89 J
4-Ethyltoluene	21
Benzene	39
Chloroform	140
Ethanol	1.4 U
Tetrachloroethene	3.7
Vinyl Chloride	0.038 U

FTA-01G	
Chemical	Depth (feet bgs)
	3.5
	Result (µg/m^3)
1,3-Butadiene	3.8
2-Hexanone	12 U
4-Ethyltoluene	3.1 J
Benzene	4.1
Chloroform	0.98 J
Ethanol	1.1 J
Tetrachloroethene	0.81 J
Vinyl Chloride	1.9 U

FTA-04G	
Chemical	Depth (feet bgs)
	5.5
	Result (µg/m^3)
1,3-Butadiene	8.3
2-Hexanone	2.9 U
4-Ethyltoluene	0.31 J
Benzene	12
Chloroform	10
Ethanol	1.4 UJ
Tetrachloroethene	83
Vinyl Chloride	0.024 J

FTA-05G	
Chemical	Depth (feet bgs)
	12
	Result (µg/m^3)
1,3-Butadiene	16 U
2-Hexanone	120 U
4-Ethyltoluene	31 J
Benzene	39
Chloroform	36 U
Ethanol	56 UJ
Tetrachloroethene	50 U
Vinyl Chloride	19 U

FTA-06G	
Chemical	Depth (feet bgs)
	8
	Result (µg/m^3)
1,2,4-Trimethylbenzene	100
1,3-Butadiene	4.1
2-Hexanone	5.9 U
4-Ethyltoluene	17
Benzene	49
Chloroform	200
Ethanol	22 J
Tetrachloroethene	4.5
Vinyl Chloride	0.058 J

FTA-07G	
Chemical	Depth (feet bgs)
	4
	Result (µg/m^3)
1,3-Butadiene	6.6 U
2-Hexanone	61 U
4-Ethyltoluene	19
Benzene	16
Chloroform	40
Ethanol	28 UJ
Tetrachloroethene	3.0 J
Vinyl Chloride	0.76 U

LEGEND

- SEDIMENT CORE LOCATION
- SURFACE WATER SAMPLING LOCATION
- EXISTING MONITORING WELL
- INACCESSIBLE MONITORING WELL
- ABANDONED MONITORING WELL
- DPT DORING/MICROWELL
- SOIL GAS SAMPLE LOCATION
- SD STORM DRAIN
- UGP UNDERGROUND POWER
- F FUEL LINE
- FENCE

NOTES:

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2. J = DETECTED WITH AN ESTIMATED CONCENTRATION.
3. UJ = THE ANALYTE WAS ANALYZED FOR BUT WAS NOT DETECTED. THE REPORTED QUANTITATION LIMIT IS APPROXIMATE AND MAY BE INACCURATE OR IMPRECISE.
4. µg/m^3 = MICROGRAMS PER CUBIC METERS.
5. bgs = BELOW GROUND SURFACE.
6. DREDGE SPOIL AREA HISTORICALLY USED AS A PUBLIC WORKS STORAGE YARD AND HAD SEVERAL WAREHOUSE BUILDINGS.
7. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
8. BASE MAP DATA: URS, FIGURE 3-7, SEPTEMBER 2007.

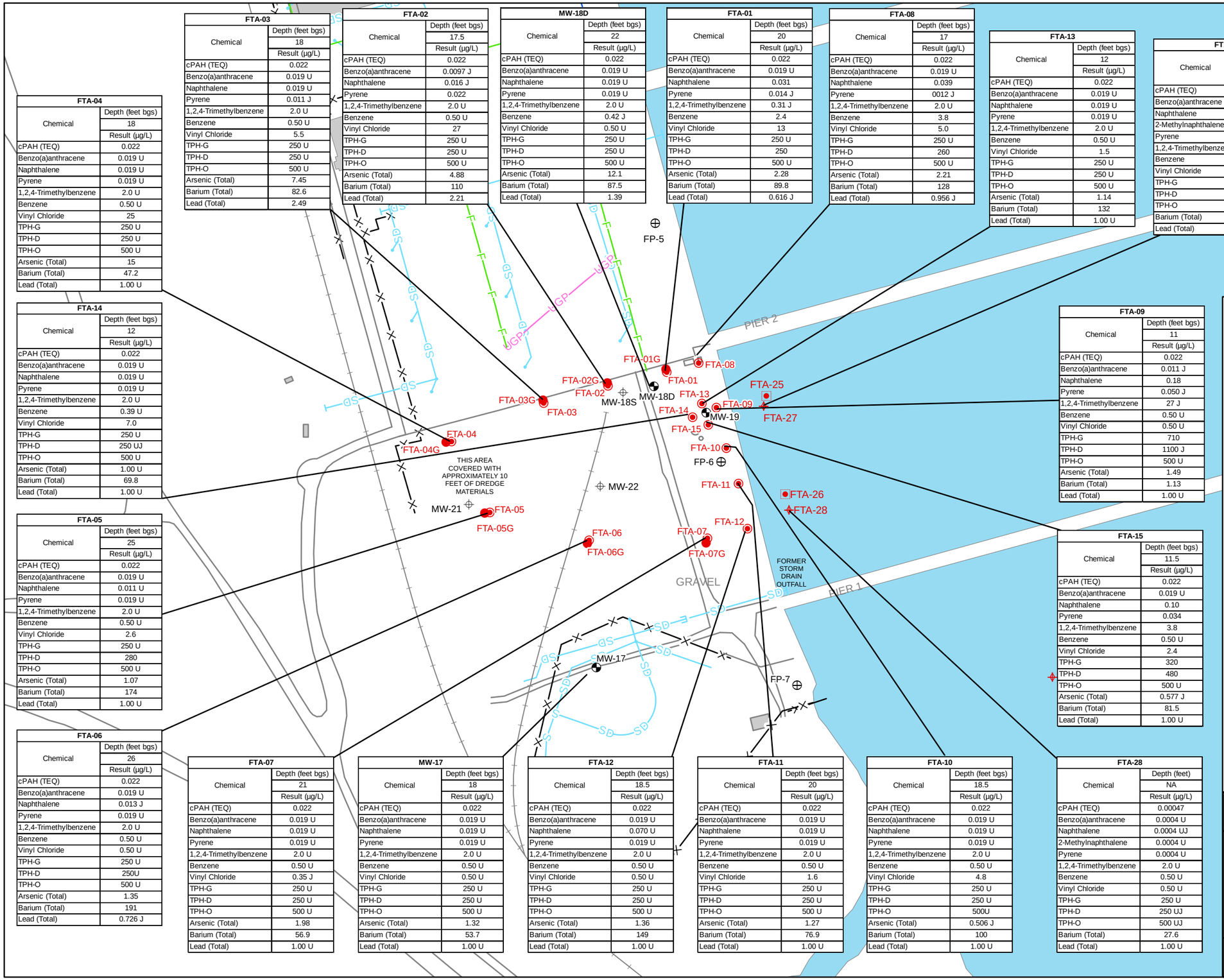
CDM

U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

FIRE TRAINING AREA SOIL GAS ANALYTICAL RESULTS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 4-10



FTA-03	
Chemical	Depth (feet bgs)
	18
	Result (µg/L)
cPAH (TEQ)	0.022
Benzo(a)anthracene	0.019 U
Naphthalene	0.019 U
Pyrene	0.011 J
1,2,4-Trimethylbenzene	2.0 U
Benzene	0.50 U
Vinyl Chloride	5.5
TPH-G	250 U
TPH-D	250 U
TPH-O	500 U
Arsenic (Total)	7.45
Barium (Total)	82.6
Lead (Total)	2.49

FTA-02	
Chemical	Depth (feet bgs)
	17.5
	Result (µg/L)
cPAH (TEQ)	0.022
Benzo(a)anthracene	0.0097 J
Naphthalene	0.016 J
Pyrene	0.022
1,2,4-Trimethylbenzene	2.0 U
Benzene	0.50 U
Vinyl Chloride	27
TPH-G	250 U
TPH-D	250 U
TPH-O	500 U
Arsenic (Total)	4.88
Barium (Total)	110
Lead (Total)	2.21

MW-18D	
Chemical	Depth (feet bgs)
	22
	Result (µg/L)
cPAH (TEQ)	0.022
Benzo(a)anthracene	0.019 U
Naphthalene	0.019 U
Pyrene	0.019 U
1,2,4-Trimethylbenzene	2.0 U
Benzene	0.42 J
Vinyl Chloride	0.50 U
TPH-G	250 U
TPH-D	250 U
TPH-O	500 U
Arsenic (Total)	12.1
Barium (Total)	87.5
Lead (Total)	1.39

FTA-01	
Chemical	Depth (feet bgs)
	20
	Result (µg/L)
cPAH (TEQ)	0.022
Benzo(a)anthracene	0.019 U
Naphthalene	0.031
Pyrene	0.014 J
1,2,4-Trimethylbenzene	0.31 J
Benzene	2.4
Vinyl Chloride	13
TPH-G	250 U
TPH-D	250
TPH-O	500 U
Arsenic (Total)	2.28
Barium (Total)	89.8
Lead (Total)	0.616 J

FTA-08	
Chemical	Depth (feet bgs)
	17
	Result (µg/L)
cPAH (TEQ)	0.022
Benzo(a)anthracene	0.019 U
Naphthalene	0.039
Pyrene	0012 J
1,2,4-Trimethylbenzene	2.0 U
Benzene	3.8
Vinyl Chloride	5.0
TPH-G	250 U
TPH-D	260
TPH-O	500 U
Arsenic (Total)	2.21
Barium (Total)	128
Lead (Total)	0.956 J

FTA-13	
Chemical	Depth (feet bgs)
	12
	Result (µg/L)
cPAH (TEQ)	0.022
Benzo(a)anthracene	0.019 U
Naphthalene	0.019 U
Pyrene	0.019 U
1,2,4-Trimethylbenzene	2.0 U
Benzene	0.50 U
Vinyl Chloride	1.5
TPH-G	250 U
TPH-D	250 U
TPH-O	500 U
Arsenic (Total)	1.14
Barium (Total)	132
Lead (Total)	1.00 U

FTA-27	
Chemical	Depth (feet)
	NA
	Result (µg/L)
cPAH (TEQ)	0.00049
Benzo(a)anthracene	0.0004 U
Naphthalene	0.0004 UJ
2-Methylnaphthalene	0.0004 U
Pyrene	0.0004 U
1,2,4-Trimethylbenzene	2.0 U
Benzene	0.50 U
Vinyl Chloride	0.50 U
TPH-G	250 U
TPH-D	250 U
TPH-O	500 U
Barium (Total)	26.8
Lead (Total)	1.00 U

FTA-04	
Chemical	Depth (feet bgs)
	18
	Result (µg/L)
cPAH (TEQ)	0.022
Benzo(a)anthracene	0.019 U
Naphthalene	0.019 U
Pyrene	0.019 U
1,2,4-Trimethylbenzene	2.0 U
Benzene	0.50 U
Vinyl Chloride	25
TPH-G	250 U
TPH-D	250 U
TPH-O	500 U
Arsenic (Total)	15
Barium (Total)	47.2
Lead (Total)	1.00 U

FTA-14	
Chemical	Depth (feet bgs)
	12
	Result (µg/L)
cPAH (TEQ)	0.022
Benzo(a)anthracene	0.019 U
Naphthalene	0.019 U
Pyrene	0.019 U
1,2,4-Trimethylbenzene	2.0 U
Benzene	0.39 U
Vinyl Chloride	7.0
TPH-G	250 U
TPH-D	250 UJ
TPH-O	500 U
Arsenic (Total)	1.00 U
Barium (Total)	69.8
Lead (Total)	1.00 U

FTA-05	
Chemical	Depth (feet bgs)
	25
	Result (µg/L)
cPAH (TEQ)	0.022
Benzo(a)anthracene	0.019 U
Naphthalene	0.011 U
Pyrene	0.019 U
1,2,4-Trimethylbenzene	2.0 U
Benzene	0.50 U
Vinyl Chloride	2.6
TPH-G	250 U
TPH-D	280
TPH-O	500 U
Arsenic (Total)	1.07
Barium (Total)	174
Lead (Total)	1.00 U

FTA-06	
Chemical	Depth (feet bgs)
	26
	Result (µg/L)
cPAH (TEQ)	0.022
Benzo(a)anthracene	0.019 U
Naphthalene	0.013 J
Pyrene	0.019 U
1,2,4-Trimethylbenzene	2.0 U
Benzene	0.50 U
Vinyl Chloride	0.50 U
TPH-G	250 U
TPH-D	250U
TPH-O	500 U
Arsenic (Total)	1.35
Barium (Total)	191
Lead (Total)	0.726 J

FTA-09	
Chemical	Depth (feet bgs)
	11
	Result (µg/L)
cPAH (TEQ)	0.022
Benzo(a)anthracene	0.011 J
Naphthalene	0.18
Pyrene	0.050 J
1,2,4-Trimethylbenzene	27 J
Benzene	0.50 U
Vinyl Chloride	0.50 U
TPH-G	710
TPH-D	1100 J
TPH-O	500 U
Arsenic (Total)	1.49
Barium (Total)	1.13
Lead (Total)	1.00 U

FTA-15	
Chemical	Depth (feet bgs)
	11.5
	Result (µg/L)
cPAH (TEQ)	0.022
Benzo(a)anthracene	0.019 U
Naphthalene	0.10
Pyrene	0.034
1,2,4-Trimethylbenzene	3.8
Benzene	0.50 U
Vinyl Chloride	2.4
TPH-G	320
TPH-D	480
TPH-O	500 U
Arsenic (Total)	0.577 J
Barium (Total)	81.5
Lead (Total)	1.00 U

FTA-07	
Chemical	Depth (feet bgs)
	21
	Result (µg/L)
cPAH (TEQ)	0.022
Benzo(a)anthracene	0.019 U
Naphthalene	0.019 U
Pyrene	0.019 U
1,2,4-Trimethylbenzene	2.0 U
Benzene	0.50 U
Vinyl Chloride	0.35 J
TPH-G	250 U
TPH-D	250 U
TPH-O	500 U
Arsenic (Total)	1.98
Barium (Total)	56.9
Lead (Total)	1.00 U

MW-17	
Chemical	Depth (feet bgs)
	18
	Result (µg/L)
cPAH (TEQ)	0.022
Benzo(a)anthracene	0.019 U
Naphthalene	0.019 U
Pyrene	0.019 U
1,2,4-Trimethylbenzene	2.0 U
Benzene	0.50 U
Vinyl Chloride	0.50 U
TPH-G	250 U
TPH-D	250 U
TPH-O	500 U
Arsenic (Total)	1.32
Barium (Total)	53.7
Lead (Total)	1.00 U

FTA-12	
Chemical	Depth (feet bgs)
	18.5
	Result (µg/L)
cPAH (TEQ)	0.022
Benzo(a)anthracene	0.019 U
Naphthalene	0.070 U
Pyrene	0.019 U
1,2,4-Trimethylbenzene	2.0 U
Benzene	0.50 U
Vinyl Chloride	0.50 U
TPH-G	250 U
TPH-D	250 U
TPH-O	500 U
Arsenic (Total)	1.36
Barium (Total)	149
Lead (Total)	1.00 U

FTA-11	
Chemical	Depth (feet bgs)
	20
	Result (µg/L)
cPAH (TEQ)	0.022
Benzo(a)anthracene	0.019 U
Naphthalene	0.019 U
Pyrene	0.019 U
1,2,4-Trimethylbenzene	2.0 U
Benzene	0.50 U
Vinyl Chloride	1.6
TPH-G	250 U
TPH-D	250 U
TPH-O	500 U
Arsenic (Total)	1.27
Barium (Total)	76.9
Lead (Total)	1.00 U

FTA-10	
Chemical	Depth (feet bgs)
	18.5
	Result (µg/L)
cPAH (TEQ)	0.022
Benzo(a)anthracene	0.019 U
Naphthalene	0.019 U
Pyrene	0.019 U
1,2,4-Trimethylbenzene	2.0 U
Benzene	0.50 U
Vinyl Chloride	4.8
TPH-G	250 U
TPH-D	250 U
TPH-O	500U
Arsenic (Total)	0.506 J
Barium (Total)	100
Lead (Total)	1.00 U

FTA-28	
Chemical	Depth (feet)
	NA
	Result (µg/L)
cPAH (TEQ)	0.00047
Benzo(a)anthracene	0.0004 U
Naphthalene	0.0004 UJ
2-Methylnaphthalene	0.0004 U
Pyrene	0.0004 U
1,2,4-Trimethylbenzene	2.0 U
Benzene	0.50 U
Vinyl Chloride	0.50 U
TPH-G	250 U
TPH-D	250 UJ
TPH-O	500 UJ
Barium (Total)	27.6
Lead (Total)	1.00 U

LEGEND

- SEDIMENT CORE LOCATION
- SURFACE WATER SAMPLING LOCATION
- EXISTING MONITORING WELL
- INACCESSIBLE MONITORING WELL
- ABANDONED MONITORING WELL
- DPT DORING/MICROWELL
- SOIL GAS SAMPLE LOCATION
- SD — STORM DRAIN
- UGP — UNDERGROUND POWER
- F — FUEL LINE
- X — FENCE

NOTES:

1. U = NOT DETECTED ABOVE THE STATED REPORTING LIMIT.
2. J = DETECTED WITH AN ESTIMATED CONCENTRATION.
3. UJ = THE ANALYTE WAS ANALYZED FOR BUT WAS NOT DETECTED. THE REPORTED QUANTITATION LIMIT IS APPROXIMATE AND MAY BE INACCURATE OR IMPRECISE.
4. TPH-G = GASOLINE RANGE PETROLEUM HYDROCARBONS.
5. TPH-D = DIESEL RANGE PETROLEUM HYDROCARBONS.
6. TPH-O = OIL RANGE PETROLEUM HYDROCARBONS.
7. cPAH = CARCINOGENIC POLYCYCLIC AROMATIC HYDROCARBONS. THIS INCLUDES: BENZO(A)PYRENE, BENZO(A)ANTHRACENE, BENZO(B)FLUORANTHENE, BENZO(K)FLUORANTHENE, CHRYSENE, DIBENZO(A,H)ANTHRACENE, AND INDENO(1,2,3-CD)PYRENE.
8. TEQ = TOXIC EQUIVALENT; CALCULATED FOR HUMAN RECEPTOR UNLESS OTHERWISE NOTED.
9. µg/L = MICROGRAMS PER LITER.
10. bgs = BELOW GROUND SURFACE.
11. DREDGE SPOIL AREA HISTORICALLY USED AS A PUBLIC WORKS STORAGE YARD AND HAD SEVERAL WAREHOUSE BUILDINGS.
12. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
13. BASE MAP DATA: URS, FIGURE 3-7, SEPTEMBER 2007.

0 110 220 440
Feet

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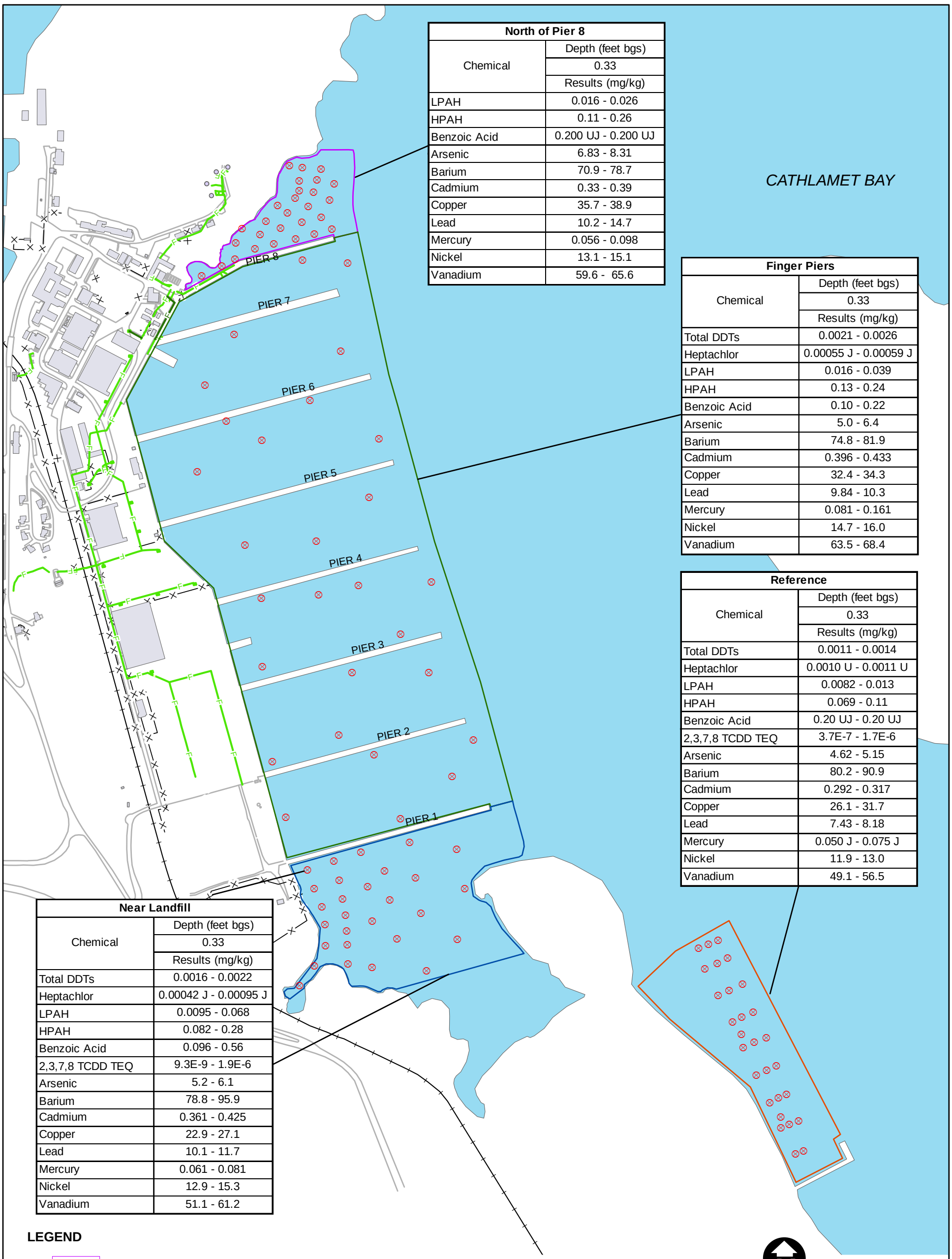
SEATTLE DISTRICT
SEATTLE, WASHINGTON

FIRE TRAINING AREA GROUND AND SURFACE WATER ANALYTICAL RESULTS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 4-11



North of Pier 8	
Chemical	Depth (feet bgs)
	0.33
	Results (mg/kg)
LPAH	0.016 - 0.026
HPAH	0.11 - 0.26
Benzoic Acid	0.200 UJ - 0.200 UJ
Arsenic	6.83 - 8.31
Barium	70.9 - 78.7
Cadmium	0.33 - 0.39
Copper	35.7 - 38.9
Lead	10.2 - 14.7
Mercury	0.056 - 0.098
Nickel	13.1 - 15.1
Vanadium	59.6 - 65.6

Finger Piers	
Chemical	Depth (feet bgs)
	0.33
	Results (mg/kg)
Total DDTs	0.0021 - 0.0026
Heptachlor	0.00055 J - 0.00059 J
LPAH	0.016 - 0.039
HPAH	0.13 - 0.24
Benzoic Acid	0.10 - 0.22
Arsenic	5.0 - 6.4
Barium	74.8 - 81.9
Cadmium	0.396 - 0.433
Copper	32.4 - 34.3
Lead	9.84 - 10.3
Mercury	0.081 - 0.161
Nickel	14.7 - 16.0
Vanadium	63.5 - 68.4

Reference	
Chemical	Depth (feet bgs)
	0.33
	Results (mg/kg)
Total DDTs	0.0011 - 0.0014
Heptachlor	0.0010 U - 0.0011 U
LPAH	0.0082 - 0.013
HPAH	0.069 - 0.11
Benzoic Acid	0.20 UJ - 0.20 UJ
2,3,7,8 TCDD TEQ	3.7E-7 - 1.7E-6
Arsenic	4.62 - 5.15
Barium	80.2 - 90.9
Cadmium	0.292 - 0.317
Copper	26.1 - 31.7
Lead	7.43 - 8.18
Mercury	0.050 J - 0.075 J
Nickel	11.9 - 13.0
Vanadium	49.1 - 56.5

Near Landfill	
Chemical	Depth (feet bgs)
	0.33
	Results (mg/kg)
Total DDTs	0.0016 - 0.0022
Heptachlor	0.00042 J - 0.00095 J
LPAH	0.0095 - 0.068
HPAH	0.082 - 0.28
Benzoic Acid	0.096 - 0.56
2,3,7,8 TCDD TEQ	9.3E-9 - 1.9E-6
Arsenic	5.2 - 6.1
Barium	78.8 - 95.9
Cadmium	0.361 - 0.425
Copper	22.9 - 27.1
Lead	10.1 - 11.7
Mercury	0.061 - 0.081
Nickel	12.9 - 15.3
Vanadium	51.1 - 61.2

LEGEND

- NORTH OF PIER 8
- FINGER PIERS
- NEAR LANDFILL
- REFERENCE AREA
- FUEL LINE PIPELINE
- FUEL OIL PIPELINE (NOT CONFIRMED)
- FENCE
- RAILROAD

SAMPLE LOCATIONS

- IMS SURFACE SEDIMENT GRAB SAMPLE LOCATION

NOTES

1. U = NOT DETECTED ABOVE THE STATED REPORTING LIMIT.
2. J = DETECTED WITH AN ESTIMATED CONCENTRATION.
3. UJ = THE ANALYTE WAS ANALYZED FOR BUT WAS NOT DETECTED. THE REPORTED QUANTITATION LIMIT IS APPROXIMATE AND MAY BE INACCURATE OR IMPRECISE.
4. LPAH = LOW MOLECULAR WEIGHT POLYCYCLIC AROMATIC HYDROCARBONS. THIS INCLUDES: ACENAPHTHENE, ACENAPHTHYLENE, ANTHRACENE, FLUORENE, NAPHTHALENE, AND PHENANTHRENE.
5. HPAH = HIGH MOLECULAR WEIGHT POLYCYCLIC AROMATIC HYDROCARBONS. THIS INCLUDES: BENZO(A)PYRENE, BENZO(A)ANTHRACENE, TOTAL BENZOFLUORANTHENES, BENZO(G,H,I)PERYLENE, CHRYSENE, DIBENZO(A,H)ANTHRACENE, FLUORANTHENE, INDENO(1,2,3,-C,D)PYRENE, AND PYRENE.
6. TOTAL DDTs = SUM OF P,P'-DICHLORODIPHENYLDICHLOROETHANE, P,P'-DICHLORODIPHENYLDICHLOROETHYLENE, AND P,P'-DICHLORODIPHENYLTRICHLOROETHANE.
7. 2,3,7,8 TCDD TEQ = 2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN
8. TEQ = TOXIC EQUIVALENT; CALCULATED FOR HUMAN RECEPTORS UNLESS OTHERWISE NOTED.
9. mg/kg = MILLIGRAMS PER KILOGRAM.
10. bgs = BELOW GROUND SURFACE.
11. ORIGINAL PRODUCED IN COLOR INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
12. BASE MAP DATA: URS FIGURE 3-5, SEPTEMBER 2007.
13. IMS = INCREMENTAL MULTIPLE SAMPLING

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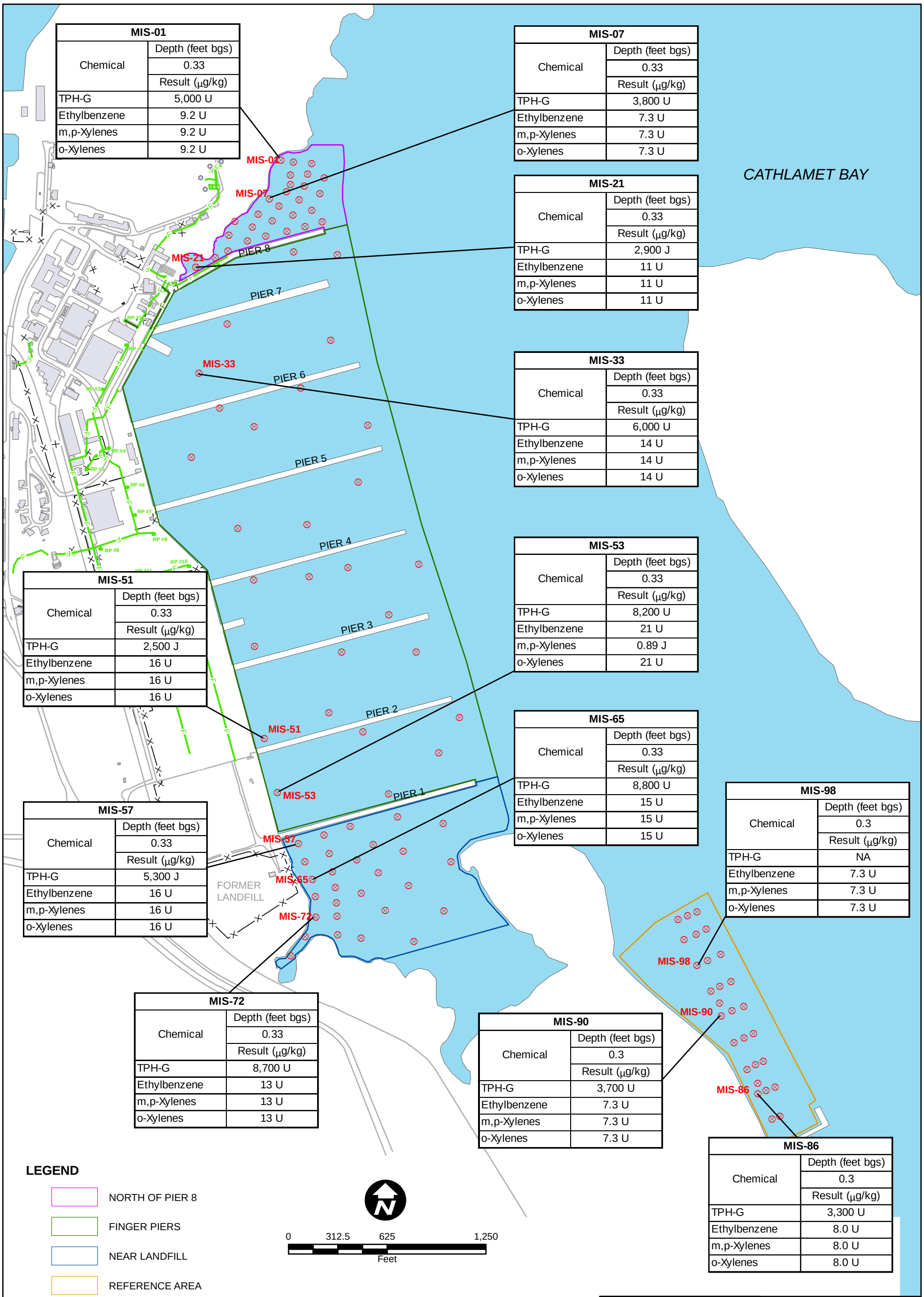
SEATTLE DISTRICT
SEATTLE, WASHINGTON

AQUATIC DECISION UNITS - INCREMENTAL SAMPLING SEDIMENT ANALYTICAL RESULTS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 4-12



MIS-01	
Chemical	Depth (feet bgs)
	0.33
	Result (µg/kg)
TPH-G	5,000 U
Ethylbenzene	9.2 U
m,p-Xylenes	9.2 U
o-Xylenes	9.2 U

MIS-07	
Chemical	Depth (feet bgs)
	0.33
	Result (µg/kg)
TPH-G	3,800 U
Ethylbenzene	7.3 U
m,p-Xylenes	7.3 U
o-Xylenes	7.3 U

MIS-21	
Chemical	Depth (feet bgs)
	0.33
	Result (µg/kg)
TPH-G	2,900 J
Ethylbenzene	11 U
m,p-Xylenes	11 U
o-Xylenes	11 U

MIS-33	
Chemical	Depth (feet bgs)
	0.33
	Result (µg/kg)
TPH-G	6,000 U
Ethylbenzene	14 U
m,p-Xylenes	14 U
o-Xylenes	14 U

MIS-53	
Chemical	Depth (feet bgs)
	0.33
	Result (µg/kg)
TPH-G	8,200 U
Ethylbenzene	21 U
m,p-Xylenes	0.89 J
o-Xylenes	21 U

MIS-51	
Chemical	Depth (feet bgs)
	0.33
	Result (µg/kg)
TPH-G	2,500 J
Ethylbenzene	16 U
m,p-Xylenes	16 U
o-Xylenes	16 U

MIS-65	
Chemical	Depth (feet bgs)
	0.33
	Result (µg/kg)
TPH-G	8,800 U
Ethylbenzene	15 U
m,p-Xylenes	15 U
o-Xylenes	15 U

MIS-57	
Chemical	Depth (feet bgs)
	0.33
	Result (µg/kg)
TPH-G	5,300 J
Ethylbenzene	16 U
m,p-Xylenes	16 U
o-Xylenes	16 U

MIS-98	
Chemical	Depth (feet bgs)
	0.3
	Result (µg/kg)
TPH-G	NA
Ethylbenzene	7.3 U
m,p-Xylenes	7.3 U
o-Xylenes	7.3 U

MIS-72	
Chemical	Depth (feet bgs)
	0.33
	Result (µg/kg)
TPH-G	8,700 U
Ethylbenzene	13 U
m,p-Xylenes	13 U
o-Xylenes	13 U

MIS-90	
Chemical	Depth (feet bgs)
	0.3
	Result (µg/kg)
TPH-G	3,700 U
Ethylbenzene	7.3 U
m,p-Xylenes	7.3 U
o-Xylenes	7.3 U

MIS-86	
Chemical	Depth (feet bgs)
	0.3
	Result (µg/kg)
TPH-G	3,300 U
Ethylbenzene	8.0 U
m,p-Xylenes	8.0 U
o-Xylenes	8.0 U

LEGEND

- NORTH OF PIER 8
- FINGER PIERS
- NEAR LANDFILL
- REFERENCE AREA
- FUEL LINE PIPELINE
- FUEL OIL PIPELINE (NOT CONFIRMED)
- FENCE
- RAILROAD

SAMPLE LOCATIONS

- IMS SURFACE SEDIMENT GRAB SAMPLE LOCATION

NOTES

1. U = NOT DETECTED ABOVE THE STATED REPORTING LIMIT.
2. J = DETECTED WITH AN ESTIMATED CONCENTRATION.
3. TPH-G = GASOLINE RANGE PETROLEUM HYDROCARBONS.
4. µg/kg = MICROGRAMS PER KILOGRAM.
5. bgs = BELOW GROUND SURFACE.
6. ORIGINAL PRODUCED IN COLOR INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
7. BASE MAP DATA: URS FIGURE 3-5, SEPTEMBER 2007.
8. IMS = INCREMENTAL MULTIPLE SAMPLING

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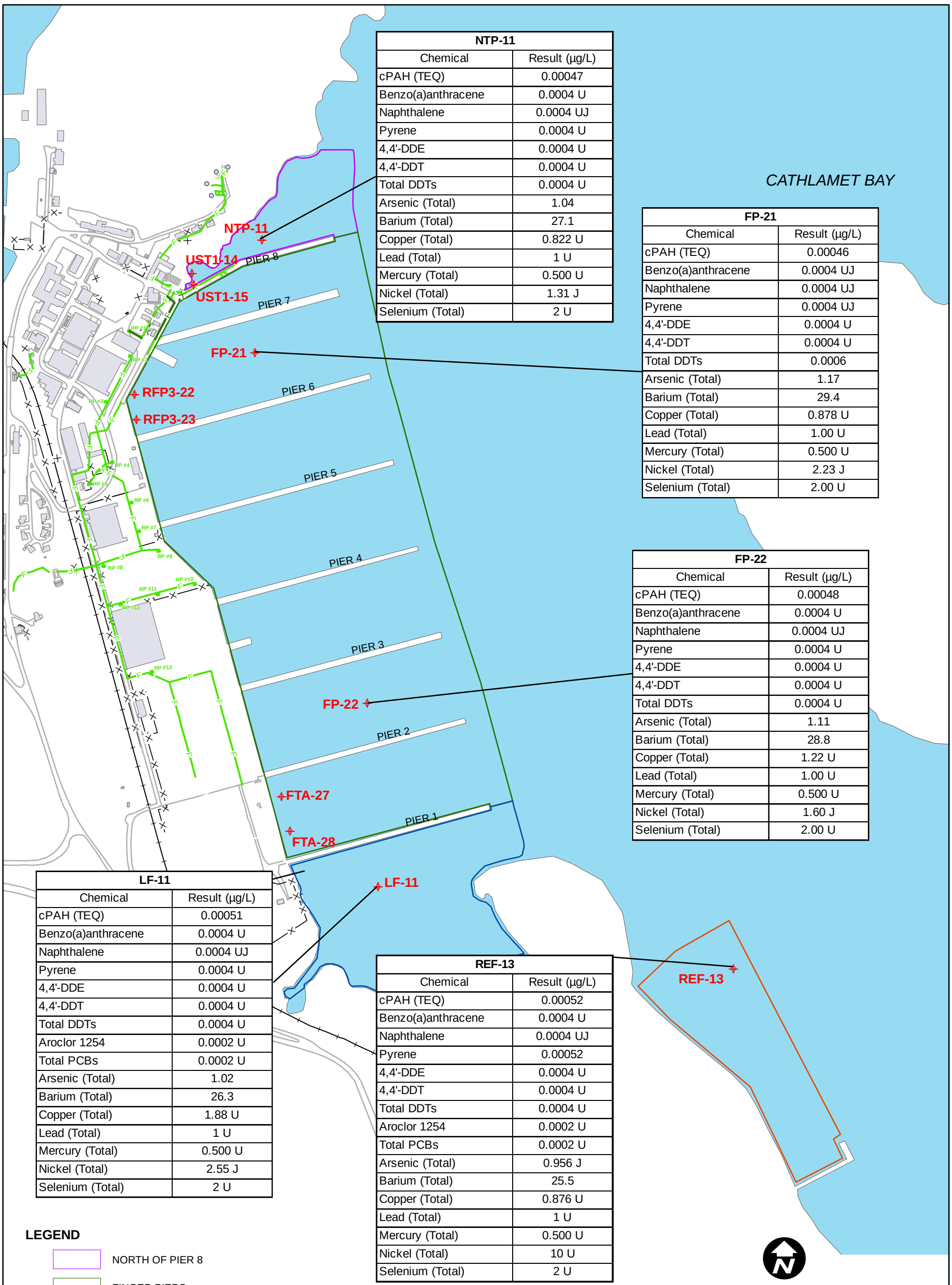
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

AQUATIC DECISION UNITS - DISCRETE SEDIMENT ANALYTICAL RESULTS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 4-13



NTP-11	
Chemical	Result (µg/L)
cPAH (TEQ)	0.00047
Benzo(a)anthracene	0.0004 U
Naphthalene	0.0004 UJ
Pyrene	0.0004 U
4,4'-DDE	0.0004 U
4,4'-DDT	0.0004 U
Total DDTs	0.0004 U
Arsenic (Total)	1.04
Barium (Total)	27.1
Copper (Total)	0.822 U
Lead (Total)	1 U
Mercury (Total)	0.500 U
Nickel (Total)	1.31 J
Selenium (Total)	2 U

FP-21	
Chemical	Result (µg/L)
cPAH (TEQ)	0.00046
Benzo(a)anthracene	0.0004 UJ
Naphthalene	0.0004 UJ
Pyrene	0.0004 UJ
4,4'-DDE	0.0004 U
4,4'-DDT	0.0004 U
Total DDTs	0.0006
Arsenic (Total)	1.17
Barium (Total)	29.4
Copper (Total)	0.878 U
Lead (Total)	1.00 U
Mercury (Total)	0.500 U
Nickel (Total)	2.23 J
Selenium (Total)	2.00 U

FP-22	
Chemical	Result (µg/L)
cPAH (TEQ)	0.00048
Benzo(a)anthracene	0.0004 U
Naphthalene	0.0004 UJ
Pyrene	0.0004 U
4,4'-DDE	0.0004 U
4,4'-DDT	0.0004 U
Total DDTs	0.0004 U
Arsenic (Total)	1.11
Barium (Total)	28.8
Copper (Total)	1.22 U
Lead (Total)	1.00 U
Mercury (Total)	0.500 U
Nickel (Total)	1.60 J
Selenium (Total)	2.00 U

LF-11	
Chemical	Result (µg/L)
cPAH (TEQ)	0.00051
Benzo(a)anthracene	0.0004 U
Naphthalene	0.0004 UJ
Pyrene	0.0004 U
4,4'-DDE	0.0004 U
4,4'-DDT	0.0004 U
Total DDTs	0.0004 U
Aroclor 1254	0.0002 U
Total PCBs	0.0002 U
Arsenic (Total)	1.02
Barium (Total)	26.3
Copper (Total)	1.88 U
Lead (Total)	1 U
Mercury (Total)	0.500 U
Nickel (Total)	2.55 J
Selenium (Total)	2 U

REF-13	
Chemical	Result (µg/L)
cPAH (TEQ)	0.00052
Benzo(a)anthracene	0.0004 U
Naphthalene	0.0004 UJ
Pyrene	0.00052
4,4'-DDE	0.0004 U
4,4'-DDT	0.0004 U
Total DDTs	0.0004 U
Aroclor 1254	0.0002 U
Total PCBs	0.0002 U
Arsenic (Total)	0.956 J
Barium (Total)	25.5
Copper (Total)	0.876 U
Lead (Total)	1 U
Mercury (Total)	0.500 U
Nickel (Total)	10 U
Selenium (Total)	2 U

LEGEND

- NORTH OF PIER 8
- FINGER PIERS
- NEAR LANDFILL
- REFERENCE AREA
- FUEL LINE PIPELINE
- FUEL OIL PIPELINE (NOT CONFIRMED)
- FENCE
- RAILROAD

SAMPLE LOCATIONS

- SURFACE WATER SAMPLE LOCATION AND NUMBER

NOTES

1. U = NOT DETECTED ABOVE THE STATED REPORTING LIMIT.
2. J = DETECTED WITH AN ESTIMATED CONCENTRATION.
3. UJ = THE ANALYTE WAS ANALYZED FOR BUT WAS NOT DETECTED. THE REPORTED QUANTITATION LIMIT IS APPROXIMATE AND MAY BE INACCURATE OR IMPRECISE.
4. cPAH = CARCINOGENIC POLYCYCLIC AROMATIC HYDROCARBONS. THIS INCLUDES: BENZO(A)PYRENE, BENZO(A)ANTHRACENE, BENZO(B)FLUORANTHENE, BENZO(K)FLUORANTHENE, CHRYSENE, DIBENZO(A,H)ANTHRACENE, AND INDENO(1,2,3-CD)PYRENE.
5. 4,4'-DDE = P,P'-DICHLORODIPHENYLDICHLOROETHANE
6. 4,4'-DDT = P,P'-DICHLORODIPHENYLTRICHLOROETHANE
7. TOTAL DDTs = SUM OF P,P'-DICHLORODIPHENYLDICHLOROETHANE, P,P'-DICHLORODIPHENYLDICHLOROETHYLENE, AND P,P'-DICHLORODIPHENYLTRICHLOROETHANE.
8. TOTAL PCBs = SUM OF ALL ANALYZED POLYCHLORINATED BIPHENYL AROCLORS.
9. TEQ = TOXIC EQUIVALENT; CALCULATED FOR HUMAN RECEPTORS UNLESS OTHERWISE NOTED.
10. µg/L = MICROGRAMS PER LITER.
11. ORIGINAL PRODUCED IN COLOR INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
12. BASE MAP DATA: URS FIGURE 3-5, SEPTEMBER 2007.

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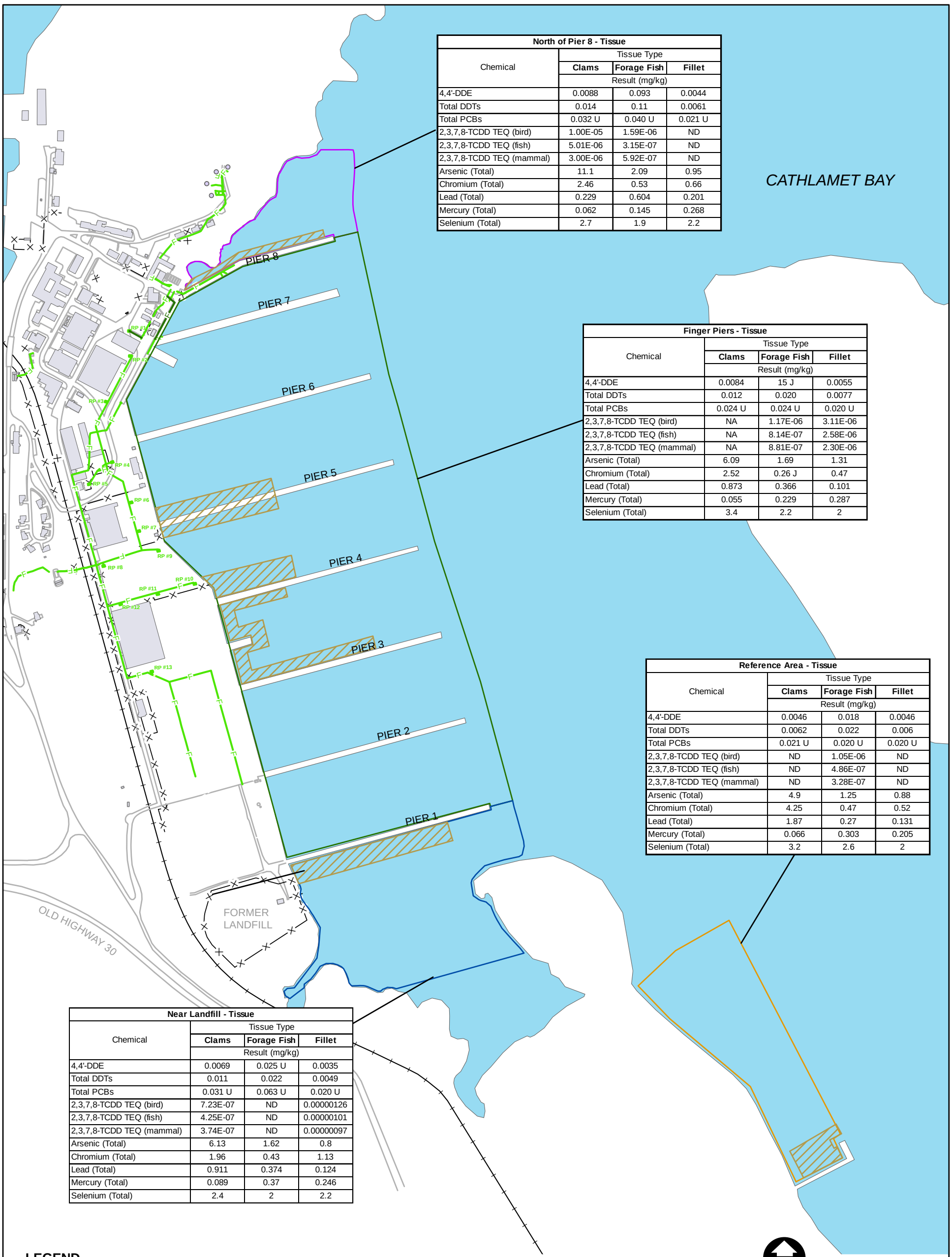
AQUATIC DECISION UNITS - SURFACE WATER ANALYTICAL RESULTS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 4-14



North of Pier 8 - Tissue			
Chemical	Tissue Type		
	Clams	**Forage Fish**	**Fillet**
	Result (mg/kg)		
4,4'-DDE	0.0088	0.093	0.0044
Total DDTs	0.014	0.11	0.0061
Total PCBs	0.032 U	0.040 U	0.021 U
2,3,7,8-TCDD TEQ (bird)	1.00E-05	1.59E-06	ND
2,3,7,8-TCDD TEQ (fish)	5.01E-06	3.15E-07	ND
2,3,7,8-TCDD TEQ (mammal)	3.00E-06	5.92E-07	ND
Arsenic (Total)	11.1	2.09	0.95
Chromium (Total)	2.46	0.53	0.66
Lead (Total)	0.229	0.604	0.201
Mercury (Total)	0.062	0.145	0.268
Selenium (Total)	2.7	1.9	2.2

Finger Piers - Tissue			
Chemical	Tissue Type		
	Clams	**Forage Fish**	**Fillet**
	Result (mg/kg)		
4,4'-DDE	0.0084	15 J	0.0055
Total DDTs	0.012	0.020	0.0077
Total PCBs	0.024 U	0.024 U	0.020 U
2,3,7,8-TCDD TEQ (bird)	NA	1.17E-06	3.11E-06
2,3,7,8-TCDD TEQ (fish)	NA	8.14E-07	2.58E-06
2,3,7,8-TCDD TEQ (mammal)	NA	8.81E-07	2.30E-06
Arsenic (Total)	6.09	1.69	1.31
Chromium (Total)	2.52	0.26 J	0.47
Lead (Total)	0.873	0.366	0.101
Mercury (Total)	0.055	0.229	0.287
Selenium (Total)	3.4	2.2	2

Reference Area - Tissue			
Chemical	Tissue Type		
	Clams	**Forage Fish**	**Fillet**
	Result (mg/kg)		
4,4'-DDE	0.0046	0.018	0.0046
Total DDTs	0.0062	0.022	0.006
Total PCBs	0.021 U	0.020 U	0.020 U
2,3,7,8-TCDD TEQ (bird)	ND	1.05E-06	ND
2,3,7,8-TCDD TEQ (fish)	ND	4.86E-07	ND
2,3,7,8-TCDD TEQ (mammal)	ND	3.28E-07	ND
Arsenic (Total)	4.9	1.25	0.88
Chromium (Total)	4.25	0.47	0.52
Lead (Total)	1.87	0.27	0.131
Mercury (Total)	0.066	0.303	0.205
Selenium (Total)	3.2	2.6	2

Near Landfill - Tissue			
Chemical	Tissue Type		
	Clams	**Forage Fish**	**Fillet**
	Result (mg/kg)		
4,4'-DDE	0.0069	0.025 U	0.0035
Total DDTs	0.011	0.022	0.0049
Total PCBs	0.031 U	0.063 U	0.020 U
2,3,7,8-TCDD TEQ (bird)	7.23E-07	ND	0.00000126
2,3,7,8-TCDD TEQ (fish)	4.25E-07	ND	0.00000101
2,3,7,8-TCDD TEQ (mammal)	3.74E-07	ND	0.00000097
Arsenic (Total)	6.13	1.62	0.8
Chromium (Total)	1.96	0.43	1.13
Lead (Total)	0.911	0.374	0.124
Mercury (Total)	0.089	0.37	0.246
Selenium (Total)	2.4	2	2.2

LEGEND

- FISH COLLECTION LOCATIONS
- NORTH OF PIER 8
- FINGER PIERS
- NEAR LANDFILL
- REFERENCE AREA
- FUEL LINE PIPELINE
- FUEL OIL PIPELINE (NOT CONFIRMED)
- FENCE
- RAILROAD

NOTES

1. U = NOT DETECTED ABOVE THE STATED REPORTING LIMIT.
2. J = DETECTED WITH AN ESTIMATED CONCENTRATION.
3. ND = NOT DETECTED.
4. NA = NOT ANALYZED.
5. 4,4'-DDE = P,P'-DICHLORODIPHENYLDICHLOROETHANE.
6. TOTAL DDTs = SUM OF P,P'-DICHLORODIPHENYLDICHLOROETHANE, P,P'-DICHLORODIPHENYLDICHLOROETYLENE, AND P,P'-DICHLORODIPHENYLTRICHLOROETHANE.
7. TOTAL PCBs = SUM OF ALL ANALYZED POLYCHLORINATED BIPHENYL AROCLORS.
8. 2,3,7,8 TCDD = 2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN
9. TEQ = TOXIC EQUIVALENT; CALCULATED FOR HUMAN RECEPTORS UNLESS OTHERWISE NOTED.
10. mg/kg = MILLIGRAMS PER KILOGRAM.
11. ORIGINAL PRODUCED IN COLOR INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
12. BASE MAP DATA: URS FIGURE 3-5, SEPTEMBER 2007.

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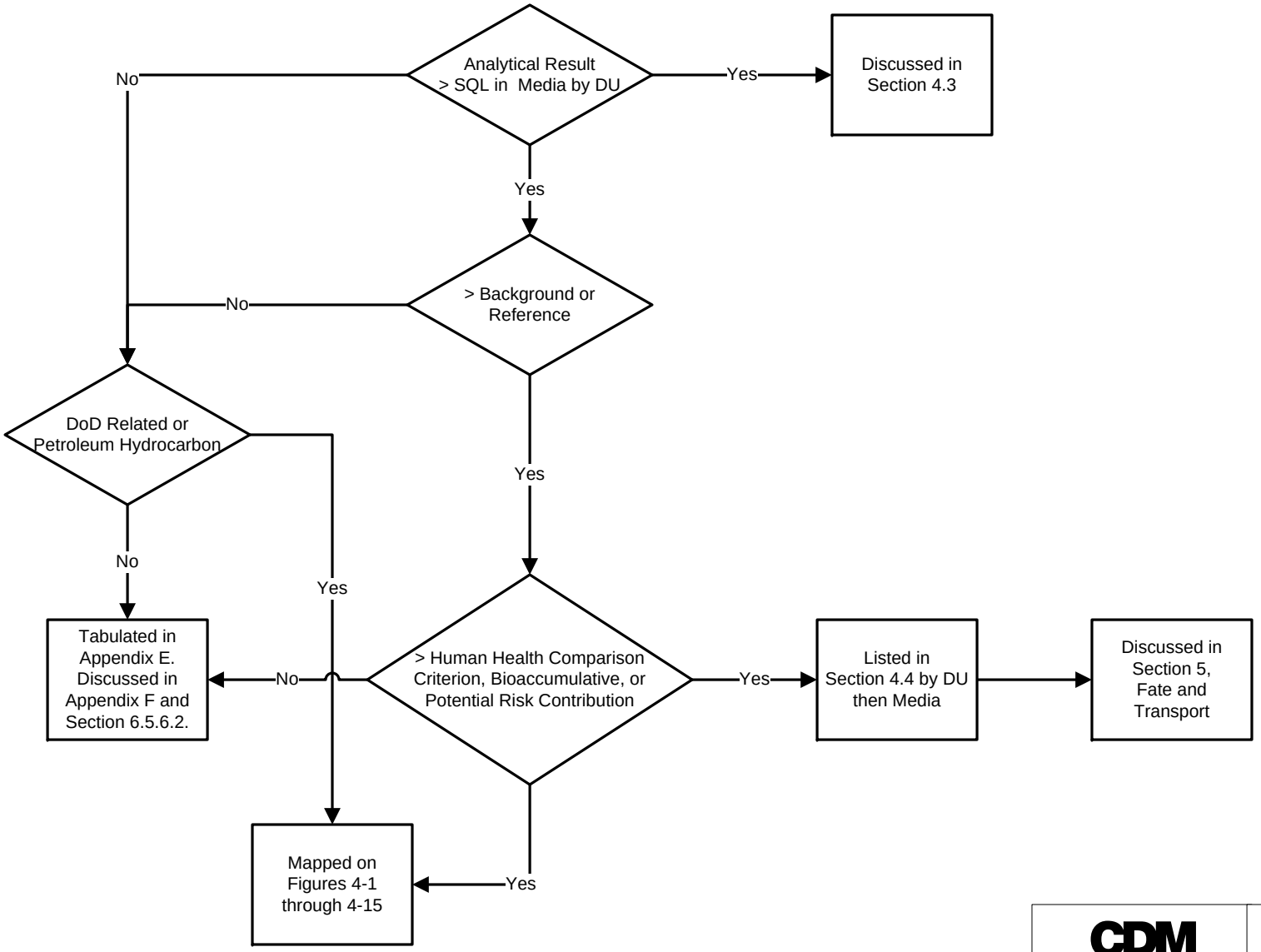
AQUATIC DECISION UNITS - TISSUE ANALYTICAL RESULTS

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 4-15



Definitions:
SQL = Sample Quantitation Limit
DoD = Department of Defense
DU = Decision Unit
> = Greater Than

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IDENTIFICATION OF CONSTITUENTS
FOR FATE AND TRANSPORT

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 4-16

Section 5
Fate and Transport

This section describes the fate and transport mechanisms for the select chemicals detected in soil, soil gas, groundwater, surface water, surface sediment, and tissue for the Study Area. A discussion of fate and transport processes and physical and chemical properties of these chemicals is presented in **Section 5.2** and is followed by an evaluation of fate and transport mechanisms and a CSM. In addition, chemicals that are bioaccumulative (i.e., lead, PCBs, and dioxins/furans) or are related to the fate of the chemicals identified in Section 4 (i.e., PCE) are also discussed in this section. Transport pathways and chemical fate are considered when developing the human health (in **Section 6**) and ecological (in **Section 7**) risk assessments. A summary of the importance of each fate and transport process for each chemical category is provided in **Table 5-1.**

5.1 Chemicals Selected for Evaluation

Chemicals identified for further evaluation in **Section 4.4** followed the decision logic of **Figure 4-16**. These constituents were consistently detected in terrestrial and aquatic DUs with concentrations greater than comparison criteria and their reference or background values or have potential to bioaccumulate. In addition, specific chemical groups are included if parent products or degradation by products are present, such as the chlorinated ethenes. To simplify the discussion in this section, the chemicals were consolidated by media (and chemical class, where applicable) as follows.

- Arsenic in soil, groundwater, surface water, surface sediment, and tissue
- Iron and manganese in groundwater
- Lead and mercury in soil, sediment, and tissue
- Selenium in tissue
- TPH-D and TPH-G in soil and groundwater
- Benzene and chloroform in soil gas
- Tetrachloroethene, trichloroethene, vinyl chloride, 1,2,4-trimethylbenzene, naphthalene, and benzene in groundwater
- cPAHs in soil, groundwater, sediment, and tissue
- Total PCBs in sediment and tissue
- Total DDT in sediment and tissue

- Dioxins/furans in soil, groundwater, and sediment

5.2 Fate and Transport Processes

Fate and transport processes identify the phase in which a chemical exists, and the physical transport is related to the dynamics of the environment and the mobility and bioavailability of the compound. The discussion of "fate" identifies degradation potential, phase changes, and associated properties that affect the concentration of a chemical. The most important fate and transport processes depend on the environment and on the chemical-specific properties of these chemicals. The major fate and transport processes are described in the following sections, along with a summary of the important processes for the major classes of compounds (i.e., metals, PAHs).

5.2.1 Physical Transport Processes

The dynamics of the environment and the mobility and bioavailability of compounds are all related to physical transport.

5.2.1.1 Erosion and Deposition

The primary physical transport in aquatic environments that affect chemical distribution can be determined by evaluating suspended particulate matter and sediment erosion and deposition patterns. The deposition and erosion of sediments is controlled by the energy of the environment, salinity, turbidity of the river flow, and anthropogenic processes (e.g., dredging, boat traffic).

5.2.1.2 Energy of the Environment

High-energy environments within an estuary result in suspension of sediment; sediments are deposited in low energy areas. The most important high-energy environments are areas influenced by tides. The tidal cycles have an important influence on sediment transport and deposition. During ebb tides, sediment is suspended and carried seaward; during flood tides, sediments are suspended and carried landward. Marine sediments can be carried into the estuary and mixed with land-derived sediments during the flood tide. The energy is increased during spring tide because of the larger than normal tidal range. Maximum turbidity within the Tamar and Weser estuaries was observed during spring tide (Grabemann et al. 1997).

Low energy environments include marshes, embayments, and areas behind obstructions (such as piers and breakwaters). Deposition of sediment can occur after the flood and ebb tides, during periods of slack water. Slack tide velocities are typically only about 0.2 meters per second (m/s), which allows for flocculation and settling of particles up to 200 μm in diameter (Grabemann and Krause 1989).

5.2.1.3 Salinity

Salinity can have a major effect on the suspended sediment load within estuaries as well as on the deposition of contaminated sediment. Suspended particles that have a higher specific gravity than water (>1 gram per cubic centimeter [g/cm^3]) would be

expected to settle out if it were not for the repulsive forces between negatively charged particles that resist gravity. Adsorption of positively charged ions from high salinity seawater can neutralize the surface charge on the particles and result in settling. Numerous investigators have found that turbidity maxima occur within the freshwater portions of estuaries because of salinity induced settling (Grabemann et al. 1997; Menon et al. 1998). Often, the maximum turbidity area is just upgradient of the freshwater saltwater interface where salinity is low and tidal energy is relatively high. Although the tidal energy typically increases seaward, the effect is neutralized by salinity-induced settling. The location of the saltwater/freshwater interface and the zone of maximum turbidity can change seasonally because of changes in flow. The zone of maximum turbidity moves up-estuary during low flow in the Weser and Tumar estuaries because of the relative dominance of tidal inflows compared to river flows (Grabemann et al. 1997).

5.2.1.4 Turbidity of the River Flow

The sediment load within the river inflow is the ultimate source of sediment (and often contamination) into an estuary. Sediment loads can be an order of magnitude higher than normal during spring high flow and during flood and storm events.

5.2.1.5 Anthropogenic Effects

Dredging for ship channels and the associated river traffic can stir up sediment within a river. However, the removal of enough dredged sediment can change the sediment mass balance in the system and produce a sediment-limited system, as was observed for the Weser estuary (Grabemann et al. 1997).

5.2.1.6 Surface Water Transport

Flushing is defined as the average amount of time that fresh water spends in an estuary (Alber and Sheldon 1999). In general, estuaries with a greater input of river flow and a smaller volume have short flushing times. Estuaries with lower freshwater inflows and greater volumes have long flushing times. Flushing time can be estimated from the salinity of the estuary compared to that of seawater and the total volume of each segment of the estuary as follows:

$$t_f = \text{freshwater volume/freshwater input}$$

$$= \sum [(S_{sw}-S_i/S_{sw})V_i] / Q$$

where:

t_f = flushing time
S_{sw} = seawater salinity
S_i = salinity of volume segment i
V_i = volume of segment i
Q = freshwater input

Flushing time is a reliable predictor of the residence time of a chemical in the estuary for conservative compounds (Dyer 1973). In other words, the equation is valid if none of the fate and transport properties described previously are acting on the particular chemical under consideration. For conservative chemicals, the concentration of the compound downstream from a point source (such as an outfall) can be predicted using the following:

$$C_x = (P/Q)\ f_x$$

where:

C_x = concentration of the chemical at a point x, downstream of the outfall
P = rate of supply of the chemical (mass of chemical/time)
f_x = fraction of fresh water at point x (calculated from salinity)

The concentration of the chemical downstream of the outfall is directly proportional to the fraction of freshwater (inversely proportional to the fraction of seawater). Upstream (up-estuary) of the outfall, the concentration of the chemical does not decrease dramatically as is often true for point sources discharging to river systems. In estuaries, tidal forces or onshore winds can transport chemicals landward, or upgradient of the outfall. The concentration of the chemical at a point upgradient of the outfall is given by:

$$C_y = C_O\ (S_y/S_O)$$

where:

C_y = concentration of chemical at point *y* upstream of the outfall
C_O = concentration of chemical at outfall *O*
S_y = salinity at point *y*
S_O = salinity at outfall *O*

Upgradient of the outfall, the concentration of the chemical is directly proportional to the salinity because of the landward flow of higher salinity water caused by tides and onshore winds.

The relationships just presented, although quite useful under the right conditions, are severely limited because they are valid only for conservative chemicals. Very few chemicals can be considered conservative or are mobile enough to be approximated as a conservative compound. Most chemicals will be either transformed into another compound or transferred from the water phase to either the solid or gas phase to some extent within an estuary. The extent to which the fate and transport processes will act on a given chemical will depend on the chemical properties discussed and on the conditions within the water column and sediment of the estuary.

The fate and transport properties discussed act on most chemicals, such that the flushing equations for conservative species are generally not valid. The degree to

which fate and transport processes cause a deviation from the conservative flushing behavior depends on the properties of the chemical and on the environmental conditions and processes within the estuary. Numerous investigators have studied non-conservative behavior in estuaries and have identified the key conditions for many different contaminants. The most important conditions are as follows:

- Salinity
- Grain size of the sediment
- TOC of the sediment
- Turbidity
- pH and oxidation/reduction potential
- Salinity

Salinity is perhaps the most important parameter affecting the fate and transport of both organic compounds and metals within estuaries. Increases in salinity from near zero within the river discharge to seawater levels can dramatically shift the equilibrium of the chemicals between the dissolved and particulate phases. In addition, salinity changes can control the sediment load within the water column, resulting in an even more pronounced effect.

The "salting out" effect is the dominant process controlling hydrophobic organic compounds in the estuarine environment. Means (1995) performed an extensive study of the variability of PAH adsorption with salinity within Lafitte Bayou and Pass Fourchon/Lake Champagne, Louisiana. A significant increase in the soil/water distribution coefficient (K_d) values was reported with increasing salinity. For example, at a salinity of 9 they measured a K_d value of 5,146 liters per kilogram (L/kg) for pyrene; at a salinity of 32, a K_d of 9,578 L/kg was obtained. Brunk et al. (1997) found that the phenanthrene K_d value was 55% higher in saltwater than in fresh water. Salting out affects most organic compounds to some degree, but is less significant for charged or polar molecules such as low molecular weight phenols, alcohols, and carboxylic acids. Brunk et al. (1997) found that salinity increases can result in the precipitation of organic coatings onto the surfaces of suspended particulate matter, increasing the available adsorption sites for hydrophobic organic compounds (which increases the K_d). Bates et al. (1987) found that the concentrations of aromatic hydrocarbons within the Puget Sound, Washington were controlled by a rapid vertical flux, where contaminated sediments were removed from the water column. Bates et al. (1987) did not attempt to determine the removal mechanism, and it has since been attributed to removal of suspended particulate matter in response to salinity increases (Means 1995).

The combined processes of salting out of chemicals in the aqueous phase, precipitation of organic compounds onto suspended particles, and salinity-induced

flocculation of suspended particulate matter effectively remove hydrophobic chemicals from the water column.

5.2.1.7 Sediment TOC

Sediment TOC, as discussed previously, is an important parameter for determining partitioning between organic compounds and sediments. Within the York Estuary, Virginia, sediment TOC concentrations of only 0.1% are required before organic carbon adsorption of chlorinated methoxyphenols predominates (Gunderson et al. 1997). Brunk et al. (1997) found that adsorption of phenanthrene onto clay minerals is increased because of precipitation of organic coatings onto clay particles.

5.2.1.8 pH and Oxidation/Reduction Potential

The pH and oxidation/reduction (redox) potential can be very important within estuaries because of the mixing of seawater and river water and flooding and evaporation cycles within marsh areas. Turbulence caused by tidal action can increase the dissolved oxygen (DO) levels and, consequently, the redox state within the tidal influenced zones of the estuary.

Organics

The pH of an estuary is typically higher than that of the river input because of the high alkalinity of seawater. Rivers that flow through exposed carbonate rocks or are fed by groundwater from carbonate aquifers would be about the same pH as seawater; however, most other rivers will have a lower pH. The increase in pH on an organic compound is usually minimal, except for compounds with carboxyl or hydroxyl substituent. For example, pentachlorophenol is much more mobile at high pH than at low pH because of the hydroxyl group, which gives the molecule an acid/base character. Chlorinated methoxyphenols are more soluble and have lower K_d values at high pH (when the molecule is negatively charged) than at lower pH (when the molecule is neutral and more hydrophobic) (Gunderson et al. 1997).

Theoretically, organic compounds can be completely oxidized to carbon dioxide and water within estuaries. However, abiotic oxidation is relatively unimportant except perhaps in the surface water where photo-oxidation may occur. Of much greater importance is the biotransformation of organic compounds within the estuarine environment. The more oxic, higher redox conditions within the turbulent tidal areas can result in aerobic biotransformation. The process will be most important for the more soluble and easily degraded compounds such as the aromatic VOCs (i.e., benzene, toluene, phenols, and so on). Other, less mobile and less bioavailable compounds such as the dioxins/furans, SVOCs, pesticides, and LPAH compounds will not easily biodegrade to any great extent.

Within consistently flooded marshes and other low energy environments, organic matter within fine-grained sediments can produce anoxic conditions, which favor anaerobic biotransformation. Chlorinated organic compounds such as PCE can be reduced and sequentially dechlorinated to form cis-1,2-DCE, vinyl chloride , ethene, and ethane.

Inorganic Constituents

An increase in DO can result in the oxidation of ferrous iron and manganese and the resultant removal of metals via coprecipitation. Turner (2000) found that sediments within estuaries have an iron to manganese ratio ranging from <10 to 100, suggesting that iron is removed to a greater extent than manganese within the estuaries. The oxidation kinetics of ferrous iron (iron (II)) are dependent on the dominant iron species in solution. It was found that free ferrous iron (Fe2+) has an oxidation half life of days to weeks, and $Fe(OH)_2^0$ has a half life of a few seconds (King 1998). Therefore, an increase in pH can increase the fraction of $Fe(OH)_2^0$ and can result in a much faster oxidation rate. The carbonate species $Fe(CO_3)^{2-}$ was found to control ferrous iron oxidation rates in sea water because of the high alkalinity and relatively fast oxidation rate of the species. Therefore, when ferrous iron from a river input is mixed with oxygenated, higher pH, higher alkalinity seawater within an estuary, conversion of iron(II) to the much less mobile iron(III) is predicted. Coprecipitation of metals would likely be the result. Sediment concentrations of chromium, copper, lead, and zinc could be correlated with iron concentrations within the Clyde, Dee, Forth, Lohghor, Mersey, and Poole Harour estuaries in the United Kingdom (Turner 2000). Copper from sulfidic sources (i.e., mine drainage) was found to correlate more strongly with iron oxides; copper from industrial sources correlated with anthropogenic organics.

The pH and redox conditions are particularly important within stagnant marshes and salt flats where fine sediments are subjected to repeated flooding and evaporation cycles. When the marshes are flooded, the organics within the marsh sediments can create sulfate-reducing conditions, resulting in the production of sulfide and the precipitation of metal sulfide minerals such as pyrite. However, following evaporation of the stagnant water the sulfides can become reoxidized, resulting in acid production and remobilization of metals during heavy rains or spring tides when the areas become flooded. Anisfeld and Benoit (1997) compared two marshes in Connecticut, one with a tide gate, which prevented tidal inflow, and another without a gate. They found that in the more stagnant, gated marsh the DO, metals, sulfate, acidity, ammonia, and nitrate levels were much higher than in the more consistently flooded, ungated marsh. The high nitrate and ammonia levels were attributed to oxidation of nitrogen-containing organic matter within the fine-grained marsh sediments. Borrego et al. (2002) found jarosite ($HFe_3(SO_4)_2(OH)_6$) and other hydrated sulfide minerals within the tidal flats above the spring tide line at the Odiel and Tinto estuaries in southwestern Spain. The tidal flats were sterile and contained the highest sediment zinc concentrations anywhere within the estuarine systems. The mineralogy and chemical composition of the sediments in these isolated marsh areas can be very similar to the precipitates found on the surfaces of mine tailings dumps where sulfide minerals oxidize in response to wetting and drying cycles within the piles.

5.2.2 Chemical Transport Processes

Chemical transport processes determine the phase in which a chemical exists in the environment.

5.2.2.1 Adsorption/Desorption

One of the most important geochemical processes affecting the rate of migration of chemicals is the adsorption to or desorption from soil, sediments, or suspended particulate matter. An organic chemical will strongly adsorb to organic soil or sediment; therefore, the chemical will be relatively immobile and will not be leached or transported from the source. If the chemical is weakly adsorbed, the chemical can be transported within the water. The degree of adsorption also affects other transformation reactions such as volatilization, hydrolysis, and biodegradation. The rates of such reactions are directly dependent on the degree of adsorption.

In the following discussions, the term "adsorption" is used because the most important processes causing retention of organic molecules are adsorption processes as opposed to absorption processes. Some texts have preferred to use the more generic term "sorption" to avoid any mechanistic connotations (Callahan et al. 1979). In selected cases, the word "partitioning" is used.

The distribution of chemicals between water and the sediment or suspended particles is often described by the soil/water distribution coefficient, or K_d. The distribution coefficient is a constant relating the thermodynamic activities of the two phases:

$$Kd = \frac{\alpha S}{\alpha W}$$

where:

αS = activity of the chemical in the sediment (or suspended particles)
αW = activity of the chemical in the water (aqueous phase)

Because the activities are equal to the activity coefficients multiplied by the chemical concentrations and the activity coefficients approach unity for environmental concentrations, the distribution coefficient is usually defined as the ratio of concentrations in the solid and water phase (Freeze and Cherry 1979) or as:

$$Kd = \frac{Cs}{Cw} = \frac{\text{mass of solute on the solid phase per unit mass of solid phase}}{\text{concentration of solute in solution}}$$

Cs is usually expressed in terms of mg/kg (ppm in the solid) and Cw is expressed in terms of mg/L (or ppm in the water, if the density equals one). Therefore, the units on K_d are:

$$\frac{mg/Kg}{mg/L} = \frac{L}{Kg} \text{ or } \frac{mL}{g}$$

Organic Compounds

For organic compounds, the value of K_d increases with increasing organic carbon content of the sediment. Typically, K_d values are not available in the literature for all organic carbon contents possible in soils and sediments. Therefore, K_d is usually normalized for the amount of organic carbon in the soil resulting in a new parameter, K_{OC}, the organic-carbon partition coefficient.

$$K_{oc} = \frac{Kd}{foc}$$

where:

foc = the fraction of natural organic carbon in the sediment
= % TOC/100
= (mg/kg TOC) × 10^6

This relation implies that adsorption is linearly related to the amount of organic carbon in the soil or sediment. Although K_d may vary greatly in different sediments, K_{oc} usually does not vary by more than a factor of two to three (Goring 1962). K_{oc} can be defined as follows:

$$K_{oc} = \frac{\text{mg of adsorbed chemical/K g of organic carbon}}{\text{mg of chemical in solution/L of solution}}$$

Some earlier investigations reported adsorption results based on soil organic matter (rather than soil organic carbon). The ratio of organic matter to organic carbon varies by soil type, but typically, a value of 1.724 is used to convert organic matter to organic carbon. That is,

$$K_{oc} = 1.724\ K_{om}$$

or

$$\text{Log } K_{oc} = \log 1.724 + \log K_{om}$$

Many studies have shown that the organic matter present in the sediment dominates the adsorption process. However, as the fraction of organic carbon becomes small,

adsorption of organic chemicals to inorganic surfaces (mostly clays) becomes important. The critical level of organic carbon (foc*) is the concentration below which the inorganic fraction dominates the adsorption process. McCarty et al. (1981) developed the following equation to calculate foc*:

$$foc^* = \frac{(SA)}{200} \frac{1}{K_{ow}^{0.84}}$$

where:

SA = surface area of soil (square meters per gram [m^2/g])
K_{ow} = octanol-water partition coefficient

When foc is higher than foc*, the K_{oc} value can be estimated from the solubility of the compound in water or the octanol/water partition coefficient (K_{ow}). High values of K_{ow} indicate the compound is hydrophobic and partitions out of the water and into the organic phase. Therefore, by evaluating K_{ow} and solubility data, the relative importance of adsorption onto organic matter within the sediment can be determined.

In general, adsorption is most important for dioxins/furans, pesticides, PCBs, and SVOCs and less so for the VOCs. However, other factors can affect the adsorption of organic compounds, two most common are:

- Ionic strength of the water (salinity)
- pH of the water

The salinity can have an extremely important effect on the adsorption of organic chemicals because of the process called salting out. Essentially, water with a high concentration of dissolved ions (salts) has less water available for dissolving hydrophobic compounds or species. The ions, being charged, tend to attract the polar water molecules, while leaving nonpolar organic compounds with less water to dissolve in to. Therefore, hydrophobic compounds will have even more tendency to partition to organic matter within the soil or sediment. The process can occur not only with organic compounds but also with noncharged species such as $HgCl_2$ and organically complexed mercury (Turner et al. 2001).

Inorganics

Inorganic species adsorb to mineral and chemical precipitate surfaces within soil or sediment. Generally, inorganic adsorption is independent of the amount of organic carbon, with the exception of mercury, cyanide, and copper.

The K_d values listed in **Table 5-2** have some wide ranges of values because of the large number of variables that can affect the measurements. The most important of these variables are:

- pH of water

- grain-size of the adsorbing media (soil or sediment)
- concentrations of competing ions present
- ionic strength of the water (salinity)
- mineralogy and organic carbon content of the adsorbing media

The pH of the water can have an effect on both the speciation of the inorganic constituents and the surface charge of the adsorbing media. At low pH values, the surfaces of most sediment minerals are positively charged, and tend to repel cations (such as lead) and attract anions (such as arsenic). At high pH, the surfaces tend to be negative and attract metals. The speciation of the ions can work against this trend by changing the charge on the ion itself. For instance, at high pH, metals (such as lead, iron, and manganese) can combine with hydrous oxides in solution, forming an aqueous complex with a neutral or negative charge.

The smaller the grain size of the absorbing media, the greater the adsorption because adsorption is a surface phenomenon. Grain size has been found to be the most important parameter for explaining adsorption of inorganic species within groundwater and in most surface water environments (Borrego et al. 2002).

Ions of similar character can compete for adsorption sites on the soil or sediment particles. For example, sulfate and phosphate can compete for the same sites on a solid and adsorb to a lesser extent together (in the same solution) than they do when measured separately. Adsorbed ions can be desorbed from the surfaces of soils and sediment when introduced to a solution of different chemistry, especially when the salinity is high. This process is called ion exchange and is very important in estuaries where saltwater and contaminated sediment mix. The ionic strength of the water can decrease the concentration of ions actually seen by the surfaces of the adsorbing media, which has the effect of decreasing the K_d. The process is important in estuaries because of the high ionic strength of saltwater.

The mineralogy of the soil or sediment can influence the degree of adsorption of metals or inorganics. For instance, arsenic and selenium have a strong affinity for iron-containing minerals, and mercury is attracted to organic matter.

5.2.2.2 Volatilization/Condensation

Volatilization is the process by which a chemical is transferred from soil or water into the atmosphere. For the discussion of transport in the aquatic environment, the chemicals of concern are typically at low concentrations (below saturation) and exist dissolved in the water phase and not as non-aqueous phase liquids. The chemicals of concern in the air will exist as a gaseous molecule.

The relation between the concentrations in the air and in the free water is described by the following equilibrium:

$$K_H = \frac{1}{H} = \frac{[\text{Conc. in water}]\ (\text{mg/L})}{[\text{Conc. in air}]\ (\text{mg/L})}$$

where H is Henry's law constant. From this equation, Henry's law constant appears to be the controlling parameter in determining the amount of volatilization. In turn, Henry's law constant is related to various factors, the most important of which is vapor pressure. A rough guide to evaluate the importance of volatilization is as follows (Olson et al. 1990).

The importance of volatilization as a transport mechanism depends on the depth of the water table or, for an estuary or river, the water layer containing the chemical, the degree of turbulence of the water, and the wind velocity just above the air/water interface.

Volatilization is important only for the VOCs (as the name implies) and some of the SVOCs, PAHs, and PCBs. The molecules with a greater atomic mass within each group tend to be less subject to volatilization than the lighter molecules. A Johnson-Ettinger model was completed and presented in **Section 6.3.5** and **Appendix L**. This model was used to assess VOC impacts to indoor air based on soil and groundwater contamination in the human health risk assessment.

5.2.2.3 Precipitation/Co-Precipitation

Precipitation is the process in which negatively and positively charged ions in solution combine to form a solid-phase compound or mineral. Given the generalized reaction,

$$nA^{+m} + mB^{-n} = A_mB_n \text{ (solid)}$$

precipitation is governed by the following equation:

$$[A^{+m}]^n\ [B^{-n}]^m = K_{sp}$$

where:

$[A^{m+}]$ = concentration of the cation in solution
$[B^{n-}]$ = concentration of the anion in solution
n = relative number of cations that form the solid phase
m = relative number of anions that form the solid phase
K_{sp} = solubility product constant

Ion A can represent positively charged ions (cations) such as zinc (Zn^{+2}), mercury (Hg^{+2}), or copper (Cu^{+2}). Ion B represents an anion such as hexavalent chromium (CrO_4^{2-}) or arsenic ($HAsO_4^{2-}$). The product of the concentrations of A^{+m} and B^{-n} in solution cannot exceed the value of K_{sp}. If either A^{+m} or B^{-n} is added to the solution to concentrations that would exceed the K_{sp}, a precipitate of A_mB_n will form until the solubility product reaches the value of K_{sp}. Solid phases or minerals that are insoluble or have low solubility in water have a low K_{sp} value; very soluble phases

have a high K_{sp}. Therefore, K_{sp} values of phases that contain one or more chemicals can be used to evaluate precipitation as a fate and transport process. K_{sp} values for some example mineral phases are provided in **Table 5-3**.

Although many of the mineral phases have relatively low K_{sp} values, they typically do not form precipitates because of the comparatively low concentrations of these chemicals present, even in waters that are considered contaminated. Typically, the levels of chemicals required to trigger human health or environmental concerns are much less than is required to reach the solubility limit. Therefore, pure-phase minerals rarely control the dissolved concentrations of chemicals. However, precipitation of impure phases is often an important control on chemical concentrations. For example, iron oxyhydroxide, which in the pure phase does not control concentrations of any metals except for iron, can and usually is a very important control on metals such as copper, lead, and zinc when impure. The process by which metals are precipitated along with iron oxyhydroxide is termed coprecipitation. Metals can substitute for iron within the structure of the mineral during precipitation, which can be a very important control on the aqueous concentrations of metals in the environment. Precipitation of iron oxyhydroxides can occur because of the oxidation of iron, which can be initiated by the mixing of groundwater with surface water or the turbulent conditions present in the tidal influenced areas of estuaries.

The only pure phases that commonly precipitate metals are the sulfide phases as evidenced by the extremely low K_{sp} values listed previously. Metal sulfides can precipitate under reducing conditions such as exist in the organic muds present in the low energy areas of many rivers and estuaries.

5.2.2.4 NAPL Dissolution and Precipitation/Co-Precipitation

Unlike inorganic compounds and metals, which tend to exist as solids at ambient temperatures, organic compounds tend to exist as nonaqueous phase liquids (NAPL). The solubility of NAPL when pure is given by the solubility for that compound under the given conditions (e.g., temperature, pressure). However, often NAPL consists of a complex mixture of compounds such as in many hydrocarbon products. The solubility of each component in the mixture is not equivalent to the solubility, however. The concentrations of each component that can exist in groundwater can be represented by Raoult's law. Raoult's law is given by:

$$C_i = X_i S_i$$

where:

C_i = the aqueous concentration of component i in the groundwater
X_i = the fraction of component i in the petroleum product
S_i = the solubility of the pure constituent i

Raoult's law is most valid as X_i approaches 1. Therefore, this equation is better suited to calculating the aqueous concentrations of constituents that make up a large fraction of the NAPL. Cline et al. (1991) also determined that Raoult's law is applicable to mixtures of structurally similar compounds.

5.2.2.5 Degradation/Transformation Processes

The discussion in the following subsection addresses physical and biological processes leading to the fate of selected chemical constituents.

Abiotic Degradation/Transformation

Oxidation/Reduction - Oxidation is the loss of electrons during a chemical reaction. Typical abiotic oxidation reactions would include treatment processes using chlorine, ozone, or hydrogen peroxide. The result of complete reaction is conversion of the organic molecules to carbon dioxide and water. Such powerful abiotic oxidizing agents do not occur naturally in groundwater or estuarine environments. Oxidation can occur through two major pathways: either the polar reaction or free-radical reaction pathways. Typically, free-radical reactions are more common because less activation energy is required. Before an oxidation reaction can occur via the free-radical pathway, a free-radical must be formed by the removal of a single electron from a molecule. This can occur through thermal energy, radiant energy, high-energy particles, and other mechanisms. Free-radical concentrations of the single oxygen in natural surface water is approximately 10^{-12} molar concentration (M) and results from the photodisassociation of the water molecule. Once the free radicals are formed, they will react with organic molecules present to form an intermediate organic free radical, which usually reacts further.

Reduction of organic compounds (i.e. the addition of electrons to a molecule) can transform organic chemicals. For example, chlorinated organic compounds can be transformed into less chlorinated or unchlorinated compounds by reduction reactions. Typically, the process is biologically mediated.

Photolysis - Photochemical transformation may occur by one of several processes depending upon the chemical structure and substances in the environment. Direct photolysis occurs when the chemical absorbs light and is then transformed from an excited state by rearrangement, dissociation, oxidation, or other mechanisms. The rate of reaction depends upon the sunlight photo flux, the light absorption coefficients of the chemical, and the efficiency of conversion of the absorbed light in the chemical reaction.

Indirect photolysis occurs when substances present in the aquatic environment absorb light to form excited chemical species or free radicals, which interact with the chemical of concern to produce a reaction. Single oxygen and oxy radicals are examples of intermediates, which can result in transformations of chemicals. Since these intermediates result from photoreactions of naturally occurring substances and the chemical does not undergo photochemical reaction itself, the reaction should not be referred to as photolysis but rather photo-induced free radical reactions. Some of

the examples discussed under the oxidation section are actually these types of reactions. An example of a photolysis reaction of hazardous chemicals is the reaction of chlorinated dibenzodioxins with UV light to produce two toluene-like molecules, which can then be biologically attacked.

Biotic Degradation/Transformation

Removal or transformation of organic chemicals from the subsurface environment can occur through the action of microorganisms that may be attached to the sediment or suspended particles.

Biodegradation of organic chemicals by microorganisms ultimately produces microbial cells, water, and carbon dioxide (i.e., complete "mineralization"). The enzymes produced by the microorganisms are essentially responsible for the degradation of the organic chemicals. Whether or not a chemical is transformed by enzymes depends on the configurations alignment of the enzyme with the organic chemical during reaction. If an ideal configuration of the enzyme and organic chemicals occurs, the reaction will occur. Persistent chemicals have less favorable alignments, and non-reacting (or recalcitrant chemicals) fail to bond or produce any favorable alignments.

Typically, biodegradation rates are found to be proportional to both the substrate, the organic compound providing the energy source, and microbial numbers. However, some organics, termed secondary substrates, do not provide sufficient energy to support growth of the microbial biomass. In this case, a primary substrate must be present. When enzymes, produced for degradation of the primary substrate, can serve to degrade the secondary substrate, this is termed cometabolism.

Microbes can facilitate either oxidation or reduction of organics under oxic (or aerobic) or anoxic (anaerobic) conditions, respectively. During the oxidation reaction, electrons are donated to an electron acceptor, generally oxygen, which is reduced. Reduction of organics requires the presence of an appropriate electron donor, such as other organics, nitrate, hydrogen, or glucose. Biodegradation can occur when the combined oxidation and reduction half reactions are energetically favorable.

Biodegradation is predicted using degradation kinetics and rate equations or expressions that describe the reduction of contaminant with time. Three rate equations that have been developed are the power rate law, the Monod, and the Michaelis-Menton equations. The power rate law, the simplest method, is in the following form:

$$\frac{-dC}{dt} = kC^n$$

where :

C = substrate concentration

t = time
k = rate constant for chemical disappearance
n = 0 for zero order reactions; 1 for first order reactions

Concentration and the natural log of the concentration vary linearly with time in zero and first order reactions, respectively. The rate constant is determined by fitting laboratory or field data to the equation. Published rate constants can be used to estimate the relative importance of biodegradation for a given compound or class of compounds in the estuarine environment. Often, the degradation rate is expressed as the half-life of the compound, which is defined as the time required for biotransformation to one-half of the starting concentration.

Although a discussion of the biotransformation of each of the thousands of organic compounds is beyond the scope of the current discussion, an evaluation of biodegradation trends for organic compounds and groups is appropriate. Dragun (1988) lists the following "rules of thumb," which relate the chemical structure of the organic compounds within a given group with the biodegradation rate:

- Hydroxyl and carboxyl functional groups on benzene rings usually increase biodegradation rates.
- Halogen, nitro, and sulfonate functional groups on benzene rings usually decrease biodegradation rates.
- As the number of chlorine atoms within the molecule increases, the biodegradation rate decreases.
- The presence of hydroxyl, aldehyde, carboxyl, ester, and amide functional groups on organic chemicals usually causes faster biodegradation rates.
- Water-soluble chemicals are usually degraded faster than less soluble chemicals.
- N-alkanes, n-alkylaromatics, and aromatic compounds in the C_{10} to C_{22} range are usually readily biodegradable.
- N-alkanes, n-alkylaromatics, and aromatic hydrocarbons in the C_5 to C_9 range are biodegradable, but in most environments, volatilization competes very effectively with biodegradation as a fate process.
- Gaseous n-alkanes (C_1-C_4) are biodegradable but are usually used by a narrow range of specialized hydrocarbon degraders.
- The n-alkanes, n-alkylaromatics, and aromatic hydrocarbons above C_{22} have very low water solubilities, which result in slow rates of microbial degradation.
- Condensed or fused aromatic and cycloparaffinic molecules with four or more rings have very low biodegradation rates.

- Rate of oxidation of straight chain aliphatic hydrocarbons is correlated to chain length; in general, short chains are not as quickly degraded as long chains.
- Unsaturated aliphatic organics have faster biodegradation rates than corresponding saturated aliphatic organics.

A list of half lives for representative compounds and groups is provided in **Table 5-4**. Under laboratory conditions where the bacteria responsible for biotransformation are carefully cultured and maintained under ideal conditions, the half live of a given compound is dramatically shorter (biotransformation rate is faster) than under field conditions. Note that the degradation of chlorinated pesticides, dioxins, and large molecule PAHs is much slower than for the VOCs, SVOCs, and smaller PAHs.

Reductive dechlorination-The fate and transport of chlorinated solvents in groundwater and soil gas is significantly affected by biodegradation rates, which vary by compound. For chlorinated ethenes, the primary biodegradation mechanism is reductive dechlorination. During this process, anaerobic bacteria use organic compounds as electron donors and chlorinated ethenes as electron acceptors. This results in sequential removal of a chlorine atom from the chlorinated ethenes, and replacement by a hydrogen atom. For PCE, the reductive dechlorination process occurs as follows:

PCE → TCE → cis-1,2-dichloroethene (cis-1,2-DCE) → vinyl chloride → ethene.

The reductive dechlorination process requires reducing dissolved phase constituents in the aquifer. Reducing conditions develop when sufficient electron donor is present in the aquifer such that various terminal electron acceptors are consumed by bacteria in the groundwater. Generally, terminal electron accepting processes progress from aerobic, to nitrate reducing, to iron reducing, to sulfate reducing, to methanogenesis (reduction of carbon dioxide to produce methane). Partial reductive dechlorination of PCE and TCE to cis-DCE can occur under iron or sulfate reducing conditions, but complete dechlorination to ethene requires methanogenic conditions.

The three primary requirements for the reductive dechlorination process to be driven to completion (e.g. dechlorination to ethene) are: 1) adequate spatial distribution of a suitable electron donor to achieve strongly reducing conditions, 2) a microbial community capable of complete reductive dechlorination of the chloroethenes, and 3) appropriate geochemical conditions (e.g. no extreme pH conditions).

The electron donor that drives reductive dechlorination can be organic carbon that is naturally present in the aquifer. It can also be added under engineered conditions, which is known as bio stimulation. Also, certain contaminants such as BTEX compounds, which may have been released to the aquifer along with the chlorinated ethenes can serve as electron donors. In this case, the coupled reactions of BTEX compounds being used as an electron donor and chlorinated ethenes being used as the electron acceptors results in simultaneous biodegradation of both compounds. This process will continue until one of the contaminants (usually BTEX) is consumed.

5.3 Chemical Specific Fate and Transport Processes

This section includes discussions of fate and transport processes, as they pertain to specific chemical classes identified in the study area.

5.3.1 Petroleum Hydrocarbons

Predominantly, petroleum hydrocarbon compounds occur in the environment because of spills or leaks. The type of petroleum product released relates to the fate and transport processes that act on the constituent compounds. The principal refined petroleum products that fall into the range of the TPH analysis (EPA Method 8015 modified) include gasoline, mineral spirits, kerosene, and diesel fuel (Baugh and Lovegreen 1992). Although general compositions of these materials may be representative of a "typical" petroleum product, a specific chemical breakdown is not possible because of variations in the composition of the source crude oil and in the refining techniques used. **Table 5-5** lists typical percentages of alkanes, cyclic alkanes, aromatics, and iso-alkanes in each of the TPH products. In general, gasoline is higher in aromatics compared to diesel, kerosene, and mineral spirits, as well as being higher in BTEX compounds. Diesel fuel tends to be composed of heavier hydrocarbons than gasoline, containing between 9 and 20 carbon atoms compared to 6 to 10 for gasoline. Mineral spirits is considered a light fuel, with a predominance of C_6 to C_{11} compounds and negligible BTEX compounds. Kerosene is somewhat heavier than gasoline and has a lower percentage of aromatics.

AVGAS is a form of gasoline that was developed for use in piston engine aircraft. Up to six different grades of AVGAS were produced through 1945, with varying octane ratings up to 125. As stated in **Section 1.4.2**, Tongue Point Naval Air Station was used as an amphibious seaplane base with construction beginning in 1939 (Roberts, 2000) and the arrival of aircraft such as the for PBY Catalina's beginning in 1943 (Freeman 2010). In 1944 the PBY Catalina's at Tongue Point were replaced by larger and more capable PBM Mariners. Anti-submarine patrols from Tongue Point were discontinued with the end of World War 2 in 1945, and the station was placed in a caretaker status in 1946 (Freeman 2010). This history indicates that AVGAS was only used at the NAS from 1943 to 1946. The PBY Catalina's specified AN-F-28 Grade 100/130 AVGAS. This AVGAS had octane levels of 100/130, was dyed green, and contained a maximum of 4 grams of TEL per US gallon (or 1.1 g/l) (Kerley, 1993). In June 1944, the military fuel specification AN-F-33 was published for 145 Octane fuel with 4.6 ml/gal of TEL and marked the peak in AVGAS development. One gram of TEL contains 600 milligrams of inorganic lead.

AVGAS is in some ways similar to gasoline in that it is a light distillate (C_4-C_{10}); however, the stringent specifications for AVGAS (i.e., antiknock ratings, volatility, freezing point, calorific values, and so on) require a strictly controlled refining process that results in a more uniform product. As shown in **Table 5-5**, AVGAS contains mainly branched isoalkanes, which provide the required octane rating while maintaining low freezing points. The main isoalkane used is isooctane, with minor amounts of isopentane added to meet minimum volatility requirements (Westbrook

2003). BTEX compounds, which are typically added to automotive gasoline (MOGAS) to increase the octane rating, are limited to mainly toluene, because benzene has too high a freezing point to meet AVGAS specifications.

AVGAS additives include tetraethyl lead (TEL) for antiknock performance, metal deactivators, color dyes, oxidation inhibitors, corrosion inhibitors, icing inhibitors, and static dissipaters. As stated in **Section 1.4.3.1**, AVGAS was stored in the four ASTs at the Former AST Fuel Storage Area DU during the period 1943 to 1945 when aircraft were fueled at the facility. To prevent the formation of lead oxides following fuel combustion, ethylene dibromide (EDB) is typically used in AVGAS as a lead "scavenger."

Diesel fuel no. 2, which is mostly used in cars and trucks, is characterized by a slightly heavier composition compared to AVGAS, with most molecules in the C_9 to C_{20} range and consisting of mostly cyclic alkanes and aromatics (**Table 5-5**). No. 4 diesel, which is typically used in locomotives, ships, and other engines, where slow speeds and constant loads are the rule, is a heavier distillate than diesel no. 2, with molecules in the $+C_{25}$ range.

The dominant fate processes that act on a hydrocarbon spill will depend not only on the composition of the petroleum product but also on site-specific conditions. Depending on the type of processes operating at a specific site, the ultimate phase of the hydrocarbon compounds can include the gas, the liquid (NAPL), or the aqueous or adsorbed forms. The NAPL may be present floating on the water table, coating soil grains, or filling pore spaces in the saturated and unsaturated zones. The gas phase is present in the vadose zone (unsaturated zone) in interstitial pore spaces in the soil; the aqueous phase is present within pore waters in the saturated zone. Adsorbed hydrocarbons may be present on the surfaces of the soil matrix in either the saturated or the unsaturated zones. The site-specific factors that affect each fate process described previously, as well as the relative susceptibility of various types of hydrocarbons to each fate and transport process, is discussed next.

Vaporization of petroleum products can be an important process for some organic constituents, provided site conditions are favorable. Vaporization from the original NAPL may be described by Raoult's law, just as with water solubility (as described previously).

Organic compounds that have high vapor pressures (V_P) and Henry's law constants (H) will be more susceptible to vaporization than the other hydrocarbons, and will tend to accumulate in the soil gas within the vadose zone. H and V_P values for a selected set of hydrocarbons are given in **Table 5-6**. In general, it may be seen from the V_P data that the compounds most likely to volatilize from the NAPL are the light alkanes (C_5 to C_7), followed by the aromatics and cycloalkanes, the heavy alkanes (C_8 to C_{16}), and the PAHs. Therefore, an old NAPL would be depleted in the light alkanes, aromatics, and cycloalkanes relative to the PAHs and heavy alkanes because of volatilization. The Henry's law data indicate that volatilization of hydrocarbons

from solution is most likely for the alkanes, followed by the cycloalkanes, aromatics, and PAHs.

An important consideration when weighing the importance of volatilization is whether equilibrium is maintained between the NAPL and solution and the soil gas. Where the soil gas is prevented from migrating, equilibrium is more likely than where organic vapors are free to escape to the surface. Clearly, nonequilibrium conditions tend to drive volatilization. The two most important processes that affect the mobility of soil gas are diffusion and advection. Diffusion is the movement of an organic constituent from areas of high concentration (i.e., the soil gas) to areas of low concentration (i.e., the atmosphere). Diffusion is a chemical-specific process and is given by Fick's first law:

$$J = D_o(dc/dx)$$

where:

J = mass flux (g/cm^2–s)
D_o = diffusion coefficient (cm^2/s)
c = concentration of individual components (g/cm^3)
x = distance between the two points (cm)
dc/dx = concentration gradient

Therefore, the higher the diffusion coefficient, the greater the mass flux. According to Dragun (1988), D_o of an organic compound is inversely proportional to the square root of its molecular weight at a given temperature. Therefore, the lighter gases tend to migrate more readily than the heavier ones.

In advection, soil gas moves in a response to a pressure gradient. Unlike diffusion, advection is a mostly site-specific process. Advection is given by Darcy's law:

$$Va = q/o_a) (ka/u(P + pg)) dh/dl$$

where:

Va = vapor velocity in the soil (centimeter per second [cm/s])
q = volume of vapor across unit area per unit time (cubic centimeter per square centimeter per second [$cm^3/cm^2/s$])
o_a = air filled porosity of the soil
ka = soil air permeability (cm^2)
u = dynamic viscosity of the air-vapor mixture (gram per centimeter second[g/cm-s])
P = pressure of air vapor ($g/cm\text{-}s^2$)
p = density of air-vapor mixture (g/cm^3)
g = acceleration due to gravity (cm/s^2)
h = elevation (cm)
I = distance of transport (cm)

The density and viscosity of the air-vapor mixture are chemical-specific parameters, but the most important parameters are site-specific, namely soil permeability and porosity, transport distance, and elevation. According to the formula just given, advection is most important at sites having a thin, porous, and permeable vadose zone. In addition, advection may be more important at high elevations where the atmospheric pressure is slightly less than at sea level.

When liquid petroleum products encounter groundwater in the subsurface, solubility controls limit the amount of each hydrocarbon that will partition into the aqueous phase. **Table 5-6** lists the solubilities of selected hydrocarbons. In general, the less saturated hydrocarbons tend to be more soluble than the alkanes, and the smaller organic molecules are more soluble than the larger ones. Because many TPH hydrocarbons dissolve in groundwater, each constituent will not reach its solubility, as shown in **Table 5-6**, which represents the solubility in pure water (see previous discussion on Raoult's law).

The site-specific variables that contribute to hydrocarbon solubility include ambient temperature and pressure, pH, salinity, particulate matter content, and concentrations of other compounds in the aqueous phase (Chen 1992). Most organic compounds are more soluble at higher temperatures and lower pressures. pH may be important if an OH functional group exists on the organic compound such as with phenols and alcohols; however, these constituents are generally at low concentrations in petroleum products. High-salinity groundwater and saline surface waters tend to have lower organic solubility because of the salting out effect (Bockris and Reddy 1973). The effect of particulates is that unfiltered samples with a high content of suspended organic matter tend to have higher concentrations of hydrocarbons because of the affinity of organic chemicals for organic matter.

Based on the relatively low K_{OC} values (**Table 5-6**), the AVGAS additive EDB has a low to moderate tendency to adsorb to soils or sediment. In surface waters such as streams, rivers, and bays, EDB has a short half-life (1 to 5 days) because of volatilization (vapor pressure and Henry's law constant are high). Within groundwater, fresh EDB releases would be present within the groundwater (because of high water solubility and low Koc). However, for older releases, EDB tends to biodegrade (half-life is 1 to 2 months) and is often at concentrations below the analytical detection limit.

5.3.2 Volatile Organic Compounds

Three VOCs with RBCs (trichloroethene, vinyl chloride, and benzenes) were detected in groundwater and soil gas in the Study Area. This section includes a brief historical use summary of the VOCs and a summary of the fate and transport processes that may affect the compounds.

5.3.2.1 Trichloroethene

TCE is now mainly used as a solvent to remove grease from metal parts. It is also used as a solvent in other ways, and is used to make other chemicals. TCE can be

found in some household products, including typewriter correction fluid, paint removers, adhesives, and spot removers. Most TCE deposited in surface waters or on soil surfaces volatilizes into the atmosphere, although its high mobility in soil may result in substantial percolation to subsurface regions before volatilization can occur. In these subsurface environments, TCE is only slowly degraded and may be relatively persistent (Agency for Toxic Substances and Disease Registry [ATSDR] 1997).

The relatively short predicted half-life of TCE in the atmosphere indicates that long-range transport is unlikely (Class and Ballschmiter 1986). It is moderately soluble in water, and experimental data have shown that scavenging by rainwater occurs rapidly (Jung et al. 1992). TCE can, however, be expected to revolatilize back to the atmosphere after being deposited by wet deposition. Evaporation from dry surfaces can be predicted from the high vapor pressure. The Henry's law constant value of 2.0×10^{-2} atmosphere cubic meters per mole (atm-m^3/mol) at 20°C suggests that TCE partitions rapidly to the atmosphere from surface water. The major route of removal of TCE from water is volatilization (EPA 1985). Laboratory studies have demonstrated that TCE volatilizes rapidly from water (Chodola et al. 1989; Dilling 1977; Okouchi 1986). Although volatilization is rapid, actual volatilization rates are dependent on temperature, water movement and depth, associated air movement, and other factors.

Volatilization of TCE from soil is slower than it is from water but more rapid than that of many other VOCs (Park et al. 1988). Sorption of organic compounds to soil has been found to be most reliably predicted when related to the organic carbon content of the soil (Kenaga 1980; Urano and Murata 1985). Experimentally measured soil organic carbon sorption coefficients (K_{OC} values) for TCE range from 106 to 460 (Garbarini and Lion 1986).

To assess bioaccumulation in the environment, the levels of TCE in the tissues of a wide range of organisms were determined (Pearson and McConnell 1975). Species were chosen to represent several trophic levels in the marine environment. The maximum overall increase in concentration between sea water and the tissues of animals at the top of food chains, such as fish liver, sea bird eggs, and seal blubber, was less than 100-fold for TCE. Biomagnification in the aquatic food chain does not appear to be important (Pearson and McConnell 1975).

Oxidation of TCE in the aquatic environment does not appear to be a significant fate process, probably because of TCE having already been oxidized by the chlorine atoms. The rate of hydrolysis is too slow to be an important transformation process (EPA 1979b). Biotransformation was strongly indicated as a factor in the degradation of TCE in soil and groundwater pollution (Milde et al. 1988). Degradation of TCE by anaerobes via reductive dehalogenation can be problematic because a common product is vinyl chloride, a known carcinogen (Ensley 1991). Since neither biodegradation nor hydrolysis occurs at a rapid rate, most TCE present in surface waters can be expected to volatilize into the atmosphere.

5.3.2.2 Vinyl Chloride

Vinyl chloride is a manufactured substance that does not occur naturally; however, it can be formed in the environment. A significant source of vinyl chloride can be attributed to the bacterial degradation of chlorinated solvents such as TCE, tetrachloroethene (PCE), and 1,1,1-trichloroethane rather than from industrial sources. A commonly occurring degradation sequence is as follows:

PCE → TCE → cis-dichloroethene (DCE) → vinyl chloride → ethene → ethane

The reaction rate depends on many factors, such as the concentration of organic substrate, and competing electron acceptors, such as sulfate. At some sites, the sequence stops at cis-DCE because of high concentrations of sulfate or the absence of the appropriate bacteria to convert cis-DCE to vinyl chloride and ultimately to ethane.

When released to the atmosphere, vinyl chloride is expected to be removed by reaction with photochemically generated hydroxyl radicals (half-life = 1 to 2 days). Reaction products include hydrochloric acid, formaldehyde, formyl chloride, acetylene, chloroacetaldehyde, chloroacetylchloranil, and chloroethylene epoxide.

When vinyl chloride is released to water, volatilization is expected to be the primary environmental fate process. In waters containing photosensitizers such as humic materials, sensitized photodegradation may also be important. Sensitized photodegradation can occur when a molecule other than the compound of interest absorbs light, promoting it to an excited state; a transfer of energy occurs between the excited state of the photosensitizer and the compound of interest, which involves no direct absorption of photons by that particular compound. When released to soil, vinyl chloride either volatilizes rapidly from soil surfaces or leaches readily through soil, ultimately entering groundwater (ATSDR 2006).

Based on a vapor pressure of 2,660 millimeters mercury (mmHg) at 25°C, all vinyl chloride in the atmosphere is expected to exist solely as a gas (Eisenreich et al. 1981; Verschueren 1983). Consequently, removal from the atmosphere by dry deposition is not expected to be an important fate process. The primary transport process for vinyl chloride from natural water systems is volatilization into the atmosphere. The Henry's law constant of vinyl chloride has been measured as 0.0278 atm-m^3/mol at 24.8°C (Gossett 1987), which suggests that vinyl chloride should partition rapidly to the atmosphere. The half-life for vinyl chloride volatilization from a typical pond, river, and lake has been estimated to be 43.3, 8.7, and 34.7 hours, respectively. Predicted half-lives should be considered rough estimates because the presence of various salts in natural water systems can affect the volatility of vinyl chloride significantly (EPA 1979b). Many salts have the ability to form complexes with vinyl chloride and can increase its water solubility; therefore, the presence of salts in natural waters may significantly influence the amount of vinyl chloride remaining in the water (EPA 1979b). The half-life of vinyl chloride in bodies of water is also affected by depth and turbidity.

The relatively high vapor pressure of vinyl chloride indicates that the compound volatilizes quite rapidly from dry soil surfaces (Verschueren 1983). The effective half-life (because of volatilization and degradation) of vinyl chloride incorporated 10 cm deep in dry soil is predicted to be 12 hours (Jury et al. 1984). Vinyl chloride is soluble in water and thus can leach through the soil and enter groundwater before evaporation can occur (Cowfer and Magistro 1983).

The soil organic carbon adsorption coefficient (K_{OC}) for vinyl chloride was estimated to range from 14 to 131 (Kenaga and Goring 1980). These K_{OC} values suggest a very low sorption tendency, meaning that this compound would be highly mobile in soil. Thus, vinyl chloride has the potential to leach into groundwater. Vinyl chloride's small octanol/water partition coefficient (log K_{OW} = 1.23) indicates that the potential for bioconcentration in aquatic organisms is low (EPA 1982a). Using a log K_{OW} of 1.23, the bioconcentration factor (BCF) for vinyl chloride is estimated at 3. The high volatility of vinyl chloride minimizes results in minimal bioaccumulation. Relatively low tissue concentrations found in fish suggested that vinyl chloride is not biomagnified in aquatic food chains to any substantial degree (Lu et al. 1977).

5.3.2.3 Benzene and Trimethylbenzenes

Benzene has been used extensively as a solvent in the chemical and drug industries, as a starting material and intermediate in the synthesis of numerous chemicals, and as a gasoline additive (National Toxicology Program 1994). Benzene and trimethylbenzenes, as a component of gasoline, occur naturally in crude oil and are byproducts of oil refining processes (Brief et al. 1980; Holmberg and Lundberg 1985). Benzene is especially important for unleaded gasoline because of its anti-knock characteristics. For this reason, the concentration of aromatics such as trimethylbenzenes and benzene in unleaded fuels has increased (Brief et al. 1980). The percentage by volume of benzene in unleaded gasoline is approximately 1% to 2% (Northeast States for Coordinated Air Use Management [NESCAUM] 1989).

The EPA has listed benzene as a hazardous air pollutant and a hazardous waste (EPA 1981). In addition, sufficient evidence is available to support classifying benzene as a human carcinogen (Group A) (Integrated Risk Information System [IRIS] 2007). One result of EPA's action is that the widespread use of benzene as a solvent has decreased in recent years. Many products that used benzene as solvents in the past have replaced it with other organic solvents; however, benzene may still occur as a trace impurity in these products. Less than 2% of the amount produced is used as a solvent in products such as trade and industrial paints, rubber cements, adhesives, paint removers, artificial leather, and rubber goods. In the past, certain consumer products (such as some paint strippers, carburetor cleaners, denatured alcohol, and rubber cement used in tire patch kits and arts and crafts supplies) contained small amounts of benzene (Young et al. 1978). Other consumer products that contained benzene were certain types of carpet glue, textured carpet liquid detergent, and furniture wax (Wallace et al. 1987).

Chemical degradation reactions, primarily reaction with hydroxyl radicals, limit the atmospheric residence time of benzene to only a few days, and possibly to only a few hours. Benzene released to soil or waterways is subject to volatilization, photo-oxidation, and biodegradation. Biodegradation, principally under aerobic conditions, is an important environmental fate process for water- and soil-associated benzene (ATSDR 2007a).

The high volatility of benzene is the controlling physical property in the environmental transport and partitioning of this chemical. Benzene is considered to be highly volatile, with a vapor pressure of 95.2 mmHg (at 25°C); trimethylbenzenes has a vapor pressure of 2.03 mmHg. Benzene is moderately soluble in water, with a solubility of 1,780 mg/L at 25°C, and the Henry's law constants for benzene (5.5×10^{-3} atm-m^3/mol at 25°C) and trimethylbenzenes (5.18×10^{-3} atm-m^3/mol at 25 °C) indicate that these compounds partition readily to the atmosphere from surface water (Mackay and Leinonen 1975). Since benzene is soluble in water, some minor removal from the atmosphere via wet deposition may occur. A substantial portion of any benzene in rainwater that is deposited to soil or water will be returned to the atmosphere via volatilization. Benzene released to soil surfaces partitions to the atmosphere through volatilization, to surface water through runoff, and to groundwater as a result of leaching. K_{OC} for benzene and trimethylbenzenes has been measured at values of 60 to 83 and 472, respectively (Karickhoff 1981; Kenaga 1980), indicating that benzene is highly mobile in soil and readily leaches into groundwater. Other parameters that influence leaching potential include the soil type (e.g., sand versus clay), amount of rainfall, depth of the groundwater, and extent of degradation. Benzene is subject to indirect photolysis in sunlit surface water, but does not undergo direct photolysis.

Benzene is readily degraded in the soil, sediment, and water under aerobic conditions. Microbial degradation of benzene in aquatic environments is influenced by many factors, including microbial population, dissolved oxygen, nutrients, other sources of carbon, inhibitors, temperature, pH, and initial concentration of benzene. Vaishnav and Babeu (1987) reported biodegradation half-lives for benzene in surface water (river water) and groundwater of 16 and 28 days, respectively. Benzene was found to be resistant to biodegradation in surface water taken from a harbor and supplemented with either nutrients (nitrogen and phosphorus) or acclimated microbes; however, biodegradation did occur, with a half-life of 8 days, in surface water enriched with both nutrients and microbes (Vaishnav and Babeu 1987). At very high levels, as may be the case of a petroleum spill, benzene (and other compounds contained in petroleum) is toxic to microorganisms and the rate of degradation is slow compared to low initial starting concentrations.

Benzene biodegradation under anaerobic conditions does not readily occur. It has been demonstrated that when mixtures of benzene, toluene, xylenes, and ethylbenzene are present in an anaerobic environment, substrate hydrocarbons are used sequentially, with toluene usually being the first to be degraded, followed by

the isomers of xylene in varying order. Benzene and ethylbenzene tend to be degraded last, if they are degraded at all (Edwards and Grbić-Galić 1992).

5.3.3 Polycyclic Aromatic Hydrocarbons

For the purposes of describing environmental fate, the PAHs have been grouped into low and high molecular weight classes, as follows:

- LPAHs: acenaphthene, acenaphthylene, anthracene, fluorene, and phenanthrene.
- HPAHs: benz(a)anthracene, benzo(b)fluoranthene, benzo(j)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, benzo(a)pyrene, benzo(e)pyrene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-c,d)pyrene, and pyrene.

Transport and partitioning of PAHs in the environment are basically determined by physicochemical properties such as water solubility, V_P, Henry's law constant, K_{OW}, and K_{OC}. In general, PAHs have low water solubilities. The Henry's law constant is the partition coefficient that expresses the ratio of the chemical's concentrations in air and water at equilibrium and is used as an indicator of a chemical's potential to volatilize. The K_{OC} indicates the chemical's potential to bind to organic carbon in soil and sediment. The K_{OW} is used to estimate the potential for an organic chemical to move from water into lipid and has been correlated with bioconcentration in aquatic organisms. Some of the transport and partitioning characteristics (e.g., Henry's law constant, K_{OC}, and K_{OW}) of the 17 PAHs are roughly correlated to their molecular weights (ATSDR 1995).

PAHs released to the atmosphere are subject to short- and long-range transport and are removed by wet and dry deposition onto soil, water, and vegetation. In surface water, PAHs can volatilize, photolyze, oxidize, biodegrade, bind to suspended particles or sediments, or accumulate in aquatic organisms (with bioconcentration factors often in the 10 to 10,000 range). In sediments, PAHs can biodegrade or accumulate in aquatic organisms. PAHs in soil can volatilize, undergo abiotic degradation (photolysis and oxidation), biodegrade, or accumulate in plants. PAHs in soil can dissolve into groundwater and be transported within an aquifer.

PAHs are present in the atmosphere in the gaseous phase or sorbed to particulates. The phase distribution of PAHs in the atmosphere is important in determining their fate because of the difference in rates of chemical reactions and transport between the two phases. The phase distribution of any PAH depends on the vapor pressure of the PAH, the atmospheric temperature, the PAH concentration, the affinity of the PAH for the atmospheric suspended particles (K_{OC}), and the nature and concentrations of the particles (Back et al. 1991). In general, PAHs having two to three benzene rings (naphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, phenanthrene) are present in air predominantly in the vapor phase. PAHs that have four benzene rings (fluoranthene, pyrene, chrysene, benz(a)anthracene) exist in both vapor and particulate phases, and PAHs having five or more benzene rings (benzo(a)pyrene, benzo(g,h,i)perylene) are found predominantly in the particle phase (Back et al. 1991).

Atmospheric residence time and transport distance depend on the size of the particles to which PAHs are sorbed and on climatic conditions, which will determine rates of wet and dry deposition.

PAH, compounds tend to be removed from the water column by volatilization to the atmosphere, by binding to suspended particles or sediments, or by being accumulated by or sorbed onto aquatic biota. The transport of PAHs from water to the atmosphere via volatilization will depend on the Henry's law constants (H_S) for these compounds. The LPAHs have Henry's law constants in the range of 10^{-3} to 10^{-5} atm-m^3/mol and HPAHs have values in the range of 10^{-5} to 10^{-8} atm-m^3/mol. Compounds with values ranging from 10^{-3} to 10^{-5} atm-m^3/mol are associated with significant volatilization, and compounds with values less than 10^{-5} volatilize from water only to a limited extent (Lyman et al. 1982). Half-lives for volatilization of HPAHs from water have been estimated to be greater than 100 hours (Southworth 1979). LPAHs can be removed by volatilization if suitable conditions (high temperature, low depth, high wind) are present (Southworth et al. 1978). The estimated half-life for volatilization of anthracene (an LPAH) is 18 hours in a stream with moderate current and wind, versus about 300 hours in a body of water with a depth of 1 meter and no current (Southworth 1979). Even for PAHs susceptible to volatilization, other processes such as adsorption, photolysis, or biodegradation may become more important than volatilization in slow-moving, deep waters.

Because of their low solubility and high affinity for organic carbon, PAHs in aquatic systems are primarily found sorbed to particles that either have settled to the bottom or are suspended in the water column. It has been estimated that two-thirds of PAHs in aquatic systems are associated with particles and only about one-third are present in the dissolved phase (Eisler 1987a). In an estuary, volatilization and adsorption to suspended sediments with subsequent deposition are the primary removal processes for HPAHs, and volatilization and biodegradation are the major removal processes for LPAHs (Readman et al. 1982). Baker et al. (1991) found that several PAHs were significantly recycled in the water column of Lake Superior. Fluorene and phenanthrene were rapidly removed from surface waters and settled through the water column to the sediment-water interface, where a large fraction of the recently settled contaminants were released back into the water column. HPAHs were found to have lower settling fluxes, but these compounds were efficiently buried in the surficial sediments with little recycling. Settling particles were found to be greatly enriched in hydrophobic organic chemicals. The Koc of a chemical is an indication of its potential to bind to organic carbon in soil and sediment. The LPAHs have Koc values in the range of 10^3 to 10^4, which indicates a moderate potential to be adsorbed to organic carbon in the soil and sediments. HPAHs have Koc values in the range of 10^5 to 10^6, which indicates stronger tendencies to adsorb to organic carbon (Southworth 1979). Sorption of PAHs to soil and sediments increases with increasing organic carbon content and with increasing surface area of the sorbent particles. Karickhoff et al. (1979) reported adsorption coefficients for sorption of pyrene to sediments as follows:

- Sand: 9.4 to 68
- Silt: 1,500 to 3,600
- Clay: 1,400 to 3,800

PAHs may volatilize from soil. Volatilization of acenaphthene, acenaphthylene, anthracene, fluorene, and phenanthrene (LPAHs) from soil may be substantial (Coover and Sims 1987; Southworth 1979; Wild and Jones 1993). However, of the 14 PAHs studied in two soils, volatilization was found to account for about 20% of the loss of 1-methylnaphthalene and 30% of the loss of naphthalene. Volatilization was not an important loss mechanism for anthracene, phenanthrene, fluoranthene, pyrene, chrysene, benz(a)anthracene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, benzo(a)pyrene, and indeno(1,2,3-c,d)pyrene (Park et al. 1990).

PAHs have been detected in groundwater as a result of migration directly from contaminated surface waters or through the soil (Ehrlich et al. 1982; Wilson et al. 1986). PAHs have been shown to be transported laterally within contaminated aquifers (Ehrlich et al. 1982).

PAHs can be accumulated in aquatic organisms from water, sediments, and food. In fish and crustaceans, BCFs have generally been reported in the range of 10 to 10,000 (Eisler 1987a). In general, bioconcentration was greater for the HPAHs than for the LPAHs. The ability of fish to metabolize PAHs may explain why benzo(a)pyrene frequently is not detected or is found only at very low levels in fish from environments heavily contaminated with PAHs (Varanasi and Gmur 1980, 1981). Some mollusks and other aquatic invertebrates are unable to metabolize PAHs efficiently (Varanasi et al. 1985). Varanasi et al. (1985) ranked the extent of benzo(a)pyrene metabolism by aquatic organisms as follows: fish > shrimp > amphipod crustaceans > clams. Biomagnification, the systematic increase in tissue concentrations moving up a food chain, has not been reported because of the tendency of many aquatic organisms to eliminate these compounds rapidly (Eisler 1987a). Sediment-associated PAHs can be accumulated by bottom-dwelling invertebrates and fish (Eisler 1987a). For example, Great Lakes sediments containing elevated levels of PAHs were reported to be the source of the body burdens of the compounds in bottom-dwelling invertebrates (Eadie et al. 1983). Varanasi et al. (1985) found that benzo(a)pyrene was accumulated in fish, amphipod crustaceans, shrimp, and clams when estuarine sediment was the source of the compound. Approximate tissue to sediment ratios were 0.6 to 1.2 for amphipods, 0.1 for clams, and 0.05 for fish and shrimp. A food web model, including bio accumulation of PAHs, was completed during the ecological risk assessment and is presented in **Section 7.5** and **Appendix M**.

5.3.4 Polychlorinated Biphenyls

PCBs were produced from the chlorination of the aromatic compound biphenyl; these are referred to collectively as a PCB congener. The mixture of chlorinated aromatic

organic compounds containing the biphenyl structure has the general formula $C_{12}H_{10-n}Cl_n$, where n ranges from 1 to 10 chlorine atoms. PCBs were sold in the United States under the trade name Aroclor. Each commercial Aroclor is a mixture of PCB congeners that make up the percentage of chlorine desired for the product.

The relevant physical and chemical parameters for PCBs that affect fate and transport include water solubility, V_P, Henry's law constant, K_{OC}, and K_{OW}. **Table 5-7** presents these characteristics for each of the Aroclors of interest.

The chemical mobility of a compound refers to its tendency to be transported among environmental media (water, sediment, air, and biota) through sorption, solubilization, volatilization, and bioaccumulation, resulting in widespread distribution away from the original site of deposition. Rather than being transformed, persistent compounds are merely redistributed among environmental media. PCBs, for example, are known to be highly persistent in the environment, but under appropriate conditions, they could be transformed by various biogeochemical processes.

The properties for each Aroclor depend on PCB congeners in the commercial mixture. Each Aroclor has unique properties, toxicities, and potential for transformation. Higher K_{OC} and K_{OW} values mean stronger sorption to organic matter in the sediment and an increased tendency for fat solubility, as well as an increased tendency for the organic compounds such as PCBs to bioaccumulate and biomagnify. **Table 5-7** shows that PCBs are relatively insoluble in water. Generally, Aroclor mixtures with a lower weight percentage of chlorine (e.g., Aroclor 1221) will have higher water solubility than an Aroclor with a higher percentage of chlorine (e.g., Aroclor 1260). The K_{OW} values vary with chlorination level, as indicated by the data in **Table 5-7**. For example, the log K_{OW} for Aroclor 1221 is 4.7, and the log K_{OW} for Aroclor 1260 is 6.8. This means that the lower chlorinated PCB mixtures are more likely to dissolve in water than the greater chlorinated PCB mixtures. Alternatively, higher chlorinated PCBs have a higher tendency to sorb to sediment particles or be taken up by biota.

PCBs were most likely discharged to the Study Area as stormwater or effluent discharge. After deposition, these mixtures were "weathered" by biodegradation, dissolution, evaporation/volatilization, and other environmental processes. The PCB mixtures found in the sediment samples are dominated by the higher chlorinated PCBs (i.e., Aroclor 1254). Aroclor 1254 has a log K_{ow} value of 6.5; higher K_{ow} values are more persistent, less soluble, and less environmentally mobile, because they sorb strongly to sediment and any organic particulate or colloidal matter in the water column or sediments. These Aroclors can bioaccumulate in aquatic organisms as the result of combined uptake through food, incidental sediment ingestion, and absorption from the water. Greater bioaccumulation of Aroclors will occur in the fatty tissues (lipids) than in the muscle or whole body of aquatic organisms. Therefore, organisms with higher lipid concentrations will generally have greater concentrations of Aroclors in their tissue. This pathway is discussed in the CSM (**Figures 5-1** and **5-2**) and considered in the BERA discussions of Section 7. PCBs

were not, however, detected above SQLs in whole body fish or soft tissues of clams. PCBs were detected in some sediment samples, but except for RFP and FTA discrete samples, detected concentrations remained below ODEQ-recommended SLVs, including those for bioaccumulation. Food web modeling was therefore not performed for PCBs. PCBs were found to be elevated above SLVs for the RFP and FTA discrete sediment samples collected offshore. Risks associated with PCBs in these discrete sediment samples (RFP and FTA offshore locations) are described in the BERA **Sections 7.4.1.5 and 7.5.2**.

5.3.5 Pesticides

Historically, DDT was used extensively throughout the United States for insect control between 1940 and 1973 (United States Department of Health and Human Services [USDHHS] 1992). It has been estimated that more than 2 billion kg of DDT was used before domestic use of DDT was banned in 1973. Because global use has continued, production of DDT continued in the United States long after domestic applications ceased. Measurable amounts of DDT and its metabolites are still found in the air, water, sediment, and soil in and around the United States Direct and indirect releases from these and similar sites may continue to act as a source of DDT to the environment.

DDT is very persistent in soil and sediment, with a half-life estimated between 2 and 15 years. Routes of loss and degradation include runoff, volatilization, photolysis, and biodegradation (aerobic and anaerobic). These processes generally occur very slowly. DDE and DDD are the initial breakdown products of DDT in the soil environment. Both sister compounds are also highly persistent, and have chemical and physical properties similar to DDT. Because of its extremely low solubility in water, DDT is retained to a greater degree by soil and sediment with higher proportions of organic matter. Highly organic soils treated with DDT tend to retain the pesticide and its byproducts in the surface layers. As with many other chlorinated organic chemicals, DDT sorbs tightly to organic matter. Because of the compound's persistence, wind and water erosion have made the compound virtually ubiquitous in the environment.

Over very long periods, DDT can eventually leach into groundwater, especially in soils low in organic matter. Residues in surface soils are much more likely to be broken down, or otherwise dissipated, than in subsurface deposits. Studies in Arizona have shown that volatilization losses may be relatively fast (50% in 5 months) in soils with very low organic matter content (desert soils) and high irradiance of sunlight. In other soils (e.g., Hood River and Medford, Oregon), this rate may be as low as 17% to 18% over 5 years. In summary, volatilization loss depends on the amount of DDT applied, proportion of soil organic matter, proximity to soil-air interface, and amount of sunlight. Available data from throughout the United States indicate that concentrations in the 1970s averaged from 0.02 to 0.18 ppm (USDHHS 1993).

DDT reaches surface waters primarily by runoff, atmospheric transport, drift, or direct application (e.g., to control mosquito-borne malaria). The reported half-life for DDT in the water environment ranges from a few days for fast-moving environments (where the compound is at or near the surface of the water) to more than 150 years (Spectrum Laboratories 1998). The main degradation and loss pathways in the aquatic environment are volatilization, photodegradation, adsorption to water-borne particulates (including sedimentation), and uptake by aquatic organisms, which store DDT and DDT metabolites in their tissues. A food web model, which includes the uptake and biomagnification of DDT, was completed during the ecological risk assessment and is presented in **Section 7.5** and **Appendix M**. Information from data collected between 1980 and 1983 indicated that DDT was widely detected in ambient surface water samples in the U.S. at a median level of 1 nanogram per liter (ng/L) (part per trillion) (USDHHS 1993).

Volatilization of DDT from soil surfaces and water is known to occur (USDHHS 1993). Once in the atmosphere, DDT will eventually photo-oxidize to carbon dioxide and hydroxyl radicals, with an estimated half-life of approximately 2 days for the latter. However, the presence of DDT in samples far from known sources indicates that DDT photodegradation is slower than estimated (USDHHS 1993). Both wet and dry deposition are significant mechanisms of removal from the air column. Measured atmospheric concentrations of DDT and its metabolites have shown a steady decrease since cancellation of domestic use and restrictions in other countries.

5.3.6 Dioxins and Furans

Chlorinated dioxins (CDDs) are a family of compounds that includes some extremely toxic and potent congeners. The two most toxic of the CDDs in mammals are 2,3,7,8-TCDD and 1,2,3,7,8-PeCDD (Buser 1987; Poland and Knutson 1982; Safe 1986; World Health Organization [WHO] 1998). In general, the more toxic congeners to mammals appear to be the 2,3,7,8-substituted tetra-, penta-, and hexachloro- compounds, (e.g., 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, and 1,2,3,7,8,9-HxCDD) (Poland and Knutson 1982; Safe 1986; WHO 1998).

CDDs usually occur in the environment concurrently with other chemicals such as chlorinated dibenzofurans (CDFs) (ATSDR 1998). CDDs and CDFs are highly persistent compounds and have been detected in air, water, soil, sediments, animals, and foods. CDFs include 135 congeners, which are structurally similar to CDDs and which elicit a number of similar toxicological and biochemical responses in animals. CDDs and CDFs are released to the environment during combustion processes (e.g., municipal solid waste, medical waste, and industrial hazardous waste incineration, and fossil fuel and wood combustion); during the production, use, and disposal of certain chemicals (e.g., PCBs, chlorinated benzenes, chlorinated pesticides); during the production of bleached pulp by pulp and paper mills; and during the production and recycling of several metals (Buser et al. 1985; Czuczwa and Hites 1986a, 1986b; Oehme et al. 1987, 1989; Zook and Rappe 1994). The EPA has developed procedures for estimating risks associated with exposures to mixtures of CDDs and CDFs in environmental matrices (EPA 1989b). This approach is based on the assignment of

2,3,7,8-TCDD toxic equivalence factors (TEFs) to CDD/CDF congeners or homologues in complex mixtures (ATSDR 1998).

CDDs and CDFs are ubiquitous in the environment and are found at low background levels (parts per trillion or parts per quadrillion) in the air, water, and soil. Lower levels are found in biological and environmental samples from less industrialized rural regions than in those from more industrialized urban regions (Czuczwa and Hites 1986a; Des Rosiers 1987; Edgerton et al. 1989; Tiernan et al. 1989). HpCDD and OCDD are the most common CDDs found in environmental samples (Christmann et al. 1989b; Clement et al. 1985, 1989; Pereira et al. 1985; Reed et al. 1990; Tashiro et al. 1989a; Tiernan et al. 1989).

The environmental fate and transport of CDDs involve volatilization, long-range transport, wet, and dry deposition, photolysis, bioaccumulation, and biodegradation (Kieatiwong et al. 1990). CDDs strongly partition to soils and sediments. Because of their low vapor pressure, low aqueous solubility, and strong sorption to particulates, CDDs are generally immobile in soils and sediments. Although most biological and nonbiological transformation processes are slow, photolysis has been shown to be relatively rapid. Photolysis is probably the most important transformation process in environmental systems into which sunlight can penetrate (Kieatiwong et al. 1990). Estimates of the half-life of 2,3,7,8-TCDD on the soil surface range from 9 to 15 years, whereas the half-life in subsurface soil may range from 25 to 100 years (Paustenbach et al. 1992). CDDs have been shown to bioaccumulate in both aquatic and terrestrial biota. CDDs have a high affinity for lipids and, thus, will bioaccumulate largely in organisms with a high fat content.

Fate and transport data for dioxins and furans indicate that these compounds are extremely immobile (see **Table 5-8**). For example, the median organic carbon partition coefficient for 2,3,7,8-TCDD is 2,750,000. In other words, the compound concentration is about 2.8 million times lower in water than in organic carbon (natural organic carbon in the soil). Given that only a small fraction of most soils consist of organic carbon, perhaps 1% (fraction = 0.01), the water would still have 2,3,7,8-TCDD concentrations 27,500 times less than in the soil (2,750,000 × 0.01 = 27,500). Therefore, transport of these compounds via porous media flow (dissolved in water) or within a river is likely to be insignificant.

Another mode of transport that is possible is "facilitated transport." The process involves the transport of colloids of clay, iron oxide, or organic matter (containing dioxins or furans or both) within the water. Although this process is possible, it has rarely been documented in the literature, and requires specific field conditions to occur.

5.3.7 Inorganic Constituents

This section includes a brief summary of the fate and transport processes of the inorganic chemicals that are detected chemicals for the study area. For reference,

Table 5-2 lists the soil/water distribution coefficients (K_d) for several important inorganic species.

5.3.7.1 Iron

Although iron is not typically a contaminant, its fate and transport can strongly influence other metals and inorganics because of coprecipitation. The oxidation state of iron is an important parameter for predicting the precipitation of iron oxyhydroxide and the fate and transport of many metals. The formation of iron oxyhydroxide occurs by oxidation of iron (II) to iron (III) (usually by oxygen) followed by a precipitation or coprecipitation reaction as follows:

$$Fe^{2+} + \frac{1}{2} O_2 + 2H^+ = Fe^{3+} + H_2O$$

$$Fe^{3+} (aq) + 2H_2O = FeOOH (solid) + H^+ (precipitation)$$

or

$$(1-x)Fe^{3+} (aq) + xCr^{3+} (aq) + 2H_2O = Fe_{1-x}Cr_xOOH (solid) + H^+ (aq) (coprecipitation)$$

5.3.7.2 Arsenic

Arsenic is naturally occurring in local soils and bedrock and is associated with iron in oxide and sulfide minerals. Previous work (Stein et al. 2004) indicates that groundwater oxidation-reduction potential (ORP) exerts considerable control on arsenic mobility, primarily through three mechanisms:

- Precipitation of hydrous ferric oxides (HFO) and sorption of arsenic
- Reductive dissolution of HFO and arsenic release
- Formation of iron or arsenic sulfide phases

The stoichiometric equation in **Section 5.3.7.1** is for substitution of chromium into iron oxyhydroxide; however, many other metal substitutions can occur simultaneously. The arsenate ion (AsO_4^{3-}) can substitute for hydroxide in the liquid phase, particularly when arsenic concentrations are high and the pH is low (Whiting 1992). Arsenic forms organic compounds, mostly through metabolism. For example, arsenic is often found in organic form in fish tissue.

5.3.7.3 Manganese

Manganese, like iron, is mobile in the reduced phase (Mn^{2+}) and relatively immobile in the more oxidized phase (Mn^{4+}). The relevant reaction, which involves both oxidation of manganese and precipitation of manganese dioxide, is as follows:

$$Mn^{2+} + O_2 = MnO_2 (solid)$$

Manganese can coprecipitate other metals such as copper and cobalt as follows:

$$(1-x)Mn^{2+} + xCu^{2+} + 2O_2 = Mn_{1-x}Cu_xO_2 \text{ (solid)}$$

5.3.7.4 Mercury

Mercury exists as mercury(I), mercury(II), and metallic mercury. Metallic mercury is much less soluble than the oxidized versions, which are strongly complexed by organics and chloride present in saline groundwater and estuaries. Mercury can be metabolized to methyl mercury in aquatic systems.

Salinity can result in the removal of neutral metals species via salting out (i.e., $HgCl_2^0$, Turner et al. 2001) or in ionic strength effects for metal ions. Increases in salinity result in an increase in ionic strength, which reduces the activity of the species in solution. The result is increased solubilities and decreased K_d values compared to the values obtained for fresh water. Turner et al. (2001) performed modeling to show that formation of $HgCl_4^{2-}$ would decrease the mercury K_d. Depending on the speciation, either decreased mobility (via salting out of the neutral species) or increased mobility (due to ionic strength effects on mercury ions) can result from an increase in salinity. Similar trends would occur for other metals.

5.3.7.5 Lead

The AVGAS most likely used at Tongue Point NAS was 100 octane and contained a maximum of 4 grams of TEL per US gallon (or 1.1 g/l). In June 1944, the military fuel specification AN-F-33 was published for 145 Octane with 4.6 ml/gal of TEL and marked the peak in avgas development (Kerley 1993). One gram of TEL contains 600 milligrams of inorganic lead. TEL is a hydrophobic compound and tends to partition into hydrocarbons when present. In the absence of light, TEL within hydrocarbons is very stable (Mulroy and Ou 1998). In the absence of hydrocarbons, TEL in soil biodegrades to inorganic lead within 14 days (Mulroy and Ou 1998). Inorganic lead has low mobility in the soil environment because of the formation of lead carbonates and phosphates and the adsorption of lead onto soil organic matter, clay minerals, and other soil particles (Electric Power Research Institute [EPRI] 1984).

5.3.7.6 Selenium

Selenium has been extensively studied in aquatic systems since the mid-1980s, when observed toxic impacts to birds nesting at the Kesterson Reservoir (Merced County, California) were first associated with elevated selenium concentrations. Several reviews and assessments of selenium have been published, including those by Hamilton (2004), Ohlendorf (2003), the ATSDR (2003), Luoma and Presser (2000), Eisler (2000), Frankenberger and Engberg (1998), DOI (1998), and Frankenberger and Benson (1994). In addition to these recent reports, Lemly and Smith (1987) describe in detail selenium cycling in aquatic systems. A brief summary of the salient features of general selenium biogeochemistry follows.

Selenium is a naturally occurring element found in rocks and soils. It occurs in several forms, including multiple oxidation states, which vary depending on ambient conditions (such as pH, Eh [ORP], and microbial activity) as well as the environmental medium (such as water, sediment, or biological tissue). Biologically

significant oxidation states include selenide (Se^{2-}), elemental selenium (Se^{0}), selenite (Se^{4+}), and selenate (Se^{6+}).

The behavior of selenium in the environment is largely influenced by its oxidation state as well as physical factors such as geology, climate, and hydrology. Selenium is often more abundant in environmental media in areas with Upper Cretaceous marine sedimentary rocks and other formations naturally high in selenium (DOI 1998). Climate also affects selenium distribution, because it behaves differently in arid climates than in humid or wet climates. In areas that have a local geologic source of selenium, concentrations and the potential for toxic effects generally increase as aridity increases. Hydrology can increase selenium contamination by acting as a transporting agent, and certain receiving water bodies may become sinks for the mobilized selenium. Selenium is transported via rivers, streams, creeks, groundwater, and irrigation drainage water. These physical factors influence the fate and transport of selenium in various environmental media.

As outlined by Lemly and Smith (1987), dissolved selenium entering an aquatic system can (1) be absorbed or ingested by organisms, (2) bind or complex with particulate matter, or (3) remain free in solution. Although most selenium is either taken up by organisms or bound to particulate matter over time, selenium does not remain constant in the system. Instead, biological, chemical, and physical processes move selenium through the system such that selenium stored in sediments can be cycled back into the biota and remain at elevated concentrations even when inputs of dissolved selenium are reduced or stopped. The processes involved in the immobilization and mobilization of selenium in aquatic ecosystems are detailed in Lemly and Smith (1987).

Briefly, waterborne selenium (selenite, selenate, and organic selenium) is sequestered into sediment through chemical and microbial reduction, followed by adsorption to clay and organic carbon and coprecipitation or settling. Additionally, selenium in animal and plant tissues is deposited as detritus and is consolidated over time through the process of sedimentation. Within the sediment, further chemical and microbial reduction of sequestered selenium results in insoluble organic, mineral, elemental, or adsorbed selenium.

However, as previously indicated, selenium is usually not permanently sequestered in sediment. Selenium is mobilized from sediment through oxidation and methylation processes and through direct uptake by plants and bottom-dwelling organisms. The operative processes include oxidation and methylation of inorganic and organic selenium by roots and microorganisms, and oxidation of sediments by plant photosynthesis. Additionally, burrowing of benthic invertebrates and foraging of fish and wildlife result in the biological mixing and oxidation of sediments. Water circulation and mixing (from physical perturbations such as currents, wind, stratification, precipitation, and upwelling) and associated oxidation serve to mobilize selenium. However, it is the uptake of selenium by rooted plants and by terrestrial and aquatic fauna that contribute most to the mobilization of selenium.

5.4 Conceptual Site Model Summary

Based on the fate and transport processes discussed, two conceptual site models were developed for the study area. **Figure 5-1** depicts the conceptual site model for the northern portion of the Study Area. This area includes the following DUs: AST Fuel Storage Area, UST Site No. 1, Refueling Pit 3, UST Site No. 4, and the Incinerator Building. This figure includes the aquatic areas down gradient of these DUs. **Figure 5-2** depicts the conceptual site model for the southern portion of the Study Area, which includes the Fire Training Area DU, the Aquatic - Near Landfill DU, and the southern portion of the Aquatic - Finger Piers DU. For the purposes of discussion, this section is divided into the terrestrial and the aquatic environment.

5.4.1 Terrestrial Locations

This section discusses the transport pathways in the following terrestrial DUs: AST Fuel Storage Area, UST Site No. 1, Refueling Pit 3, UST Site No. 4, Fire Training Area, and the Incinerator Building.

5.4.1.1 Petroleum Hydrocarbons

The maximum TPH results for soil and groundwater for the fuel-impacted areas are summarized in **Tables 5-9** and **5-10**, respectively. The type of hydrocarbon present is a function of both the source material (type of fuel) and the degree of weathering. The lighter hydrocarbons (gas range) have a greater tendency to partition into the groundwater than the heavier hydrocarbons. Therefore, the light end of the diesel range TPH, which overlaps with the gasoline range TPH, is leached into the groundwater preferentially to the heavy end. In general, it appears as though the hydrocarbons present were largely derived from the diesel fuel releases. The high motor oil TPH concentration in the AST Fuel Storage Area DU may reflect the use of oil to prevent corrosion of the tank foundations, as discussed in **Section 1**.

BTEX concentrations within the fuel-impacted areas were low in both soil and groundwater. AVGAS typically contained very high concentrations of toluene (5% to 18%), and diesel generally contained relatively low concentrations of BTEX. The low BTEX concentrations in the fuel-impacted areas represent either the lack of an AVGAS signature or removal via significant biodegradation or volatilization to soil gas. The maximum soil gas concentration for BTEX was a toluene value of 1,500 $\mu g/m^3$ for sample RFP3-17 (Refueling Pit 3 Area). Using the Henry's law constant, provided in **Table 5-11,** results in a corresponding groundwater concentration of 0.39 µg/L, which is below the SQL of 0.50 µg/L for toluene. Therefore, the low BTEX concentrations are likely due to the low concentrations of these compounds within diesel fuel or the long period of time since AVGAS was last used at the site (not since 1950) combined with the relatively fast biodegradation rate of the BTEX compounds.

EDB was not above the analytical detection limit for any of the soil or groundwater samples analyzed. Given the relatively rapid biodegradation of EDB (see **Section 5.3.1**) and the fact that AVGAS has not been used or stored at the site in nearly 60 years, the absence of detectable levels of EDB is expected.

5.4.1.2 Polycyclic Aromatic Hydrocarbons

The most significant PAHs within the soil of the fuel-impacted areas were phenanthrene, fluorene, acenaphthene, and, in the former AST Fuel Storage Area, benzo(a)pyrene, all of which were detected at concentrations up to several thousand micrograms per kilogram. The concentrations of these compounds in groundwater are much lower (see **Table 5-12**) or are below the reporting limit. The low groundwater concentrations reflect the low mobility of the PAHs. Wells MW-06 and MW-08 in the UST Site No. 1 contained free product or a visible sheen, which is reflected in the higher PAH concentrations in groundwater. The persistence of the PAHs is due to the anoxic (or low oxygen) conditions within the subsurface, which has resulted in low rates of biodegradation.

5.4.1.3 Lead

A summary of the lead values for the fuel-impacted areas is shown in **Table 5-13**. The lead is present predominantly in the soil or associated with the particulate fraction of the groundwater, which is consistent with the low mobility of lead discussed previously. The soil lead was most likely originally TEL, which has degraded to the inorganic form over the past 60 years or in some cases may exist as TEL within residual product.

5.4.1.4 Vinyl Chloride

Vinyl chloride was found in the groundwater in the Fire Training Area at concentrations ranging from <0.50 to 27 µg/L during the 2008 RI sampling event. None of the soil results had vinyl chloride concentrations above the sample quantitation limit. The vinyl chloride detected in the groundwater was most likely derived from the use of waste oil used in fire training activities; two waste oil tanks were located within the Fire Training Area. Chlorinated solvents such as PCE and TCE were used as degreasing agents and were commonly found within waste oil.

As described in **Section 5.2.2.5**, PCE and TCE are susceptible to reductive dechlorination under reducing geochemical conditions. The geochemical conditions in groundwater at the FTA are generally sulfate-reducing to methanogenic (methane-producing), as indicated by depressed sulfate concentrations, elevated iron, and the presence of dissolved methane in FTA-04, FTA-09 and MW-18D groundwater. These geochemical conditions in the Fire Training Area DU are conducive to reductive dechlorination of chlorinated solvents. However, the presence of vinyl chloride indicates that while reductive dechlorination has occurred, the rate and extent was not sufficient to remove all of the chlorinated solvents present at the site. During reductive dechlorination, the reducing step from vinyl chloride to ethene/ethane can be the slowest, or rate limiting step, and if sufficient electron donor is not present to drive the process to completion, vinyl chloride can be transported further from the initial source area.

In evaluating the 2008 FTA groundwater samples, it appears that reductive dechlorination has occurred along the northern and northeastern portions of the Fire

Training Area DU. It is likely that co-released petroleum compounds served as electron donors to drive the initial stages of reductive dechlorination. This would have resulted in biodegradation of the parent compounds PCE and TCE in groundwater, production of some cis-DCE and vinyl chloride, and biodegradation of the petroleum compounds. **Figure 5-3A** shows the distribution of total chlorinated ethenes in 1995 and 1996. The map of Figure 5-3A uses two sets of contours to depict the lateral distribution of total chlorinated ethenes. The greenish color represents the distribution based upon the 41 direct push locations (HGW) sampled once in September 1995, and the purple color is based upon wells sampled in August 1996 **Figure 5-3A** shows that daughter products from chlorinated ethene reductive dechlorination (represented by total chlorinate ethenes) have laterally migrated from the source area (MW-18D) southwest towards (MW-22). In November 1995, the source of the chlorinated ethenes was located near MW-18D, with a total chlorinated ethenes concentration of 70.3 µg/L and a vinyl chloride concentration of 67 µg/L. This maximum vinyl chloride concentration indicates that the degradation was more advanced at the source than at locations further away from the source. In particular, 61.7 µg/L of total chlorinated ethenes was measured at well MW-22 (August 1996). At this location, cis-DCE was the predominant detected compound, with a concentration of 42 µg/L (see **Table 4-22** of *Limited Remedial Investigation Phase II Landfill Site, Former Tongue Point Naval Air Station, Astoria, Oregon [*URS Greiner Woodward Clyde. 1999a]). The detected cis-DCE concentration in August 1996 represents chlorinated ethenes that are undergoing biodegradation to vinyl chloride. However, MW-22 was not sampled again because it was rendered inaccessible in 2001 by the dredge spoils stockpile.

Figure 5-3B shows the 2008 distribution of chlorinated ethenes. Overall chlorinated ethenes concentrations have declined in the northeastern and southwestern portions of the Fire Training Area DU from 1996 to 2008, most notably the reduction in vinyl chloride concentration from the historically high concentrations in MW-18D (67 µg/L in November 1995) to non-detect during this RI sampling event. Some of the vinyl chloride may have biodegraded to ethene and then ethane; ethane concentrations ranged from 0.76 to 32 µg/L. Also, the highest cis-DCE concentration in 2008 was only 4.3 µg/L at FTA-14 (see **Table 4-7c**), which is an order of magnitude less than the maximum concentration of cis-DCE is MW-22. These data suggest that additional reductive dechlorination occurred from 1995/1996 to 2008, such that vinyl chloride is the predominant daughter product based on 2008 data.

Although the 2008 sampling points had limited distribution because of restricted access, the northern edge of the DU was the most accessible. As noted on **Figure 4-11 and Figure 5-4**, low concentrations of vinyl chloride remain along the northern portion of the Fire Training Area DU, specifically at FTA-01 (13 µg/L), FTA-02 (27 µg/L) and FTA-04 (25 µg/L). Although geochemical conditions at the site are reducing, it appears as though reductive dechlorination has stalled in these areas, possibly from a lack of electron donors. The presumed electron donor in the area is petroleum hydrocarbons, which is consumed quickly over time. In addition, the predominant component of chlorinated ethenes at the locations is vinyl chloride,

which is slow to degrade under anaerobic conditions. The 2008 vinyl chloride distribution appears to have more of northerly and westerly component compared to the 1995/1996 data, with the westernmost well having a vinyl chloride concentration of 25 µg/L (FTA-04).

However, it is important to note that different depths were sampled in the HGW locations compared to the wells and the 2008 FTA locations. This is illustrated by the cross section in **Figure 5-4**. In September 1995, the HGW sample locations were used for screening purposes and were sampled from 13 to 15 feet bgs. Therefore, the HGW locations show the horizontal extent of chlorinated ethenes, but do not delimit the vertical extent. As documented in the Landfill LRI, Table 3-3 shows a downward vertical gradient of 0.081 feet/foot in the well pair MW-18S/MW-18D (URS Grenier Woodward Clyde 1999a). Therefore, the light green contours from 1995 HGW locations provide data for the upper or shallowest portion of the chlorinated ethenes plume. As shown in **Figure 5-4**, the two highest vinyl chloride concentrations measured in 2008 were from samples collected a few feet deeper than the 1995/1996 data. Therefore, it is possible that the 1995/1996 samples were not deep enough to measure these slightly higher concentrations. In addition, vinyl chloride was detected at HGW-02 at 14 µg/L in 1995, which suggests that migration of daughter products toward the west was occurring and the concentrations from HGW locations were likely biased low because of the shallower depth. Another contributing factor to the distribution is the degradation of cis-DCE to the south and west, as documented in well MW-22 in 1996. This migration may be controlled by subsurface lithology, as the Astoria Formation/alluvium contact becomes shallower on the western portion of the Fire Training Area DU (see **Figure 5-4**).

Overall, the 2008 sampling did indicate that concentrations of cis-DCE and vinyl chloride were significantly lower compared to the 1995/1996 data, particularly in the source area. However, the 2008 RI sampling did not completely delineate the northern and northwestern boundary of the vinyl chloride plume. The fact that FTA-04 still has vinyl chloride at 27 µg/L suggests that lower concentrations may extend further in those directions. Still, the vinyl chloride present along the northern and northwestern portions of the Fire Training Area DU can be attributed to incomplete reductive dechlorination of parent compounds released in the source area. The range of vinyl chloride concentrations present in the 2008 data would be expected based on the levels of cis-DCE that were present historically (e.g. complete conversion of 42 µg/L cis-DCE yields 27 µg/L vinyl chloride). The process has slowed owing to the anaerobic conditions along the northern margins of the Fire Training Area DU due to pavement cap that limits the infiltration of precipitation. The occurrence of vinyl chloride may be unbounded at concentrations of 27 µg/L, but based upon historic information the degradation from DCE to vinyl chloride indicates that residual vinyl chloride concentrations would be expected to be at this concentration (20-27 µg/L) based upon the maximum DCE concentration (as measured in August 1996) in MW-22 (42 µg/L). Therefore, an additional source area is not suspected to be present in the northwest portion of the Fire Training Are DU.

In terms of the vadose zone, the presence of oxygen significantly inhibits PCE attenuation, whereas, the reductive daughter products vinyl chloride and ethene/ethane are readily degraded aerobically. Therefore, PCE tends to accumulate in the vadose zone and is generally transported the furthest away from the source area. This can be seen in the soil gas sample collected from borings FTA-02G and FTA-04G. Generally, anaerobic reductive dechlorination of chlorinated solvents does not occur in the vadose zone, so unless a source of cis-DCE, trans-DCE and vinyl chloride exists in the vadose zone, it is more likely that these compounds are present due to volatilization from a groundwater plume. As for the source of PCE in the vadose zone, there are three possible scenarios: 1) a source may be present in the vadose zone; 2) a source may be present in groundwater and contaminants are subsequently volatilizing to the vadose zone; or 3) a combination of both, i.e. a source is at the water table interface and is discharging to both the vadose zone and to groundwater. In any case, it is apparent that any PCE dissolved into groundwater has been rapidly attenuated in the anaerobic groundwater. Conversely, PCE accumulates and is transported in soil gas because it is relatively recalcitrant to biological degradation mechanisms in the vadose zone.

5.4.1.5 Pesticides

The pesticide breakdown product 4,4-DDE was detected in near-shore sediment off shore of the Fire Training Area and within sediments in the aquatic DUs. Soil concentrations of total DDT in soil were not reported above the SQL in soils collected from the Fire Training Area. Total DDT concentrations in sediments from the aquatic DUs were of the same order of magnitude as the sediment sample from the aquatic reference area. Based on the results of DDT in samples from the Fire Training Area, the source of the total DDT in sediment is most likely not from the Study Area. Because the concentrations are similar to those in the reference sample, the detected concentrations in sediment most likely represent ubiquitous concentrations found in the Columbia River.

5.4.1.6 Dioxins/Furans

The concentration of 2,3,7,8-TCDD TEQ concentrations of sediment collected from the Near Landfill DU ranged from 5.3E-8 to 1.8E-6mg/kg (See **Table 4-10b**). These concentrations are significantly lower than historical levels before the landfill remedial action (URS Greiner Woodward-Clyde 1999a; 1999b). Similar concentrations of TCDD TEQ were found in sediments from the aquatic reference area (9.6E-7 mg/kg), indicating that concentrations of dioxins/furans currently present in surface sediments off shore of the landfill reflect regional background levels and are not related to a historical release from the landfill. Concentrations of 2,3,7,8 TCDD TEQ in soil collected from the Fire Training Area ranged from 2.8×10^{-7} to 1.5×10^{-6} mg/kg.

5.4.2 Aquatic Locations

This section discusses the transport pathways in the following aquatic DUs: North of Pier 8, Finger Piers Area, and Near Landfill. This section includes the aquatic areas

immediately downgradient of UST Site No. 1, Refueling Pit 3, and Fire Training Area in Cathlamet Bay.

5.4.2.1 Petroleum Hydrocarbons

The TPH-D and TPH-O concentrations for the aquatic areas are generally higher than for the reference area, indicating some influence from the site. The source of the TPH was most likely the diesel fuel and possibly the historical AVGAS releases. The low concentrations of TPH-G are most likely due to the lower tendency for these compounds to adsorb to the sediments, combined with the higher biodegradation rates relative to the heavier hydrocarbons. A summary of the TPH results for the sediment of each aquatic DU is shown in **Table 5-14**.

The results are similar to the terrestrial DU TPH data, in which the concentrations for the aquatic DU were higher than for the reference area. PAHs tend to partition from the water column into sediment where they become buried and removed from the system unless disturbed by dredging. A summary of the results for a select suite of PAHs is shown in **Table 5-15**.

The only BTEX compound detected was a single detection of 0.89 µg/kg m,p-xylenes in sample MIS-53 in the Finger Piers DU. Toluene and benzene were not analyzed for -in the sediments. In addition, EDB was not measured in the aquatic sediments and is not discussed.

5.4.2.2 Inorganic Constituents

In most cases, the ranges of metals concentrations were slightly higher for the areas adjacent to the Study Area compared to the reference area. Lead concentrations are significantly higher within the areas adjacent to the site as opposed to the reference location, most likely because of historic releases of lead-bearing AVGAS from the AST Fuel Storage Area. The metals were probably removed from solution by coprecipitation with iron oxyhydroxides, as discussed previously; however, this could not be confirmed because iron concentrations were not measured within the sediment. A summary of the metals concentrations within the sediment of the aquatic DUs is shown in **Table 5-16**.

5.5 Summary of Fate and Transport

This section gives summaries of the fate and transport of chemicals within the Study Area. The following discussion is divided into terrestrial and aquatic environments.

5.5.1 Terrestrial Locations

The most important fate and transport mechanisms for the terrestrial areas are adsorption and biodegradation, with some volatilization playing a role for the light hydrocarbons (VOCs, including BTEX). AVGAS and diesel components that are resistant to (or not subject to) biodegradation and which tend to partition onto the soil are the components that have remained at the site, including PAHs, dioxins/furans, lead, TPH-D, and TPH-O. Other components that are more mobile or biodegradable,

or both are not as prevalent in the soil or are not detectable in the system. These compounds include VOCs such as BTEX, EDB, and TPH-G. In areas where free product remains (UST Site No. 1 and Fire Training Area), aqueous concentrations of diesel-related components tend to be higher within the groundwater because of partitioning from the product. The free product maintains anaerobic conditions, which tends to limit biodegradation of the hydrocarbons and TEL.

5.5.2 Aquatic Locations

The fate and transport within the aquatic DUs tend to be controlled by the behavior of the sediments. Estuaries tend to be areas of sediment deposition, partially because of the effect of varying salinity gradients. Salinities within the Study Area depend on tidal stage and output from Bonneville Dam (Hughes and Rattray 1980). A low-energy, depositional environment is created off shore of the Study Area when river velocities slow because the finger piers impede the local currents. Any affected surface water would be flushed out of the Study Area by input from the Columbia River or by tidal action. Active sedimentation tends to bury the impacted sediments under nonimpacted sediments, which removes them from the system unless dredging is conducted or they are otherwise disturbed. The concentrations of AVGAS and diesel fuel components and metals are higher in the buried sediments of the aquatic DUs when compared to the reference area, suggesting that some releases have occurred in the past. The reducing conditions in the buried sediments tend to preserve the PAHs and hydrocarbons there because of the lack of aerobic biodegradation.

Table 5-1
Summary of the Importance of Each Fate and Transport Process by Chemical Class
Tongue Point Multi-Sites Project, Astoria, Oregon

Transport Process	VOCs	PAHs	PCBs	Pesticides	Dioxins/ Furans	Metals/ Inorganics
Physical Transport Mechanisms						
Erosion/Deposition (Aquatic Environment)	Int.	Int.	Int.	Int.	Int.	Int.
Surface Water Transport (Aquatic Environment)	Int.	Int.	Int.	Int.	Int.	Int.
Groundwater Transport (Terrestrial Environment)	High	Low-Int.	Low	Low	Low	Int.
LNAPL Transport (Terrestrial Environment)	High	Low-Int.	Low	Low	Low	No
Chemical Transport Mechanisms						
Adsorption/ Desorption	Low - Int.[1]	High	High[1]	Int.-High[1]	High[1]	High[2]/ Usually at low pHs
Volatilization/ Condensation	High	Low	Low-Int.	Low	Low	Hg only /No
Precipitation/ Coprecipitation	Low[3]	Low[3]	Low[3]	Low[3]	High	Fe, Mn/ High
NAPL Dissolution	High	Low[3]	Low[3]	Low[3]	No	No
Abiotic Transformation	Low	Low	Low	Low	Low	Oxidation/ Reduction
Degradation/ Biotransformation	Low-High	Low-High	Low-High	Low	Low	None/Low

Notes:

1. Increased in estuaries and saline waters by "salting out" effect
2. An important exception is chromium(VI).
3. Can form non-aqueous phase liquid (NAPL) when salted out

VOCs = volatile organic compounds
PAHs = polycyclic aromatic hydrocarbons
PCBs = polychlorinated biphenyls
Inorganics = iron and manganese
LNAPL = light non-aqueous phase liquids
Int. = intermediate

Table 5-2
Partition Coefficients for Inorganic Species
Tongue Point Multi-Sites Project, Astoria, Oregon

Name	Species	Partition Coefficient (K_d) (for Silt)[1]
Arsenic(III)	H_3AsO_3	1.0-8.3
Arsenic(V)	$HAsO_4^{2-}$	1.9-18
Cadmium	Cd^{2+}	40.4
Cobalt	Co^{2+}	1339
Copper	Cu^{2+}	1.4-333
Chromium(III)	Cr^{3+}	470-150,000
Chromium(VI)	$HCrO_4^{2-}$	1 - 1800
Lead	Pb^{2+}	4.5-7640
Mercury(II)	Hg^{2+}	5012-1,000,000[2]
Nickel	Ni^{2+}	299
Selenium(IV)	Se^{4+}	1.2-8.6
Zinc	Zn^{2+}	1339

Notes:

1. Thibault *et al.* 1990, except where noted otherwise
2. Measured in estuaries (Turner *et al.* 2001)

Table 5-3
Solubility Product Constants for Selected Minerals
Tongue Point Multi-Sites Project, Astoria, Oregon

Mineral	**Formula**	**Log K_{sp}**
Iron Oxyhydroxide	FeOOH	10^{-37}
Birnessite	MnO_2	$10^{18.1}$
Pyrite	FeS_2	$10^{-18.5}$
Covellite	CuS	10^{-23}
Siderite	$FeAsO_4$	$10^{-10.6}$
Mercury(I) Hydroxide	$Hg_2(OH)_2$	$10^{5.3}$
Lead Chromate	$PbCrO_4$	$10^{-13.7}$

Notes:

K_{sp} = solubility product constant

Table 5-4
Biotransformation Half Lives of Organic Compounds and Groups
Tongue Point Multi-Sites Project, Astoria, Oregon

Compound or Group	Laboratory Half Life*	Field Determined Half Life*
Benzene (aromatic VOC)	1 week	1 to 2 months
Naphthalene (a LPAH)	1 week	1 month
Chlorinated aliphatics (VOCs and SVOCs)	1 month	1 year
Phenanthrene (a LPAH)	1 month	-
Benzofluoranthene (a HPAH)	3 months	-
Chlorinated pesticides	1 year	decades
TCDD (a dioxin)	2 years	decades

Notes:

* = Half lives were averaged from multiple sources, including ATSDR, EPA, and journals.
VOC = volatile organic compound
PAH = polynuclear aromatic hydrocarbon
SVOC = semi-volatile organic compound
TCDD = tetrachlorodibenzo-p-dioxin
ATSDR = Agency for Toxic Substances and Disease Registry
EPA = United States Environmental Protection Agency

Table 5-5
Typical Compositions of TPH Hydrocarbon Products
Tongue Point Multi-Sites Project, Astoria, Oregon

Type of Petroleum	Carbon Range	% BTEX	% Alkanes	% Cyclic Alkanes	% Aromatics	% Highly Branched Iso-Alkanes	Other
Automotive Gasoline (MOGAS)[a]	C_6-C_{10}	15 – 25 (40% for premium)	35	2	45	18	
Diesel[b]	C_9-C_{20}	<1	37.6	37.6	20.2	3.5	---
Kerosene[c]	C_6-C_{17}	13.7	68.6		17.7		
Mineral Spirits[d]	C_6-C_{11}	---	50	40	10	---	
Aviation Gasoline (AVGAS)	C_4-C_{10}	5-18 (toluene)	3-20	minor		75-92	

Notes:

[a] Custance *et al.* 1992
[b] MacKay *et al.* 1989
[c] Coleman *et al.* 1984
[d] Gosselin *et al.* 1984
% = percent
BTEX = benzene, toluene, ethylbenzene, and xylenes

Table 5-6
Physical Properties of Selected Hydrocarbons, PAHs, and Other Compounds at 25°C
Tongue Point Multi-Sites Project, Astoria, Oregon

Constituent	Formula	Molecular Weight (g/mol)	H (atm-m^3/mol)	V_P at 25°C (mm Hg)	Solubility (mg/L)	Log K_{OW}	Log K_{OC}
Alkanes							
Pentane	C_5H_{12}	72.15	1.24[f]	513[a]	38.5[e]	3.62[e]	2.2806[g]
Hexane	C_6H_{14}	86.2	1.03_e – 02[d]	151.5[e]	9.5[a]	4.11[e]	2.5893[g]
Heplane	C_7H_{16}	100.2	2.02[e]	45.8[e]	2.93[e]	4.66[e]	2.9358[g]
Octane	C_8H_{18}	114.2	3.15[e]	14.1[e]	0.66[a]	5.18[a]	3.2634[g]
Nonane	C_9H_{20}	128.3	7.08[a]	4.35[a]	0.155[a]	5.88[a]	5.67[a]
Decane	$C_{10}H_{22}$	148.28	9.04[a]	1.59[a]	0.052[a]	6.34[a]	6.13[a]
Undecane	$C_{11}H_{24}$	156.31	13.5[a]	0.56[a]	0.014[a]	6.88[a]	6.67[a]
Dodecane	$C_{12}H_{26}$	170.33	7.84[a]	0.23[a]	0.011[a]	7.42[a]	7.17[a]
Tridecane	$C_{13}H_{28}$	184.37	1.73[a]	0.0099[a]	0.012[a]	7.96[a]	7.7[a]
Tetradecane	$C_{14}H_{30}$	198.38	0.66[a]	0.0003[a]	0.013[a]	8.5[a]	8.22[a]
Pentadecane	$C_{15}H_{32}$	212.42	0.25[a]	0.0009[a]	0.014[a]	9.04[a]	8.74[a]
Hexadecane	$C_{16}H_{34}$	226.4	0.1[a]	0.0003[a]	0.015[a]	9.58[a]	9.26[a]

Table 5-6 (continued)
Physical Properties of Selected Hydrocarbons, PAHs, and Other Compounds at 25°C
Tongue Point Multi-Sites Project, Astoria, Oregon

Constituent	Formula	Molecular Weight (g/mol)	H (atm-m^3/mol)	V_P at 25°C (mm Hg)	Solubility (mg/L)	Log K_{OW}	Log K_{OC}
Branched Iso-Alkanes							
Isopentane	C_5H_{12}	72.2	1.4[b]	689[b]	48[b]	2.30[b]	1.45[g] 2.09[h]
Isooctane	C_6H_{18}	114.2	3.01[b]	49.3[b]	0.56[c] 2.44[b]	4.09[b]	3.43 (soil)[b] 4.35 (seds)[b]
Aromatics							
Benzene	C_6H_6	78.1	5.36e-03[b]	95.19[b]	1791[b]	2.13[b]	1.3419[g]
Ethylbenzene	C_8H_{10}	106.2	8.57e-03[a]	9.5[c]	152[c]	3.15[c]	1.9845[g]
Toluene	C_7H_8	92.1	6.31e-03[b]	28.4[b]	535[b]	2.73[b]	1.7199[g]
m-Xylene	C_8H_{10}	106.2	7.80e-03[b]	8.3[b]	146[b]	3.2[b]	2.016[g]
1,2,3-Trimethylbenzene	C_9H_{12}	120.2	5.79e-03[d]	2.8[d]	75[d]		
1,3,5-Trimethylbenzene	C_9H_{12}	120.2	7.89e-03[f]	2.44[a]	48[e]	3.58[e]	2.2554[g]
n-Propylbenzene	C_9H_{12}	120.2	9.51e-03[f]	3.37[e]	55[e]	3.69[e]	2.3247[g]
Isopropylbenzene	C_9H_{12}	120.2	1.42e-02[f]	4.58[e]	50[e]	3.66[e]	2.3058[g]
n-Butylbenzene	$C_{10}H_{14}$	134.2	1.29e-02[f]	1.03[e]	13.8[e]	4.28[e]	2.6964[g]
1,2,4,5-Tetramethylbenzene	$C_{10}H_{14}$	134.2	2.46e-02[f]	0.495[e]	3.48[e]	4[e]	2.52[g]

Table 5-6 (continued)
Physical Properties of Selected Hydrocarbons, PAHs, and Other Compounds at 25°C
Tongue Point Multi-Sites Project, Astoria, Oregon

Constituent	Formula	Molecular Weight (g/mol)	H (atm-m^3/mol)	V_P at 25°C (mm Hg)	Solubility (mg/L)	Log K_{OW}	Log K_{OC}
Aromatics (continued)							
Pentylbenzene	$C_{11}H_{16}$	148.25	6.02e-03[f]	0.33[e]	10.5[e]	4.9[a]	3.087[g]
Hexylbenzene	$C_{12}H_{18}$	162.28	210e-02[f]	0.102[e]	1.02[e]	5.22[e]	3.2886[g]
Cycloalkanes							
Cyclopentane	C_5H_{10}	70.14	1.85e-01[f]	318[e]	156[e]	3[e]	1.89[g]
Cyclohexane	C_6H_{12}	84.2	193e-01[d]	95.2[e]	55[e]	3.44[e]	2.1672[g]
Methylcyclohexane	C_7H_{14}	98.19	4.20e-01	46.4[e]	14[e]	2.82[e]	1.7766[g]
PAHs							
Naphthalene	$C_{10}H_8$	128.2	4.07e-04[f]	0.078[e]	31.7[e]	3.35[e]	3.14[h]
1-Methylnaphthalene	$C_{11}H_{10}$	142.2	3.81e-04[f]	0.059[e]	28.4[e]	3.87[e]	3.66[h]
Biphenyl	$C_{12}H_{10}$	154.2	2.40e-04[f]	0.009[e]	7.48[e]	4.03[e]	3.82[h]
Acenapthene	$C_{12}H_{10}$	154.2	1.53e-04[j]	0.01 – 0.001[j]	4.24[j]	4.33[j]	3.85[j]
Fluorene	$C_{13}H_{10}$	166.2	7.00e-06[f]	6.00e-05[a]	1.84[e]	4.18[e]	3.97[h]
Anthracene	$C_{14}H_{10}$	178.2	3.37e-05[f]	6.00e-06[e]	0.041[e]	4.63[e]	4.42[h]
Phenanthrene	$C_{14}H_{10}$	178.2	2.14e-05[f]	1.20e-04[e]	1.29[e]	4.57[e]	4.36[h]
Fluoranthene	$C_{16}H_{10}$	202.3	9.04e-06[f]	9.10e-06[e]	0.263[e]	5.22[e]	5.01[h]

Table 5-6 (continued)
Physical Properties of Selected Hydrocarbons, PAHs, and Other Compounds at 25°C
Tongue Point Multi-Sites Project, Astoria, Oregon

Constituent	Formula	Molecular Weight (g/mol)	H (atm-m^3/mol)	V_P at 25°C (mm Hg)	Solubility (mg/L)	Log K_{OW}	Log K_{OC}
PAHs (continued)							
Pyrene	$C_{16}H_{10}$	202.3	8.71e-06[f]	4.50e-06[e]	0.135[e]	5.22[e]	5.01[h]
Chrysene	$C_{18}H_{12}$	228.3	4.27e-06[f]	2.90e-08[e]	0.002[e]	5.79[a]	5.58[h]
Benzo(a)pyrene	$C_{20}H_{12}$	252.3	4.71e-07[f]	5.50e-09[0]	0.0038[e]	6.04[e]	5.83[h]
Other							
1,2-dibromoethane (ethylenedibromide [EDB])	$C_2H_4Br_2$	187.9	6.67e-04[b]	11.2[b]	4,150[b]	1.96[b]	1.23[g] 1.75[h] 1.15-2.20[i]
Dichlorodiphenyltrichloroethane (*p,p'*-DDT)[i]	$C_{14}H_9Cl_5$	354.5	8.3e-06	1.6e-07	0.025	6.91	5.18

Notes:

[a] Custance *et al.* 1992
[b] Howard 1990
[c] Verschueren 1983
[d] Ducreux 1990
[e] Mackey and Shiu 1992
[f] Estimated using H = (V_p)(MW)(16.04)/(WS)(T) where MW is the molecular weight in g/mole, WS is the water solubility. And T is the Kelvin Temperature.
[g] Estimated using Log K_{oc} = 0.63 Log K_{ow}
[h] Estimated using Log $K_{=}$ = Log K_{ow} - 0.21
[i] EPA Technical Factsheet Undated
[j] Lehr 2000
°C = degrees Celsius
atm-m^3/mol = atmospheres cubic meters per mole
g/mol = grams per mole

Table 5-6 (continued)
Physical Properties of Selected Hydrocarbons, PAHs, and Other Compounds at 25°C
Tongue Point Multi-Sites Project, Astoria, Oregon

Notes:

H – Henry's law constant
K_{OC} = organic-carbon partition coefficient
K_{OW} = octanol-water partition coefficient
mg/L = milligrams per liter
mm Hg = millimeters mercury
PAH = polycyclic aromatic hydrocarbon
V_P = vapor pressure

Table 5-7
Physical and Chemical Properties of Polychlorinated Biphenyls
Tongue Point Multi-Sites Project, Astoria, Oregon

Property	Aroclor 1016	Aroclor 1221	Aroclor 1232	Aroclor 1242	Aroclor 1254	Aroclor 1260	Aroclor 1262	Aroclor 1268
Molecular weight [1]	257.9	200.7	232.2	266.5	328	357.7	389	453
Color [1]	Clear	Clear	Clear	Clear	Light yellow	Light yellow	No data	Clear
Physical state [1]	Oil	Oil	Oil	Oil	Viscous liquid	Sticky resin	No data	Viscous liquid
Melting point (°C) [1]	No data	1	No data	No data	No data	No data	No data	No data
Boiling point (°C) [1]	325–356	275–320	290–325	325–366	365–390	385–420	390–425	435–450
Density [1] (g/cm^3 at 25 °C)	1.37	1.18	1.26	1.38	1.54	1.62	1.64	1.81
Odor [1]	No data	No data	No data	Mild hydrocarbon	Mild hydrocarbon	No data	No data	No data
Solubility [1] (mg/L):								
in Water	0.42 (25 °C)	0.59 (24 °C)	0.45 (25 °C)	0.34 (25 °C); 0.10 (24 °C)	0.012; 0.057 (24 °C)	0.00271; 0.08 (24 °C)	0.052 (24 °C)	0.300 (24 °C)
in Organic solvents	Very soluble	Very soluble	Very soluble	Very soluble	Very soluble	Very soluble	No data	Soluble
Partition coefficients:								
Log K_{ow} [1]	5.6	4.7	5.1	5.6	6.5	6.8	No data	No data
Log K_{oc} [2]	107,285	No data	No data	No data	No data	822,422	No data	No data
Vapor pressure [1] (mm Hg at 25 °C)	$4x10^{-4}$	$6.7x10^{-3}$	$4.06x10^{-3}$	$4.06x10^{-4}$	$7.71x10^{-5}$	$4.05x10^{-5}$	No data	No data
Henry's law constant [1] (m^3/mol at 25 °C)	$2.9x10^{-4}$	$3.5x10^{-3}$	No data	$5.2x10^{-4}$	$2.0x10^{-3}$	$4.6x10^{-3}$	No data	No data
Flashpoint [1], °C	170	141–150	152–154	176–180	No data	No data	195	195

Table 5-7 (continued)
Physical and Chemical Properties of Polychlorinated Biphenyls
Tongue Point Multi-Sites Project, Astoria, Oregon

Notes:

Information listed obtained from:
1 = Agency for Toxic Substances and Disease Registry (ATSDR), Toxicological Profile for Polychlorinated Biphenyls (PCBs), November 2000. Available at: http://www.atsdr.cdc.gov/toxprofiles/tp17.html
2 = Criteria from Table 747-1: Soil Organic Carbon-Water Coefficient Values: Nonionizing Organics, Model Toxics Control Act, Chapter 70.105D RCW and Cleanup Regulation Chapter 173-340 WAC, October 2005, Publication No. 94-06.
°C = degrees Celsius
g/cm^3 = grams per cubic centimeter
mg/L = milligrams per liter
K_{OC} = organic-carbon partition coefficient
K_{OW} = octanol-water partition coefficient
mm Hg = millimeters mercury

Table 5-8
Summary of Fate and Transport Parameters for Dioxins and Furans
Tongue Point Multi-Sites Project, Astoria, Oregon

Parameter Abbreviation	Solubility Range (mg/L)	Log K_{oc} Range
2,3,7,8-TCDD	7.2×10^{-6} - 6.9×10^{-4}	3.06 - 7.58
1,2,3,7,8-PeCDD	9.6×10^{-5} - 8.2×10^{-3}	4.85 - 6.38
1,2,3,4,7,8-HxCDD	4.0×10^{-6} - 4.4×10^{-5}	5.02 - 7.10
1,2,3,6,7,8-HxCDD*	4.0×10^{-6} - 4.4×10^{-5}	5.02 - 7.10
1,2,3,7,8,9-HxCDD*	4.0×10^{-6} - 4.4×10^{-5}	5.02 - 7.10
1,2,3,4,6,7,8-HpCDD	2.0×10^{-6} - 8.5×10^{-4}	5.47 - 7.80
OCDD	7.0×10^{-8} - 1.8×10^{-4}	5.92 - 7.90
2,3,7,8-TCDF	4.0×10^{-4} - 3.5×10^{-3}	5.20 - 7.50
1,2,3,7,8-PeCDF*	2.4×10^{-4} - 5.2×10^{-4}	5.59 - 7.40
2,3,4,7,8-PeCDF	2.4×10^{-4} - 5.2×10^{-4}	5.59 - 7.40
1,2,3,4,7,8-HxCDF	8.3×10^{-6}	7.40
1,2,3,6,7,8-HxCDF*	8.3×10^{-6}	7.40
2,3,4,6,7,8-HxCDF*	8.3×10^{-6}	7.40
1,2,3,7,8,9-HxCDF*	8.3×10^{-6}	7.40
1,2,3,4,6,7,8-HpCDF	1.4×10^{-6} - 1.1×10^{-5}	6.00 - 7.90
1,2,3,4,7,8,9-HpCDF**	1.4×10^{-6} - 1.1×10^{-5}	5.00 - 6.70
OCDF	4.0×10^{-8} - 1.5×10^{-6}	6.00 - 7.40

Notes:

*Solubility and partition coefficient values assumed to be equivalent to those of the most similar compound.
** Solubility values assumed to be equivalent to those of the most similar compound.
mg/L = milligrams per liter
K_{OC} = organic-carbon partition coefficient
HxCDD = hexachlorodibenzo-p-dioxin
HxCDF = hexachlorodibenzofuran
HpCDD = heptachlorodibenzo-p-dioxin
HpCDF - heptachlorodibenzofuran
OCDD = octachlorodibenzo-p-dioxin
OCDF = octachlorodibenzofuran
PeCDD = pentachlorodibenzo-p-dioxin
PeCDF = pentachlorodibenzofuran
TCDD = tetrachlorodibenzo-p-dioxin
TCDF = tetrachlorodibenzofuran

Table 5-9
Summary of Maximum Soil TPH Results for the Fuel-Impacted Areas
Tongue Point Multi-Sites Project, Astoria, Oregon

Decision Unit	**Gasoline Range[1]**	**Diesel Range[1]**	**Motor Oil[1]**
AST Fuel Storage Area	320	2,400	7,300
UST Site No. 1	2,200	13,000	150
Refueling Pit 3	28	34	150
UST Site No. 4	75	13	120
Residual NAPL Screening Values[2]	*N/A*	*2,000 – 20,000*	*5,000 – 40,000*

Notes:

1. Units are mg/kg (2008 data)
2. Screening values (API 2000, ODC 2000)

AST = aboveground storage tank
NAPL = non-aqueous phase liquid
UST = underground storage tank
No. = number
N/A = not applicable
mg/kg = milligrams per kilogram
API = American Petroleum Institute

Table 5-10
Summary of Maximum Groundwater TPH Results for the Fuel-Impacted Decision Units
Tongue Point Multi-Sites Project, Astoria, Oregon

Decision Unit	Gasoline Range[1]	Diesel Range[1]	Motor Oil[1]
AST Fuel Storage Area	<250	760	<500
UST Site No. 1	540	610	<500
Refueling Pit 3	3,000	<250	<500
UST Site No. 4	-	-	-

Notes:

1. Units are µg/L (2008 data)

AST = aboveground storage tank
UST = underground storage tank
No. = number
µg/L = micrograms per liter

Table 5-11
Henry's Law Constants
Tongue Point Multi-Sites Project, Astoria, Oregon

Vapor Pressure (mm Hg)	H (atm-m^3/mol)
Compound mostly in air	
$< 10^{-7}$	$< 5 \times 10^{-5}$
Compound mostly in air	
$> 10^{-2}$	$> 5 \times 10^{-3}$

Notes:

H = Henry's law constant
mm Hg = millimeters mercury
atm-m^3/mol = atmospheres cubic meters per mole

Table 5-12
Summary of the Maximum Concentrations in Groundwater for Selected PAH Compounds
Tongue Point Multi-Sites Project, Astoria, Oregon

Decision Unit	Benzo(a)pyrene[1]	Phenanthrene[1]	Fluorene[1]	Acenaphthene[1]
AST Fuel Storage Area	<0.019	<0.019	<0.019	<0.019
Refueling Pit 3	<0.019	0.027	<0.019	0.014
UST Site No. 1	<0.019	0.66[2]	2.6[2]	1.2[2]
UST Site No. 4	-	-	-	-

Notes:

1. Units are µg/L (2008 Data)
2. Free product or sheen observed in well

µg/L = micrograms per liter
AST = aboveground storage tank
UST = underground storage tank
No. = number

Table 5-13
Summary of Lead Results for the Fuel-Impacted Terrestrial Decision Units Tongue Point Multi-Sites Project, Astoria, Oregon

Decision Unit	Soil Lead (mg/kg)	Lead in Groundwater (µg/L)
AST Fuel Storage Area	6.1 - 262	0.583 (T)
Refueling Pit 3	9.2 – 20.4	0.94 – 1.1 (D) 0.66 – 1.9 (T)
UST Site No. 1	3.0 – 14.6	0.70 (T)
UST Site No. 4	2.0 – 13.5	-

Notes:

T = Total
D = Dissolved
AST = aboveground storage tank
UST = underground storage tank
No. = number
mg/kg = milligrams per kilogram
µg/L = micrograms per liter

Table 5-14
Summary of TPH Concentrations Within Sediment of the Aquatic Decision Units
Tongue Point Multi-Sites Project, Astoria, Oregon

Parameter	Finger Pier[1]	Near Landfill[1]	North of Pier 8[1]	Reference[1]
Diesel Range Hydrocarbons	14 – 38	14 – 23	11 – 16	7.8 - 10
Gasoline Range Hydrocarbons	2.5	5.3	2.9	-
Motor Oil Range Hydrocarbons	21 - 150	93 - 140	56 - 74	44 - 66

Notes:

1. Units in µg/kg (2008 data)

µg/kg = micrograms per kilogram

Table 5-15
Summary of Concentrations in Aquatic Decision Unit Sediments for Selected PAH Compounds
Tongue Point Multi-Sites Project, Astoria, Oregon

Parameter	Finger Pier[1]	Near Landfill[1]	North of Pier 8[1]	Reference[1]
Benzo(a)pyrene	14 - 21	7.3 - 17	9.5 - 32	7.2 - 11
Phenanthrene	7 - 29	5 - 55	8.6 - 16	4.1 – 7.5
Fluorene	0.93 – 2.1	0.56 – 3.3	0.80 – 1.4	0.50 – 0.62
Acenaphthene	0.84 – 1.8	0.40 – 2.4	0.51 – 0.91	0.35 – 0.58

Notes:

1. Units in µg/kg

µg/kg = micrograms per kilogram
PAH = polycyclic aromatic hydrocarbon

Table 5-16
Summary of Selected Metal/Inorganic Concentrations Within Sediment of the Aquatic Decision Units
Tongue Point Multi-Sites Project, Astoria, Oregon

Parameter	Finger Pier[1]	Near Landfill[1]	North of Pier 8[1]	Reference[1]
Arsenic	4.7 – 6.4	5.2 – 6.1	7.6 – 8.3	4.6 – 5.2
Chromium	17 - 19	15 - 18	17 - 20	14 - 15
Copper	31 - 34	24 - 27	36 - 39	26 - 31
Lead	10 - 11	10 -12	10 -15	7.4 – 8.2
Mercury	0.081 – 0.16	0.061 – 0.081	0.056 – 0.098	0.050 – 0.075
Zinc	75 - 86	70 - 80	77 - 84	60 - 69

Notes:

1. Units in µg/kg (2008 data)

µg/kg = micrograms per kilogram

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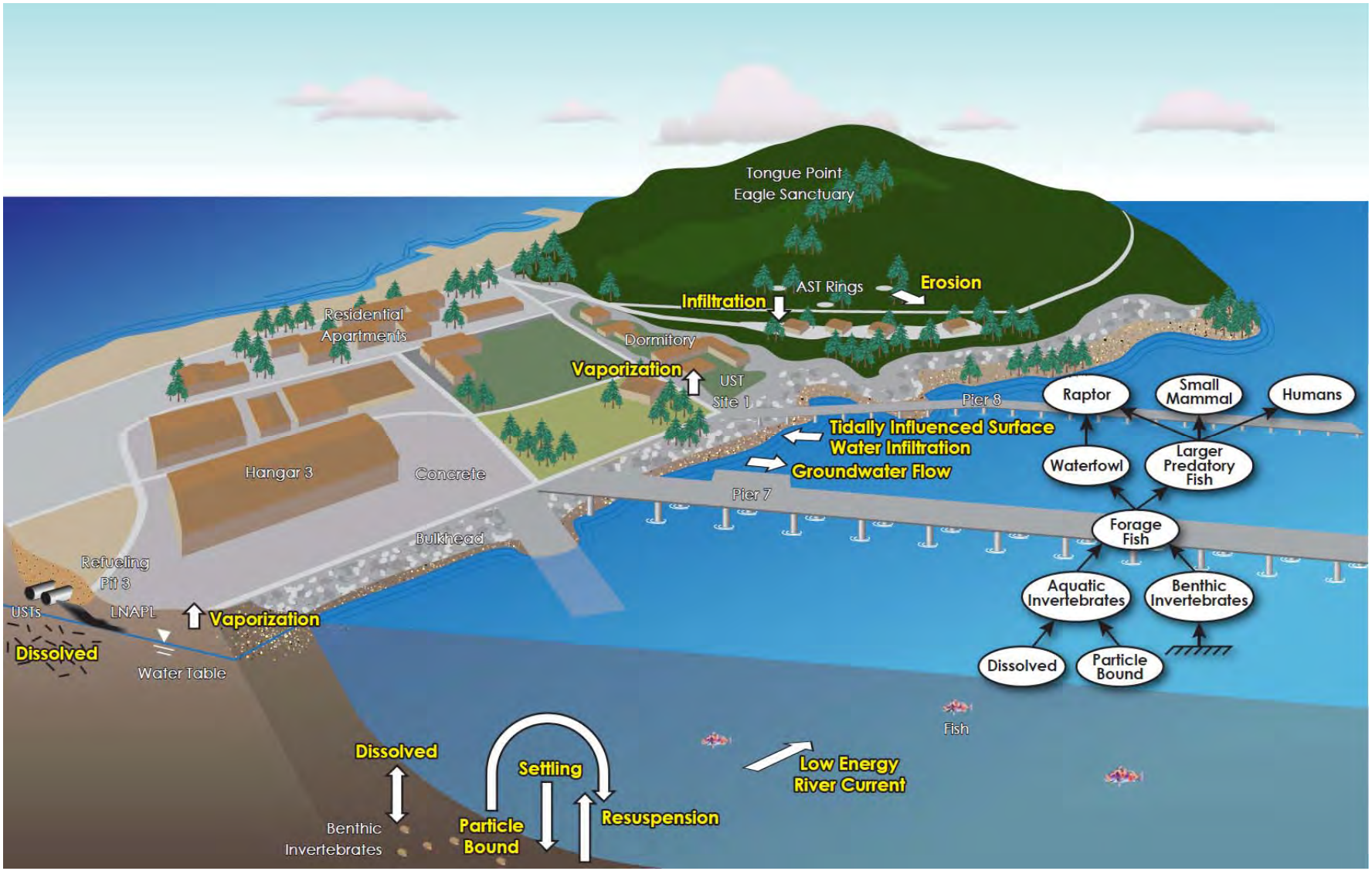


NOTES:

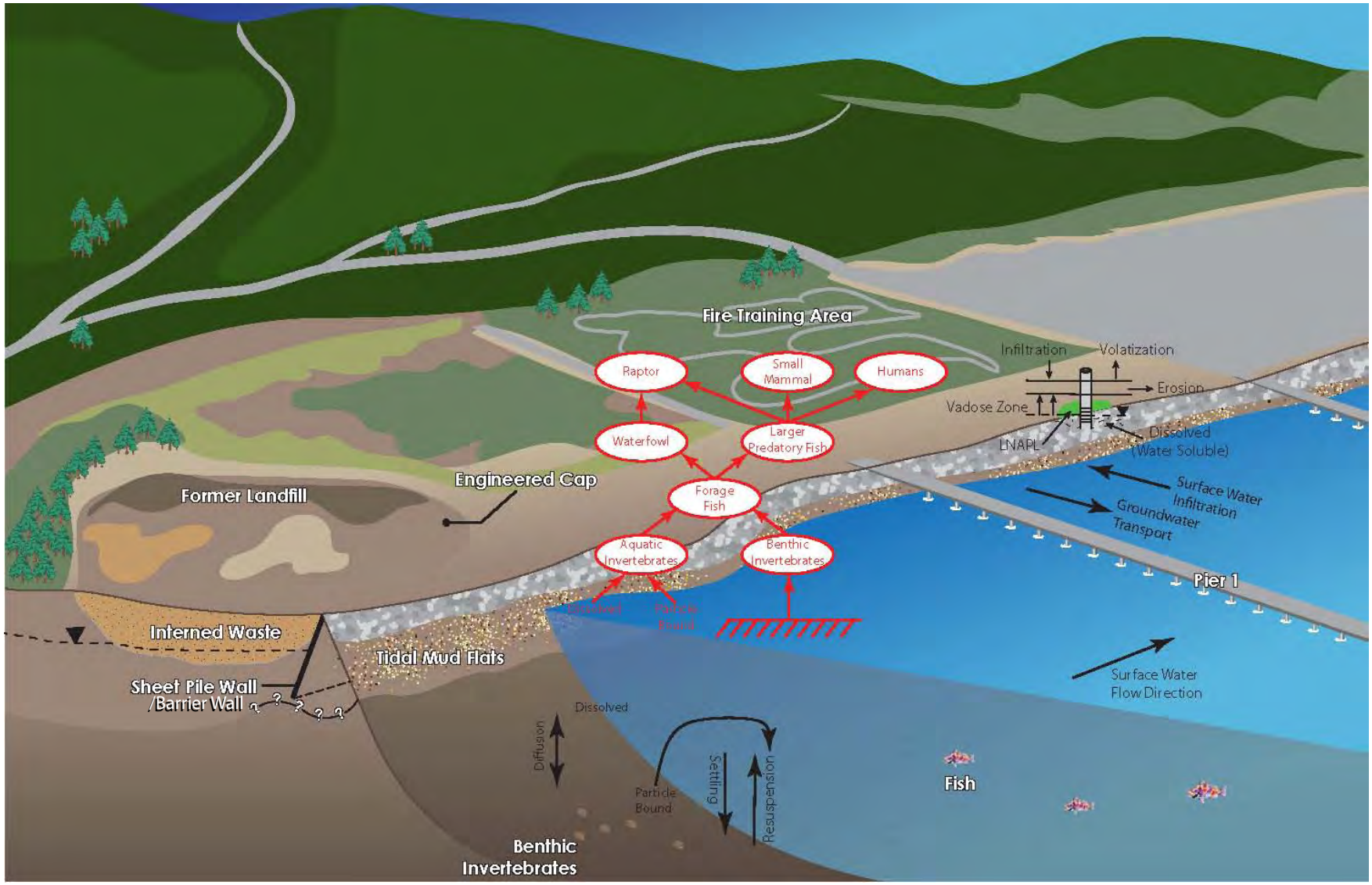
1. AST = aboveground storage tank
2. LNAPL = light non-aqueous phase liquid
3. UST = underground storage tank

CDM	U.S. ARMY CORPS OF ENGINEERS SEATTLE DISTRICT SEATTLE, WASHINGTON

CONCEPTUAL SITE MODEL
NORTHERN PORTION OF STUDY AREA

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 5-1

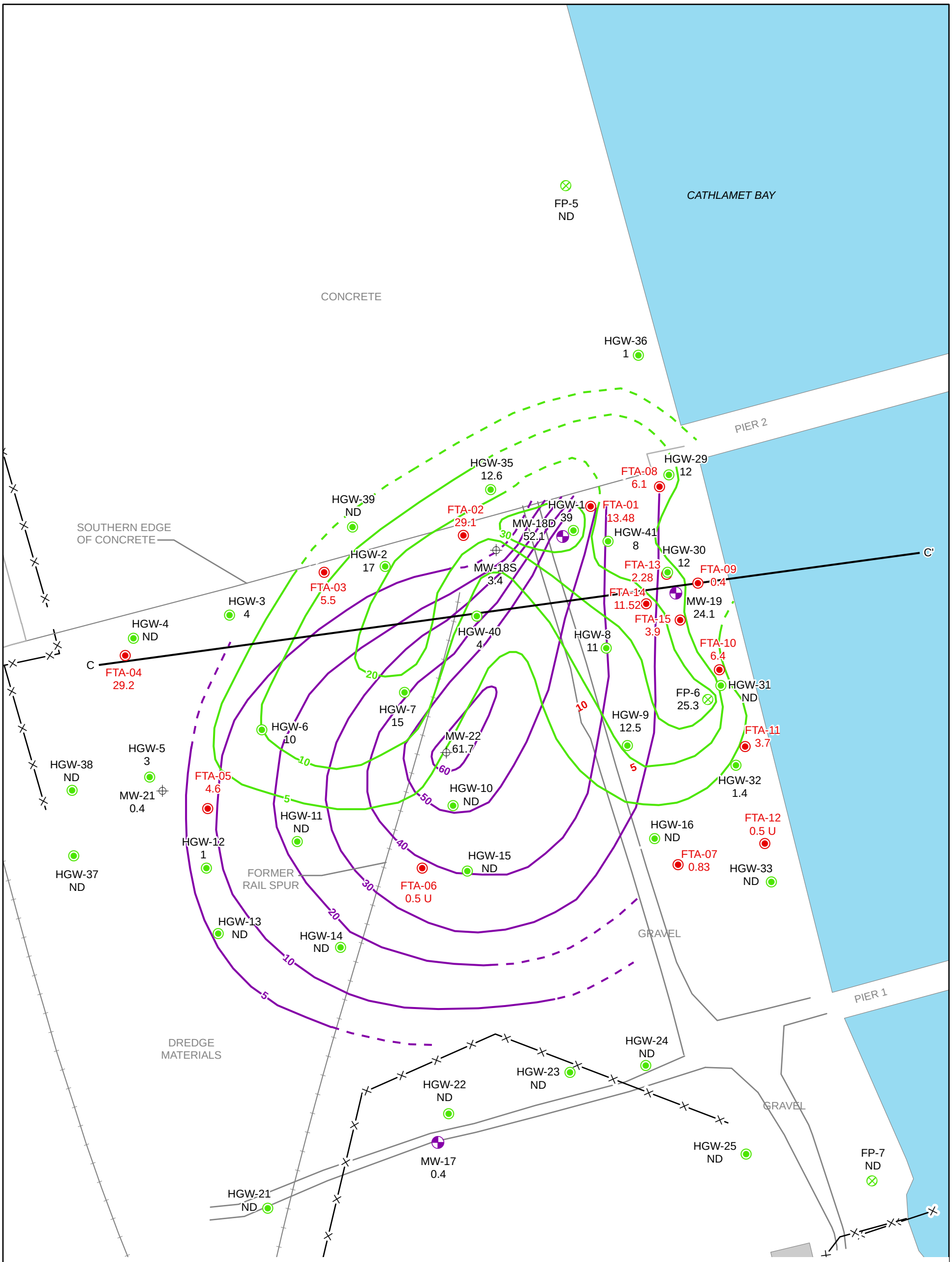


CDM	U.S. ARMY CORPS OF ENGINEERS SEATTLE DISTRICT SEATTLE, WASHINGTON

CONCEPTUAL SITE MODEL
SOUTHERN PORTION OF STUDY AREA

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 5-2



NOTES:

1. WELLS MW-18S, MW-21, AND MW-22 ARE NOT ACCESSIBLE BECAUSE OF DREDGE SPOIL PILES PLACED IN 2001.
2. DREDGE SPOIL AREA HISTORICALLY USED AS A PUBLIC WORKS STORAGE YARD AND HAD SEVERAL WAREHOUSE BUILDINGS.
3. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
4. BASE MAP DATA: URS, FIGURE 3-7, SEPTEMBER 2007.
5. DPT = DIRECT PUSH TECHNOLOGY
6. µg/L = MICROGRAMS PER LITER
7. ND = NOT DETECTED AT LIMIT OF 1U µg/L.
8. TOTAL CHLORINATED ETHENES IS THE SUM OF cis-1,2-DICHLOROETHENE, TETRACHLOROETHENE, trans-1,2-DICHLOROETHENE TRICHLOROETHENE AND VINYL CHLORIDE.
9. ANALYTICAL RESULTS WERE FROM THE TONGUE POINT LANDFILL LIMITED RI - URS GREINER WOODWARD CLYDE, 1999a.

LEGEND

- EXISTING WELL
- INACCESSIBLE WELL
- ABANDONED WELL
- HYDROPUNCH GROUNDWATER SAMPLE LOCATION (9/1995)
- GROUNDWATER SAMPLE LOCATION (9/2008)
- CONCENTRATIONS OF TOTAL CHLORINATED ETHENES DETECTED AT GROUNDWATER SAMPLE LOCATIONS (MW) ug/L (1996) DASHED WHERE INFERRED
- CONCENTRATIONS OF TOTAL CHLORINATED ETHENES DETECTED AT (HGW) HYDROPUNCH GROUNDWATER SAMPLE LOCATIONS ug/L (1995) DASHED WHERE INFERRED
- CROSS-SECTION C-C' (SEE FIGURE 5-4)

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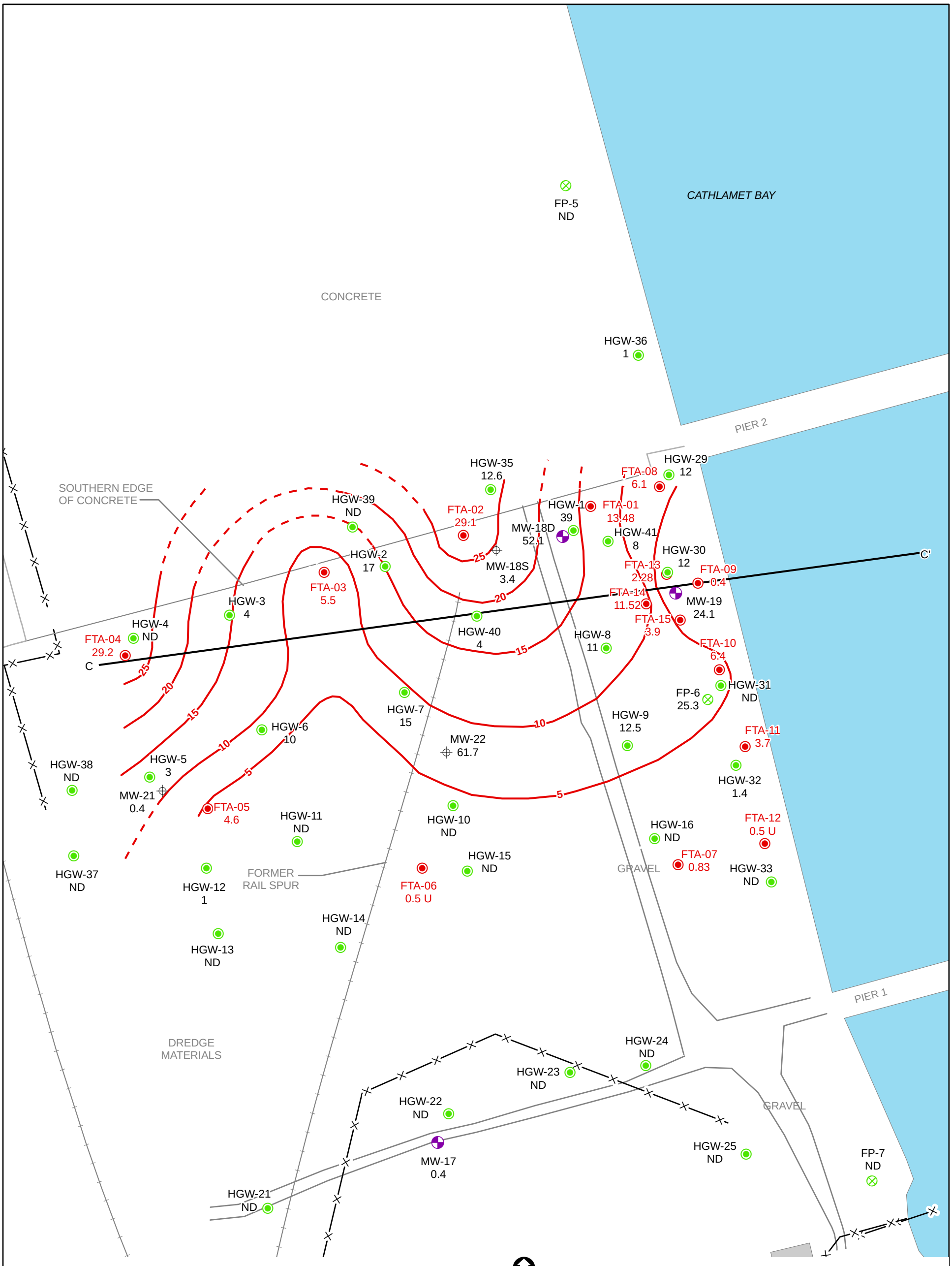
SEATTLE, WASHINGTON

Total Chlorinated Ethenes in Groundwater (1995 and 1996)

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 5-3A



NOTES:

1. WELLS MW-18S, MW-21, AND MW-22 ARE NOT ACCESSIBLE BECAUSE OF DREDGE SPOIL PILES.
2. DREDGE SPOIL AREA HISTORICALLY USED AS A PUBLIC WORKS STORAGE YARD AND HAD SEVERAL WAREHOUSE BUILDINGS.
3. ORIGINAL PRODUCED IN COLOR, INFORMATION MAY BE MISSING FROM BLACK AND WHITE REPRODUCTIONS.
4. BASE MAP DATA: URS, FIGURE 3-7, SEPTEMBER 2007.
5. DPT = DIRECT PUSH TECHNOLOGY
6. µg/L = MICROGRAMS PER LITER
7. TOTAL CHLORINATED ETHENES IS THE SUM OF cis-1,2-DICHLOROETHENE, TETRACHLOROETHENE, trans-1,2-DICHLOROETHENE TRICHLOROETHENE AND VINYL CHLORIDE

LEGEND

- EXISTING WELL
- INACCESSIBLE WELL
- ABANDONED WELL
- HYDROPUNCH GROUNDWATER SAMPLE LOCATION (9/1995)
- GROUNDWATER SAMPLE LOCATION (9/2008)
- CONCENTRATIONS OF TOTAL CHLORINATED ETHENES DETECTED AT MONITORING WELL AND DPT LOCATIONS ug/L (2008) DASHED WHERE INFERRED
- CROSS-SECTION C-C' (SEE FIGURE 5-4)

CDM

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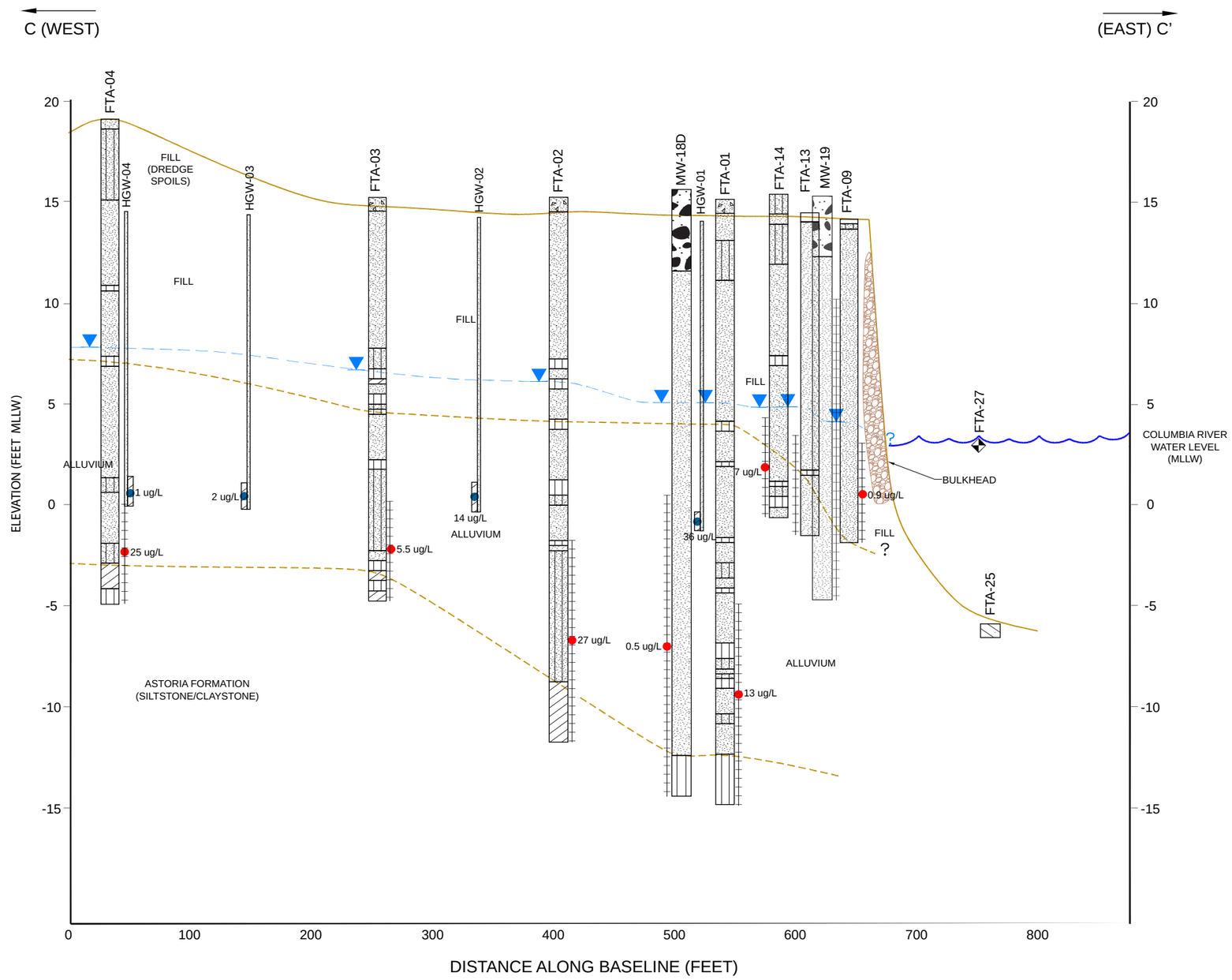
SEATTLE DISTRICT
SEATTLE, WASHINGTON

Total Chlorinated Ethenes in Groundwater (2008)

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 5-3B



HORIZONTAL SCALE: 1" = 100'

VERTICAL SCALE: 1" = 6'

LEGEND

BORING/MICROWELL ID (MW-01)

SCREENED INTERVAL

TOTAL BORING DEPTH

SURFACE WATER SAMPLE LOCATION

SURFACE SEDIMENT SAMPLE LOCATION

GROUNDWATER ELEVATION, SEPTEMBER 2008

VINYL CHLORIDE CONCENTRATION (SEPTEMBER 2008) SAMPLED AT MIDPOINT SCREEN INTERVAL

VINYL CHLORIDE CONCENTRATION (SEPTEMBER 1995) TOTAL DEPTH IS 15' BGS SAMPLE SCREENED 13 - 15 FT BGS

RIP-RAP SHORE LINE

CONCRETE

? INFERRED

MLLW MEAN LOWER LOW WATER

SEE TABLE 3-8 FOR BORING/MICROWELL AND MONITORING WELL ELEVATIONS SURVEYED IN 2008.

LITHOLOGIC LEGEND

GP POORLY GRADED GRAVEL; GRAVEL-SAND MIXTURES, WITH LITTLE TO NO FINES

SP POORLY GRADED SAND; SAND-GRAVEL MIXTURES, WITH LITTLE TO NO FINES

SM SILT; SILT, CLAY, SAND MIXTURES, MAY CONTAIN TRACE ORGANICS, WOOD, PLANT OR SHELL DEBRIS

ML SILTY SAND; SAND, GRAVEL MIXTURES, MINOR FINES

CL CLAY; CLAY, SILT, SAND MIXTURES, MAY CONTAIN TRACE ORGANICS, WOOD, PLANT OR SHELL DEBRIS

SC CLAYEY SAND; SAND, CLAY, GRAVEL MIXTURES

CDM

U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

GEOLOGIC CROSS SECTION C-C'
FIRE TRAINING AREA

TONGUE POINT MULTI-SITES PROJECT
REMEDIAL INVESTIGATION REPORT
DELIVERY ORDER 008 CONTRACT NO. W912DW-06-D-1002
ASTORIA, OREGON

FIGURE 5-4

Section 6
Human Health Risk Assessment

The purpose of the human health risk assessment (HHRA) is to quantitatively evaluate risks to human health associated with Study Area-specific chemicals under current and future anticipated conditions in the absence of any remedial action. This section presents the baseline HHRA as part of the RI for the TPMS, as outlined in the Technical Memorandum for Human Health Risk Assessment (CDM 2009b). It provides support for determining whether remedial action is necessary, and a basis for determining the extent of any remediation deemed necessary.

6.1 Introduction

A Study Area for the TPMS was defined to include upland source areas and aquatic areas that may have received releases from these source areas and/or from historical DoD operations at the finger piers.

Six upland decision units (DUs) and three aquatic DUs were identified for the Study Area. These nine DUs represent the areas where historical DoD operations may have released chemicals in the past, and which could be areas of exposure to DoD-related chemicals, and/or may remain, in theory, sources that release chemicals to other decision units. DUs are shown on **Figure 1-2** and are listed below:

- AST Fuel Storage Area
- UST Site No. 1
- Refueling Pit 3
- UST Site No. 4
- Fire Training Area
- Incinerator Building
- Aquatic area north of Pier 8, which includes area offshore of AST and UST Site 1 (Aquatic-North of Pier 8)
- Aquatic area offshore of the landfill, south of Pier 8 (Aquatic-Near Landfill)
- Aquatic area associated with the finger piers (Aquatic-Finger Piers)

6.1.1 Purpose and Objectives

The purpose of the HHRA is to evaluate current and future human health risks resulting from exposures to chemicals at the TPMS under no action and institutional control conditions. Specific objectives of this risk assessment consist of:

- identifying chemicals of potential concern (COPCs)
- identifying exposure pathways and associated receptor populations
- quantifying chemical intake (exposure) for each receptor population
- assessing the toxicity of COPCs
- characterizing risks associated with exposure to COPCs
- evaluating uncertainties and limitations of the risk assessment
- identifying risk driver that may be the focus of risk management decisions

6.1.2 Dual CERCLA and ODEQ Processes

A primary activity within the Study Area during the DoD era was fueling of ships and seaplanes at the piers. Thus, diesel fuel was used extensively during this time, and is known to have been released from at least some source areas where diesel fuel was stored (e.g., UST Site No. 1). CERCLA excludes petroleum, oil, and lubricants (POL) such as gasoline and diesel fuel, from its list of hazardous substances. However, these POL substances may constitute pollutants or contaminants, and would be addressed as Resource Conservation and Recovery Act (RCRA) corrective actions following the Defense Environmental Restoration Program's (DERP's) Containerized Hazardous, Toxic, and Radioactive Waste Projects (CON/HTRW) response actions. The State of Oregon does not follow the CERCLA exclusion of petroleum hydrocarbons. Therefore, POL are considered by ODEQ risk based corrective action guidance. As presented in Section 1.3, DoD implements CERCLA responses that identify and incorporate applicable standards, thereby satisfying its RCRA obligations along with its CERCLA obligations. The substantive provisions of the ODEQ environmental cleanup process, by the State's RCRA authority (Oregon Administrative Rules [OAR] 340-122-0205 through 340-122-0360), for petroleum release sites are applicable standards per RCRA.

For evaluation in this RI, the characterization of risks was conducted to address both CERCLA requirements and applicable standards per RCRA. For four DUs (AST, UST Site No. 1, Refueling Pit 3, and UST Site No. 4), petroleum hydrocarbons were stored, piped, and used for fueling of ships and aircraft. For these DUs, petroleum hydrocarbons are expected COPCs and risks are assessed separately per CERCLA and RCRA. For the remaining DUs, where DoD did not store petroleum or use it as fuel following the implementation of RCRA, risks are assessed only following CERCLA guidance, and POL stored or used as fuel, are not included. However, the CERCLA risk assessments performed in this report include individual chemicals that may once have been components of petroleum hydrocarbon fuels. These CERCLA DUs are the former Incinerator, the Former Fire Training Area, and the aquatic DUs. For all of these CERCLA DUs, risks are characterized only using the CERCLA process, and petroleum hydrocarbons are addressed only through consideration of individual

chemicals that may have once been part of fuels. Thus, in the risk characterization section, a dual risk characterization and presentation of risks is developed.

Specifically, for the upland DUs associated with petroleum storage and distribution, a risk assessment is performed following ODEQ guidance (2000, 2003, 2007a, 2007b, and 2010a,b). For all DUs, a risk assessment is performed following CERCLA guidance (EPA 1989a, 1991a, 1997c, 2002a, 2002b, 2002c, 2004a, 2008a, 2009a, and 2010). The list below identifies the assessment approach for each DU:

- CERCLA and ODEQ Dual Risk Characterization – AST, UST Site 1, Refueling Pit 3, and UST Site 4
- CERCLA Risk Characterization only – Incinerator Building, Fire Training Area, Aquatic-North of Pier 8, Aquatic – Near Landfill, and Aquatic – Finger Piers

The dual process begins with the risk characterization. Thus, a single screening of chemicals to identify COPC was performed using ODEQ methods, and all COPC identified for any of the DU, including containerized petroleum hydrocarbons, were carried through all of the risk calculations. However, to be consistent with the CERCLA petroleum exclusion, for those DUs evaluated only by the CERCLA process, petroleum hydrocarbons were not listed as COPCs **Tables 6-9 through 6-13**, or in risk summary **Tables 6-37 through 6-41**. Petroleum hydrocarbons were carried through the risk calculations and results of these calculations are reported in Appendix L, Tables L6 for DUs where they were selected as COPC.

6.1.3 Organization

This baseline HHRA includes the following subsections:

- Section 6.1 – Introduction
- Section 6.2 - Data Evaluation and Screening
- Section 6.3 - Exposure Assessment
- Section 6.4 - Toxicity Assessment
- Section 6.5 - Risk Characterization, including Uncertainty Analysis
- Section 6.6 - Summary and Conclusions

For efficiency, data evaluation and screening, exposure assessment and toxicity assessment are performed only once (no dual track), and include consideration of containerized petroleum hydrocarbons. Only in the risk characterization section (Section 6.5), are CERCLA and ODEQ risk assessment processes distinguished.

6.2 Data Evaluation and Screening

This section presents a summary of analytical data that were collected to support the quantitative HHRA, a discussion of the screening process, and a description of COPC identified in the screening. This risk evaluation uses only analytical results of samples collected during this RI investigation, along with analytical results obtained by the USACE from the Incinerator Building DU during an independent sampling event in the October 2007.

6.2.1 Data Evaluation and Usability

This section presents a summary of the data usability assessment and a determination of how data are to be used in the HHRA.

6.2.1.1 Quality Assurance/Quality Control Results

All data acquired during this RI were validated through an independent third party subcontractor following procedures in EPA National Functional Guidelines for Inorganic Data Review (EPA 2004c) and EPA National Functional Guidelines for Organic Data Review (EPA 2008b). The complete data validation and data usability assessment review is provided in **Appendix F**. A summary of the data quality assessment pertinent to the HHRA is discussed below.

Generally, data from the RI field investigation were determined to be suitable for the risk assessment purposes as defined in data quality objectives (DQOs) in the QAPP (CDM 2008b). Some data were, however, not usable and were flagged as rejected, as indicated by an "R" qualifier. These data were not used for any reporting purpose or during the risk assessment evaluation.

One aspect of data quality critical to risk assessment is adequacy of SQLs for chemical analyses. In general, reporting limits did not exceed risk-based screening criteria as listed in the QAPP (CDM 2008b). However, in some cases, as discussed below, SQLs did not meet DQOs.

Another important aspect of data quality is data completeness. The QAPP required an overall completeness of 90 percent, and actual completeness was over 98 percent. From this standpoint, QAPP objectives were achieved. However, lack of sufficient sample volume did limit completeness of a key data set – dioxin/furan analyses for reference area sediment. In addition, several results for VOCs were rejected, lowering completeness for these analytes.

Issues of SQLs and data completeness are discussed in detail below.

- Sediment SQLs exceeded screening levels for several organic compounds, particularly for some pesticides and Aroclors. Laboratory case narratives reported that associated chromatographs indicated the presence of interfering non-target compounds that prevented adequate resolution of target compounds. Sediment samples had low percent solids content, generally around 50%, which contributed to SQLs above the

screening levels being elevated above screening levels. If a particular compound was detected below the SQL but above the MDL, it was reported as an estimated result. Thus, the data set for some pesticides and Aroclors is somewhat limited by high reporting limits and a higher frequency of estimated results.

- Groundwater and surface water SQLs exceeded screening values for PAHs and pesticides. Laboratory SQLs for pesticide compounds and PAH, compounds were 0.0004 µg/L and 0.019 µg/L, respectively. These limits are below the maximum reporting limit required by the QAPP (CDM 2008b) of 0.0005 µg/L and 0.020 µg/L, respectively. Screening levels for PAH and some pesticides are extremely low, and it is not uncommon for SQLs to exceed these levels.

- The intended seven analyses for dioxin/furan congeners for sediment samples from the reference area were not possible because sufficient sample mass was not available to support the analyses. Instead, IS aliquots from the reference sample were homogenized, combined into three larger samples, and analyzed. Three analyses of the reference sediment IS somewhat lower the confidence in the mean concentrations of dioxin/furan congeners and estimates of TCDD TEQ SQLs were affected. SQLs for reference samples were up to two-fold higher than SQLs from sediment samples from the Near Landfill DU. SQLs are inversely proportional to sample volume. A sample size of 9 to 10 grams was used for the samples from the Near Landfill and a sample size of 5 to 6 grams was used for the reference area samples. Since any reported concentrations would be corrected for sample size and moisture content, the difference in sample weight between the two sample groups is negated when positive detections are reported.

- Nondetected results for volatile chemicals from five soil samples were rejected because temperature in the cooler, when received by the laboratory, exceeded specified preservation limits. VOC in rejected samples did not appear to be present at detectable concentrations when the samples were analyzed. However, temperatures in the cooler could have resulted in loss of VOC. Various nondetected results of semivolatile chemicals were rejected from two samples because of low surrogate recoveries, and from eight samples because of low LCS recoveries. Details are provided in **Section 3.8.3.2** and in **Appendix F**.

6.2.1.2 Data Analysis

Some manipulation of raw data reported from the analytical laboratory is necessary in order to prepare data sets for (1) screening for COPCs and (2) calculation of exposure point concentrations (see Section 6.3). This data analysis is described in detail below.

The data set includes results from a number of field and laboratory duplicate analyses. Chemical concentrations reported from the analysis of field and laboratory duplicates are used only for QA/QC purposes and are not included in data sets for risk evaluation. Thus, duplicate samples are not used in COPC screening or in calculation of exposure point concentrations. All concentrations qualified as estimated (i.e., J-flagged data) are included in risk assessment data sets without

adjustment or modification. Analytical data from each DU are evaluated separately in the HHRA, both in screening for COPC and for calculation of exposure point concentrations. Thus, data are organized by DU in all risk assessment data sets.

Groups of similar chemicals, including dioxins/furans, carcinogenic PAHs (cPAHs), total DDT, and total PCBs are evaluated as a group rather than as individual entities. This approach is dictated both by available data on toxicity of individual members of these groups, and by the recognition that exposure always involves several or all members of the group. Treatment of these groups of chemicals is described below.

Toxicity equivalents (TEQ) for 2,3,7,8-TCDD are calculated by summing the products of concentrations and congener-specific TEFs for individual congeners. The World Health Organization 2005 TEF values are shown in **Table 6-1** (Van den Berg et al. 2006). Because dioxin/furan data sets contain at least 10% of congener concentrations below the SQL and because nondetected data are reported with multiple SQLs, the Kaplan-Meier (K-M) statistical method was implemented to more rigorously address estimation of TCDD TEQ and, later in this Section, to calculate exposure point concentrations.

The K-M method is a nonparametric statistical method that does not rely on assumptions about data distributions and does not use parameters such as mean or standard deviation. Instead of assuming a fraction of the SQL, the K-M method considers only the relative order (or rank) of the data. This approach is particularly appropriate for dioxin/furan data sets with many nondetects and multiple SQLs that were reported among IS for sediment samples for the 17 congeners 2, 3, 7, 8-sustituted dioxin/furan congeners. ProUCL version 4.00.04 (EPA 2009b) was used to implement the K-M method and to estimate average dioxin/furan TEQ concentrations. Total 2,3,7,8-TCDD TEQ were then estimated by multiplying average TEQ by the number of congeners. ProUCL requires a dataset to have at least two detected congeners. For individual samples in which only one of the congeners was detected, the detected congener concentration is assumed to be the average concentration for 2,3,7,8- TCDD TEQ.

Seven PAHs have been classified by EPA as probable human carcinogens. These cPAHs include benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene. Toxicity criteria are currently available only for benzo(a)pyrene. The remaining cPAHs are assessed using PAH-specific relative potency factors (RPFs) that express the potency of these cPAHs relative to benzo(a)pyrene (EPA 1993b). Concentrations of cPAHs are combined by summing the products of concentrations and RPF. RPFs for cPAH are shown in **Table 6-1**. The results are referred to as benzo(a)pyrene equivalent concentrations. When the analytical result of a specific cPAH in a given sample is less than its SQL, it is assigned a value equal to one-half of the SQL when calculating benzo(a)pyrene equivalents. cPAH data sets consist of 90 percent or more detected values; thus, it not necessary to use the K-M method to handle non-detected values in the manner used for dioxins/furans described above.

Analytical results of PCBs are reported as Aroclor mixtures of 1061, 1221, 1232, 1242, 1248, 1254, and 1260. Total PCBs are calculated using only detected concentrations for the seven Aroclor mixtures, as described in the Washington Department of Ecology's Sediment Management Standards (WAC 173-204). That is, if only Aroclor 1254 was positively detected in a sample, the Aroclor 1254 concentration was used to represent total PCBs in that sample. Since Aroclor 1254 was the only mixture detected in samples from the Study Area, Aroclor 1254 concentrations and total PCB concentrations are equivalent. For individual samples in which none of the Aroclor mixtures was detected, total PCBs were assigned a value equal to the highest SQL of the Aroclors.

Total DDT is calculated by summing analytical results reported above the SQL for DDD, DDE, and DDT. For individual samples in which the chemicals were not reported above the SQL, total DDT was given a value equal to the highest SQL of the chemicals.

Data for metals in groundwater are available for both filtered and unfiltered (total) samples. However, only data from the total analyses of inorganics (unfiltered samples) were used in the risk assessment. See **Section 3.3.6.2** for further discussions. Typically, groundwater is assumed to be used with minimal treatment as potable water and, thus, total metals concentrations are most applicable for estimating exposure. The tabulation of analytical results in Appendix E provides both total and dissolved results.

6.2.1.3 Summary of Analytical Results

The evaluation and summary of analytical results are based on those chemicals and chemical compounds that were reported at concentrations greater than the SQL in one or more samples. The human health screening process and definition of specific groups of chemicals in the process follows from the ODEQ HHRA guidance (2010a) and OAR 340-122-0080(5) definition: Chemicals detected at the site which have not been screened should be designated as "Chemicals of Interest" (COIs), while those that have been screened-in should be designated as "Chemicals of Potential Concern" (COPCs). Accordingly, in Section 6 discussions, if a reported concentration is above the SQL in one or more samples in a DU, the chemical is referred to as a COI for that DU. A statistical summary chemicals with concentrations greater than their SQL are presented by medium and DU in **Tables 4-2 through 4-10**. These chemicals are considered, in Section 6, as COI and are carried through the screening for COPCs.

6.2.2 Chemical Screening

Many chemicals have been detected in soil, soil gas, groundwater, surface water, sediment, and tissue from samples collected at the Study Area. Screening of analytical data was conducted to determine which chemicals should be further evaluated in the risk assessment. Screening helps focus the assessment on COI that could pose a human health risk.

This section presents an overview of the COPC screening process, the selection of screening criteria, and the identification of COPCs for evaluation in the quantitative risk assessment. Chemicals detected in biota samples from the aquatic DUs are used for characterization of possible human exposure from consumption of fish taken from the Study Area. These data are not evaluated in the screening process, but they are compared to ODEQ acceptable tissue levels (ATLs) in the lines of evidence discussions in **Section 6.5.4** (ODEQ 2007a). Analytical data collected from the reference area are used for comparisons to data from the aquatic DUs as a means to separate Study Area- and non-Study Area-related health risks.

For soil samples, the summary of analytical results is subdivided by depth range to support risk evaluations. Surface soil is defined as soil present from ground surface to a depth of 3 feet bgs and is considered available for contact for residents and workers. Subsurface soil is defined as soil present at depths from 3 feet to 10–15 feet bgs and is considered available for contact for construction workers and excavation workers only (ODEQ 2003). As a result of exposure considerations, sample results from AST-11, (19 to 20 feet bgs) and AST-12 (19 to 20 feet bgs) are excluded from the dataset used for statistical evaluation of data in Appendix L, Table L3-1.1b. The results are mapped on **Figure 4-1.**

6.2.2.1 Screening Process

The screening process is conducted in accordance with the QAPP (CDM 2008b) and ODEQ guidance (2000, 2003, 2007a, 2009d, and 2010a). All chemicals detected in Study Area media are considered as COIs and were subject to screening for identification of COPCs. The decision process for identifying COPCs is summarized as follows:

Frequency of Detection Screen

Chemicals detected at a frequency less than 5% in any given environmental medium are often excluded for further screening. COIs in the Study Area, however, were not eliminated on this basis, because total sample sizes for individual decision units are generally less than 20.

Background/Reference Screen for Inorganic Constituents in Soil and Sediment

- *Soil* – No Study Area-specific background soil samples were collected. ODEQ background soil/sediment values for arsenic, cadmium, lead, mercury, and selenium (ODEQ 2002) are used for screening against background concentrations. Maximum detected concentrations of these metals in soil were compared to ODEQ background values. Inorganic constituents were retained for further screening if maximum detected concentrations exceeded background values, or if no background concentration was available.

- *Sediment* – Study Area-specific reference concentrations for inorganic constituents acquired from sediments from the Aquatic - Reference Area were compared to concentrations in sediment samples collected from aquatic DUs. The reference area

was chosen to represent concentrations of sediment constituents unrelated to the former DoD activity within the Study Area. Concentrations of COI in the reference area are thus used as Study Area-specific reference concentrations. This comparison was performed by using marginal plots and hypothesis testing. Details of this screening process are provided in **Section 6.2.3.1**.

Concentration-Risk Screen

All COIs retained in background/reference screen were further evaluated in a concentration-risk screen, as required under ODEQ guidance. The concentration-risk screen is performed by comparing maximum detected concentrations or 90% upper confidence limits of mean concentrations (90%UCL) of each COI with a risk-based screening level. Where maximum concentrations of COI exceed screening levels, the COI is identified as a COPC, as described below.

- Individual COI Screen – compares maximum detected concentrations or the 90%UCL concentrations to respective SLs.
- Multiple COIs Screen – chemicals detected in a medium are evaluated in comparison to other chemicals detected in the same medium.
- Cross-Medium Screen – chemicals detected in one medium are evaluated in other related media to ensure that no chemical is inappropriately eliminated. The cross-medium screen is performed for those media that people are likely to come into contact under the same exposure scenario. For example, a worker engaging in excavation activities may come into contact with surface soil, subsurface soil, and groundwater in an excavation trench. Likewise, people visiting the shoreline may come into contact with surface water and sediment. Based on these considerations, soil and groundwater are grouped together and surface water and sediment are grouped together for the cross-medium screen.

The combination of surface water and sediment for cross-medium screen is conservative for TPMS and inclusion of chemicals identified by this combination assures risks are not underestimated. Beach areas and access along the TMPS shoreline are extremely limited. In most cases, the shoreline is vertical bulkhead dropping to riprap, such that access is limited and recreational opportunities practically non-existent.

The decision process for the concentration-risk screen has been divided into eight discrete steps, as discussed below and illustrated in **Figure 6-1**. These steps were developed in collaboration with ODEQ (CDM 2009a) to help navigate through the complex concentration-risk screen process. The first four steps involve screening of individual COI and screening of multiple COI as described previously. If a chemical passes individual and multiple COI screens, but is identified as a COPC during the cross-medium screen as described in Step 5, it is further evaluated in the screening process following procedures described in Steps 6 to 8. The concentration-risk screen process is summarized as follows:

- Steps 1 to 4: Individual COI screen and multi-COI screen.
- Step 5: All chemicals are evaluated in the cross-medium screen. If a chemical is identified as a COPC in Medium 2 based solely on the cross-medium screen (e.g., a chemical is identified as a COPC in surface water based only on identification as COPC in sediment), the screening process moves to Step 6. Chemicals in Medium 2 not otherwise identified as COPC in Steps 1 through 4 are eliminated as COPCs.
- Step 6: Is the chemical analyzed in Medium 2? If it is not analyzed in Medium 2, the chemical is retained as a COPC and is qualitatively evaluated in the uncertainty analysis of the HHRA; if it is analyzed in Medium 2, the screening process moves to Step 7.
- Step 7: Is the chemical detected in Medium 2? If it is detected in the medium, the chemical is retained as a COPC and is quantitatively evaluated in the HHRA; if the chemical is not detected in Medium 2, the screening process moves to Step 8.
- Step 8: If the chemical is not detected in Medium 2, the maximum SQL of the chemical is compared to the SL. If the maximum SQL exceeds the SL, the chemical is retained as a COPC and is qualitatively evaluated in the uncertainty analysis of the HHRA. If the maximum SQL is below the SL, the chemical is not a COPC in Medium 2 and further evaluation is not required.

6.2.2.2 Selection of Screening Levels

Screening levels are obtained from the most recent ODEQ and EPA sources. DU-specific screening levels are developed for TPHs. Details on selection of screening levels are provided in this section.

Screening levels for various media addressed in this assessment are obtained from the following hierarchical order of ODEQ and EPA sources. Risk-based SLs are not identified for calcium, magnesium, potassium, and sodium. These essential minerals are not evaluated as COPCs in health risk assessments.

<u>Surface Soil (0 to 3 ft bgs)</u>

- ODEQ (2009d) RBCs for soil (soil ingestion, dermal contact, and inhalation) for residential scenario
- EPA (2010) RSLs for residential soil
- DU-specific RBCs for TPH-D and TPH-G for residential soil

<u>Subsurface Soil (> 3 to 15 ft bgs) or Surface and Subsurface Soil Combined</u>

- ODEQ (2009d) RBCs for soil (soil ingestion, dermal contact, and inhalation) for construction worker
- EPA (2010) RSLs for industrial soil

- DU-specific RBCs for TPH-D and TPH-G for soil for construction worker

Groundwater

- ODEQ (2009d) RBCs for groundwater (ingestion and inhalation from tap water) for residential scenario
- EPA (2010) RSLs for tap water
- DU-specific RBCs for TPH-D and TPH-G for tap water

Surface Water

- ODEQ (2009b) water quality criteria for human health for consumption of water and organism (OAR 340-041 **Tables 33A and 33B**)
- National Recommended Water Quality Criteria for consumption of water and organism (EPA 2009d)
- ODEQ (2009d) RBCs for groundwater (ingestion and inhalation from tap water) for residential scenario
- EPA (2010) RSLs for tap water

Sediment

- ODEQ (2007a) Sediment Bioaccumulation Screening Level Values for humans
- ODEQ (2009d) RBCs for soil (soil ingestion, dermal contact, and inhalation) for residential scenario
- EPA (2010) RSLs for residential soil
- DU–specific RBCs for TPH-D and TPH-G for residential soil (for near-shore sediment only)

Soil Gas

- ODEQ (2009d) RBCs for residential air. To calculate soil gas screening levels, an attenuation factor of 200 is applied to RSLs for residential scenarios (UST Site 1) and an attenuation factor of 1,000 is applied to RSLs for industrial/commercial scenarios (Refueling Pit 3 and the Fire Training Area) (ODEQ 2010b).
- EPA (2010) RSLs for residential air. To calculate soil gas screening levels, an attenuation factor of 200 is applied to air RBCs for residential scenarios and an attenuation factor of 1,000 is used for industrial/commercial scenarios.
- EPA's Subsurface Vapor Intrusion Guidance (2002c) target shallow soil gas concentrations are used when RSLs and RBCs are not available. Since these concentrations are based on an attenuation factor of 10, an additional attenuation factor of 20 is applied to account for a total attenuation factor of 200 for residential scenarios.

An additional factor of 100 is applied to account for a total attenuation factor of 1,000 for industrial/commercial scenarios.

Methods for evaluating degradable hydrocarbons such as benzene include examination of oxygen levels in the vadose zone. Often, chemicals such as benzene in soil gas are degraded over short distances, and vapor migration is substantially overestimated using techniques appropriate for chlorinated volatile organic compounds. Although these methods were being refined in 2010, they were not integrated into the data collection and evaluations of this RI. Therefore, no correction for biodegradation was made either in the COPC screening or in the screening level risk assessment. Selection of degradable hydrocarbons as COPCs and estimation of risks due to vapor intrusion for these COPC are best viewed as worst case evaluations.

Risk-based SLs are not available for the following COIs: acenaphthylene, benzo(g,h,i)perylene, phenanthrene, endosulfan sulfate, n-heptane, thallium, 2,3,5-trimethylnaphthalene, and 2,2,4-trimethylpentane. Based on similarities in chemical structure and physiological activities, surrogate screening levels are used as indicated below.

- Pyrene is used as a surrogate for benzo(g,h,i)perylene and benzo(e)pyrene because they have similar four or more fused benzene rings.
- Endosulfan is used as a surrogate for endosulfan sulfate. Endosulfan sulfate is a breakdown product of endosulfan and has a structure similar to its parent compound.
- Fluoranthene is used as a surrogate for phenanthrene (ODEQ 2010a), again based on structural similarity.
- n-Heptane and 2,2,4-trimethylpentane are light molecular weight aliphatics belonging to C5-C8 aliphatic fractions. In accordance with ODEQ (2003), cyclohexane is used as a surrogate for these light weight molecular weight aliphatics.

Chemicals without screening levels or appropriate surrogates are retained as COPCs. However, they can only be qualitatively evaluated in the uncertainty analysis of the HHRA.

DU-specific TPH RBCs are calculated using the ODEQ spreadsheet for Calculating RBCs for Total Petroleum Hydrocarbons (http://www.deq.state.or.us/lq/rbdm.htm) and the following DU-specific data:

- TPH fraction data analyzed for VPH and EPH fractions
- Corresponding data for BTEX, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, and naphthalene

Analytical data used in the calculation and details of the TPH RBC calculations are provided in **Appendix L2**. DU-specific TPH RBCs are summarized in **Table 6-2**.

6.2.3 Identification of Chemicals of Potential Concern

Surface soil, subsurface soil or surface soil/subsurface soil, groundwater, surface water, sediment, and soil gas analytical data for each DU are summarized in Tables L3-1.1 to L3-9.1 in **Appendix L3.** These tables list the range of detected concentrations, detection frequencies, and range of SQLs. Background levels used for screening soil inorganic COIs to help identify COPCs are presented in these tables where applicable.

Note that characterization of sediments for TPMS utilized IMS. For TPMS, IS were composites of 28 subsamples collected at nodes of a grid. Each of these composite samples was analyzed seven times, and each result is, therefore, an estimate of the mean sediment concentration characterized by the 28 subsamples. After several analyses, the standard deviation of the results is an estimate of the standard error of the mean.

To use IMS, DUs are defined before sampling to include appropriate exposure units for human health and/or ecological risks. Within these units, population variance is not addressed by design (see **Sections 4.3.8.4 and 6.5.6.2**). Within DUs, only the mean concentration is needed as an appropriate exposure point concentration. Thus, when screening to identify COPC in sediments, all comparisons and statistical tests are based on comparison of mean concentrations.

6.2.3.1 Sediment Reference Screen

A screen based on comparison to reference concentrations for sediments is critical to the appropriate assessment of possible DoD-related releases from the TPMS. The Study Area is located in Cathlamet Bay on the lower Columbia River and a myriad of upstream sources have contributed a wide variety of contaminants to the river system in the past. These contaminants represent a substantial background against which sediments offshore of the TPMS must be compared.

Mean concentrations of inorganic constituents in sediment samples collected from the three aquatic DUs (North of Pier 8, Finger Piers, and the Near Landfill) are compared to concentrations measured in sediment from the aquatic reference area. Fourteen inorganic constituents, including antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, silver, vanadium, and zinc, were addressed. Comparisons were performed using marginal plots, Student's *t*-test, and Wilcoxon-Mann-Whitney (WMW) test.

A marginal plot expands a simple scatter plot by adding box plots in the margins. Scatter plots are prepared by assigning concentrations of a given inorganic constituent in sediment samples from an aquatic DU to the vertical axis and concentrations of the same constituent in sediment samples from the reference area to the horizontal axis. On each scatter plot is a diagonal line that represents perfect correspondence between

data sets. The more two data sets agree the more the scatters tend to cluster closely in the vicinity of the diagonal line; if two data sets are numerically identical, the scatters fall on the diagonal line exactly. When all points plot above the diagonal line, DU concentrations exceed those of the reference area. In contrast, when all points plot below the diagonal line, DU concentrations remain below reference area concentrations. The box plot along the top of the graph displays a simple data summary that includes minimum, median, maximum, and 25 and 75 percentile concentrations. The box plot on the right of the graph displays the same graphic summary for the constituent dataset from the aquatic DU. Marginal plots for inorganic constituents are presented in **Appendix L4** by DUs.

Marginal plots are combined with statistical hypothesis testing to complete the sediment reference screen. Both parametric and nonparametric statistical methods are employed for comparison of metal concentrations from an aquatic DU and those from the reference area. Parametric methods are used because IS results provide estimates of mean concentrations within DUs. Estimates of the mean are typically normally distributed and parametric methods are applicable. Since the number of results available to evaluate data distribution for each dataset was seven in most cases, nonparametric methods were used to evaluate differences without making assumptions about underlying distributions. The Student's two-sample *t*-test is used when a dataset follows a normal distribution. The WMW test is a nonparametric test for comparison between two populations without relying on data distributions. It evaluates differences by comparing the relative ranks of data points from two data sets when data from both sources are sorted into a single list.

The null hypothesis (H_0) and the alternative hypothesis (H_A) for the *t*-test and the WMW test to evaluate the mean of two populations are:

H_0: Mean concentration of a metal in the composite sample from an aquatic DU is less than or equal to that in the composite sample from the reference area.

H_A: Mean concentration of a metal in the composite sediment sample from an aquatic DU is greater than the concentration in the composite sample from the reference area.

For both hypothesis tests, an error rate is set at a 0.05 significance level. Hypothesis tests were performed using ProUCL Version 4.00.04.

The sediment reference screen is interpreted based on results obtained visually from the marginal plots combined with results from the statistical hypothesis tests. Details on the reference screen are presented in **Appendix L4**. Conclusions of the reference screen are discussed here and summarized in **Table 6-3**.

Consistent results from *t*-tests and WMW tests were typically obtained for all data sets, indicating that data distributions have no important effect on outcomes of hypothesis testing. Results of hypothesis testing are consistent with those obtained

visually from marginal plots. Concentrations of most metals in sediment from the three aquatic DUs are slightly higher than concentrations from the reference area. In most cases, the level of exceedance is quite small, indicating little difference in concentrations of metals in DU sediments compared to reference sediments. A few exceptions are noted. Concentrations of barium in reference sediments exceed those of the DUs. Copper concentrations in reference sediments exceed those of the Near Landfill DU. Concentrations of manganese in Finger Piers and the Near Landfill DUs are below or essentially the same as those of the reference area. Concentrations of selenium and silver in North of Pier 8 DU are below or nearly equal to those of the reference area. Selenium was not detected in sediments in Finger Piers and the Near Landfill DUs. Concentrations of vanadium in the Near Landfill DU are below or essentially equal to those of the reference area.

The results of the sediment evaluation are consistent with the conclusion that reference area and aquatic DU concentrations of inorganic constituents are similar and that no signature related to DoD past practices is obvious in aquatic DU sediments. This finding is not unexpected, since DoD operations ceased over 60 years ago. Subsequent and ongoing uses of the Study Area were and are not likely to release contaminants to sediments. This conclusion is supported by historical data that indicate the DoD-era releases are evident beneath at least 8 feet of sediments. The aquatic portions of the Study Area is depositional (2.1 inches per year) and any DoD-related releases to sediments are now buried to the extent that they are removed from the biotic zone (see **Section 4.3**).

This conclusion that concentrations of many sediment constituents are similar in reference area and DU sediments is supported by comparisons of current data with data collected in 1995 within the area now designated as the Finger Piers DU. These data were collected systematically and analyzed for a suite of inorganic constituents, cPAHs, diesel range petroleum hydrocarbons, and tributyltin (TBT). Thirty-two discrete samples were collected and analyzed, providing a data set to which current data can be compared. A detailed analysis is presented in **Section 4.3.9.4**; a summary of results of the comparison is provided here as it pertains to sediment screening.

In general, mean concentrations of inorganic constituents were very similar between data collected in 1995 and the IS from 2008. Moreover, the standard errors of these means were similar. These findings and the similar numbers of samples/subsamples in the two data sets, suggest that variability (or heterogeneity) in sediments represented by the two data sets is similar.

Profiles for organic constituents were different. In all three cases -- diesel range petroleum hydrocarbon, B(a)P and TBT -- concentrations reported in 1995 were much higher than concentrations reported from the IMS. For example, the mean concentration of TBT in 1995 was 28 times higher than the concentration reported in 2008. The reason(s) for these differences is/are not known. However, it is not likely the result of localized chemical heterogeneity being sampled in 1995 that was subsequently missed in 2008. Coefficients of variation for the 1995 data sets ranged

from 0.2 to 0.3, indicating low variability among samples. The differences between 1995 and 2008 mean concentrations appear to reflect lower concentrations in 2008.

No suggestion of ongoing release of diesel fuel, cPAH, or TBT is found in these data. Instead, sediments appear to be cleaner currently with respect to these constituents than in the past. Diesel fuel was used extensively during DoD operations at TPMS and this constituent could serve as a reasonable surrogate for releases from the site to sediments. Lack of evidence of any such release thus suggests that upland DUs, including AST, UST Site No.1, Refueling Pit 3 and UST Site No.4 are not current sources of COI to sediments.

TBT is interesting to note since this chemical was not in use at the time of historical DoD operations. Thus, it is a marker for releases from some source(s) subsequent to cessation of DoD activities. The decrease in concentration for TBT suggests that sediment deposited in and around the Finger Piers currently could be less affected by past upstream contamination than was sediment deposited in 1995. The parallel decrease in diesel range hydrocarbons, B(a)P and TBT could thus reflect the downward trend in concentrations of some COI reported for the lower Columbia River sediment in general. Again, data are entirely consistent with the transport of well-mixed sediment in the lower Columbia River, with subsequent deposition in Cathlamet Bay including offshore of TPMS.

Thus, sediment concentrations appear to represent sediment quality upstream of TPMS. The amount of sediment in the Lower Columbia River is quite large and the river system continues to receive input from numerous sources. Chemicals in these sources have and continue to move downstream with sediment and to deposit off-shore of TPMS. It seems reasonable that sediment quality would not change dramatically over the course of 15 years, given the large amount of sediment in the system and continuing input along the river. Recently deposited sediment and sediment deposited in 1995 are likely to be similar for many constituents.

The findings suggest that areas of significant high concentrations are unlikely to exist within the Finger Piers DU. Variability is low in the 1995 data sets, a result expected if the main source of sediment constituents is from upstream of TPMS. Since the 1995 data seem to corroborate 2008 data based on IMS, it is reasonable to conclude that localized areas of high concentrations for inorganic constituents and benzo(a)pyrene do not exist. This finding and the results of the sediment screening above provide strong evidence that TPMS has not been and is not currently a source of some important COI in surface sediments.

6.2.3.2 Calculation of Upper Confidence Limit Concentrations

In accordance with ODEQ 2003 guidance, the screening concentration used to select COPCs is the lowest of (1) the maximum detected concentration of a chemical in a given medium or (2) the 90%UCL of the mean concentration (Oregon Administrative Rule 340-122-2 0084[1][f]). However, maximum detected concentrations only are used for soil gas screening per ODEQ guidance (ODEQ 2010b).

Computation of 90%UCL concentrations is facilitated by the use of ProUCL (EPA 2009b). The ProUCL program tests a dataset for normal, lognormal, and gamma, distributions and provides additional UCL calculations to accommodate data sets that do not follow a defined distribution. UCLs are calculated using 5 parametric and 10 nonparametric methods, depending on data distribution.

- For normal distributions, the Student's *t*-statistic is used to calculate the UCL.
- For lognormal distributions, one of four different computation methods is used to calculate the UCL, depending on the skewness of the data set (as indicated by the standard deviation of log-transformed data) and sample size.
- For gamma distributions, one of two computation methods is used to calculate the UCL based on a "k value," which is the shape parameter of a gamma distribution. For values of $k \geq 0.1$, the exposure point concentration term is computed using an adjusted gamma UCL of the mean (when $0.1 \leq k \leq 0.5$) or an approximate gamma UCL of the mean (when $k > 0.5$). For values of $k < 0.1$, a UCL is obtained using either the bootstrap-t method or Hall's bootstrap method when the sample size is small (less than 15), or the approximate gamma for larger data sets.
- For data sets that do not fit defined distribution, ProUCL calculates and recommends a UCL from one 10 nonparametric methods (EPA 2009b).

ProUCL makes recommendations for appropriate UCL estimates only for calculation of 95th, or higher, percentiles. To determine an appropriate 90%UCL value, the method recommended for calculation of a 95%UCL is used to calculate a 90%UCL.

UCLs were not calculated for data sets with fewer than four detected concentrations. In such cases, maximum concentrations were used as the screen concentration. Maxima were also used for data sets 90%UCLs exceeded maximum detected concentrations.

Results of UCL calculations are presented in Tables L3-1.1 through L3-9.1 in **Appendix L3**. ProUCL outputs are presented in **Appendix L5**.

6.2.3.3 Chemicals of Potential Concern

The decision process for identifying COPCs through individual COI, multiple COIs, and cross-medium screens is provided in Tables C-1.1 to C-9.1 in **Appendix L3**. Chemicals identified as COPCs based solely on the cross-medium screen are further evaluated following procedures described in **Section 6.2.2.1**. Results of cross-medium COPC evaluation are presented in **Table 6-4**.

COPCs identified for further evaluation in the risk assessment are discussed below. Results and rationale for identifying COPCs in all nine DUs are summarized in **Tables 6-5 to 6-13**.

AST Fuel Storage Area (Table 6-5)

- *Soil* – Carcinogenic PAHs are identified as COPCs in surface soil. These chemicals are quantitatively evaluated in the HHRA. Although not analyzed in soil, arsenic is identified as a COPC in both surface and subsurface soil as a result of the cross-medium screen. Arsenic is retained for qualitative analysis.

- *Groundwater* – Arsenic is identified as a COPC in groundwater and is quantitatively evaluated in the HHRA. Carcinogenic PAHs were not detected in groundwater but are retained as COPCs as a result of the cross-medium screen. They are qualitatively evaluated in the HHRA. Note that the inclusion of cPAHs in this screen is a result of SQLs that exceed SLs. cPAHs were not detected in groundwater.

UST Site No.1 (Table 6-6)

- *Soil* – Carcinogenic PAHs, TPH-D, and TPH-G were detected in soil at concentrations below their respective SLs; however, they are identified as COPCs in subsurface soil because of the cross-medium screen. They are quantitatively evaluated in the HHRA. Arsenic and manganese were not analyzed in soil, but are identified as COPCs as a result of the cross-medium screen. Arsenic and manganese are qualitatively evaluated in the HHRA.

- *Groundwater* – Carcinogenic PAHs, arsenic, manganese, TPH-D, and TPH-G are identified as COPCs in groundwater and are quantitatively evaluated in the HHRA.

- *Soil Gas* – 1,2,4-Trimethylbenzene, 1,3,5-trimethylbenzene, benzene, chloroform, ethylbenzene, naphthalene, and PCE are identified as COPCs in soil gas and are evaluated quantitatively in the HHRA for intrusion of vapors into indoor air. 2-Propanol, 4-ethyltoluene, ethanol, and tetrahydrofuran are retained as COPCs because of the lack of SLs. They are qualitatively evaluated in the HHRA.

- *Surface Water (near shore at possible discharge location)* – Arsenic is identified as a COPC in surface water. Carcinogenic PAHs are detected in surface water only at concentrations below SLs; however, they are retained as COPCs as a result of the cross-medium screen. Arsenic and cPAHs are quantitatively evaluated in the HHRA. Total DDT was not analyzed in surface water, but is retained as a COPC as a result of the cross-medium screen. It is qualitatively evaluated in the HHRA. 2,3,5-Trimethylnaphthalene is retained as a COPC because of the lack of SL. It is qualitatively evaluated in the HHRA.

- *Sediment (near shore at possible discharge location)* – Carcinogenic PAHs, total DDT, and mercury were detected and are identified as COPCs in sediment. These chemicals are quantitatively evaluated in the HHRA. Arsenic is detected in sediment at concentrations below the SL; however, it is identified as a COPC as a result of the cross-medium screen. It is quantitatively evaluated in the HHRA.

Refueling Pit 3 (Table 6-7)

- *Soil* – TPH-G was detected in soil at concentrations below the SL; however, it is identified as a COPC as a result of the cross-medium screen. It is qualitatively evaluated in the HHRA. Arsenic was not analyzed in soil but is identified as a COPC because of the cross-medium screen. It is retained for qualitative evaluation.

- *Groundwater* – TCE, arsenic, and TPH-G are identified as COPCs in groundwater and are quantitatively evaluated in the HHRA.

- *Soil Gas* – 2-Propanol and 4-ethyltoluene are retained as COPCs because of the lack of SLs. They are qualitatively evaluated in the HHRA for intrusion of vapors into indoor air.

- *Surface Water (near shore at possible discharge location)* – Arsenic is identified as a COPC in surface water and is quantitatively evaluated in the HHRA. Total DDT was not detected in surface water; however, it is retained as a COPC as a result of the cross-medium screen and its maximum SQL exceeds the SL. Although not analyzed in surface water, total PCBs are identified as COPCs as a result of the cross-medium screen. Total DDT and total PCBs are qualitatively evaluated in the HHRA.

- *Sediment (near shore at possible discharge location)* – Carcinogenic PAHs, total DDT, total PCBs, arsenic, and mercury are identified as COPCs in sediment. They are quantitatively evaluated in the HHRA.

UST Site No. 4 (Table 6-8)

No COPCs are identified at UST Site 4. This DU is not further evaluated in the risk assessment.

Incinerator Building (Table 6-9)

Dioxin/furan TEQ is identified as COPC in surface soil. It is quantitatively evaluated in the HHRA. Thallium is retained as a COPC because of the lack of SL. It is qualitatively evaluated in the HHRA.

Fire Training Area (Table 6-10)

- *Soil* –. Carcinogenic PAHs and dioxin/furan TEQ were detected in soil at concentrations below their respective SLs; however, they are identified as COPCs as a result of the cross-medium screen. They are quantitatively evaluated in the HHRA. Manganese is not analyzed in soil but is identified as a COPC as a result of the cross-medium screen. It is qualitatively evaluated in the HHRA.

- *Groundwater* –Benzene, vinyl chloride, cPAHs, dioxin/furan TEQ, arsenic, and manganese are identified as COPCs in groundwater. They are quantitatively evaluated in the HHRA.

- *Soil Gas* – 1,3-Butadiene, benzene, chloroform, and PCE are identified as COPCs in soil gas and are quantitatively evaluated in the HHRA. 2-Hexanone, 2-propanol, 4-

ethyltoluene, and ethanol were retained as COPCs because of the lack of SLs. They are qualitatively evaluated in the HHRA.

- *Surface Water (near shore at possible discharge location)* – Arsenic is identified as a COPC in surface water and is quantitatively evaluated in the HHRA. Total DDT was not detected in surface water; however, it is retained as a COPC as a result of the cross-medium screen and its maximum SQL exceeds the SL. Although not analyzed in surface water, total PCBs are also identified as COPCs as a result of the cross-medium screen. Total DDT and total PCBs are qualitatively evaluated in the HHRA.

- *Sediment (near shore at potential discharge location)* – Carcinogenic PAHs, total DDT, total PCBs, lead, and mercury are identified as COPCs in sediment. They are quantitatively evaluated in the HHRA. Arsenic was detected in sediment at concentrations below the SL; however, it is identified as a COPC as a result of the cross-medium screen. It is retained for quantitative analysis.

Aquatic - North of Pier 8 (Table 6-11)

- *Surface Water* – Arsenic is the only chemical identified as a COPC in surface water and is quantitatively evaluated in the HHRA.

- *Sediment* – Carcinogenic PAHs, arsenic, cadmium, chromium, lead, mercury, and manganese are identified as COPCs in sediment and are quantitatively evaluated in the HHRA.

Aquatic - Finger Piers (Table 6-12)

- *Surface Water* – Arsenic is identified as a COPC in surface water and is quantitatively evaluated in the HHRA. Total DDT was not detected in surface water; however, it is retained as a COPC as a result of the cross-medium screen. Although not analyzed in surface water, total PCBs are identified as COPCs as a result of the cross-medium screen. Total DDT and total PCBs are qualitatively evaluated in the HHRA.

- *Sediment* – Carcinogenic PAHs, total DDT, total PCBs, arsenic, lead, and mercury are identified as COPCs in sediment. They are quantitatively evaluated in the HHRA.

Aquatic - Near Landfill (Table 6-13)

- *Surface Water* – Arsenic is identified as a COPC in surface water and is quantitatively evaluated in the HHRA. Dioxin/furan TEQ and total DDT were not detected in surface water; however, they are retained as COPCs as a result of the cross-medium screen. They are qualitatively evaluated in the HHRA.

- *Sediment* – Carcinogenic PAHs, dioxin/furan TEQ, total DDT, total PCBs, and mercury are identified as COPCs in sediment. They are quantitatively evaluated in the HHRA. Arsenic was detected in sediment at concentrations below the SL; however, it is identified as a COPC as a result of the cross-medium screen. It is retained for quantitative analysis.

6.3 Exposure Assessment

As a component of the human health risk assessment, the exposure assessment strives to predict human exposure to COPCs in affected media within the Study Area and in the vicinity. This exposure assessment describes exposure scenarios in which people may come into contact with study-area related COPCs, and provides equations and parameters to quantify exposure. Results of the exposure assessment are integrated with chemical-specific toxicity information to characterize potential risks in the HHRA in **Section 6.5**, Risk Characterization.

6.3.1 Conceptual Site Exposure Model

A conceptual site exposure model (CSEM) describes sources of chemicals at a Study Area, their release to and transport through environmental media (e.g., soil and air), and potentially affected media. These aspects of the exposure assessment are illustrated diagrammatically as a CSEM. The CSEM provides a roadmap to the HHRA and is crucial to understanding the release, fate, and transport of chemicals in a particular Study Area and to facilitate evaluating remedial technologies for specific media.

The preliminary CSEM developed for the QAPP was refined in this risk assessment based on analytical data collected during the RI field investigation (CDM 2008b). As a result, several CSEMs specific for DUs were developed. CSEMs are included as **Figures 6-2 through 6-6** for the six upland DUs and **Figure 6-7** for the aquatic DUs. These figures illustrate likely source areas, primary and secondary release/transport mechanisms, exposure media, potential exposure pathways, and potential human receptors.

6.3.1.1 Source Areas and Release Mechanisms

As previously described, primary source areas include AST Fuel Storage Area, UST Site No. 1, Refueling Pit 3, UST Site No. 4, the Incinerator Building, and the Fire Training Area DUs. UST Sites No. 1 and 4 and Refueling Pit 3 may have released petroleum products into the subsurface, and potential spills at the AST Fuel Storage Area are likely to have affected both surface and subsurface soil. The majority of soils affected by releases from UST Site No. 1, Refueling Pit 3, and UST Site No. 4 were excavated and disposed of offsite in accordance with ODEQ regulations. However, residual Study Area-related chemicals still exist in subsurface soil at these DUs. LNAPL is present in an isolated area adjacent to MW-19 of UST Site No. 1. Source areas associated with fuel storage and fueling operations are evaluated in this risk assessment using ODEQ methods, which include consideration of containerized petroleum hydrocarbons.

The remaining two source areas are only addressed using CERCLA guidance. Chemicals released as air emissions may have deposited as particles onto surface soil near the Incinerator Building. The Fire Training Area may be a historical source of chlorinated solvents, perhaps because these solvents were used during fire training exercises. Chlorinated organic chemicals are present in shallow groundwater at the

Fire Training Area. Fuels may have been used at the Fire Training Area, and petroleum hydrocarbons were identified as COPCs in soil and groundwater during COPC screening process. These hydrocarbons are excluded by CERCLA regulations, but risk calculations are available in Appendix L, **Tables L6-6.1.3, L6-6.1.4, L6-6.2.3, and L6-6.2.4.**

Some of the wastes associated with DoD activity were placed at the southern end of the Study Area in the Former Tongue Point Landfill. The landfill received construction debris and other solid wastes. Waste oil and diesel fuel, as well as sludge removed from mothballed ships, were reportedly burned in a pit or tank located within the landfill (URS Greiner Woodward Clyde 1999a). Chemicals associated with the landfill may have been released to sediments in Cathlamet Bay, although data justifying this conjecture are limited. Particularly, some monitoring data collected soon after the construction of the landfill suggested that dioxins/furans, PCBs, and PAHs have been present in landfill leachate. Data are not available that demonstrate a release to near-shore sediments adjacent to the landfill. A remedial action for the landfill was completed in 2003; it included removal of near-shore sediments, re-contouring, placement of a bentonite slurry wall, and ongoing recovery of LNAPL (petroleum product) with continued long-term groundwater monitoring. The landfill is therefore unlikely to be an ongoing source of COPCs.

Possible releases of materials from the landfill into Cathlamet Bay are considered in this risk assessment mainly through comparison of dioxin/furan concentrations and homolog profiles from reference area sediments to sediment concentrations and profiles from the Landfill DU. These comparisons are discussed in earlier sections of this RI report and subsequently uncertainties analysis later in this Section.

Past DoD operations may have resulted in releases in the area surrounding the finger piers. For example, fueling and maintenance of ships docked at the finger piers could have resulted in spills, leaks, or other releases of fuels, paints, and perhaps other materials to surface water, and some of these releases could have resulted in subsequent impact to sediments. Chemicals that may have been released during DoD activities are currently not accessible to biota in the aquatic DUs because of post-DoD sediment that has accumulated from 1962 to present. This layer of sediment separates chemicals associated with DoD activities from the sediment near-surface biotic zone. Cathlamet Bay is a depositional environment with little or no potential for scouring to expose DoD-era sediments. Currently, DoD era sediments can be considered "capped". Previous characterization of deeper sediments is available to evaluate future dredging that could exposure these sediments. The possible release of DoD era sediments is not addressed in this RI, or this HHRA.

6.3.1.2 Exposure Pathways

For risks to be realized, a complete exposure pathway must exist. A complete pathway requires the following elements (EPA 1989a):

- A source and mechanism for release of constituents

- A transport or retention medium
- A point of potential human contact (exposure point) with the affected medium
- An exposure route (e.g., ingestion, dermal contact, and inhalation) at the exposure point

If any of these elements is missing, no complete exposure pathway exists.

Based on analytical data from the RI, chemicals that may have been released from historical DoD activities are present in soil, shallow groundwater, and soil gas in the upland DUs. Constituents in surface water, surface sediment, and biota within finger pier DUs in Cathlamet Bay have a more tenuous connection to historical DoD activity, but are assessed because of the theoretical potential for ongoing releases from upland sources. Potential risks related to DoD activity in the Study Area and non-DoD activity risks and hazards associated with the aquatic DUs are discussed further in the risk characterization and uncertainties analysis.

Three exposure routes through which individuals could potentially be exposed to chemicals in these media are ingestion, inhalation, and dermal contact. For example, TPH released from the AST Fuel Storage Area may have contaminated surface soil in the vicinity. An adolescent trespasser may get small amounts of soil on his hands and subsequently transfer some of this soil to his mouth during common hand-to-mouth activity. Exposure would occur when this soil is swallowed and some contaminants in soil are absorbed in the gastrointestinal tract. This trespasser might get some soil on his/her skin and some constituents released from the AST might be absorbed through the skin. Finally, the trespasser could disturb soil such that some material is temporarily suspended in air as dust. Some of this dust may be inhaled and deposited into the deep lung.

Possible exposure pathways at the Study Area are:

- Direct contact with chemicals in soil (i.e., incidental ingestion, dermal contact, and inhalation of particulates and volatiles)
- Direct contact with chemicals in surface water and sediment in Cathlamet Bay (i.e., incidental ingestion and dermal contact)
- Direct contact with chemicals in groundwater during excavation activities (i.e., incidental ingestion and dermal contact)
- Direct contact with chemicals in groundwater while using as drinking water (i.e., ingestion, dermal contact, and inhalation)
- Consumption of fish and shellfish that may have accumulated chemicals from surface water and sediment

- Inhalation of vapors in indoor air as a result of subsurface vapor intrusion

Identification of these pathways does not imply that exposure is currently occurring or that such exposure is associated with significant human health risk. Instead, identification of exposure pathways as complete only suggests that the potential for exposure exists. Additional evaluation is necessary to determine the magnitude of human health risks.

Not all of the above exposure pathways are complete for each of the DUs. Potential exposure pathways associated with specific DUs are identified in the DU-specific CSEMs (**Figures 6-2 to 6-7**) and are discussed in the following sections.

6.3.1.3 Potential Receptors

Based on past release areas, current and anticipated future land uses, and identified potential exposure pathways, likely current and future receptors at the Study Area are identified as follows:

- Residents at the Job Corps Center housing units and future residents at UST Site No. 1
- Students of the Job Corps Center at UST Site No. 1
- Indoor workers at the Job Corps Center and future indoor workers at UST Site No. 1, Refueling Pit 3, and Fire Training Area
- Outdoor workers at the Incinerator Building
- Construction workers throughout the Study Area
- Trespassers at the AST Fuel Storage Area and the Incinerator Building
- Recreational users at UST Site No. 1, Refueling Pit 3, Fire Training Area, and three aquatic DUs
- Anglers at the three aquatic DUs

As indicated, current exposure pathways are limited and some receptors would only be present in the future over much of the Study Area (e.g., residents and workers over portion of the Study Area outside of the current Job Corps Center). Key characteristics of DUs and associated potential receptors are discussed next.

<u>AST Fuel Storage Area</u>

AST Fuel Storage was addressed using CERCLA guidance and ODEQ guidance; thus, risk for containerized petroleum hydrocarbons was characterized per ODEQ guidance. Chemicals associated with AVGAS, such as TPHs and PAHs, have been found in surface soil, subsurface soil, and shallow groundwater at the AST Fuel Storage Area. The AST Fuel Storage Area is located on USFWS property within the Tongue Point Eagle Sanctuary, where land use and public access are restricted.

However, the possibility exists that trespassers, especially adolescents, could still gain access to this area. While trespassing, they may be exposed to chemicals in surface soil via incidental ingestion, dermal contact, and inhalation of particulates and VOC in air. Students at the Job Corps Center may be the most likely trespassers at the AST Fuel Storage Area and, thus, are likely to be the most highly exposed individuals to surface soil at the AST Fuel Storage Area.

UST Site No. 1

UST Site No. 1 was addressed using CERCLA guidance and ODEQ guidance; thus, risk for petroleum hydrocarbons was characterized following ODEQ guidance. Residual petroleum fuel related chemicals are present in subsurface soil, shallow groundwater, and soil gas in UST Site No. 1. Some of these chemicals have been found in near-shore surface water and sediment in Cathlamet Bay.

Currently, UST Site No. 1 and its surrounding area are used as a Job Corps Center vocational training facility. On-property staff housing, the Tongue Point Street Housing Area, is located approximately 190 feet north/northeast of UST Site No. 1. Dormitory 4 is located within 50 feet of the UST Site No. 1. Additionally, an office building is situated directly adjacent to UST Site No. 1. This building contains two offices and a large area that functions as a common room and lounge for the students (**Figure 1-2**). Potential current and future receptors associated with UST Site No. 1 include residents, students, indoor workers, recreational users, and construction workers (**Figure 6-3**).

Residents

Currently, Job Corps Center residents have unrestricted access to the shoreline and could visit the shore or engage in water recreation activities in Cathlamet Bay. Most of the shoreline at the Study Area is, however, unattractive for recreational activities. In the finger pier areas, the shore is lined with riprap and is steep and difficult to negotiate. No actual beach areas exist. Thus, exposure to surface water and sediments for current and future residents is possible, but would most likely be limited and occur only infrequently in the summer. Current and future residents are evaluated for exposure to surface water and sediment in a swimming scenario. Routes of exposure include incidental ingestion of and dermal contact with surface water and sediment.

Tongue Point Street Housing is located approximately 190 feet north/northeast of UST Site No. 1. This distance indicates that the vapor intrusion pathway is incomplete for current residents. However, if residential houses were built close to the impacted area in UST Site No. 1 in the future, residents may be exposed to volatile COPC intruding from the subsurface into an enclosed building.

Future development of the shallow groundwater resource at the Study Area is unlikely; however, in theory, potable water wells could be installed in the future. Future residents could hypothetically be exposed to groundwater via domestic uses.

Because this exposure pathway is so unlikely, ingestion of drinking water is the only exposure route quantitatively evaluated for future residents.

For the risk assessment, a combined resident scenario with 6 years as a young child and 24 years as an adult is evaluated.

Students

Dormitory 4 of the Job Corps Center is located within 50 feet of the UST Site No. 1 source area. Current students could be exposed to Study Area-related chemicals in the subsurface via vapor intrusion.

Similar to residents, students of Job Corps Center could be exposed to surface water and sediment while swimming or engaging in water recreation activities. However, exposure to surface water and sediments would most likely be limited and occur only infrequently in summer. Students are evaluated for exposure to surface water and sediment in a swimming scenario. Routes of exposure include incidental ingestion of and dermal contact with surface water and sediment.

Indoor Workers

Workers who spend most of the workday indoors include, for example, office workers and teachers. Both current and future indoor workers may be exposed to vapor released from the subsurface into an enclosed building via vapor intrusion in the vicinity of UST Site No. 1.

Future development of shallow groundwater resource at the Study Area is unlikely; however, in theory, potable water wells could be installed in the future. Future indoor workers could be exposed to groundwater via ingestion of water while at work.

Recreational Users

Most of the landward portion of the Study Area adjacent to the finger piers is paved. The shoreline along the Job Corps Center and the finger pier area is constructed of boulder riprap fill extending approximately 6 to 10 feet horizontally. The boulder riprap fill comprises rock 2 to 4 feet in diameter extending vertically 5 to 7 feet above the mean high tide water level. No actual beach areas exist. The Study Area still has a configuration consistent with a working port, and the shoreline and waterway of Cathlamet Bay adjacent to the Study Area are not popular recreation destinations.

Upland access to the shoreline is restricted by perimeter fences and locked gates at the Job Corps Center. Although unlikely, current and future recreational visitors could gain access to the Study Area while engaging in water recreation activities in boats in Cathlamet Bay. The primary exposure medium for these activities would be water; although individuals may come in contact with sediments if boats are temporarily beached at the Study Area shoreline or via sediments that have been re-suspended in the water column. Routes of exposure under a recreational user scenario include

incidental ingestion of and dermal contact with surface water and sediment. Adult and adolescents (between 12 and 18 years in age) are selected as potential receptors.

Construction Workers

If construction occurs at UST No. Site 1 in the future, workers involved with the construction could be exposed to subsurface soils. If excavation for a building foundation or utility installation is performed, construction workers and utility workers might intercept shallow groundwater. Because a construction worker scenario is based on more frequent and longer exposure compared to an excavation worker scenario, exposure estimates for a construction worker are higher than those for an excavation worker. The construction worker exposure scenario will provide a conservative basis for evaluating potential exposures to other workers such as utility, phone, and cable company workers engaging in excavation activities. A separate excavation worker scenario is thus not quantitatively evaluated in the risk assessment. Routes of exposure under a construction worker scenario include incidental ingestion of soil, dermal contact with soil and groundwater, and inhalation of fugitive dust and volatiles in an excavation trench.

Refueling Pit 3

Refueling Pit 3 was addressed using CERCLA guidance and ODEQ guidance; thus, risk for petroleum hydrocarbons was characterized following ODEQ guidance. Residual petroleum fuel related chemicals are present in subsurface soil, shallow groundwater, and soil gas in Refueling Pit 3. Some of these chemicals have been found in near-shore surface water and sediment in Cathlamet Bay.

Currently, Refueling Pit 3 and surrounding areas are used as a Job Corps Center vocational training facility. Hangar 1 is used as a wood workshop as part of the training facility (**Figure 1-2**). This DU was and still is covered with concrete pavement approximately 12 to 18 inches thick extending to a seawall approximately 110 feet to the east. The area around Refueling Pit 3 is considered an unlikely future location for residential housing because it is located within the limited space of approximately 100 feet between Hangar 1 and the shoreline near industrial Pier 6. Potential current and future receptors associated with Refueling Pit 3 thus include indoor workers, recreational users, and construction workers (**Figure 6-4**).

Indoor Workers

Both current and future indoor workers may be exposed to vapor released from the subsurface into an enclosed building via vapor intrusion in the vicinity of Refueling Pit 3. However, all VOCs detected in soil gas at Refueling Pit 3 were eliminated in the screening process, except 2-propanol and 4-ethyltoluene. These two VOCs are retained as COPCs because of the lack of screening levels and toxicity values. Potential exposure and health risk associated with these chemicals are likely to be insignificant for indoor workers. Thus, exposure pathways associated with soil gas in Refueling Pit 3 are not evaluated quantitatively. A qualitatively evaluation is included in the uncertainties discussion.

Future development of the shallow groundwater resource at the Study Area is unlikely; however, in theory, potable water wells could be installed in the future. Future indoor workers could be exposed to groundwater via ingestion of water for an on-site well while at work.

Recreational Users

Similar to UST Site No. 1, the shoreline along Refueling Pit 3 is lined with riprap and is steep and difficult to negotiate. No actual beach areas exist. Upland access to the shoreline is restricted by perimeter fences and locked gates at the Job Corps Center. Although unlikely, current and future recreational visitors could gain access to the Study Area while engaging in water recreation activities in boats in Cathlamet Bay. The primary exposure medium for these activities could be water, although individuals may come in contact with sediments if boats are temporarily beached at the Study Area shoreline or via sediments that have been re-suspended in the water column. Routes of exposure under a recreational user scenario include incidental ingestion of and dermal contact with surface water and sediment. Adults and adolescents (between 12 and 18 years in age) are selected as potential receptors.

Construction Worker

If construction takes place at Refueling Pit 3, in the future workers could be exposed to subsurface soil and shallow groundwater during excavation for building foundations or utilities. Routes of exposure under a construction worker scenario include incidental ingestion of soil, dermal contact with soil and groundwater, and inhalation of fugitive dust and volatiles in an excavation trench.

UST Site No.4

No COPCs were identified for this UST Site No. 4 DU and it is not characterized further in the risk assessment.

Incinerator Building

This DU was address using only CERCLA guidance that excludes POL stored and used as fuels. The incinerator is located in an area removed from developed areas and at the bottom of a steep hillside immediately adjacent to the right of way of South Gate Road and the railroad. "Incinerator" is something of a misnomer for this small facility. The structure appears to have been a simple fire box with no controls on temperature, feed rate, or emissions. Apparently, the Navy used the fire box to burn papers that they wanted permanently destroyed. Nevertheless, the term incinerator has been used for this former facility for some time and this nomenclature is continued in this document.

The incinerator structure is abandoned. The area is currently overgrown with vegetation. Access to the incinerator is poorly controlled, however, and trespassers could and apparently have visited the area, as evidenced by bottles and other trash in the area. If construction takes place at the DU in the future, for example, to remove the incinerator structure, workers involved with the construction could be exposed to

chemicals in soil. Future outdoor workers could come into contact with soil while engaging in outdoor activities such as landscaping and maintenance operations. Future residential development on this DU is highly unlikely because of its steep topography and its proximity to the road and the railroad. Thus, potential current and future receptors associated with the Incinerator DU include current and future trespassers, and future outdoor workers and construction workers (**Figure 6-5**). These receptors may be exposed to soil via incidental ingestion, dermal contact, and inhalation of fugitive dust and volatiles.

A small amount of ash is still located in the firebox and chimney of the burner structure. The firebox is too small to enter, and exposure directly to ash does not appear likely. Thus, the approach to evaluating direct contact with soils assumes implicitly that ash will not be available for direct contact.

Fire Training Area

Residual petroleum fuel related chemicals and chlorinated organic chemicals are present in subsurface soil, shallow groundwater, and soil gas in the Fire Training Area. Some of these chemicals have been found in near-shore surface water and sediment in Cathlamet Bay.

This DU is being used for long-term storage of dredged materials. The northern part of the Fire Training Area is covered with concrete, and the eastern section is covered with gravel. The rest of the DU is covered with dredged material with an average height of approximately 10 feet above the original ground surface. The dredged sediment piles create a rough topography with heavy vegetation that presents a practical limitation on actual use of the property. Future use of the area is likely to remain industrial/commercial owing to its location adjacent to ongoing industrial activity and its being bordered to the south by the closed landfill. Potential current and future receptors associated with the Fire Training Area thus include indoor workers, recreational users, and construction workers (**Figure 6-6**).

Indoor Workers

The DU is currently vacant with no buildings or structures. The vapor intrusion pathway is thus incomplete under current scenario. However, if buildings were erected in the future, volatile chemicals in subsurface may potentially migrate into enclosed buildings via vapor intrusion. Future indoor workers may be exposed to indoor volatile COPCs via vapor intrusion.

Future development of the shallow groundwater resource at the Study Area is unlikely; however, in theory, potable water wells could be installed in the future. Future indoor workers could be exposed to groundwater via ingestion of water while at work.

Recreational Users

Most of the landward portion of the Study Area adjacent to the finger piers is paved. Along the southern area at piers 1 and 2 where the Fire Training Area is located, the

shoreline is covered with overgrown vegetation. No actual beach areas exist. Upland access to the shoreline is restricted by perimeter fences and locked gates at the ODSL properties. Although unlikely, current and future recreational visitors could gain access to the Study Area while engaging in water recreation activities in boats in Cathlamet Bay. The primary exposure medium for these activities would be water, although individuals could come in contact with sediments if boats are temporarily beached at the Study Area shoreline or via sediments that have been resuspended in the water column. Routes of exposure under a recreational user scenario include incidental ingestion of and dermal contact with surface water and sediment. Adults and adolescents (between 12 and 18 years in age) are selected as potential receptors.

Construction Workers

If construction takes place at the Fire Training Area in the future, workers involved in construction could be exposed to subsurface soils. If excavation for a building foundation or utility installation is performed, workers might intercept shallow groundwater. Routes of exposure under a construction worker scenario include incidental ingestion of soil, dermal contact with soil and groundwater, and inhalation of fugitive dust and volatiles in an excavation trench.

Aquatic DUs

Petroleum hydrocarbons (TPH-D and TPH-O), PAHs, total DDT, and metals are present in finger pier sediment in Cathlamet Bay. PAHs, lindane, and inorganic constituents are present in surface water. Some bioaccumulative chemicals such as total DDT, dioxins/furans, and some inorganic constituents were reported in fish and shellfish. However, most chemicals found in surface water, sediment, and biota from aquatic DUs are found in surface water, sediment, and biota from the upgradient reference area at similar concentrations. Therefore, the presence of these chemicals in the aquatic DUs is probably not related to previous DoD activities in the area. They may be attributable to other upstream source areas since the Columbia River receives surface water runoff and storm water discharge from various industrial and agricultural areas upstream. This issue is discussed in several later subsections of this HHRA.

The shoreline and waterway of Cathlamet Bay in the Study Area are not popular recreation destinations. Upland access to the Tongue Point shoreline is restricted by the perimeter fences and locked gates at Job Corps Center and the ODSL properties, and restricted access to the USFWS property. Although unlikely, people recreating or visiting the aquatic DUs in Cathlamet Bay could be exposed to chemicals in surface water, sediment, and fish and shellfish. Potential receptors for the aquatic DUs, thus, include recreational users and anglers (**Figure 6-7**).

Recreational Users

Although unlikely, current and future recreational users could gain access to the Study Area while engaging in water recreation activities in boats in the bay. Routes of exposure under a recreational user scenario include incidental ingestion of and

dermal contact with surface water and sediment. Adults and adolescents (between 12 and 18 years in age) are selected as potential receptors.

Anglers

The angler population is defined as those individuals who catch and consume fish from the Study Area. They may come into contact with surface water and sediment while fishing in Cathlamet Bay or engaging in shoreline activities such as clamming at low tides. Further, fish and shellfish caught or collected at the aquatic finger pier area could be impacted with chemicals. Routes of exposure under an angler scenario include incidental ingestion of and dermal contact with surface water and sediment, and ingestion of fish/shellfish. Adult anglers are selected as potential receptors.

6.3.1.4 Summary of Exposure Pathways

The following exposure pathways are considered to be complete and are quantitatively evaluated in the HHRA. Summaries of these exposure pathways are graphically illustrated in **Figures 6-2 through 6-6** for the six upland DUs and in **Figure 6-7** for the aquatic DUs.

AST

Current and Future Land-Use Scenarios

- Trespassers as adolescents 12 to 18 years old. Exposure to surface soil through incidental ingestion, dermal contact, and inhalation of particulates and volatiles.

UST Site No. 1

Current Land-Use Scenario

- Indoor workers exposure to indoor air (vapor intrusion) through inhalation.
- Residents - swimming scenario exposure to surface water through incidental ingestion and dermal contact and exposure to sediment through incidental ingestion and dermal contact.
- Students (adult) exposure to indoor air (vapor intrusion) through inhalation**.** Exposure to surface water through incidental ingestion and dermal contact and exposure to sediment through incidental ingestion and dermal contact.
- Recreational users as adults and adolescents (12 to 18 years old), exposure to surface water through incidental ingestion and dermal contact and exposure to sediment through incidental ingestion and dermal contact.

Future Land-Use Scenario

- Indoor workers exposure to indoor air (vapor intrusion) through inhalation. Exposure to groundwater through ingestion.
- Residents exposure to indoor air (vapor intrusion) through inhalation. Exposure to groundwater through ingestion. Exposure to surface water through incidental

ingestion and dermal contact. Exposure to sediment through incidental ingestion and dermal contact.

- Construction workers exposure to soil through incidental ingestion, dermal contact, and inhalation of particulates and volatiles. Exposure to groundwater through dermal contact and inhalation of volatiles.

- Recreational users adults and adolescents (12 to 18 years old) exposure to surface water through incidental ingestion and dermal contact. Exposure to sediment through incidental ingestion and dermal contact.

Refueling Pit 3

Current Land-Use Scenario

- Indoor workers (qualitative evaluation only) exposure to indoor air (vapor intrusion) through inhalation.

- Recreational users adults and adolescents (12 to 18 years old) exposure to surface water through incidental ingestion and dermal contact. Exposure to sediment through incidental ingestion and dermal contact.

Future Land-Use Scenario

- Indoor workers (qualitative evaluation only) exposure to indoor air (vapor intrusion) through inhalation. Exposure to groundwater through ingestion.

- Construction workers exposure to soil through incidental ingestion, dermal contact, and inhalation of particulates and volatiles. Exposure to groundwater through dermal contact and inhalation of volatiles.

- Recreational users adults and adolescents (12 to 18 years old) exposure to surface water through incidental ingestion and dermal contact. Exposure to sediment through incidental ingestion and dermal contact.

UST Site No. 4.

No COPCs were identified for this DU and further evaluation of this DU was not performed.

Incinerator

Current Land-Use Scenario

- Trespassers adolescents (12 to 18 years old) exposure to surface soil through incidental ingestion, dermal contact, and inhalation of particulates and volatiles.

Future Land-Use Scenario

- Trespassers adolescents (12 to 18 years old) exposure to surface soil through incidental ingestion, dermal contact, and inhalation of particulates and volatiles.

- Construction workers exposure to surface soil through incidental ingestion, dermal contact, and inhalation of particulates and volatiles.

- Outdoor workers exposure to surface soil through incidental ingestion, dermal contact, and inhalation of particulates and volatiles.

Fire Training Area

Current Land-Use Scenario

- Recreational users adults and adolescents (12 to 18 years old) exposure to surface water through incidental ingestion and dermal contact. Exposure to sediment through incidental ingestion and dermal contact.

Future Land-Use Scenario

- Indoor workers exposure to indoor air (vapor intrusion) through inhalation, groundwater, and ingestion.

- Construction workers exposure to soil through incidental ingestion, dermal contact, and inhalation of particulates and volatiles. Exposure to groundwater through dermal contact, and inhalation of volatiles.

- Recreational users, as adults and adolescents (12 to 18 years old) exposure to surface water through incidental ingestion and dermal contact. Exposure to sediment through incidental ingestion and dermal contact.

Aquatic DUs – Near Landfill, Finger Piers, and North of Pier 8

Current and Future Land-Use Scenarios

- Recreational users adults and adolescents (12 to 18 years old) exposure to surface water through incidental ingestion and dermal contact. Exposure to sediment through incidental ingestion and dermal contact.

- Anglers exposure to surface water through incidental ingestion and dermal contact. Exposure to sediment through incidental ingestion and dermal contact. Exposure to fish/shellfish through ingestion.

6.3.2 Exposure Point Concentrations

Exposure point concentrations (EPCs) are concentrations of COPCs in a particular exposure medium at locations where human exposure may occur. In this HHRA, EPCs for direct exposure to soil, groundwater, surface water, and sediment are estimated directly using Study Area data. EPCs in air and indoor air are modeled using methods described in **Section 6.3.5**.

In accordance with ODEQ (2000a and 2010a) risk assessment guidance, for most media EPCs are maximum concentrations of COPC either in a given medium or as 90% UCLs on mean concentrations, whichever is lower. Details on how to calculate 90%ULC are provided in **Section 6.2.3.2**. Statistics, data distribution, UCLs of mean

concentrations, and mean concentrations for COPCs to be quantitatively evaluated in the risk assessment are summarized in **Table 6-14**. As shown in **Table 6-15**, maximum concentrations are used as EPCs for soil gas for vapor intrusion assessment (ODEQ 2010b).

6.3.3 Exposure Parameters

Estimates for intake of COPCs into the body are a key component of quantitative risk assessment. Chemical intakes are expressed in terms as the mass of substance taken into the body per unit body weight per unit time, typically milligrams per kilogram per day. Intakes are calculated as a function of chemical concentration, uptake rate, exposure frequency and duration, body weight, and average time. Assumptions for some of these variables are dependent on conditions specific to the Study Area and characteristics of potentially exposed populations.

It is not possible to estimate accurately exposures for individuals in an exposed population because (1) behavior patterns for individuals in these populations change over time, (2) day-to-day behaviors vary among individuals within a population, and (3) individual variation exists in important parameters such as inhalation rate and body weight. In this risk assessment, the exposure assessments address reasonable maximum estimates for exposures that could conceivably occur in a population. Reasonable maximum exposure (RME) is defined as exposure above the 90th percentile of the mean of the population distribution. The intent of RME is the estimate a conservative exposure case (well above the average) that is still within the range of possible exposures.

Exposure parameters for potential receptors are obtained from ODEQ and EPA guidance as much as possible. Study Area-specific parameters are used when available. RME parameters used in the risk assessment are provided in **Tables 6-16 to 6-21**. Chemical-specific properties used in intake calculations are presented in **Table 6-22**.

6.3.3.1 Residents

Current residents at the Study Area include staff of the Job Corps Center and their family members. Their exposure pattern, such as exposure frequency and exposure duration, is similar to that of industrial/commercial workers. Therefore, they are assumed to stay at the housing units for 250 days per year. Future residents are assumed to be exposed for 350 days per year (EPA 1991a). The total duration for residents is assumed to be 30 years (EPA 1991a): 24 years as an adult and 6 years as a young child. Residents are expected to be the most frequent recreational users of the site. Recreational users are discussed in **Section 6.3.3.6**.

A life expectancy of 70 years (EPA 1989a) is used for all receptor groups as the averaging time for exposure to carcinogenic chemicals. The averaging time for noncarcinogenic effects is equal to the exposure duration. A body weight of 70 kg is used for all adult residents and 15 kg for children (0 to 6 years old) under both scenarios (EPA 1991a, 2008a).

Noncarcinogenic exposure is estimated based on exposures only during the 6 years of childhood, excluding exposures experienced during adulthood. The rationale for this approach is because young children generally have higher relative intake rates when compared to older children and adults. The child resident exposure scenario provides a conservative basis for evaluating potential noncarcinogenic exposures to all other age groups.

Carcinogenic exposure estimates throughout a lifetime are affected by age-dependent intake factors. To account for the differences in daily ingestion rates, body weights, and exposure durations for young children and adults, age-adjusted intake factors are used for carcinogenic exposure estimates (EPA 1991b). This is accomplished by using factors for a child for the first years of exposure and adult factors for the remainder of the exposure period.

Groundwater

For groundwater ingestion exposure parameters, adult residents are assumed to consume 2 L of water per day (EPA 1991a). A water intake rate of 1 L/day is assumed for child residents based on a 95th percentile drinking water ingestion rate for children 0 to 6 years old (EPA 1991a, 2008a).

Surface Water and Sediment

Current and future residents are assumed to be exposed to COPCs in surface water and sediment. The incidental ingestion rate recommended by EPA (2008a) for surface water while swimming is 20 mL/hour for people between 18 and 21 years of age and 50 mL/hour for children between 6 and 15 years of age. The 20 mL/hour rate is used for adult residents; the 50 mL/hour rate is used for child residents.

It is assumed that the total body surface is exposed during swimming. Skin surface areas available for surface water contact for adults and children, respectively, are 18,000 cm^2 and 6,900 cm^2. The total body surface area for adults is based on the 50th percentiles for males and females (EPA 1997); the value for child residents is based on the weighted average total body surface area for children ages 0 to less than 6 years (EPA 2008b). For dermal contact with sediment, the assumed exposed skin surface area is limited to the head, hands, forearms, lower legs, and feet. Skin surface areas available for contact for adults and children, respectively, are 6,900 cm^2 and 2,740 cm^2. The value for adults is based on the 50th percentiles for males and females (EPA 1997); the value for children is based on weighted average surface area for children ages 0 to less than 6 years (EPA 2008a).

For the sediment exposure pathway, a dermal adherence factor of 0.3 mg/cm^2 is assumed for adults, based on the 50th percentile weighted adherence factor measured for reed gatherers (EPA 2004a), the activity determined to represent a reasonable, high-end contact for creek or pond sediments. A sediment adherence factor of 3.6, based on surface area weighted adherence factor for children ages 0 to less than 6 years playing in sediment (EPA 2008a), is used for child residents. Chemical-specific

dermal absorption fractions and dermal permeability coefficients for COPCs are presented in **Table 6-22** (EPA 2004a).

Both the adult and child residents are assumed to be exposed to COPCs in sediment and surface water two days per week from May to September (22 weeks); thus, it is assumed that exposure frequency is 44 days per year. An exposure time of 2 hours per day is assumed (EPA 2009a).

6.3.3.2 Students

In the current land-use scenario, students at the Job Corps Center are assumed to be exposed to COPCs in surface water and sediment in near-shore areas at UST Site No. 1. Additionally, students in Dormitory 4 are assumed to be exposed to volatile COPCs in subsurface via inhalation of vapors intruding from subsurface into buildings.

Job Corps Center students are assumed to stay at the housing units for 330 days per year. The total duration for students is assumed to be 2 years. These parameters are based on Study Area-specific data as described in **Section 2**. An exposure time of 24 hours per day for the inhalation exposure is used for students, based on the recommended value for residents (EPA 2009a). All other exposure parameters for students are the same as the adult resident values defined in **Section 6.3.3.1**. Note that exposure durations for students do not meet EPA's definition of chronic exposure (7 years or longer). This issue is discussed further in the toxicity assessment (**Section 6.4.2**) and in the uncertainties analysis (**Section 6.5.6**).

6.3.3.3 Workers

Indoor and outdoor workers are assumed to be exposed for 250 days per year (EPA 1991a). The exposure duration for workers is 25 years, based on the 95th percentile value for job tenure for men in the manufacturing sector (EPA 1991a).

A life expectancy of 70 years (EPA 1989a) is used for all receptor groups as the averaging time for exposure to carcinogenic chemicals. The averaging time for noncarcinogenic effects is equal to the exposure duration, or 25 years. A body weight of 70 kg is assumed (EPA 1991a).

<u>Indoor Workers</u>

Current and future indoor workers at UST Site No. 1 (office building) and Refueling Pit 3 (Hangar 1), and future indoor workers at UST Site No. 1, Refueling Pit 3, and Fire Training Area, are assumed to be exposed to COPCs in subsurface via inhalation of vapors emanating from subsurface into buildings.

Although unlikely, future indoor workers are also assumed to be exposed to COPCs in groundwater via ingestion of groundwater as drinking water. Indoor workers are assumed to consume 1 L/day of water (EPA 1991a).

Outdoor Workers

Future outdoor workers at the Incinerator DU are assumed to be exposed to surface soil. The incidental soil ingestion rate of outdoor workers is assumed to be 100 mg/day (EPA 2002a). For dermal contact with soil, the worker is assumed to wear a short-sleeved shirt, long pants, and shoes; therefore, the exposed skin surface is limited to the head, hands, and forearms. The resulting exposed skin surface area is 3,300 cm^2, the average of the 50th percentile for males and females greater than 18 years of age (EPA 2004a). A dermal adherence factor of 0.2 mg/cm^2 is assumed (EPA 2002a). The chemical-specific dermal absorption fractions for COPCs are presented in **Table 6-22**.

6.3.3.4 Trespassers

In current and future use scenarios, adolescent trespassers (12 to 18 years old) are assumed to be exposed to COPCs in surface soil at the AST Fuel Storage Area and the Incinerator Building via incidental ingestion, dermal contact, and inhalation of fugitive dust and volatiles. Exposure time and frequency for trespassers are assumed to be 2 hours per day for 100 days per year (EPA 2009a). Exposure duration for adolescent trespassers is 6 years.

In the absence of soil ingestion rate for adolescents, the rate for children in the 1 to less than 6 years old age range of 100 mg/day (EPA 2008b) or 10 mg/hour, assuming a residential exposure time of 10 hours per day based on professional judgment, is used. For dermal contact with soil, the trespasser is assumed to wear a short-sleeved shirt, shorts, and shoes; therefore, exposed skin surface is limited to the head, hands, forearms, and lower legs. Exposed skin surface area is 5,700 cm^2, based on the weighted average surface area for head, hands, forearms, and lower legs for children ages 11 to 21 years (EPA 2008b). A soil adherence factor of 0.07, based on surface area weighted soil adherence factor for children between 11 to 21 years of age playing in soil activities (EPA 2008b). The chemical-specific dermal absorption fractions for COPCs are presented in **Table 6-22**.

A life expectancy of 70 years (EPA 1989a) is used for all receptor groups as the averaging time for exposure to carcinogenic chemicals. The averaging time for noncarcinogenic effects is equal to the exposure duration, or 6 years. A body weight of 64 kg is used for adolescents, based on average mean body weight for children ages 11 to 21 years (EPA 2008a).

6.3.3.5 Construction Workers

Exposure pathways evaluated for future construction workers at UST Site No. 1, Refueling Pit 3, Incinerator Building, and Fire training Area include incidental ingestion of and dermal contact with soil and inhalation of volatiles and particulates. Future construction workers are assumed to come into contact with groundwater via dermal contact and inhalation of vapors while engaging in excavation activities in a construction trench.

For the soil ingestion exposure pathway, construction workers are assumed to ingest 330 mg of soil per day (EPA 2002a). This value is based on the 95th percentile value for adult soil intake rates for short exposure frequencies and durations (EPA 2002a). For dermal contact with soil, the construction worker is assumed to wear a short-sleeved shirt, long pants, and shoes; therefore, the exposed skin surface is limited to the head, hands, and forearms. Exposed skin surface area for workers is 3,300 cm^2, the average of the 50th percentile for males and females greater than 18 years of age (EPA 2002a). A dermal adherence factor of 0.3 mg/cm^2 is assumed (EPA 2002a), corresponding to the 95th percentile value that has been measured for construction workers. For dermal contact with groundwater, exposed skin surface area for construction workers is 5,700 cm^2 (ODEQ 2003). The chemical-specific dermal absorption factors for COPCs are presented in **Table 6-22**.

All but the Fire Training Area are significantly less than 1 acre (UST Site No. 1, 0.46 acre; Refueling Pit 3, 0.84 acre; and the Incinerator Building, 0.27 acre), and any construction, particularly excavation and foundation work, would be very unlikely to require an entire year to complete. Excavation and foundation work are tasks most likely to be associated with intimate contact with chemicals in surface or subsurface soil. Thus construction workers are assumed to be exposed to soil for 100 days per year. A possible exception is the Fire Training Area. This area is larger (approximately 5.5 acres), and excavation and foundation activities could go on for a longer period of time. Thus, the risk assessment uses an exposure frequency of 250 days per year for the Fire Training Area. Construction workers are anticipated to spend much less time, i.e., one-third of time, engaging in excavation activities in a trench when they may potentially come into contact with shallow groundwater. Thus, they are assumed to be exposed to groundwater for 4 hours per day (ODEQ 2003) for 34 days per year for UST Site No. 1, Refueling Pit 3, and the Incinerator Building under the RME scenario. For the Fire Training Area, they are assumed to be exposed to groundwater for 4 hours per day for 84 days per year. The exposure duration for construction workers is 1 year.

A life expectancy of 70 years (EPA 1989a) is used for all receptor groups as the averaging time for exposure to carcinogenic chemicals. The averaging time for noncancer effects is equal to the exposure duration, 365 days. A body weight of 70 kg is assumed for construction workers (EPA 2002a).

6.3.3.6 Recreational Users

Recreational users are evaluated for exposure to COPCs through incidental ingestion of and dermal contact with surface water and sediment while engaging in water recreation activities in Cathlamet Bay. Adults and adolescents (12 to 18 years old) are selected as potential receptor populations for the recreational scenario.

Both the adult and adolescent recreational users are assumed to spend 2 days per week from May to September (22 weeks) in Cathlamet Bay. Assuming 22 weeks, the RME exposure frequency is 44 days per year. An exposure time of 2 hours per day is assumed (EPA 2009a).

Recreational users are assumed to be nearby residents; thus, the exposure duration for adult recreational user is assumed to be 24 years. The exposure duration for adolescents is 6 years.

The incidental ingestion rate recommended by EPA (2008b) for surface water while swimming is 20 mL/hour for people ages 18 to 21 years and 50 mL/hour for children ages 6 to 15 years. Incidental ingestion of surface water while engaging in water recreation activities is unlikely to occur at the same rate as swimming; thus the incidental ingestion rate is assumed to be one-tenth the water ingestion rate for a swimming scenario, or 2 mL/hour for adults and 5 mL/hour for adolescents. In the absence of ingestion rates for sediment, a mean soil ingestion rate of 100 mg/day or 10 mg/hour (assuming a residential exposure time of 10 hours per day) for children between 1 to 21 years in age is used (EPA2008a) for adolescents. One-tenth of the mean soil ingestion rate for adult residents, or 5 mg/hour, is used for adult recreational users (EPA 1997c).

For dermal contact with surface water and sediment, recreational users are assumed to wear a short-sleeved shirt and shorts (with permeable shoes); therefore, exposed skin is limited to the face, hands, forearms, lower legs, and feet. For adolescents, exposed skin surface area is 5,900 cm^2, based on the weighted average surface area for face, hands, forearms, lower legs, and feet for children ages 11 to 21 years (EPA 2008a). For adults, exposed skin surface area is 6,100 cm^2, based on the 50th percentiles for males and females (EPA 1997c). For the sediment exposure pathway, a dermal adherence factor of 0.3 mg/cm^2 is assumed for adults, based on the 50th percentile weighted adherence factor measured for reed gatherers (EPA 2004a). A sediment adherence factor of 4.8, based on surface area weighted adherence factor for children ages 11 to 21 years playing in sediment (EPA 2008a), is used for adolescents. The chemical-specific dermal absorption fractions for COPCs are presented in **Table 6-22**.

A life expectancy of 70 years (EPA 1989a) is used for all receptor groups as the averaging time for exposure to carcinogenic chemicals. The averaging time for noncancer effects is equal to the exposure duration. A body weight of 70 kg is used for adult recreational users and 64 kg for adolescents, based on average mean body weight for children ages 11 to 21 years (EPA 2008a).

6.3.3.7 Anglers

Anglers are assumed to be exposed to COPCs through incidental ingestion of and dermal contact with surface water and sediment while fishing and clamming, and ingestion of fish/shellfish caught from Cathlamet Bay at the Near Landfill, Finger Piers, and North of Pier 8 aquatic DUs. Adults are selected as potential receptor populations for the angler scenario.

Anglers are assumed to fish in the Study Area for 2 days per week from May to September. Assuming 22 weeks, the exposure frequency is 44 days per year. They are assumed to fish for 4 hours per day, based on professional judgment. Anglers are

assumed to be nearby residents; thus, the exposure duration is assumed to be 24 years.

The incidental ingestion rate recommended by EPA (2008a) for surface water while swimming is 20 mL/hour for people ages 18 to 21 years. Incidental ingestion of surface water while fishing is unlikely to occur at the same rate as swimming; thus, the incidental ingestion rate is assumed to be one-tenth the water ingestion rate, or 2 mL/hour, for a swimming scenario. In the absence of ingestion rates for sediment, the mean soil ingestion rate for adult residents of 50 mg/day (EPA 1997c), or 5 mg/hour assuming a residential exposure time of 10 hours per day based on professional judgment, is used for anglers (EPA 1997c).

For dermal contact with surface water and sediment, anglers are assumed to wear a short-sleeved shirt and shorts (permeable shoes); therefore, exposed skin is limited to the face, hands, forearms, lower legs, and feet. Exposed skin surface area is 6,100 cm^2, based on the average 50th percentile value for males and females (EPA 2004a). For the sediment exposure pathway, a dermal adherence factor of 0.3 mg/cm^2 is assumed, based on the 50th percentile weighted adherence factor measured for reed gatherers (EPA 2004a). The chemical-specific dermal absorption fractions for COPCs are presented in **Table 6-22**.

Fish ingestion rate is assumed to be 17.5 g/day based on ODEQ's recommendation (2009a). The exposure frequency for fish ingestion is assumed to be 350 days per year.

A life expectancy of 70 years (EPA 1989) is used for all receptor groups as the averaging time for exposure to carcinogenic chemicals. The averaging time for noncancer effects is equal to the exposure duration. A body weight of 70 kg is used for anglers.

6.3.4 Daily Intake Calculations

Exposure to COPCs in soil, groundwater, surface water, sediment, and fish/shellfish is expressed as daily intake (DI), which is the estimated daily chemical dose for an individual averaged over the exposure duration for each exposure scenario. The DI for each exposure route is provided in this section. Exposure point concentrations for soil, groundwater, surface water, and sediment are summarized in **Table 6-14**. Exposure parameters used in the DI calculation are provided in **Tables 6-16 to 6-21**. Chemical-specific properties used in the DI calculations are presented in **Table 6-22**.

The DI for ingestion is calculated by Equation 6-1:

$$DI_o = \frac{EPC \times IR \times EF \times ED \times CF}{BW \times AT} \qquad (6-1)$$

where:

DI_o	=	daily intake from oral exposure (mg/kg-day)
EPC	=	chemical-specific exposure point concentration (µg/L, mg/kg, or µg/kg)
IR	=	ingestion rate (mg/day for soil and sediment and L/day for water; g/day for fish/shellfish ingestion)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
CF	=	conversion factor varies depending on scenario (soil, sediment, water or fish/shellfish ingestion)
BW	=	body weight (kg)
AT	=	averaging time (days), equivalent to the ED for noncarcinogens and 70 years for carcinogens

The DI for dermal exposure from water is given by Equation 6-2:

$$DI_{dw} = \frac{EPC \times SA \times PC \times EF \times ED \times CF}{BW \times AT} \qquad (6-2)$$

The DI for dermal exposure from soil or sediment is given by Equation 6-3:

$$DI_{ds} = \frac{EPC \times SA \times AF \times ABS \times EF \times ED \times CF}{BW \times AT} \qquad (6-3)$$

where:

DI_{dw}	=	daily intake from dermal exposure to water (mg/kg-day)
DI_{ds}	=	daily intake from dermal exposure to soil or sediment (mg/kg-day)
EPC	=	chemical-specific exposure point concentration (µg/L or mg/kg)
SA	=	skin surface area exposed (cm^2)
PC	=	permeability constant (cm/hour)
AF	=	soil/sediment adherence factor (mg/cm^2)
ABS	=	dermal absorption faction from soil/sediment (unitless)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
CF	=	conversion factor (mg/1000 µg)
BW	=	body weight (kg)
AT	=	averaging time (days), equivalent to the ED for noncarcinogens and 70 years for carcinogens

6.3.5 Inhalation Exposure Algorithms

In accordance with EPA Risk Assessment Guidance for Superfund, Part F, Supplemental Guidance for Inhalation Exposure (EPA 2009a), inhalation exposure could be categorized as acute, subchronic, and chronic exposures, based on exposure duration and exposure pattern. Chronic exposure is generally used for continuous or near-continuous inhalation exposures that occur for 7 years or more. Subchronic exposure refers to repeated exposures for more than 30 days up to 7 years. Acute exposure includes exposures lasting 24 hours or less or intermittent exposures that occur at a series of short periods (e.g., 4 hours) separated by several days of no exposure.

6.3.5.1 Inhalation Exposure for Receptors

Based on exposure duration and exposure pattern, inhalation exposure for selected receptor populations is classified as follows:

- Chronic exposure
  - *Indoor workers* - inhalation of indoor air via vapor intrusion
  - *Outdoor workers* – inhalation of particulates and volatiles released from soil
- Subchronic exposure
  - *Students* - inhalation of indoor air via vapor intrusion
  - *Construction workers* - inhalation of particulates and volatiles released from soil, inhalation of volatiles from groundwater
- Acute exposure
  - *Trespassers* - inhalation of particulates and volatiles released from soil

Exposure concentrations for inhalation exposure to carcinogens and chronic and subchronic exposure to noncarcinogens are calculated as shown in Equation 6-4 (EPA 2009a):

$$EC = \frac{CA \times ET \times EF \times ED}{AT} \qquad (6-4)$$

where:

EC	=	exposure concentration, $\mu g/m^3$
CA	=	concentration in air, $\mu g/m^3$
ET	=	exposure time, hours/day
EF	=	exposure frequency, days/year
ED	=	exposure duration, years
AT	=	averaging time, hours, equivalent to the ED for noncarcinogens

and 70 years for carcinogens

Exposure concentrations for acute exposure to noncarcinogens are given as Equation 6-5 (EPA 2009a):

$$EC = CA \qquad (6-5)$$

$$CA = \frac{CS}{PEF\ or\ VF} \qquad (6-6)$$

Concentration of particulates or volatile from soil into air is calculated as follows:

$$CA = \frac{CS}{PEF\ or\ VF} \qquad (6-6)$$

where:

CA	=	concentration in air, µg/m^3
CS	=	concentration in soil, mg/kg
PEF	=	particulate emission factors from soil, m^3/kg
VF	=	volatilization factors for a volatile COPC, m^3/kg

6.3.5.2 Vapor Intrusion Modeling

For current land use scenarios, vapor intrusion evaluation is performed separately for two buildings (Dormitory 4 and the office building) at UST Site No. 1. These buildings are chosen because they are currently occupied and are located close to source areas for VOC. In accordance with ODEQ guidance (2003), only those soil gas data collected within 50 ft of a residential building (e.g., Dormitory 4) and within 10 ft of a commercial building (e.g., office building) are used in the vapor intrusion evaluation. Maximum detected concentrations in soil gas are used as EPCs (ODEQ 2010b).

Concentrations in indoor air are estimated using Johnson and Ettinger (J&E) soil gas models, Version 3.1 (EPA 2004b). DU-specific parameters regarding subsurface conditions, including soil type, bulk density, total porosity, water-filled porosity, soil vapor permeability, building parameters, and VOC concentrations in soil gas, are used in the model. Default J&E or DoD (2006) recommended input parameters are used where DU-specific values are not available. Input parameters for the J&E model are presented in **Table 6-23**.

For future land-use scenarios, all soil gas data collected from a DU are used in the vapor intrusion evaluation since a building may be built in a location close to the source areas. Default J&E input parameters for a residential house is used for future

land-use scenarios. Since land use at the Fire Training Area is likely to remain industrial/commercial, the use of J&E default building parameters for a residential house is very conservative. Therefore, this evaluation is performed for screening purpose only.

6.3.5.3 Trench Model

Migration of volatiles from groundwater into an excavation pit for construction worker scenario is estimated using a construction/utility trench model by the Virginia Department of Environmental Quality (VDEQ 2008). The trench model is based on a combination of a vadose zone model to estimate volatilization of organic vapors from groundwater into a trench and a box model to estimate dispersion of the VOCs from the air inside the trench into the above-ground atmosphere to estimate the air concentration in a construction trench.

VOC concentration in a trench is estimated using Equation 6-7:

$$C_{pit} = (C_{GW})(VF) \qquad (6-7)$$

where:

C_{pit} = concentration of VOC in the pit (µg/m^3)
C_{GW} = concentration of VOC in groundwater (µg/L)
VF = volatilization factor (L/m^3) derived from Equation 6-8

Volatilization factor, VF, is estimated using Equation 6-8:

$$VF = \frac{(K_i)(A)(F)(10^{-3})(10^4)(3600)}{(ACH)(V)} \qquad (6-8)$$

where:

K_i = overall mass transfer coefficient of VOC (cm/sec) derived from Equation 6-9
A = area of excavation pit (m^2)
F = fraction of floor through which VOC can enter
ACH = air exchange per hour (/hr)
V = volume of excavation pit (m^3)
10^{-3} = conversion factor (L/cm^3)
10^4 = conversion factor (cm^2/m^2)
3600 = conversion factor (s/hr)

$$K_i = \frac{1}{\frac{1}{k_{iL}} + \frac{RT}{H_i k_{iG}}} \qquad (6-9)$$

Overall mass transfer coefficient of VOC is given by Equation 6-9:

where:

k_{iL}	=	liquid-phase mass transfer coefficient of VOC (cm/s) derived from Equation 6-10
R	=	ideal gas constant (atm-m^3/mol- ^{0}K)
T	=	average system absolute temperature (^{0}K)
H	=	Henry's law constant of i (atm-m^3/mol)
k_{iG}	=	gas-phase mass transfer coefficient of i (cm/s) derived from Equation 6-11

Liquid-phase mass transfer coefficient of VOC is given by Equation 6-10:

$$k_{iL} = \left(\frac{MW_{O2}}{MW_i}\right)^{0.5} + \frac{T}{298} \times k_{L,O2} \qquad (6-10)$$

where:

k_{iL}	=	liquid-phase mass transfer coefficient of i (cm/s)
MW_{O2}	=	molecular weight of oxygen (g/mol)
MW_i	=	molecular weight of VOC (g/mol)
$K_{L,O2}$	=	liquid-phase mass transfer coefficient of oxygen at 25 ^{0}C (cm/s)

Gas-phase mass transfer coefficient of VOC is given by Equation 6-11:

$$k_{iG} = \left(\frac{MW_{H2O}}{MW_i}\right)^{0.335} + \left(\frac{T}{298}\right)^{1.005} \times k_{G,H2O} \qquad (6-11)$$

where:

k_{iG}	=	gas-phase mass transfer coefficient of VOC(cm/s)
MW_{O2}	=	molecular weight of water (g/mol)
MW_i	=	molecular weight of VOC (g/mol)
$K_{G,H2O}$	=	gas-phase mass transfer coefficient of water vapor at 25°C (cm/s)

The input parameters for the Trench model and predicted trench air concentrations are provided in **Table 6-24**.

6.4 Toxicity Assessment

Toxicity criteria were obtained from the following hierarchy of sources established in Office of Solid Waste and Emergency Response (OSWER) directive 9285.7-53 (EPA 2003):

- Tier 1—EPA's Integrated Risk Information System (IRIS)
- Tier 2—EPA's Provisional Peer Reviewed Toxicity Values (PPRTVs)
- Tier 3—Other Toxicity Values: Tier 3 includes additional EPA and non-EPA sources of toxicity information, such as the California EPA (CalEPA) and the Agency for Toxic Substances and Disease Registry (ATSDR)

6.4.1 Health Effects Criteria for Noncarcinogens

For chemicals that exhibit noncarcinogenic (e.g., systemic) effects, many authorities consider organisms to have repair and detoxification capabilities that must be exceeded by some critical concentration (threshold) before a health effect is manifested. This threshold view holds that a range of exposures from just above zero to some finite value can be tolerated by the organism without an appreciable risk of adverse effects.

Health criteria for chemicals exhibiting noncarcinogenic effects for use in risk assessment are generally EPA-derived reference doses (RfDs) due to oral or dermal exposures and reference concentrations (RfCs) due to inhalation exposure. The RfD or RfC is an estimate of average daily exposure to an individual (including sensitive individuals) that is likely to be without appreciable risk of deleterious effects during a lifetime. The RfD is expressed in units of milligrams of chemical per kilogram of body weight per day (mg/kg-day), and the RfC is expressed in units of milligrams of chemical per cubic meter of air (mg/m^3).

RfDs and RfCs are usually derived either from human studies involving workplace exposures or from animal studies, and are adjusted using uncertainty factors to ensure that they are unlikely to underestimate the potential for adverse noncarcinogenic effects to occur. Uncertainty factors reflect scientific judgment regarding the various types of data used to estimate the RfD/RfC and range between 1 and 10. For example, a factor of 10 may be introduced to account for possible differences in response between humans and animals in prolonged exposure studies. Other factors of 10 may be used to account for variation in susceptibility among individuals in the human population, use of data from a study with less-than-lifetime exposure, and use of data from a study that did not identify a no-observed-adverse-effect level (NOAEL).

RfDs and RfCs provide benchmarks against which estimated doses (i.e., those projected from human exposures to various environmental conditions) might be compared. Doses that are significantly higher than the RfD/RfC may indicate an increased potential of hazard from the exposure, and doses that are less than the

RfD/RfC are not likely to be associated with adverse health effects. Note that an exceedance of a reference dose or concentration does not predict a specific disease.

RfCs are derived for acute, subchronic, and chronic exposures. The chronic RfC is generally used for continuous or near-continuous inhalation exposures that occur for 7 years or more. The subchronic RfC is used for repeated exposures for more than 30 days up to 7 years. The acute RfC is used for exposures lasting 24 hours or less or for intermittent exposures that occur at a series of short periods (e.g., 4 hours) separated by several days of no exposure (EPA 2009a).

Toxicity criteria similar to RfCs are reference exposure levels (RELs) developed by Cal/EPA and minimal risk levels (MRLs) by ATSDR. Cal/EPA RELs are derived for acute (i.e., 1 to 7 hours), 8-hour, and chronic (i.e., greater than 8 years) exposures. ADSTR MRLs are developed for acute (1 to 14 days), intermediate (more than 14 days to 364 days), and chronic exposures (1 year and more).

6.4.2 Health Effects Criteria for Carcinogens

For chemicals that exhibit carcinogenic effects, EPA and other scientific authorities recognize that one or more molecular events can evoke changes in a single cell or a small number of cells that can lead to malignancy. This non threshold theory of carcinogenesis purports that any level of exposure to a carcinogen can result in some finite possibility of causing cancer. Generally, regulatory agencies assume the non threshold hypothesis for carcinogens in the absence of information concerning the mechanisms of carcinogenic action for the chemical. The slope factor (SF) (in units of $[\text{mg/kg body weight-day}]^{-1}$) is a number which, when multiplied by the lifetime average daily dose of a potential carcinogen (in mg/kg body weight-day), yields the upper-bound lifetime excess cancer risk associated with exposure at that dose. The SF is developed for exposure through oral route.

When the units are risk per micrograms per cubic meter ($\mu g/m^3$), it is called inhalation unit risk (IUR). The IUR is the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to a chemical at a concentration of 1 $\mu g/m^3$ in air.

Upper bound is a term used by EPA to reflect the conservative nature of the SFs and IURs; risks estimated using SFs and IURs are considered unlikely to underestimate actual risks and may overestimate risks for a given exposure. Excess lifetime cancer risks are generally expressed in scientific notation and are probabilities. An excess lifetime cancer risk of 1×10^{-6} (one in one million), for example, represents the incremental probability that an individual will develop cancer as a result of exposure to a carcinogenic chemical over a 70-year lifetime under specified exposure conditions.

In practice, SFs and IURs estimates are derived from the results of human epidemiology studies or chronic animal bioassays. Animal studies are conducted for a range of doses, including a high dose, to detect possible adverse effects. Since

humans are typically exposed at lower doses than those used in animal studies, data are adjusted via mathematical models. Data from animal studies are typically fitted to the linearized multistage model to obtain a dose-response curve. However, EPA evaluates a range of possible models based on the available data before conducting the extrapolation. The most appropriate model to reflect the data is selected based on an analysis of the data set.

The 95% UCL slope of the dose-response curve, subject to various adjustments and an interspecies scaling factor, is applied to derive the health protective SF and IUR estimates for humans. Dose-response data from human epidemiological studies are fitted to dose-time-response curves. These models provide rough, but reasonable, estimates of the upper limits on lifetime risk. SF and IUR estimates based on human epidemiological data are derived using health protective assumptions and, as such, they too are considered unlikely to underestimate risks.

Therefore, while actual risks associated with exposures to potential carcinogens are unlikely to be higher than the risks calculated using an SF and IUR estimate, they could be considerably lower, and they may even be zero. In addition, there are varying degrees of confidence in the weight of evidence for carcinogenicity of a given chemical. EPA (1986) has proposed a system for characterizing the overall weight of evidence based on the availability of animal, human, and other supportive data. The weight-of-evidence classification is an attempt to determine the likelihood that an agent is a human carcinogen and thus qualitatively affects the estimation of potential health risks. Three major factors are considered in characterizing the overall weight of evidence for human carcinogenicity:

- The availability and quality of evidence from human studies
- The availability and quality of evidence from animal studies
- Other supportive information that is assessed to determine whether the overall weight of evidence should be modified

Under EPA's risk assessment guidelines (EPA 1986, 1996, 1999a), classification of the overall weight of evidence had the following five categories:

- Group A - Human Carcinogen: There is at least sufficient evidence from human epidemiological studies to support a causal association between an agent and cancer.
- Group B - Probable Human Carcinogen: There is at least limited evidence from epidemiological studies of carcinogenicity in humans (Group B1), or, in the absence of adequate data in humans, there is sufficient evidence of carcinogenicity in animals (Group B2).
- Group C - Possible Human Carcinogen: There is inadequate evidence of carcinogenicity in humans.

- Group D - Not Classified: There is inadequate data or no existing data for the chemical.
- Group E - No Evidence of Carcinogenicity in Humans: There is no evidence for carcinogenicity in at least two adequate animal tests in different species, or in both epidemiological and animal studies.

The EPA 2005 Cancer Guidelines provide an update to the Cancer Guidelines (EPA 1986, 1996, 1999c). The 2005 Cancer Guidelines emphasize the value of understanding the biological changes that a chemical can cause and how these changes might lead to the development of cancer. They also discuss methods to evaluate and use such information, including information about an agent's postulated mode of action, or the series of steps and processes that lead to cancer formation. Mode-of-action data, when available and of sufficient quality, may be useful in drawing conclusions about the potency of an agent, its potential effects at low doses, whether findings in animals are relevant to humans, and which populations or life stages may be particularly susceptible. In the absence of mode-of-action information, default options are available to allow the risk assessment to proceed.

The 2005 Guidelines (EPA 2005a) recommend that an agent's human carcinogenic potential be described in a weight-of-evidence narrative rather than the previously identified letter categories (A = known, B = probable, C = possible, D = not classifiable, and E = non-human carcinogen). The narrative summarizes the full range of available evidence and describes any conditions associated with conclusions about an agent's hazard potential. For example, the narrative may explain that an agent appears to be carcinogenic by some routes of exposure but not others (e.g., by inhalation but not ingestion). Similarly, a hazard may be attributed to exposures during sensitive life stages of development but not at other times. The narrative summarizes uncertainties and key default options that have been invoked.

The following are the five recommended standard hazard descriptors:

- Carcinogenic to human
- Likely to be carcinogenic to humans
- Suggestive evidence of carcinogenic potential
- Inadequate information to assess carcinogenic potential
- Not likely to be carcinogenic to humans

EPA is evaluating the carcinogenic weight of evidence of chemicals through the IRIS chemical process. In this process, chemicals are nominated, and all chemicals are evaluated consistent with the 2005 Guidelines and a narrative developed describing the Weight of Evidence. The IRIS chemical file is then reviewed, first through internal EPA consensus review and then external peer-review. The requirements for in-depth analysis of mode-of-action data and the review process does not allow the equating of

a chemical evaluated under the old system with the letter classification using the 2005 Classification narrative; rather, a full analysis of the data is required. The 2005 Cancer Guidelines include Supplemental Guidance on the evaluation of early lifetime exposures including the mutagenic mode of action for carcinogenesis. The Supplemental Guidance provides procedures for evaluating chemicals that are carcinogens and either using the data in the development of the potency factors or using age dependent adjustment factors. For chemicals with mutagenic mode of action, the following ratio is applied to the chronic daily intake (EPA 2005b):

- Age 0 to less than 2 years: 10
- Age 2 to less than 16 years: 3
- Age greater than or equal to 16 years: 1

The Supplemental Guidance provides for the evaluation of data on early lifetime exposures where children may be more susceptible. The application of these adjustments for specific chemicals is noted in the text of the risk assessment and, where appropriate, in the presentation of calculated risks.

6.4.3 Dermal Toxicity Criteria

They are no EPA-derived toxicity criteria based specifically on toxicity studies involving dermal exposures. In the absence of dermal-specific RfDs or SFs, oral toxicity factors are used, assuming that once a chemical is absorbed into the bloodstream, the health effects are similar regardless of whether the route of exposure is oral or dermal. However, because oral toxicity criteria are based on administered or applied doses (intakes), they need to be adjusted, using oral absorption rates, to be applicable to dermally-absorbed doses. According to EPA guidance (2004a), it is necessary to adjust only oral toxicity criteria for evaluating dermal exposures if the oral absorption of the soluble compound is less than 50%. For the COPCs in the risk assessment, this adjustment was necessary for several inorganic constituents, including cadmium, chromium, manganese, and mercury.

6.4.4 Toxicological Criteria

Tables 6-25 to 6-28 summarize the chronic RfDs and chronic, subchronic, and acute RfCs used to estimate noncarcinogenic effects. When a subchronic or acute RfC is not available for a specific chemical, the RfC based on the next longer duration of exposure is used as a conservative estimate that would be protective for shorter exposure duration. For instance, where the subchronic RfC is not available, chronic RfC is used. **Tables 6-29 and 6-30** summarize the cancer SFs and IURs used to estimate cancer risks. These criteria are the most current data, obtained from the November 2010 on-line version of IRIS, PPRTVs provided by EPA Superfund Technical Support Center (STSC), the December 2009 on-line version of ATSDR, and the July 2009 on-line version of Cal/EPA Office of Environmental Health Hazard Assessment (OEHHA) Toxicity Criteria Database. The use of surrogate toxicity values is noted in **Tables 6-25 through 6-30**.

No current EPA consensus toxicity values for TCE are available. The ODEQ (2009c) recommends the use of EPA's 2001 National Center for Environmental Assessment (NCEA) draft TCE toxicity values (EPA 2001b). Several limitations are noted with draft toxicity values, including:

- The NCEA values were provided in a draft health risk assessment. As discussed in the OSWER Directive 9285.7-53, which is EPA's current policy on the selection of toxicity values for use in HHRA, draft toxicity assessment values generally are not appropriate for use until they have been through peer review, the peer review comments have been addressed in a revised draft, and the revised draft is publicly available. The NCEA draft values were not peer reviewed.

- In the NCEA draft health risk assessment, the upper end of the SF of 0.4 per mg/kg-day was based on a New Jersey drinking water cohort study. The draft risk assessment derived a unit risk of 1×10^{-5} per µg/L in drinking water and subsequently converted this unit risk to an oral SF. No IUR was developed.

- In 2006, the National Academy of Sciences provided review comments on the EPA NCEA 2001 draft health risk assessment of TCE. The National Academy of Sciences committee found several weaknesses in the techniques used in the draft health risk assessment. Problems included the use of subjective, tiered systems to classify and weigh studies, separate analyses of case-control and cohort studies, and that these analyses did not consider identifying amounts of exposure in the studies. The committee concluded that evidence on cancer and other health risks from TCE exposure had strengthened since 2001 and recommended that new analyses be developed to synthesize collective evidence on cancer risk. EPA released a Draft *Toxicological Review of Trichloroethylene (TCE): In Support of the Summary Information in the Integrated Risk Information System (IRIS)* in November 2009 (IRIS 2009b). The draft document has not, at the time of this writing, been finalized by EPA.

To be consistent with OSWER Directive 9285.7-53, Cal/EPA's cancer toxicity values are used to evaluate potential risk for TCE. The Cal/EPA's values are the most current values available, are peer reviewed, and are Tier 3 toxicity values. In a memorandum dated January 15, 2009, EPA recommended the use of the Cal/EPA's cancer toxicity values. However, this memorandum was withdrawn by EPA in April 2009 for further evaluation of the recommendations regarding the noncancer TCE toxicity value. The EPA April 2009 memorandum states that in the interim, toxicity values for TCE should be consistent with the OSWER Directive 9285.7-53. EPA continually uses the Cal/EPA cancer toxicity values, as demonstrated in the most current RSLs for Chemical Contaminants at Superfund Sites released by EPA in May 2010. The effect of the NCEA's draft toxicity values for TCE on the estimates of cancer risk in the HHRA is discussed in the uncertainty section of the HHRA report.

Risks from exposure to lead are not quantified following the exposure models for other COPCs. EPA considers lead to be a special case because of the difficulty in

identifying the "threshold." Health risks from lead are evaluated based on comparisons to state background levels.

6.5 Risk Characterization

The section presents risk estimates for all exposure scenarios presented in **Section 6.3**. Risks due to exposures to COPCs at the TPMS are evaluated by integrating toxicity and exposure assessments into quantitative expressions of cancer risk and noncancer hazards. Equations used to calculate risk estimates are presented, followed by the calculated results. These estimates are useful for characterizing risks to people who could be exposed to chemicals found at the TPMS, as well as for identifying those COPCs with greatest contributions to risk estimates.

As previously discussed, risk characterization is presented separately for assessment performed under ODEQ and CERCLA guidance.

6.5.1 Risk Estimate Calculations

Carcinogenic risks and noncarcinogenic health effects are evaluated separately because of fundamental differences in their critical toxicity values. Equations for each type of effect are presented in separate subsections that follow.

6.5.1.1 Carcinogenic Risks

The potential for cancer risks is estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a carcinogen. The upper-bound excess lifetime cancer risk is estimated by multiplying the estimated exposure level (DI) by the cancer SF for oral and dermal routes of exposure. For inhalation, the upper-bound excess lifetime cancer risk is estimated by multiplying the estimated exposure concentration (EC) in air by the IUR.

$$Risk = DI \times SF \qquad (6-12)$$

$$or$$

$$Risk = EC \times IUR \qquad (6-13)$$

where:

Risk	=	estimated chemical-specific individual excess lifetime cancer risk
DI	=	chemical-specific daily intake (mg/kg-day)
SF	=	route- and chemical-specific cancer slope factor $(mg/kg\text{-}day)^{-1}$
EC	=	exposure concentration in air ($\mu g/m^3$)
IUR	=	chemical-specific inhalation unit risk $(\mu g/m^3)^{-1}$

Excess lifetime cancer risks are expressed as probabilities. An excess lifetime cancer risk of 1×10^{-6} indicates that one out of a million (1,000,000) individuals might get cancer as a result of site-related exposure. This cancer risk is incremental; that is, it is

in addition to the "background" cancer risk of 1 in 2 for men and 1 in 3 for women that currently exists in the United States (American Cancer Society 2009).

EPA recently provided additional guidance for children's cancer risk assessment (EPA 2005b), and ODEQ provided instructions on implementation of this guidance (ODEQ 2007b). Carcinogenic PAHs, which have been identified as having mutagenic mode of action, may have a greater carcinogenic impact if exposure occurs during childhood (EPA 2005b). Dose estimates for residents are adjusted upward to include both early-life exposures that may result in the occurrence of cancer during childhood and early-life exposures that may contribute to cancers later in life. Vinyl chloride and chromium (VI) are also identified as having mutagenic mode of action. However, vinyl chloride and total chromium are identified as COPCs only at the Fire Training Area and the Incinerator Building, respectively. Since residential land, use is not anticipated at these two DUs, earlier-life exposure is not a concern and thus is not considered in cancer risk calculations.

6.5.1.2 Noncarcinogenic Risks

The potential for noncancer health effects is evaluated by comparing an exposure level over a specified time period with an RfD or RfC derived for a similar exposure period. This ratio of exposure to toxicity is referred to as a hazard quotient (HQ):

$$HQ = \frac{DI}{RfD} \qquad (6-14)$$

or

$$HQ = \frac{EC}{RfC} \qquad (6-15)$$

where:

HQ	=	estimated chemical-specific hazard quotient
DI	=	chemical-specific daily intake (mg/kg-day)
RfD	=	route- and chemical-specific reference dose (mg/kg-day)
EC	=	exposure concentration in air (µg/m^3)
RfC	=	chemical-specific inhalation reference concentration (µg/m^3)

The HQ is recommended by EPA as a way to quantify the potential for noncancer health effects (EPA 1989a). HQs are not probabilities; the likelihood of an adverse effect does not usually increase according to any formula with the calculated value. An HQ greater than 1 indicates adverse health effects from the chemical exposure, although the same HQ may not equate to the same magnitude of adverse health effects for all chemicals. HQ interpretation considers the shape and slope of the dose-response curve in the area of observation, the magnitude of uncertainty and modifying factors to the RfD/RfC, and the confidence assigned to the RfD/RfC by EPA.

HQs for individual COPCs with similar toxicological effects (i.e., the same target organs or tissues) may be summed to yield an effect-specific hazard index (HI) (EPA 1989a). This HI assumes that a level of exposure exists below which it is unlikely even for sensitive populations to experience adverse health effects. The effect-specific HI can be calculated by summing HQs for chemicals with similar toxicological effects (e.g., development) or target organs (e.g., liver). If the sum of all HQs is less than 1, no effect-specific HIs are calculated because they would not exceed 1.

HQs for TPHs are calculated differently because there are no ODEQ published toxicity values for TPHs. Based on DU-specific TPH fraction data and exposure factor, an RBC based on a noncancer HQ of 1 is calculated using the ODEQ spreadsheet for calculating RBCs for total petroleum hydrocarbons (http://www.deq.state.or.us/lq/rbdm.htm). A noncancer HQ attributed to TPH is then calculated by comparing an EPC of TPH with the RBC:

$$HQ = \frac{EPC}{RBC} \qquad (6-16)$$

where:

HQ	=	estimated chemical-specific hazard quotient
EPC	=	medium-specific exposure point concentration (mg/kg for soil and µg/L for groundwater)
RBC	=	DU-specific and receptor-specific risk-based concentration for TPH (mg/kg for soil and µg/L for groundwater)

6.5.1.3 Acceptable Risk Thresholds

Individual and cumulative acceptable risk levels for carcinogens and noncarcinogens are defined by the Oregon Administrative Record (OAR 340-122-115). At upper-bound exposure, acceptable risk level is an excess lifetime cancer risk (ELCR) of less than or equal to 1×10^{-6} for individual carcinogens and 1×10^{-5} for multiple carcinogens. Acceptable risk level to noncarcinogens is a HI less than or equal to 1.

Per the CERCLA regulations and the NCP, target cumulative incremental cancer risk range for multiple carcinogens and multiple exposure pathways is 10^{-6} to 10^{-4}. Threshold of noncarcinogens is a HI less than or equal to 1.

6.5.2 Risk Characterization Using ODEQ Methods

A subset of DUs was assessed using ODEQ methods, including AST Fuel Storage Area, UST Site No.1, and Fueling Pit 3. The section presents risk characterization results for cancer and noncancer effects for these four DUs and presents results that include consideration of petroleum hydrocarbons stored and used as fuel during the DoD era. Risk estimates presented are based on RME scenarios and are developed by taking into account various conservative assumptions about the frequency and duration of exposure, as well as the toxicity of COPCs. Cancer risk and noncancer hazard calculations for all COPCs are presented in **Appendix L6** and are summarized

in **Tables 6-31 to 6-33**. Risk characterization results are summarized next for each receptor population by DU.

6.5.2.1 AST Fuel Storage Area

Trespassers visiting the AST may come into contact with cPAHs in surface soil through incidental ingestion of and dermal contact with soil, and inhalation of particulates and volatiles released from soil. Carcinogenic risk estimates for adolescent trespassers are summarized in **Table 6-31**. Total upper-bound excess cancer risk is 2×10^{-8}, almost three orders of magnitude below the ODEQ acceptable cancer risk of 1×10^{-5} for multiple carcinogens. Noncancer hazard is not evaluated for cPAHs because of lack of toxicity values.

Arsenic was selected as a COPC for groundwater in this DU, but because no exposure scenarios involve use of groundwater for drinking purposes, no risks were calculated for exposure to groundwater. Containerize petroleum hydrocarbons were not selected as COPCs for either soil or groundwater at the AST DU.

6.5.2.2 UST Site No. 1

Risks are estimated for the following receptors at UST Site No. 1 under current and/or future land use:

- Current land-use scenario:
  - Residents
  - Students
  - Indoor workers
  - Recreational users (adults and adolescents)
- Future land-use scenario:
  - Residents
  - Indoor workers
  - Construction workers
  - Recreational users (adults and adolescents)

Carcinogenic and noncancer risk estimates for each receptor are described next and summarized in **Table 6-32**.

<u>Residents</u>

Residents may come into contact with COPCs in surface water and sediment while swimming. Additionally, UST Site No. 1 could, in theory, be developed for

residential use in the future, in which case future residents may be exposed to COPCs in subsurface via vapor intrusion or ingestion of groundwater as drinking water.

For current residents, the total upper-bound excess cancer risk is 4×10^{-6}, below the ODEQ acceptable ELCR of 1×10^{-5} for multiple carcinogens. The noncancer HI is estimated to be 0.04, well below the regulatory acceptable HI of 1.

For future residents, the total upper-bound excess cancer risk is 1×10^{-4}, exceeding the ODEQ acceptable ELCR of 1×10^{-5} for multiple carcinogens. The majority of the total excess cancer risk is attributable to arsenic (93%) in groundwater. However, the maximum and the 90%UCL concentrations of arsenic in groundwater, 6.65 µg/L, and 4.52 µg/L, respectively, are below the state and federal MCL of 10 µg/L. The total noncarcinogenic HI is estimated to be 12, exceeding the regulatory acceptable HI of 1. HIs exceed 1 for blood, liver, kidney, body weight, and nervous system endpoints. The majority of blood, liver, kidney, and nervous system HIs is attributable to gasoline and diesel range hydrocarbons in groundwater. These risks are based on hypothetical future use of groundwater as a potable water supply.

Students

Current students could be exposed to Study Area-related chemicals in subsurface via vapor intrusion. Additionally, they could be exposed to surface water and sediment while swimming or engaging in water recreational activities.

The estimated total upper-bound excess cancer risk for current students is 5×10^{-8}, which includes risks from both vapor intrusion and from recreating along the TPMS shore. This estimate is more than two orders of magnitude below the ODEQ acceptable total cancer risk of 1×10^{-5}. The estimated noncancer HI is 0.04, well below the regulatory acceptable HI of 1.

Indoor Workers

Both current and future indoor workers may be exposed to vapor released from the subsurface into an enclosed building via vapor intrusion. Future indoor workers could be exposed to groundwater via ingestion of water while at work.

For current indoor workers, the estimated total upper-bound excess cancer risk is 3×10^{-8}, well below the ODEQ acceptable ELCR of 1×10^{-5} for exposure to multiple carcinogens. The noncancer HI is 0.0026, well below the regulatory acceptable HI of 1.

For future indoor workers, the total upper-bound excess cancer risk is 2×10^{-5} which exceeds the ODEQ acceptable ELCR of 1×10^{-5} for exposure to multiple carcinogens. This estimated cancer risk is almost entirely attributable to arsenic (98%) in groundwater, assuming future use of groundwater as a potable water supply. Again, both maximum and 90%UCL arsenic concentrations in groundwater are below state and federal MCLs. The noncarcinogenic HI is 3, exceeding the acceptable HI of 1. Target organ HIs exceed 1 for blood, liver, kidney, and body weight endpoints.

Petroleum hydrocarbons in groundwater are the major noncarcinogenic hazard drivers.

Construction Workers

If construction takes place at UST Site No. 1 in the future, construction workers could be exposed to COPCs through incidental ingestion of soil, dermal contact with soil and groundwater, and inhalation of fugitive dust and VOCs in an excavation trench.

The total upper-bound excess cancer risk for future construction workers is estimated to be 1×10^{-7}, well below the ODEQ acceptable ELCR of 1×10^{-5} for exposure to multiple carcinogens. The total noncancer HI is 0.5, below the regulatory acceptable HI of 1.

Recreational Users

Current and future recreational users may be exposed to COPCs through incidental ingestion of and dermal contact with surface water and sediment.

The estimated total upper-bound excess cancer risks for recreational adults and adolescents are 3×10^{-7} and 1×10^{-6}, respectively, both below the ODEQ acceptable ELCR of 1×10^{-5}. The total noncancer HI is 0.002 for recreational adults and 0.02 for recreational adolescents, both below the regulatory acceptable HI of 1.

6.5.2.3 Refueling Pit 3

Current and future recreational users, future indoor workers, and construction workers could be exposed to COPCs in soil, groundwater, surface water, and sediment at Refueling Pit 3. Carcinogenic and noncancer risk estimates for each receptor are described next and summarized in **Tables 6-33**.

Indoor Workers

Hypothetically, groundwater would be used as a potable water supply and indoor workers could be exposed to COPCs while drinking groundwater. The total upper-bound excess cancer risk is estimated to be 3×10^{-5}, which exceeds the ODEQ acceptable ELRC of 1×10^{-5} for exposure to multiple carcinogens This estimated cancer risk is almost entirely attributable to ingestion of arsenic (99.9%) in groundwater. Once again, both maximum and 90%UCL arsenic concentrations in groundwater, 9.49 µg/L, and 5.4 µg/L, respectively, are below the state and federal MCL of 10 µg/L. The total noncancer HI is estimated to be 7, exceeding the regulatory acceptable HI of 1. Target organ HIs exceed 1 for blood, liver, kidney, and body weight. The majority of the blood, liver, kidney, and body weight HIs is attributable to gasoline range TPH in groundwater.

Construction Workers

If construction takes place at Refueling Pit 3 in the future, construction workers could be exposed to COPCs through incidental ingestion of soil, dermal contact with soil and groundwater, and inhalation of fugitive dust and volatiles in an excavation trench.

The total upper-bound excess cancer risk for future construction workers is 9×10^{-9}, three orders of magnitude below the ODEQ acceptable ELCR of 1×10^{-5} for exposure to multiple carcinogens. The total noncancer HI is 0.2, below the regulatory acceptable HI of 1.

Recreational Users

Current and future recreational users may be exposed to COPCs through incidental ingestion of and dermal contact with surface water and sediment. The total upper-bound excess cancer risk for recreational adults and adolescents is 5×10^{-7} and 2×10^{-6}, respectively, below the ODEQ acceptable ELCR of 1×10^{-5} for exposure to multiple carcinogens. The total noncancer HI is 0.003 for recreational adults and 0.05 for recreational adolescents, well below the regulatory acceptable HI of 1.

6.5.2.4 UST Site No. 4

No COPCs were identified for UST Site No. 4. Quantitative risk characterization is thus not warranted for this DU.

6.5.3 Risk Characterization Using CERCLA Methods

All DUs are assessed using CERCLA methods. The section presents risk characterization results for cancer and noncancer effects for these DUs and presents results that exclude consideration of containerized petroleum hydrocarbons. Risk estimates presented are based on RME scenarios and are developed by taking into account various conservative assumptions about the frequency and duration of exposure, as well as the toxicity of COPCs. Cancer risk and noncancer hazard calculations for all COPCs are presented in **Appendix L6** and are summarized in **Tables 6-34 to 6-41**. Risk characterization results are summarized next for each receptor population by DU.

6.5.3.1 AST Fuel Storage Area

Trespassers visiting the AST may come into contact with cPAHs in surface soil through incidental ingestion of and dermal contact with soil, and inhalation of particulates and volatiles released from soil. Carcinogenic risk estimates for adolescent trespassers are summarized in **Table 6-34**. Total upper-bound excess cancer risk is 2×10^{-8}, almost two orders of magnitude below the *de minimis* level or lower bound of the EPA target cancer risk range of 10^{-6} to 10^{-4}. Noncancer hazard is not evaluated for cPAHs because of lack of toxicity criteria.

6.5.3.2 UST Site No. 1

Risks are estimated for residents, students, indoor workers, and recreational users under current conditions, and residents, indoor workers, construction workers, and recreational users under the future land-use scenario.

Carcinogenic and noncancer risk estimates for each receptor are described below and summarized in **Table 6-35**.

Residents

Residents may come into contact with COPCs in surface water and sediment while swimming. Additionally, UST Site No. 1 could, in theory, be developed for residential use in the future, in which case future residents may be exposed to COPCs in subsurface via vapor intrusion or ingestion of groundwater as drinking water.

For current residents, the total upper-bound excess cancer risk is 4×10^{-6}, within the EPA target cancer risk range of 10^{-6} to 10^{-4}. The noncancer HI is estimated to be 0.04, well below the EPA's noncancer threshold of 1.

For future residents, the total upper-bound excess cancer risk is 1×10^{-4}, at the upper bound of the EPA target cancer risk range of 10^{-6} to 10^{-4}. This risk is attributable to arsenic in groundwater. Arsenic concentrations do not exceed the MCL of 10 µg/L. The total noncancer HI is estimated to be 2. A target organ specific HI exceeds 1 for the nervous system. Arsenic in groundwater is again responsible for almost all health hazards. These risks are based on hypothetical future use of groundwater as a potable water supply.

Students

Current students could be exposed to Study Area-related chemicals in subsurface via vapor intrusion. Additionally, they could be exposed to surface water and sediment while swimming or engaging in water recreational activities.

The estimated total upper-bound excess cancer risk for current students is 5×10^{-8}, well below the lower bound of the EPA target cancer risk target range of 10^{-6} to 10^{-4}. The estimated noncancer HI is 0.04, well below the EPA noncancer threshold of 1.

Indoor Workers

Both current and future indoor workers may be exposed to vapor released from the subsurface into an enclosed building via vapor intrusion. Future indoor workers could be exposed to groundwater via ingestion of water while at work.

For current indoor workers, the estimated total upper-bound excess cancer risk is 3×10^{-8}, well below the lower bound of the EPA target cancer risk range of 10^{-6} to 10^{-4}. The noncancer HI is 0.0026, well below the EPA noncancer threshold of 1.

For future indoor workers, the total upper-bound excess cancer risk is 2×10^{-5}, within the EPA target cancer risk range of 10^{-6} to 10^{-4}. The noncancer HI is 0.2, below the EPA noncancer threshold of 1.

Construction Workers

If construction takes place at UST Site No. 1 in the future, construction workers could be exposed to COPCs through incidental ingestion of soil, dermal contact with soil and groundwater, and inhalation of fugitive dust and volatiles in an excavation trench.

The total upper-bound excess cancer risk for future construction workers is estimated to be 1×10^{-7}, an order of magnitude below the lower bound of the EPA target cancer risk target range of 10^{-6} to 10^{-4}. The total noncancer HI is 0.3, below the EPA noncancer threshold of 1.

Recreational Users

Current and future recreational users may be exposed to COPCs through incidental ingestion of and dermal contact with surface water and sediment.

The estimated total upper-bound excess cancer risks for recreational adults and adolescents are 3×10^{-7} and 1×10^{-6}, respectively, below or at the lower bound of the EPA cancer risk target range of 10^{-6} to 10^{-4}. The total noncancer HI is 0.002 for recreational adults and 0.02 for recreational adolescents, both of which are below the EPA noncancer threshold of 1.

6.5.3.3 Refueling Pit 3

Current and future recreational users, future indoor workers, and construction workers could be exposed to COPCs in soil, groundwater, surface water, and sediment at Refueling Pit 3. Carcinogenic and noncancer risk estimates for each receptor are described next and summarized in **Tables 6-36**.

Indoor Workers

Hypothetically, groundwater would be used as a potable water supply and indoor workers could be exposed to COPCs while drinking groundwater. The total upper-bound excess cancer risk is estimated to be 3×10^{-5}, within the EPA cancer risk target range of 10^{-6} to 10^{-4}. The total noncancer HI is estimated to be 0.2, below the EPA noncancer threshold of 1.

Construction Workers

If construction takes place at Refueling Pit 3 in the future, construction workers could be exposed to COPCs through incidental ingestion of soil, dermal contact with soil and groundwater, and inhalation of fugitive dust and volatiles in an excavation trench.

The total upper-bound excess cancer risk for future construction workers is 9×10^{-9}, over two orders of magnitude below the lower bound of the EPA cancer risk target range of 10^{-6} to 10^{-4}. The total noncancer HI is 0.002, below the EPA noncancer threshold of 1.

Recreational Users

Current and future recreational users may be exposed to COPCs through incidental ingestion of and dermal contact with surface water and sediment. The total upper-bound excess cancer risk for recreational adults and adolescents is 5×10^{-7} and 2×10^{-6}, respectively, below or within the EPA cancer target risk range of 10^{-6} to 10^{-4}. The total

noncancer HI is 0.003 for recreational adults and 0.05 for recreational adolescents, below the EPA noncancer threshold of 1.

6.5.3.4 UST Site No. 4

No COPCs are identified for UST Site No. 4. Quantitative risk characterization is thus not warranted for the DU.

6.5.3.5 Incinerator Building

Current and future trespassers, future outdoor workers, and construction workers may be exposed to soil via incidental ingestion, dermal contact, and inhalation of fugitive dust and volatiles. Carcinogenic and noncancer risk estimates for each receptor are described next and summarized in **Table 6-37**.

Outdoor Workers

The total upper-bound excess cancer risk for future outdoor workers is 7×10^{-7}, below the lower bound of the EPA target cancer risk range of 10^{-6} to 10^{-4}. The total noncancer HI is 0.02, below the EPA noncancer threshold of 1.

Construction Workers

The total upper-bound excess cancer risk for future construction workers is 4×10^{-8}, well below the lower bound of the EPA target cancer risk range of 10^{-6} to 10^{-4}. The total noncancer HI is 0.02, below the EPA noncancer threshold of 1.

Trespassers

The total upper-bound excess cancer risk for trespassers is 2×10^{-8}, two orders of magnitude below the lower bound of the EPA target cancer risk range of 10^{-6} to 10^{-4}. The total noncancer HI is 0.002, below the EPA noncancer threshold of 1.

6.5.3.6 Fire Training Area

Current and future recreational users, future indoor workers, and construction workers could be exposed to COPCs in soil, groundwater, surface water, and sediment at the Fire Training Area. Carcinogenic and noncancer risk estimates for each receptor are described next and summarized in **Table 6-38**.

Indoor Workers

Future indoor workers may be exposed to indoor vapor via vapor intrusion. Additionally, groundwater could hypothetically be used as a potable water supply, which would generate a complete exposure pathway for ingestion of COPCs in groundwater for indoor workers. The total upper-bound excess cancer risk is estimated to be 7×10^{-5}, within the EPA target cancer risk range of 10^{-6} to 10^{-4}. The total noncancer HI is 0.5, below the EPA noncancer threshold of 1.

Construction Workers

If construction takes place at the Fire Training Area in the future, construction workers could be exposed to COPCs through incidental ingestion of soil, dermal

contact with soil and groundwater, and inhalation of fugitive dust and volatiles in an excavation trench.

The total upper-bound excess cancer risk for future construction workers is estimated to be 8×10^{-7}, below the lower bound of the EPA target cancer risk range of 10^{-6} to 10^{-4}. The total noncancer HI is calculated to be 0.4, below the EPA noncancer threshold of 1.

Recreational Users

Current and future recreational users may be exposed to COPCs through incidental ingestion of and dermal contact with surface water and sediment. The total upper-bound excess cancer risk for recreational adults and adolescents is estimated to be 4×10^{-7} and 2×10^{-6}, below or within the EPA target cancer risk range of 10^{-6} to 10^{-4}. The total noncancer HI is 0.003 for recreational adults and 0.04 for recreational adolescents, below the EPA noncancer threshold of 1.

6.5.3.7 Aquatic Decision Units

Recreational users and anglers recreating in or visiting the aquatic DUs in Cathlamet Bay could be exposed to chemicals in surface water, sediment, and fish caught from the bay. Carcinogenic and noncancer risk estimates for each receptor are described next. **Tables 6-39 through 6-41** presents risk characterizations by aquatic DUs.

Recreational Users

Current and future recreational users may be exposed to COPCs through incidental ingestion of and dermal contact with surface water and sediment. The calculated total upper-bound excess cancer risks for recreations users at the three aquatic DUs are below or within the EPA target cancer risk range of 10^{-6} to 10^{-4}. The highest excess cancer risk, for the recreational adolescents at North of Pier 8, has a value of 2×10^{-6}. All of the three calculated total HI s are below 1. The highest HI for the recreational adolescents at Finger Piers and the Near Landfill DU is 0.03.

Anglers

Anglers may be exposed to COPCs through incidental ingestion of and dermal contact with surface water and sediment, and through consumption of fish.

Carcinogenic and noncancer risk estimates for anglers are described next and summarized in **Tables 6-39 to 6-41**. The list below provides the non-cancer risk estimates.

- *North of Pier 8* **-** (**Table 6-39**) **–** The total upper-bound excess cancer risk is estimated to be 1×10^{-4}, at the upper bound of the EPA target cancer risk range of 10^{-6} to 10^{-4}. The majority of the total excess cancer risk is attributable to arsenic (96%) in fish fillet. The total noncancer HI is 1, a value equal to the EPA target HI of 1. Arsenic also is the main contributor to noncancer risk.

- *Finger Piers* - (**Table 6-40**) – The total upper-bound excess cancer risk is estimated to be 2×10^{-4}, slightly exceeding the upper bound of the EPA target cancer risk range of 10^{-6} to 10^{-4}. The majority of the total excess cancer risk is attributable to arsenic (78%) and dioxins/furans (13%) in fish fillet. The total noncancer HI is estimated to be 2, exceeding the EPA noncancer threshold of 1. Target organ HI exceeds 1 for developmental effect. Arsenic and dioxins/furans in fish fillet are drivers for noncancer health hazards.

- *Near Landfill* - (**Table 6-41**) –The total upper-bound excess cancer risk is estimated to be 1×10^{-4}, at the upper bound of the EPA target cancer risk range of 10^{-6} to 10^{-4}. The majority of the total excess cancer risk is attributable to arsenic (84%) and dioxins/furans (9%) in fish fillet. The total noncancer HI is estimated to be 1, and is a value equal to the EPA noncancer target HI of 1. Arsenic is the main contributor to noncancer risk.

Cancer risks due to ingestion of chromium, while a small fraction of total risk, also exceeded the ODEQ threshold of 1×10^{-6} (3×10^{-6} to 5×10^{-6}). These risk estimates assume that all chromium in fish tissue is present as CrVI, the more toxic form of Cr. Cr in the fish tissue is likely to be present as CrIII which is very poorly absorbed from the gut and much less toxic. Thus, risk estimated for Cr via ingestion of fish from the TPMS are likely greatly exaggerated. Further, Cr is probably present only at typical background or reference concentrations. This issues is further discussed in **Section 6.5.4.2.**

6.5.4 Multiple Lines of Evidence Evaluation

Some of the highest risk estimates among all DUs and all exposure pathways are associated with consumption of locally caught fish. COPCs that contribute substantively to these risk estimates – arsenic and dioxins/furans as TCDD TEQ – are ubiquitous in sediments. Risk estimates based on these COPCs must be judged against a significant non-Study Area related background. The evaluation in this section places risk estimates based on fish consumption in perspective relative to this natural and/or anthropogenic background.

According to ODEQ, appreciable fishing occurs in Cathlamet Bay for sturgeon. However, sturgeon is not expected to frequent the shallow water in the areas around the finger piers. Thus, a major focus for fishing near the TPMS has no obvious connection with the Study Area. A fishing pier does exist at the reference area, suggesting that fishing for other species does occur in the Bay. Such fishing would be limited to boaters near the finger piers because land access is controlled and fishing is not currently allowed by Job Corp Center rules. Residents at the TPMS do not report significant boating/fishing activity near or between the piers. Current information indicates that the number and mass of fish taken from the Study Area is likely negligible.

Some uncertainty was introduced into the risk assessment because primary target fish species could not be collected during the field effort. Sculpin was therefore collected

as representative species, albeit as a secondary target for collection. Data from sculpin are therefore not directly representative of COPC concentrations in likely target species, and estimates of health risk from fish consumption based on these data can only represent some range finding.

However, sculpin are year-round residents that have continuous close association with sediments. Moreover, they have small home ranges compared to the size of the aquatic DUs. Sculpin thus have direct and continuous association with sediments in the Study Area. These factors make sculpin a reasonable surrogate for target species that have larger home ranges or that migrate through the area seasonally. Sculpin data and associated risk estimates for anglers cannot therefore be dismissed out of hand. Sculpin data can reasonably provide order of magnitude estimates for possible human health risks and, equally importantly, can form a basis for comparisons with historical data from Cathlamet Bay, the Reference Area, and nearby upgradient areas along the Lower Columbia River.

Because of the above limitations of available fish data, the risk assessment for fish consumption for anglers includes a qualitative multiple line-of-evidence approach. The line-of-evidence approach addresses the issue of whether risks from consumption of locally caught fish can be reasonably attributable to releases from DoD era sources.

The following lines of evidence are used for further evaluating fish consumption risks:

- Comparison of fish tissue levels to ODEQ (2007a) Acceptable Tissue Levels (ATLs)
- Comparisons of sediment and fish data from aquatic DUs to the Reference Area
- Comparison of chemical concentrations in fish from aquatic DUs to concentrations in fish samples from the lower Columbia River system
- Comparison of RI sediment samples to historical data from previous Finger Piers investigations

6.5.4.1 Comparison to ODEQ Acceptable Tissue Levels

Chemical concentrations detected in fish fillet samples are compared to ATLs established by ODEQ (2007a) for the general/recreational population. These comparisons are presented in **Table 6-42**. Detected concentrations of total DDT, lead, mercury, selenium, and tributyl tin in fish tissues from the Study Area are below their respective ATLs. Not surprisingly, none of these COPCs were major contributors to risks or hazards associated with fish consumption. These COPC, seem unlikely to be of concern for fish consumption, since they are not taken up to a significant extent into tissues of a bottom-dwelling fish that spends most or all of its life in close contact with Study Area sediments.

Concentrations of dioxins/furans, measured as 2,3,7,8-TCDD and 2,3,7,8-TCDD TEQs, are above ATLs. Arsenic concentrations in fish fillets from all aquatic DUs and the

Reference Area exceed the risk-based ATL of 0.0062 mg/kg wet weight (ww). No ATL is available for chromium. Total DDT (which was a minor contributor to cancer risk), dioxins/furans, arsenic, and chromium are further evaluated in the lines of evidence process below.

6.5.4.2 Comparisons to Reference Area and Background Concentrations

Arsenic and dioxins/furans are risk drivers for the fish consumption scenario in this HHRA. If concentrations of these COPCs mostly or wholly reflect natural and/or anthropogenic sources, risks associated with releases from TPMS would drop to negligible levels. Arsenic and dioxins/furans (and other minor risk contributors to total risk such as total DDT and chromium) are present in sediment and tissues from the Reference Area and other "background" areas of Cathlamet Bay. Thus, it is critical to evaluate Study Area versus reference and background concentrations of these COPCs to help establish if any fraction of total cancer risk can be attributed to TPMS.

Total DDT, dioxin/furan, arsenic, and chromium concentrations detected in fish fillet and sediment samples from aquatic DUs were qualitatively compared to those found in the Reference Area and background concentrations reported in literature. These comparisons are provided in **Table 6-43**.

Arsenic

The excess cancer risk estimates associated with fish consumption are almost entirely driven by concentrations of arsenic in fish. That is, arsenic accounts for 85% of cancer risk for the Finger Piers and Near Landfill, and 96% of cancer risk for the North of Pier 8. These risk estimates do not consider the percent of the total arsenic risk that may be attributable to background sources, such as arsenic that occurs naturally in the Columbia River basin, or to arsenic from anthropogenic sources. **Table 6-43** shows that the arsenic concentration in the fish fillet samples from the Reference Area (0.88 mg/kg ww) would yield a human health cancer risk estimated of 1×10^{-4} if consumption rates similar to those used in the Study Area were used to estimate risks. Similar arsenic concentrations are found in fish fillet from the North of Pier 8 (0.95 mg/kg ww), and Near Landfill (0.8 mg/kg ww) DUs; a slightly higher arsenic concentration was reported in fish tissue from the Finger Piers DU (1.31 mg/kg ww).

These concentrations of arsenic in tissue samples do not correlate with arsenic concentrations in sediment samples. Arsenic concentrations in sediment from the aquatic DUs -- Finger Piers - 5.3 mg/kg, North of Pier 8 - 7 mg/kg, and the Near Landfill - 6 mg/kg – are lowest for the finger piers where the highest arsenic concentrations were reported in tissue. All differences, however, are small and it is likely that all of the reported data are within the expected range of values based upon ambient concentrations. That is, for arsenic, it seems likely that no real differences exists in concentrations from sediment or tissue and that all risks due to possible exposure to arsenic in fish tissue, regardless of species, is related to background rather than to past DoD activity at TPMS.

Further support to the conclusion that arsenic occurrence in sediment is homogenous in the Finger Pier area and not related to DoD release is that four IS samples for the reference area and three DUs have essentially the same results. If arsenic had been released from upland sources, the arsenic concentrations in samples from one or more of the DUs would have reflected areas with substantially higher arsenic concentrations, and/or the near shore discrete sediment samples would have detected concentrations elevated compared to off shore concentrations. The near shore discrete samples were collected at identified possible release points. Additional discussion of this topic is included below and in the discussion of historical data in **Section 4.3.8.4**. In addition to concentrations being fairly consistent, all mean arsenic concentrations in sediments from the Study Area, including both the historic LRI data, are at or below the ODEQ (2007a) regional default background sediment concentration of 7 mg/kg. Mean arsenic concentrations at the Study Area are similar to concentrations in natural background found in Washington State (Washington Department of Ecology 1994) and western United States (USGS 1984).

Dioxins/Furans

Dioxins/furans are ubiquitous in the environment. Sources are many, such as fuel combustion (particular diesel fuel), forest fires, backyard burning, and wood stoves. Incineration of waste materials that contain chlorine, such as medical waste and municipal waste, and certain types of chemical manufacturing can result in releases of dioxins/furans. Dioxins/furans enter the aquatic environment through non-point source runoff, through direct atmospheric deposition to surface water, or through point source discharge associated with certain industrial practices. Dioxins/furans are hydrophobic chemicals that preferentially accumulate in organic-rich sediments and they often accumulate in tissues of aquatic organisms. Thus, it is not surprising that dioxins/furans are found in sediments from the reference area and from the Near Landfill DU.

Table 6-43 shows that the mean concentration of TCDD TEQs in sediment is higher at the Reference Area than at the Near Landfill (9.6×10^{-7} vs. 5.4×10^{-7} mg/kg ww). This result is somewhat surprising because sediment particle size was smaller near the landfill and this sediment was rich in organic matter. These characteristics would favor adsorption of dioxins/furans onto sediment. The results thus favor the interpretation that dioxins/furans in sediment are the result of deposition of sediment, rather than release of dioxins/furans from the landfill.

Further, as discussed in **Section 4.3.5.1**, homolog profiles for dioxins/furans are consistent with similar profiles from wood burning. This observation is again an indication that dioxins/furans may be from common natural and/or anthropogenic sources rather than some operation during the DoD era.

TCDD TEQ in fish fillet ranged from 9.7×10^{-7} mg/kg ww at the Near Landfill DU to 2.3×10^{-6} mg/kg ww at Finger Piers DU. Dioxins/furans were not detected in fish fillet from the Reference Area. As discussed in **Section 3.8.3.6**, non-detect results for many congeners in the Reference Area and aquatic DUs make it impossible to accurately

compare fish tissue concentrations. These data typically reported SQLs in the range of 2 to $5x10^{-7}$ mg/kg. These SQL are in the range of detected concentrations, indicating that the lack of detections is a matter of low tissue concentrations than any difficulty with the analyses. Additional discussion of TCDD TEQ concentrations in fish tissue is included in **Section 6.5.4.3**.

Overall, consideration of background suggests that, regardless of fish species, risks associated with dioxins/furans in fish tissue are likely associated with non-Study Area-related sources.

Chromium

Similar to arsenic, chromium occurs naturally in all sediments and soils and is found in sediments of the Columbia River basin. Mean concentrations of chromium in sediments range from 14.83 mg/kg at the Reference Area to 18.53 mg/kg at the North of Pier 8, considerably below a background soil concentration of 56 mg/kg found in western states (USGS 1984) and a background concentration of 78.46 mg/kg found in Washington State (Washington State Department of Ecology 1994). Chromium concentrations in fish fillet at the North of Pier 8 (0.66 mg/kg) and Finger Piers (0.47 mg/kg) are similar to concentrations in the Reference Area (0.52 mg/kg). Chromium concentration in fish fillet is higher at the Near Landfill (1.13 mg/kg) than at the Reference Area. Chromium seems unlikely to be a significant Study Area-related COPC. Concentrations of chromium in sediment are low relative to typical background concentrations, and differences among tissue concentrations are small enough to reflect variations typically observed in environmental samples and among analytical results.

Total DDT

Total DDT concentrations in fish fillet and sediment are similar at the three aquatic DUs and the Reference Area. Lack of difference among tissue and sediment concentrations is again suggestive that total DDT concentrations in the DUs result from upgradient sources, rather than a release from TPMS. This conclusion is consistent with historical information about past practices within the study area, which contains no indication that DDT was stored or used during DoD operations.

6.5.4.3 Comparison to the Lower Columbia River System

Dioxins/furans, DDT and its degradation products DDD and DDE are hydrophobic chemicals that preferentially accumulate in organic-rich sediments and tissues. They are ubiquitous in the environment and in the food that people consume. A substantial database exists for these chemical groups from the Lower Columbia River. These two groups are therefore used to assess data from TPMS against the lower Columbia River basin in general.

Dioxins and Furans

Dioxins and furans were commonly detected in fish samples at nearby areas along the lower Columbia River (USFWS 2004). Concentrations of 2,3,7,8-TCDD and 2,3,7,8-

TCDF in fish samples collected from Cathlamet Bay, from Lewis and Clark NWR (USFWS 2004) and from Columbia River basin are summarized in **Table 6-45**. These concentrations are compared to 2,3,7,8-TCDD and 2,3,7,8-TCDF concentrations found in fish fillet samples collected from aquatic DUs of the TPMS. As indicated by table footnotes, the concentrations obtained from the reference documents are analytical results of composite samples. Some results are single values from a single composite. When sample quantity was sufficient and if results were above detection limits, the values reported are the geometric mean of either two or four composite samples.

As indicated in **Table 6-45**, concentrations of 2,3,7,8-TCDD and 2,3,7,8-TCDF in fish fillets for the TPMS are similar to those concentrations observed in fish from nearby areas from Columbia River and are lower than those from Cathlamet Bay and Lewis and Clark NWR. 2,3,7,8-TCDD concentrations were $2x10^{-6}$ mg/kg ww in northern pikeminnow and $2.4x10^{-6}$ mg/kg ww in peamouth chub (USWFS 2004), concentrations commensurate with a cancer risk estimated of 2×10^{-4} or higher if consumption rates similar to those used in the angler fish consumption scenario were used to estimate risks.

Two sculpin samples were collected in 2000 from the Columbia River near Tongue Point (Nicks and Tillitt 2003). They used the H4IIE bioassay to assess and characterize exposure to planar halogenated hydrocarbons (PHHs) such as PCBs, chlorodibenzo-p-dioxins (CDDs) and chlorodibenzofurans (CDFs). The H4IIE bioassay is a semi-quantitative assay that measures the overall toxic potency of PHHs in the extracts of fish. The dioxin-like toxic potency of chemicals found in fish collected in the Columbia River near Tongue Point is based on the ability of the extracts of those fish to increase 7-ethoxyresorufin-O-deethylase activity in the H4IIE rat hepatoma cell line. The results of the induction caused by the extracts are evaluated relative to that of 2,3,7,8-TCDD. The resultant TCDD-TEQ is a measure of the exposure that the fish have received to this class of compounds. A mean 2,3,7,8-TCDD-TEQ concentration of $4.2x10^{-6}$ mg/kg, with a range from $3.0x10^{-7}$ to $2.4x10^{-6}$ mg/kg, is reported in sculpin tissue. 2,3,7,8-TCDD TEQ concentrations found in fish fillet at the TPMS ranged from nondetect to $2.3x10^{-6}$ mg/kg, which are in the lower range of concentrations found by Nicks and Tillitt (2003). It is noted that the TCDD-EQs may not be totally comparable to the TEQs reported herein because the EQs were based on H4IIE bioassays. In particular, H4IIE assays measure all dioxin-like chemicals, including coplanar PCB congeners. TCDD equivalents for dioxin/furan congeners only could be overestimated by this assay. However, PCB concentrations in fish from the DUs were very low and likely would have contributed little to H4IIE activity if such assays had been run. Thus, TCDD-TEQ from Study Area fish may be a reasonable approximation of total H4IIE activity.

Sculpin from the Study Area do not appear to be substantively different in terms of TCDD-TEQ concentrations in tissues. This conclusion includes data from tissue samples from fish collected in Cathlamet Bay, and from other sculpin collected near TPMS. The comparison, though not definitive, is certainly consistent with other lines

of evidence that suggest that dioxin/furan concentrations are commensurate with background in sediments in the Lower Columbia River.

DDT, DDE, and DDD

Although DDT levels in the Columbia River have decreased over the last 20 years, DDT and its breakdown products, DDE and DDD, are still regularly detected in the fish of the Columbia River and many of its tributaries, such as the Yakima River (EPA Region 10 2009). The primary source of DDT to the Columbia River Basin is erosion and runoff from agricultural soils in which DDT is still present (EPA Region 10 2009).

Concentrations of DDT, DDE, and DDD in fish samples collected from Cathlamet Bay, around islands within the Lewis and Clark National Wildlife Refuge (NWR), and from the Columbia River basin are summarized in **Table 6-44**. These concentrations are compared to those detected in fish fillet samples collected from aquatic DUs of the TPMS.

DDT concentrations in prickly sculpin fillet samples collected at the TPMS are lower than those concentrations found in sucker, peamouth chub, and northern pike minnow collected from Cathlamet Bay (USFWS 2004). Additionally, DDT concentrations in prickly sculpin fillet samples from the TPMS are similar to those found in channel catfish and small mouth bass collected from Columbia River basin (EPA Region 10 2002).

DDE concentrations in prickly sculpin fillet samples collected at the TPMS are lower than those found in sucker, peamouth chub, and northern pike minnow collected from Cathlamet Bay (USFWS 2004) and large scale sucker, channel catfish, white sturgeon, and smallmouth bass from Cathlamet Bay (EPA Region 10 2002).

DDD concentrations in prickly sculpin fillet samples collected at the TPMS are lower than those found in sucker, peamouth chub, and northern pike minnow collected from Cathlamet Bay (USFWS 2004).

Based on these comparisons, maximum DDT, DDE, and DDD concentrations in fish tissue collected from aquatic DUs are generally lower than those found in fish collected at two nearby reference locations (USFWS 2004) and the Columbia River. This finding is again consistent with the conclusion that concentrations of DDTs at the Study Area most likely reflect regional background levels.

6.5.4.4 Comparison to Historical Sediment Data

A final line of evidence comes from comparison of COPC concentrations detected in surface sediments from the Finger Piers DU and surface and core sample sediment data for the Near Landfill DU to historical sediment data from previous investigations.

The details in **Section 4.3.9.4** show that concentrations of dioxins/furans reported for surface sediment samples collected in 1997 along perimeter of the landfill were

generally greater than concentrations reported in the 2008 IS from the Near Landfill DU. Since the 1997 data were collected before the removal action was completed in June 2006, the comparison of these data suggests that the landfill may not be an ongoing source of dioxins/furans to surface sediment. This conclusion is supported by the similarity of dioxin/furan concentrations in the 2008 sediment samples in the reference area and the Near Landfill DU. The 2008 data support the conclusion that dioxin/furan concentrations in sediments near the landfill are typical of those concentrations found throughout Cathlamet Bay.

As further evaluation, with more detail in **Section 4.3.9.4**, the dioxin/furan homolog profiles **Figure 6-8** presents historical sediment samples from near the landfill collected in 1997 and 1999. These profiles are essential the same as profiles developed from the 2008 data from sediment samples collected from the Near Landfill DU and in the Reference Area (**Figure 6-9).** All profiles are dominated by OCDD, which is common for dioxins/furans found in areas where no known specific sources have been identified. These profiles again suggest that dioxins furans in sediments near TPMS are typical or ambient for the Lower Columbia River and for Cathlamet Bay in particular.

A second data set was used to evaluate the IS for the Finger Piers DU. As discussed in **Section 4.3.8.4**, comparisons of data from discrete surface sediments samples collected in 1995 around the finger piers and the IS from the Finger Piers DU show that variability of several COPC in sediments is relatively low and indicate that localized areas of heterogeneity are unlikely to be present. These comparisons indicate that sediment deposition from upstream of TPMS is the simplest explanation for homogeneity of chemical concentrations in sediments at the Finger Piers. Sediments from upstream are mixed thoroughly during transport and deposited uniformly around the Finger Piers. Such sediments would be relatively homogeneous.

Calculations of "synthetic" standard error for COPC measured in both 1995 and 2008 data sets suggest that mean concentrations estimated using IS are robust. Data from 1995 show significant homogeneity (**Table 4-9d**). Similar homogeneity, based on the assumption that coefficients of variation in 1995 and 2088 would be much the same, indicates that IS means and 90% UCLs of the mean calculated using synthetic standard errors differ by only a few percent (2 to 7%). These small differences would not alter exposure point concentrations significantly and would not alter the conclusions of the risk assessment.

As previously stated, except in cases of extreme heterogeneity, IS methods can be expected to provide estimates of the mean that are directly useable in risk assessments. The data from 1995 provide evidence that, in fact, such extreme heterogeneity does not exist for several COPC selected for evaluation in this risk assessment. This evidence is consistent with the interpretation that sediments depositing in the finger piers area reflect sediment being carried downstream in the Columbia rather than local sources.

The analysis of the 1995 data set for surface sediments in and around the finger piers does not include key COPC, such as dioxins/furans and total DDT. However, when combined with the other information that suggests COPCs most associated with risk in sediment seem to have a source in background and upstream sediments, the comparison with 1995 data supports the main conclusion that data from the IS are representative of chemical concentrations throughout the finger piers and landfill area. In addition, the IS data provide the same picture of mean sediment concentrations as would many discrete samples.

6.5.4.5 Summary of Possible Risks to Anglers

Quantitative risk analyses suggest that cancer risks associated with consumption of fish taken from the aquatic DUs are at or slightly above the EPA target risk range. The line-of-evidence approach, however, indicates that such high risks are unlikely to be related to releases from the TPMS.

First, excess cancer risk associated with fish consumption is almost entirely driven by concentrations of arsenic in fish tissue, yet arsenic is apparently present only at levels typical of local background. No obvious relationship between arsenic in tissue and arsenic in sediment exists in the Study Area. Further, available data provide no evidence of a historical source of arsenic at the TPMS, either in Study Area soils or in near-shore sediments. Without arsenic, risks from fish consumption at the Finger Piers would drop substantially from 2×10^{-4} to 3×10^{-5}. Note again that these risks are "range finding" only. However, the basic concept of arsenic existing only at background levels applies regardless of fish species.

Second, the only other COPC that contributes significantly to angler risks is 2,3,7,8-TCDD TEQ. The comparison of the Reference Area and the Near Landfill suggests that concentrations of TCDD TEQ and homolog profiles do not differ between the two units. In fact, if any difference does exist, TCDD TEQs are slightly lower at the Near Landfill than at the Reference Area.

Third, dioxin/furan concentrations in sculpin tissue collected at the TPMS are entirely consistent with the range of concentrations reported from nearby sampling stations in the Lower Columbia River. These comparisons include other small home-range species and other sculpin species, and represent a robust data set for addressing the issue of TPMS-specific releases. Therefore, the presence of these chemicals in the aquatic DUs is not related to DoD activities. They are likely attributable to other upstream source areas since the Columbia River receives surface water runoff and storm water discharge from various industrial and agricultural areas upstream.

Fourth, detected concentrations of total DDT, lead, mercury, selenium, and tributyl tin do not exceed ODEQ ATLs. As expected, these COPCs do not represent a notable risk to anglers. This conclusion is well supported because, as indicated in above discussions, data from sculpin tissue samples are similar to concentrations in tissue samples from other fish species with different life habit within Cathlamet Bay. That

is, no reason was uncovered to suggest that sculpin would not reasonably represent fish tissue concentrations for fish caught in the Study Area and consumed.

In conclusion, excess cancer risks associated with fish consumption from the Study Area reflect risks attributable to chemicals at concentrations similar to ambient conditions or background. Study Area-related risks due to consumptions of locally caught fish do not appear be significant.

6.5.5 Lead

Lead is considered a COPC in sediments at UST Site No. 1, Fire Training Area, North of Pier 8, and Finger Piers. Lead concentrations in sediments were compared to regional default background inorganic concentrations established by ODEQ (2007a). These comparisons indicate that the maximum or the 90%UCL concentrations of lead in sediments from the DUs are below the ODEQ background concentration of 17 mg/kg.

6.5.6 Uncertainty Analysis

As in any risk assessment, the estimates of health threats (cancer risks and noncancer health effects) have numerous associated uncertainties. The primary areas of uncertainty and limitations are qualitatively discussed here. In general, the main areas of uncertainty are the following:

- Environmental data
- Exposure point concentrations and exposure parameters
- Toxicological data
- Risk characterization

6.5.6.1 Environmental Data

Uncertainty is involved in the estimation of chemical concentrations. Uncertainty in analytical data may stem from errors inherent in sampling or laboratory procedures. One of the most effective methods to minimize procedural or systematic error is to subject data to a strict QC review. The QC review procedure helps eliminate many laboratory errors. However, even with all data vigorously validated, it should be realized that error is inherent in all laboratory procedures.

<u>Upland DU Definition</u>

Samples from upland portions of the DU were collected from known and suspected areas of contamination (biased sampling) to delineate the nature and extent of contamination. This approach is justified on the basis that areas of contamination were identified in previous investigations, and more current data for these areas were needed to complete the RI/FS process. This sampling method provided reasonable confidence that risks would be adequately addressed at known or suspected contaminated areas within the DU. However, this approach would not find

previously unknown areas of contamination. Previous investigations of historical records, of the physical site setting, and of existing contamination suggest that the likelihood that a substantial area of contamination at the DU was missed is small. In addition, as detailed in the sampling rationale in the QAPP (CDM 2008b) some DUs included a step-out rational in the sampling program to expand the extent of the DU. Thus, uncertainties associated with bias sampling in upland portions of DUs are unlikely to have substantive impact on the conclusions of the risk assessment.

Cross-Media Screening

Although not analyzed or not detected during the RI, several chemicals are identified as COPCs as a result of soil-groundwater and surface water-sediment cross-medium screens. For soil, these chemicals are arsenic at AST Fuel Storage Area, UST Site No. 1, and Refueling Pit 3, plus manganese in soil at the Fire Training Area. In groundwater, the cross media constituents are cPAHs at AST Fuel Storage Area. For surface water, the cross media chemicals are; total DDT and total PCBs at Refueling Pit 3, Fire Training Area, Aquatic - Finger Piers; and total DDT in surface water at UST Site No. 1 and the Aquatic - Near Landfill;, and dioxins/furans in surface water at the Aquatic - Near Landfill.

Carcinogenic PAHs, DDT, PCBs, and dioxins/furans are virtually insoluble in water and have a propensity to adsorb to soil and sediment instead of dissolution in water. The immobility of these compounds is confirmed by RI data. With the exception of a single detected value for cPAHs, none of these compounds are reported at concentrations greater than the SQL in groundwater or surface water samples. cPAHs were detected in only one groundwater sample from UST Site 1. Therefore, it unlikely that they are present in groundwater and surface water at levels that would cause significant health risks to human. The uncertainty surrounding the presence and concentrations of these chemicals in surface water and groundwater is low.

Arsenic

Like other inorganic constituents, arsenic occurs naturally in the environment in the absence of any human influence. The regional default arsenic background concentration for soil and sediment is 7 mg/kg (ODEQ 2007a). Mean and 90%UCL concentrations of arsenic found in soil and sediment are below or at the state background concentration for all DUs. Furthermore, arsenic is not related to past DoD activities conducted at the Study Area. Therefore, it is unlikely to be present in soil at concentrations above the state background. Further, if arsenic in soil is not related to past activity at the DU, then arsenic in groundwater is likely to be naturally occurring. High risk due to hypothetical use of site groundwater for drinking is not likely to be site related. The uncertainty associated with arsenic in soil is relatively low and unlikely to have substantive impact on risk estimates. In addition, the 90%UCL concentrations of arsenic in groundwater are below the state and federal drinking water standard of 10 μg/L.

Manganese

Manganese is identified as a COPC in soil at the UST Site No. 1 and Fire Training Area because it is present in groundwater at concentrations above the screening level. Manganese occurs naturally in soil with a regional background soil concentration in Clatsop County, Oregon, of 714 mg/kg (USGS 2010). Manganese is commonly found in groundwater from weathering of manganese bearing minerals and rocks such as basalt that is common to the Columbia River area. In local areas, concentrations of manganese can range up to several mg/L. Under reducing conditions (anaerobic), manganese (II) is soluble as Mn^{2+} resulting in pronounced Manganese in groundwater. As discussed in **Section 2.4.2.6** and shown in **Table 2-1**, the geochemical conditions of groundwater at the Fire Training Area are tending toward anaerobic. For the UST Site No. 1, similar anaerobic conditions are expected because both of these DUs have groundwater influenced by LNAPL in which the biological activity consumes available oxygen. Reported manganese concentrations in groundwater ranged from 0.237 to 1.46 mg/L at the UST Site 1 and 1.11 to 5.17 mg/L at the Fire Training Area. No Study Area-specific soil manganese data are available. The lack of soil manganese data may underestimate risks to construction workers at the UST Site 1 and Fire Training Area.

Data with "J" Qualifiers

Additional uncertainty is associated with chemical concentrations reported below quantitation limits, and with detected concentrations reported between the SQL and the MDL. In both cases, use of the data in calculating EPCs interjects estimations for some concentrations into the data. These values are estimated and may result in over- or underestimating risks.

6.5.6.2 Exposure Point Concentrations and Exposure Parameters

Several areas of uncertainty affect exposure parameter estimation. These include the estimation of EPCs, the use of IS approach, the treatment of nondetected data, and parameter values used to estimate chemical intake (e.g., ingestion rate, exposure frequency).

Exposure Point Concentrations

Generally, a baseline risk assessment evaluates mean concentrations over an exposure unit, considering all exposures within that area as equally possible. Risks associated with chronic exposures are then assessed by evaluating those average or mean concentrations with exposure factors and the appropriate exposure/toxicity values. Use of a 90% UCL of the mean is simply to ensure that the average concentration is not underestimated. Because the UCL is influenced by sample size and variability of chemical concentrations, the approach to estimating EPCs can result in the default use of the maximum detected concentration. This source of uncertainty may overestimate the risk.

IS Approach

The IS approach was used to develop robust estimates of mean concentrations for use in the risk assessment. Different lines of evidence indicate that this goal was achieved. Comparisons of concentrations among DUs and the reference area, suggest similar concentrations for all COPC, and are entirely consistent with "background" concentrations in the Lower Columbia River sediments that deposit in near shore areas at TPMS. Comparisons with historical data developed in **Section 4.3.8.4** and **Section 4.3.9.4**, support the conclusion that no measurable releases to sediment are ongoing from upland sources (including the landfill). In addition, tissue data from species closely associated with site sediments do not show concentrations of chemical constituents unusual for the lower Columbia River. Overall, no evidence exists to suggest that IS results underestimate or over estimate, exposure point concentrations for surface sediments. Uncertainty associated with means estimated by IS appear to be low.

Nondetected Constituents

Methods for management of datasets with significant numbers of nondetected chemical concentrations when calculating UCL are all associated with some uncertainty. A nondetected result does not indicate whether the chemical is absent from the medium, or present at a concentration below the SQL.

Chemicals with analytical results greater than their SQL were referred to as COI and were assessed in the screening evaluation. ProUCL software utilized to calculate EPCs uses rigorous parametric and nonparametric (i.e., bootstrap, Kaplan-Meier, and regression on order statistics) statistical methods to address datasets with non-detects. It has the capability of assigning a hypothetical interpolated result for non-detected concentrations based on the distribution of detected concentrations, as explained further in **Section 6.2.3.2**. Given the rigorous statistical treatment of non-detected concentrations, EPCs produced by ProUCL can be considered unbiased estimates of the upper confidence interval of the mean. The uncertainty associated with these calculations is relatively low.

For chemicals that were positively detected fewer than four times within a dataset, the EPC chosen was the maximum detected concentration. The use of a single detected concentration does not account for lower concentrations in the dataset or for non-detect data that indicated the absence of a chemical above the SQL in many sampling locations. The resulting EPC is likely to overestimate the "true" UCL on the mean, but no statistically reliable means to estimate the UCL is available for these datasets.

Chemicals that were not detected in a specific medium, but were identified as COPCs based solely on the cross-medium screen were further evaluated by comparing SQLs to screening levels. All chemicals with SQLs greater than screening levels were retained as COPCs. These chemicals are evaluated in the uncertainty assessment in **Section 6.5.6.1**.

Several chemicals were never detected in a DU, but SQLs exceeded applicable screening levels in a large number of sample results. These chemicals are discussed below by medium.

Groundwater – Groundwater screening levels developed by the ODEQ or the EPA are the chemical concentrations in drinking water below which any impacts to human health are negligible or absent. These screening levels are developed without consideration of technical feasibility and/or costs for chemical analyses. As a consequence, screening levels for some chemicals, particularly highly toxic chemicals such as 1,2-dibromoethane (EDB), are extremely low. Even with the best available analytical technology, it is not uncommon for SQLs to exceed these screening levels. **Table 6-46** shows a list of chemicals where SQLs exceeded applicable groundwater screening levels. Note that, although SQLs exceed screening levels, they are less than drinking water standards except for EDB and beryllium. With the exception of benzene, TCE, and vinyl chloride, chemicals listed in **Table 6-46** were never detected in groundwater samples in the study area during the RI. Benzene and vinyl chloride were detected in the Fire Training Area while TCE was detected at Refueling Pit 3.

Although it is not specifically documented whether EDB or 1,2-DCA were used as an additive with TEL to the AVGAS used at these DUs, the potential exists and assumption is made that EDB and 1,2-DCA were additives to leaded AVGAS used at Former Tongue Point Naval Air Station to convert lead oxides to lead halides. The use of fuel additives containing EDB and 1,2-DCA in the United States started in the early 1940's and peaked from 1969 to 1972 (Wilson et al. 2008, Falta 2005). As explained in **Section 1.4** and **Section 5.3.1**, AVGAS was used and stored in the study area at AST, UST Site 1, and UST Site 4 between 1943 to 1946 associated with aircraft operations. If EDB were released, it would be a minor component associated with other AVGAS components (BTEX and TMBs) and would be associated with high concentrations of lead. In addition, the constituents EDB and 1,2-DCA in the dissolved phase would volatilize or biodegrade rapidly in the presence of petroleum hydrocarbons. The absence of high concentrations of any of these compounds indicates that releases of AVGAS in the areas did not occur or were not sufficient to leave significant traces nearly 60 years later. Under anaerobic conditions, EDB and 1,2-DCA can be degraded by methane producing bacteria through dehalogenation. Extensive biodegradation of BTEX and petroleum compounds could also be achieved through the use of BTEX compounds as energy source for the dehalogenation. If trace levels of EDB or 1,2-DCA were released, they are likely be degraded (see **Section 5.3.1**). Therefore, it seems unlikely that EDB and 1,2-DCA are present in these areas.

Chlorinated organic compounds are Study Area-related chemicals at Refueling Pit 3 and the Fire Training Area. It is not known whether the lack of detections of PCE and vinyl chloride at Refueling Pit 3 and the lack of detections of PCE and TCE at the Fire Training Area, truly indicate the absence of these VOC. It seems likely, for example, that PCE and/or TCE was the parent chemical(s) for subsequent generation of vinyl chloride at the Fire Training Area. In addition, PCE was reported in soil gas in this location. Some residual PCE may still be present at concentrations below the SQL,

and risks associated with use of groundwater for drinking could be somewhat underestimated.

High molecular weight PAHs, PCBs, and dioxins/furans are virtually insoluble in water and adsorb tightly to organic matter in soil and sediment. It is unlikely that they are present in groundwater at levels that would cause significant health risks to human. The uncertainty surrounding the presence of these undetected chemicals in groundwater is low.

Soil –SQLs for EDB and pentachlorophenol exceeded applicable screening levels in two samples at UST Site1 and one sample at the Fire Training Area. The reason for elevated SQLs is sample extract dilution. For example, elevated SQL for EDB in UST1-03 reflects the greater degree of analytical dilution required due to matrix interference from TPHs. EDB does not appear to be present at the Study Area as discussed above in this section. Pentachlorophenol is considered not to have been released in the Study Area. Neither EDB nor pentachlorophenol have been reported in any sample from any medium during any of the previous investigations. Thus, neither chemical is likely to be present in soil.

Surface Water - Similar to groundwater, several chemicals were never detected in surface water, but SQLs exceeded applicable screening levels for a number of samples. These chemicals include EDB, 1,2-DCA, vinyl chloride, iron, thallium, DDD, DDE, DDT, aldrin, dieldrin, hexachlorobenzene, and dioxins/furans. DDD, DDE, DDT, aldrin, dieldrin, hexachlorobenzene, and dioxins/furans are virtually insoluble in water and adsorb tightly to organic matter in sediment. The uncertainty surrounding the absence of these undetected chemicals in surface water is low. Although considered AVGAS additives, the highly degradable properties of EDB and 1,2-DCA support the conclusion that they are not Study Area-related chemicals, as discussed above in this section and Section 5.4.1. Vinyl chloride has only been detected in groundwater in the Fire Training Area. Groundwater could, in theory, discharge to surface water in Cathlamet Bay. If any such discharge were occurring, vinyl chloride would be lost to air rapidly due to it high volatility. Additionally, mixing with flowing surface water in the would greatly reduce concentrations.

Soil Gas –SQLs for EDB at all DUs and SQLs for hexachlorobutadiene at Refueling Pit 3 exceeded applicable soil gas screening levels. EDB is not likely to have been released in significant quantities as a component of AVGAS, and is unlikely to be present in soil or groundwater (see above discussions in this section). Thus, it is reasonable to conclude that it is also unlikely to be present in soil gas. Sample dilutions were required for several soil gas samples due to the presence of high concentrations of other analytes, such as difluoroethane and isopropylbenzene. As a result, SQLs for many VOCs were elevated in a few samples. Since the majority of VOCs with elevated SQLs were not detected in soil or groundwater, it is unlikely that they are present in soil gas. The uncertainty surrounding the absence of these chemicals in soil gas is low.

Fewer issues were encountered with non-detect results were encountered for IM samples of sediment, thus, mitigating problems caused by using censored data sets and lessening the chance of missing significant contamination. Still some issues with detection limits were encountered. Part of the reason for nondetect values in Study Area data is the low concentrations of many chemicals, particularly in surface sediments. These low concentrations are consistent with typical background in lower Columbia River sediments. Overall, censored data might cause some under-or over estimation of EPCs, but the impact of this uncertainty is judged to below, particularly because many non-detected chemicals have no obvious connection to the TPMS and, thus, they would make not contribution to risk even if present as concentrations below SQLs .

Nondetected data from IM samples were a particular issue for tissues for some COPCs. EPCs in such cases are uncertain and could either under- or overestimate risks. Tissue data were difficult for reasons discussed elsewhere, and confidence in use of these data for assessment of human health risk is low. These data were, however, less important for human health risk than were sediment concentrations. Evaluation of sediment concentrations suggests little impact to surface sediments from releases from upland DUs. Thus, regardless of uncertainty in tissue concentrations, risk attributable to a Study Area release, via consumption of locally caught fish, appears to be minimal.

Exposure Parameters

Exposure parameter values used are uncertain. For example, assumptions are made for exposure time, frequency, and duration of chemical exposures, as well as for the quantity of material ingested, inhaled, or absorbed. In general, assumptions are made based on reasonable maximum exposures and, in most cases; values are specified by either EPA or ODEQ guidance documents. In the case of the dermal absorption factor, chemical-specific values based on EPA guidance are not available for most metals. Dermal risk associated with these chemicals cannot be quantitatively evaluated for the risk assessment, which introduces some uncertainty in total risk and total hazard estimates. However, the choices made for exposure parameters are protective and are unlikely to underestimate possible risks. Cancer risks and health hazards could be overestimated based on use of conservative exposure parameters in estimating risks. Certainly, the goal of estimating a risk well above the average and at the upper end of those possible was likely achieved. Such estimates typically form the basis for risk management and are not atypical of ODEQ or CERCLA risk assessments.

Workers were assessed assuming exposure to soil for 100 d/yr. for all upland decision units except for the former Fire Training Area. ODEQ typically uses an exposure frequency of 250 d/yr., which assumes a typical 5-day workweek with two weeks of vacation. Given the nature of the upland DUs, an exposure frequency of 100 d/yr. is more reasonable. However, the selection of exposure frequency has no impact on the conclusions of the risk assessment. Worker risks associated with exposure to soil were too low for an increase by a factor of 2.5 to raise risks to a level of concern.

Risk estimates for people that take and consume fish from the Finger Piers area were calculated assuming a consumption rate of 17.5 g/d. This rate is based on a national survey that included people who normally eat fish as well as people that seldom or never eat fish. Such a broad average consumption rate is reasonable for the site since (1) the area does not seem to be highly productive, (2) fishing typically does not take place between or near the finger piers, (3) much better fishing success is achieved in waters upstream in Cathlamet Bay and (4) the area is small and unlikely to provide the number and size of fish to sustain a higher consumption rate.

Oregon Department of Environmental Quality recently adopted the use of a fish consumption rate of 175 g/d for setting water quality criteria. This higher consumption rate is reasonable for generic standards designed to be protective for essentially all exposure conditions. However, it is not likely to be applicable to the Finger Piers area at TPMS. Nevertheless, risk estimates based on this higher consumption rate could provide some perspective on regional ambient risks for fish taken from the lower Columbia. Recall here that sediment and fish tissue data collected to support the RI were quite similar to sediment and fish tissue data collected elsewhere and upstream in the river.

Angler risks associated with fish consumption would increase from 2×10^{-4} to 3×10^{-5} to 2×10^{-3} to 3×10^{-4} if the higher consumption rate were used. These risks ignore the contribution from arsenic, which appears to be present only at background or reference concentrations. As previously discussed, these risks appear to be similar to risks elsewhere in the lower Columbia River and multiple lines of evidence suggest that the site makes no substantive contribution.

6.5.6.3 Toxicological Data

A large source of uncertainty is inherent in the derivation of the EPA toxicity values (i.e., RfDs, RfCs, SFs, and IURs). In many cases, data must be extrapolated from animals to humans by the application of uncertainty factors to an estimated NOAEL or lowest-observed-adverse-effect level for noncancer effects. Although designed to be protective, it is likely in many cases that uncertainty factors overestimate the magnitude of differences that may exist between humans and animals, and among humans.

In some cases, however, toxicity values may be based on studies that did not detect the most sensitive adverse effects. For example, many studies did not measure possible toxic effects on the immune system. Moreover, some chemicals may cause subtle effects not easily recognized in animal studies.

In addition, derivation of cancer SFs often involves linear extrapolation of effects at high doses to effects at lower doses commonly seen in environmental exposure settings. Currently, it is not known whether linear extrapolation is appropriate. Probably, the shape of the dose response curve for carcinogenesis varies with different chemicals and mechanisms of action. It is not possible at this time, however, to describe such differences in quantitative terms.

It is likely that the assumption of linearity is conservative and yields SFs that are unlikely to lead to underestimation of risks. Yet, for specific chemicals, the current method could underestimate SFs, and hence underestimate risks.

Use of the EPA established toxicity values could either overestimate or underestimate risks, but it is difficult to determine either the direction or the magnitude of any errors. In general, however, it is likely that the criteria err on the side of protectiveness for most chemicals.

Acute and Subchronic Exposure

Inhalation RfCs are derived for acute, subchronic, and chronic exposures, based on the exposure duration and exposure pattern (EPA 2009a). Chronic exposure is generally used for continuous or near-continuous inhalation exposures that occur for 7 years or longer, such as for resident and site worker exposure. Subchronic exposure refers to repeated exposures for more than 30 days up to 7 years, such as for construction worker exposure. Acute exposure includes exposures lasting 24 hours or less or intermittent exposures that occur for a series of short periods (e.g., 4 hours) separated by several days of no exposure, such as for trespasser and recreational user exposure. Subchronic or acute RfCs are not available for some metals. In accordance with RAGS Part F (EPA 2009a), the RfC based on the next longer exposure duration is used as a conservative estimate that would be protective for the shorter exposure duration. This source of uncertainty may overestimate the inhalation hazard for students, construction workers, trespassers, and recreational users.

Mutagenic Carcinogens

Some carcinogenic chemicals such as benzo(a)pyrene can operate by a mutagenic mode of action that may have a greater impact if exposure occurs during childhood (EPA 2005b). EPA (2006 and 2010a) and ODEQ (2007b) recommend that the risk calculations for mutagens for children include both early-life exposures that may result in the occurrence of cancer during childhood and early-life exposures that may contribute to cancers later in life. Because benzo(a)pyrene is used as an index chemical when assessing other cPAHs, other cPAHs were evaluated for early-life exposure (EPA 2006). Since mutagenic carcinogens were not identified as risk drivers in the HHRA, this uncertainty has little or no impact on conclusions of the risk assessment.

Chromium

Total chromium, instead of valence-specific, data was collected from the Study Area. Chromium can exist in several oxidation states ranging from Cr(II) to hexavalent chromium (Cr VI). Only two oxidation states, chromium (III) and chromium (VI), are widely studied because of their predominance and stability in the ambient environment and their toxicological characteristics. Chromium (III) is poorly absorbed, regardless of the route of exposure, whereas chromium (VI) is more readily absorbed. Toxicological studies show that chromium (VI) is generally more toxic than chromium (III). Chromium (VI) is classified as a likely to be carcinogenic in

humans by oral route (EPA 2010) and a Group A - known human carcinogen by the inhalation route of exposure (IRIS 1998). In the absence of valence-specific data, total chromium is evaluated using the chromium (VI) toxicity criteria, assuming that the chromium (VI) to chromium (III) concentration ratio is 1:6 (EPA 2010). This assumption may overestimate or underestimate the risk attributed to total chromium.

Bioavailability

Another important source of uncertainty is bioavailability. Toxicity factors are often based on observed dose-response relationships when the chemical is dissolved in water or is in some other readily soluble form. For instance, the oral SF for arsenic is based on exposure of a large Taiwanese population to dissolved arsenic in drinking water. However, trace elements such as arsenic in soil may exist in forms that are not readily absorbed. In this risk assessment, relative bioavailability factors have not been applied to arsenic or any other metals. Use of toxicity factors that are not adjusted for relative bioavailability may cause overestimation of risks.

Trichloroethene (TCE)

TCE is identified as a COPC in groundwater at Refuelling Pit 3. Risks from TCE via hypothetical future use of groundwater as a potable water supply is evaluated for future indoor workers from ingestion of water. There are no current EPA consensus toxicity values. EPA recommends use of the Cal/EPA's SF of 0.015 per mg/kg-day. EPA (2001b) provided a range of SFs (0.02 to 0.4 per mg/kg-day) in a document entitled *Trichloroethylene Health Risk Assessment: Synthesis and Characterization* (External Review Draft). ODEQ (2009c) recommends using the upper end estimate of carcinogenic potency, 0.4 per mg-kg-day. Using ODEQ's recommended NCEA carcinogenic toxicity values resulted in TCE cancer risk for future indoor workers at Refueling Pit 3 of 3×10^{-6}. This estimated risk is two orders of magnitude higher than the risk estimated using the Cal/EPA's toxicity values. However, cancer risk associated with TCE is minimal and the overall cumulative cancer risks are 3×10^{-5} regardless of which toxicity value is used. Therefore, the alternative of using the NCEA draft toxicity values would have no effect on overall risk estimates.

No current EPA consensus noncancer toxicity values for TCE. The Cal/EPA's chronic REL is listed in **Table 6-26** for information purposes. The New York State Department of Health (NYSDOH) has developed an air guideline for TCE. The Cal/EPA's REL is based on a pre-2000 review of literature and used the Vandervort and Polakoff (1973) study to develop a chronic REL of 600 $\mu g/m^3$ based on neurological effects (Cal/EPA 1999). NYSDOH is based on a pre-2007 review of the literature on the noncancer health effects of TCE. NYSDOH used the Rasmussen et al (1993) study to derive a noncancer air guideline of 10 $\mu g/m^3$ based on neurological effects (NYSDOH 2006b). Because ingestion of drinking water is the only exposure route quantitatively evaluated for future receptors at Refueling Pit 3, the TCE inhalation RfC value has no impact to overall hazard estimates for future indoor workers.

Chemicals Without Toxicity Criteria

2-Hexanone, 4-ethyltoluene, ethanol, 2-propanol, tetrahydrofuran, and 2-propanol are detected in soil gas samples. They are not quantitatively evaluated in the risk assessment because of the lack of toxicity values. These chemicals are not listed as "subsurface contaminants demonstrating sufficient volatility and toxicity" by EPA's Subsurface Vapor Intrusion Guidance (2002c). Therefore, the uncertainty associated with these chemicals is relatively low. Trace level of 2,3,5-trimethylnaphthalene was detected in surface water in UST Site No. 1 at 0.00054 µg/L. No toxicity criteria are available for 2,3,5-trimethylnaphthalene. 1-Methylnaphthalene is structurally similar to 2,3,5-trimethylnaphthalene. The screening level for 1-methylnaphthalene is 2.3 µg/L. Risk associated with the trace level of 2,3,5-trimethylnaphthalene is likely to be minimal. Toxicity criteria for thallium were removed from IRIS database in 2009 (IRIS 2009a). Thallium is not screened or quantitatively evaluated in the HHRA. This source of uncertainty may underestimate the risk. However, because of low toxicity and trace concentrations, it seems unlikely that any of the above chemicals would be a risk driver for risk management decisions.

Total Petroleum Hydrocarbons

Risks for TPHs are calculated using DU-specific TPH fraction data and toxicity surrogates for TPH fractions developed by ODEQ (2003). ODEQ has only developed noncancer toxicity values for TPH fractions, using the reference dose for the most toxic known component to represent a conservative noncancer risk for the fraction. EPA (2009f) has published PPRTVs for low, medium, and high carbon range aliphatic and aromatic hydrocarbons. In addition to noncancer toxicity values, EPA has also provided carcinogenic toxicity values for low and medium carbon range aliphatics, and low and high carbon range aromatics. These PPRTVs are not used in the HHRA because TPH fraction data for the Study Area are limited to one soil sample per DU.

6.5.6.4 Risk Characterization

Possible unacceptable risks for TPMS were estimated only consumption of fish taken from the aquatic DUs and for domestic use of shallow groundwater at or near some upland DUs. The former risk estimates are subject to important uncertainties in two areas. First, the use of sculpin as a surrogate for target species for anglers, and second, the importance of non-site related impacts on sediment and tissue concentrations of COPC. Use of shallow groundwater within the Study Area is unlikely because a high quality municipal water supply is readily available and serving the area.

Sculpin as a Surrogate Species

An important area of uncertainty in risk assessment results is the use of sculpin data to represent small home-range species that might be taken near the TPMS. Sculpin are not targeted by anglers, and their relatively low fat content could underestimate accumulation of COPCs in other species. These uncertainties suggest that quantitative risk results be used only for purposes of range finding. However, sufficient data from other investigations indicate that COPCs are found in tissues of

other species collected from the lower Columbia River, Cathlamet Bay, and the identified Reference Area for the Study Area at concentrations similar to those noted in sculpin. This finding is consistent with the conclusion that COPCs in tissues of sculpin collected from the aquatic DUs represent background from the lower Columbia River and do not reflect releases from TPMS. Thus, the specific use of sculpin in quantitative risk assessment remains subject to uncertainty, and it is difficult to extrapolate from sculpin to other species. However, the more important conclusion that concentrations of chemicals in fish tissue are not related to a DoD release is well supported. This conclusion is particularly crucial for dioxins/furans. This chemical group was historically detected in seepage or runoff from the landfill, and the landfill could have been, in theory, a source of dioxins/furans to sediments, and, hence, to fish. The removal action at the landfill was completed in June 2006 and sculpin collected during the 2008 RI sampling likely reflect only post-remediation conditions. Lack of elevated concentrations of dioxins/furans in sculpin tissues and the similarity of these concentrations to concentrations in other fish tissue samples, including those from sculpin, collected from nearby upstream locations indicates that the concentrations reported from the Landfill DU are expected from fish taken anywhere in the Bay.

Arsenic

Arsenic was found in solid media (soil/sediment) only at concentrations typical of regional background and at concentrations similar to those reported from the reference area. Further, as discussed in **Section 6.3.8**, arsenic concentrations in sediment reported in 2008 are consistent with concentrations reported from a field effort in 1995, despite the long time lag and differences in sampling locations. Arsenic in sediment is unlikely to be site related and risk due to arsenic in fish tissue are likely to be typical of lower Columbia River/Cathlamet Bay background. Since arsenic is likely to represent the bulk of risk from fish consumption, this conclusion suggests that most risk estimated in earlier sections is not related to TPMS. That is, site-related risks could be overestimated by a factor of up to 50 times.

The absence of elevated arsenic in soil within the upland DUs suggests that risks associated with arsenic in groundwater is unrelated to releases from historical DoD operations. Upland DUs were specifically identified at known source areas, and groundwater samples were extracted from locations likely to be influenced by these sources. If arsenic had been released historically, some evidence of this release would be expected in soils in source areas. In addition, groundwater close to such source areas (DUs) would be expected to show higher arsenic concentrations than groundwater at other DUs were arsenic was not released. Instead, similar concentrations of arsenic are found in all soil and groundwater samples across the site. Arsenic does not appear to be related to historical DoD operations. The 90%UCL concentrations of arsenic in groundwater at the Study Area are below the state and federal MCL of 10 µg/L.

Chemical Mixtures

Uncertainty exists in assessing risks associated with mixtures of chemicals. In this assessment, the effects of exposure to each contaminant present have initially been considered separately. However, these substances occur together at the site, and individuals may be exposed to mixtures of the chemicals. Prediction of how these mixtures of chemicals will interact must be based on an understanding of the mechanisms of such interactions. Individual chemicals may interact chemically in the body, yielding a new toxic component or causing different effects at different target organs. Suitable data are not available to rigorously characterize the effects of chemical mixtures. Consequently, as recommended by EPA (1989), chemicals present at the site are assumed to act additively, and health risks are evaluated by summing excess lifetime cancer risks and calculating HIs for noncancer health effects.

This approach to assessing risk associated with mixtures of chemicals assumes that no notable synergistic or antagonistic interactions occur among the chemicals. To the extent that these assumptions are incorrect, actual risks could be underestimated or overestimated. As a result of the uncertainties described, this risk assessment should not be construed as presenting absolute risks or hazards. Rather, the risk assessment is designed to present a conservative analysis that allows for interpretation of TPMS-related risks under a standard set of guidelines, defined target risks and state and federal policy.

Use of Current Data to Assess Future Risks and Hazards

Using current media concentrations to reflect future concentrations adds another uncertainty to this HHRA. Concentrations of COPCs in the upland DU are also likely to decrease because sources have been removed (AST Fuel Storage Area, UST Site No. 4, Refueling Pit 3) or partially removed via tank removal (UST Site No. 1), or no large source has been identified (Fire Training Area). Use of current data to assess risks over chronic time periods is likely to overestimate risks, perhaps by a large margin.

6.5.7 Identification of Risk Drivers

Table 6-47 presents the risk characterization summary for all receptor scenarios by DU using the ODEQ methods, including those receptor scenarios with risk estimates exceeding the ODEQ acceptable ELCR cancer risk of 1×10^{-5} for exposure to multiple chemicals and noncancer HI of 1. **Table 6-48** presents the risk characterization summary for all receptor scenarios by DU using CERCLA methods, including those receptor scenarios with risk estimates at or exceeding the upper bound of the EPA target cancer risk range of 10^{-4} and HI of 1. Subsets of COPCs are identified as risk drivers based on the relative percentage of the total human health risk and the absolute magnitude of the risk posed by these COPCs for the ODEQ process (**Table 6-49)** and CERCLA process (**Table 6-50).**

6.5.7.1 Upland Decision Units

For upland DUs, significant cancer risks and noncancer hazards are predicted only for hypothetical future use of groundwater as a potable water supply. Risks and/or

hazards exceed the above defined target risks only for future indoor workers and residents at UST Site No. 1 and Refueling Pit 3. These risks are (1) due almost entirely to exposure to arsenic in groundwater, which appears to be present only at background levels and is below state and federal drinking water standards, and (2) based on hypothetical future use of groundwater as a potable water supply. Thus, no Study Area-related cancer risk drivers are identified.

Significant Study Area-related noncancer hazard is estimated for use groundwater as a potable water supply. This noncancer hazard is associated with exposure to gasoline and diesel range petroleum hydrocarbons at UST Site No.1. Both of these constituents are identified as risk drivers likely related to historical DoD operations. Arsenic and manganese contributed to elevated HI estimates at UST Site No.1 based on consumption of shallow groundwater by future residents. As discussed above neither arsenic nor manganese appears to be site related. Moreover, HI for these two inorganic constituents was only 2 (rounded up from 1.6). Study Area-related exposure to arsenic and manganese at UST Site No.1 seems low and neither constituent is identified as a risk driver.

Note that no Study-Area related risk drivers were identified for the following upland DUs – AST, UST Site No. 4, Refueling Pit 3, and Incinerator Building. However, for the Fire Training Area DU, a total cancer risk of 7×10^{-5} was estimated for future workers exposed to VOCs via potable use of groundwater. This risk exceeds the ODEQ acceptable ELCR of 1×10^{-5} for exposure to multiple carcinogens. For this area, vinyl chloride and arsenic contributed about equally to total risk. Since arsenic in groundwater does not appear to be site related, only vinyl chloride is identified as a risk driver for the groundwater at the Fire Training Area DU.

6.5.7.2 Aquatic DUs

Cancer risks to anglers are almost entirely due to consumption of fish, as opposed to direct contact with sediment or surface water, or from consumption of locally collected clams. Risks from consumption of arsenic in fish make up the majority of the total excess cancer risk: 78% at the Near Landfill, 85% at Finger Piers, and 96% at North of Pier 8. Dioxins/furans contributed essentially all of the remaining cancer risks for fish consumption.

As discussed at length in **Section 6.5.4**, essentially all risks associated with arsenic and dioxins/furans in fish tissue can be considered background risks, not related to historical DoD operations and including the landfill. These considerations indicate that no Study Area-related risk drivers can be identified for fish tissues.

Risks associated with direct contact with sediments and surface water for recreational users were uniformly low (4×10^{-7} to 2×10^{-6}). Likewise total HI estimates were all less than 0.04. Thus, no risk drivers were identified for sediments or surface water for any of the aquatic DUs.

6.6 Summary and Conclusions

This human health risk assessment presents a quantitative estimate of cancer risk and health hazard associated with COPCs at the TPMS under current and possible future land-use conditions. These quantitative estimates are discussed qualitatively to highlight uncertainties and put the estimates into proper perspective with respect to former DoD activities. Methods and procedures are consistent with both current ODEQ and EPA guidance for human health risk assessments.

6.6.1 Upland Decision Units

Considering current land use, no upper-bound excess cancer risk estimates exceed the ODEQ acceptable ELCR of 1×10^{-5} for exposure to multiple carcinogens and thus all estimates fall within or below the EPA target cancer risk range of 10^{-4} to 10^{-6}. In addition, all of the calculated noncancer HIs are below the ODEQ and EPA threshold of 1. These results support the conclusion that COPCs identified in soil and groundwater at AST, UST Site No. 1, Refueling Pit 3, UST Site No.4, Incinerator Building and Fire Training Area DUs are not likely to cause adverse health effects for any human receptors that currently use upland areas of the TPMS.

Under future land-use scenarios, calculated upper-bound excess cancer risks exceed the ODEQ acceptable risk level of 1×10^{-5} for the indoor worker scenario at UST Site No. 1 and Refueling Pit 3. Both the ODEQ threshold and EPAs risk range are exceeded or equaled for the resident scenario at the UST Site No. 1. Similarly noncancer HIs exceed the ODEQ and EPA threshold HI of 1 for indoor workers at UST Site No. 1 and Refueling Pit 3, and residents at UST Site No. 1.

Carcinogenic risks are (1) due almost entirely to exposure to arsenic (UST Site No. 1 and Refueling Pit 3), which appears to be present only at background levels and is below the state and federal drinking water standard, and (2) based on hypothetical future use of groundwater as a potable water supply. Thus, cancer risks are unlikely to be related to the Study Area, and are unlikely to be realized via installation of drinking water wells in the future.

One exception occurs at the Fire Training Area DU. Vinyl chloride-related risks from consumption of groundwater at this DU are 3×10^{-5} and exceed the ODEQ acceptable ELCR. Vinyl chloride is likely to be related to use of chlorinated solvents, such as PCE and TCE, during fire training exercises. Both of these solvents degrade to vinyl chloride when oxygen concentrations are sufficiently low. Total risk from consumption of groundwater at the Fire Training Area is 7×10^{-5}, with arsenic being the other major contributor. As discussed, arsenic is likely present only at background concentrations.

At UST Site No. 1, hazards are associated with gasoline and diesel range petroleum hydrocarbons which are likely to be Study Area-related. Small contributions to hazards are made by arsenic and manganese, but both are, again, likely to be associated with background rather than DoD activities.

6.6.2 Aquatic Decision Units

For current and future land-use scenarios, upper-bound excess cancer risks to recreational users are below or within the EPA target risk range of 10^{-6} to 10^{-4}. In addition, all of the computed HIs for the recreational user scenarios are below 1. Recreational users of the shoreline at TPMS are unlikely to experience significant exposure.

Upper-bound cancer risks for the angler scenario for North of Pier 8 and Near Landfill are 1×10^{-4}, at the upper end of the EPA target risk range of 10^{-6} to 10^{-4}. The upper-bound cancer risk for the angler scenario for the Finger Piers DU is 2×10^{-4}, which exceeds the upper bound of the EPA target risk range of 10^{-6} to 10^{-4}. These calculated cancer risks are almost entirely due to consumption of fish caught from aquatic DUs, as opposed to direct contact with sediment and surface water.

Risks from exposure to arsenic in fish make up the majority of the total excess cancer risk: 78% at the Near Landfill DU, 85% at Finger Piers DU, and 96% at North of Pier 8 DU. Risks from dioxins/furans in fish tissue make up the rest of the calculated cancer risk. Additionally, the noncancer HI exceeds the regulatory threshold of 1 at the Finger Piers DU. Arsenic and dioxins/furans are the noncancer hazard drivers for this DU.

Quantitative risk estimates for fish consumption are uncertain because the most appropriate target species for anglers could not be collected, and sculpin were used as a surrogate. Multiple line-of-evidence approach, however, indicates that sculpin data can be used in comparative fashion, along with other Study Area, Cathlamet Bay, and Lower Columbia River data, to support conclusions concerning fish consumption. These lines of evidence demonstrate that arsenic and dioxins/furans in surface sediment and fish tissues at the aquatic DUs most likely reflect typical ambient concentrations from sediment moving downstream to TPMS, and are not related to past DoD activities. They are, thus, likely to be attributable to upstream sources. Certainly many upstream sources exist that could be important contributors of dioxins/furans, such as storm water discharges, the lower Willamette River, and agricultural runoff.

In conclusion, cancer risks and hazards that exceed ODEQ and/or EPA targets appear to be limited to groundwater at UST Site No.1 and Fire Training Area DUs.

Gasoline range petroleum hydrocarbons (UST Site No. 1) and vinyl chloride (Fire Training Area) are the only risk drivers identified for these two DUs. All other risks estimates that exceed regulatory targets appear to be consistent with local background or background typical of sediments in the lower Columbia River in general and Cathlamet Bay in particular. Groundwater is not currently used for drinking water within the Study Area. Future potable use of groundwater is unlikely because a high quality municipal water supply is readily available and serves the vicinity.

Table 6-1
Toxicity Equivalence Factors for Dioxins/Furans and Relative Potency Factors for Carcinogenic PAHs
Tongue Point Multi-Sites Project, Astoria, Oregon

Carcinogenic PAHs	**Relative Potency Factor**
Benzo(a)pyrene	1
Benzo(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.01
Chrysene	0.001
Dibenz(a,h)anthracene	1
Indeno(1,2,3-cd)pyrene	0.1
Dioxins and Furans	**Toxicity Equivalence Factor**
2,3,7,8-TCDD	1
1,2,3,7,8-PeCDD	1
1,2,3,4,7,8-HxCDD	0.1
1,2,3,6,7,8-HxCDD	0.1
1-2-3-7-8-9-HxCDD	0.1
1,2,3,4,6,7,8-HpCDD	0.01
OCDD	0.0003
2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDF	0.03
2,3,4,7,8-PeCDF	0.3
1,2,3,4,7,8-HxCDF	0.1
1,2,3,6,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDF	0.1
2,3,4,6,7,8-HxCDF	0.1
1,2,3,4,6,7,8-HpCDF	0.01
1,2,3,4,7,8,9-HpCDF	0.01
OCDF	0.0003

Source: EPA May 2010, Regional Screening Levels for Chemical Contaminants at Superfund Sites

Notes:

PAHs - polycyclic aromatic hydrocarbons
2,3,7,8-TCDD - 2,3,7,8-Tetrachlorodibenzo-p-dioxin
1,2,3,7,8-PeCDD - 1,2,3,7,8-Pentachlorodibenzo-p-dioxin
1,2,3,4,7,8-HxCDD - 1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin
1,2,3,6,7,8-HxCDD - 1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin
1,2,3,7,8,9-HxCDD - 1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin
1,2,3,4,6,7,8-HpCDD - 1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin
OCDD - 1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin
2,3,7,8-TCDF - 2,3,7,8-Tetrachlorodibenzofuran
1,2,3,7,8-PeCDF - 1,2,3,7,8-Pentachlorodibenzofuran
2,3,4,7,8-PeCDF - 2,3,4,7,8-Pentachlorodibenzofuran
1,2,3,4,7,8-HxCDF - 1,2,3,4,7,8-Hexachlorodibenzofuran
1,2,3,6,7,8-HxCDF - 1,2,3,6,7,8-Hexachlorodibenzofuran
1,2,3,7,8,9-HxCDF - 1,2,3,7,8,9-Hexachlorodibenzofuran
2,3,4,6,7,8-HxCDF - 2,3,4,6,7,8-Hexachlorodibenzofuran
1,2,3,4,6,7,8-HpCDF - 1,2,3,4,6,7,8-Heptachlorodibenzofuran
1,2,3,4,7,8,9-HpCDF - 1,2,3,4,7,8,9-Heptachlorodibenzofuran
OCDF - 1,2,3,4,6,7,8,9-Octachlorodibenzofuran

Table 6-2
Decision Unit-Specific Risk-Based Concentrations for Total Petroleum Hydrocarbons
Tongue Point Multi-Sites Project, Astoria, Oregon

Decision Unit	Soil (mg/kg)		Groundwater (µg/L)
	Residential	Construction Worker	
AST Fuel Storage Area	4,800	20,000	410
UST Site No. 1 (1)	2,500	16,000	330
Refueling Pit 3	3,000	18,000	340
UST Site No. 4	2,900	19,000	180
Fire Training Area	4,100	20,000	200

Notes:

(1) Based on the more conservative Risk-Based Concentrations calculated from two samples from UST Site No.1

mg/kg - milligram per kilogram
µg/L - microgram per liter

Table 6-3
Summary Results of Sediment Reference Screen
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical of Interest	Location	Marginal Plot shows Site ≤ Reference?	Hypothesis Testing: (1) Site Mean ≤ Reference Mean				Selected for Concentration-Risk Screen?
			Student's *t*-test		Nonparametric WMW test		
			p-value	Accept H_0?	*p*-value	Accept H_0?	
Antimony	Aquatic Finger Piers	No	0.000	No	0.001	No	Yes
	Aquatic North of Pier 8	No	0.001	No	0.001	No	Yes
	Aquatic Near Landfill	No	0.000	No	0.002	No	Yes
Arsenic	Aquatic Finger Piers	No	0.036	No	0.021	No	Yes
	Aquatic North of Pier 8	No	0.000	No	0.001	No	Yes
	Aquatic Near Landfill	No	0.001	No	0.001	No	Yes
Barium	Aquatic Finger Piers	Yes	0.999	Yes	0.996	Yes	No
	Aquatic North of Pier 8	Yes	1.000	Yes	0.999	Yes	No
	Aquatic Near Landfill	Yes	0.786	Yes	0.945	Yes	No
Cadmium	Aquatic Finger Piers	No	0.000	No	0.001	No	Yes
	Aquatic North of Pier 8	No	0.000	No	0.001	No	Yes
	Aquatic Near Landfill	No	0.000	No	0.001	No	Yes
Chromium	Aquatic Finger Piers	No	0.000	No	0.001	No	Yes
	Aquatic North of Pier 8	No	0.000	No	0.001	No	Yes
	Aquatic Near Landfill	No	0.003	No	0.004	No	Yes
Copper	Aquatic Finger Piers	No	0.000	No	0.001	No	Yes
	Aquatic North of Pier 8	No	0.000	No	0.001	No	Yes
	Aquatic Near Landfill	Yes	1.000	Yes	0.998	Yes	No
Lead	Aquatic Finger Piers	No	0.000	No	0.001	No	Yes
	Aquatic North of Pier 8	No	0.000	No	0.001	No	Yes
	Aquatic Near Landfill	No	0.000	No	0.001	No	Yes
Manganese	Aquatic Finger Piers	Yes	0.445	Yes	0.601	Yes	No
	Aquatic North of Pier 8	No	0.000	No	0.001	No	Yes
	Aquatic Near Landfill	Yes	1.000	Yes	0.998	Yes	No
Mercury	Aquatic Finger Piers	No	0.001	No	0.001	No	Yes
	Aquatic North of Pier 8	No	0.026	No	0.028	No	Yes
	Aquatic Near Landfill	No	0.004	No	0.005	No	Yes
Nickel	Aquatic Finger Piers	No	0.000	No	0.001	No	Yes
	Aquatic North of Pier 8	No	0.000	No	0.001	No	Yes
	Aquatic Near Landfill	No	0.001	No	0.003	No	Yes
Selenium(2)	Aquatic North of Pier 8	Yes	0.124	Yes	0.525	Yes	No
Silver	Aquatic Finger Piers	No	0.000	No	0.001	No	Yes
	Aquatic North of Pier 8	Yes	0.075	Yes	0.080	Yes	No
	Aquatic Near Landfill	No	0.000	No	0.004	No	Yes
Vanadium	Aquatic Finger Piers	No	0.000	No	0.001	No	Yes
	Aquatic North of Pier 8	No	0.000	No	0.001	No	Yes
	Aquatic Near Landfill	Yes	0.151	Yes	0.261	Yes	No
Zinc	Aquatic Finger Piers	No	0.000	No	0.001	No	Yes
	Aquatic North of Pier 8	No	0.000	No	0.001	No	Yes
	Aquatic Near Landfill	No	0.000	No	0.001	No	Yes

Notes:

WMW - Wilcoxon-Mann-Whitney test

(1) The null hypothesis (H_0) and the alternative hypothesis (H_A) for the t-test and the WMW test to evaluate the mean of two populations are:

H_0: Mean concentration of a metal in the composite sample from an aquatic DU is less than or equal to that in the composite sample from the reference area

H_A: Mean concentration of a metal in the composite sediment sample from an aquatic DU is greater than the concentration in the composite sample from the reference area

Hypothesis testing is performed using ProUCL version 4.00.04 with 5% level of significance.

(2) Selenium is not detected at Aquatic Finger Piers and Aquatic Near Landfill.

Table 6-4
Evaluation of Cross-Medium Chemical of Potential Concern
Tongue Point Multi-Sites Project, Astoria, Oregon

Decision Unit	Medium	Chemical	Chemical of Potential Concern?	Quantitative (Quant) or Qualitative (Qual) Analysis?	Comment (1)
AST Fuel Storage Area	Groundwater	Carcinogenic PAHs	Yes	Qual	SQL>SL
	Surface Soil	Arsenic	Yes	Qual	no data
	Surface/ Subsurface Soil	Arsenic	Yes	Qual	no data
UST Site No. 1	Subsurface Soil	Carcinogenic PAHs	Yes	Quant	detected, C<SL
		Arsenic	Yes	Qual	no data
		Diesel Range Hydrocarbons	Yes	Quant	detected, C<SL
		Gasoline Range Hydrocarbons	Yes	Quant	detected, C<SL
		Manganese	Yes	Qual	no data
	Surface Water	Carcinogenic PAHs	Yes	Quant	detected, C<SL
		Total DDT	Yes	Qual	no data
		Mercury	No	NA	SQL<SL
	Sediment	Arsenic	Yes	Quant	detected, C<SL
Refueling Pit 3	Subsurface Soil	Trichloroethene	No	NA	SQL<SL
		Arsenic	Yes	Qual	no data
		Gasoline Range Hydrocarbons	Yes	Quant	detected, C<SL
	Surface Water	Carcinogenic PAHs	No	NA	SQL<SL
		Total DDT	Yes	Qual	SQL>SL
		Total PCBs	Yes	Qual	no data
		Mercury	No	NA	SQL<SL
	Sediment	Arsenic	Yes	Quant	detected, C<SL
Fire Training Area	Subsurface Soil	Benzene	No	NA	SQL<SL
		Vinyl chloride	No	NA	SQL<SL
		Carcinogenic PAHs	Yes	Quant	detected, C<SL
		Dioxin/Furan TEQ	Yes	Quant	detected, C<SL
		Arsenic	No	NA	C<BKG
		Manganese	Yes	Qual	no data
		Diesel Range Hydrocarbons	Yes	Quant	detected, C<SL
		Gasoline Range Hydrocarbons	Yes	Quant	detected, C<SL
	Surface Water	Carcinogenic PAHs	No	NA	SQL<SL
		Total DDT	Yes	Qual	SQL>SL
		Total PCBs	Yes	Qual	no data
		Lead	No	NA	SQL<SL
		Mercury	No	NA	SQL<SL
	Sediment	Arsenic	Yes	Quant	detected, C<SL
Aquatic - North of Pier 8	Surface Water	Carcinogenic PAHs	No	NA	SQL<SL
		Mercury	No	NA	SQL<SL
Aquatic - Finger Piers	Surface Water	Carcinogenic PAHs	No	NA	SQL<SL
		Total DDT	Yes	Qual	SQL>SL
		Total PCBs	Yes	Qual	no data
		Mercury	No	NA	SQL<SL
Aquatic - Near Landfill	Surface Water	Carcinogenic PAHs	No	NA	SQL<SL
		Total DDT	Yes	Qual	SQL>SL
		Total PCBs	No	NA	SQL<SL
		Mercury	No	NA	SQL<SL
		Dioxin/Furan TEQ	Yes	Qual	SQL>SL
	Sediment	Arsenic	Yes	Quant	detected, C<SL

Notes:

PAHs - polycyclic aromatic hydrocarbons
TPH - total petroleum hydrocarbon
DDD - p,p'-dichlorodiphenyldichloroethane
DDE - p,p'-dichlorodiphenyldichloroethylene
DDT - p,p'-dichlorodiphenyltrichloroethane
SQL - sample quantitation level
SL - screening level
(1) Comment:
SQL>SL: sample quantitation limit exceeding screening level
SQL<SL: sample quantitation limit below screening level
C<SL: concentration below screening level
no data : not analyzed in the given medium
C<BKG: concentration below state background value

Total DDT - 4,4'-DDT, 4,4'-DDD, and 4,4'-DDE
Total PCBs - Aroclor 1260, Aroclor 1254, Aroclor 1221, Aroclor 1232, Aroclor 1016, and Aroclor 1242
TEQ - toxicity equivalent
NA - not applicable
C - concentration
BKG - background

Table 6-5

Identification of Chemicals of Potential Concern - AST Fuel Storage Area

Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical of Interest	Surface Soil		Surface/Subsurface Soil		Groundwater	
	Quant	Qual	Quant	Qual	Quant	Qual
Semi-Volatile Organic Compounds						
Carcinogenic PAHs	Yes [a]		No	No		Yes [b]
Inorganics						
Arsenic		Yes [c]		Yes [c]	Yes [a]	

Notes:

Quant = chemical of potential concern (COPC) for quantitative analysis
Qual = COPC for qualititative analysis
Yes = Selected as COPC
No = Detected, but not selected as COPC
PAH = Polycyclic aromatic hydrocarbon
Carcinogenic PAHs = benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene

a = Concentration > screening level (SL)
b = Cross media COPC; Not detected and sample quantitation limit (SQL) > SL
c = Cross media COPC; Not analyzed

- COPC using ODEQ and CERCLA methods

Table 6-6

Identification of Chemicals of Potential Concern - UST Site No. 1
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	Subsurface Soil		Groundwater		Surface Water		Sediment		Soil Gas	
	Quant	Qual	Quant	Qual	Quant	Qual	Quant	Qual	Quant	Qual
Volatile Organic Compounds										
1,2,4-Trimethylbenzene	--	--	No	No	--	--	--	--	Yes [a]	
1,3,5-Trimethylbenzene	--	--	--	--	--	--	--	--	Yes [a]	
2-Propanol	--	--	--	--	--	--	--	--		Yes [b]
4-Ethyltoluene	--	--	--	--	--	--	--	--		Yes [b]
Benzene	--	--	--	--	--	--	--	--	Yes [c]	
Chloroform	--	--	--	--	--	--	--	--	Yes [a]	
Ethanol	--	--	--	--	--	--	--	--		Yes [b]
Ethylbenzene	--	--	--	--	--	--	--	--	Yes [a]	
Naphthalene	--	--	--	--	--	--	--	--	Yes [a]	
Tetrachloroethene	--	--	--	--	--	--	--	--	Yes [a]	
Tetrahydrofuran	--	--	--	--	--	--	--	--		Yes [b]
Semi-Volatile Organic Compounds										
2,3,5-Trimethylnaphthalene	--	--	--	--		Yes [b]	--	--	--	--
Carcinogenic PAHs	Yes [d]		Yes [c]		Yes [d]		Yes [c]		--	--
Pesticides/PCBs										
Total DDT	--	--	--	--		Yes [e]	Yes [c]		--	--
Inorganics										
Arsenic		Yes [e]	Yes [c]		Yes [c]		Yes [d]		--	--
Manganese	--	Yes [e]	Yes [c]		No	No	No	No		
Mercury	--	--	--	--	-- [f]		Yes [c]		--	--
Total Petroleum Hydrocarbons										
Diesel Range Hydrocarbons	Yes [d]		Yes [c]		--	--	No	No	--	--
Gasoline Range Hydrocarbons	Yes [d]		Yes [c]		--	--	--	--	--	--

Notes:

Quant = chemical of potential concern (COPC) for quantitative analysis
Qual = COPC for qualititative analysis
Yes = Selected as COPC
No = Detected, but not selected as COPC
-- = Not detected or analyzed

PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyls
DDD - p,p'-dichlorodiphenyldichloroethane
DDE - p,p'-dichlorodiphenyldichloroethylene
DDT - p,p'-dichlorodiphenyltrichloroethane

Carcinogenic PAHs = benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene
Total DDT = 4,4'-DDT, 4,4'-DDD,and 4,4'-DDE

a = COPC on multiple basis in a medium; Concentration < SL
b = No SL
c = Concentration > screening level (SL)

d = Cross media COPC; Concentration < SL
e = Cross media COPC; Not analyzed
f = Sample quantitation limit (SQL) < SL

- COPC using ODEQ methods
- COPC using ODEQ and CERCLA methods

Table 6-7

Identification of Chemicals of Potential Concern - Refueling Pit 3
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	Subsurface Soil		Groundwater		Surface Water		Sediment		Soil Gas	
	Quant	Qual	Quant	Qual	Quant	Qual	Quant	Qual	Quant	Qual
Volatile Organic Compounds										
2-Propanol	--	--	--	--	--	--	--	--		Yes [a]
4-Ethyltoluene	--	--	--	--	--	--	--	--		Yes [a]
Trichloroethene	-- [b]		Yes [c]		--	--	--	--	--	--
Semi-Volatile Organic Compounds										
Carcinogenic PAHs	No	No	--	--	-- [b]		Yes [c]		--	--
Pesticides/PCBs										
Total DDT	--	--	--	--		Yes [d]	Yes [c]		--	--
Total PCBs	--	--	--	--		Yes [e]	Yes [c]		--	--
Inorganics										
Arsenic		Yes [e]	Yes [c]		Yes [c]		Yes [f]	--	--	--
Mercury	--	--	--		-- [b]		Yes [c]		--	--
Total Petroleum Hydrocarbons										
Gasoline Range Hydrocarbons	Yes [f]		Yes [c]		--	--	--	--	--	--

Notes:

Quant = chemical of potential concern (COPC) for quantitative analysis
Qual = COPC for qualititative analysis
Yes = Selected as COPC
No = Detected, but not selected as COPC
-- = Not detected or analyzed

PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyls
DDD = p,p'-dichlorodiphenyldichloroethane
DDE = p,p'-dichlorodiphenyldichloroethylene
DDT = p,p'-dichlorodiphenyltrichloroethane

Carcinogenic PAHs = benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene
Total DDT = 4,4'-DDT, 4,4'-DDD,and 4,4'-DDE
Total PCBs = Aroclor 1260, Aroclor 1254, Aroclor 1221, Aroclor 1232, Aroclor 1248, Aroclor 1016, and Aroclor 1242

a = No SL
b = SQL < SL
c = Concentration > screening level (SL)
d = Cross media COPC; Not detected and sample quantitation limit (SQL) > SL
e = Cross media COPC; Not analyzed
f = Cross media COPC; Concentration < SL

- COPC using ODEQ methods
- COPC using ODEQ and CERCLA methods

CDM

Table 6-8

Identification of Chemicals of Potential Concern - UST Site No. 4
Tongue Point Multi-Sites Project, Astoria, Oregon

No COPC identified at this decision unit.

Table 6-9
Identification of Chemicals of Potential Concern - Incinerator Building
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	Surface Soil	
	Quant	Qual
Dioxin/Furan		
Dioxin/Furan TEQ	Yes [a]	
Inorganics		
Thallium	[b]	Yes [b]

Notes:

Quant = chemical of potential concern (COPC) for quantitative analysis
Qual = COPC for qualititative analysis
PAH = polycyclic aromatic hydrocarbon
TEQ = toxicity equivalent
Yes = Selected as COPC

Carcinogenic PAHs= benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene

a = Concentration > screening level (SL)
b = No SL

- COPC using CERCLA methods

Table 6-10
Identification of Chemicals of Potential Concern - Fire Training Area[(1)]
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	Subsurface Soil		Groundwater		Surface Water		Sediment		Soil Gas	
	Quant	Qual	Quant	Qual	Quant	Qual	Quant	Qual	Quant	Qual
Volatile Organic Compounds										
1,3-Butadiene	--	--	--	--	--	--	--	--	Yes [a]	
2-Hexanone	--	--	--	--	--	--	--	--		Yes [b]
2-Propanol	--	--	--	--	--	--	--	--		Yes [b]
4-Ethyltoluene	--	--	--	--	--	--	--	--		Yes [b]
Benzene	-- [c]		Yes [d]		--	--	--	--	Yes [a]	
Chloroform	--	--	--	--	--	--	--	--	Yes [d]	
Ethanol	--	--	--	--	--	--	--	--		Yes [b]
Tetrachloroethene	--	--	--	--	--	--	--	--	Yes [a]	
Vinyl chloride	-- [c]		Yes [d]		--		--	--	No	No
Semi-Volatile Organic Compounds										
Carcinogenic PAHs	Yes [e]		Yes [d]		-- [c]		Yes [d]		--	--
Dioxin/Furan										
Dioxin/Furan TEQ	Yes [e]		Yes [d]		--	--	--	--	--	--
Pesticides/PCBs										
Total DDT	--	--	--	--		Yes [f]	Yes [d]		--	--
Total PCBs	--	--	--	--		Yes [g]	Yes [d]		--	--
Inorganics										
Arsenic	No [h]		Yes [d]		Yes [d]		Yes [e]		--	--
Lead	No	No	No	No	-- [c]		Yes [d]		--	--
Manganese		Yes [f]	Yes [d]		No	No	No	No	--	--
Mercury	--	--	--	--	-- [c]		Yes [d]		--	--

Table 6-10 (continued)
Identification of Chemicals of Potential Concern - Fire Training Area
Tongue Point Multi-Sites Project, Astoria, Oregon

Notes:

(1) Fuels may also have been used at the Fire Training Area, and petroleum hydrocarbons were identified as COPCs in soil and groundwater during COPC screening process. These hydrocarbons are excluded by CERCLA.

Quant = chemical of potential concern (COPC) for quantitative analysis
Qual = COPC for qualititative analysis
Yes = Selected as COPC
No = Detected, but not selected as COPC
-- = Not detected or analyzed

PAH = polycyclic aromatic hydrocarbon
TEQ = toxicity equivalent
PCB = polychlorinated biphenyls
DDD = p,p'-dichlorodiphenyldichloroethane
DDE =p,p'-dichlorodiphenyldichloroethylene
DDT = p,p'-dichlorodiphenyltrichloroethane

Carcinogenic PAHs = benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene
Total DDT = 4,4'-DDT, 4,4'-DDD,and 4,4'-DDE
Total PCBs = Aroclor 1260, Aroclor 1254, Aroclor 1221, Aroclor 1232, Aroclor 1248, Aroclor 1016, and Aroclor 1242

a = COPC on multiple basis in a medium; Concentration < SL
b = No SL
c = SQL < SL
d = Concentration > screening level (SL)

e = Cross media COPC; Concentration < SL
f = Cross media COPC; Not detected and sample quantitation limit (SQL) > SL
g = Cross media COPC; Not analyzed
h = maximum concentration less than background concentration

- COPC using CERCLA methods

Table 6-11

Identification of Chemicals of Potential Concern - Aquatic North of Pier 8
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	Surface Water		Sediment	
	Quant	Qual	Quant	Qual
Semi-Volatile Organic Compounds				
Carcinogenic PAHs	-- [a]		Yes [b]	
Inorganics				
Arsenic	Yes [b]		Yes [b]	
Cadmium	--	--	Yes [c]	
Chromium	--	--	Yes [c]	
Lead	--	--	Yes [c]	
Manganese	No	No	Yes [c]	
Mercury	-- [a]		Yes [b]	

Notes:

Quant = chemical of potential concern (COPC) for quantitative analysis
Qual = COPC for qualititative analysis
Yes = Selected as COPC
No = Detected, but not selected as COPC
-- = Not detected or analyzed
PAH = polycyclic aromatic hydrocarbon

Carcinogenic PAHs = benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene

a = Sample quantitation limit (SQL) < SL
b = Concentration > screening level (SL)
c = COPC on multiple basis in a medium; Concentration < SL

- COPC using CERCLA methods

CDM

Table 6-12

Identification of Chemicals of Potential Concern - Aquatic Finger Piers
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	Surface Water		Sediment	
	Quant	Qual	Quant	Qual
Semi-Volatile Organic Compounds				
Carcinogenic PAHs	-- [a]		Yes [b]	
Pesticides/PCBs				
Total DDT		Yes [c]	Yes [b]	
Total PCBs		Yes [d]	Yes [b]	
Inorganics				
Arsenic	Yes [b]		Yes [e]	
Lead	--	--	Yes [e]	
Mercury	-- [a]		Yes [b]	

Notes:

Quant = chemical of potential concern (COPC) for quantitative analysis
Qual = COPC for qualititative analysis
Yes = Selected as COPC
No = Detected, but not selected as COPC
-- = Not detected or analyzed

PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyls
DDD = p,p'-dichlorodiphenyldichloroethane
DDE = p,p'-dichlorodiphenyldichloroethylene
DDT = p,p'-dichlorodiphenyltrichloroethane

Carcinogenic PAHs = benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene
Total DDT = 4,4'-DDT, 4,4'-DDD,and 4,4'-DDE
Total PCBs = Aroclor 1260, Aroclor 1254, Aroclor 1221, Aroclor 1232, Aroclor 1248, Aroclor 1016, and Aroclor 1242

a = SQL < SL
b = Concentration > screening level (SL)
c = Cross media COPC; Not detected and sample quantitation limit (SQL) > SL
d = Cross media COPC; Not analyzed
e = COPC on multiple basis in a medium; Concentration < SL

- COPC using CERCLA methods

CDM

Table 6-13

Identification of Chemicals of Potential Concern - Aquatic Near Landfill
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical	Surface Water		Sediment	
	Quant	Qual	Quant	Qual
Semi-Volatile Organic Compounds				
Carcinogenic PAHs	-- [a]		Yes [b]	
Dioxin/Furan				
Dioxin/Furan TEQ		Yes [c]	Yes [b]	
Pesticides/PCBs				
Total DDT		Yes [c]	Yes [b]	
Total PCBs	-- [a]		Yes [b]	
Inorganics				
Arsenic	Yes [b]		Yes [d]	
Mercury	-- [a]	--	Yes [b]	

Notes:

Quant = chemical of potential concern (COPC) for quantitative analysis
Qual = COPC for qualititative analysis
Yes = Selected as COPC
No = Detected, but not selected as COPC
-- = Not detected or analyzed

PAH = polycyclic aromatic hydrocarbon
TEQ = toxicity equivalent
PCB = polychlorinated biphenyls
DDD = p,p'-dichlorodiphenyldichloroethane
DDE = p,p'-dichlorodiphenyldichloroethylene
DDT = p,p'-dichlorodiphenyltrichloroethane

Carcinogenic PAHs = benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene
Total DDT = 4,4'-DDT, 4,4'-DDD,and 4,4'-DDE
Total PCBs = Aroclor 1260, Aroclor 1254, Aroclor 1221, Aroclor 1232, Aroclor 1248, Aroclor 1016, and Aroclor 1242

a = SQL < SL
b = Concentration > screening level (SL)
c = Cross media COPC; Not detected and sample quantitation limit (SQL) > SL
d = Cross media COPC; Concentration < SL

- COPC using CERCLA methods

Table 6-14
Exposure Point Concentrations
Tongue Point Multi-Sites Project, Astoria, Oregon

Decision Unit	Medium	Chemical of Potential Concern	Unit	No. of Samples	Reasonable Maximum Exposure		Statistics [1]
					EPC	Rationale	
AST Fuel Storage Area	Surface Soil	Carcinogenic PAHs [2]	mg/kg	12	1.28E-01	90% UCL	KM (Chebyshev)
	Groundwater	Arsenic	µg/L	1	6.05E-01	maximum	-
UST Site No. 1	Subsurface Soil	Carcinogenic PAHs [2]	mg/kg	5	1.29E-01	maximum	-
		Diesel Range Hydrocarbons	mg/kg	5	1.30E+04	maximum	-
		Gasoline Range Hydrocarbons	mg/kg	5	1.90E+03	maximum	-
	Groundwater	Carcinogenic PAHs [2]	µg/L	7	2.24E-02	maximum	-
		Arsenic	µg/L	7	4.52E+00	90% UCL	Student's-t
		Manganese	µg/L	7	1.24E+03	90% UCL	Student's-t
		Diesel Range Hydrocarbons	µg/L	7	4.10E+02	90% UCL	KM (t)
		Gasoline Range Hydrocarbons	µg/L	7	5.40E+02	maximum	-
	Sediment	Carcinogenic PAHs [2]	mg/kg	2	6.01E-02	maximum	-
		Total DDT [3]	mg/kg	2	4.70E-03	maximum	-
		Arsenic	mg/kg	2	4.50E+00	maximum	-
		Mercury	mg/kg	2	1.23E-01	maximum	-
	Surface Water	Carcinogenic PAHs [2]	µg/L	2	6.08E-04	maximum	-
		Arsenic	µg/L	2	9.39E-01	maximum	-
Refueling Pit 3	Subsurface Soil	Gasoline Range Hydrocarbons	mg/kg	4	2.80E+01	maximum	-
	Groundwater	Trichloroethene	µg/L	9	1.80E+00	maximum	-
		Arsenic	µg/L	9	5.36E+00	90% UCL	KM (t)
		Gasoline Range Hydrocarbons	µg/L	9	3.00E+03	maximum	-
	Sediment	Carcinogenic PAHs [2]	mg/kg	2	1.63E-01	maximum	-
		Total DDT [3]	mg/kg	2	8.50E-03	maximum	-
		Total PCBs [4]	mg/kg	2	6.20E-02	maximum	-
		Arsenic	mg/kg	2	5.40E+00	maximum	-
		Mercury	mg/kg	2	9.60E-02	maximum	-
	Surface Water	Arsenic	µg/L	2	9.97E-01	maximum	-

Table 6-14 (continued)
Exposure Point Concentrations
Tongue Point Multi-Sites Project RI/FS
Former Tongue Point Naval Air Station, Astoria, Oregon

Decision Unit	Medium	Chemical of Potential Concern	Unit	No. of Samples	Reasonable Maximum Exposure		Statistics [1]
					EPC	Rationale	
Incinerator Building	Surface Soil	Dioxin/Furan TEQ	mg/kg	5	1.45E-05	90% UCL	Student's-t
Fire Training Area	Subsurface Soil	Chromium	mg/kg	15	1.56E+01	90% UCL	Approximate Gamma
		Carcinogenic PAHs [2]	mg/kg	15	2.13E-01	90% UCL	KM (Percentile Bootstrap)
		Dioxin/Furan TEQ	mg/kg	3	1.54E-06	maximum	-
		Diesel Range Hydrocarbons	mg/kg	15	6.17E+03	90% UCL	KM (Chebyshev)
		Gasoline Range Hydrocarbons	mg/kg	15	2.60E+02	maximum	-
	Groundwater	Benzene	µg/L	17	3.80E+00	maximum	-
		Vinyl Chloride	µg/L	17	1.19E+01	90% UCL	KM (Chebyshev)
		Carcinogenic PAHs [2]	µg/L	17	2.20E-02	maximum	-
		Dioxin/Furan TEQ	µg/L	3	4.11E-06	maximum	-
		Arsenic	µg/L	17	6.49E+00	90% UCL	KM (Chebyshev)
		Manganese	µg/L	17	2.44E+03	90% UCL	Approximate Gamma
		Diesel Range Hydrocarbons	µg/L	17	3.68E+02	90% UCL	KM (Percentile Bootstrap)
		Gasoline Range Hydrocarbons	µg/L	17	6.70E+02	maximum	-
	Sediment	Carcinogenic PAHs [2]	mg/kg	2	3.96E-02	maximum	-
		Total DDT [3]	mg/kg	2	2.17E-03	maximum	-
		Total PCBs [4]	mg/kg	2	2.00E-02	maximum	-
		Arsenic	mg/kg	2	6.52E+00	maximum	-
		Lead	mg/kg	2	1.78E+01	maximum	-
		Mercury	mg/kg	2	1.16E-01	maximum	-
	Surface Water	Arsenic	µg/L	2	9.98E-01	maximum	-

Table 6-14 (continued)
Exposure Point Concentrations
Tongue Point Multi-Sites Project RI/FS
Former Tongue Point Naval Air Station, Astoria, Oregon

Decision Unit	Medium	Chemical of Potential Concern	Unit	No. of Samples	Reasonable Maximum Exposure		Statistics [1]
					EPC	Rationale	
Aquatic North of Pier 8	Sediment	Carcinogenic PAHs [2]	mg/kg	7	3.40E-02	90% UCL	Student's-t
		Arsenic	mg/kg	7	7.80E+00	90% UCL	Student's-t
		Cadmium	mg/kg	7	3.64E-01	90% UCL	Student's-t
		Chromium	mg/kg	7	1.90E+01	90% UCL	Student's-t
		Lead	mg/kg	7	1.24E+01	90% UCL	Modified-t
		Manganese	mg/kg	7	5.95E+02	90% UCL	Student's-t
		Mercury	mg/kg	7	7.83E-02	90% UCL	Student's-t
	Surface Water	Arsenic	µg/L	1	1.04E+00	maximum	-
	Fish Fillet	Total DDT [3]	mg/kg	1	6.14E-03	maximum	-
		Arsenic	mg/kg	1	9.50E-01	maximum	-
		Chromium	mg/kg	1	6.60E-01	maximum	-
		Lead	mg/kg	1	2.01E-01	maximum	-
		Mercury	mg/kg	1	2.68E-01	maximum	-
		Selenium	mg/kg	1	2.20E+00	maximum	-
Aquatic - Finger Piers	Sediment	Carcinogenic PAHs [2]	mg/kg	7	2.81E-02	90% UCL	Student's-t
		Total DDT [3]	mg/kg	7	2.24E-03	90% UCL	Student's-t
		Total PCBs [4]	mg/kg	7	3.52E-03	90% UCL	Student's-t
		Arsenic	mg/kg	7	5.64E+00	90% UCL	Approximate Gamma
		Lead	mg/kg	7	1.02E+01	90% UCL	Student's-t
		Mercury	mg/kg	7	1.16E-01	90% UCL	Modified-t
	Surface Water	Arsenic	µg/L	2	1.17E+00	maximum	-
	Fish Fillet	Total DDT [3]	mg/kg	1	7.67E-03	maximum	-
		Dioxin/Furan TEQ	mg/kg	1	2.30E-06	maximum	-

Table 6-14 (continued)
Exposure Point Concentrations
Tongue Point Multi-Sites Project RI/FS
Former Tongue Point Naval Air Station, Astoria, Oregon

Decision Unit	Medium	Chemical of Potential Concern	Unit	No. of Samples	Reasonable Maximum Exposure		Statistics [1]
					EPC	Rationale	
Aquatic - Finger Piers	Fish Fillet	Arsenic	mg/kg	1	1.31E+00	maximum	-
		Chromium	mg/kg	1	4.70E-01	maximum	-
		Lead	mg/kg	1	1.01E-01	maximum	-
		Mercury	mg/kg	1	2.87E-01	maximum	-
		Selenium	mg/kg	1	2.00E+00	maximum	-
		Tributyl Tin as ion	mg/kg	1	7.40E-04	maximum	-
Aquatic - Near Landfill	Sediment	Carcinogenic PAHs [3]	mg/kg	7	1.95E-02	90% UCL	Student's-t
		Dioxin/Furan TEQ	mg/kg	7	8.72E-07	90% UCL	Student's-t
		Total DDT [3]	mg/kg	7	1.81E-03	90% UCL	Student's-t
		Total PCBs [4]	mg/kg	7	4.21E-03	90% UCL	Student's-t
		Arsenic	mg/kg	7	5.72E+00	90% UCL	Student's-t
		Mercury	mg/kg	7	7.59E-02	90% UCL	Student's-t
	Surface Water	Arsenic	mg/kg	1	1.02E+00	maximum	-
	Fish Fillet	Total DDT [3]	mg/kg	1	4.89E-03	maximum	-
		Dioxin/Furan TEQ	mg/kg	1	9.69E-07	maximum	-
		Arsenic	mg/kg	1	8.00E-01	maximum	-
		Chromium	mg/kg	1	1.13E+00	maximum	-
		Lead	mg/kg	1	1.24E-01	maximum	-
		Mercury	mg/kg	1	2.46E-01	maximum	-
		Selenium	mg/kg	1	2.20E+00	maximum	-
		Tributyl tin as ion	mg/kg	1	8.00E-04	maximum	-

Table 6-14 (continued)
Exposure Point Concentrations
Tongue Point Multi-Sites Project RI/FS
Former Tongue Point Naval Air Station, Astoria, Oregon

Notes:

PAH = Polycyclic aromatic hydrocarbon
PCB = Polychlorinated biphenyl
TEQ = Toxicity equivalent
90% UCL = 90 percentile of upper confidence limit

DDD = p,p'-dichlorodiphenyldichloroethane
DDE = p,p'-dichlorodiphenyldichloroethylene
DDT = p,p'-dichlorodiphenyltrichloroethane

(1) Statistics:
KM(Chebyshev) - UCL based upon Kaplan-Meier estimates using the Chebyshev inequality
Student's-t - UCL based on Student's t-statistic assuming normal distribution of the dataset
KM(t) - UCL based upon Kaplan-Meier estimates using the Student's t-distribution cutoff value
KM (Percentile Bootstrap) - UCL based upon Kaplan-Meier estimates using the percentile bootstrap method
KM(BCA) - UCL based upon Kaplan-Meier estimates using the bias-corrected accelerated bootstrap method
Modified-t - UCL based on modified t-statistic (adjusted for skewness).
Approximate Gamma - UCL calculated assuming gamma distribution of the dataset
(2) Carcinogenic PAHs = benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.
(3) Total DDT = 4,4'-DDT, 4,4'-DDD,and 4,4'-DDE
(4) Total PCBs = Aroclor 1260, Aroclor 1254, Aroclor 1221, Aroclor 1232, Aroclor 1248, Aroclor 1016, and Aroclor 1242

Table 6-15
Soil Gas and Predicted Indoor Air Concentrations
Tongue Point Multi-Sites Project, Astoria, Oregon

UST Site No.1							
Chemical of Potential Concern	Unit	Current Land Use				Future Land Use	
		Soil Gas EPC		Indoor Air Concentration		Soil Gas EPC[3]	Indoor Air Concentration
		DORM 4[1]	Office[2]	DORM 4	Office		
1,2,4-Trimethylbenzene	µg/m^3	330	330	2.91E-01	7.08E-02	330	1.84E-01
1,3,5-Trimethylbenzene	µg/m^3	150	150	1.31E-01	3.21E-02	150	8.31E-02
Benzene	µg/m^3	20	130	2.22E-02	3.44E-02	130	9.53E-02
Chloroform	µg/m^3	2.1	2.1	2.62E-03	5.75E-04	5	4.11E-03
Ethylbenzene	µg/m^3	54	54	5.60E-02	1.31E-02	54	3.53E-02
Naphtahlene	µg/m^3	3.8	3.8	3.29E-03	8.04E-04	3.8	2.08E-03
Tetrachloroethene	µg/m^3	19	19	1.91E-02	4.51E-03	19	1.21E-02

Notes:

(1) Based on maximum detected concentrations from UST1-06 and UST1-07
(2) Based on maximum detected concentrations from UST1-07 and UST1-08
(3) Based on maximum detected concentrations from UST1

Fire Training Area			
Chemical of Potential Concern	Unit	Soil Gas EPC[1]	Indoor Air Concentration
1,3-Butadiene	µg/m^3	16	3.44E-03
Benzene	µg/m^3	49	4.22E-03
Chloroform	µg/m^3	220	2.21E-02
Tetrachloroethene	µg/m^3	83	5.91E-03

Notes:

(1) Based on maximum detected concentrations from Fire Training Area

Table 6-16
Exposure Parameters for Soil
Tongue Point Multi-Sites Project, Astoria, Oregon

Receptor Population	Receptor Age	Scenario Time Frame	Exposure Point	Parameter Code	Parameter Definition	Unit	Reasonable Maximum Exposure	
							Value	Reference
Outdoor Worker	Adult	Future	Surface Soil	CS	Chemical Concentration in Soil	mg/kg	See Table 6-14	See Table 6-14
				CF1	Conversion Factor 1	kg/mg	1E-06	--
				IR-S	Ingestion Rate of Soil	mg/day	100	ODEQ 2003
				SA	Skin Surface Area Available for Contact	cm^2	3,300	ODEQ 2003
				AF	Adherence Factor	mg/cm^2	0.1	ODEQ 2003
				ABS	Absorption Factor	unitless	See Table 6-22	See Table 6-22
				ET	Exposure Time	hrs/day	8	EPA 2009
				EF	Exposure Frequency	days/year	250	ODEQ 2003
				ED	Exposure Duration	years	25	ODEQ 2003
				BW	Body Weight	kg	70	ODEQ 2003
				AT-C	Averaging Time (Cancer)	days	25,550	ODEQ 2003
				AT-N	Averaging Time (Noncancer)	days	9,125	ODEQ 2003
Construction Worker	Adult	Future	Surface/ Subsurface Soil	CS	Chemical Concentration in Soil	mg/kg	See Table 6-14	See Table 6-14
				CF1	Conversion Factor 1	kg/mg	1E-06	--
				IR-S	Ingestion Rate of Soil	mg/day	330	ODEQ 2003
				SA	Skin Surface Area Available for Contact	cm^2	3,300	ODEQ 2003
				AF	Adherence Factor	mg/cm^2	0.3	ODEQ 2003
				ABS	Absorption Factor	unitless	See Table 6-22	See Table 6-22
				ET	Exposure Time	hrs/day	8	EPA 2009
				EF	Exposure Frequency	days/year	100	Professional Judgment (1)
				EF	Exposure Frequency - Fire Training Area	days/year	250	OEPA 2009
				ED	Exposure Duration	years	1	ODEQ 2003
				BW	Body Weight	kg	70	ODEQ 2003
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	365	EPA 1989
Trespasser	Adolescent (12 to18 yrs)	Current/ Future	Surface Soil	CS	Chemical Concentration in Soil	mg/kg	See Table 6-14	See Table 6-14
				CF1	Conversion Factor 1	kg/mg	1E-06	--
				IR-S	Ingestion Rate of Soil	mg/hr	10	EPA 2008 (2)
				SA	Skin Surface Area Available for Contact	cm^2	5,700	EPA 2008
				AF	Adherence Factor	mg/cm^2	0.07	EPA 2008
				ABS	Absorption Factor	unitless	See Table 6-22	See Table 6-22
				ET	Exposure time	hr/day	2	EPA 2009
				EF	Exposure Frequency	days/year	100	EPA 2009 (3)
				ED	Exposure Duration	years	6	EPA 1991
				BW	Body Weight	kg	64	EPA 2008
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	2,190	EPA 1989

Table 6-16 (continued)
Exposure Parameters for Soil
Tongue Point Multi-Sites Project RI/FS
Former Tongue Point Naval Air Station, Astoria, Oregon

Notes:

RME = Reasonable Maximum Exposure
(1) Construction workers are assumed to be exposed to soil for 100 days per year, assuming 100 workdays over 5 months.
(2) In the absence of soil ingestion rate for adolescents, the rate for children in the 1 to <6 year old age range of 100 mg/day (EPA 2008) or 10 mg/hr, assuming a residential exposure time of 10 hours per day based on professional judgment, is used.
(3) RME value is based on the upper end value of exposure frequency for trespassers (EPA 2009).

Sources:

EPA 1989: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.
EPA 1991: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors. Interim Final. OSWER Directive 9285.6-03.
EPA 1997: Exposure Factors Handbook. Vol. 1: General Factors. ORD. EPA/600/P-95/002Fa.
EPA 2002a: Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. OSWER 9355.4-24.
EPA 2004: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment Final. EPA/540/R/99/005.
EPA 2008: Child-Specific Exposure Factors Handbook. EPA/600/R-06/096F.
EPA 2009: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Part F, Supplemental Guidance for Inhalation Risk Assessment. EPA-540-R-070-002.
ODEQ 2003: Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites.

Table 6-17
Exposure Parameters for Groundwater
Tongue Point Multi-Sites Project, Astoria, Oregon

Receptor Population	Receptor Age	Scenario Time Frame	Exposure Point	Parameter Code	Parameter Definition	Unit	Reasonable Maximum Exposure	
							Value	Reference
Resident	Adult	Future	Tap Water	CW	Chemical Concentration in Water	µg/L	See Table 6-14	See Table 6-14
				CF1	Conversion Factor 1	mg/µg	0.001	--
				IR-W	Ingestion Rate of Water	L/day	2	EPA 1991
				EF	Exposure Frequency	days/year	350	EPA 1991
				ED	Exposure Duration	years	24	EPA 1991
				BW	Body Weight	kg	70	EPA 1991
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	8,760	EPA 1989
	Child (0-6 yrs)	Future	Tap Water	CW	Chemical Concentration in Water	µg/L	See Table 6-14	See Table 6-14
				CF1	Conversion Factor 1	mg/µg	0.001	--
				IR-W	Ingestion Rate of Water	L/day	1	EPA 2008 (1)
				EF	Exposure Frequency	days/year	350	EPA 1991
				ED	Exposure Duration	years	6	EPA 1991
				BW	Body Weight	kg	15	EPA 2008 (2)
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	2,190	EPA 1989
Indoor Worker	Adult	Future	Tap Water	CW	Chemical Concentration in Water	µg/L	See Table 6-14	See Table 6-14
				CF1	Conversion Factor 1	mg/µg	0.001	--
				IR-W	Ingestion Rate of Water	L/day	1	EPA 1991
				EF	Exposure Frequency	days/year	250	EPA 1991
				ED	Exposure Duration	years	25	EPA 1991
				BW	Body Weight	kg	70	EPA 1991
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	9,125	EPA 1989
Construction Worker	Adult	Future	Groundwater	CW	Chemical Concentration in Water	µg/L	See Table 6-14	See Table 6-14
				CF1	Conversion Factor 1	mg/µg	0.001	--
				SA	Skin Surface Area Available for Contact	cm^2	5,700	ODEQ 2003
				PC	Permeability Coefficient	cm/hr	See Table 6-22	See Table 6-22
				CF2	Conversion Factor 2	L/cm^3	0.001	--
				ET	Exposure Time	hr/day	4	ODEQ 2003
				EF	Exposure Frequency	days/year	34	Professional judgment (3)

Table 6-17 (continued)
Exposure Parameters for Groundwater
Tongue Point Multi-Sites Project, Astoria, Oregon

Receptor Population	Receptor Age	Scenario Time Frame	Exposure Point	Parameter Code	Parameter Definition	Unit	Reasonable Maximum Exposure	
							Value	Reference
Construction Worker continued	Adult	Future	Groundwater	EF	Exposure Frequency - Fire Training Area	days/year	83	Professional judgment (3)
				ED	Exposure Duration	years	1	ODEQ 2003
				BW	Body Weight	kg	70	ODEQ 2003
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	365	EPA 1989

Notes:

RME = Reasonable Maximum Exposure.
(1) Based on the 95th percentile drinking water intake rate for children 1 -10 years old (EPA 1991 and 2008).
(2) Based on weighted mean body weight for children ages 0 to < 6 years (EPA 2008).
(3) Construction workers are assumed to spend 1/3 of time during the duration of a construction project in a trench.

Sources:

EPA 1989: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.
EPA 1991: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors. Interim Final. OSWER Directive 9285.6-03.
ODEQ 2003: Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites.

Table 6-18
Exposure Parameters for Surface Water
Tongue Point Multi-Sites Project, Astoria, Oregon

Receptor Population	Receptor Age	Scenario Time Frame	Exposure Point	Parameter Code	Parameter Definition	Unit	Reasonable Maximum Exposure	
							Value	Reference
Student	Adult	Current	Surface Water	CW	Chemical Concentration in Water	µg/L	See Table 6-14	See Table 6-14
				CF1	Conversion Factor 1	mg/µg	0.001	--
				IR-W	Ingestion Rate of Water	L/hr	0.02	EPA 2008 (1)
				SA	Skin Surface Area Available for Contact	cm^2	18,000	EPA 1997
				PC	Permeability Coefficient	cm/hr	See Table 6-22	See Table 6-22
				CF2	Conversion Factor 2	L/cm^3	0.001	--
				ET	Exposure Time	hr/day	2	EPA 2009 (2)
				EF	Exposure Frequency	days/year	44	professional judgment (3)
				ED	Exposure Duration	years	2	site-specific (4)
				BW	Body Weight	kg	70	EPA 1991
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	730	EPA 1989
Resident	Adult	Current/Future	Surface Water	CW	Chemical Concentration in Water	µg/L	See Table 6-14	See Table 6-14
				CF1	Conversion Factor 1	mg/µg	0.001	--
				IR-W	Ingestion Rate of Water	L/hr	0.02	EPA 2008 (1)
				SA	Skin Surface Area Available for Contact	cm^2	18,000	EPA 1997
				PC	Permeability Coefficient	cm/hr	See Table 6-22	See Table 6-22
				CF2	Conversion Factor 2	L/cm^3	0.001	--
				ET	Exposure Time	hr/day	2	EPA 2009 (2)
				EF	Exposure Frequency	days/year	44	EPA 1991
				ED	Exposure Duration	years	24	EPA 1991
				BW	Body Weight	kg	70	EPA 1991
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	8,760	EPA 1989
Resident	Child (0-6 yrs)	Current/Future	Surface Water	CW	Chemical Concentration in Water	µg/L	See Table 6-14	See Table 6-14
				CF1	Conversion Factor 1	mg/µg	0.001	--
				IR-W	Ingestion Rate of Water	L/hr	0.05	EPA 2008 (5)
				SA	Skin Surface Area Available for Contact	cm^2	6,400	EPA 2008 (6)
				PC	Permeability Coefficient	cm/hr	See Table 6-22	See Table 6-22
				CF2	Conversion Factor 2	L/cm^3	0.001	--
				ET	Exposure Time	hr/day	2	EPA 2009 (2)
				EF	Exposure Frequency	days/year	44	professional judgment (3)
				ED	Exposure Duration	years	6	EPA 1991
				BW	Body Weight	kg	15	EPA 2008 (7)
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	2,190	EPA 1989

Table 6-18 (continued)
Exposure Parameters for Surface Water
Tongue Point Multi-Sites Project, Astoria, Oregon

Receptor Population	Receptor Age	Scenario Time Frame	Exposure Point	Parameter Code	Parameter Definition	Unit	Reasonable Maximum Exposure	
							Value	Reference
Recreational User	Adult	Current/Future	Surface Water	CW	Chemical Concentration in Water	µg/L	See Table 6-14	See Table 6-14
				CF1	Conversion Factor 1	mg/µg	0.001	--
				IR-W	Ingestion Rate of Water	L/hr	0.002	EPA 2008 (8)
				SA	Skin Surface Area Available for Contact	cm^2	6,100	EPA 2004 (13)
				PC	Permeability Coefficient	cm/hr	See Table 6-22	See Table 6-22
				CF2	Conversion Factor 2	L/cm^3	0.001	--
				ET	Exposure Time	hr/day	2	EPA 2009 (2)
				EF	Exposure Frequency	days/year	44	professional judgment (3)
				ED	Exposure Duration	years	24	EPA 1991
				BW	Body Weight	kg	70	EPA 1991
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	8,760	EPA 1989
Recreational User	Adolescent (12 to18 yrs)	Current/Future	Surface Water	CW	Chemical Concentration in Water	µg/L	See Table 6-14	See Table 6-14
				CF1	Conversion Factor 1	mg/µg	0.001	--
				IR-W	Ingestion Rate of Water	L/hr	0.005	EPA 2008 (9)
				SA	Skin Surface Area Available for Contact	cm^2	5,900	EPA 2008 (10)
				PC	Permeability Coefficient	cm/hr	See Table 6-22	See Table 6-22
				CF2	Conversion Factor 2	L/cm^3	0.001	--
				ET	Exposure Time	hr/day	2	EPA 2009 (2)
				EF	Exposure Frequency	days/year	44	professional judgment (3)
				ED	Exposure Duration	years	6	EPA 1991
				BW	Body Weight	kg	64	EPA 2008 (11)
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	2,190	EPA 1989
Angler	Adult	Current/Future	Surface Water	CW	Chemical Concentration in Water	µg/L	See Table 6-14	See Table 6-14
				CF1	Conversion Factor 1	mg/µg	0.001	--
				IR-W	Ingestion Rate of Water	L/hr	0.005	EPA 2008 (9)
				SA	Skin Surface Area Available for Contact	cm^2	6,100	EPA 2004 (13)
				PC	Permeability Coefficient	cm/hr	See Table 6-22	See Table 6-22
				CF2	Conversion Factor 2	L/cm^3	0.001	--
				ET	Exposure Time	hr/day	4	professional judgment (12)
				EF	Exposure Frequency	days/year	44	professional judgment (12)
				ED	Exposure Duration	years	24	EPA 1991
				BW	Body Weight	kg	70	EPA 1991
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	8,760	EPA 1989

Table 6-18 (continued)
Exposure Parameters for Surface Water
Tongue Point Multi-Sites Project, Astoria, Oregon

Notes:

RME = Reasonable Maximum Exposure
(1) Based on mean water ingestion rate while swimming for people between 18 and 21 years of age (EPA 2008).
(2) The RME value is based on the upper end value of exposure time for recreational users (EPA 2009).
(3) Assuming 2 days per week for 22 weeks per year (May to September) for the RME scenario.
(4) Based on Job Corps Center students average length of stay at the site of 9 months to 2 years.
(5) In absence of age-specific value, water ingestion rate is based on the mean rate while swimming for children between 6 and 15 years of age (EPA 2008).
(6) Based on the weighted average total body surface area for children ages 0 to less than 6 years (EPA 2008).
(7) Based on weighted mean body weight for children ages 0 to < 6 years (EPA 2008).
(8) Based on one tenth of the mean water ingestion rate while swimming for people between 18 and 21 years of age (EPA 2008).
(9) Based on one tenth of the mean water ingestion rate while swimming for children between 6 and 15 years of age (EPA 2008).
(10) Based on the weighted average surface area for face, hands, forearms, lower legs, and feet for children ages 11 to 21 years (EPA 2008).
(11) Based on average mean body weight for children ages 11 to 21 years (EPA 2008).
(12) Assuming 4 hours per day, 2 days per week for 22 weeks per year (May to September) for the RME scenario.
(13) Based on the average surface area for face, hands, forearms, lower legs, and feet for adults (EPA 2004).

Sources:

EPA 1989: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.
EPA 1991: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors. Interim Final. OSWER Directive 9285.6-03.
EPA 1997: Exposure Factors Handbook. Vol. 1: General Factors. ORD. EPA/600/P-95/002Fa.
EPA 2004: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment Final. EPA/540/R/99/005.
EPA 2008: Child-Specific Exposure Factors Handbook. EPA/600/R-06/096F.
EPA 2009: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Part F, Supplemental Guidance for Inhalation Risk Assessment. EPA-540-R-070-002.

Table 6-19
Exposure Parameters for Sediment
Tongue Point Multi-Sites Project, Astoria, Oregon

Receptor Population	Receptor Age	Scenario Time Frame	Exposure Point	Parameter Code	Parameter Definition	Unit	Reasonable Maximum Exposure	
							Value	Reference
Student	Adult	Current	Sediment	CS	Chemical Concentration in Sediment	mg/kg	See Table 6-14	See Table 6-14
				CF1	Conversion Factor 1	kg/mg	1E-06	--
				IR-S	Ingestion Rate of Sediment	mg/hr	5	EPA 1997 (1)
				SA	Skin Surface Area Available for Contact	cm^2	6,900	EPA 1997 (2)
				AF	Adherence Factor	mg/cm^2	0.3	EPA 2004
				ABS	Absorption Factor	unitless	See Table 6-22	See Table 6-22
				ET	Exposure Time	hrs/day	2	EPA 2009 (3)
				EF	Exposure Frequency	days/year	44	professional judgment (4)
				ED	Exposure Duration	years	2	site-specific (5)
				BW	Body Weight	kg	70	EPA 1991
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	730	EPA 1989
Resident	Adult	Current/ Future	Sediment	CS	Chemical Concentration in Sediment	mg/kg	See Table 6-14	See Table 6-14
				CF1	Conversion Factor 1	kg/mg	1E-06	--
				IR-S	Ingestion Rate of Sediment	mg/hr	5	EPA 1997 (1)
				SA	Skin Surface Area Available for Contact	cm^2	6,900	EPA 1997 (2)
				AF	Adherence Factor	mg/cm^2	0.3	EPA 2004
				ABS	Absorption Factor	unitless	See Table 6-22	See Table 6-22
				ET	Exposure Time	hrs/day	2	EPA 2009 (3)
				EF	Exposure Frequency	days/year	44	professional judgment (4)
				ED	Exposure Duration	years	24	EPA 1991
				BW	Body Weight	kg	70	EPA 1991
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	8,760	EPA 1989
Resident	Child (0 to 6 yrs)	Current/ Future	Sediment	CS	Chemical Concentration in Sediment	mg/kg	See Tables B-3.3c	See Tables B-3.3c
				CF1	Conversion Factor 1	kg/mg	1E-06	--
				IR-S	Ingestion Rate of Sediment	mg/hr	10	EPA 2008 (6)
				SA	Skin Surface Area Available for Contact	cm^2	2,740	EPA 2008 (7)
				AF	Adherence Factor	mg/cm^2	3.6	EPA 2008 (8)
				ABS	Absorption Factor	unitless	See Table 6-22	See Table 6-22
				ET	Exposure Time	hrs/day	2	EPA 2009 (3)
				EF	Exposure Frequency	days/year	44	professional judgment (4)
				ED	Exposure Duration	years	6	EPA 1991
				BW	Body Weight	kg	15	EPA 2008 (8)
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	2,190	EPA 1989

Table 6-19 (continued)
Exposure Parameters for Sediment
Tongue Point Multi-Sites Project, Astoria, Oregon

Receptor Population	Receptor Age	Scenario Time Frame	Exposure Point	Parameter Code	Parameter Definition	Unit	Reasonable Maximum Exposure	
							Value	Reference
Recreational User	Adult	Current/ Future	Sediment	CS	Chemical Concentration in Sediment	mg/kg	See Table 6-14	See Table 6-14
				CF1	Conversion Factor 1	kg/mg	1E-06	--
				IR-S	Ingestion Rate of Sediment	mg/hr	5	EPA 1997 (1)
				SA	Skin Surface Area Available for Contact	cm^2	6,100	EPA 2004 (13)
				AF	Adherence Factor	mg/cm^2	0.3	EPA 2004
				ABS	Absorption Factor	unitless	See Table 6-22	See Table 6-22
				ET	Exposure Time	hrs/day	2	EPA 2009 (3)
				EF	Exposure Frequency	days/year	44	professional judgment (4)
				ED	Exposure Duration	years	24	EPA 1991
				BW	Body Weight	kg	70	EPA 1991
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	8,760	EPA 1989
Recreational User	Adolescent (12 to18 yrs)	Current/ Future	Sediment	CS	Chemical Concentration in Sediment	mg/kg	See Table 6-14	See Table 6-14
				CF1	Conversion Factor 1	kg/mg	1E-06	--
				IR-S	Ingestion Rate of Sediment	mg/hr	10	EPA 2008 (6)
				SA	Skin Surface Area Available for Contact	cm^2	5,900	EPA 2008 (9)
				AF	Adherence Factor	mg/cm^2	4.8	EPA 2008 (10)
				ABS	Absorption Factor	unitless	See Table 6-22	See Table 6-22
				ET	Exposure Time	hrs/day	2	EPA 2009 (3)
				EF	Exposure Frequency	days/year	44	professional judgment (4)
				ED	Exposure Duration	years	6	EPA 1991
				BW	Body Weight	kg	64	EPA 2008 (11)
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	2,190	EPA 1989
Angler	Adult	Current/ Future	Sediment	CS	Chemical Concentration in Sediment	mg/kg	See Table 6-14	See Table 6-14
				CF1	Conversion Factor 1	kg/mg	1E-06	--
				IR-S	Ingestion Rate of Sediment	mg/hr	5	EPA 1997 (1)
				SA	Skin Surface Area Available for Contact	cm^2	6,100	EPA 2004 (13)
				AF	Adherence Factor	mg/cm^2	0.3	EPA 2004
				ABS	Absorption Factor	unitless	See Table 6-22	See Table 6-22
				ET	Exposure Time	hrs/day	4	professional judgment (12)
				EF	Exposure Frequency	days/year	44	professional judgment (12)
				ED	Exposure Duration	years	24	EPA 1991
				BW	Body Weight	kg	70	EPA 1991
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	8,760	EPA 1989

Table 6-19 (continued)
Exposure Parameters for Sediment
Tongue Point Multi-Sites Project, Astoria, Oregon

Notes:

RME = Reasonable Maximum Exposure
(1) In the absence of sediment ingestion rate, the mean adult soil ingestion rate of 50 mg/day or 5 mg/hr (assuming a residential exposure time of 10 hours per day) is used (EPA 1997).
(2) Based on surface area for head, hands, forearms, lower legs, and feet for adults (EPA 1997).
(3) The RME value is based on the upper end value of exposure time for recreational users (EPA 2009).
(4) Assuming 2 days per week for 22 weeks per year (May to September) for the RME scenario.
(5) Based on Job Corps Center students average length of stay at the site of 9 months to 2 years.
(6) In the absence of sediment ingestion rate, the mean soil ingestion rate of 100 mg/day or 10 mg/hr (assuming a residential exposure time of 10 hours per day) for children between 1 to 21 years in age is used (EPA 2008).
(7) Based on the weighted average surface area for head, hands, forearms, lower legs, and feet for children ages 0 to <6 years (EPA 2008).
(8) Based on surface area weighted adherence factor for children ages 0 to <6 years playing in sediment (EPA 2008).
(9) Based on the weighted average surface area for face, hands, forearms, lower legs, and feet for children ages 11 to 21 years (EPA 2008).
(10) Based on surface area weighted adherence factor for children ages 11 to 21 years playing in sediment (EPA 2008).
(11) Based on average mean body weight for children ages 11 to 21 years (EPA 2008).
(12) Assuming 4 hours per day, 2 days per week for 22 weeks per year (May to September) for the RME scenario.
(13) Based on the average surface area for face, hands, forearms, lower legs, and feet for adults (EPA 2004).

Sources:

EPA 1989: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.
EPA 1991: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors. Interim Final. OSWER Directive 9285.6-03.
EPA 1997: Exposure Factors Handbook. Vol. 1: General Factors. ORD. EPA/600/P-95/002Fa.
EPA 2004: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment Final. EPA/540/R/99/005.
EPA 2008: Child-Specific Exposure Factors Handbook. EPA/600/R-06/096F.
EPA 2009: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Part F, Supplemental Guidance for Inhalation Risk Assessment. EPA-540-R-070-002.

Table 6-20
Exposure Parameters for Fish/Shellfish
Tongue Point Multi-Sites Project, Astoria, Oregon

Receptor Population	Receptor Age	Scenario Time Frame	Exposure Point	Parameter Code	Parameter Definition	Unit	Reasonable Maximum Exposure	
							Value	Reference
Angler	Adult	Current/ Future	Fish/Shellfish	CS	Chemical Concentration in Fish/Shellfish	mg/kg	Table 6-14	-
				CF1	Conversion Factor 1	kg/mg	1E-06	--
				IR-F	Ingestion Rate of Fish/Shellfish	g/day	17.5	ODEQ 2009 (1)
				EF	Exposure Frequency	days/year	350	ODEQ 2009
				ED	Exposure Duration	years	24	EPA 1991
				BW	Body Weight	kg	70	EPA 1991
				AT-C	Averaging Time (Cancer)	days	25,550	EPA 1989
				AT-N	Averaging Time (Noncancer)	days	8,760	EPA 1989

Notes:

RME = Reasonable Maximum Exposure
(1) Based on personal communication with Mr. Paul Seidel of ODEQ in May 2009
(2) Based on the recommended mean value for freshwater anglers (EPA 1997)
(3) Anglers are assumed to consume fresh fish/shellfish caught from the study area only during days when they are fishing in the area, which is 44 days per year for the RME scenario.

Sources:

EPA 1989: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.
EPA 1991: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors. Interim Final. OSWER Directive 9285.6-03.
ODEQ. 2009: Personal communication with Mr. Paul Seidel of ODEQ. May.

Table 6-21
Exposure Parameters for Indoor Air
Tongue Point Multi-Sites Project, Astoria, Oregon

Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Unit	RME	
						Value	Reference
Indoor Worker	Adult	Indoor Air	CA	Chemical Concentration in air	µg/m^3	Chemical Specific	Table 6-15
			ET	Exposure Time	hrs/day	8	EPA 2009 (1)
			EF	Exposure Frequency	days/year	250	ODEQ 2003
			ED	Exposure Duration	years	25	ODEQ 2003
			AT-C	Averaging Time (Cancer)	hrs	613,200	ODEQ 2003
			AT-N	Averaging Time (Noncancer)	hrs	219,000	ODEQ 2003
Student	Adult	Indoor Air	CA	Chemical Concentration in air	µg/m^3	Chemical Specific	Table 6-15
			ET	Exposure Time	hrs/day	24	EPA 2009 (2)
			EF	Exposure Frequency	days/year	330	site-specific (3)
			ED	Exposure Duration	years	2	site-specific (3)
			AT-C	Averaging Time (Cancer)	hrs	613,200	ODEQ 2003
			AT-N	Averaging Time (Noncancer)	hrs	17,520	ODEQ 2003
Resident Future	Adult	Indoor Air	CA	Chemical Concentration in air	µg/m^3	Chemical Specific	Table 6-15
			ET	Exposure Time	hrs/day	24	EPA 2009 (2)
			EF	Exposure Frequency	days/year	350	ODEQ 2003
			ED	Exposure Duration	years	24	EPA 1991
			AT-C	Averaging Time (Cancer)	days	613,200	ODEQ 2003
			AT-N	Averaging Time (Noncancer)	days	210,240	ODEQ 2003

Table 6-21 (continued)
Exposure Parameters for Indoor Air
Tongue Point Multi-Sites Project, Astoria, Oregon

Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Unit	RME	
						Value	Reference
Resident Future	Child (0 to 6 yrs)	Indoor Air	CA	Chemical Concentration in air	$\mu g/m^3$	Chemical Specific	Table 6-15
			ET	Exposure Time	hrs/day	24	EPA 2009 (2)
			EF	Exposure Frequency	days/year	350	ODEQ 2003
			ED	Exposure Duration	years	6	EPA 1991
			AT-C	Averaging Time (Cancer)	days	613,200	EPA 1989
			AT-N	Averaging Time (Noncancer)	days	52,560	EPA 1989

Notes:

RME = Reasonable Maximum Exposure
(1) Based on the recommended exposure time for workers (EPA 2009).
(2) Based on the recommended exposure time for residents (EPA 2009).
(3) Job Corps Center students average length of stay at the site is 9 months to 2 years. They take two breaks during the year, one in the winter for 2½ weeks and one in the summer for 2½ weeks.

Sources:

EPA 1989: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.
EPA 1991: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors. Interim Final. OSWER . Directive 9285.6-03.
EPA 2009: Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Part F, Supplemental Guidance for Inhalation Risk Assessment. EPA-540-R-070-002.
ODEQ 2003: Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites.

Table 6-22
Chemical-Specific Information Used for Intake Calculations
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical of Potential Concern	Permeability Coefficient [1] (cm/hr) (water)	Dermal Absorption Fraction [1] (soil)	Henry's Law Constant [2] (atm-m^3/mol)	Diffusion Coefficient in Air [2] (cm^2/s)	Diffusion Coefficient in Water [2] (cm^2/s)	Soil-water partition Coefficient [2] (cm^3/g)
Volatile Organic Compounds						
1,2,4-Trimethylbenzene	NA	NA	NA	NA	NA	NA
1,3,5-Trimethylbenzene	NA	NA	NA	NA	NA	NA
1,3-Butadiene	1.6E-02	NA	NA	NA	NA	NA
2-Hexanone	NA	NA	NA	NA	NA	NA
2-Propanol	NA	NA	NA	NA	NA	NA
4-Ethyltoluene	NA	NA	NA	NA	NA	NA
Benzene	1.5E-02	NA	5.6E-03	8.8E-02	9.8E-06	3.5E-01
Chloroform	6.8E-03	NA	3.7E-03	1.0E-01	1.0E-05	2.4E-01
Ethanol	5.4E-04	NA	NA	NA	NA	NA
Ethylbenzene	4.9E-02	NA	7.9E-03	7.5E-02	7.8E-06	2.2E+00
Isopropylbenzene	NA	NA	NA	NA	NA	NA
Tetrachloroethene	3.3E-02	NA	1.8E-02	7.2E-02	8.2E-06	9.3E-01
Tetrahydrofuran	NA	NA	NA	NA	NA	NA
Trichloroethene	1.2E-02	NA	1.0E-02	7.9E-02	9.1E-06	1.0E+00
Vinyl chloride	5.6E-03	NA	2.7E-02	1.1E-01	1.2E-05	1.1E-01
Semi-Volatile Organic Compounds						
2,3,5-Trimethylnaphthalene	NA	1.0E-01	NA	NA	NA	NA
2-Methylnaphthalene	NA	1.0E-01	NA	NA	NA	NA
Carcinogenic PAHs	7.0E-01	1.3E-01	1.1E-06	4.3E-02	9.0E-06	6.1E+03
Di-n-butylphthalate	2.4E-02	1.0E-01	9.4E-10	4.4E-02	7.9E-06	2.0E+02
Naphthalene	4.7E-02	1.0E-01	4.8E-04	5.9E-02	7.5E-06	1.2E+01
Dioxin/Furan						
Dioxin/Furan TEQ	8.1E-01	3.0E-02	NA	NA	NA	NA
Pesticides/PCBs						
Total DDT	2.7E-01	3.0E-02	8.1E-06	1.4E-02	5.0E-06	1.6E+04
Total PCBs	NA	1.4E-01	NA	NA	NA	NA
Inorganics						
Arsenic	1.0E-03	3.0E-02	NA	NA	NA	NA
Cadmium	1.0E-03	1.0E-03	NA	NA	NA	NA
Chromium [3]	2.0E-03	NA	NA	NA	NA	NA
Cobalt	4.0E-04	NA	NA	NA	NA	NA
Iron	NA	NA	NA	NA	NA	NA
Lead	NA	NA	NA	NA	NA	NA
Manganese	1.0E-03	NA	NA	NA	NA	NA
Mercury	1.0E-03	NA	1.1E-02	3.1E-02	6.3E-06	NA
Total Petroleum Hydrocarbons						
Diesel Range Hydrocarbons	NA	NA	NA	NA	NA	NA
Oil Range Hydrocarbons	NA	NA	NA	NA	NA	NA
Gasoline Range Hydrocarbons	NA	NA	NA	NA	NA	NA

Notes:

PAH = Polycyclic aromatic hydrocarbon
PCB = Polychlorinated biphenyl
TEQ = Toxicity equivalent
Total DDT = 4,4'-DDT, 4,4'-DDD,and 4,4'-DDE
Total PCBs = Aroclor 1260, Aroclor 1254, Aroclor 1221, Aroclor 1232, Aroclor 1248, Aroclor 1016, and Aroclor 1242.

DDD - p,p'-dichlorodiphenyldichloroethane
DDE - p,p'-dichlorodiphenyldichloroethylene
DDT - p,p'-dichlorodiphenyltrichloroethane

(1) Source: EPA. 2004. Risk Assessment Guidance for Superfund. Part E.
(2) Sources: EPA. 1996. Soil Screening Guidance (SSG): Technical Background Document. Appendix C.
Henry's Law Constant = Dimensionless Henry's Law Constant / 41
(3) Chromium (VI) values used for chromium

Table 6-23
Johnson and Ettinger Soil Gas Model Input Parameters
Tongue Point Multi-Sites Project, Astoria, Oregon

Parameter Definition	Parameter	Unit	Johnson & Ettinger Model Default	Input Value				Basis for Input Value
				Current Scenario		Future Scenario		
				Dorminitory 4	Office Building	UST Site No.1	Fire Training Area	
Depth below grade to bottom of enclosed space floor	L_F	cm	15	15	15	15	15	J&E Default
Soil gas sampling depth below grade	L_{WT}	cm	150	152	152	152	168 (1)	Decision Unit-specific
Average soil temperature	T_S	^oC	10	11	11	11	11	Decision Unit-specific
Soil vapor pemeability	k_v	cm^2	1.00E-08	4.63E-08	4.63E-08	4.63E-08	4.30E-08	Decision Unit-specific
SCS soil type directly above water table	-	-	Sand	Silty sand (SM)	Silty sand (SM)	Silty sand (SM)	Poorly-graded sand with silt (SP-SM)	Decision Unit-specific
Vadose zone soil dry bulk density	r_b^A	g/cm^3	1.66	1.38	1.38	1.38	1.42	Decision Unit-specific
Vadose zone soil total porosity	n^A	unitless	0.375	0.467	0.467	0.467	0.464	Decision Unit-specific
Vadose zone soil water-filled porosity	q_w^A	cm^3/cm^3	0.054	0.171	0.171	0.171	0.285	Decision Unit-specific
Vadose zone soil air-filled porosity	q_A^A	cm^3/cm^3	0.321	0.296	0.296	0.296	0.179	Decision Unit-specific
Enclosed Space floor thickness	L_{crack}	cm	10	10	10	10	10	J&E Default
Soil-Bulding pressure differetial	DP	$g/cm\text{-}s^2$	40	40	40	40	40	J&E Default
Enclosed Space floor length	L_B	cm	1000	771	1837	1000	1000	Decision Unit-specific and J&E Default(2)
Enclosed Space floor width	W_B	cm	1000	771	1224	1000	1000	Decision Unit-specific and J&E Default(2)
Enclosed Space height	HB	cm	244	244	244	244	244	Decision Unit-specific and J&E Default(2)
Floor-wall seam crack width	w	cm	0.1	0.1	0.1	0.1	0.1	J&E Default
Indoor air exchange rate	ER	/hr	0.25	0.5	1	0.5	0.5	DoD (3)
Average vapor flow rate into building	Q_{soil}	L/m	5	5	5	5	5	J&E Default

Notes:

J&E - Johnson & Ettinger Soil Gas - ADV Model, Version 3.1 DoD - Department of Denfense

(1) Average soil gas sampling depth
(2) Decision unit-specific building parameters are used for current scenarios. Default J&E building parameters for a residential house will be used for future land-use scenario. Since land use at Fire Training Area will likely remain industrial/commercial, the use of J&E default building parameters for a residential house is very conservative. Therefore, this evaluation should be considered as a screening evaluation only.
(3) Department of Defense. 2009. DoD Vapor Intrusion Handbook.

CDM

Table 6-24
Trench Model Input Parameters and Predicted Trench Air Concentrations
Tongue Point Multi-Sites Project, Astoria, Oregon

Trench Model Input Parameters			
Parameter	**Value**	**Unit**	**Source**
For Emission Flux and Concentration in Trench			
Conversion Factor 1	0.001	L/cm^3	-
Conversion Factor 2	10,000	cm^2/m^2	-
Conversion Factor 3	3600	s/hr	-
Fraction of Floor	1	unitless	VDEP default
Air Exchange Rate	2	/hr	VDEP default
Trench dimensions			
Length	8	ft	VDEP default
Width	3	ft	VDEP default
Depth	8	ft	VDEP default
Width/Depth	0.38	unitless	-

Predicted Trench Air Concentrations			
Decision Unit	**Medium**	**Chemical of Potential Concern**	**Concentration in Trench ($\mu g/m^3$)**
UST Site No.1	Groundwater	Carcinogenic PAHs	2.52E-03
		Diesel Range Hydrocarbons	1.99E+03
		Gasoline Range Hydrocarbons	3.40E+03
Refueling Pit 3	Groundwater	Trichloroethene	1.24E+01
		Gasoline Range Hydrocarbons	1.89E+04
Fire Training Area	Groundwater	Benzene	3.39E+01
		Vinyl Chloride	1.19E+02
		Carcinogenic PAHs	2.52E-03
		Diesel Range Hydrocarbons	1.78E+03
		Gasoline Range Hydrocarbons	4.22E+03

Notes:

VDEP - Virginia Department of Environmental Quality, 2008, Voluntary Remediation Program Risk Assessment Guidance

Table 6-25
Non-Cancer Toxicity Data - Oral/Dermal
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical of Potential Concern	Oral RfD (mg/kg-day)	Gastrointestinal Absorption [1]	Absorbed RfD[2] (mg/kg-day)	Primary Target Organ/ Critical Effect	Combined Uncertainty/ Modifying Factor	RfD		Notes
						Source[3]	Date[4]	
Volatile Organic Compounds								
1,2,4-Trimethylbenzene	NA	1	NA	NA	NA	NA	NA	-
1,3,5-Trimethylbenzene	1.0E-02	1	1.0E-02	liver	10,000	PPRTV	04/22/2009	Screening PPRTV value
1,3-Butadiene	NA	1	NA	NA	NA	IRIS	11/01/2010	-
Benzene	4.0E-03	1	4.0E-03	blood	300	IRIS	11/01/2010	-
Chloroform	1.0E-02	1	1.0E-02	liver	100	IRIS	11/01/2010	-
Ethylbenzene	1.0E-01	1	1.0E-01	liver/kidney	1,000	IRIS	11/01/2010	-
Isopropylbenzene	1.0E-01	1	1.0E-01	kidney	1,000	IRIS	11/01/2010	-
Tetrachloroethene	1.0E-02	1	1.0E-02	liver	1,000	IRIS	11/01/2010	-
Trichloroethene	NA	1	NA	NA	NA	IRIS	11/01/2010	-
Vinyl chloride	3.0E-03	1	3.0E-03	liver	30	IRIS	11/01/2010	-
Semi-Volatile Organic Compounds								
Carcinogenic PAHs	NA	1	NA	NA	NA	NA	NA	based on benzo(a)pyrene
Naphthalene	2.0E-02	1	2.0E-02	body weight	3,000	IRIS	11/01/2010	-
Dioxin/Furan								
Dioxin/Furan TEQ	1.0E-09	1	1.0E-09	developmental	90	ATSDR	12/01/2009	based on 2,3,7,8-TCDD
Pesticides/Polychlorinated Biphenyls								
Total DDT	5.0E-04	1	5.0E-04	liver	100	IRIS	11/01/2010	based on DDT
Total PCBs	2.0E-05	1	2.0E-05	eye/finger/toe nail	300	IRIS	11/01/2010	based on Aroclor 1254
Inorganics								
Arsenic	3.0E-04	1	3.0E-04	skin	3	IRIS	11/01/2010	-
Cadmium	1.0E-03	0.025	2.5E-05	kidney	10	IRIS	11/01/2010	based on cadmium (diet)
Chromium	3.0E-03	0.025	7.5E-05	NA	900	IRIS	11/01/2010	based on hexavalent chromium
Cobalt	3.0E-04	1	3.0E-04	heart/blood/thyroid gland	3000	PPRTV	08/25/2008	-
Iron	7.0E-01	1	7.0E-01	gastrointestinal tract	1.5	PPRTV	09/11/2006	-
Lead	NA	1	NA	NA	NA	IRIS	11/01/2010	-
Manganese	1.4E-01	0.04	5.6E-03	central nervous system	1	IRIS	11/01/2010	
Mercury	3.0E-04	0.07	2.1E-05	immune system	1,000	IRIS	11/01/2010	based on mercuric chloride
Selenium	0.005	NA	0.005	clinical selenosis	3	IRIS	11/01/2010	
Tributyl Tin as ion	0.0003	NA	0.0003	Immunosuppression	100	IRIS	11/01/2010	based on tributyltin oxide
Total Petroleum Hydrocarbons								
Diesel Range Hydrocarbons[5]	NA	1	NA	blood/liver/kidney/body weight	NA	ODEQ	09/24/2003	-
Gasoline Range Hydrocarbons[5]	NA	1	NA	blood/liver/kidney/body weight	NA	ODEQ	09/24/2003	-

Table 6-25 (continued)
Non-Cancer Toxicity Data - Oral/Dermal
Tongue Point Multi-Sites Project, Astoria, Oregon

Notes:

NA = Not Available
RfD = Reference dose
DDT = p,p'-dichlorodiphenyltrichloroethane
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin

PAH = Polycyclic aromatic hydrocarbon
PCB = Polychlorinated biphenyl
TEQ = Toxicity equivalent
Total DDT = 4,4'-DDT, 4,4'-DDD,and 4,4'-DDE
Total PCBs = Aroclor 1260, Aroclor 1254, Aroclor 1221, Aroclor 1232, Aroclor 1248, Aroclor 1016, and Aroclor 1242

(1) Gastrointestinal absorption values are obtained from Regional Screening Levels for Chemical Contaminants at Superfund Sites (EPA 2009).
(2) The Absorbed RfD is equal to the oral RfD multiplied by the gastrointestinal absorption value (EPA 2004).
(3) Sources:
ATSDR = Agency for Toxic Substances and Disease Registry
IRIS = Integrated Risk Information System
PPRTV = Provisional Peer Reviewed Toxicity Value
(4) IRIS values were obtained from the EPA's online database, April 2010 (http://www.epa.gov/iris/). Publication dates of other sources are as listed.
(5) There are no ODEQ published toxicity values for TPHs. Based on TPH fraction data and exposure factor, a risk-based concentration (RBC) based on a noncancer HQ of 1 is calculated using the ODEQ spreadsheet for calculating RBCs for total petroleum hydrocarbons.

Table 6-26
Non-Cancer Toxicity Data - Inhalation Chronic
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical of Potential Concern	Inhalation RfC		Primary Target Organ(s)/ Critical Effects	Combined Uncertainty/ Modifying Factor	RfC		Notes
	Type (1)	Value (mg/m^3)			Source(2)	Date (3)	
Volatile Organic Compounds							
1,2,4-Trimethylbenzene	Chronic	7.0E-03	blood	3,000	PPRTV	06/11/2007	-
1,3,5-Trimethylbenzene	Chronic	NA	NA	NA	NA	NA	
1,3-Butadiene	Chronic	2.0E-03	reproductive	1,000	IRIS	11/01/2010	-
Benzene	Chronic	3.0E-02	blood	300	IRIS	11/01/2010	-
Chloroform	Chronic	3.0E-01	liver/kidney/development	300	Cal/EPA	12/18/2008	-
Ethylbenzene	Chronic	1.0E+00	development	300	IRIS	11/01/2010	-
Isopropylbenzene	Chronic	4.0E-01	kidney	1,000	IRIS	11/01/2010	-
Tetrachloroethene	Chronic	2.7E-01	nervous system	100	ATSDR	12/01/2009	-
Trichloroethene	Chronic	6.0E-01	nervous system/eyes	100	Cal/EPA	12/18/2008	-
Vinyl chloride	Chronic	1.0E-01	liver	30	IRIS	11/01/2010	-
Semi-Volatile Organic Compounds							
Carcinogenic PAHs	Chronic	NA	NA	NA	NA	NA	-
Naphthalene	Chronic	3.0E-03	nasal	3,000	IRIS	11/01/2010	-
Dioxin/Furan							-
Dioxin/Furan TEQ	Chronic	4.0E-08	liver/endocrine/respiratory system/blood/development	100	Cal/EPA	12/18/2008	-
Pesticides/Polychlorinated Biphenyls							-
Total DDT	Chronic	NA	NA	NA	NA	NA	-
Total PCBs	Chronic	NA	NA	NA	NA	NA	-
Inorganics							
Arsenic	Chronic	1.5E-05	development/cardiovascular system/nervous system/lung/skin	30	Cal/EPA	12/18/2008	-
Cadmium	Chronic	2.0E-05	kidney/respiratory system	30	Cal/EPA	12/18/2008	-
Chromium	Chronic	1.0E-04	respiratory system	300	IRIS	11/01/2010	based on hexavalent chromium particulates
Cobalt	Chronic	6.0E-06	respiratory system	300	PPRTV	08/25/2008	-
Iron	Chronic	NA	NA	NA	NA	NA	-
Lead	Chronic	NA	NA	NA	NA	NA	-
Manganese	Chronic	5.0E-05	nervous system	1,000	IRIS	11/01/2010	-
Mercury	Chronic	3.0E-04	nervous system	30	IRIS	11/01/2010	-

Table 6-26 (continued)
Non-Cancer Toxicity Data - Inhalation Chronic
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical of Potential Concern	Inhalation RfC		Primary Target Organ(s)/ Critical Effects	Combined Uncertainty/ Modifying Factor	RfC		Notes
	Type (1)	Value (mg/m^3)			Source(2)	Date (3)	
Total Petroleum Hydrocarbons							
Diesel Range Hydrocarbons(4)	Chronic	NA	NA	NA	NA	NA	-
Gasoline Range Hydrocarbons(4)	Chronic	NA	NA	NA	NA	NA	-

Notes:

NA = Not Available
RfC = Reference Concentration
MRL = Minimal Risk Level
REL = Reference Exposure Level
PAH = Polycyclic aromatic hydrocarbon
PCB = Polychlorinated biphenyl

TEQ = Toxicity equivalent
Total DDT = 4,4'-DDT, 4,4'-DDD,and 4,4'-DDE
Total PCBs = Aroclor 1260, Aroclor 1254, Aroclor 1221, Aroclor 1232, Aroclor 1248, Aroclor 1016, and Aroclor 1242
DDT - p,p'-dichlorodiphenyltrichloroethane
2,3,7,8-TCDD - 2,3,7,8-tetrachlorodibenzo-p-dioxin

(1) RfC types: acute, subchronic, and chronic.
(2) Sources:
ATSDR = Agency for Toxic Substances and Disease Registry
Cal/EPA = California Environmental Protection Agency
IRIS = Integrated Risk Information System
PPRTV = Provisional Peer Reviewed Toxicity Value

ATSDR inhalation MRL is converted from units in ppmv to mg/m^3 using the following equation:

MRL (mg/m^3) = (ppmv)(1 kg/1000 g)(P/RT)(molecular weight)
where P = ambient air pressure, 1 atmosphere (atm)
R = Ideal gas constant, 8.2×10^{-5} atm-m^3/mol-^{0}K
T = Absolute temperature, 298.15 Kelvin (^{0}K)

(3) IRIS values were confirmed against the EPA's online database, http://www.epa.gov/iris, April 2010. Publication dates of other sources are as listed.
(4) There are no ODEQ published toxicity values for TPHs. Based on TPH fraction data and exposure factor, a risk-based concentration (RBC) based on a noncancer HQ of 1 is calculated using the ODEQ spreadsheet for calculating RBCs for total petroleum hydrocarbons.

Table 6-27
Non-Cancer Toxicity Data - Inhalation Subchronic
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical of Potential Concern	Inhalation RfC		Primary Target Organ(s)/ Critical Effects	Combined Uncertainty/ Modifying Factor	RfC		Notes
	Type [1]	Value (mg/m^3)			Source[2]	Date	
Volatile Organic Compounds							
1,2,4-Trimethylbenzene	Subchronic	7.0E-02	blood	300	PPRTV	06/11/2007	based on a more conservative endpoint
1,3,5-Trimethylbenzene	Subchronic	1.0E-02	neurobehavioral	3000	PPRTV	04/22/2009	-
1,3-Butadiene	Subchronic	NA	NA	NA	NA	NA	-
Benzene	Subchronic	1.9E-01	immune system	300	ATSDR	12/01/2009	-
Chloroform	Subchronic	2.4E-01	liver	300	ATSDR	12/01/2009	-
Ethylbenzene	Subchronic	3.0E+00	nervous system	300	ATSDR	12/01/2009	-
Isopropylbenzene	Subchronic	NA	NA	NA	NA	NA	-
Tetrachloroethene	Subchronic	NA	NA	NA	NA	NA	-
Trichloroethene	Subchronic	5.4E-01	nervous system	300	ATSDR	12/01/2009	-
Vinyl chloride	Subchronic	NA	NA	NA	NA	NA	used chronic RfC
Semi-Volatile Organic							
Carcinogenic PAHs	Subchronic	NA	NA	NA	NA	NA	-
Naphthalene	Subchronic	NA	NA	NA	NA	NA	-
Dioxin/Furan							-
Dioxin/Furan TEQ	Subchronic	NA	NA	NA	NA	NA	-
Pesticides/Polychlorinated Biphenyls							-
Total DDT	Subchronic	NA	NA	NA	NA	NA	-
Total PCBs	Subchronic	NA	NA	NA	NA	NA	-
Inorganics							
Arsenic	Subchronic	1.5E-05	development/cardiovascular system/nervous system/lung/skin	30	Cal/EPA	12/18/2008	-
Cadmium	Subchronic	NA	NA	NA	NA	NA	-
Chromium	Subchronic	3.0E-04	respiratory system	30	ATSDR	12/01/2009	based on hexavalent chromium particulates
Cobalt	Subchronic	2.0E-05	respiratory system	100	PPRTV	08/25/2008	-
Iron	Subchronic	NA	NA	NA	NA	NA	-
Lead	Subchronic	NA	NA	NA	NA	NA	-
Manganese	chronic	3.0E-04	nervous system	100	ATSDR	12/01/2009	-
Mercury	Subchronic	NA	NA	NA	NA	NA	used chronic RfC
Total Petroleum Hydrocarbons							
Diesel Range Hydrocarbons	Subchronic	NA	NA	NA	NA	NA	-
Gasoline Range Hydrocarbons	Subchronic	NA	NA	NA	NA	NA	-

Table 6-27 (continued)
Non-Cancer Toxicity Data - Inhalation Subchronic
Tongue Point Multi-Sites Project, Astoria, Oregon

Notes:

NA = Not Available
RfC = Reference Concentration
MRL = Minimal Risk Level
REL = Reference Exposure Level
PAH = Polycyclic aromatic hydrocarbon
PCB = Polychlorinated biphenyl

TEQ = Toxicity equivalent
Total DDT = 4,4'-DDT, 4,4'-DDD,and 4,4'-DDE
Total PCBs = Aroclor 1260, Aroclor 1254, Aroclor 1221, Aroclor 1232, Aroclor 1248, Aroclor 1016, and Aroclor 1242
DDT - p,p'-dichlorodiphenyltrichloroethane
2,3,7,8-TCDD - 2,3,7,8-tetrachlorodibenzo-p-dioxin

(1) RfC types: acute, subchronic, and chronic.
(2) Sources:
ATSDR = Agency for Toxic Substances and Disease Registry
Cal/EPA = California Environmental Protection Agency
IRIS = Integrated Risk Information System
PPRTV = Provisional Peer Reviewed Toxicity Value

ATSDR inhalation MRL is converted from units in ppmv to mg/m^3 using the following equation:

MRL (mg/m^3) = (ppmv)(1 kg/1000 g)(P/RT)(molecular weight)
where P = ambient air pressure, 1 atmosphere (atm)
R = Ideal gas constant, 8.2×10^{-5} atm-m^3/mol-^{0}K
T = Absolute temperature, 298.15 Kelvin (^{0}K)

Table 6-28
Non-Cancer Toxicity Data - Inhalation Acute
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical of Potential Concern	Inhalation RfC		Primary Target Organ(s)/ Critical Effects	Combined Uncertainty/ Modifying Factor	RfC		Notes
	Type [1]	Value (mg/m^3)			Source[2]	Date	
Volatile Organic Compounds							
1,2,4-Trimethylbenzene	Acute	NA	NA	NA	NA	NA	-
1,3,5-Trimethylbenzene	Acute	NA	NA	NA	NA	NA	-
1,3-Butadiene	Acute	2.2E-01	development	90	ATSDR	12/01/2009	-
Benzene	Acute	1.3E+00	reproductive system/development	100	Cal/EPA	12/18/2008	-
Chloroform	Acute	1.5E-01	reproductive system/development	30	Cal/EPA	12/18/2008	-
Ethylbenzene	Acute	4.3E+01	nervous system	30	ATSDR	12/01/2009	-
Isopropylbenzene	Acute	NA	NA	NA	NA	NA	-
Tetrachloroethene	Acute	2.0E+01	central nervous system/respiratory	60	Cal/EPA	12/18/2008	-
Trichloroethene	Acute	1.1E+01	nervous system	30	ATSDR	12/01/2009	-
Vinyl chloride	Acute	1.8E+02	system/eyes	10	Cal/EPA	12/18/2008	-
Semi-Volatile Organic							
Carcinogenic PAHs	Acute	NA	NA	NA	NA	NA	-
Naphthalene	Acute	NA	NA	NA	NA	NA	-
Dioxin/Furan							-
Dioxin/Furan TEQ	Acute	NA	NA	NA	NA	NA	-
Pesticides/Polychlorinated Biphenyls							-
Total DDT	Acute	NA	NA	NA	NA	NA	-
Total PCBs	Acute	NA	NA	NA	NA	NA	-
Inorganics							
Arsenic	Acute	2.0E-04	development/cardiovascular system/nervous system	1,000	Cal/EPA	12/18/2008	-
Cadmium	Acute	3.0E-05	reproductive	300	ATSDR	12/01/2009	-
Chromium	Acute	NA	NA	NA	NA	NA	-
Cobalt	Acute	NA	NA	NA	NA	NA	-
Iron	Acute	NA	NA	NA	NA	NA	-
Lead	Acute	NA	NA	NA	NA	NA	-
Manganese	Acute	NA	NA	NA	NA	NA	-
Mercury	Acute	6.0E-04	nervous system/development	3,000	Cal/EPA	12/18/2008	-
Total Petroleum Hydrocarbons							
Diesel Range Hydrocarbons	Acute	NA	NA	NA	NA	NA	-
Gasoline Range Hydrocarbons	Acute	NA	NA	NA	NA	NA	-

Table 6-28 (continued)
Non-Cancer Toxicity Data - Inhalation Acute
Tongue Point Multi-Sites Project, Astoria, Oregon

Notes:

NA = Not Available
RfC = Reference Concentration
MRL = Minimal Risk Level
REL = Reference Exposure Level
PAH = Polycyclic aromatic hydrocarbon
PCB = Polychlorinated biphenyl

TEQ = Toxicity equivalent
Total DDT = 4,4'-DDT, 4,4'-DDD,and 4,4'-DDE
Total PCBs = Aroclor 1260, Aroclor 1254, Aroclor 1221, Aroclor 1232, Aroclor 1248, Aroclor 1016, and Aroclor 1242
DDT - p,p'-dichlorodiphenyltrichloroethane
2,3,7,8-TCDD - 2,3,7,8-tetrachlorodibenzo-p-dioxin

(1) RfC types: acute, subchronic, and chronic.
(2) Sources:
ATSDR = Agency for Toxic Substances and Disease Registry
Cal/EPA = California Environmental Protection Agency
IRIS = Integrated Risk Information System
PPRTV = Provisional Peer Reviewed Toxicity Value

ATSDR inhalation MRL is converted from units in ppmv to mg/m^3 using the following equation:

MRL (mg/m^3) = (ppmv)(1 kg/1000 g)(P/RT)(molecular weight)
where P = ambient air pressure, 1 atmosphere (atm)
R = Ideal gas constant, 8.2×10^{-5} atm-m^3/mol-^{0}K
T = Absolute temperature, 298.15 Kelvin (^{0}K)

Table 6-29
Cancer Toxicity Data - Oral/Dermal
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical of Potential Concern	Oral Slope Factor (mg/kg-day)$^{-1}$	Gastrointestinal Absorption (1)	Absorbed Slope Factor(2) (mg/kg-day)$^{-1}$	Mutagen (3)	Weight of Evidence/ Cancer Guideline Description	Oral Slope Factor		Notes
						Source(4)	Date (5)	
Volatile Organic Compounds								
1,2,4-Trimethylbenzene	NA	1	NA	--	inadequate information to assess carcinogenic potential	PPRTV	06/11/2007	-
1,3,5-Trimethylbenzene	NA	1	NA	--	Inadequate information to assess carcinogenic potential	PPRTV	04/22/2009	-
1,3-Butadiene	3.4E+00	1	3.4E+00	--	B2	Cal/EPA	07/01/2009	-
Benzene	5.5E-02	1	5.5E-02	--	A	IRIS	11/01/2010	oral SF ranges from 0.015 to 0.055 per mg/kg-day
Chloroform	3.1E-02	1	3.1E-02	--	B2	Cal/EPA	07/01/2009	chloroform-induced carcinogenicity is secondary to cytotoxicity and regenerative hyperplasia
Ethylbenzene	NA	1	NA	--	D	IRIS	11/01/2010	-
Isopropylbenzene	NA	1	NA	--	D	IRIS	11/01/2010	-
Tetrachloroethene	5.4E-01	1	5.4E-01	--	2A	Cal/EPA	07/01/2009	-
Trichloroethene	5.9E-03	1	5.9E-03	--	2A	Cal/EPA	07/01/2009	-
Vinyl chloride	7.2E-01	1	7.2E-01	M	A	IRIS	11/01/2010	based on lifetime exposure during adulthood
Semi-Volatile Organic Compounds								
Carcinogenic PAHs	7.3E+00	1	7.3E+00	M	B2	IRIS	11/01/2010	based on benzo(a)pyrene
Naphthalene	NA	1	NA	-	C	IRIS	11/01/2010	-
Dioxin/Furan								
Dioxin/Furan TEQ	1.3E+05	1	1.3E+05	-	B2	Cal/EPA	07/01/2009	based on 2,3,7,8-TCDD
Pesticides/Polychlorinated Biphenyls								
Total DDT	3.4E-01	1	3.4E-01	-	B2	IRIS	11/01/2010	based on DDT
Total PCBs	2.0E+00	1	2.0E+00	--	B2	IRIS	11/01/2010	-
Inorganics								
Arsenic	1.5E+00	1	1.5E+00	--	A	IRIS	11/01/2010	-
Cadmium	NA	NA	NA	--	NA	NA	NA	-
Chromium	7.1E-02	0.025	7.1E-02	M	D	NJDEP	04/01/2010	assume chromium(VI) to chromium(III) ratio is 1:6
Cobalt	NA	NA	NA	--	NA	NA	NA	-
Iron	NA	NA	NA	--	C	PPRTV	07/29/2005	-
Lead	NA	NA	NA	--	B2	IRIS	11/01/2010	-
Manganese	NA	NA	NA	--	D	IRIS	11/01/2010	-
Mercury	NA	NA	NA	--	D	IRIS	11/01/2010	-
Total Petroleum Hydrocarbons								
Diesel Range Hydrocarbons	NA	NA	NA	-	NA	NA	NA	-
Gasoline Range Hydrocarbons	NA	NA	NA	-	NA	NA	NA	-

Table 6-29 (continued)
Cancer Toxicity Data - Oral/Dermal
Tongue Point Multi-Sites Project, Astoria, Oregon

Notes:

NA = Not Available
SF = slope factor
TEQ = Toxicity equivalent
DDT - p,p'-dichlorodiphenyltrichloroethane
Total PCBs = Aroclor 1260, Aroclor 1254, Aroclor 1221, Aroclor 1232, Aroclor 1248, Aroclor 1016, and Ar

Total DDT = 4,4'-DDT, 4,4'-DDD,and 4,4'-DDE
PAH = Polycyclic aromatic hydrocarbon
PCB = Polychlorinated biphenyl
2,3,7,8-TCDD - 2,3,7,8-tetrachlorodibenzo-p-dioxin

EPA Weight of Evidence (EPA 1986, EPA 1996):
A - Human Carcinogen
B1 - Probable human carcinogen
B2 - Probable human carcinogen
C - Possible human carcinogen
D - Not classifiable as human carcinogen
2A - International Agency for Research Center (IARC) Classification, Probably carcinogenic to human

(1) Source: Exhibit 4.1 of Risk Assessment Guidance for Superfund Part E (EPA 2004)
(2) The dermal Slope Factor is assumed to equal the oral Slope Factor. No adjustment factor was applied.
(3) From Regional Screening Levels for Chemical Contaminants at Superfund Sites (EPA 2009).
(4) Sources:
Cal/EPA = California Environmental Protection Agency
IRIS = Integrated Risk Information System
PPRTV = Provisional Peer Reviewed Toxicity Value
(5) IRIS values were obtained from the EPA's online database, April 2010 http://www.epa.gov/iris/ and publication dates of other sources are as listed.

Table 6-30
Cancer Toxicity Data - Inhalation
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical of Potential Concern	Inhalation Unit Risk $(\mu g/m^3)^{-1}$	Mutagen [1]	Weight of Evidence/ Cancer Guideline Description	Unit Risk		Notes
				Source[2]	Date [3]	
Volatile Organic Compounds						
1,2,4-Trimethylbenzene	NA	--	inadequate information to assess carcinogenic potential	PPRTV	06/11/2007	-
1,3,5-Trimethylbenzene	NA	--	Inadequate information to assess carcinogenic potential	PPRTV	04/22/2009	-
1,3-Butadiene	3.0E-05	--	carcinogenic to humans	IRIS	11/01/2010	-
Benzene	7.8E-06	--	A	IRIS	11/01/2010	IUR ranges from 2.2×10^{-6} to 7.8×10^{-6} per $\mu g/m^3$
Chloroform	2.3E-05	--	B2	IRIS	11/01/2010	-
Ethylbenzene	NA	--	D	IRIS	11/01/2010	-
Isopropylbenzene	NA	--	D	IRIS	11/01/2010	-
Tetrachloroethene	5.9E-06		2A	Cal/EPA	07/01/2009	-
Trichloroethene	2.0E-06	--	2A	Cal/EPA	07/01/2009	-
Vinyl chloride	4.4E-06	M	A	IRIS	11/01/2010	based on lifetime exposure during adulthood
Semi-Volatile Organic Compounds						
Carcinogenic PAHs	1.1E-03	M	B2	Cal/EPA	07/01/2009	based on benzo(a)pyrene
Naphthalene	3.4E-05	-	A	Cal/EPA	07/01/2009	-
Dioxin/Furan						
Dioxin/Furan TEQ	3.8E+01	-	B2	Cal/EPA	07/01/2009	based on 2,3,7,8-TCDD
Pesticides/Polychlorinated Biphenyls						
Total DDT	9.7E-05	-	B2	IRIS	11/01/2010	based on DDT
Total PCBs	1.0E-04	--	B2	IRIS	11/01/2010	-
Inorganics						
Arsenic	4.3E-03	--	A	IRIS	11/01/2010	-
Cadmium	1.8E-03	--	B1	IRIS	11/01/2010	-
Chromium	1.7E-03	--	A	IRIS	11/01/2010	assume chromium(VI) to chromium(III) ratio is 1:6
Cobalt	9.0E-03	--	likely to be carcinogenic to humans	PPRTV	08/25/2008	-
Iron	NA	--	C	PPRTV	07/29/2005	-
Lead	NA	--	B2	IRIS	11/01/2010	-
Manganese	NA	--	D	IRIS	11/01/2010	-
Mercury	NA	--	D	IRIS	11/01/2010	-
Total Petroleum Hydrocarbons						
Diesel Range Hydrocarbons	NA	--	NA	NA	NA	-
Gasoline Range Hydrocarbons	NA	--	NA	NA	NA	-

Table 6-30 (continued)
Cancer Toxicity Data - Inhalation
Tongue Point Multi-Sites Project, Astoria, Oregon

Notes:

NA = Not Available
PAH = Polycyclic aromatic hydrocarbon
PCB = Polychlorinated biphenyl
TEQ = Toxicity equivalent
Total DDT = 4,4'-DDT, 4,4'-DDD,and 4,4'-DDE
Total PCBs = Aroclor 1260, Aroclor 1254, Aroclor 1221, Aroclor 1232, Aroclor 1248, Aroclor 1016, and Aroclor 1242.
DDT - p,p'-dichlorodiphenyltrichloroethane
2,3,7,8-TCDD - 2,3,7,8-tetrachlorodibenzo-p-dioxin

(1) From Regional Screening Levels for Chemical Contaminants at Superfund Sites (EPA 2009).
(2) Sources:
Cal/EPA = California Environmental Protection Agency
IRIS = Integrated Risk Information System
PPRTV = Provisional Peer Reviewed Toxicity Value
(3) IRIS values were obtained from the EPA's online database, April 2010 http://www.epa.gov/iris/.
Publication date of other sources is as listed.
OEHHA 2009, Technical Support Document for Cancer Potency Factors:
Methodologies for derivation, listing of available values, and adjustments to allow for early
life stage exposures.

EPA Weight of Evidence (EPA 1986, EPA 1996):
A - Human Carcinogen
B1 - Probable human carcinogen
B2 - Probable human carcinogen
C - Possible human carcinogen
D - Not classifiable as human carcinogen

EPA Weight of Evidence Narrative (EPA 2005):
Carcinogenic to humans
Likely to be carcinogenic to humans
Suggestive evidence of carcinogenic potential
Inadequate information to assess carcinogenic potential
Not likely to be carcinogenic to humans
2A - International Agency for Research Center Classification, Probably
carcinogenic to human

Table 6-31
Risk Characterization Summary - AST Fuel Storage Area
ODEQ Methods
Tongue Point Multi-Sites Project, Astoria, Oregon

Exposure Scenario	Medium	Excess Cancer Risk	Hazard Index
Current and Future Land Use Scenarios			
Trespasser	Surface Soil	2E-08	--
	Total	2E-08	--

Table 6-32
Risk Characterization Summary - UST Site No. 1
ODEQ Methods
Tongue Point Multi-Sites Project, Astoria, Oregon

Exposure Scenario	Medium	Excess Cancer Risk	Hazard Index	Risk Contributor	
				Cancer	Noncancer
Current Land Use Scenario					
Indoor Worker	Indoor Air	3E-08	0.003	--	--
	Total	3E-08	0.003	--	--
Resident	Sediment	4E-06	0.04	--	--
	Surface Water	4E-07	0.003	--	--
	Total	4E-06	0.04	--	--
Student	Indoor Air	1E-08	0.04	--	--
	Sediment	3E-08	0.002	--	--
	Surface Water	7E-09	0.0003	--	--
	Total	5E-08	0.04	--	--
Current and Future Land Use Scenarios					
Recreational User Adult	Sediment	3E-07	0.002	--	--
	Surface Water	2E-08	0.00005	--	--
	Total	3E-07	0.002	--	--
Recreational User Adolescent	Sediment	1E-06	0.02	--	--
	Surface Water	7E-09	0.00009	--	--
	Total	1E-06	0.02	--	--
Future Land Use Scenario					
Indoor Worker	Indoor Air	8E-08	0.007	--	--
	Groundwater	**2E-05**	**3**	Arsenic **2E-05**	--
	Total	**2E-05**	**3**	--	--
	Hazard index by target organ/effect: Blood HI = **2**; Liver HI = **2**; Kidney HI = **2**; Body weight HI = **2**				Diesel Range Hydrocarbons 1; Gasoline Range Hydrocarbons 1
Construction Worker	Subsurface Soil	7E-08	0.5	--	--
	Groundwater	5E-08	0.04	--	--
	Total	1E-07	0.5	--	--
Resident	Indoor Air	4E-07	0.03	--	--
	Groundwater	**1E-04**	**11**	Arsenic **1E-04**	--
	Sediment	4E-06	0.04	--	--
	Surface Water	4E-07	0.003	--	--
	Total	**1E-04**	**12**	--	--
	Hazard index by target organ/effect: Blood HI = **10**; Liver HI = **10**; Kidney HI = **10**; Development HI = 1; Nervous system HI = **2**; Lung HI = 1; Cardiovascular system HI = 1; Skin HI = 1; Body weight HI = **10**				Diesel Range Hydrocarbons **5**; Gasoline Range Hydrocarbons **5**

Notes:

Bolded values exceed ODEQ acceptable risk thresholds.

Table 6-33
Risk Characterization Summary - Refueling Pit 3
ODEQ Methods
Tongue Point Multi-Sites Project, Astoria, Oregon

Exposure Scenario	Medium	Excess Cancer Risk	Hazard Index	Risk Contributor	
				Cancer	Noncancer
Current and Future Land Use Scenarios					
Recreational User Adult	Sediment	5E-07	0.003	--	--
	Surface Water	9E-09	0.00006	--	--
	Total	5E-07	0.003	--	--
Recreational User Adolescent	Sediment	2E-06	0.05	--	--
	Surface Water	4E-09	0.0001	--	--
	Total	2E-06	0.05	--	--
Future Land Use Scenario					
Indoor Worker	Groundwater	**3E-05**	**7**	Arsenic **3E-05**	
	Total	**3E-05**	**7**	--	--
	Hazard index by target organ/effect: Blood HI = **7** Liver HI = **7** Kidney HI = **7** Body weight HI = **7**				Gasoline Range Hydrocarbons **7**
Construction Worker	Subsurface Soil	--	0.0008	--	--
	Groundwater	9E-09	0.2	--	--
	Total	9E-09	0.2	--	--

Notes:

Bolded values exceed ODEQ acceptable risk thresholds.

Table 6-34
Risk Characterization Summary - AST Fuel Storage Area
CERCLA Methods
Tongue Point Multi-Sites Project, Astoria, Oregon

Exposure Scenario	Medium	Excess Cancer Risk	Hazard Index
Current and Future Land Use Scenarios			
Trespasser	Surface Soil	2E-08	--
	Total	2E-08	--

Table 6-35
Risk Characterization Summary - UST Site No. 1
CERCLA Methods
Tongue Point Multi-Sites Project, Astoria, Oregon

Exposure Scenario	Medium	Excess Cancer Risk	Hazard Index	Risk Contributor	
				Cancer	Noncancer
Current Land Use Scenario					
Indoor Worker	Indoor Air	3E-08	0.003	--	--
	Total	3E-08	0.003	--	--
Resident	Sediment	4E-06	0.04	--	--
	Surface Water	4E-07	0.003	--	--
	Total	4E-06	0.04	--	--
Student	Indoor Air	1E-08	0.04	--	--
	Sediment	3E-08	0.002	--	--
	Surface Water	7E-09	0.0003	--	--
	Total	5E-08	0.04	--	--
Current and Future Land Use Scenarios					
Recreational User Adult	Sediment	3E-07	0.002	--	--
	Surface Water	2E-08	0.00005	--	--
	Total	3E-07	0.002	--	--
Recreational User Adolescent	Sediment	1E-06	0.02	--	--
	Surface Water	7E-09	0.00009	--	--
	Total	1E-06	0.02	--	--
Future Land Use Scenario					
Indoor Worker	Indoor Air	8E-08	0.007	--	--
	Groundwater	2E-05	0.2	--	--
	Total	2E-05	0.2	--	--
Construction Worker	Subsurface Soil	7E-08	0.3	--	--
	Groundwater	5E-08	0.0007	--	--
	Total	1E-07	0.3	--	--
Resident	Indoor Air	4E-07	0.03	--	--
	Groundwater	**1E-04**	**2**	Arsenic **1E-04**	
	Sediment	4E-06	0.04	--	--
	Surface Water	4E-07	0.003	--	--
	Total	**1E-04**	**2**	--	--
	Hazard index by target organ/effect: Development HI = 1 Nervous system HI = **2** Lung HI = 1 Cardiovascular system HI = 1 Skin HI = 1				Arsenic 1

Notes:

Bolded values ≥ CERCLA acceptable risk thresholds.

Table 6-36
Risk Characterization Summary - Refueling Pit 3
CERCLA Methods
Tongue Point Multi-Sites Project, Astoria, Oregon

Exposure Scenario	Medium	Excess Cancer Risk	Hazard Index
Current and Future Land Use Scenarios			
Recreational User Adult	Sediment	5E-07	0.003
	Surface Water	9E-09	0.00006
	Total	5E-07	0.003
Recreational User Adolescent	Sediment	2E-06	0.05
	Surface Water	4E-09	0.0001
	Total	2E-06	0.05
Future Land Use Scenario			
Indoor Worker	Groundwater	3E-05	0.2
	Total	3E-05	0.2
Construction Worker	Groundwater	9E-09	0.0009
	Total	9E-09	0.0009

Notes:

Bolded values ≥ CERCLA acceptable risk thresholds.

Table 6-37
Risk Characterization Summary - Incinerator Building
CERCLA Methods
Tongue Point Multi-Sites Project, Astoria, Oregon

Exposure Scenario	Medium	Excess Cancer Risk	Hazard Index
Current and Future Land Use Scenarios			
Trespasser Adolescent	Surface Soil	2E-08	0.002
	Total	2E-08	0.002
Future Land Use Scenario			
Outdoor Worker	Surface Soil	7E-07	0.02
	Total	7E-07	0.02
Construction Worker	Surface Soil	4E-08	0.02
	Total	4E-08	0.02

Table 6-38
Risk Characterization Summary - Fire Training Area
CERCLA Methods
Tongue Point Multi-Sites Project, Astoria, Oregon

Exposure Scenario	Medium	Excess Cancer Risk	Hazard Index
Current and Future Land Use Scenarios			
Recreational User Adult	Sediment	4E-07	0.003
	Surface Water	9E-09	0.00006
	Total	4E-07	0.003
Recreational User Adolescent	Sediment	2E-06	0.04
	Surface Water	4E-09	0.0001
	Total	2E-06	0.04
Future Land Use Scenario			
Indoor Worker	Indoor Air	6E-08	0.0004
	Groundwater	7E-05	0.5
	Total	7E-05	0.5
Construction Worker	Subsurface Soil	1E-07	0.3
	Groundwater	7E-07	0.2
	Total	8E-07	0.4

Table 6-39
Risk Characterization Summary - Aquatic North of Pier 8
CERCLA Method
Tongue Point Multi-Sites Project, Astoria, Oregon

Exposure Scenario	Medium	Excess Cancer Risk	Hazard Index	Risk Contributor	
				Cancer	Noncancer
Current and Future Land Use Scenarios					
Recreational User Adult	Sediment	5E-07	0.003	--	--
	Surface Water	9E-09	0.00006	--	--
	Total	5E-07	0.003	--	--
Recreational User Adolescent	Sediment	2E-06	0.04	--	--
	Surface Water	4E-09	0.0001	--	--
	Total	2E-06	0.04	--	--
Angler	Fish Fillet	**1E-04**	1	Arsenic 1E-04	
	Sediment	6E-07	0.004	--	--
	Surface Water	2E-08	0.0002	--	--
	Total	**1E-04**	1	--	--

Notes:

Bolded values ≥ CERCLA acceptable risk thresholds.

Table 6-40
Risk Characterization Summary - Aquatic - Finger Piers
CERCLA Methods
Tongue Point Multi-Sites Project, Astoria, Oregon

Exposure Scenario	Medium	Excess Cancer Risk	Hazard Index	Risk Contributor	
				Cancer	Noncancer
Current and Future Land Use Scenarios					
Recreational User Adult	Sediment	4E-07	0.002	--	--
	Surface Water	1E-08	0.00007	--	--
	Total	4E-07	0.002	--	--
Recreational User Adolescent	Sediment	1E-06	0.03	--	--
	Surface Water	5E-09	0.0001	--	--
	Total	1E-06	0.03	--	--
Angler	Fish Filet	**2E-04**	**2**	Arsenic **2E-04**	1
				Dioxin/Furan TEQ 2E-05	-- 0.6
	Sediment	4E-07	0.003	--	--
	Surface Water	3E-08	0.0002	--	--
	Total	**2E-04**	**2**	--	--
	Hazard index by target organ/effect: Development HI = **2** Nervous system HI = 1 Lung HI = 1 Cardiovascular system HI = 1 Skin HI = 1				

Notes:

Bolded values ≥ CERCLA acceptable risk thresholds.

Table 6-41
Risk Characterization Summary - Aquatic - Near Landfill
CERCLA Methods
Tongue Point Multi-Sites Project RI/FS

Exposure Scenario	Medium	Excess Cancer Risk	Hazard Index	Risk Contributor	
				Cancer	Noncancer
Current and Future Land Use Scenarios					
Recreational User Adult	Sediment	4E-07	0.002	--	--
	Surface Water	9E-09	0.0001	--	--
	Total	4E-07	0.002	--	--
Recreational User Adolescent	Sediment	1E-06	0.03	--	--
	Surface Water	4E-09	0.0001	--	--
	Total	1E-06	0.03	--	--
Angler	Fish Fillet	**1E-04**	1	Arsenic **1E-04**	Arsenic 0.6
				Dioxin/Furan TEQ 1E-05	--
	Sediment	4E-07	0.003	--	--
	Surface Water	2E-08	0.0002	--	--
	Total	**1E-04**	1	--	--

Notes:

Bolded values ≥ CERCLA acceptable risk thresholds.

Table 6-42
Comparison of ODEQ Acceptable Tissue Levels to Chemical Concentrations in Fish Fillet
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical of Potential Concern	Prickly Sculpin Fillet Concentration[1]				ODEQ Acceptable Tissue Levels for Humans[1]
	North of Pier 8	Finger Piers	Near Landfill	Reference Area	General/Recreatonal
Total DDT	0.00614	0.0196	0.00489	0.00627	0.027
2,3,7,8-TCDD (ng/kg)	1.93 U	**0.481 J**	2.1 U	2.1 U	0.062
2,3,7,8-TCDF (ng/kg)	1.93 U	2.08 U	2.1 U	2.1 U	0.62
2,3,7,8-TCDD TEQ (ng/kg)	NC	**2.295**	**0.969**	NC	0.062
Arsenic	**0.95**	**1.31**	**0.8**	**0.88**	0.0062
Chromium	0.66	0.47	1.13	0.52	NA
Lead	0.201	0.101	0.124	0.131	0.5
Mercury	0.268	0.287	0.246	0.205	0.4
Selenium	0.268	0.287	0.246	0.205	20
Tributyl Tin as ion	0.013 U	0.00074 J	0.0008 J	0.0055 U	1.2

Notes:

Bold indicates that reported concentration exceeds ODEQ ATL.
Total DDT - 4,4'-DDT, 4,4'-DDD, and 4,4'-DDE
2,3,7,8-TCDD - 2,3,7,8-Tetrachlorodibenzo-p-dioxin
2,3,7,8-TCDF - 2,3,7,8-Tetrachlorodibenzofuran
TEQ - toxicity equivalent
J - qualifier for estimated value
U - qualifier for non-detected value
NC = Not Calculated; COPC not detected in media type at location noted; or in historical results not detected at reporting limits
NA - value not available
(1) All units in mg/kg wet weight unless otherwise noted.

Table 6-43
Comparison of Aquatic Decision Unit Fish and Sediment Data to Reference and Background Levels
Tongue Point Multi-Sites Project, Astoria, Oregon

Chemical of Potential Concern	North of Pier 8	Finger Piers	Near Landfill	Reference Area	Background Concentration		
					ODEQ[1]	Ecology[2]	Western United States[3]
Prickly Sculpin Fillet Concentration[4]							
Total DDT	0.00614	0.0196	0.00489	0.00627	NA	NA	NA
2,3,7,8-TCDD TEQ (ng/kg)	NC	2.295	0.969	NC	NA	NA	NA
Arsenic	0.95	1.31	0.8	0.88	NA	NA	NA
Chromium	0.66	0.47	1.13	0.52	NA	NA	NA
Mean Sediment Concentration[4]							
Total DDT	No Data	0.00204	0.00152	0.00106	NA	NA	NA
2,3,7,8-TCDD TEQ (ng/kg)	No Data	No Data	0.54	0.96	NA	NA	NA
Arsenic	7	5	6	5	7	8.47	7
Chromium	18.53	18.41	16.24	14.83	NA	78.46	56

Notes:

NC = Not Calculated; COPC not detected in media type at location noted; or in historical results not detected at reporting limits
NA - value not available
No Data = Analyte not analyzed in medium or at location noted
(1) ODEQ Regional Default Background Concentrations for Soil/Sediment
(2) Washington State Department of Ecology (Ecology), 1994. *Natural Background Soil Metals Concentrations in Washington State* , Publication No. 94-115.
Table 17: Background Values Summary Statistics, 90th Percentile from Group "W".
(3) USGS 1984. *Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States* . USGS Professional Paper 1270.
(4) All units in mg/kg wet weight unless otherwise noted.

Table 6-44
Comparison of Tongue Point Fish DDT Data to Columbia River Basin Data
Tongue Point Multi-Sites Project, Astoria, Oregon

	Tongue Point[1]	Cathlamet Bay[2]	Lewis & Clark NWR[2]	EPA[3]
DDT[4]				
Sucker	NA	0.34	NA	NA
Peamouth chub	NA	0.65	NA	NA
Northern pikeminnow	NA	0.09	NA	NA
Sucker (composite)	NA	0.07	0.05	NA
Peamouth chub (composite)	NA	0.24	0.09	NA
Prickly sculpin (fillet)	0.0012	NA	NA	NA
Largescale Sucker	NA	NA	NA	<0.002 - 0.092
Channel Catfish	NA	NA	NA	0.002 - 0.087
Rainbow Trout	NA	NA	NA	<0.002 - 0.005
White Sturgeon	NA	NA	NA	0.002 - 0.003
Smallmouth Bass	NA	NA	NA	0.023 - 0.048
DDE[4]				
Sucker	NA	0.34	NA	NA
Peamouth chub	NA	0.65	NA	NA
Northern pikeminnow	NA	0.09	NA	NA
Sucker (composite)	NA	0.07	0.05	NA
Peamouth chub (composite)	NA	0.24	0.09	NA
Prickly sculpin (fillet)	0.0055	NA	NA	NA
Largescale Sucker	NA	NA	NA	0.014 - 0.74
Channel Catfish	NA	NA	NA	0.33 - 1.3
Rainbow Trout	NA	NA	NA	0.004 - 0.054
White Sturgeon	NA	NA	NA	0.1 - 1.4
Smallmouth Bass	NA	NA	NA	0.48 - 1.2
DDD[4]				
Sucker	NA	0.07	NA	NA
Peamouth chub	NA	0.07	NA	NA
Northern pikeminnow	NA	0.02	NA	NA
Sucker (composite)	NA	0.01	0.01	NA
Peamouth chub (composite)	NA	0.06	0.01	NA
Prickly sculpin (fillet)	0.00065 - 0.00097	NA	NA	NA

Notes:

NA - value not available
(1) Maximum concentration reported from TPMS aquatic decision units
(2) USFWS. 2004. Environmental Contaminants in Aquatic Resources from the Columbua River. Final Report.
(3) EPA 2002. Columbia River Basin Fish Contaminant Survey 1996-1998.
(4) All units in mg/kg wet weight.

Table 6-45
Comparison of Tongue Point Fish Dioxin/Furan Data to Columbia River Basin Data
Tongue Point Multi-Sites Project, Astoria, Oregon

Fish Species	2,3,7,8-TCDD[1]			2,3,7,8-TCDF[1]				2,3,7,8-TCDD TEQ[1]	
	Cathlamet Bay[2]	Lewis & Clark NWR[2]	Tongue Point	Cathlamet Bay[2]	Lewis & Clark NWR[2]	Columbia River[3]	Tongue Point	Columbia River[3]	Tongue Point
Northern pikeminnow[4]	2	NA	NA	24	NA	NA	NA	NA	NA
Sucker[4]	1.1	0.9	NA	9.5	5.5	NA	NA	NA	NA
Peamouth chub[4]	2.4	1.8	NA	34 E	12 E	NA	NA	NA	NA
Largescale Sucker[5]	NA	NA	NA	NA	NA	0.1 - 1.5	NA	0.9	NA
Rainbow Trout[5]	NA	NA	NA	NA	NA	0.1 - 0.3	NA	NA	NA
White Sturgeon[6]	NA	NA	NA	NA	NA	2.5 - 54	NA	4.3	NA
Mountain whitefish[5]	NA	NA	NA	NA	NA	0.14 - 14	NA	6.3	NA
Prickly sculpin[7]	NA	NA	1.93 U - 0.481 J	NA	NA	NA	1.93 U	NA	NC - 2.295

Notes:

2,3,7,8-TCDD - 2,3,7,8-Tetrachlorodibenzo-p-dioxin
2,3,7,8-TCDF - 2,3,7,8-Tetrachlorodibenzofuran
NA - value not available
E - Interference. Result is estimated maximum possible concentration
TEQ - toxicity equivalent
NWR - National Wildlife Reserve
U - qualifier for non-detected value
NC = Not Calculated; COPC not detected in media type at location noted; or in historical results not detected at reporting limits

(1) All units in ng/kg.
(2) USFWS. 2004. Environmental Contaminants in Aquatic Resources from the Columbia River. Final Report.
(3) EPA 2002. Columbia River Basin Fish Contaminant Survey 1996-1998.
(4) Data are for a single composite sample of whole body fish.
(5) Data are for composite fish fillets with skin.
(6) White sturgeon were individual fish and fillets without skin
(7) Data are for a single composite sample of fish fillet with skin.

Table 6-46
Comparison of Sample Quantitation Limit to Groundwater Screening Levels
Tongue Point Multi-Sites Project RI/FS
Former Tongue Point Naval Air Station, Astoria, Oregon

Chemical	Unit	Sample Quantitation Limit	Screening Level(1)	National Primary Drinking Water Standards(2)	Detected in Groundwater at the Study Area?	Desion Unit with Detection
1,2-Dibromoethane (EDB)	µg/L	2	0.0057	0.05	No	na
1,2-Dichloroethane	µg/L	0.5	0.13	5	No	na
Benzene	µg/L	0.5	0.35	5	Yes	Fire Training Area
Benzo(a)pyrene	µg/L	0.02	0.0029	0.2	No	na
Dibenz(a,h)anthracene	µg/L	0.02	0.0029	NA	No	na
Beryllium	µg/L	200	73	4	No	na
Tetrachloroethene	µg/L	0.5	0.091	5	No	na
Trichloroethene	µg/L	0.5	0.029	5	Yes	Regueling Pit 3
Vinyl Chloride	µg/L	0.5	0.025	2	Yes	Fire Training Area
Aroclor 1221	µg/L	0.04	0.0068	0.5(3)	No	na
Aroclor 1232	µg/L	0.02	0.0068	0.5(3)	No	na

na - not applicable

NA - not available

(1). Based on ODEQ RBCs for groundwater or EPA RSLs for tap water
(2). EPA National Primary Drinking Water Standards (web page http://www.epa.gov/safewater/contaminants/index.html),
(3). Based on PCBs

Table 6-47
Summary of Cancer Risk and Noncancer Hazards
ODEQ Methods
Tongue Point Multi-Sites Project, Astoria, Oregon

Decision Unit	Scenario Timeframe	Exposure Scenario	Excess Cancer Risk	Hazard Index	
AST Fuel Storage Area	Current/Future	Trespasser	2E-08	Total =	--
UST Site No. 1	Current	Indoor Worker	3E-08	Total =	0.003
		Resident	4E-06	Total =	0.04
		Student	5E-08	Total =	0.04
	Current/Future	Recreational User Adult	3E-07	Total =	0.002
		Recreational User Adolescent	1E-06	Total =	0.02
	Future	Indoor Worker	**2E-05**	Total =	**3**
				Hazard index by target organ/effect:	
				Blood HI =	**2**
				Liver HI =	**2**
				Kidney HI =	**2**
				Body weight HI =	**2**
		Construction Worker	1E-07	Total =	0.5
		Resident	**1E-04**	Total =	**12**
				Hazard index by target organ/effect:	
				Blood HI =	**10**
				Liver HI =	**10**
				Kidney HI =	**10**
				Development HI =	1
				Nervous system HI =	2
				Lung HI =	1
				Cardiovascular system HI =	1
				Skin HI =	1
				Body weight HI =	**10**
Refueling Pit 3	Current/Future	Recreational User Adult	5E-07	Total =	0.003
		Recreational User Adolescent	2E-06	Total =	0.05
	Future	Indoor Worker	**3E-05**	Total =	**7**
				Hazard index by target organ/effect:	
				Blood HI =	**7**
				Liver HI =	**7**
				Kidney HI =	**7**
				Body weight HI =	**7**
		Construction Worker	9E-09	Total =	0.2

Notes:

Bolded values exceed ODEQ acceptable risk thresholds.

Table 6-48
Summary of Cancer Risk and Noncancer Hazards
CERCLA Methods
Tongue Point Multi-Sites Project, Astoria, Oregon

Decision Unit	Scenario Timeframe	Exposure Scenario	Excess Cancer Risk	Hazard Index	
AST Fuel Storage Area	Current/Future	Trespasser	2E-08	Total =	--
UST Site No. 1	Current	Indoor Worker	3E-08	Total =	0.003
		Resident	4E-06	Total =	0.04
		Student	5E-08	Total =	0.04
	Current/Future	Recreational User Adult	3E-07	Total =	0.002
		Recreational User Adolescent	1E-06	Total =	0.02
	Future	Indoor Worker	**2E-05**	Total =	0.2
		Construction Worker	1E-07	Total =	0.3
		Resident	**1E-04**	Total =	**2**
				Hazard index by target organ/effect:	
				Development HI =	1
				Nervous system HI =	**2**
				Lung HI =	1
				Cardiovascular system HI =	1
				Skin HI =	1
Refueling Pit 3	Current/Future	Recreational User Adult	5E-07	Total =	0.003
		Recreational User Adolescent	2E-06	Total =	0.05
	Future	Indoor Worker	**3E-05**	Total =	0.2
		Construction Worker	9E-09	Total =	0.0009
Incinerator Building	Current/ Future	Trespasser Adolescent	2E-08	Total =	0.002
	Future	Outdoor Worker	7E-07	Total =	0.02
		Construction Worker	4E-08	Total =	0.02
Fire Training Area	Current/ Future	Recreational User Adult	4E-07	Total =	0.003
		Recreational User Adolescent	2E-06	Total =	0.04
	Future	Indoor Worker	**7E-05**	Total =	0.5
		Construction Worker	8E-07	Total =	0.4
Aquatic North of Pier 8 Area	Current/ Future	Recreational User Adult	5E-07	Total =	0.003
		Recreational User Adolescent	2E-06	Total =	0.04
		Angler	**1E-04**	Total =	1
Aquatic Finger Pier Area	Current/ Future	Recreational User Adult	4E-07	Total =	0.002
		Recreational User Adolescent	1E-06	Total =	0.03
		Angler	**2E-04**	Total =	**2**
				Hazard index by target organ/effect:	
				Development HI =	**2**
				Nervous system HI =	1
				Lung HI =	1
				Cardiovascular system HI =	1
				Skin HI =	1
Aquatic Near Landfill Area	Current/ Future	Recreational User Adult	4E-07	Total =	0.002
		Recreational User Adolescent	1E-06	Total =	0.03
		Angler	**1E-04**	Total =	1

Notes:

Bolded chemicals exceed CERCLA or ODEQ target risk thresholds.

Table 6-49
Summary of Risk Drivers for the ODEQ Methods
ODEQ Methods
Tongue Point Multi-Sites Project, Astoria, Oregon

Decision Unit	Scenario Timeframe	Exposure Scenario	Medium	Chemical of Potential Concern	EPC	Units	Risk Driver?	Cancer Risk	Contribution to Total Risk (%)	Hazard Quotient
UST Site No.1	Future	Indoor Worker	Groundwater	Arsenic(1)	4.52E+00	µg/L	no	**2E-05**	97.32%	0.1
		Resident	Groundwater	Carcinogenic PAHs	2.24E-02	µg/L	no	8E-06	6.71%	NA
				Arsenic(1)	4.52E+00	µg/L	no	**1E-04**	89.02%	1
				Manganese	1.24E+03	µg/L	no	NA	NA	1
				Diesel Range Hydrocarbons	4.10E+02	µg/L	**yes**	NA	NA	**5**
				Gasoline Range Hydrocarbons	5.40E+02	µg/L	**yes**	NA	NA	**5**
			Sediment	Carcinogenic PAHs	6.01E-02	mg/kg	no	2E-06	1.97%	NA
				Arsenic(1)	4.50E+00	mg/kg	no	2E-06	1.55%	0.04
Refueling Pit 3	Future	Indoor Worker	Groundwater	Arsenic(1)	5.36E+00	µg/L	no	**3E-05**	99.87%	0.2

Notes:

Bolded chemicals are risk drivers and bolded values exceed ODEQ acceptable risk thresholds.

NA - not applicable

(1) Arsenic is present in groundwater and sediment at background levels. Thus it is not identified as a risk driver.

Table 6-50
Summary of Risk Drivers for the CERCLA Methods
Tongue Point Multi-Sites Project, Astoria, Oregon

Decision Unit	Scenario Timeframe	Exposure Scenario	Medium	Chemical of Concern	EPC	Units	Risk Driver?	Cancer Risk	Contribution to Total Risk (%)	Hazard Quotient
UST Site No.1	Future	Resident	Groundwater	Arsenic(1)	4.52E+00	µg/L	no	**1E-04**	89.02%	1
				Manganese	1.24E+03	µg/L	no	NA	NA	1
Fire Training Area	Future	Indoor Worker	Groundwater	**Vinyl Chloride**	5.36E+00	µg/L	**yes**	**3E-05**	44.55%	0
Aquatic - North of Pier 8	Current/ Future	Angler	Fish Fillet	Arsenic(1)	9.50E-01	mg/kg	no	**1E-04**	96.19%	0.8
Aquatic - Finger Piers	Current/ Future	Angler	Fish Fillet	Arsenic(1)	1.31E+00	mg/kg	no	**2E-04**	85.26%	1
Aquatic - Near Landfill	Current/ Future	Angler	Fish Fillet	Arsenic(1)	8.00E-01	mg/kg	no	**1E-04**	84.89%	0.6

Notes:

Bolded chemicals are risk drivers and bolded values exceed CERCLA or ODEQ target risk thresholds.

NA - not applicable

(1) Arsenic is present in groundwater and fish fillet at background levels. Thus it is not identified as a risk driver.

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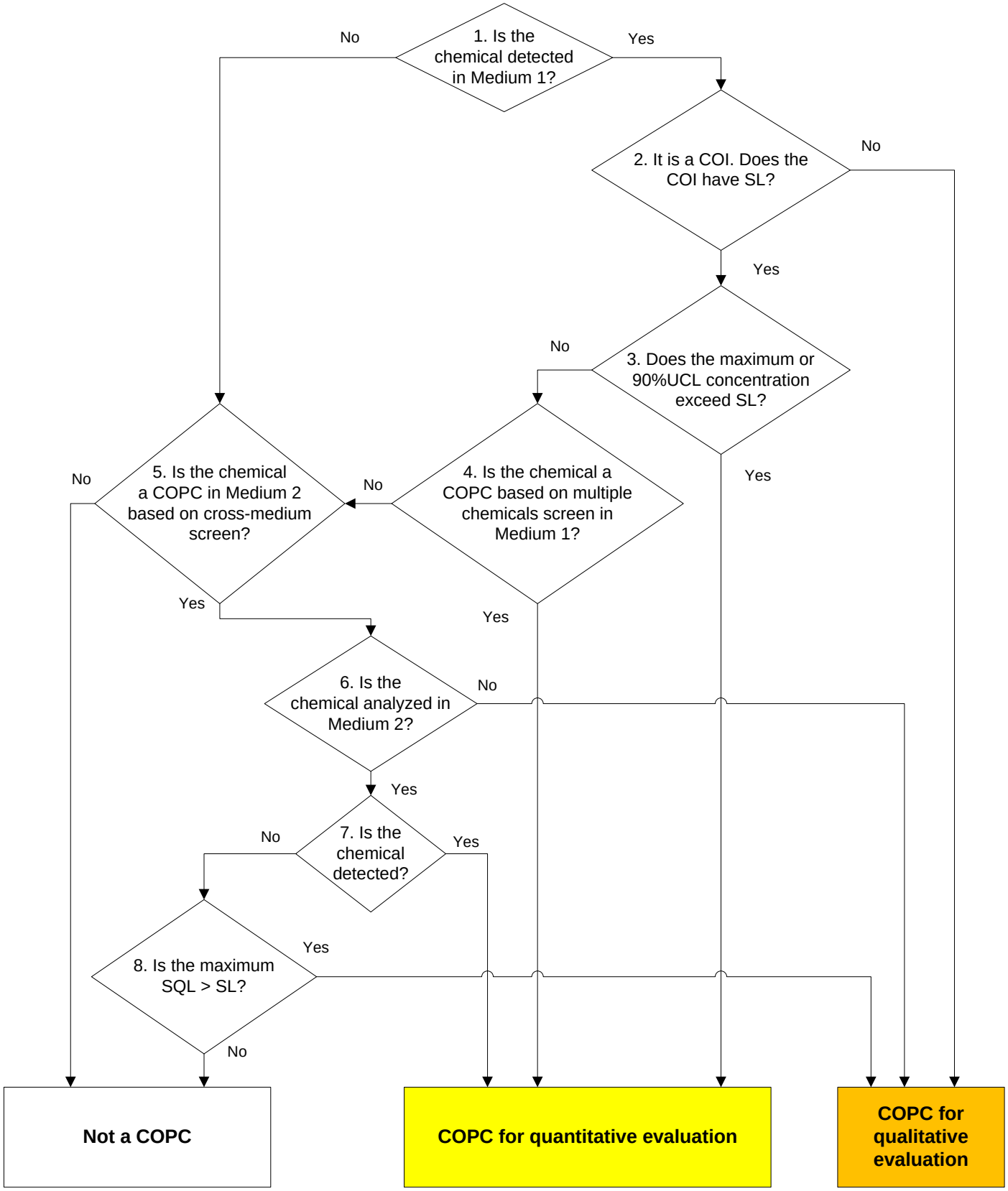
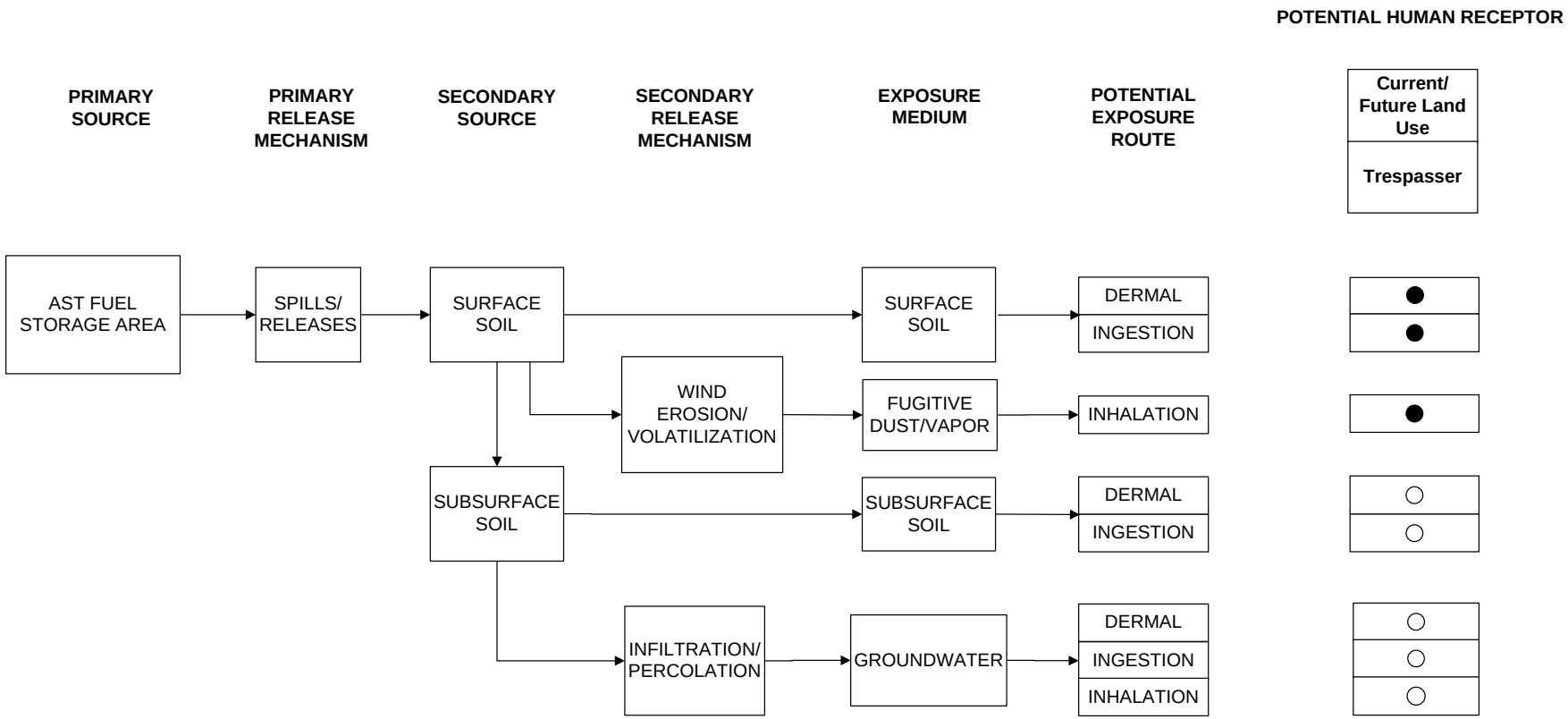
Figure 6-1
Chemical of Potential Concern Identification Flowchart
Tongue Point Multi-Sites Project
Astoria, Oregon



COI – Chemical of interest
COPC – Chemical of potential concern
SQL – sample quantitation limit
SL – Screening level



LEGEND

● Complete exposure pathway

○ Incomplete exposure pathway

AST: Above ground storage tank

CDM

CDM

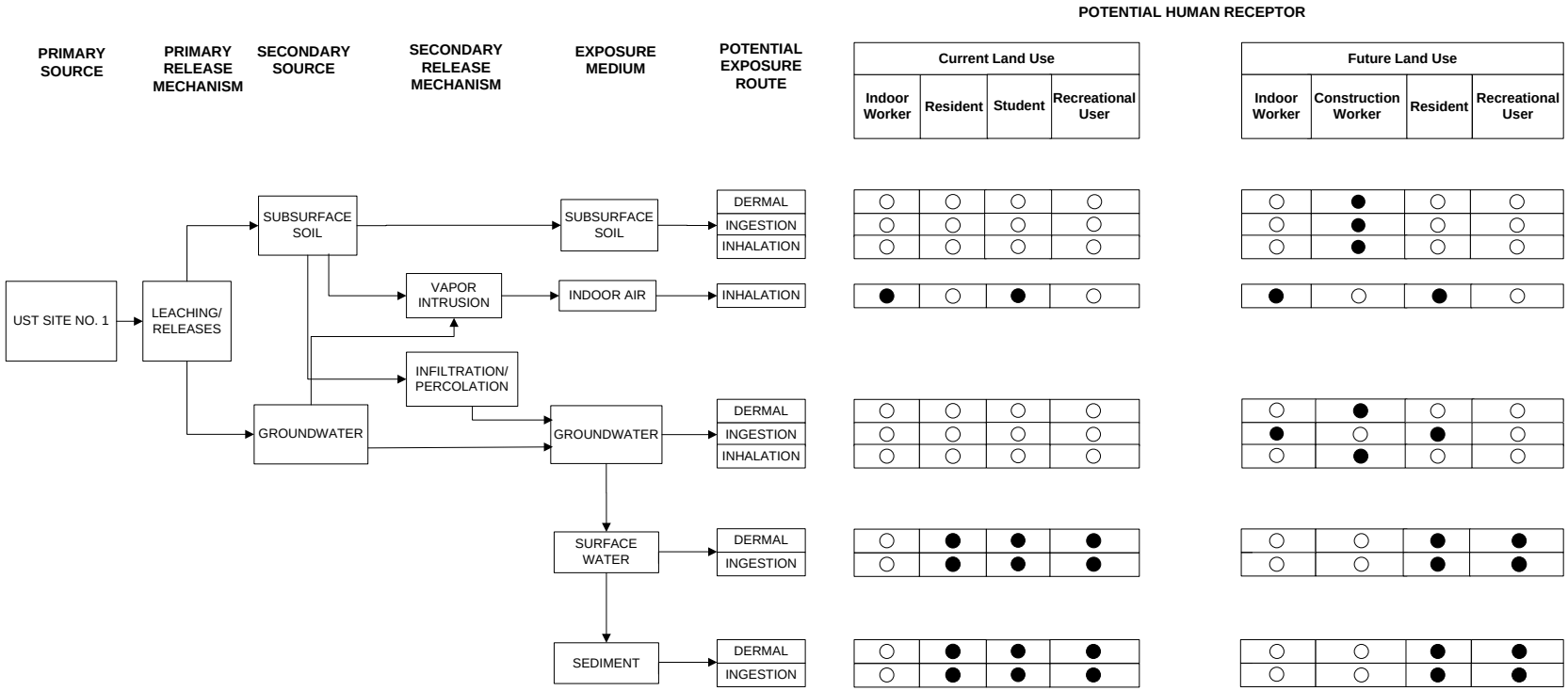
U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

TONGUE POINT MULTI-SITES PROJECT
DELIVERY ORDER NO. 008 CONTRACT NO. W912DW-06-D-1002

CONCEPTUAL SITE EXPOSURE MODEL
AST FUEL STORAGE AREA

ASTORIA 33756130 OREGON

FIGURE 6-2



LEGEND

● Complete exposure pathway

○ Incomplete exposure pathway

UST: Underground storage tank

CDM

U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

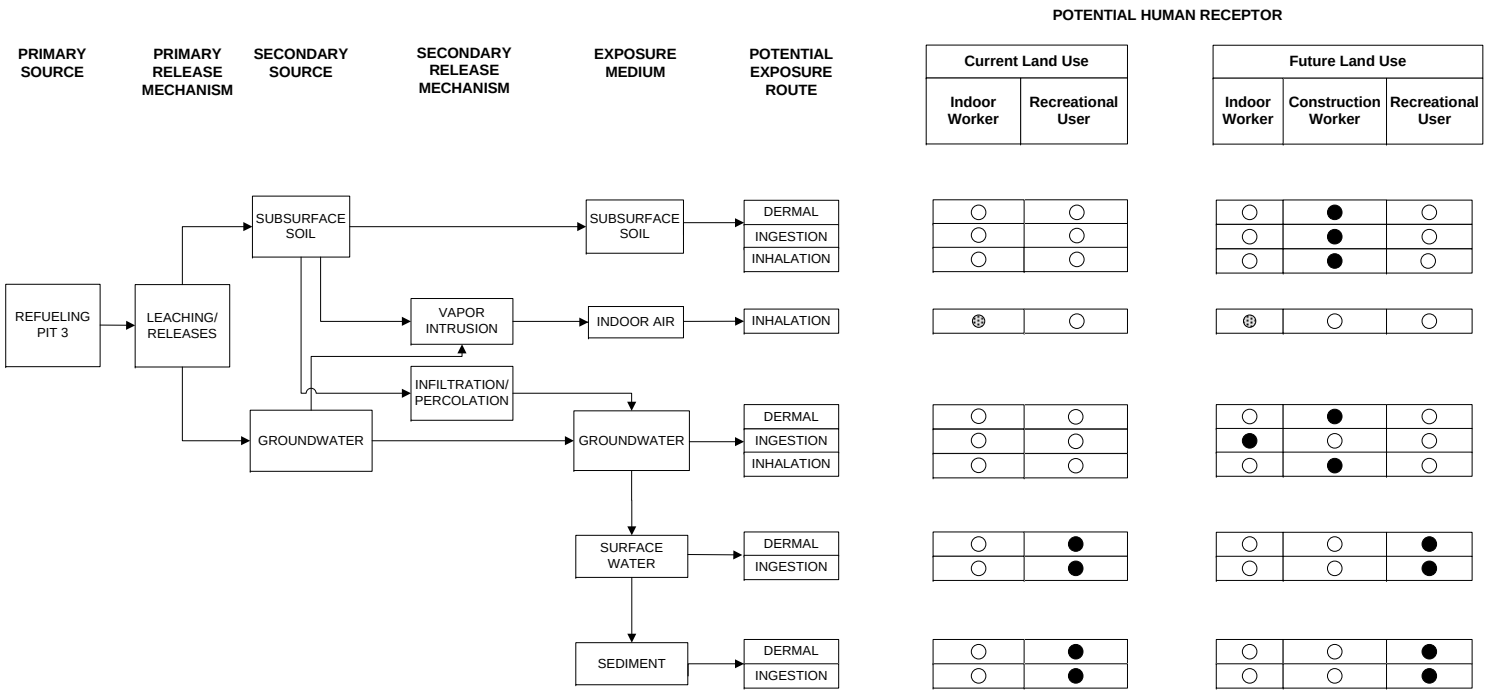
TONGUE POINT MULTI-SITES PROJECT

DELIVERY ORDER NO. 008 CONTRACT NO. W912DW-06-D-1002

CONCEPTUAL SITE EXPOSURE MODEL
UST SITE NO. 1

ASTORIA 33756130 OREGON

FIGURE 6-3



LEGEND

● Complete exposure pathway

○ Incomplete exposure pathway

⊛ Complete exposure pathway qualitatively evaluated

AST: Above ground storage tank

UST: Underground storage tank

CDM

CDM

U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

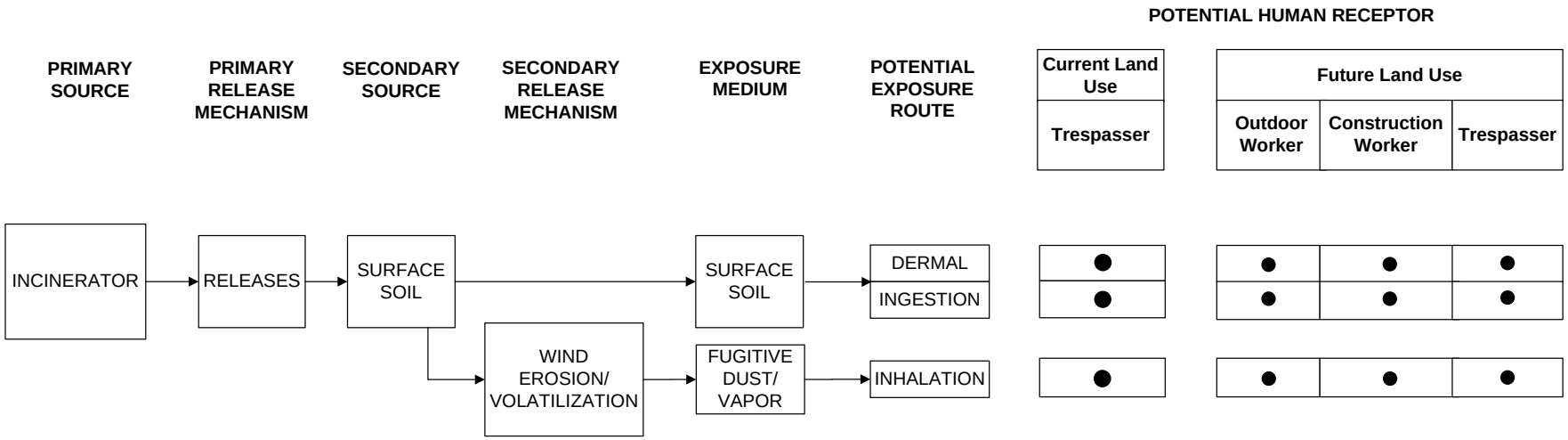
TONGUE POINT MULTI-SITES PROJECT

DELIVERY ORDER NO. 008 CONTRACT NO. W912DW-06-D-1002

CONCEPTUAL SITE EXPOSURE MODEL
REFUELING PIT 3

ASTORIA 33756130 OREGON

FIGURE 6-4



LEGEND

● Complete exposure pathway

○ Incomplete exposure pathway

CDM

CDM

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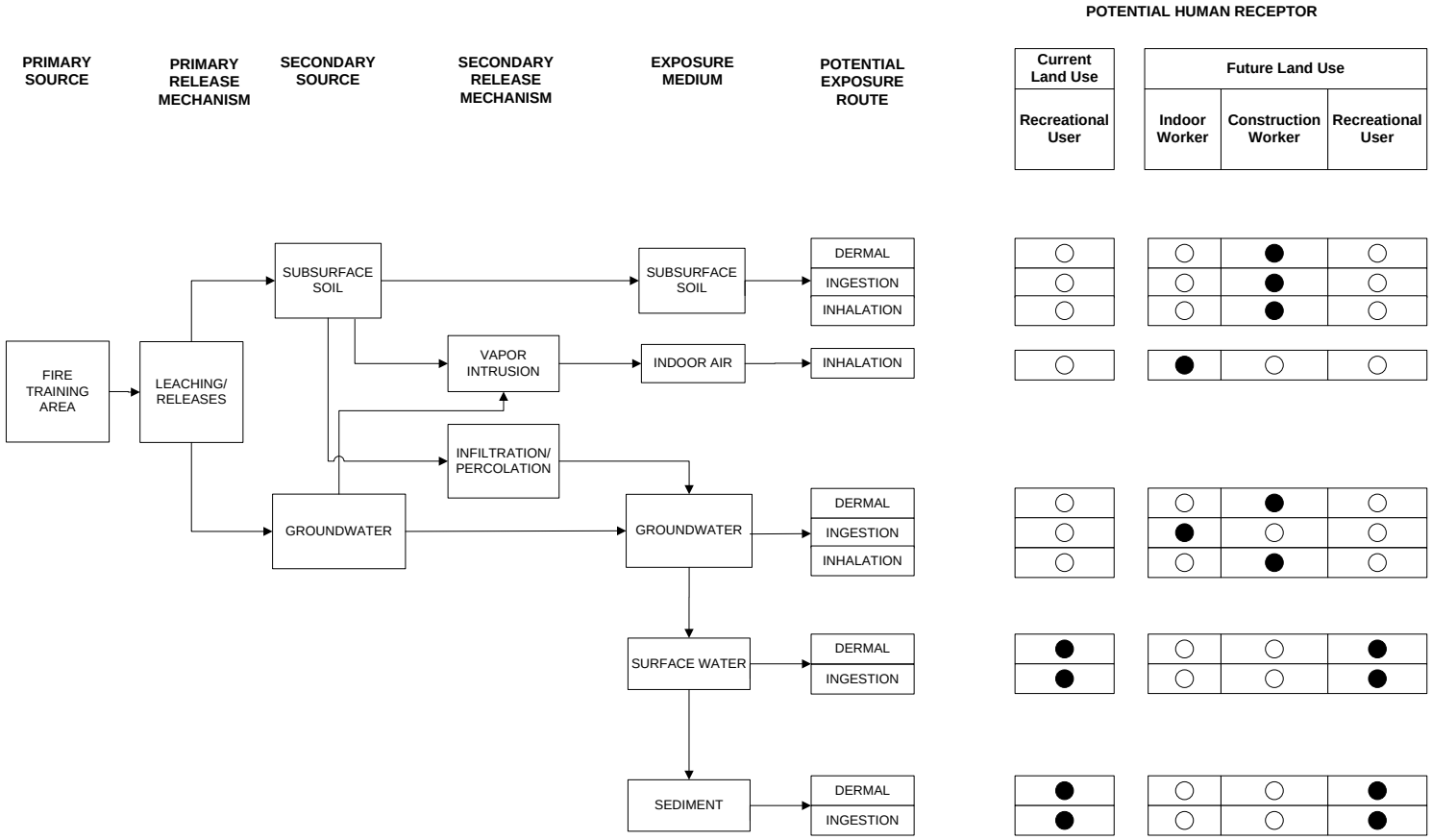
SEATTLE DISTRICT
SEATTLE, WASHINGTON

TONGUE POINT MULTI-SITES PROJECT
DELIVERY ORDER NO. 008 CONTRACT NO. W912DW-06-D-1002

CONCEPTUAL SITE EXPOSURE MODEL
INCINERATOR BUILDING

ASTORIA 33756130 OREGON

FIGURE 6-5



LEGEND

● Complete exposure pathway

○ Incomplete exposure pathway

CDM

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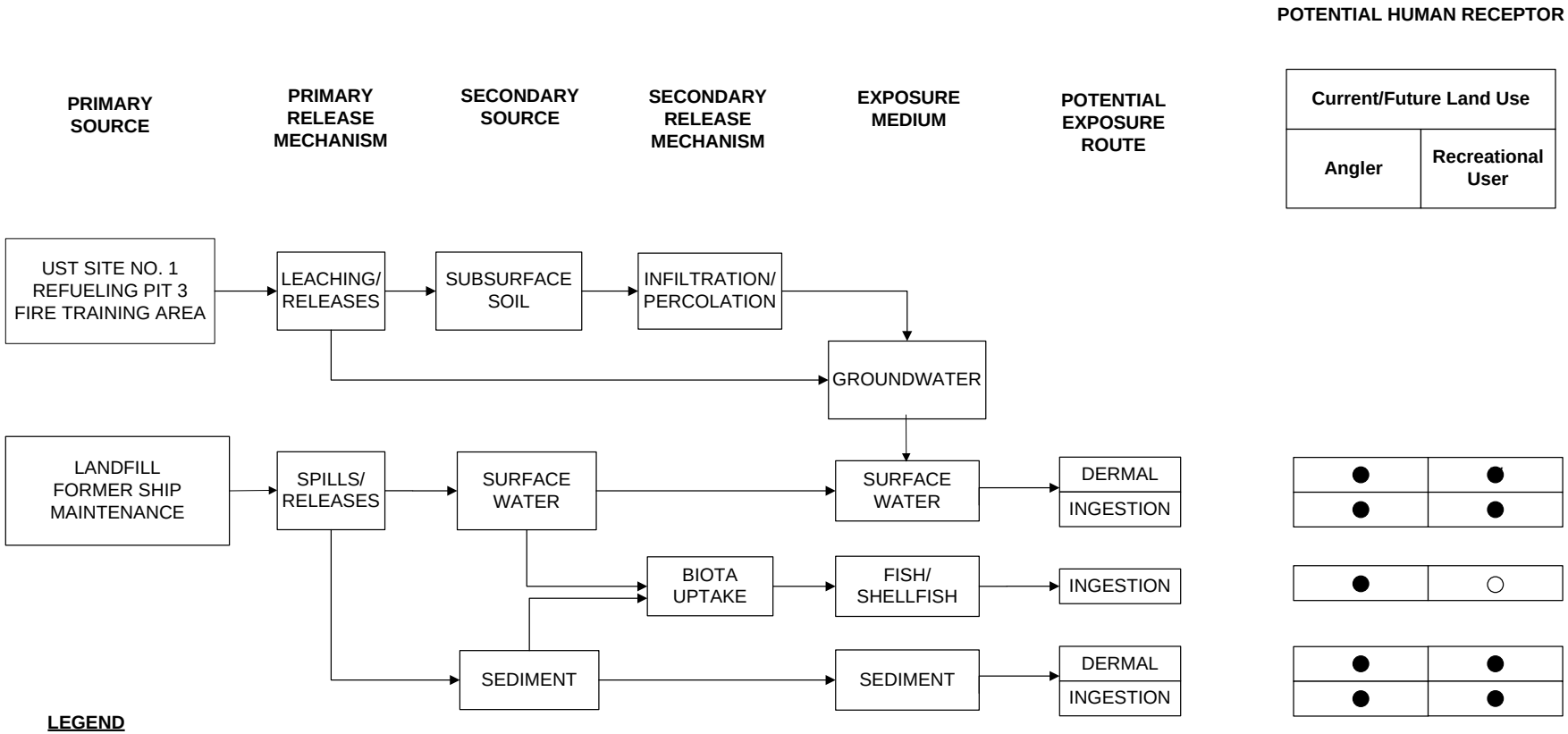
SEATTLE DISTRICT
SEATTLE, WASHINGTON

TONGUE POINT MULTI-SITES PROJECT
DELIVERY ORDER NO. 008 CONTRACT NO. W912DW-06-D-1002

CONCEPTUAL SITE EXPOSURE MODEL
FIRE TRAINING AREA

ASTORIA 33756130 OREGON

FIGURE 6-6



LEGEND

● Complete exposure pathway

○ Incomplete exposure pathway

AST: Above ground storage tank

UST: Underground storage tank

CDM

CDM

U.S. ARMY
CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

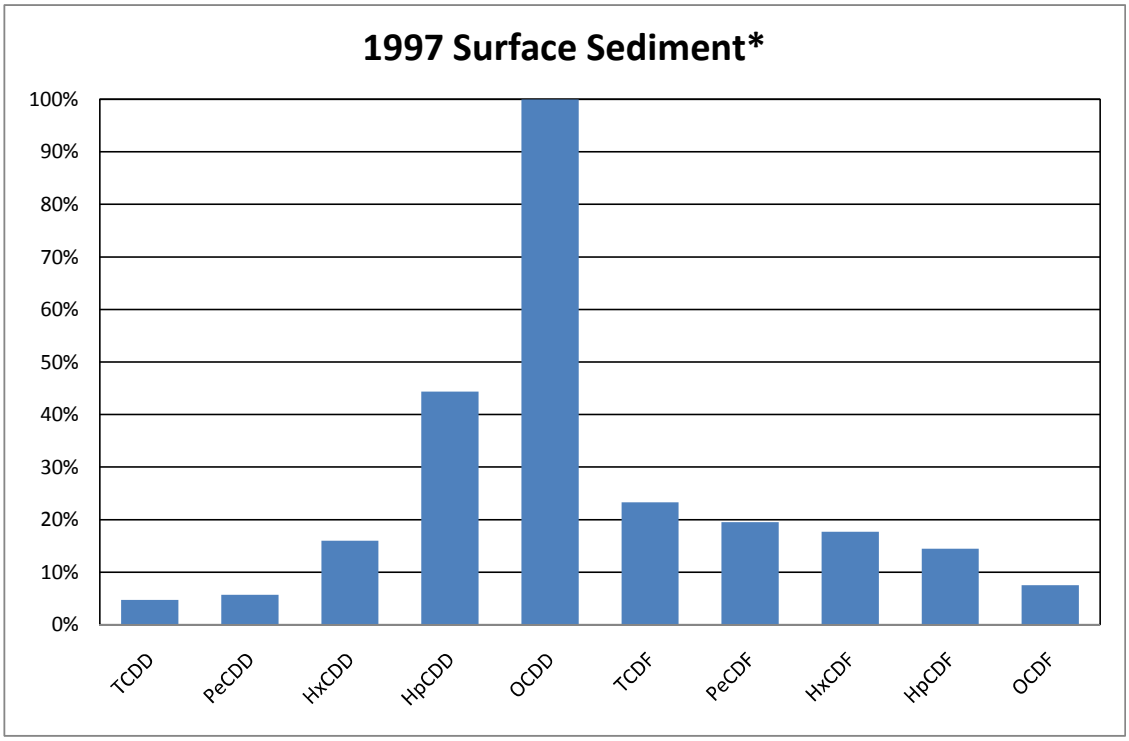
TONGUE POINT MULTI-SITES PROJECT
DELIVERY ORDER NO. 008 CONTRACT NO. W912DW-06-D-1002

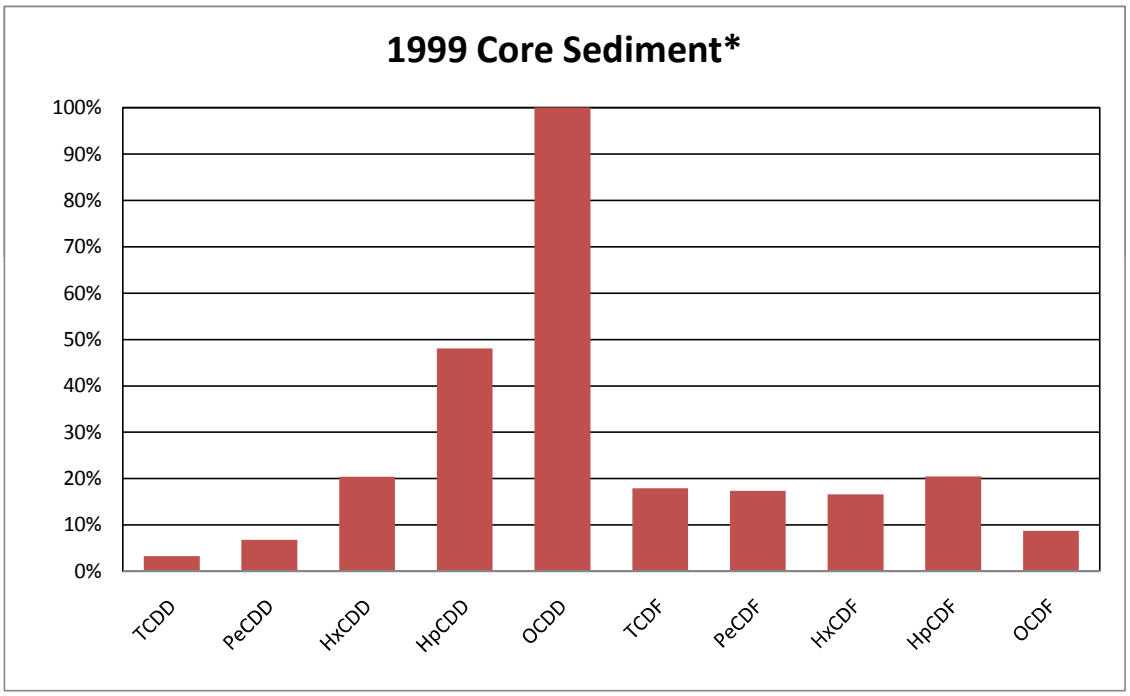
CONCEPTUAL SITE EXPOSURE MODEL
AQUATIC DECISION UNITS

ASTORIA 33756130 OREGON

FIGURE 6-7

Figure 6-8
Dioxin/Furan Homolog Profiles for Historical Sediment Samples from Near Landfill
Tongue Point Multi-Sites Project
Astoria, Oregon





Legend:

TCDD	Total Tetrachlorodibenzo-p-dioxin	TCDF	Total Tetrachlorodibenzofuran
PeCDD	Total Pentachlorodibenzo-p-dioxin	PeCDF	Total Pentachlorodibenzofuran
HxCDD	Total Hexachlorodibenzo-p-dioxin	HxCDF	Total Hexachlorodibenzofuran
HpCDD	Total Heptachlorodibenzo-p-dioxin	HpCDF	Total Heptachlorodibenzofuran
OCDD	Total Octachlorodibenzo-p-dioxin	OCDF	Total Octachlorodibenzofuran

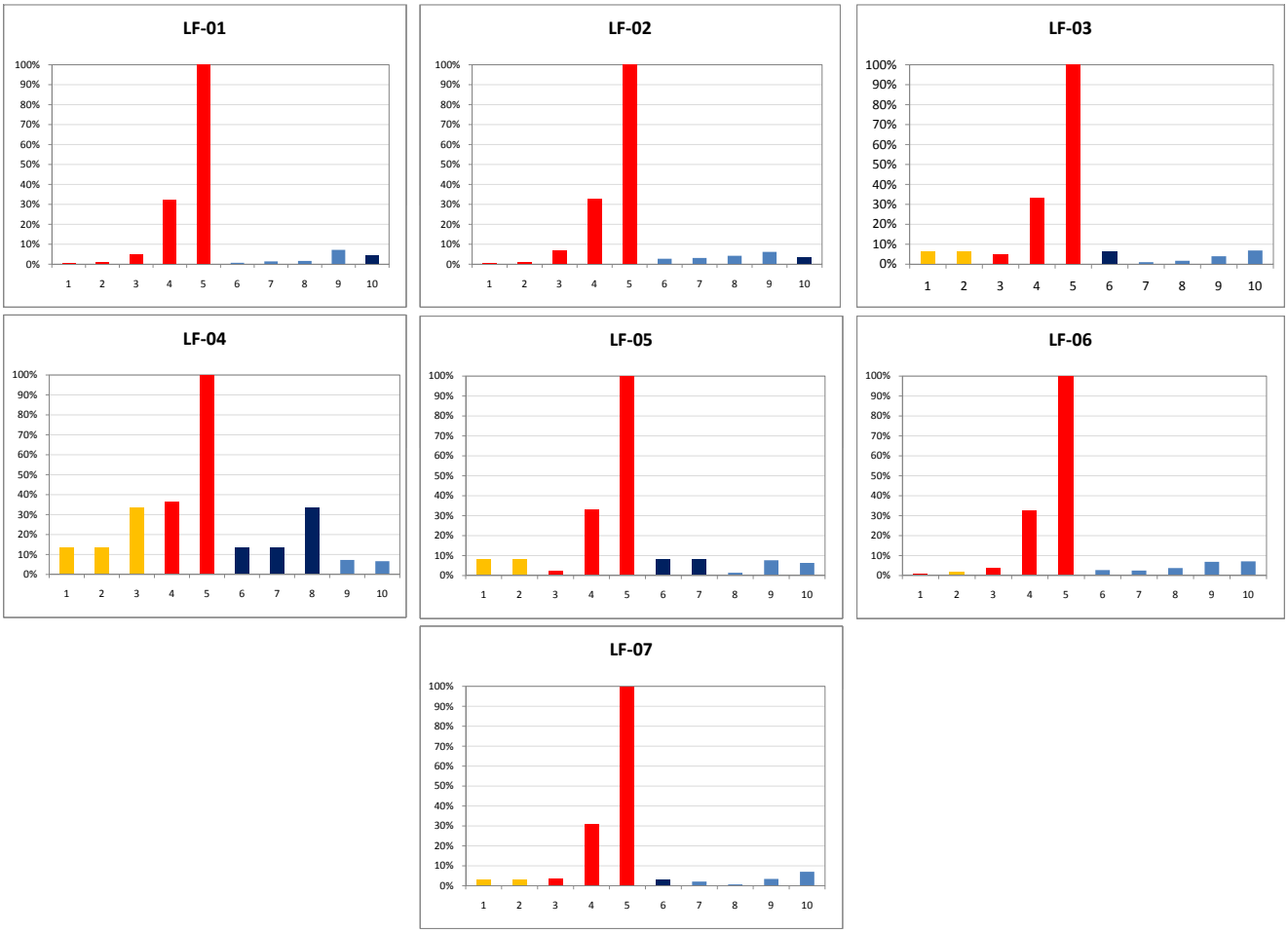
Notes:

Percentages on vertical scale are mean concentrations normalized to OCDD concentrations.

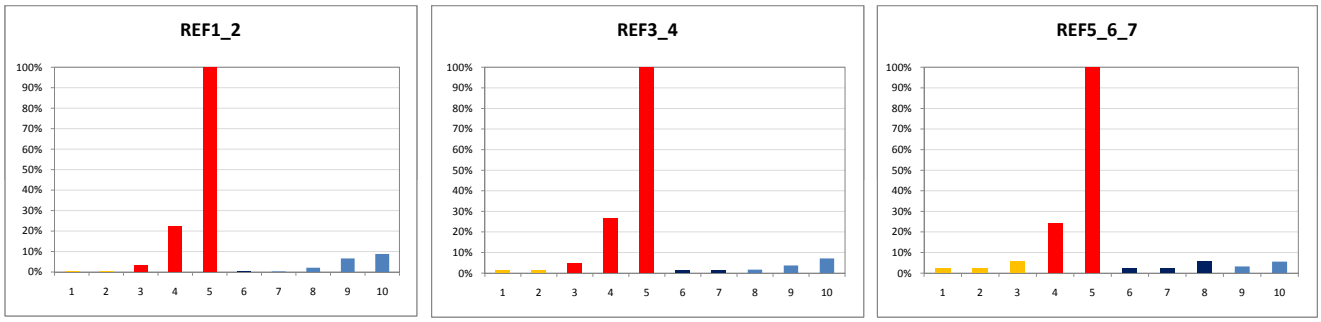
*Data from URS Grenier Woodward Clyde, 1998 and 2000a.

Figure 6-9
Dioxin/Furan Homolog Profiles for Sediment Samples
from Near Landfill and Reference Area
Tongue Point Multi-Sites Project
Astoria, Oregon

Aquatic Near Landfill



Aquatic Reference



Legend:

TCDD	Total Tetrachlorodibenzo-p-dioxin	TCDF	Total Tetrachlorodibenzofuran
PeCDD	Total Pentachlorodibenzo-p-dioxin	PeCDF	Total Pentachlorodibenzofuran
HxCDD	Total Hexachlorodibenzo-p-dioxin	HxCDF	Total Hexachlorodibenzofuran
HpCDD	Total Heptachlorodibenzo-p-dioxin	HpCDF	Total Heptachlorodibenzofuran
OCDD	Total Octachlorodibenzo-p-dioxin	OCDF	Total Octachlorodibenzofuran

- detected dioxin concentration
- nondetect dioxin concentration based on one half of sample quantitation limit (½ SQL)
- detected furan concentration
- nondetect furan concentration based on ½ SQL

Notes:
Percentages on vertical scale are mean concentrations normalized to OCDD concentrations.

Section 7
Baseline Ecological Risk Assessment

ODEQ guidance for conducting ERAs (ODEQ 2001) describes a multistep process. Level I (scoping) and Level II (screening) of this process have been completed, and the results of these steps were submitted in June 2009 to ODEQ as a technical memorandum (TM) (CDM 2009a), which is provided as **Appendix M1**. The information in Appendix M1 comprises the ODEQ Level I and Level II steps in the ODEQ ecological risk assessment process. The Level I scoping process is presented in the technical memorandum Section 1 and Section 2 and Attachment 1 Ecological Scoping Checklist. The Appendix M1 technical memorandum includes the ODEQ Level II Screening steps presented in the technical memorandum Section 3, Section 4, and Section 5. The Level II screening of chemicals detected or estimated in abiotic media and biota (i.e., fish and clams) compares maximum detected concentrations and, in some cases, 90th percentile concentrations to ODEQ-recommended screening level values (SLVs) per ODEQ Level II ERA guidance. Chemicals associated with hazard quotients exceeding 1.0 and hazardous chemicals for which SLVs have not been derived are retained for further investigation. Therefore, these chemicals are evaluated in the Level III assessment, which is the Baseline ERA or BERA. This section presents the third step of the ODEQ ERA process, Level III (Baseline Risk Assessment Report) and is analogous to the Baseline Ecological Risk Assessment (BERA) step described in U.S. EPA guidance (EPA 1997b) for conducting ERAs at Superfund sites.

7.1 Introduction

This Level III BERA is organized as described in the ODEQ guidance (ODEQ 2001), with minor deviations to account for Study Area-specific considerations. This Level III evaluation follows or is consistent with the guidance and recommendations described in U.S. EPA guidance for conducting ERAs at Superfund sites (EPA 1997b).

Section 7.1 provides introductory information. **Section 7.2** presents problem formulation, including assessment and measurement endpoints and risk hypotheses. **Section 7.3** presents exposure assessment information for ecological receptors and chemical concentration data. **Section 7.4** serves as the ecological response or effects assessment, where relevant ecotoxicology information is presented. **Section 7.5**, on risk characterization, integrates effects and exposure information to derive risk estimates. **Section 7.6** discusses uncertainties with all the important steps in the Level III process, and as such provides a discussion of the level of confidence attained in the information presented. **Section 7.7** summarizes the conclusions of the Level III report. The references used to conduct the assessment are listed in **Section 9**. References used to conduct the Level I and II scoping and screening steps completed in support of the Level III report are listed in **Appendix M1**.

7.1.1 Study Area History and Description

A detailed history and description is presented in **Section 1**. No further information regarding study area history is presented in this section. A brief description of the ecological importance of each DU follows.

Not all of these DUs provide significant or suitable ecological habitat; this conclusion is based on size of the area and habitat suitability for receptors of interest. The Incinerator Building DU is very small and provides little habitat for ecological receptors. The AST Fuel Storage Area DU is also small, but is located in a wooded area; therefore, it provides a small amount of suitable habitat for some ecological receptors. Of the UST DUs, only UST Site No. 4 provides habitats useful for ecological receptors. The Fire Training Area is disturbed, primarily because of placement of dredged materials and dominance of vegetation associated with poor quality habitat, but ecological receptors tolerant of disturbed conditions have potential to use this area at least intermittently. All of the aquatic DUs provide suitable habitat for aquatic and water-dependent receptors. Included in the category of aquatic DUs are nearshore discrete sediment sampling locations (e.g., RFP 3 [sediment] and FTA [sediment]) identified and being evaluated for links to onsite/terrestrial source areas.

7.1.2 Summary of Level II Screening

The results of the Level I Scoping and Level II Screening steps (**Appendix M1)** supported the need to perform subsequent steps of the ERA process. This need is based on the identification of multiple chemicals of ecological concern (CPECs) in abiotic media and in biological media (i.e., clams and fish) from one or more locations of interest. The CPECs resulting from Level II screening are shown by medium and by DU in **Table 7-1**. Note that some of the CPECs in this table are based in part on the results of the cross-media screening, and some of these CPECs were not identified as CPECs based on concentrations measured independently in surface water or sediment. CPECs identified based solely on multimedia screening are not evaluated further in this report because of the overly conservative results of the multimedia screens. Others (various classes of petroleum hydrocarbons) are shown on this table as CPECs. In these cases, this CPEC designation is based on (1) lack of ODEQ-recommended ecological screening values (and not necessarily on toxicity or other similar criteria), and (2) on ODEQ guidance that suggests that these chemicals can be designated as hazardous to ecological receptors. This designation differs from EPA guidance for CERCLA, which does not include petroleum hydrocarbons as hazardous materials. Petroleum hydrocarbons were not quantitatively evaluated at the Level I/II screening stage because generally accepted ecological screening levels or other useful ecotoxicity data for petroleum have not been adopted by ODEQ. Petroleum hydrocarbons are quantitatively evaluated at the end of this section using alternative ecological screening levels and the results of this evaluation are summarized in **Section 7.7**.

This listing of media, DUs, and chemicals warranting further investigation, shown on **Table 7-1** with 'X', is based on the results of comparing maximum detected concentrations to ODEQ-recommended SLVs. These initial exposure concentrations are refined in the Level III evaluation, where average (arithmetic mean) exposure concentrations replace maximum detected concentrations to provide a more realistic estimation of exposures for selected ecological receptors. **Appendix M2** presents the Level III screening tables, which include arithmetic mean concentrations in abiotic and biological media. The media- and DU-specific CPECs for which additional quantitative analyses are performed in this Level III evaluation are as follows.

DUs associated with surface soil exposures include the AST Fuel Storage Area, where lead is identified as the single CPEC, and the Fire Training Area, where chromium in the only CPEC identified.

DUs associated with sediment exposures and the corresponding CPECs identified for each include the following:

- UST Site No. 1 (discrete nearshore samples), where seven SVOCs, DDE, DDT, total DDT, Lindane, barium, cadmium, copper, lead, mercury, selenium, and vanadium are identified as CPECs.
- Refueling Pit 3 (discrete nearshore samples), where eleven SVOCs, DDE, DDT, total DDT, heptachlor, heptachlor epoxide, Aroclor-1254, arsenic, barium, cadmium, copper, lead, mercury, nickel, and vanadium are identified as CPECs.
- Fire Training Area (discrete nearshore samples), where the following are selected as CPECs: Indeno(1,2,3-cd)pyrene, DDE, total DDT, Aroclor-1254, arsenic, barium, cadmium, copper, lead, mercury, nickel, selenium, and vanadium.
- Aquatic - North of Pier 8, where three SVOCs, arsenic, cadmium, copper, lead, mercury, nickel, and vanadium are selected as CPECs.
- Aquatic - Finger Piers, where CPECs include two SVOCs, DDE, DDT, total DDT, heptachlor, arsenic, cadmium, copper, lead, mercury, nickel, and vanadium.
- Aquatic - Near Landfill, where identified CPECs include four SVOCs, dioxins and furans TEQ, total DDT, heptachlor, arsenic, cadmium, lead, and mercury.

DUs associated with surface water exposures include UST Site No. 1 (discrete nearshore), Refueling Pit 3 (discrete nearshore), Fire Training Area (discrete nearshore), Aquatic - North of Pier 8, Aquatic - Finger Piers, and Aquatic - Near Landfill. The single CPEC identified for each of these DUs, including the aquatic Reference area, is barium.

CPECs identified for whole body fish include total DDT, dioxins and furans TEQ, arsenic, chromium, lead, mercury, and selenium. CPECs identified for soft tissue clam include dioxins and furans TEQ, arsenic, chromium, lead, mercury, and

selenium. Total DDT is not identified as a CPEC for clam based on chemical screening but is evaluated to support other lines of evidence.

These CPECs, media, and DUs (including the reference location as applicable) are evaluated to determine if they warrant additional evaluation in the ODEQ ERA process. This determination is based on size and habitat suitability of the DUs; level of contamination compared to background, reference, and SLVs; types of contaminants detected; and data availability. The last criterion is used to determine if qualitative or quantitative risk estimation can be performed. For example, the risks based on petroleum hydrocarbons in soils or sediments initially could not be reliably quantified for two reasons. First, universally accepted ecological screening values or toxicity values associated with this class of chemicals are not generally available. Washington State DOE has published some screening levels for a few types of petroleum hydrocarbons, but ODEQ has not adopted these as recommended screening levels. Second, petroleum hydrocarbons are complex mixtures of chemicals with varying characteristics, including toxicity, persistence, and bioavailability.

Petroleum hydrocarbons are not designated hazardous constituents within the CERCLA regulations, but are considered hazardous for the ODEQ regulations and were evaluated subsequent to completion of Level II screening. Surrogate SLVs for petroleum hydrocarbons in sediment and in surface soils were compiled and compared to detected concentrations of TPH-G (gasoline range hydrocarbons), TPH-D (diesel range hydrocarbons), and TPH-O (oil range hydrocarbons). These comparisons and associated conclusions are not included in Appendix M but are provided in **Section 7.7**. The comparison tables are presented in **Section 4.3.10** and shown in **Table 4.11**.

7.1.3 Assessment Objectives and Scope

The objective of the Level III report, based on ODEQ guidance (2001), is to determine whether a site, if left un-remediated, would pose unacceptable current or reasonably likely future risks to ecological receptors. The purpose of the Level III evaluation is to determine the following:

- If significant ecological effects are occurring at a DU
- The probable causes of these effects
- The source of stressors causing these effects
- The consequences of leaving the DU un-remediated

The scope of the Level III report includes additional investigations and evaluations of risk for those media, DUs, chemicals, and ecological receptors that were found to be associated with unacceptable risk at Level I and II of the ERA process. This scope is further refined by addressing comments received from ODEQ on the Level I and II

assessments. The revised initial scope for this BERA was based on the five activities listed below:

- Derivation of risk estimates (as hazard quotients or HQs) for the major CPECs identified in the Level I/ II assessments as those requiring further investigation.
- Comparison of the analytical results of fish and clam tissue data from the upgradient Reference station and the Finger Pier DUs to available values from other studies of the Lower Columbia River area.
- Evaluation of risks for water-dependent avian and mammalian receptors that may be exposed to bioaccumulative chemicals (dioxins/furans, DDT(total), heptachlor (total), cadmium, and mercury) from ingestion of clams and fish, using quantitative risk estimation via food web modeling where sufficient input data allow for modeling.
- Evaluation of risks for omnivorous avian and mammalian receptors with small foraging ranges that may be exposed via diet to lead in soils at the AST Fuel Storage Area DU, using food web modeling.
- Comparison of ODEQ Biota-Sediment Accumulation Factors (BSAF) to site-specific BSAFs for dioxin/furans and DDT in sediments to clam tissue.

Based on the aforementioned criteria, the DUs carried forward in the Level III evaluation and subject to refined risk estimation or qualitative discussion are:

- AST Fuel Storage Area (surface soil)
- UST Site No. 1 (surface water and nearshore discrete sediment)
- Refueling Pit 3 (surface water and nearshore discrete sediment)
- Fire Training Area (surface soil, surface water, and nearshore discrete sediment)
- Aquatic - North of Pier 8 (surface water, sediment, fish, clam)
- Aquatic - Finger Piers (surface water, sediment, fish, clam)
- Aquatic - Near Landfill (surface water, sediment, fish, clam)
- Aquatic - Reference Area (surface water, sediment, fish, clam)

The following DUs are not evaluated further for the reasons cited:

- Incinerator Building – Very small, limited ecological habitat
- UST Site No. 4 – Only CPECs are petroleum hydrocarbons (as defined by ODEQ but not CERCLA), and CPEC designation is based solely on lack of screening levels

7.2 Problem Formulation

The problem formulation phase establishes the goals and describes the scope and focus of the assessment. This phase considers site-specific regulatory and policy issues and requirements, and identifies possible stressors (i.e., CPECs) and ecological resources at risk. An important outcome of problem formulation is the conceptual site exposure model (CSEM), which describes potential exposure scenarios, including contaminant sources, transport mechanisms, exposure media, exposure routes, and receptors. The CSEM depicted on **Figures 7-1, Ecological Pathways, and 7-2 Food Web,** are directly from the Level I/II evaluation (**Appendix M1**), and these figures are considered applicable to this Level III report without modification. A somewhat unique exposure scenario depicted on **Figure 7-1** and evaluated in this assessment is the possibility that three onsite DUs may have in the past or currently release chemical constituents from onshore source areas (i.e., the DUs) to nearshore sediments. These three DUs are the UST Site No. 1,Refueling Pit No. 3, the Fire Training Area. Linked to the CSEM are descriptions of the relationship between chemical stressors, ecological receptors, assessment endpoints, and measurement endpoints. Each component is defined and described in the following sections.

7.2.1 Assessment Endpoints

Assessment endpoints identify the ecological values to be protected (e.g., abundance and diversity of aquatic macro invertebrates or fish). Assessment endpoints are directly related to remedial action goals and objectives determined for the study area. Appropriate assessment endpoints are developed by risk assessors and often consider guidance from relevant regulatory agencies. Based upon the Level I and II evaluations, fieldwork, and surveys, refined assessment endpoints for the Level III BERA were developed. The refined endpoints are the following:

- Protection of terrestrial plant and soil invertebrate populations and communities from adverse effects on survival, growth, or reproduction.
- Protection of omnivorous terrestrial small mammal and avian populations and communities linked to surface soil via diet from adverse effects on survival, growth, or reproduction.
- Protection of aquatic invertebrate populations and communities from adverse effects on survival, growth, or reproduction.
- Protection of resident and anadromous (i.e., salmonid) fish individuals (species of special concern) and populations and communities (non-listed taxa) from adverse effects on survival, growth, or reproduction.
- Protection of piscivorous/carnivorous water-dependent avian and mammalian individuals (special status species) and local populations and communities from adverse effects on survival, growth, or reproduction.

Five species of protected salmonid fish have potential to be exposed to site-related chemicals. These are Chinook salmon (*Oncorhynchus tshawyicha;* five evolutionarily significant units (ESUs)), coho salmon (*Oncorhynchus kisutch*; one ESU), chum salmon (*Oncorhynchus keta*; one ESU), sockeye salmon (*Oncorhynchus nerka*; one ESU), and steelhead (*Oncorhynchus mykiss*; five ESUs). Because of their special status, protection of these receptors at the individual organism level is warranted.

7.2.2 Risk Hypotheses

Risk hypotheses or risk questions are used to direct the investigation toward specific goals linked to risk characterization. These risk hypotheses are answered using information provided in three phases of the evaluation. First, the exposure assessment phase of this evaluation considers chemical concentrations to which receptors may be exposed. Second, in the effects assessment phase the evaluation uses chemical concentrations associated with no effects or low levels of adverse effects in exposed biota. In the third step, the risk hypotheses can be resolved in the risk characterization phase using the results obtained from food web modeling.

Risk questions derived for the Level III report are based on specific media, chemicals, DUs, and representative receptor groups that were found to warrant further evaluation in the Level I and II assessments. Risk questions, i.e., hypotheses phrased in the form of questions, are:

- Are chemical concentrations in surface soils sufficiently elevated to contribute to adverse effects related to the survival, growth, or reproduction of terrestrial plants and invertebrates, represented by earthworms?
- Are chemical concentrations in food items linked to surface soils sufficiently elevated to contribute to adverse effects related to the survival, growth, or reproduction of omnivorous terrestrial small mammal and bird populations and communities?
- Are chemical concentrations in sediments sufficiently elevated to adversely affect the survival, growth, or reproduction of benthic macroinvertebrates?
- Are chemical concentrations in surface water sufficiently elevated to adversely affect the survival, growth, or reproduction of salmonid fish individuals (special status species) and non-salmonid fish populations and communities?
- Are chemical concentrations in resident fish and clams sufficiently elevated to adversely affect the survival, growth, or reproduction of piscivorous/water-dependent birds and mammals?

7.2.3 Measurement Endpoints

Measurement endpoints are quantitative expressions of observed or measured biological responses to stressors (i.e., CPECs) relevant to selected assessment endpoints. Measurement endpoints are used where assessment endpoints cannot be directly measured or evaluated. For example, ensuring the survival and growth of

aquatic invertebrates (an assessment endpoint) can be evaluated using an appropriate measurement endpoint such as a low effect level determined in toxicity tests with a sensitive representative invertebrate receptor. Measurement endpoints selected for this Level III report include SLVs and toxicity reference values (TRVs), primarily those recommended by ODEQ.

For this report, ecologically significant effects are defined as those affecting survival, growth, or reproduction of selected representative receptors. Other endpoints such as effects on behavior or histopathologic effects are not considered because these cannot be easily or directly linked to ecologically significant endpoints that can impair populations or communities. Protection of populations and communities is a major goal of the ERA process; protection of individual organisms is warranted for species of special concern (e.g., threatened or endangered species).

Because of the potential for certain organic chemicals and metals detected in sampled media to accumulate in biological tissues and exert adverse effects in upper trophic level biota via ingestion of prey, this report considers bioaccumulation and adverse effects in upper trophic level organisms to be especially important. Food web modeling is performed for soil-associated receptors exposed to lead (AST Fuel Storage Area) and for sediment-associated receptors exposed to a subset of the most highly bioaccumulative organic chemicals and detected inorganics (Aquatic DUs). **Appendix M3** provides the Aquatic (sediment-associated) Food Web Model and **Appendix M4** provide the Terrestrial (soil-associated) Food Web Model. The measurement endpoints for all of these food web models are dietary TRVs expressed as average daily doses of bioaccumulative CPECs.

7.2.3.1 Measure of Exposure

Exposure point concentrations used in the previous steps of the ERA process (Level I and II) included the maximum detected concentrations. In this Level III step, these maximum detected concentrations are replaced by arithmetic mean concentrations to provide a more realistic and representative estimate of exposure.

7.2.3.2 Measures of Effect

Effects concentrations for the Level III BERA are summarized below by media and in order of preference or use, where multiple steps are incorporated into the process. Primary exposure media are shown in italic type.

Measures of effect for surface soil are those associated with direct contact and those associated with dietary exposures. These are listed below, in order of preference.

For direct contact exposures the initial preferred effects data are the lowest of Level II Screening Level Values for Plants, Invertebrates, Birds, and Mammals (ODEQ 2001), followed in refinement steps by the Level II Screening Level Values for Plants and Invertebrates (ODEQ 2001).

For dietary exposure (food web modeling), the preferred effects data are the toxicity Reference Values for Individuals and Populations (ODEQ 2007).

Measures of effect for sediment were made for exposure categories of direct contact and dietary exposures. Preferred sources of effects data are presented below for each of these categories.

For direct contact exposures the preferred initial effects data are the lowest of Level II Sediment Freshwater, Marine, and Bioaccumulation Screening Level Values (ODEQ 2001). Use of these values is based on the assumption that both marine and freshwater condition can be observed within the study area. At the refinement step, the preferred effects data for evaluating direct contact exposures include the Level II Freshwater Screening Level Values for Sediment (ODEQ 2001). Use of these values at the refinement step is based on the assumption that at most times the onsite conditions are most similar to freshwater environments.

For dietary exposure (food web modeling), the preferred effects data are the Toxicity Reference Values for Individuals and Populations (ODEQ 2007).

Measures of effect for surface water are limited to exposures based on direct contact and ingestion. The preferred effects data for these exposures are the Level II Surface Water Screening Level Values for Aquatic Life (ODEQ 2001).

Measures of effect for biological tissues are, for this assessment, based on chemical concentrations in whole body fish and soft tissue clam. The preferred source of effects values for biological tissues are the Freshwater Critical Tissue Concentrations (CTLs) for fish, shellfish, and other aquatic organisms (ODEQ 2007). The CTLs are used based on the assumption that these values are most appropriate for assessing risks to fish and clams based on tissue residues. An independent evaluation of risks to salmonid fish is performed using tissue residue effect thresholds derived by Meador (2000). Risks to consumers of fish and clams are best evaluated using food web modeling that incorporates site-specific fish and clam data.

7.2.3.3 Measures of Characteristics

Some of the characteristics of a DU may affect potential exposure for ecological receptors. For example, DUs covered with asphalt provide little suitable habitat for ecological receptors and exposure is unlikely. It is expected that ecological receptors will be most attracted to locations where cover and foraging opportunities are greatest. Some receptors tolerant of disturbed conditions will use or occur in the Fire Training Area, but the surface material to which receptors may be exposed is primarily dredged sediments that have been placed on land. Based on DU-specific characteristics and the expected behavior of potential ecological receptors, the four aquatic DUs and the AST Fuel Storage Area have the greatest potential to serve as exposure areas for ecological receptors. The three offshore sediment sampling locations linked to small onshore terrestrial DUs (FTA, RFP 3, UST Site No. 1) provide suitable habitat for sediment-associated receptors, but these three areas are assessed

only on a local scale for the specific purpose of evaluating CPEC migration to aquatic environments.

7.2.3.4 Analysis Plan Summary

The following is a summary of the specific analyses performed in this Level III report.

The Level III evaluation completed a derivation of risk estimates (expressed as hazard quotients or HQs) for CPECs identified in the Level I/II assessments as those requiring further investigation. These HQs are based on the arithmetic mean EPCs in surface water, sediment, surface soil, and biota compared to (1) the same screening levels used in the Level I/II analyses and, where EPCs are found to be elevated, (2) refined screening levels (including CTLs for biota), where applicable and as described previously. These refined HQs based on arithmetic mean chemical concentrations provide a more realistic estimation of risks based on direct contact/ingestion exposures (abiotic media) and on chemical residue levels in biota (fish and clams) compared to the initial estimates used in the Level I/II process, which were based on maximum detected concentrations.

The Level III assessment completed a comparison of the analytical results of fish and clam tissue data from the Aquatic - Reference Area and the Aquatic - Finger Piers DU to available "literature" values from three existing studies from the Lower Columbia River area. The comparisons use the mean values from chemical data sets available in the existing studies. The comparison is an additional line of evidence to support the selection and use of the Tongue Point reference station data in the RI/RA reports.

Where data allow, aquatic food web modeling was performed to evaluate risks for selected avian and mammalian receptors that may be exposed to the most highly bioaccumulative chemicals detected in abiotic media and biota. The most highly bioaccumulative chemicals detected at the Study Area were DDE, DDD, and DDT (evaluated as total DDT), total heptachlor, dioxins/furans, cadmium, and mercury. The decision to perform aquatic food web modeling is based first on comparisons of chemical concentrations in sediments from reference and onsite DUs. Food web modeling is considered warranted where onsite concentrations in sediments exceed those from reference area sediments. Second, the decision considers data availability. For example, quantitative comparisons of risks estimated for onsite upper trophic level receptors to reference area receptors from dietary exposures to dioxins/furans using food web modeling are not possible because dioxins and furans were not detected in fish from the Near Landfill DU nor were they detected in clams from the Reference DU.

Risks associated with food web exposure for piscivorous/carnivorous avian and mammalian receptors are based on diets linked to ingestion of aquatic invertebrates (represented by clams) and smaller forage fish (represented by whole body sculpin). Site-specific clam and fish tissue data from the Reference Area and Aquatic DUs form the basis of these analyses, and therefore these data are critical for modeling. Where sufficient input data allow, dose-based or dietary TRVs for individual and population

level effects, as presented by ODEQ (2007), are compared to estimated average daily doses for modeled receptors to derive dose-based HQs. Aquatic (sediment-associated) food web modeling is performed for total DDT and mercury because sufficient data are available for these CPECs for the Aquatic DUs and Reference Area.

Terrestrial food web modeling is performed to evaluate risks for omnivorous and vermivorous avian and mammalian receptors with small foraging ranges that may be exposed to lead (the only CPEC identified) in soils at the AST Fuel Storage Area DU, via consumption of terrestrial plants and earthworms. Soil data for the AST DU form the basis of these analyses, supplemented by literature-based, soil-to-plant and soil-to-worm bioaccumulation factors (BAFs) for lead. Dose-based or dietary TRVs for individual and population level effects (ODEQ 2007) are compared to estimated daily doses for modeled receptors to derive dose-based HQs.

ODEQ BSAFs are used to model the existing concentrations of dioxin/furans and DDT in sediments to clam tissue (i.e., sediment-to-clam transfer). The comparisons of modeled tissue concentrations to the measured tissue concentrations are discussed in **Section 7.5.2**.

7.3 Exposure Analysis

Exposure analysis evaluates and summarizes available exposure data, including CPEC concentrations in abiotic and biological media as well as exposure-related information for ecological receptors. Exposure data serve as input into the final stage of risk assessment, risk characterization.

7.3.1 Habitats and Receptors Considered

This section summarizes the aquatic and terrestrial ecological resources applicable to the Study Area.

7.3.1.1 Aquatic Resources

The Study Area is located in the lower portion of the tidal-fluvial zone (Simenstad et al. 1990) of the Columbia River estuary, adjacent to the Lewis and Clark National Wildlife Refuge. This zone is characterized by the dominance of freshwater inputs from the Columbia River. Salinities near the Study Area vary widely both seasonally and over individual tidal cycles. In shallow subtidal areas, such as those adjacent to the Study Area, bottom salinities range from about 0.0 ppt at low tide (Emmett et al. 1984) to as high as 15 ppt during high tide and low river flow condition (Ingles 1989). Salinity in the navigation channel off Tongue Point and North Channel is considerably higher, because of the intrusion of the salt wedge up the channel, and ranges from 20 to 25 ppt during low Columbia River flow conditions (Fox et al. 1984).

Aquatic habitat near the Study Area (i.e., a radius of approximately 0.5 miles) is predominantly shallow subtidal habitat dominated by fine sediments. Benthic invertebrate sampling was conducted at approximate 2-week intervals between April 18 and September 14, 1984, in the Maritime Administration (MARAD) basin less than

1 mile east-southeast of the Study Area (Emmett et al. 1986). This basin is located in Cathlamet Bay south-southeast of Mott Island and south of Lois Island. A total of 26 taxa were collected during the sampling interval. Total numbers of organisms averaged from 64,696 per square meter during June and July to 231,392 per square meter during August and September. These numbers were relatively high compared with other shallow subtidal areas sampled in the tidal-fluvial zone during the same interval. The harpacticoid copepod (*Collana canadensis*), the ostracod (*Limnocythera* sp.), oligochaetes, and nematodes were the numerically dominant components of the benthic samples. *Collana canadensis* is a prime food source for the mysid shrimp (*Neomysis mercedes*), which is heavily used by higher-order predators. The amphipod (*Corophium salmonis*), which has been shown to be a major component of the diet of fishes within the tidal-fluvial zone, was moderately abundant in the 1984 samples. Other moderately abundant taxa included the Asian clam (*Corbicula fluminea*), the polychaete (*Neanthes limnicola*), and other ostracods. The sand shrimp (*Crangon franscisorum*), a relatively large and mobile macro invertebrate, is present near the Study Area.

Because of the relatively high densities of benthic invertebrates, the area around Tongue Point is considered an important feeding area for fish and other higher-order predators (Ingles 1989). Fish sampling in the Tongue Point area has been conducted using bottom trawls (Emmett et al. 1984; McCabe 1987), beach seines (Olhausen 1980; Cates 1983), and gill nets (Ingles 1989). Trawling was conducted monthly at North Tongue Point for 24 months and monthly off the mouth of the John Day River from March through September. Seining was conducted over a 2-year period at sites around the MARAD basin. Gill nets were set at the end of and along the south side of Pier 1 and in the MARAD basin.

Sturgeon larvae and fry do not tolerate salinities greater than 11 ppt and, therefore, they probably use the area near the Study Area only periodically. Shad densities appear to be highest in the winter, but 1- and 2-year-old shad are present in the estuary year-round. Although the area is essentially fresh, marine fish such as Pacific tomcod, Northern anchovy, Pacific herring, and shiner perch are present during low flow periods. Adult herring can be highly abundant at the entrance to Tongue Point. Other species present year-round include longfin smelt, peamouth, large-scale sucker, and starry flounder.

Juvenile salmonids are present throughout the year, with highest densities in the spring. Juvenile fall Chinook numbers peak in late summer, and are primarily found closer to the main channel. Although they are present in the MARAD basin, their numbers do not approach those found near the main channel (McCabe 1987; Smith 1981). Fall Chinook born the same year were by far the most abundant. This is to be expected, as they frequent shallow water.

Fish collected from the Tongue Point area (Ingles 1989) contained concentrations of PCBs and the pesticide DDE that were above the EPA guidelines set for protection of aquatic resources [the data are cited as unpublished in the (Ingles 1989) report]. In

particular, PCB residues were similar to dietary concentrations shown to cause reproductive problems in mink (Ingles 1989).

In September and October 2008, fish and clam samples were collected from multiple aquatic DUs within the Study Area, including the reference location upstream of the landfill. The fish were collected with hook and line and Gee-type minnow traps. The two species of fish collected were prickly sculpin (*Cottus asper*) and three-spined stickleback (*Gasterosteus aculeatus*). Clams [Asiatic (*Corbicula* sp.)] were collected concurrently with surface sediment using a Van Veen sampler. Chemical data for tissues of these collected aquatic organisms serve as key inputs into the risk estimations for this Level III evaluation, and **Table 3-21** of **Appendix M2** presents the results of the fish and clam tissue analyses. PCBs were not detected above laboratory sample quantitation limits for fish or clam tissues from any aquatic DU location. Therefore, PCBs are not retained as CPECs for fish and clam tissue in the Level III assessment. The range of sample quantitation limits for PCBs in fish and clam tissues was 10 ug/kg to 40 ug/kg. These limits are less than tissue-based thresholds as discussed in **Section 7.4.1.5** and **Section 7.7.3** and allow confidence in use of the PCB data. Additionally, fish and clams collected in October 2008 are intended to serve as surrogates for other exposed fish and aquatic invertebrate receptors for the Level III assessment.

7.3.1.2 Terrestrial Habitat and Wildlife Resources

The following information is based on a limited literature search and field observations made in May of 2008. **Figure 2-1** in **Appendix M1** is a general habitat map of the area.

Habitats within 2 miles of the Study Area include the open water habitat of Cathlamet Bay, upland conifer forest at the tip of Tongue Point, upland/riparian forest on Mott and Lois Islands within the Lewis and Clark National Wildlife Refuge and on the Tongue Point peninsula, emergent wetlands, flats and subtidal areas, Mill Creek, and the John Day River.

The upland/riparian forests, including the area adjacent to the AST 4 DU, are characterized by red alder in the more recently cleared areas and black cottonwood trees in the upland/wetland mixed habitats. Other overstory trees include bigleaf maple, Douglas fir, Sitka spruce, and western hemlock. Several black cottonwood trees and conifers are large enough to provide perching sites for raptors such as bald eagles and ospreys. Understory vegetation includes many native species, such as red elderberry, salmonberry, and thimbleberry, with the herbaceous species including sword fern, as well as lady fern and horsetail in the wetter areas. Himalayan blackberry, an invasive non-native plant, occurs in dense stands where the ground has been disturbed. Wetland areas may be dominated by reed canary grass. Mill Creek drains generally to the northeast, emptying into an emergent tidal marsh/mudflat wetland located on the southeastern portion of the Study Area, near the landfill (see **Figure 2-2** in **Appendix M1**).

A visit to the Study Area was completed on May 6 and 7, 2008. The ecological checklist documenting that visit is provided in **Appendix M1** as **Attachment 1**, with an associated photo log as **Attachment 2**. Wildlife species observed are listed in **Appendix M1** as **Table 2-1**. In May 2008, a bald eagle was observed perched in evergreen trees just above where Mill Creek empties, east of the landfill. A number of puddle ducks (i.e., mallard, widgeon, gadwall, shoveler, and teal), bay ducks (i.e., greater scaup, lesser scaup, and bufflehead), and geese (i.e., Canada geese) were observed in the mudflat area and in and around the piers. Many birds that consume fish, at least part of the time, were identified, including osprey, eagle, kingfisher, great-blue heron, gulls (i.e., California, ring-billed, and Western), Caspian tern, common loon, and double-crested cormorant. Flocks of red-winged blackbirds and dunlins were observed near the wetland and mudflat areas. Other common species, including hawks, robins, swallows, sparrows, finches, wrens, crows, pigeons, killdeer, starlings, buntings, scrub-jays, and warblers, were seen.

Mammals observed within the vicinity of the Study Area include black-tailed deer, rabbit, feral cats, mice, raccoon, and opossum. Other mammals reported to be in the area include nutria, river otter, harbor seal, and mountain lion (USFWS, personal communication 2009).

Spring, summer, and fall stocks of Snake River Chinook salmon (*Oncorhynchus tshawytscha*) are listed as threatened, and Snake River stocks of sockeye salmon (*O. nerka*) are listed as endangered under the federal Endangered Species Act of 1973. Both juveniles and adults of Snake River Chinook and sockeye pass through the Columbia River estuary. Shallow subtidal habitat near the Study Area is rich in food organisms eaten by juvenile salmonids. Juvenile Chinook salmon (origin unknown) have been shown to occur near the Study Area in relatively large numbers. Sockeye salmon were not found in any of the fish samples collected by the National Marine Fisheries Service in the mid-1980s. However, it is possible that Snake River sockeye salmon could occur near the Study Area. See **Appendix M1, Attachment 3** for the letter from the U.S. Fish and Wildlife Service (USFWS) responding to queries about threatened and endangered species.

Peregrine falcons (*Falco peregrinus*), formerly listed as federally endangered, are known to use the Study Area and general vicinity during migration and as winter residents within the Columbia River estuary. In the past, individual peregrine falcons have been observed foraging and perching within the Study Area vicinity. Peregrines feed on waterfowl, which are abundant within the estuary, concentrating in large numbers within the intertidal flats and marsh habitats.

Of the species observed at the Study Area (**Appendix M1** Table 2-1), only three were listed species. These were bald eagle (state threatened) and bufflehead (state sensitive species). Crayfish of unidentified species were observed; and although some species in the region are species of concern, populations of most are considered currently stable. Individual eagles were observed near the outlet of Mill Creek and flying over the Tongue Point area. Bufflehead were seen in the mudflat area, in the open water

north of the pier area, and in and around the piers. Crayfish were seen at the edges of the water as well as at the base of some of the piers.

The physical conditions of most of the DUs are either disturbed or covered by pavement; therefore, federal- or state-listed threatened or endangered plant species are not expected to be present.

7.3.2 Exposure Point Concentrations

EPCs are chemical concentrations representing those to which receptors may be exposed. EPCs serve as input into risk calculations, and are derived for all media-specific CPECs identified at the Level I/II stage of the ERA process. These include EPCs for both abiotic media (e.g., surface water, sediment, soil) and biotic media (e.g., fish tissue).

EPCs selected for use in the Level III assessment include the arithmetic mean (average) of measured concentrations of chemicals in surface water, sediment, surface soil, whole body forage fish (primarily sculpin), and soft tissue clams. These EPCs are presented on **Table 7-2** (surface soil), **Table 7-3** (surface water), **Table 7-4** (sediment), and **Table 7-5** (fish and clam). EPCs for some biological tissues are estimated using literature-based bioaccumulation factors (BAFs). This approach is used for terrestrial plants and soil-associated invertebrates based on lead concentrations measured in surface soils at AST Fuel Storage Area. In other cases (e.g., total DDT evaluations), site-specific values and literature-based values from other nearby areas are compared.

7.3.2.1 EPCs for Abiotic Media

EPCs for abiotic media form the basis for risk estimation based on direct contact exposures; the EPCs for biological media (i.e., fish and clams) are used to confirm exposure, to evaluate risks directly to those biota, and in some cases to serve as inputs into food web modeling. EPCs can reflect various levels of exposure, such as the average, reasonable upper range, or maximum exposure. Most often, and where data quantity allow, the single EPC most often used to represent central tendency exposures is the 95% upper confidence limit (UCL) of the arithmetic mean concentration. However, for this Level III report, several combinations of DU, media type, and CPEC data do not provide a sufficient number of samples to calculate a valid and confident 95%UCL. A component of the Level II screening included calculation of the 90%UCL where data allowed such calculations. Arithmetic mean concentrations of selected sediment CPECs from three aquatic DUs were compared to 90%UCLs to determine the relative difference in these two statistics. A summary of these results is provided in **Table 7-6**.

As can be seen on **Table 7-6**, the arithmetic mean concentrations of these selected sediment CPECs closely approximates the 90%UCL concentrations in most cases. Comparison of risk estimates across all locations is most informative if the EPC is the same for all locations and CPECs. Therefore, based on data availability, the arithmetic mean concentration is selected as the Level III EPC for CPECs in surface water, sediment, surface soil, and biota.

In a few cases where a particular chemical was not detected in a specific medium type or location, half the maximum reporting limit is used as a surrogate EPC. This situation is for the most part limited to surface water concentrations for CPECs, especially those subject to food web modeling. In these cases, the soil or sediment CPEC evaluated in the food web model is not a surface water CPEC, but surface water concentrations are needed to address the drinking water portion of the model, which is a minor contribution to total dose. Finally, the detection frequency of dioxins and furans in surface water was too low to allow use of the Kaplan-Meier method for deriving average dioxin and furan concentrations in surface water. In this case, half the reporting limit was used in the calculation of the average concentration to represent those constituents reported as non detects.

7.3.2.2 EPCs for Food Web Modeling

With few exceptions, EPCs for abiotic data (surface water, sediment, and surface soil) used in food web models are arithmetic mean values. The few exceptions include some locations where individual surface water CPECs were not detected. In these cases, half the maximum reporting limit is used to represent the surface water concentration for input into the food web models.

Biological data used in the food web models include both measured and estimated values. Measured values are used where such data exist for the exposure area and CPECs. In cases where location-specific data are lacking, estimated values are used. Estimated values are based on site-specific or literature-based BAFs or BSAFs. These BAFs are based on paired abiotic and biological samples, such as sediment and fish or terrestrial plants and soil, where:

BAF = CPEC concentration in biological sample / CPEC concentration in abiotic medium

In some cases, the resulting BAFs are applied to locations where specific biological data are lacking. For example, the literature-based soil-to-terrestrial plant BAF is applied to relevant surface-soil CPEC concentrations to estimate plant CPEC concentrations:

Estimated plant CPEC concentration = Soil-to-Plant BAF × Measured Soil CPEC Concentration

EPCs for biological samples (terrestrial plants, soil-associated invertebrates, clams, and fish) are based on the following, which serve as input into food web modeling:

- Terrestrial plants – Average CPEC concentration in surface soil multiplied by the literature-based (U.S. EPA 1999) soil-to-plant BAF.
- Terrestrial invertebrates – Average CPEC concentration in surface soil multiplied by the literature-based (U.S. EPA 1999) soil-to-invertebrate BAF.
- Aquatic invertebrates – Average CPEC concentration measured in soft body clam tissue.

- Fish – Average whole-body sculpin CPEC concentration.

7.3.2.3 Exposure Data for Food Web Modeling

Food web modeling is a process that estimates the daily contaminant dose (in mg contaminant per kg body weight per day [mg/kg-d]) for the receptor of concern via consumption of food, water, and incidental ingestion of contaminated sediment or soil. Food web modeling is applicable only to contaminants that significantly bioaccumulate. The Level I/II screening and subsequent ODEQ comments on the associated TM identified the following chemicals as bioaccumulative and of concern for this Level III report: lead in surface soil at AST Fuel Storage Area; and dioxins/furans, total DDT, mercury, and cadmium in aquatic sediments, fish, and clams. These species are considered candidates for food web modeling, and data availability is the primary criterion for deciding if food web modeling can be reliably performed for a specific combination of DU, media type, and CPEC.

Food web modeling requires that the relationships between source media (e.g., surface soil) and prey be known or estimated, and model input data (discussed below) therefore include contaminant concentrations in abiotic media and food items as well as transfer factors (or BAFs) that relate concentrations in one compartment (e.g., soil) to another (e.g., worms). The initial output of food web modeling is the daily dose that is compared to one or more dose-based thresholds for adverse effects.

Food web modeling can be used to calculate media-specific PRGs, based in part on back calculations incorporating the BAFs. These values are calculated and tabulated for general comparative purposes and are not intended for use as remedial goals. For this Level III report, contaminant-specific PRGs are calculated using food web modeling for each selected receptor, and provided in the last table within **Appendices M3** (aquatic) and **M4** (terrestrial).

7.3.2.4 Food Web Model Equations

As mentioned previously, the primary output of the food web model is an estimation of average daily dose from ingestion of CPEC-contaminated food items. This estimation is based on the following formula from EPA (1993):

$$ADD_{pot} = \sum_{K=1}^{n} (C_k * FR_k * NIR_k)$$

Where:

ADD_{pot}	=	average daily dose (mg CPEC/kg BW-day)
C_k	=	average CPEC concentration in the kth food type (mg/kg)
FR_k	=	dietary fraction of intake of the kth food type (range 0 to 1.0)
NIR_k	=	normalized ingestion rate of the kth food type (wet weight of prey ingested per day, kg/d) by the predator
n	=	number of contaminated food types

Normalized ingestion is the ingestion rate normalized for body weight:

$$NIR = IR / BW$$

Where:

NIR	=	normalized ingestion rate (kg food/kg BW-d) of the predator
IR	=	ingestion rate (kg/d) of the predator
BW	=	body weight (kg) of the predator

This term is expressed as wet weight, or NIRww.

For species for which incidental soil or sediment ingestion is significant, an additional term is added to the equation just presented:

$$ADD_{pot} = \sum_{K=1}^{n} (C_k * FR_k * NIR_k) + (NIR_{dw} * C_{Soil} * FR_{Soil})$$

The use of both NIRww and NIRdw is required because CPEC concentrations in biota serving as prey are expressed as wet weight and soil (or sediment) CPEC concentrations are expressed as dry weight. The term C_{Soil} represents the mean contaminant concentration in soil or sediment, and FR_{Soil} represents the fraction of soil or sediment incidentally ingested.

The use of both NIRww and NIRdw is required because CPEC concentrations in biota serving as prey are expressed as wet weight and soil (or sediment) CPEC concentrations are expressed as dry weight. The term C_{Soil} represents the mean contaminant concentration in soil or sediment, and FR_{Soil} represents the fraction of soil or sediment incidentally ingested.

The concentration of CPECs in food items can be based on directly measured values or on values estimated using BAFs. BAFs as they relate to food web modeling have been introduced and are discussed in detail in subsequent sections of this report.

The site foraging factor (SFF) is commonly added to the last equation (multiplied in the numerator) to account for the fact that some animals forage over a wide range. Ingestion of contaminated prey may therefore be adjusted by the portion of time foraging takes place in contaminated areas. This adjustment is most appropriate where predators with large foraging ranges are evaluated at small sites. SFF values can be calculated for a DU or a subarea.

7.3.2.5 Food Web Model Input Parameters

Each of the input parameters introduced, in addition to other parameters used to support the food web model with assumptions made for each, are discussed in the paragraphs below.

Exposure Media

Exposure media represent the primary media to which specific receptors or categories of receptors may be exposed. The primary exposure medium for terrestrial receptors is surface soil, and sediment serves as the primary exposure medium for aquatic and water-dependent receptors. Receptors for food web modeling are selected so that a single solid medium (e.g., surface soil) is the primary exposure medium. Food web modeling will result in an infinite number of estimated doses if various combinations of exposure to more than one solid medium are allowed. Selection of appropriate receptors linked to a single solid medium reduces the uncertainties associated with model output and limits the number of possible results. This approach is valid if the combination of receptor and media is reasonable based on life history (e.g., deer mice are more appropriately linked to surface soils than to river sediments). This approach also allows for the calculation of media-specific contaminant concentration that can serve as preliminary remediation goals. One example of a preliminary remedial goal for an ecological receptor is the milligrams of lead per kilogram of surface soil that is protective of shrews.

Bioaccumulation Factor

Bioaccumulation factors express the relationship of chemical concentrations in abiotic media and biota. BSAFs are based on the ratio of contaminant concentrations in biological samples, usually whole body (mg/kg ww or dw), to contaminant concentrations in surface soil or sediment (mg/kg dw). BAFs and BSAFs consider uptake from all sources, including ingestion of food items, soil or sediment, and water (via drinking). As discussed previously, site-specific BAFs are available for some CPECs, locations, and medium types, but not for all.

Home / Foraging Range / Site Foraging Factor

An animal's home or foraging range can greatly affect its exposure to environmental contaminants. For example, animals with home ranges entirely within a contaminated study area will have greater exposure potential than animals with home ranges that substantially exceed the contaminated area (assuming locations outside the study area are less contaminated). This assumption may not always hold true, however, because home range values are often only estimates of the average area used by a particular species. It is not unreasonable to assume that an individual animal with a large home range will, at times, remain within a smaller area if that area provides adequate food and cover. This is especially true for animals that are nesting or have young. In addition, models that estimate dietary exposures, including those used in this BERA, are very sensitive to variability in home range estimates. Average home ranges for adult animals are presented in the models.

Standard practice in assessing dietary exposures for wildlife includes the derivation of an SFF. This term most often describes the ratio of the site area to the average home or foraging range for the species of concern. SFF values range from 0 to 1.0. It is apparent that animals with large home ranges are less likely to be significantly exposed to site-related contamination than animals that live entirely within site boundaries. However, as stated previously, the use of home ranges for estimating exposure likelihood has certain critical limitations. First, home range estimates are based on overall use, yet certain individuals or populations may use smaller areas for foraging and cover if conditions are suitable. In addition, dietary exposure models are extremely sensitive to variability in the input parameter identified here as SFF. It is not uncommon for dietary exposure models to predict zero or nearly no risk for species associated with highly contaminated sites solely because their average home range is very large. Where reasonable potential exists to suspect that a particular receptor species may in fact forage completely within the site boundaries, the SFF is set to 1.0. Because the areas of concern to this report are surrounded by what appears to be higher quality habitats, SFFs are not assumed to equal 1.0 in all cases and instead are calculated by the equation:

$$SFF = \text{Exposure Area (hectares)} / \text{Average Foraging Area (hectares)}$$

Values greater than 1.0 (exposure area > foraging area) are set to 1.0, indicating that foraging is assumed to occur 100% of the time within the exposure area. Foraging areas were obtained directly or calculated from studies referenced in *EPA Exposure Factors Handbook, Volume I* (EPA 1993a).

Dietary Fraction

Dietary fraction is an estimate of the fraction of total diet contributed by each prey type. For this assessment, estimates of dietary fraction are based on values reported in the literature (primarily EPA 1993a). Where more than one literature source of dietary information is available, estimates are based on the average of all relevant literature sources or the values most relevant to coastal Pacific environments. In some cases, these values are adjusted for the availability of site data for major prey items. That is, where reasonable, diets are adjusted to be 100% fish or 100% aquatic invertebrates, or the total diet comprises various fractions of these prey items for which site-specific data are available. The fraction of soil and sediment incidentally ingested is included if such ingestion is deemed significant for the receptor in question. EPA (1993a) provides estimates of soil and sediment incidentally ingested for several receptor species of concern for this report. Where such values are not provided, they are estimated using receptor life history information and best professional judgment.

Average Ingestion Rate

Average ingestion rates (kg/d) are determined for species of concern from values in the literature. Most data are taken from EPA's *Wildlife Exposure Factor Handbook, Volume I* (1993a). Ingestion rates are presented as both wet weight and dry weight—the latter is used for ingestion of soil or sediment. This is because soil and sediment

CPEC concentrations are expressed as milligrams per kilogram dry weight, while plant and animal dietary items are expressed as milligrams per kilogram wet weight. Wet weight and dry weight food ingestion rates are derived using different methods, so they are not directly comparable (i.e., they do not differ solely based on the percent moisture in food items). The former are mostly reported directly from experimental studies, and the latter are based primarily on equations presented in the EPA *Exposure Factors Handbook* (EPA 1993a).

Average Body Weight

Average body weights (kilograms) for representative adult organisms are based on values presented in literature sources. Where more than one source was consulted, the value used is based on the average of all species-specific adult body weights presented. In some cases, average body weights can be substantially different for males and females of the same species. Where this is the case, values used are based on the average of values reported for adult males and females.

Model Output

The primary model output is an estimate of the average daily dose (APDD, mg CPEC/kg BW-d) for upper trophic level organisms from ingestion of contaminated prey and abiotic media. APDD values may over- or underestimate actual doses because of site-specific diet or foraging habits. In addition, actual doses probably vary seasonally and spatially. Because much of the input data are averaged from multiple studies and seasons, estimated doses resulting from the food web models are assumed to adequately represent the annual average daily dose. These estimated doses are compared to dose-based individual TRVs and population TRVs to derive HQs (ODEQ 2007).

7.4 Ecological Response Analysis

The following discussion is an overview of ecotoxicity for the most hazardous chemicals detected in site abiotic media and biological tissues. These include lead in soils and mercury, DDT, and dioxins and furans in sediments, surface water, and biota. Two additional toxic and bioaccumulative chemicals were detected in some sediments at low levels, heptachlor, and cadmium. The evaluation of risks from these two chemicals is limited to comparison to reference locations because data are insufficient for food web modeling.

7.4.1 Toxicity Profiles

Summaries of toxicity data and general fate and transport information are provided here for the major CPECs identified in the Level III assessment. These CPECs are considered the most important based on detected concentrations, ecotoxicity, environmental persistence, and, in some cases, bioaccumulation/biomagnification potential.

7.4.1.1 Lead

Lead is a common toxic metal and is detectable in all phases of the environment and biological systems. Lead has been shown to be minimally soluble but toxic to birds, mammals, amphibians, and reptiles in terrestrial environments. Toxicity to mammals is known to include increased mortality, reproductive effects, reduced growth, alterations of blood chemistry, and behavioral changes. Lead affects the nervous system, blood system, gastrointestinal system, and reproductive system. It is known to be a powerful neurotoxin and acts by depressing neurotransmission through inhibition of cholinergic function, impairment of dopamine uptake, and the disruption of other neurotransmitters. Lead causes anemia by impairment of blood cell production and shortening of the lifespan of a blood cell (Goyer 1993). Lead is a confirmed animal carcinogen, causing tumors in multiple sites. Feeding studies using bank voles (*Clethrionomys glareolus*) caused mortality and impaired development in young voles when their mothers received lead-contaminated food (HSDB 2010). A sharp decrease in pregnancy was noted in rats receiving an oral dose of lead acetate of 390 mg/kg/day, with an identified LOAEL of 39 mg/kg/day (HSDB 2010). Northern leopard frogs (*Rana pipiens*) exposed to 25 ppm lead exhibited loss of erect posture, sloughing of skin, excretion of bile, and hypertrophy of the liver, spleen, and stomach. Mortality of the frogs increased when the dose exceeded 25 ppm (HSDB 2010). A chronic ingestion study using the American kestrel determined an oral dose of 3.85 mg/kg/day to be the NOAEL value and calculated a chronic LOAEL of 38.5 mg/kg/day (Sample et al. 1996). A study of the effects of lead on growth, survival, and tissue levels in the mouse resulted in a chronic LOAEL of 1.50 mg/kg/day and a chronic NOAEL of 0.15 mg/kg/day (SRC 1990).

7.4.1.2 Mercury

Mercury is a naturally occurring element in the environment that does not readily mobilize from sediment or soil. However, mercury is extremely toxic and has no biological function. Mercury will bioaccumulate and biomagnifies as it moves through food chains. Various studies have shown that mercury is a mutagen, teratogen, and carcinogen. The inorganic forms of mercury are not as toxic as the organic forms (Eisler 1987b). Mammalian species tend to absorb organic forms of mercury through the respiratory tract, gastrointestinal tract, and skin. The organic forms can cross placental barriers. Most inorganic mercury compounds have low solubility.

Once mercury compounds are released into moist soil environments, they may dissociate depending on their solubility. Upon dissolution, mercury will be associated with either its respective anion or humic matter. Studies indicate that mercury compounds, once deposited on soil, are absorbed to the soil and do not leach. However, mercury compounds can be methylated by microorganisms indigenous to soils and fresh water. This process is mediated by various microbial populations under both aerobic and anaerobic conditions. Chronic mercury poisoning in fish can cause emaciation from appetite loss, brain lesions, diminished response to light intensity, inability to capture food, and abnormal muscle

coordination (Eisler 1987b). In general, aquatic species accumulate mercury rapidly and excretion is slow.

In mammals, subchronic exposure to mercury can cause deleterious effects on reproduction, growth and development, behavior, blood and serum chemistry, histology, and metabolism. Methyl mercury irreversibly destroys neurons of the central nervous system. Symptoms of mercury exposure may not be evident for years after initial exposure (Eisler 1987b). Smaller mammals are more sensitive to mercury exposure. In addition, carnivorous mammals have been found to have greater concentrations of mercury in the liver and kidney than herbivorous species. A chronic study of methyl mercury exposure in mallards found that a dietary concentration of 0.5 mg/kg caused pronounced behavioral and reproductive abnormalities over three generations (Eisler 1987b). The female mallards laid a high percentage of eggs outside of the nesting boxes, laid few eggs, and produced fewer ducklings than the controls. A study of the effects of mercury on growth, survival, and issue levels in the mink *(Mustela vison*) resulted in a chronic LOAEL of 0.32 mg/kg/day and a chronic NOAEL of 3.85 mg/kg/day (Sample et al. 1996).

7.4.1.3 Dioxins and Furans

Dioxins and furans are found in all compartments of the ecosystem, including air, water, and soil. Some dioxin and furan congeners are highly toxic (e.g., TCDD), and most are resistant to microbial breakdown. These contaminants are highly persistent. They are transported by prevailing winds and are deposited in sediments and soils. Recent studies of aerial transport reveal that prevailing winds can play a significant role in environmental contamination. They accumulate in animals and have been found in most species of wildlife surveyed.

Dioxins and furans do not move readily through soils and sediments because they generally attach to the particles. Soils and sediments represent the most significant "sink" for dioxins and furans. Once dioxins, particularly 2,3,7,8-TCDD, which is the most studied and highly toxic of the dioxins and furans, enter the soil and sediments, they are very slow to degrade. Dioxins and furans accumulate in biological tissue, where they have long half-lives (Health Canada 2007). Specifically, dioxins and furans are generally concentrated in fatty tissues, but bioaccumulation is variable. TEFs often are used to estimate the toxicity of other compounds relative to TCDD. TCDD has been shown to be acutely toxic, carcinogenic, teratogenic, mutagenic, and associated with adverse reproductive, immunologic, and histopathologic effects. Acceptable levels of dioxins and furans in soil are generally considered to be at or near zero. Eisler (1986) recommends a conservative surface water limit of 0.01 part per trillion (0.00001 µg/L) 2,3,7,8-TCDD to protect aquatic life. For sediments, CCME (2002) suggests a screening value of 8.5×10^{-7} mg/kg TEQ. This equates to 0.00085 µg TEQ/kg.

7.4.1.4 DDT and Related Compounds

Chlorinated pesticides such DDT and related compounds (DDE and DDD) can have the potential to be transported by air regardless of the type of the release. Airborne

pesticides can move very long distances and can be carried in the wind during application, on small particulates such as soil or on larger objects that are caught up by wind, and can volatilize off any surface to which they are applied. Once a pesticide is released to soil, it will most likely follow one of three pathways: it will move through the soil with water, attach to soil particles, or be metabolized by organisms in the soil. For chlorinated pesticides, binding to soil particles, particularly organic matter is the most important pathway. Water transport of pesticides can occur through wet deposition, runoff from surfaces, infiltration of water through the ground, ditches, storm sewers, tile lines, drains, rivers, and open water currents. Pesticides in open water systems may float on the water, diffuse into the water, or deposit onto the sediments at the bottom of the water body. Pesticides that move from the ground surface through the soil may reach shallow ground water or deeper aquifers. However, chlorinated pesticides such as DDT are highly insoluble and have low potential for migration.

Pesticides that bioaccumulate in organisms, such as DDT, are often very persistent in the environment (UMN 2003). Total DDTs are highly toxic to a wide variety of ecological receptors and readily accumulate in biological tissues. Some are known to biomagnify, resulting in higher concentrations in higher trophic level biota. For this reason, even very low concentrations of these compounds in soil, water, or sediment can contribute to severe adverse effects at the top of food webs. The adverse effect of DDT and related compounds on bald eagles (primarily eggshell thinning) is a well-known example of biomagnification from water and sediment to fish to piscivorous birds.

DDT and related compounds are persistent in the environment, and degradation by biological and other means is minimal. These compounds are lipophilic, with a tendency to accumulate in the liver and other fatty tissues of biota. Levels of DDT assumed to be safe for exposed biota are often very low because of bioaccumulation-related risks. Safe levels of total DDT in soil generally are considered to be at or below about 1 mg/kg, depending on the receptor warranting protection. For sediments, consensus-based threshold levels for total DDT are about 5 µg/kg (MacDonald et al. 2000). This threshold was derived from multiple sources and best describes the average concentrations at which adverse effects may begin to be observed. For surface water exposures, total DDT concentrations of less than 1 µg/L can cause adverse effects in exposed aquatic biota.

7.4.1.5 Polychlorinated Biphenyls (PCBs)

PCBs, which have been detected in some nearshore discrete sediment samples (as Aroclor 1254), are a group of toxic and bioaccumulative compounds that can cause adverse effects in lower and especially in upper trophic level biota. PCBs include many individual congeners, some of which are highly toxic while others are less so. PCB concentrations can be reported as concentrations of individual congeners, as total PCBs, or as Aroclors. Aroclors such as 1242, 1248, 1254, and 1260 are industry-derived mixtures of various congeners. PCBs are readily accumulated in aquatic biota and, therefore, predators linked to aquatic environments such as mink, raccoons, and

piscivorous birds can be at significant risk. Some fish can accumulate high levels of PCBs without suffering observable effects while posing substantial risks to piscivorous wildlife.

PCBs are persistent in the environment and degradation by biological and other means is minimal. PCBs bind strongly to soil and sediments and may remain there for several years. PCBs partially evaporate from soil surfaces to air. In general, the breakdown of PCBs in the water and soil occurs over several years, or even decades. Sediments containing PCBs at the bottom of a large body of water such as a lake, river, or ocean generally act as a reservoir from which PCBs may be released in small amounts to the water. PCBs are likely tightly bound to soil particles and will not migrate significantly. Most of these compounds are lipophilic, with a tendency to accumulate in the liver and other fatty tissues of biota. Levels of PCBs assumed to be safe for exposed biota are often very low due to bioaccumulation-related risks. Safe levels of total PCBs in sediment are generally considered to be at or below about 1 part per million (mg/kg), depending on the receptor warranting protection. For example, total PCB concentrations in sediment above about 60 ug/kg dry weight (0.06 mg/kg) are considered to have potential to cause adverse effects in benthic invertebrates (MacDonald et al. 2000). Fish tissue residues above 2.4 ug PCBs/g lipid have been proposed as a residue effect threshold (RET) above which juvenile salmonid fish would be expected to exhibit adverse sub lethal effects (Meador 2000). Meador (2000) also proposed a sediment effects threshold (SET) of 225 ng/g dry weight, based on a sediment-to-fish bioaccumulation factor (BSAF) of 0.16 and a mean sediment total organic carbon content of 1.5 percent.

7.4.2 Ecological Benchmark Value Estimates

Ecological benchmark values (EBVs) for assessing direct contact exposures are identified in a step-wise manner. At the first step of the BERA, the EBVs for direct contact exposures are the screening values used in the Level I/II TM, and consist of the lowest of multiple screening levels where ODEQ provides more than one value. If the HQ exceeds 1.0 at this step, then more-specific EBVs are selected (where available) for risk estimation. For upper trophic level receptors for which food web modeling is performed, EBVs are the individual and population level dietary TRVs provided by ODEQ for assessing risks from bioaccumulative chemicals (2007).

7.5 Risk Characterization

Risk characterization integrates exposure information and effects or response information to provide quantitative and sometimes qualitative expressions of risk. Risk is defined here as the potential for adverse effects to occur, and such effects are based on survival, growth, and reproduction endpoints.

7.5.1 Risk Estimation Methods

Several estimation methods and lines of evidence are used to estimate adverse effects to ecological receptors. The list below summaries those used in the evaluation of

effects for the terrestrial and aquatic DUs. Each method and line of evidence identified below has specific evaluations summarized in **Section 7.5.2**.

Hazard Quotient Method for Direct Contact Exposures - This approach is applicable to all abiotic media, whole body fish tissue, and soft clam tissue.

HQ = mean detected concentration / screening level

The HQ for a specific DU is compared to Reference Area HQ where data allow. HQs equal to or greater than 1.0 are considered unacceptable. HQs less than 1.0 are associated with acceptable risk levels. Higher HQs are not necessarily associated with more severe effects, primarily because effects levels are not equal in their ability to serve as effects thresholds or specific effects levels. Instead, higher HQs suggest a greater potential for adverse effects to occur in exposed receptors.

Comparison of Site Specific BSAF/BAFs Compared to Literature Values - This approach is applicable to total DDT. The comparison for dioxins/furans could not be performed because dioxins and furans were not consistently detected in tissue samples.

Evaluation of Near Shore Sediment Samples Relative to Suspected Source Areas - This approach is applicable to discrete sediment samples collected immediately offshore from suspected source areas (RFP 3, UST Site No. 1, and FTA nearshore discrete sediment sampling locations).

Food Web Modeling for Piscivorous Receptors - This is applicable for mink, bald eagle, great blue heron, and belted kingfisher exposed to total DDT and mercury via consumption of aquatic prey.

Food Web Modeling for Omnivorous Terrestrial Receptors - This is applicable for American robin, short-tailed shrew, and deer mouse exposed to lead in surface soils via diet at the AST DU.

Comparison of Sediment, Fish, and Clam Data Onsite to Reference Area Data - This is applicable to total DDT, dioxins/furans, and mercury.

Comparison of Tongue Point Data to Lower Columbia River Data - This approach is applicable to selected bioaccumulative CPECs, whole body fish, and soft clam tissue.

7.5.2 Risk Description

The subsections below provide estimates of effects based on the risk estimation methods and lines of evidence identified in **Section 7.5.1**.

7.5.2.1 Hazard Quotient Method for Direct Contact Exposures

The HQs resulting from replacing the maximum detected concentrations used in the Level I/II Technical Memorandum with the mean concentrations are presented in **Tables 7-2** through **7-5**. HQs that exceed the 1.0 threshold, based on the final EBVs

and mean detected concentrations, are summarized here, by DU and by medium type.

AST Fuel Storage Area

The initial HQ for lead in surface soil at the AST Fuel Storage Area is 4.2, while that of the background (based on ODEQ background value for lead in soils) is 1.1. Replacing the initial screening levels with the plant- and invertebrate-specific screening levels result in the AST Fuel Storage Area HQ of 1.4 for terrestrial plants and less than 1 for invertebrates (**Table 7-2**).

Fire Training Area

The HQ for chromium in surface soil at the Fire Training Area is 30, and this HQ is based on the soil invertebrate screening level (**Table 7-2**). For terrestrial plants, the HQ for chromium is 12. ODEQ does not provide a background value for chromium in soil, but the SLV for chromium is an often-used conservative value that generally results in elevated HQs in nearly all cases. It is likely that ambient background or reference area soils would show elevated HQs based on chromium in soil. EPA, in support of developing soil screening levels for ecological receptors (Eco-SSLs, EPA 2005), compiled extensive soil data across the nation, and derived mean metals concentrations in background soils by state. The statewide mean concentration of chromium in surface soil for Oregon is 121.6 mg/kg dry weight. This statewide background concentration equates to HQs of approximately 122 and 304 for terrestrial plants and soil invertebrates, respectively. The mean chromium concentration in FTA soils is 11.9 mg/kg dry weight, substantially below the mean soil background chromium concentration determined for Oregon by EPA.

HQs exceeding 1.0 for CPECs in surface water at the Fire Training Area include only barium, with an HQ of 6.8 (**Table 7-3**).

HQs equaling or exceeding 1.0 for CPECs in sediments at the Fire Training Area are indeno(1,2,3-cd)pyrene (1.3), Aroclor 1254 (1.9), arsenic (1.0), barium (2.0), cadmium (1.1), copper (1.5), and nickel (1.1) (**Table 7-4**). These HQs are based on the freshwater sediment SLVs provided by ODEQ (2001).

UST Site No. 1

The only HQ exceeding 1.0 for CPECs in surface water at UST Site No. 1 is for barium, with an HQ of 6.7 (**Table 7-3**).

HQs equaling or exceeding 1.0 for CPECs in sediments at UST Site No. 1 are indeno(1,2,3-cd)pyrene (1.0), DDE (2.3), and barium (1.3) (**Table 7-4**). These HQs are based on the freshwater sediment SLVs provided by ODEQ (2001).

Refueling Pit 3

The only HQ exceeding 1.0 for CPECs in surface water at Refueling Pit 3 is for barium, with an HQ of 6.9 (**Table 7-3**).

HQs equaling or exceeding 1.0 for CPECs in sediments at the Refueling Pit 3 are benzo(a)anthracene (2.3), benzo(a)pyrene (2.9),benzo(k)fluoranthene (2.0), chrysene (2.9), fluoranthene (1.9), indeno(1,2,3-cd)pyrene (4.4), phenanthrene (1.6), pyrene (3.7), DDE (1.4), DDT (1.3), heptachlor epoxide (1.2), Aroclor 1254 (7.7), barium (1.8), cadmium (1.1), and copper (1.0) (**Table 7-4**). These HQs are based on the freshwater sediment SLVs provided by ODEQ (2001).

Aquatic -North of Pier 8

The only HQ exceeding 1.0 for CPECs in surface water at the North of Pier 8 DU is for barium, with an HQ of 6.8 (**Table 7-3**).

HQs exceeding 1.0 for CPECs in sediments at the North of Pier 8 DU are arsenic (1.2), barium (1.6), and copper (1.1) (**Table 7-4**). These HQs are based on the freshwater sediment SLVs provided by ODEQ (2001).

HQs exceeding 1.0 for CPECs in fish tissue (whole body) at the North of Pier 8 DU are total DDT (2.0), lead (5.0), mercury (1.6), and selenium (79) (**Table 7-5**). These HQs are based on the CTLs provided by ODEQ (2007).

HQs exceeding 1.0 for CPECs in clam tissue (soft) at the North of Pier 8 DU are arsenic (1.7), lead (1.9), and selenium (113) (**Table 7-5**). These HQs are based on the CTLs provided by ODEQ (2007).

Aquatic - Finger Piers

The only HQ exceeding 1.0 for CPECs in surface water at the Finger Pier DU is for barium, with an HQ of 7.3 (**Table 7-3**).

The single HQ exceeding 1.0 for CPECs in sediments at the Finger Piers DU is for barium (1.6) (**Table 7-4**). This HQ is based on the freshwater SLV provided by ODEQ (2007).

HQs exceeding 1.0 for CPECs in fish tissue (whole body) at the Finger Piers DU are dioxins/furans (1.4, mammal), lead (2.7), mercury (2.7), and selenium (92) (**Table 7-5**). These HQs are based on the CTLs provided by ODEQ (2007).

HQs exceeding 1.0 for CPECs in clam tissue (soft) at the North of Pier 8 DU are lead (7.3) and selenium (142) (**Table 7-5**). These HQs are based on the CTLs provided by ODEQ (2007).

Aquatic - Near Landfill

The only HQ exceeding 1.0 for CPECs in surface water at the Near Landfill DU is for barium, with an HQ of 6.6 (**Table 7-3**).

The single HQ exceeding 1.0 for CPECs in sediments at the Near Landfill DU is for barium (1.7) (**Table 7-4**). This HQ is based on the freshwater SLV provided by ODEQ (2007).

HQs exceeding 1.0 for CPECs in fish tissue (whole body) at the Near Landfill DU are lead (3.1), mercury (4.2), and selenium (83) (**Table 7-5**). These HQs are based on the CTLs provided by ODEQ (2007).

HQs exceeding 1.0 for CPECs in clam tissue (soft) at the Near Landfill DU are lead (7.6), mercury (1.0), and selenium (100) (**Table 7-5**). These HQs are based on the CTLs provided by ODEQ (2007).

Aquatic - Reference Area

The only HQ exceeding 1.0 for CPECs in surface water at the Aquatic - Reference Area is for barium, with an HQ of 6.4 (**Table 7-3**).

The single HQ exceeding 1.0 for CPECs in sediments at the Aquatic - Reference Area is for barium (1.8) (**Table 7-4**). This HQ is based on the freshwater SLV provided by ODEQ (2007).

HQs exceeding 1.0 for CPECs in fish tissue (whole body) at the Near Landfill DU are lead (2.3), mercury (3.4), and selenium (108) (**Table 7-5**). These HQs are based on the CTLs provided by ODEQ (2007).

HQs exceeding 1.0 for CPECs in clam tissue (soft) at the Near Landfill DU are lead (16) and selenium (133) (**Table 7-5**). These HQs are based on the CTLs provided by ODEQ (2007).

7.5.2.2 Comparison of Site-Specific BSAF/BAFs to Literature Values

This approach is applicable to total DDT. Comparisons with dioxins/furans cannot be performed because dioxins and furans were not detected in whole body fish from the Near Landfill DU, nor were they detected in clams from the Reference Area. The information in **Table 7-7** presents the comparisons of Near Landfill data to the Reference Area data for total DDT.

As can be seen in **Table 7-7**, the site-specific organic carbon and lipid normalized BSAFs for fish are lower than the BSAF presented by ODEQ (2007) for total DDT. The ODEQ normalized fish BSAF is 24; the normalized fish BSAF for the Near Landfill DU and the Reference Area are 4.8 and 9.4, respectively. Clam BSAFs for the Near Landfill DU and Reference Area are 4.9 and 4.0, respectively. Measured concentrations of total DDT in fish and clams from the Near Landfill DU were about 20% of the estimated tissue concentrations using the ODEQ BSAF for fish (and applied to clams as well).

For the Reference Area, mean concentrations of total DDT for fish and clam were about 40% (fish) and about 17% (clam) of those estimated using the ODEQ BSAF of 24. Mean organic carbon in sediment was higher at the Near Landfill DU than at the Reference Area. Mean fish lipid content was also higher at the Near Landfill DU than at the Reference Area. Once normalized for organic carbon (OC) content, the total

DDT concentrations in sediment at the Reference Area and at the Near Landfill DU were nearly the same (0.117 and 0.119 mg/kg OC).

The whole body sculpin lipid content had a mean values that ranged from 2 percent at the Reference Aquatic DU to 3.8 percent at the Near Landfill Aquatic DU (overall mean equals 2.9%). One expectation regarding accumulation of lipophilic contaminants (e.g., DDT and PCBs) is that fish with higher lipid fractions would accumulate higher concentrations of lipophilic contaminants. As discussed previously, protection of salmonid fish is an important assessment endpoint for this evaluation, and salmonids are generally assumed to have relatively high lipid content. However, Meador (2000) derived a mean whole body lipid content of 2.9 percent for juvenile smolted salmonids in the Duwamish River of Washington. Meador (2000) used this mean lipid content to estimate tissue residue- and sediment-based threshold concentrations for PCBs. The mean lipid content of whole body sculpin collected from the Reference Area and Near Landfill Aquatic DUs is 2.9 percent, the same mean value used by Meador for juvenile salmonid fish. Therefore, it is unlikely that migratory juvenile salmonid fish would be more highly exposed to site-related lipophilic contaminants than resident sculpin. In consideration of their lipid content and their year-round residency, Sculpin are considered appropriate surrogates for evaluating site-related risks to non-resident salmonid fish.

7.5.2.3 Evaluation of Near-Shore Sediment Samples Relative to Suspected Source Areas

This approach is applicable to sediments collected immediately off shore from suspected source areas. This is an independent line of evidence discussed in detail in **Section 4**. A summary is provided here for the comparisons of data from onshore source areas to data from associated offshore samples, by DU.

<u>UST Site No. 1</u>

Two near-shore surface sediment samples were analyzed for TPH, VOCs, SVOCs (including PAHs), pesticides, PCBs, and inorganic chemicals. Sediment CPECs identified based on screening of maximum detected concentrations against the lowest of available ODEQ sediment SLVs include the following: six PAHs, 4,4′-DDE, 4,4′-DDT, gamma BHC (Lindane), and seven inorganic chemicals. Comparisons of arithmetic mean concentrations of these CPECs to ODEQ freshwater sediment SLVs resulted in the identification of the following CPECs as being associated with HQ equal to or exceeding 1: indeno(1.2.3-cd)pyrene, 4,4′-DDE, and barium. None of the HQs for these CPECs exceeded 2.3. Most chemical detections and maximum concentrations were reported at location UST1-13. Location UST1-13 is the closest sampling point to the area where observations have been made of stormwater/groundwater drainage from the concrete bulkhead and observations of a surface sheen were made near the shore (see **Section 1.4.3.2**) Discharges from the bulkhead can include PAHs, pesticides, and inorganic constituents from a regional area unrelated to the DU. Such chemical constituents in these discharges are not representative of a release primarily associated with the former USTs at this DU.

Refueling Pit 3

Two near-shore surface sediment samples were analyzed for TPH, VOCs, SVOCs (including PAHs), pesticides, PCBs, and inorganic chemicals. Sediment CPECs identified based on screening of maximum detected concentrations against the lowest of available ODEQ sediment SLVs include the following: nine PAHs, 4,4′-DDE, 4,4′-DDT, heptachlor, heptachlor epoxide, Aroclor-1254, and eight inorganic chemicals.

Comparisons of arithmetic mean concentrations of these CPECs to ODEQ freshwater sediment SLVs resulted in the identification of the following CPECs as being associated with risk estimates where HQ equal to or exceeds 1: eight PAHs, 4,4′-DDE, 4,4′-DDT, heptachlor epoxide, Aroclor-1254, barium, cadmium, and copper. The HQs for all remained below 5.0 except for Aroclor-1254. Aroclor-1254 was reported in both sediment samples at concentrations ranging from 0.046 to 0.062 mg/kg, exceeding the ODEQ screening level for freshwater sediment (0.007 mg/kg). The consensus-based threshold effect concentration (TEC) for total PCBs in sediment is 0.0598 mg/kg (McDonald et al. 2000)—essentially equal to the maximum detected concentration for this location. This TEC is for protection of benthic invertebrates and does not consider protection of upper trophic level receptors via food web effects. PCBs were not detected in reference area sediments, but the detection limit of 10 µg/kg (0.01 mg/kg) confounds comparisons to the ODEQ screening level that is below the reporting limit.

Most chemical detections and maximum concentrations were reported at location RFP3-21. Location RFP3-21 is approximately 35 feet off shore and east of the southern end of Refueling Pit 3 (see **Figure 3-5** and **4-5**). Sample location RFP3-20 is approximately 200 feet north from RFP3-21. Both sample locations are proximal to storm drain outfalls, and these outfalls convey water from an area significantly larger than the Refueling Pit 3 decision unit. The presence of low concentrations of these constituents does not appear to be related to possible petroleum releases at the former Refueling Pit 3 DU.

Fire Training Area

Two near-shore surface sediment samples were collected 35 feet off shore and adjacent to the Fire Training Area (FTA). Locations FTA-25 and FTA-26 are shown on **Figure 4-9**. These samples were analyzed for TPH, VOCs, SVOCs (including PAHs), pesticides, PCBs, and inorganic chemicals. Sediment CPECs identified based on screening of maximum detected concentrations against the lowest of available ODEQ sediment SLVs include the following: indeno(1.2.3-cd)pyrene, 4,4′-DDT, Aroclor-1254, and 10 inorganic chemicals.

Comparisons of arithmetic mean concentrations of these CPECs to ODEQ freshwater sediment SLVs resulted in the identification of the following CPECs as being associated with elevated risk estimates (i.e., HQ equal to or exceeding 1): indeno(1.2.3-cd)pyrene, Aroclor-1254, arsenic, barium, cadmium, copper, and nickel. The HQs for these ranged from 1.0 to 2.0.

Most chemical detections and maximum concentrations were reported at location FTA-26. The nearshore sample location FTA-26 is located in Cathlamet Bay east and downgradient of DPT boring FTA-12 and approximately 130 feet north of the storm water discharge at Pier 1. The results of nearshore sediment sampling and analysis for the FTA do not appear to support a link to the onshore FTA surface soils. The highest HQs for nearshore FTA sediments are for barium (HQ 2) and Aroclor 1254 (HQ 1.9). Neither of these chemicals was identified as surface soil CPECs for the onshore FTA.

7.5.2.4 Food Web Modeling for Piscivorous Receptors

This is applicable for mink, bald eagle, great blue heron, and belted kingfisher exposed to total DDT and mercury via consumption of aquatic prey. The total DDT food web model and the mercury food web model are provided in **Appendix M4**. The dietary or dose-based HQs for DDT and mercury are summarized as follows:

Total DDT

All HQs based on population TRVs remain below 1.0 for all receptors and for all aquatic DUs. All HQs based on individual TRVs remain below 1.0 except for belted kingfisher. HQs for belted kingfisher (representing piscivorous birds with small foraging ranges) are 1.3 for the Reference Area, 1.4 for the Near Landfill DU, and 1.3 for the Finger Piers DU.

Mercury

All HQs for both individual and population TRVs remain below 1.0 for mink and bald eagle at all aquatic DUs. HQs for great blue heron and belted kingfisher exceed 1.0. HQs for heron (individual/population) for the Reference Area are 3.7/1.9; Near Landfill HQs are 4.5/2.3; North of Pier 8 HQs have values of 1.3/<1; and Finger Piers HQs = 2.9/1.5.

HQs for kingfisher (individual/population) for the Reference Area are 12.3/6.2; Near Landfill HQs are 15.2/7.6; North of Pier 8 HQs are 6.2/3.1; and Finger Piers HQs are 9.7/4.9. These data reveal similar but slightly higher HQs for the Near Landfill DU compared to the Reference Area. HQs for the North of Pier 8 DU and the Finger Piers DU are lower than the comparable HQs for the Reference Area and the Near Landfill DU.

7.5.2.5 Food Web Modeling for Omnivorous Terrestrial Receptors

This is applicable for American robin, short-tailed shrew, and deer mouse exposed to lead in surface soils via diet at the AST DU. The lead food web model is provided as **Appendix M3**. All HQs (AST and background; robin, shrew, and mouse) remain below 1.0 except for the American robin (HQ = 1.2); representing omnivorous birds with small foraging ranges at the AST, based on the individual TRV.

7.5.2.6 Comparison of Study Area to Reference Area Data for Bioaccumulative Chemicals in Sediment, Fish, and Clam Samples

This is applicable to total DDT, dioxins/furans, and mercury. Data for heptachlor and cadmium are insufficient to support comparisons other than those discussed qualitatively, next. **Table 7-8** presents these comparisons, and **Table 7-4** presents the sediment hazard quotients resulting from comparisons of sediment CPEC concentrations to sediment SLVs.

Cadmium

Mean sediment concentrations for the aquatic DUs (not including the discrete nearshore sediment samples) range from 0.30 mg/kg (Reference Area) to 0.42 mg/kg (Finger Piers DU). The freshwater sediment SLV provided by ODEQ (2001) for protection of benthic invertebrates is 0.60 mg/kg, while the SLV for cadmium that considers bioaccumulation is 0.003 mg/kg. Mean cadmium concentrations in reference and aquatic DU sediments remain below the SLV for protection of benthic invertebrates. However, both mean concentrations of cadmium in reference sediments and Finger Piers DU exceed the bioaccumulation SLV by at least 100-fold.

Total DDT

As shown on **Table 7-8**, total DDT concentrations in sediment, fish, and clams are similar at the four locations evaluated (Reference Area, Near Landfill, North of Pier 8, and Finger Piers). The highest mean sediment concentration is found at the Finger Piers DU, and the highest fish and clam means are found at the Reference Area and North of Pier 8 DU, respectively. These data indicate food web modeling is warranted for total DDT for assessing risks to upper trophic level receptors.

Mercury

Table 7-8 shows mean concentrations of mercury in sediment ranging from 0.06 mg/kg (Reference Area) to 0.1 mg/kg (Finger Piers DU). The freshwater sediment SLV provided by ODEQ (2001) for protection of benthic invertebrates is 0.2 mg/kg, while the bioaccumulation-based SLV is 0.1 mg/kg. Mean concentrations of mercury in whole body fish (wet weight) range from 0.145 mg/kg (North of Pier 8 DU) to 0.37 mg/kg (Near Landfill DU). Mean concentrations of mercury in soft tissue clams (wet weight) range from 0.055 mg/kg (Finger Piers DU) to 0.089 mg/kg (Near Landfill DU). The freshwater CTL provided by ODEQ (2007) is 0.088 mg/kg, wet weight. These data indicate food web modeling is warranted for mercury for assessing risks to upper trophic level receptors.

Dioxins/Furans

Table 7-8 reveals that the mean concentration of TCDD TEQs (bird) in sediment is higher at the Near Landfill DU than at the Reference Area. However, the reverse is true for TEQs for mammals, where the Reference Area mean sediment TEQ exceeds that of the Near Landfill TEQ. Bird TEQ in fish ranged from 1.05×10^{-6} mg/kg (Reference Area) to 1.59×10^{-6} mg/kg (North of Pier 8 DU). Mammal TEQ in fish ranged from 3.3×10^{-7}mg/kg (Reference Area) to 8.8×10^{-6}mg/kg (Finger Piers DU).

The freshwater CTL provided by ODEQ (2007) is 6.4×10^{-6}mg/kg, wet weight, and this applies to both bird and mammal TEQs.

Dioxins/furans were not detected in whole body forage fish from the Near Landfill DU nor were they detected in clams from the Reference Area. The lack of detections in critical compartments (fish from Near Landfill and clams from the Reference Area) indicates that food web modeling cannot be reliably performed for assessing dioxin-related risks to upper trophic level receptors if the objective is to compare the Near Landfill DU to the Reference Area.

7.5.2.7 Comparison of Tongue Point Data to Lower Columbia River Data

This approach is applicable to whole body fish and soft tissue clam. **Table 7-9** provides comparisons of selected bioaccumulative CPECs in whole body sculpin and soft tissue clams collected in support of this BERA to other tissue data from other nearby sites along the lower Columbia River. To the extent data allow, these comparisons are performed for total DDT, TCDD-TEQs, and mercury. Data from other locations along the lower Columbia River are from two reports (Nicks and Tillet 2003 and Buck 2004), and data within those reports are from 1990, 1991, and 2000.

Total DDT concentrations in whole body sculpin collected at or near Tongue Point (2009 data supporting this BERA) are lower at all DUs compared to 1990 data for pike minnow, sucker, and chub. Mercury concentrations in sculpin from Tongue Point (2009) DUs range from 0.238 to 0.37 mg/kg, and concentrations in pike minnow and chub (1990 data) were 0.035 and 0.21 mg/kg, respectively.

Clam data are more limited but in general 2008 Tongue Point concentrations of total DDT and dioxins/furans are lower than those measured in *Corbicula* clams in 1991. Mean dioxin/furan concentrations in fish tissue for 2009 Tongue Point data range from 0.00000105 to 0.00000159 mg/kg. Combining 1990 data for pike minnow, sucker, and chub reveals a concentration range for dioxins and furans of 0.0000011 to 0.0000024 mg/kg (slightly higher than the 2008 Tongue Point range).

EMAP data for TCDD-EQs in sculpin at multiple locations in the lower Columbia River (2000) ranged from less than reporting limits (at five locations) to 0.0000047 mg/kg (north of Fitzpatrick). Two sculpin samples were collected in 2000 from Tongue Point, and these were associated with TCDD-TEQs of 0.0000043 and 0.0000040 mg/kg, higher than concentrations observed in sculpin in 2009 from Tongue Point DUs. It is noted that the 2000 TCDD-TEQs may not be totally comparable to the TEQs reported here (based on TEFs for birds) because the 2000 TEQs were based on H4IIE bioassays (Nicks and Tilitt 2003).

In summary, concentrations of bioaccumulative CPECs in fish and clam tissue collected in support of this BERA are generally similar to and often lower than concentrations measured in past studies from lower Columbia River sites. **Section 6.5.4** of the human health risk assessment gives a more detailed comparison of recent

Tongue Point data to similar data from other locations along the lower Columbia River.

7.6 Uncertainty Analysis

The following subsections present an overview of factors that may contribute to uncertainty in estimated values for risk and health effects.

7.6.1 CPEC Selection and Quantification

Sources of uncertainty in the selection and quantification of CPECs are limited. For most chemicals detected in site and near site media, the identification of CPECs is based on the approach recommended by ODEQ. This includes using ODEQ-recommended SLVs for comparisons to EPCs calculated from maximum detected concentrations, and performing the multimedia screening for chemicals that were detected in surface water and sediment.

The multimedia screening resulted in the retention of several chemicals as CPECs that were not retained based on the media-specific screens. The chemicals retained as CPECs based only on the multimedia screen are identified as such in the Level I/II TM, and recognized as such here. However, quantitative risk estimation is not performed for these specific chemicals because of the overly conservative nature of the multimedia screen. This approach is based on the assumption that risk estimates at the BERA stage (Level III) of the ecological risk assessment process need not be overly conservative but instead should rely on realistic EPCs and exposure scenarios.

All media cannot be sampled at all locations, so some degree of uncertainty is inherent in CPEC concentration data. The large amount of surface water, sediment, and to a lesser degree, surface soil and biota samples taken from within the Study Area, including reference locations, reduces uncertainty to an acceptable level in most cases. It is expected that the abiotic and biological samples collected have been appropriately analyzed to adequately describe the nature and extent of site-related contamination within the area of investigation.

The IS sampling design used for sediments provides a sound estimate of the mean concentrations of chemicals, but to a limited degree may result in the masking of heterogeneous distributions of contaminants. Therefore, exposures to contaminated sediments may not be ideally characterized on a localized scale, but are adequately characterized on a larger scale most relevant for mobile receptors through the aquatic study area. This approach is adequate for selecting CPECs in surface sediment. In support of IS data representing the mean for sediment data, **Section 4.3.8.4** and **Section 4.3.9.4** discuss the IS design and the results of comparisons of the 2008 surface sediment data to surface sediment data collected by the USACE in 1995.

Uncertainties in abiotic media/biota relationships are decreased by the biological sampling specifically designed to support food web modeling and certain other components of the BERA. These data are assumed appropriate and adequate for establishing BAFs and BSAFs for locations where paired sampling was not conducted.

For surface soils at the AST Fuel Storage Area DU, site-specific biological data are lacking and in this case, BAFs are based on literature values, adding uncertainty to associated risk estimates.

Finally, it is recognized that BAFs and BSAFs (both for the Study Area and literature-based) assume a linear relationship between CPEC concentrations in abiotic media and those in co-located or associated biota. In fact, the relationships between CPECs in both compartments are probably not linear and the assumed linear relationships are likely an overly simplistic representation of the true relationship. The assumption of linearity is not expected to greatly influence the outcome of the BERA, however, because the same assumptions were applied to all sampling locations (including reference).

Sampling and analyses of surface water, sediment, and surface soil for certain CPECs were limited in a few cases, and in others a CPEC was only infrequently detected. Both add uncertainty to the selection of CPECs.

7.6.2 Receptor Selection

Selection of receptors includes local biota sampled for tissue analyses and those used in aquatic and terrestrial food web models. Sampled biota included resident fish (primarily sculpin) and clams. Preferred types of fish for sampling were initially identified as salmonids and other important game species, especially those with higher lipid contents. However, at the time of sampling and based on the types of sampling methods available, sculpin were clearly the dominant fish taxa available.

Lipid content of sculpin is generally expected to be lower than that of salmonids, so tissue concentrations of some lipophilic CPECs may be underestimated using sculpin to represent other fish such as salmonids. However, the mean lipid content of whole body sculpin collected in the aquatic DUs equals the mean lipid content of smolted salmonid fish in the Duwamish River of Washington, as presented in Meador (2000). Adult salmonids may have higher lipid content than juveniles. Offsetting this possible underestimation of adult salmonid tissue residues (and associated risks) is the fact that resident fish such as sculpin can be more closely associated with sediments and possible contaminant sources onsite than migratory or anadromous fish such as salmonids. Resident sculpin are likely to be more highly exposed to site-related contamination than taxa that occur in the area only seasonally or intermittently.

Receptors selected for inclusion in the food web models span a range of possible exposures and sensitivities to modeled CPECs. Assessing risks to upper trophic level piscivorous receptors most often identifies birds with small foraging ranges and a diet high in fish consumption as the most highly exposed. The belted kingfisher fills this niche as a suitable representative for the aquatic (i.e., sediment-associated) models. Other receptors included in the aquatic models include great blue heron (moderate size foraging range), bald eagle (species of concern with large foraging range), and

mink (mammal highly sensitive to several types of contaminants, including some of those identified as CPECs at this Study Area).

For the terrestrial food web models associated with soil exposures, selected receptors include robin (omnivore with small foraging range and substantial proportion of diet as earthworms), shrew (vermivore with small foraging range), and deer mouse (less highly exposed omnivore with small foraging range). Inclusion of robin and shrew provides two receptors with significant worm consumption, resulting in upper range exposure and risk estimates because vermivores are often found to be at the highest risk among soil-associated predators.

Model input parameters include site-specific data (i.e., fish and clam tissue) to the extent possible to minimize the potential for exposure information in the model to underestimate or overestimate exposure (and risk). Some site-specific data are more uncertain than others. For example, there are uncertainties in using site clam data to represent other aquatic invertebrates. However, these uncertainties are likely biased toward overestimating exposure and risk because clams often accumulate chemicals to a higher degree than more mobile invertebrates that are not filter feeders. In other cases, uncertainty is low. For example, CPEC concentrations in whole body sculpin are likely to be adequately representative of the level of contamination likely to affect piscivorous predators that forage year-round in the areas near the landfill. This is primarily because sculpin were found to be the dominant (and in some cases the only) fish species in certain portions of the sampling area. Other fish species, including salmonids, are unlikely to be long-term residents of the areas sampled.

7.6.3 Exposure Estimation

Insufficient numbers of samples were collected in some cases to allow consistent derivation of 90% or 95%UCLs for all locations and media. Because comparisons of exposure and risk across all DUs are most informative when based on the same statistic for expressing the EPC, the arithmetic mean was selected as the Level III EPC for all CPECs. Use of the mean rather than the 95%UCL may result in lower risk estimates in some cases, but is expected to provide realistic risk estimates that can be compared from one location to another. In addition, comparisons of arithmetic mean CPEC concentrations to 90%UCL concentrations reveal very little difference between the two in most cases; the arithmetic means therefore appear to approximate the 90% UCL concentrations for selected and important CPECs.

Other major sources of uncertainty in the exposure portion of the BERA are input parameters for the food web models used to estimate risks to upper trophic level receptors. All models, including the ones used here, are associated with uncertainty. Models are sensitive to slight differences in values of certain input parameters. The uncertainties in dose estimations can be magnified if input parameters for lower trophic levels are highly uncertain, mostly because doses are based on addition and multiplication of values from lower trophic levels.

An important source of uncertainty in the exposure assessment is the variability of values associated with certain input parameters, especially values used to describe the distribution of contaminants in various media and biota. Greater uncertainty in chemical constituents food items is recognized when compared to other medias, based on data quantity and availability. For example, CPEC concentrations in fish are based on site-specific measured concentrations in resident taxa likely to be consumed by piscivores. In contrast, estimates of contaminant concentrations in aquatic invertebrates are based on measured data from resident clams, which may not be a major dietary item for many invertivores.

In some cases, contaminant concentrations in food items are estimated (using BAFs) rather than measured. Because estimated contaminant concentrations in certain food items at certain locations are not site-specific, there are uncertainties with these estimates. In most cases both measured and literature-based, data are adequate to support risk estimation in the BERA. It is unlikely that the exposure assessment underestimates exposure (and risk) because conservative approaches are used where data are more uncertain or limited. Any remaining uncertainties are probably biased towards overprotection or overestimation of risk, which is appropriate and follows regulatory guidance.

7.6.4 Response Estimation

Concentrations of CPECs associated with observed or predicted harmful effects on ecological receptors are the primary source of uncertainty in the effects assessment. These concentrations are used to calculate risk and are described as SLVs or TRVs. Dose-based or dietary TRVs used for risk estimation are taken from ODEQ guidance for assessing risks to individuals and populations.

Use of SLVs (in some cases incorporating a step-wise approach first using more conservative SLVs followed by use of less conservative SLVs) rather than species-specific TRVs adds some uncertainty to risk estimation. However, use of SLVs at the BERA stage of the assessment is in this case considered warranted given the relatively low concentrations of most CPECs, and in other cases given the exposure concentrations similar to reference.

In addition, species-specific or taxa-specific TRVs are unavailable for several CPECs, and SLVs in these cases provide a useful input into risk estimation for a larger group of receptors. This is especially true for sediment SLVs, most of which are applicable to a wide variety of benthic invertebrates. Use of SLVs rather than species-specific TRVs in many cases is expected to result in higher risk estimates and therefore is a more conservative approach.

A high degree of confidence in (and relatively low uncertainty with) some of the more well studied CPECs such as DDT, dioxins and furans, cadmium, copper, lead, and mercury is recognized. For well-studied CPECs such as these, sediment SLVs and, where applicable, dietary TRVs taken from ODEQ guidance are assumed representative of concentrations that, if not exceeded, provide adequate protection of

exposed biota and upper trophic level consumers of such biota. For other chemicals such as barium, toxicity data are limited and the associated SLVs and risk estimates are more uncertain.

The recommended dietary TRVs for assessing population level and individual organism level risks, as presented in ODEQ guidance, are mostly similar to other published NOAELs and LOAELs (i.e., those presented in Sample et al. [1996]). General agreement between these two sources in most cases increases the confidence in the results based on these dietary TRVs.

In summary, uncertainties related to effects assessment or response estimation are considered relatively low, primarily because most of the important CPECs identified for this BERA are well-studied with regard to ecotoxicity. This conclusion is most applicable to surface water- and sediment-based effects data (i.e., SLVs and TRVs), but there may be lower confidence in the soil SLVs because of fewer studies underlying these values.

7.6.5 Risk Estimation

By definition, uncertainties in risk characterization are influenced by uncertainties in exposure assessment and effects (response) assessment. The sampling and analysis of site surface water, sediment, surface soil, fish, and clams minimize uncertainties in site-specific exposure assessment. Descriptions of the magnitude and distribution of CPECs within the site and the reference areas are considered generally representative of current conditions within those areas. This is especially true for those media sampled using a multi-increment sampling approach, which is expected to provide confident estimates of average exposure concentrations.

Despite the overall confidence in exposure data, some data are clearly biased toward times of the year when sampling is easiest or most desirable. For example, fish collected during the sampling event may or may not represent the wide range of resident and migratory fish taxa that may be exposed to Study Area-related chemicals. However, data from past studies at other nearby locations in the lower Columbia River suggest that sculpin are common year-round residents and most likely represent taxa with long-term exposures to contaminants present where they are collected.

Response or effects data can contribute to overall uncertainty in risk characterization. Science and scientific investigations cannot prove any hypothesis beyond doubt. The scientific method is instead based on stating hypotheses, testing the hypotheses, and either accepting or rejecting the hypotheses based on one or more lines of evidence. Cause and effect relationships can be inferred, and evidence can support hypotheses, but cause and effect relationships can rarely be proven. Because no data are conclusive, site-specific biological and chemical data are subject to concerns of representativeness and the sensitivity of sampled species used to derive such data. Toxicity data that are not site-specific may not be very applicable to the site being investigated.

There are also concerns about laboratory-to-field extrapolation of effects data and concerns with taxa-to-taxa extrapolations. All effects data are, therefore, subject to some degree of uncertainty. Confidence in the ability of selected SLVs and TRVs to assess potential for ecological risks varies for each value selected. Although every effects value used in this and every other BERA is associated with some degree of uncertainty, it is the general trend described by the comparisons between exposure concentrations and effects concentrations and the overall confidence in such comparisons that are most important.

For the most part, higher confidence is placed in effects data for the major CPECs that are well studied and of most concern. In decreasing order of confidence, these are followed by effects data for CPECs in surface soil, minimally studied CPECs in surface water (i.e., barium), and petroleum hydrocarbons (for which generally accepted ecotoxicity data are sparse and within CERCLA are not considered hazardous constituents).

Another possible source of uncertainty is the biological data collected to support this BERA. For example, certain types of biota (e.g., plants, worms, fish, and clams) are used to represent key prey items in food web models. Each of these is assumed representative of much larger groups of organisms from which prey would actually be taken. For example, the fish collected are assumed adequately representative of fish regularly consumed by piscivorous predators. Whether or not this assumption is sound cannot be determined using available data.

In summary, sufficient numbers and types of biological data were collected in support of this BERA to serve as appropriate model input parameters. BAFs and BSAFs for most (especially aquatic) food web components are based on site-specific information, which should decrease the uncertainties associated with model outputs.

The risk characterization method itself can contribute to uncertainty. Careful calculation of EPCs, with special attention given to handling nondetect data and infrequently detected values, minimizes this source of uncertainty. Incorporating general site observations and several other lines of evidence (e.g., comparisons of site data to those from past studies associated with other nearby locations) into risk characterization reduces the dependence on strict quantitative risk estimates (i.e., HQs) that in some cases are uncertain.

Risk estimates for upper trophic level receptors based on food web modeling are probably overestimated for some CPECs for species with variable home or foraging ranges. This conclusion is based on the decision to select a mean value where a wide range exists. Whether the mean foraging range is relevant to this site or not cannot be determined with existing data. In reality, some individuals may forage only within the site boundaries, but others may forage over a wider area.

In summary, it is expected that the degree of uncertainty in exposure estimation, effects data, and risk characterization is minimized by the extensive data collection

and careful attention to detail where uncertainties are likely to be highest (e.g., calculation of EPCs for small data sets).

7.7 Conclusions

The results of the BERA are summarized next, by decision unit. Results are expressed in terms of risk estimates by media type and ecological receptor group of concern.

7.7.1 Incinerator Building, Refueling Pit 3, UST Site No. 1, UST Site No. 4

The Incinerator Building, Refueling Pit 3, and UST Site No. 1 provide little or no habitat for ecological receptors. UST Site No. 4 provides a very small amount of marginally suitable habitat for some receptors, but the nature of chemicals released to soil at the UST Site No. 4 decision unit presents no threat to ecological receptors as discussed in the following paragraphs.

No chemicals, for which generally accepted ecological screening values are available, were measured at concentrations associated with unacceptable risk. Four classes of petroleum hydrocarbons were detected in UST Site No. 4 soils. These include TPH-D TPH-G, TPH-O, and C21-C34 aliphatics. The maximum detected concentrations of these four classes of petroleum compounds in UST Site No. 4 surface soils were 13, 75, 120, and 6.2 mg/kg, respectively. A comparative evaluation was made to the Washington State Department of Ecology (WAC 173-340-7493) derived ecological screening levels for the protection of terrestrial plants and animals exposed to hazardous constituents in soil (Ecology 2001) (see **Section 4.3.10**). The recommended screening levels for the protection of soil biota presented in this source document for petroleum hydrocarbons are 100 mg/kg (TPH-G) and 200 mg/kg (TPH-D). A comparison of these surrogate SLVs (see **Table 4-11a**) to maximum detected concentrations of petroleum compounds in UST Site No. 4 soils reveals that only motor oil range hydrocarbons were detected at concentrations approaching (for TPH-D) or exceeding (for TPH-G) the recommended screening levels. The arithmetic mean concentration of oil range hydrocarbons measured in UST Site No. 4 soils equals 39.5 mg/kg, less than both the TPH-G and TPH-D screening levels. This information indicates that petroleum hydrocarbons in UST Site No. 4 surface soils are do not contribute to significant adverse ecological effects in soil-associated biota.

7.7.2 AST

Soil samples from the AST contain lead at concentrations exceeding conservative threshold criteria associated with phytotoxicity (i.e., toxicity to plants). Petroleum hydrocarbons were also detected in surface soils at this site, with the highest concentrations measured as TPH-D and TPH-O. These were not screened against the ODEQ-recommended SLVs during the Level II screening because of the paucity of generally accepted values. Comparisons of detected concentrations of these compounds to surrogate SLVs (WAC 173-340-7493) reveal that maximum detected concentrations of TPH-D (2,400 mg/kg) and TPH-O (7,300 mg/kg) exceed the surrogate SLVs (see **Section 4.3.10**). The comparisons result in maximum HQs of 12

and 37, respectively. **Table 4-11a** presents the results of these comparisons. The HQ for TPH-O is the result of comparing the maximum detected concentration to the surrogate SLV for TPH-D, because a surrogate SLV specifically for TPH-O is unavailable. Although these maximum HQs are greater than the threshold of 1.0, they do not represent significant threat to ecological receptors. The very small size of the AST decision unit relative to the vast amount of more suitable (i.e., less disturbed) habitat surrounding the AST area suggests that possible ecological effects associated with TPH exposures at the AST area would be localized and would not be associated with population level effects.

These soils contain lead at concentrations (1) unlikely to adversely affect soil invertebrates, represented by earthworms, and (2) that may adversely affect individual omnivorous /vermivorous avian receptors with small foraging ranges (represented by American robin).

Finally, AST soils contain lead at concentrations unlikely to affect (1) populations of omnivorous avian receptors with small foraging ranges, (2) small omnivorous mammals (represented by deer mouse), or (3) small vermivorous mammals (represented by short-tailed shrew).

7.7.3 All Aquatic DUs and Reference Area

Several CPECs in sediment are associated with HQs exceeding the 1.0 threshold (based on protection of benthic invertebrates), but no HQ exceeds 5.0 and in most cases the site HQs are similar to the Reference Area HQs.

Barium in surface water at all locations (including the Reference Area) is associated with HQs exceeding the 1.0 threshold (based on protection of aquatic life, which includes a wide range of salmonid and non-salmonid fish as well as water column invertebrates). However, uncertainty is evident in these HQs based on sparse ecotoxicity data for barium. Finally, all Aquatic DU HQs for barium in surface water are similar to those of the Reference Area (all HQs for Aquatic DUs and the Reference Area range from 6.4 to 7.3).

Total DDT concentrations in sediments for Aquatic DUs and the Reference Area are associated with HQs marginally exceeding the 1.0 threshold for individual small piscivorous avian receptors with small foraging ranges (represented by belted kingfisher). These HQs range from 1.3 to 1.4 for Aquatic DUs and the Reference Area. All other HQs for total DDT remain below 1.0 (populations of kingfisher and individuals and populations of other receptors).

Mercury concentrations in sediments for Aquatic DUs and the Reference Area are associated with one or more HQs exceeding the 1.0 threshold for piscivorous avian receptors (represented by great blue heron and belted kingfisher). These HQs range from <1 to 2.3 for heron populations and from 1.3 to 4.5 for heron individuals. For kingfisher, HQs range from 3.1 to 7.6 (populations) and from 6.2 to 15.2 (individuals). In all cases, the HQs for the Near Landfill DU slightly exceed those of the Reference

Area; the North of Pier 8 and Finger Piers DU HQs are slightly below those of the Reference Area.

Total DDT and mercury concentrations in site and Reference Area sediments are not associated with HQs exceeding 1.0 for bald eagle (populations or individuals) or mink (populations or individuals).

PCBs in sediments and biota have been a concern with regard to the past remedial actions associated with the landfill closure. Although PCBs were not detected above tissue-residue reporting limits in whole body fish and soft tissue clams taken from any of the aquatic DUs, a discussion of PCBs in the sediments of the aquatic DUs is included here.

Where detected, mean concentrations of Aroclor 1254 in aquatic DU sediments ranged from 3.2 µg/kg (Finger Pier DU) to 54 µg/kg (Refueling Pit 3, discrete near shore samples). Mean Aroclor 1254 concentrations for the North of Pier 8 DU and FTA discrete near shore samples equaled 4.0 and 13.5 µg/kg, respectively. These values can be compared to the SET proposed by Meador (2000) for evaluating possible adverse effects in juvenile salmonid fish. Meador (2000) proposed a series of sediment effects thresholds (SETs) based on TOC in sediment and utilizing two different BSAFs. BSAFs were set at 0.16 for assessing population level impacts, and 0.32 for assessing risks to individual organisms (applicable to protected salmonids). Approximate mean sediment TOC for aquatic DUs and the reference area equals 1 percent (fraction TOC ~ 0.01). Using this mean TOC, the associated SETs for populations and individuals is 150 µg/kg and 75 µg/kg dw, respectively. The highest average Aroclor 1254 concentration (54 µg/kg, at the RFP nearshore discrete sampling location) is below the most protective PCB SET of 75 µg/kg dw, based on the one percent average TOC content of aquatic DU sediments. These comparisons suggest that salmonid fish populations and individuals are unlikely to experience adverse sublethal effects due to PCB exposures associated with aquatic DU sediments.

As discussed in **Section 7.1.2**, petroleum hydrocarbon concentrations measured in aquatic sediments were compared to surrogate SLVs in a secondary chemical screening step subsequent to completion of the Level II screening. Maximum detected concentrations of TPH-G, TPH-D, and TPH-O from all the aquatic sediment sampling locations (UST-1, RFP, FTA, North of Pier 8, Finger Piers, and Near Landfill) were compared to Sediment Quality Standards/Screening Level 1 (SQS/SL1) values taken from the Recommended Sediment Quality Guidelines for Washington, Oregon, and Idaho (Michelsen 2010). TPH-G and TPH-D concentrations from sediment samples were compared to the TPH-diesel SQS/SL1 values, and TPH-O concentrations were compared to TPH-residual SQS/SL1 values. The sediment data comparisons are discussed in **Section 4.3.10** and shown on **Table 4-11b**. In all cases, the maximum detected concentrations were below the associated SQS/SL1 guidelines (i.e., maximum HQs remained below the threshold of 1), indicating that sediment associated ecological receptors such as benthic macroinvertebrates are unlikely to be exposed to harmful concentrations of petroleum hydrocarbons at these locations.

7.7.4 Aquatic Nearshore Sediments (discrete samples)

UST Site No. 1, RFP 3, and the FTA offshore sampling locations were selected to help evaluate the potential for migration of contaminants from specific onshore locations to nearby offshore sediments. Risk estimates for most of the sediment-associated CPECs identified for these locations are low, with most HQs not exceeding three (3). The risk estimates are summarized below by DU. Although each of the three offshore sites is associated with HQs greater than one, there does not appear to be a definitive link between the contaminants observed in the offshore sediments and associated onshore source areas. **Section 7.5.2.3** provides support for this conclusion, which is applicable to all three nearshore sediment sampling locations.

UST Site No. 1 - The arithmetic mean concentration of indeno(1,2,3)pyrene, 4,4′-DDE, and barium in sediment exceeded associated freshwater sediment SLVs, resulting in an HQs 1.0, 2.3, and 1.3, respectively.

RFP 3 - The arithmetic mean concentration of eight PAHs, 4,4′-DDE, 4,4′-DDT, heptachlor epoxide, Aroclor-1254, barium, cadmium, and copper in sediments equaled or exceeded associated freshwater sediment SLVs. Aroclor-1254 in sediments from this location is discussed in **Section 7.7.3**. HQs for the eight PAHs ranged from 1.6 to 4.4. HQs for the other CPECs that equaled or exceeded 1.0 include DDE (1.4), DDT (1.3), heptachlor epoxide (1.2) Aroclor-1254 (7.7), barium (1.8), cadmium (1.1), and copper (1.0).

FTA - The arithmetic mean concentration of two organic CPECs and five inorganic CPECs collected at this location equaled or slightly exceeded the associated freshwater sediment SLVs. These CPECs and associated HQs are: indeno(1,2,3-cd)pyrene (1.3), Aroclor-1254 (1.9), arsenic (1.0), barium (2.0), cadmium (1.1), copper (1.5) and nickel (1.1) in sediments. Aroclor-1254 in sediments from this location is discussed in **Section 7.7.3**.

The results of this BERA provide risk managers with information that can contribute to decision-making regarding whether further evaluations are warranted for the Study Area. These recommendations and decisions, based on U.S. EPA and the ODEQ guidance, are within the scope of risk management and not risk assessment. Therefore, the conclusions are presented in **Section 8.1** and recommendations are presented in **Section 8.2.**

Table 7-1
Summary of CPECs from Level I/II Screening
Tongue Point Multi-Sites Project, Astoria, Oregon

LEVEL I/II CPEC	Sediment						Surface Water						Surface Soil			Fish	Clams
	FTA	NP8	FP	LF	UST-1	RFP	FTA	NP8	FP	LF	UST-1	RFP	AST	UST-4	FTA		
Semi-Volatile Organic Compounds																	
4-Methylphenol				X						O							
Benzo(a)anthracene					X	X					O	O					
Benzo(a)pyrene		X			X	X					O	O					
Benzo(e)pyrene (4)					X	X					O	O					
Benzo(k)fluoranthene						X						O					
Benzoic Acid			X	X		X			O	O		O					
Chrysene					X	X					O	O					
Dibenzo(a,h)anthracene		X			X	X					O	O					
Fluoranthene						X						O					
Indeno(1,2,3-cd)pyrene	X	X	X		X	X	O	O	O		O	O					
Phenanthrene				X		X				O		O					
Pyrene				X	X	X				O	O	O					
Dioxin/Furan																	
Dioxins/Furans TEQ - mammal				X												X	X
Dioxins/Furans TEQ - bird				X													X
Dioxins/Furans TEQ - fish				X													
Pesticides/Polychlorinated Biphenyls																	
4,4'-DDE	X				X	X					O	O				X	
4,4'-DDT			X		X	X			O		O	O					
Total DDT	X		X	X	X	X										X	
gamma-BHC (Lindane)					X						O						
Heptachlor			X	X		X			O	O		O					
Heptachlor epoxide						X						O					
Aroclor-1254	X					X											
Inorganics																	
Arsenic	X	X	X	X		X	O	O	O	O		O				X	X
Barium	X				X	X	X	X	X	X	X	X					
Cadmium	X	X	X	X	X	X	O	O	O	O	O	O					
Chromium															X	X	X
Copper	X	X	X		X	X	O	O	O		O	O					
Lead	X	X	X	X	X	X	O	O	O	O	O	O	X			X	X
Mercury	X	X	X	X	X	X	O	O	O	O	O	O				X	X
Nickel	X	X	X			X	O		O	O		O					
Selenium	X				X		O				O					X	X
Tributyl Tin as ion									O								
Vanadium	X	X	X		X	X	O	O	O		O	O					
Volatile Petroleum Hydrocarbons																	
C10-C12 Aromatics													N				
C12-C13 Aromatics													N				
Extractable Petroleum Hydrocarbons																	
C12-C16 Aliphatics													N				
C16-C21 Aliphatics													N				
C21-C34 Aliphatics													N	N			
C16-C21 Aromatics													N				
C21-C34 Aromatics													N				
Total Petroleum Hydrocarbons																	
Diesel Range Hydrocarbons	N	N	N	N	N	N							N	N			
Motor Oil Range Hydrocarbons	N	N	N	N									N	N			
Oil Range Hydrocarbons				N	N	N							N	N			

Notes:

AST = aboveground storage tank
FP = Finger Piers
FTA = Fire Training Area
LF = Near Landfill
N = CPEC only because no screening level available
NP8 = North Pier 8
O = CPEC, multimedia screening only
RFP = Refueling Fit 3
UST - 1 = UST Site No. 1
UST - 4 = UST Site No. 4
X = CPEC, individual medium

Table 7-2
Surface Soil Hazard Quotients, Level III BERA
Tongue Point Multi-Sites Project, Astoria, Oregon

AST							
Level I/II CPEC	**Mean SS Conc (mg/kg)**	**SLV 1**	**SLV 1 HQ**	**Plant SLV**	**Plant SLV HQ**	**Invert SLV**	**Invert SLV HQ**
Lead	67.53	16	**4.2**	50	**1.4**	500	0.14

REFERENCE/BACKGROUND							
Level I/II CPEC	**Mean SS Conc (mg/kg)**	**SLV 1**	**SLV 1 HQ**	**Plant SLV**	**Plant SLV HQ**	**Invert SLV**	**Invert SLV HQ**
Lead	17	16	**1.1**	50	0.3	500	0.03

FTA							
Level I/II CPEC	**Mean SS Conc (mg/kg)**	**SLV 1**	**SLV 1 HQ**	**Plant SLV**	**Plant SLV HQ**	**Invert SLV**	**Invert SLV HQ**
Chromium	11.9	0.4	**30**	1	**12**	0.4	**30**

Notes:

AST = aboveground storage tank
CPEC = chemical of potential ecological concern
FTA = Fire Training Area
HQ = Mean Conc / SLV
SS = Surface Soil
SLV-1 = Lowest of Plant, Invertebrate, Bird, and Mammal SLV (ODEQ 2001)

Background unavailable for chromium
Plant and Invertebrate (Invert) SLV from ODEQ 2001

Table 7-3
Surface Water Hazard Quotients, Level III BERA
Tongue Point Multi-Sites Project, Astoria, Oregon

LEVEL I/II CPEC	Mean SW Conc mg/L							SLV Aq. Life mg/L	Aquatic Life HQ						
	FTA	NP8	FP	LF	UST-1	RFP	Reference		FTA	NP8	FP	LF	UST-1	RFP	Reference
Inorganics															
Barium	0.0272	0.0271	0.0291	0.0263	0.0268	0.0276	0.0255	0.004	6.8	6.8	7.3	6.6	6.7	6.9	6.4

Notes:

CPEC = chemical of potential ecological concern
FP = Finger Piers
FTA = Fire Training Area
HQ = Mean Conc / SLV
LF = Near Landfill
NP8 = North of Pier 8
RFP = Refueling Fit 3
SLV = screening level values
UST - 1 = UST Site No. 1

Aquatic Life SLV from ODEQ 2001

Table 7-4
Sediment Hazard Quotients, Level III BERA
Tongue Point Multi-Sites Project, Astoria, Oregon

LEVEL I/II CPEC	Mean SED Conc							SLV-1 mg/kg	SLV Freshwater SED mg/kg	SLV-1 HQ							Freshwater SLV HQ						
	FTA	NP8	FP	LF	UST-1	RFP	Reference			FTA	NP8	FP	LF	UST-1	RFP	Reference	FTA	NP8	FP	LF	UST-1	RFP	Reference
Semi-Volatile Organic Compounds (ug/kg)																							
Benzo(a)anthracene					21.2	75	6.24	32	32					0.7	**2.3**	0.2					0.7	**2.3**	0.2
Benzo(a)pyrene		18.93			21.9	94	8.53	32	32		0.6			0.7	**2.9**	0.3		0.6			0.7	**2.9**	0.3
Benzo(k)fluoranthene						53	3.77	27	27						**2.0**	0.1						**2.0**	0.1
Chrysene					37.3	165	10.34	57	57					0.7	**2.9**	0.2					0.7	**2.9**	0.2
Dibenzo(a,h)anthracene		3.29			3.7	16	1.46	6	33		0.5			0.1	**2.7**	0.2		0.1			0.1	0.5	0.0
Fluoranthene						210	12.20	111	111						**1.9**	0.1						**1.9**	0.1
Indeno(1,2,3-cd)pyrene	22	15.99	15.71		17.1	74.5	8.39	17	17	**1.3**	0.9	0.9		**1.0**	**4.4**	0.5	**1.3**	0.9	0.9		**1.0**	**4.4**	0.5
Phenanthrene				13.0		67.5	5.36	42	42				0.3		**1.6**	0.1				0.3		**1.6**	0.1
Pyrene			30.71	28.0	44.1	195	14.14	53	53			0.6	0.5	0.8	**3.7**	0.3			0.6	0.5	0.8	**3.7**	0.3
Dioxin/Furan (TEQ, ng/kg)																							
Dioxins/Furans TEQ for mammals				5.4E-07			9.6E-07	8.5E-04	9.0E-03				0.00064			0.0011				0.000060			0.00011
Pesticides/Polychlorinated Biphenyls (ug/kg)																							
4,4'-DDE			0.98		3.4	2.15	0.54	0.3	1.5			**3.3**		**2.3**	**7.2**	**1.8**			0.7		**2.3**	**1.4**	0.4
4,4'-DDT					1.75	5.25	0.43	0.3	4					0.4	**17.5**	**1.4**					0.4	**1.3**	0.1
Total DDT	2.14		2.04	1.52			1.06	0.3	7	**7.1**		**6.8**	**5.1**			**3.5**	0.3		0.3	0.2			0.2
gamma-BHC (Lindane)					0.58		ND	0.3	0.9					0.6							0.6		
Heptachlor				0.58		0.6	ND	0.3	10				**1.9**		**2.0**					0.1		0.1	
Heptachlor epoxide			0.37			0.75	ND	0.6	0.6			0.6			**1.2**				0.6			**1.2**	
Aroclor-1254	13.45		3.2	4.0		54	ND	7	7	**1.9**		0.5	0.6		**7.7**		**1.9**		0.5	0.6		**7.7**	
Inorganics (mg/kg)																							
Arsenic	6.04	7.47	5.34	5.54		4.9	4.95	4	6	**1.5**	**1.9**	**1.3**	**1.4**		**1.2**	**1.2**	**1.0**	**1.2**	0.9	0.9		0.8	0.8
Barium	97.55	76.07	77.7	82.7	60.7	85.7	84.96	48	48	**2.0**	**1.6**	**1.6**	**1.7**	**1.3**	**1.8**	**1.8**	**2.0**	**1.6**	**1.6**	**1.7**	**1.3**	**1.8**	**1.8**
Cadmium	0.67	0.35	0.42	0.39	0.31	0.65	0.30	0.003	0.6	**222**	**117**	**139**	**131**	0.5	**218**	**101**	**1.1**	0.6	0.7	0.7	0.5	**1.1**	0.5
Copper	55.1	37.89	33.1		32.9	36.8	29.47	10	36	**5.5**	**3.8**	**3.3**		0.9	**3.7**	**2.9**	**1.5**	**1.1**	0.9		0.9	**1.0**	0.8
Lead	17.6	11.51	10.1	10.6	8.3	15.2	7.80	30	35	0.6	0.4	0.3	0.4	0.2	0.5	0.3	0.5	0.3	0.3	0.3	0.2	0.4	0.2
Mercury	0.11	0.07	0.10	0.07	0.067	0.095	0.06	0.1	0.2	**1.1**	0.7	**1.0**	0.7	0.3	0.9	0.6	0.6	0.4	0.5	0.4	0.3	0.5	0.3
Nickel	19.75	14.17	15.2	13.8		15.6	12.5	16	18	**1.2**	0.9	**1.0**	0.9		**1.0**	0.8	**1.1**	0.8	0.8	0.8		0.9	0.7
Selenium	0.8				0.63		0.45	0.1	1	**8.0**				0.6		**4.5**	0.8				0.6		0.5
Vanadium	70.25	63.83	66.0		80.9	63.8	53.41	57	no SLV	**1.2**	**1.1**	**1.2**			**1.1**	0.9							
Zinc	98.2							3	123	**33**							0.8						

Notes:

CPEC = chemical of potential ecological concern
FP = Finger Piers
FTA = Fire Training Area
HQ = Mean Conc / SLV
LF = Near Landfill
mg/kg = milligrams per kilogram
NP8 = North of Pier 8
RFP = Refueling Pit 3
SLV = screening level values
SLV-1 = Lowest of Freshwater, Marine, and Bioaccumulation SLVs (ODEQ 2001)
µg/kg - micrograms per kilogram
UST - 1 = UST Site No. 1
Freshwater SLV from ODEQ 2001

Table 7-5
Biota Tissue Hazard Quotients, Level III BERA
Tongue Point Multi-Sites Project, Astoria, Oregon

LEVEL I/II CPEC	Mean Whole Body Forage Fish mg/kg ww				CTL mg/kg ww	CTL HQ			
	Near LF	NP8	FP	Reference		Near LF	NP8	FP	Reference
Dioxin/Furan									
Dioxins/Furans TEQ - mammal	NC	5.9E-07	8.8E-06	3.3E-07	6.4E-06	-	0.1	**1.4**	0.1
Dioxins/Furans TEQ - bird	NC	1.6E-06	1.2E-06	1.1E-06	6.4E-06	-	0.2	0.2	0.2
Pesticides/Polychlorinated Biphenyls									
Total DDT	0.0214	0.1058	0.0196	0.0222	0.054	0.4	**2.0**	0.4	0.4
Inorganics									
Arsenic	1.62	2.09	1.69	1.25	6.6	0.2	0.3	0.3	0.2
Chromium	0.43	0.53	0.26	0.47	No CTL	**-**	**-**	**-**	-
Lead	0.374	0.604	0.325	0.27	0.120	**3.1**	**5.0**	**2.7**	**2.3**
Mercury	0.370	0.145	0.238	0.303	0.088	**4.2**	**1.6**	**2.7**	**3.4**
Selenium	2.0	1.9	2.2	2.6	0.024	**83**	**79**	**92**	**108**

LEVEL I/II CPEC	Mean Soft Tissue Clam mg/kg ww				CTL mg/kg ww	CTL HQ			
	Near LF	NP8	FP	Reference		Near LF	NP8	FP	Reference
Dioxin/Furan									
Dioxins/Furans TEQ - mammal	3.7E-07	3.0E-06	No Data	NC	6.4E-06	0.1	0.5	-	-
Dioxins/Furans TEQ - bird	7.2E-07	1E-05	No Data	NC	6.4E-06	0.1	**1.6**	-	-
Pesticides/Polychlorinated Biphenyls									
Total DDT	0.0114	0.0140	0.0119	0.00614	0.054	0.2	0.3	0.2	0.1
Inorganics									
Arsenic	6.13	11.1	6.09	4.9	6.6	0.9	**1.7**	0.9	0.7
Chromium	1.96	2.46	2.52	4.25	No CTL	**-**	**-**	**-**	-
Lead	0.911	0.229	0.873	1.87	0.12	**7.6**	**1.9**	**7.3**	**16**
Mercury	0.089	0.062	0.055	0.066	0.09	**1.0**	0.7	0.6	0.8
Selenium	2.4	2.7	3.4	3.2	0.024	**100**	**113**	**142**	**133**

Notes:

CPEC = chemical of potential ecological concern
CTL = Critical Tissue Level, freshwater, ODEQ 2007
DDT = dichlorodiphenyltrichloroethane
FP = Finger Piers
HQ = Mean Conc / CTL
LF = Near Landfill
mg/kg = milligrams per kilogram
NC = Not Calculated; CPEC not detected in media type at location noted; or in historic results not detected at reporting limits.
No Data = Analyte not analyzed in medium or at location noted
NP8 = North Pier 8
TEQ = toxicity equivalent
ww = wet weight

CTL for total DDT assumed equal to CTL for DDD, DDE, and DDT (all 0.054 mg/kg ww)
Chromium in biota not assessed quantitatively because no CTL provided by ODEQ

Table 7-6
Comparison of Arithmetic Mean and 90% UCL Concentrations for Selected COPCs in Sediment
Tongue Point Multi-Sites Project, Astoria, Oregon

LEVEL I/II SEDIMENT CPEC	Units	North Pier 8		Finger Piers		Near Landfill	
		Arithmetic Mean	90% UCL	Arithmetic Mean	90% UCL	Arithmetic Mean	90% UCL
Dioxins/Furans TEQ (mammals)	ng/kg	NA	NA	NA	NA	0.54	0.87
Total DDT	µg/kg	NA	NA	2.04	2.24	1.52	1.81
Aroclor-1254	µg/kg	NA	NA	3.21	3.52	4.00	NC
Cadmium	mg/kg	0.35	0.36	0.417	0.425	0.39	0.40
Copper	mg/kg	37.89	38.5	33.13	33.5	24.8	25.5

NA - not applicable (not a CPEC or not analyzed)
NC - not calculated - data insufficient to allow calculation
Means and UCLs -based on 7 IMS samples collected at each aquatic DU

Table 7-7
Comparison of QDEQ BSAF to Measured BSAF for Total DDT in Whole Body Fish and Clam
Tongue Point Multi-Sites Project, Astoria, Oregon

	Measured Data										ODEQ
Decision Unit	**Mean SED mg/kg dw**	**Mean SED TOC fraction**	**Mean Fish mg/kg ww**	**Mean Fish Lipid fraction**	**Fish BSAF**	**NORM Fish BSAF**	**Mean Clam mg/kg ww**	**Mean Clam Lipid fraction**	**Clam BSAF**	**NORM Clam BSAF**	**NORM Fish BSAF**
Near Landfill	0.00152	0.0130	0.0214	0.0380	14.1	4.81	0.0114	0.0200	7.50	4.87	24
Reference	0.00106	0.00893	0.0222	0.0200	20.9	9.35	0.00614	0.0130	5.79	3.98	

measured data based on site specific sampling and analyses
normalized BSAF based on equation below

$$\text{BSAF} = \frac{\text{(conc tissue, mg/kg ww / fraction lipid)}}{\text{(conc sed, mg/kg dw / fraction organic carbon)}}$$

Decision Unit	**Measured Tissue Conc mg/kg lipid**		**Estimated Tissue Conc (mg/kg lipid, ODEQ BSAF)**	
	FISH	**CLAM**	**FISH**	**CLAM**
Near Landfill	0.563	0.570	2.81	2.81
Reference	1.110	0.472	2.85	2.85

tissue ww / fr lipid = tissue lipid norm
ODEQ BSAF based on sediment to fish BSAF, assumed applicable to clam also

Decision Unit	**Mean SED mg/kg dw**	**Mean SED mg/kg oc**
Near Landfill	0.00152	0.117
Reference	0.00106	0.119

sed dw / fr oc = sed oc norm

Notes:

BSAF = biota-sediment accumulation factor
dw = dry weight
mg/kg = milligrams per kilogram
ODEQ = Oregon Department of Environmental Quality
SED = sediment
TOC = total organic carbon
ww = wet weight

Table 7-8
Mean Concentrations (ppm) of Bioaccumulative Chemicals, by Compartment and Decision Unit
Tongue Point Multi-Sites Project, Astoria, Oregon

	Total DDT			
	SW Conc	**SED Conc**	**Fish Conc**	**Clam Conc**
REF	0.00000040	0.00106	0.0222	0.00614
N LF	0.00000040	0.00152	0.0214	0.0114
NP8	0.00000040	No Data	0.1058	0.0140
FP	0.00000040	0.00204	0.0196	0.0119

SW concentrations estimated using half the detection limit

	Heptachlor total			
	SW Conc	**SED Conc**	**Fish Conc**	**Clam Conc**
REF	No Data	NC	No Data	No Data
N LF	No Data	0.00058	No Data	No Data
NP8	No Data	No Data	No Data	No Data
FP	No Data	0.00056	No Data	No Data

SW concentrations estimated using half the detection limit

	Dioxins/Furans (TCDD TEQ - BIRD)			
	SW Conc	**SED Conc**	**Fish Conc**	**Clam Conc**
REF	1.54E-09	3.8E-07	1.05E-06	NC
N LF	1.54E-09	5.1E-07	NC	7.2E-07
NP8	No Data	No Data	1.59E-06	1.001E-05
FP	No Data	No Data	1.17E-06	No Data

SW concentrations estimated using half the detection limit

	Dioxins/Furans (TCDD TEQ - MAMMAL)			
	SW Conc	**SED Conc**	**Fish Conc**	**Clam Conc**
REF	1.13E-09	9.6E-07	3.3E-07	NC
N LF	1.13E-09	5.4E-07	NC	3.7E-07
NP8	No Data	No Data	5.9E-07	3.0E-06
FP	No Data	No Data	8.8E-06	No Data

SW concentrations estimated using half the detection limit

	Cadmium			
	SW Conc	**SED Conc**	**Fish Conc**	**Clam Conc**
REF	No Data	0.30	No Data	No Data
N LF	No Data	0.39	No Data	No Data
NP8	No Data	0.35	No Data	No Data
FP	No Data	0.42	No Data	No Data

SW concentrations estimated using half the detection limit

	Mercury			
	SW Conc	**SED Conc**	**Fish Conc**	**Clam Conc**
REF	0.0005	0.0600	0.303	0.0660
N LF	0.0005	0.0700	0.370	0.0890
NP8	0.0005	0.0700	0.145	0.0620
FP	0.0005	0.100	0.238	0.0550

SW concentrations estimated using half the detection limit

Notes:

DDT = dichlorodiphenyltrichloroethane
FP = Finger Piers
NC = Not Calculated (CPEC not detected in media type at location noted)
N LF = Near Landfill
NP8 = North of Pier 8
RFP = Refueling Fit 3
SW = surface water
NC = Not Calculated; CPEC not detected in media type at location noted; or in historic results not detected at reporting limits.
No Data = Analyte not analyzed in medium or at location noted

Table 7-9
Comparison of Tongue Point Fish and Clam Data to Other Columbia River Data
Tongue Point Multi-Sites Project, Astoria, Oregon
mean concentration, mg/kg

2008 Whole Body Sculpin, Tongue Point BERA[3]

	Reference	Near Landfill	North Pier 8	Finger Piers
Total DDT	0.0222	0.0214	0.1058	0.0196
TCDD TEQ (bird)	1.05E-06	NC	1.59E-06	1.17E-06
Mercury	0.3030	0.3700	0.1450	0.2380

1990 Lower Columbia River Data[1]

Cathalamet Bay		
N. pikeminnow	**sucker**	**chub**
0.135	0.45	0.75
2.00E-06	1.10E-06	2.40E-06
0.035	No Data	0.21

<' values set to half the detection limit

2008 Clam, soft tissue, Tongue Point BERA[3]

	Reference	Near Landfill	North Pier 8	Finger Piers
Total DDT	0.00614	0.0114	0.0140	0.0119
TCDD TEQ (bird)	NC	7.2E-07	1.0E-05	No Data
Mercury	0.0660	0.0890	0.0620	0.0550

[3] Level III BERA, CDM 2010

1991 Columbia River Data[2]

Cathalamet Bay	L&C NWR	JB NWR
Corbicula	**Corbicula**	**Corbicula**
0.03	0.03	0.145
1.00E-06	1.00E-06	No Data
No Data	No Data	0.008

<' values set to half the detection limit

[1,2] - Buck, J. 2004 (USFWS Final Report 1130-1F02 and 1261-1N04, May 21, 2004)

2000 Lower Columbia River EMAP[4]

	Whole Body Sculpin, TCDD-EQ (mg/kg)													
	River Mouth	**SW Sand Is**	**E. N. Astoria Br.**	**W. of Grays Pt.**	**Mid River**	**SW N. Astoria Br.**	**DS Astoria Br.**	**SW Rice Is.**	**Altoona**	**W. Jim Crow Pt.**	**NW Tongue Pt.**	**NW Tongue Pt.**	**N. Green Marsh**	**N. Fitzpatrick**
TCDD-EQ	NC	1.1E-06	NC	4.1E-06	3.8E-06	NC	2.8E-06	2.8E-06	NC	4.3E-06	4.0E-06	4.3E-06	NC	4.7E-06

[4] Nicks and Tillet, 2003 (USGS Report FY 2004-30-01, 6 October 2003)

NC = Not Calculated; CPEC not detected in media type at location noted; or in historic results not detected at reporting limits.
No Data = Analyte not analyzed in medium or at location noted
EMAP = U.S. EPA Environmental Monitoring and Assessment Program

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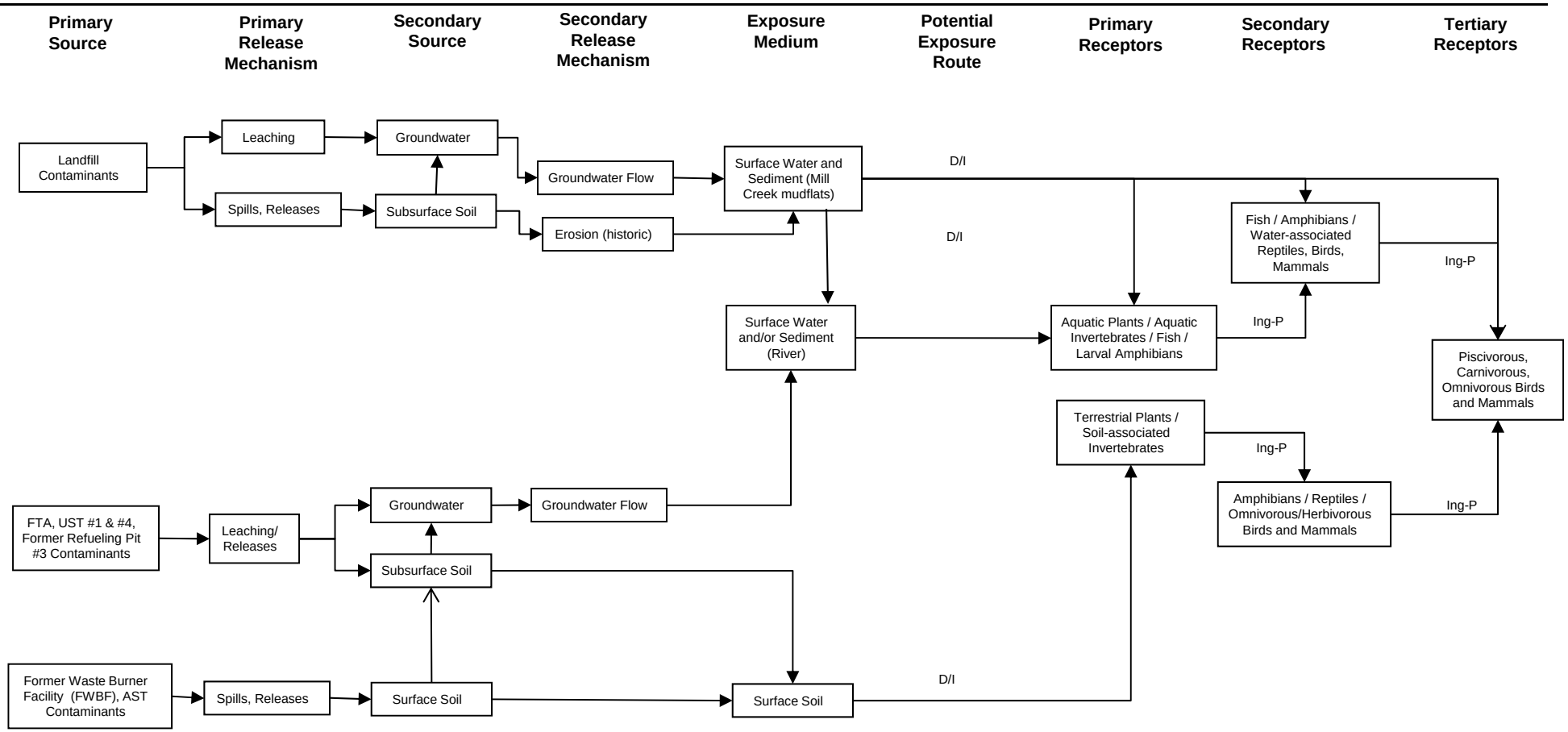


→ = Potentially Complete exposure pathway

D/I = Direct Contact / Ingestion (animals) / Uptake (plants)

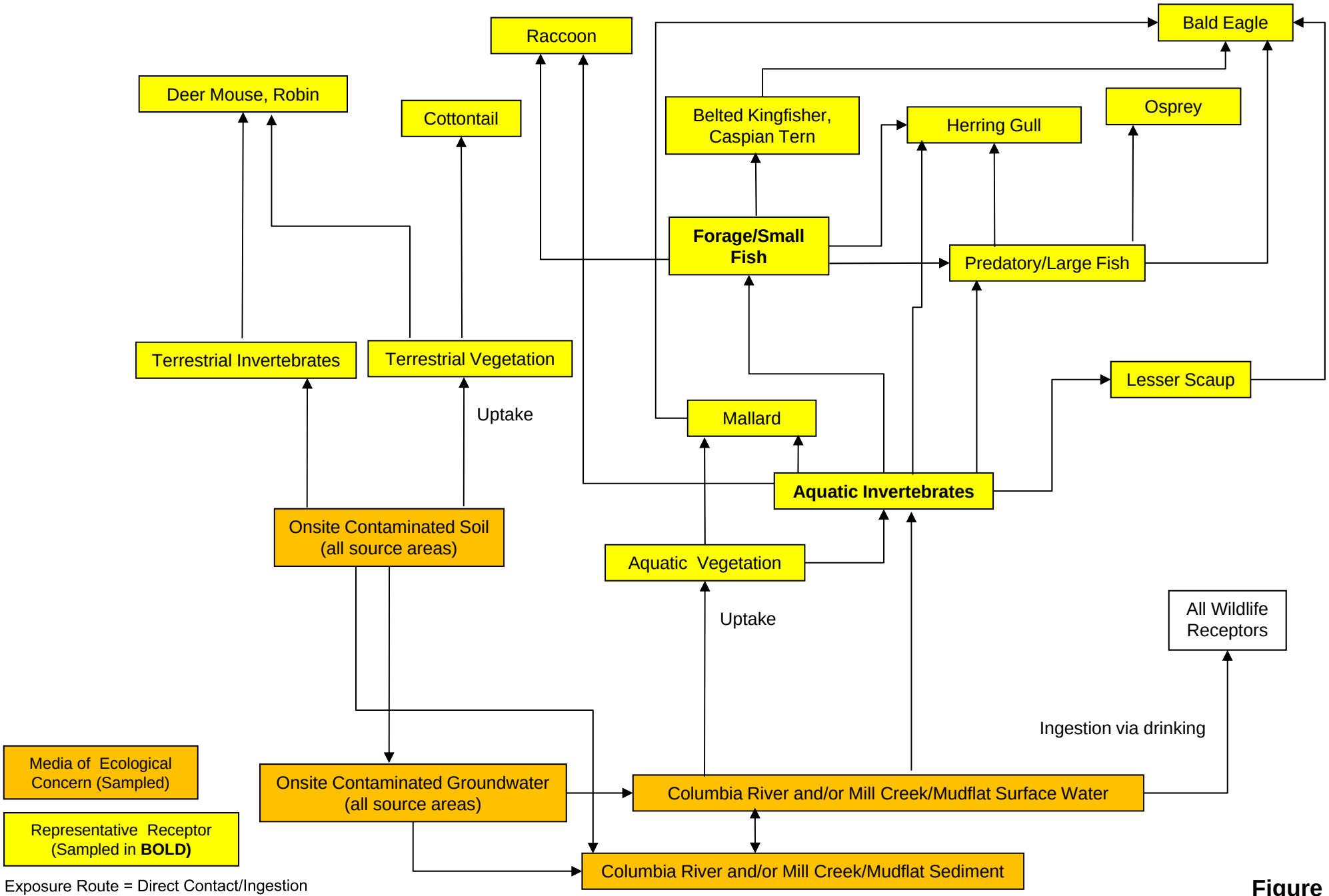
Ing-P = Ingestion of prey/food item (limited to bioaccumulative contaminants)

Figure 7-1

Preliminary Site Conceptual Exposure Model (SCEM) – Part 1 – Exposure Pathways

Ecological Risk Assessment – Tongue Point Multi-Sites Project, Astoria, Oregon

CDM



Exposure Route = Direct Contact/Ingestion unless indicated otherwise

Dietary items are restricted for food web modeling and data availability

Figure 7-2

Preliminary Site Conceptual Exposure Model (SCEM) – Part 2 – Food Web

Ecological Risk Assessment – Tongue Point Multi-Site Project, Astoria, Oregon

Section 8
Results and Conclusions

This section discusses the results of the investigation for each decision unit and presents conclusions for use in risk management decisions. This RI was performed to provide data to support an HHRA and an ERA and to identify DUs for risk-based decision-making and closure of the individual FUDS areas.

In addition, this section summarizes the nature and extent of chemical concentrations by media within each DU, and briefly summarizes the fate and transport of source-related chemicals, including pathways. A summary of the risk characterization is provided with a discussion of uncertainty and alternative exposure. The conclusions include recommendations for identifying areas within DUs that require response action and data gaps that need to be resolved in design of the response action; they also identify the preliminary RAOs to support evaluation of remedial alternatives.

8.1 Results of the RI

To simplify the presentation of the results of this RI, the discussion is separated in to DU-specific subsections.

8.1.1 RI Objectives

The objectives of this RI are:

- Characterize impacts in environmental media to identify sources of chemicals in upland areas and in near shore water areas.
- Determine if the Tongue Point Landfill interim removal action is protective of the aquatic environment, off shore and downstream of the landfill.
- Perform a baseline HHRA and a screening level ERA and, if warranted by evaluation of the screening level risk assessment, conduct a baseline ERA.
- Identify areas within the Study Area that require remedial actions. If DUs pose no threat to receptors, recommend closure.

8.1.2 Study Area Investigation

To address the RI objectives, the fieldwork was conducted from 8 September to 10 October 2008 and the following samples were collected by media in each DU:

- AST Fuel Storage Area – Nine surface soil, nine subsurface soil, and one groundwater sample(s) were collected and analyzed for compounds associated with petroleum hydrocarbon contamination.

- *UST Site No. 1* – Five subsurface soil, six soil gas, seven groundwater, one LNAPL, two near-shore surface water, and two near-shore sediment samples were collected and analyzed for compounds associated with petroleum hydrocarbon contamination.

- *Refueling Pit 3* – Four subsurface soil, six soil gas, two ambient air, nine groundwater, two near-shore surface water, and two near-shore sediment samples were collected and analyzed for compounds associated with contamination by petroleum hydrocarbons and VOCs.

- *UST Site No. 4* – Six surface and six subsurface soil samples were collected and analyzed for compounds associated with petroleum hydrocarbon contamination.

- *Fire Training Area* – Fifteen subsurface soil, seven soil gas, 17 groundwater, one LNAPL, two near-shore surface water, and two near-shore sediment samples were collected and analyzed for compounds associated with contamination by petroleum hydrocarbons and VOCs.

- *Aquatic - North of Pier 8* – Seven IS replicate surface sediment, one surface water, and three tissue samples were collected and analyzed for compounds associated with the upland AST Fuel Storage Area and UST Site No. 1 DUs and to determine if the Tongue Point Landfill had affected aquatic areas downgradient.

- *Aquatic - Finger Piers* – Seven IS replicate surface sediment, two surface water, and three tissue samples were collected and analyzed for compounds associated with upland Refueling Pit 3 and Fire Training Area DUs and to determine if the Tongue Point Landfill had affected aquatic areas downgradient. Three sediment cores were collected to determine sediment stratigraphy.

- *Aquatic - Near Landfill* – Seven IS replicate surface sediment, one surface water, and three tissue samples were collected and analyzed for compounds associated with the Tongue Point Landfill to determine if the removal action at the landfill sufficiently protects aquatic ecological receptors.

8.1.3 Physical Characteristics and Land Use of the Study Area

The total Study Area comprises 230 acres, with 85 acres located on shore and 145 acres located off shore. The terrestrial portion of the Study Area is situated within the flat-lying area on the banks of Cathlamet Bay within Columbia River and is bordered by upland areas to the southwest, the prominent Tongue Point to the north, and Mill Creek to the south. The aquatic portion lies within Cathlamet Bay immediately surrounding the finger piers. The northern portion of the Study Area, consisting of land on Tongue Point, is managed by the USFWS as the Tongue Point Eagle Sanctuary. The land use is wildlife management, habitat protection, and wildlife observation and this area has restricted access. The portion of the Study Area between Tongue Point and south to Hangar 2 is an industrial area associated with the Tongue Point Job Corps Center and includes approximately 100 residences. Facilities include classrooms, workshops, cafeterias, recreation centers, and dormitories. The

training facilities include an maritime program using a vessel docked at Pier 7. Most Job Corps Center employees and all students live onsite in residences and dormitories (Washington North Tongue Point 2006). The portion of the Study Area between Hangar 2 and Pier 1 is owned by Washington North Tongue Point and is used as a multi-use transportation logistics and intermodal facility. There are no residents living in this area.

The southernmost portion of the Study Area is property owned by the ODSL and includes the former Fire Training Area. The northwestern portion of the Fire Training Area is covered by a large dredge materials pile that was emplaced in 2001 post-DoD activities. Outside the Study Area, on ODSL property is the former Tongue Point Landfill south of the Fire Training Area. The landfill is being addressed under a separate response action. There are no residents living in the area south of Hangar 2.

The waterfront portion of the Study Area is constructed on unconsolidated fill from material dredged from the Columbia River and is paved with exception of a small portion of waterfront at UST Site 1 and near the Fire Training Area. Native surface soils are exposed in some of the upland areas and have been identified as the Templeton Ecola Silt Loam (Walsh 1987). The maximum depth explored during this investigation was 30 feet bgs in the Fire Training Area.

Groundwater occurs at a depth of approximately 5 to 8 feet bgs across the Study Area under unconfined conditions within fill and alluvium, which overlies low permeability bedrock that acts as an aquitard. The hydraulic conductivity of the shallow aquifer is 1 to 20 feet/day, as determined by the slug test performed at the Refueling Pit 3 DU. The groundwater is not used as a drinking water source and is not likely to be used for drinking water in the future because of limited yield and the existing supplied-water infrastructure.

The sediments in the aquatic DUs consist of a thick sequence of silt and sandy silt underlain by sand. The silt unit ranges from 5 to 20 feet in thickness. The silt is dark gray to black, of low to moderate plasticity, generally firm in consistency, and with a high organic content. The underlying sand unit is at least 10 feet thick (Woodward Clyde 1998). The sand is gray to dark gray, poorly graded, fine grained, and medium dense to dense. A thin gray to light gray clay layer, which was interpreted as the volcanic ash deposited during the 1980 eruption of Mount St. Helens, was observed at depths of approximately 2 feet BML in two of the sediment cores (FP-13 and FP-13A) collected during this investigation. Sediment accumulation at the Finger Piers DU between the 1995 and 2008 ranged from 1.5 to 3.2 feet over the 13.4-year period, or equivalent to a sedimentation rate of 1.3 to 2.9 inches per year. Based on this sedimentation rate, approximately 8.1 feet of sediment has accumulated since the cessation of DoD-related activities in 1962.

8.1.4 Nature and Extent of Chemicals

The summary presented here is organized by DU, discusses significant findings per media, and focuses on chemicals that were identified based on the frequency of

detection and toxicity, both of which are typically important for risk management and remedial decisions.

8.1.4.1 AST Fuel Storage Area

Lead was the only constituent selected for further evaluation of extent in surface soil. When in use, AVGAS was stored in the ASTs. AVGAS contains TEL, which has a half-life of a few weeks in surface soil, and degrades leaving residual inorganic lead. In surface soil, lead was identified with a maximum detected value of 262 mg/kg, a concentrations less than its human health-based comparison level of 400 mg/kg. Because concentrations of lead in AST surface soil were the maximum values in the Study Area, and owing to its bioaccumulative properties, lead was further evaluated for ecological effects. Petroleum hydrocarbons did not exceed the DU-specific TPH RBCs. With the exception of acenaphthene, acenaphthylene, fluorene, pentachlorophenol, and TPH-G, all maximum concentrations were detected in surface soil samples collected inside, or adjacent to the outside of the AST ring foundations.

In groundwater, the maximum concentration of arsenic (0.605 J µg/L) was an order of magnitude greater than the comparison criterion (0.038 µg/L). This maximum concentration was, however, less than the current federal MCL for inorganic arsenic of 10 ug/L.

8.1.4.2 UST Site No. 1

Seven of the 10 maximum detections of PAHs, plus the diesel and gasoline range hydrocarbons, have maximum concentrations in the soil sample collected from location UST1-01. UST1-01 was advanced in the former excavation northeast of Tank 13-1. UST1-01 is also 15 feet east of monitoring well MW-06, a monitoring well with measurable LNAPL (see **Section 3**). No constituents in soil were identified at concentrations that could be important for risk management decisions at the UST Site No.1 DU.

The maximum detected value of benzene in soil gas, 130 µg/m^3 at location UST1-08 exceeds its comparison criterion of 62 µg/m^3. Of the 34 VOC detected, 26 of the maximum concentrations were reported from borings UST1-07 and UST1-08. These locations were advanced in the area upgradient and proximal to the two USTs that were closed-in-place.

TPH-G and TPH-D were detected in groundwater above DU-specific TPH RBCs in two samples, MW-06 and UST1-01. Carcinogenic PAHs and arsenic are also evaluated in groundwater. The detected maximum concentrations were located in the groundwater samples from well MW-06 and UST1-01. MW-06 and UST1-01 are located north and northeast of the former location of UST 13-1. Historically, MW-06 has had LNAPL; 1.72 feet of LNAPL was also observed in well MW-06 during this RI.

Arsenic was detected in surface water at estimated concentrations of 0.931 J µg/L and 0.939 J µg/L in the two surface water samples collected. These concentrations exceed the comparison criterion value is 0.018 µg/L.

Total DDT bioaccumulates in aquatic systems and was reported at a concentration of 0.0047 mg/kg at location UST1-13. Carcinogenic PAHs and mercury were also detected and further evaluated. Most chemical detections and maximum concentrations of those chemicals were reported at location UST1-13. UST1-13 is immediately downgradient of the former tank cavity and is the closest sampling point to the area where observations have been made of stormwater/groundwater drainage from the concrete bulkhead has been observed and where surface sheen has been noted near the shore (see **Section 1.4.3.2**). Total DDT, cPAH and Hg would not have been released from the former fuel storage USTs at this DU. The area of these samples receives aerial dispersion and stormwater discharges associated with the current industrial use of the facility. In addition, near shore sediment could receive petroleum and PAH released from fueling of the ship currently used for training at the Job Corp Center.

8.1.4.3 Refueling Pit 3

No chemicals were tentatively identified in soils collected from the Refueling Pit 3 DU at concentrations expected to influence risk management. The majority of maximum detections were located in the soil sample collected from location RFP3-02. Boring RFP3-02 was advanced approximately 105 feet downgradient of Refueling Pit 3.

VOCs detected in soil gas at Refueling Pit 3 were not identified as chemicals that would possibly affect risk management. These VOCs, 2-propanol and 4-ethyltoluene, do not have applicable screening criteria, however, they were retained for further consideration in the risk assessment. The detected maximum concentrations were located at sample location RFP3-13. RFP3-13 is located upgradient of Refueling Pit 3 and south of the southeast corner of Hangar 1.

In groundwater at Refueling Pit 3, TPH-G was detected above DU-specific TPH RBCs, and is significant because of the concentration and its relation to past DoD activity. Gasoline residuals could be important for risk management because of RBC exceedance and its relation to past DoD activity. TCE was detected in an upgradient well (MW-03) at a concentration of 1.8 µg/L; therefore, TCE was retained for further evaluation of extent of impacts for this DU. Arsenic detected at concentrations ranging from 0.792 J µg/L to 9.49 µg/L in eight of nine groundwater samples, concentrations that exceeded its comparison criterion. Most detected maximum concentrations of arsenic were located in monitoring wells MW-03 and MW-04. Well MW-03 is located upgradient of Refueling Pit 3. Detections of chlorinated VOCs (TCE and cis-1,2-DCE) in this well indicate a source area upgradient of, and not related to, Refueling Pit 3. MW-04 is located within the limits of the former refueling pit excavation. No arsenic concentrations exceeded the MCL for inorganic arsenic.

Arsenic is also detected in surface water at estimated concentrations of 0.994 J µg/L and 0.997 J µg/L in the two surface water samples collected. These concentrations exceed the comparison criterion of 0.018 µg/L.

Carcinogenic PAHs exceeded comparison criteria at both sediment sample locations located downgradient from the pit. The total DDT concentration at both RFP3-20 and RFP3-21 exceeded the screening concentration of 0.00033 mg/kg by an order of magnitude. Total PCB concentrations in both samples also exceeded comparison criteria. Mercury was the only inorganic constituent that exceed the comparison criterion. Therefore, cPAHs, total DDTs, total PCBs, and mercury were identified for further evaluation of extent of impacts in sediment off shore of Refueling Pit 3. Most chemical detections and maximum concentrations were reported at location RFP3-21, downgradient of the former refueling pit. Sample location RFP3-20 is downriver from RFP3-21. Because DoD activity at the former Refueling Pit 3 DU was related to fuel dispensing, the presence of these chemicals may not be directly related to a release associated with this DU. Both sample locations are proximal to storm drain outfalls that are a possible source of such chemicals. The area of these samples receives aerial dispersion and stormwater discharges associated with the current industrial use of the facility. In addition, near shore sediment could receive petroleum and PAH released from fueling of the ship currently used for training at the Job Corp Center.

8.1.4.4 UST Site No. 4

In surface soil, cPAH were identified as chemicals that could influence risk management decisions. Petroleum hydrocarbons, however, did not exceed DU-specific TPH RBCs. The majority of maximum detections for hydrocarbons were from samples collected from locations UST4-01 and UST4-04. UST4-01 was advanced within the UST removal excavation limits at the approximate location of UST Tank 2. UST4-04 was advanced southwest of UST removal excavation limit.

8.1.4.5 Incinerator Building

None of the inorganic chemical concentrations exceeded comparison criteria, and no inorganic constituents were identified for further evaluation. Carcinogenic PAHs, however, exceeded comparison criteria in all five replicates. Detected concentrations of dioxins/furans (as 2,3,7,8-TCDD equivalents) were also above the comparison criteria, with the maximum detected concentration exceeding these criteria by up to an order of magnitude. Therefore, cPAHs and dioxins/furans were retained for further evaluation of extent of impacts in surface soil surrounding the Incinerator Building.

8.1.4.6 Fire Training Area

TPH-D concentration in soil at location FTA-15 exceeded DU-specific TPH RBCs. Arsenic concentrations exceed the comparison criterion by up to one order of magnitude. Most maximum detections were detected in the soil sample collected from location FTA-15. FTA-15 is about 15 feet south of monitoring well MW-19. Historically, MW-19 has had LNAPL; free product was also observed during the September 2008 fieldwork of this RI. TPH-D and arsenic were identified for further evaluation of extent of impacts.

Four VOC, 2-hexanone, 2-propanol, 4-ethyltoluene, and ethanol detected in soil gas at the Fire Training Area do not have relevant comparison criteria. These VOC were retained for further consideration in the HHRA. Most maximum concentrations were reported from location FTA-03G, which was advanced in soil adjacent to the concrete surfacing and within approximately 200 feet of the suspected original release area.

TPH-G was detected in groundwater at concentrations greater than DU-specific TPH RBCs. Three VOCs, benzene, 1,2,4-trimethylbenzene, and vinyl chloride, were also retained for further evaluation of extent of impacts. Benzene exceedances were one order of magnitude greater than its comparison criterion of 0.35 µg/L at two locations, FTA-01 and FTA-08. Vinyl chloride exceedances were one to three orders of magnitude greater than its comparison criterion of 0.025 µg/L at 12 locations. Concentrations of 1,2,4-trimethylbenzene exceeded its comparison criterion only at FTA-09 (within 15 feet of MW-19 LNAPL). Dioxins/furans (reported as 2,3,7,8-TCDD TEQ) were reported in two of three groundwater samples for which the analysis was performed, at a maximum concentration of 4.114E-06 -mg/kg at location FTA-14. The 2,3,7,8-TCDD TEQ at location FTA-14 also exceeded the applicable comparison criterion; therefore 2,3,7,8-TCDD was retained for further evaluation of extent of impacts. Two PAHs/PAH groups, naphthalene and cPAHs as B(a)P equivalents, and three inorganic constituents, arsenic, iron, and manganese, were also retained for further evaluation of extent of impacts. Most maximum concentrations were reported from location FTA-09, which is 15 feet downgradient of MW-19. Historically, MW-19 has had LNAPL; approximately 1.35 feet of free product was also observed in September 2008 during this investigation.

Arsenic was detected at estimated concentrations of 0.951 J µg/L and 0.998 J µg/L in the two surface water samples collected. These concentrations exceed the comparison criterion of 0.018 µg/L. Thus, arsenic was identified for further evaluation of extent of impacts in surface water.

Carcinogenic PAHs were retained for further evaluation of extent of impacts in sediment samples off shore of the Fire Training Area DU. In addition, total DDT concentrations at both FTA-26 and FTA-25 exceeded reference and comparison criterion of 0.00033 mg/kg by an order of magnitude. Likewise, total PCBs exceeded the comparison criterion by an order of magnitude at location FTA-25 and by two orders of magnitude at FTA-26. Among inorganic constituents, lead and mercury exceeded comparison criteria in both samples. Total DDT, total PCBs, lead, and mercury were retained for further evaluation of extent of impacts. Most detections and maximum concentrations were reported at location FTA-26, which is located in Cathlamet Bay downgradient of DPT boring FTA-12 and north of Pier 1. The documented former DoD activity at this DU suggests some uncertainty regarding whether chemicals present in near-shore sediments are related to the DU or associated with the nearby stormwater discharges.

8.1.4.7 Aquatic - North of Pier 8

Arsenic was the only constituent identified for further evaluation of extent of impacts in surface water in the Aquatic - North of Pier 8 DU. Arsenic, detected at a concentration of 1.04 µg/L exceeded the comparison criterion of 0.018 µg/L.

Carcinogenic PAHs exceeded comparison criteria in six of the replicates, but detections were of the same magnitude as the criteria. Arsenic exceeded its respective comparison criterion in four of seven replicates and mercury exceeded its respective comparison criterion in three of seven replicates. Therefore, cPAHs, arsenic, and mercury in sediment were retained for additional evaluation at the North of Pier 8 DU.

The following chemicals were detected in clam tissue collected from the North of Pier 8 aquatic DU: fluoranthene, pyrene, total DDT, dioxins/furans, arsenic, chromium, lead, mercury, and selenium. Only arsenic, lead, and selenium exceeded the comparison criteria; therefore, only these inorganic constituents were retained for additional evaluation.

The following chemicals were detected in forage fish tissue collected from the North of Pier 8 Aquatic DU: fluoranthene, pyrene, total DDT, alpha-chlordane, dieldrin, hexachlorobenzene, arsenic, chromium, lead, mercury, and selenium. Lead, mercury, and selenium exceeded the comparison criteria; a comparison criterion value for chromium in tissue is not available. Only total DDT, chromium, lead, selenium, and mercury were retained for further evaluation of extent of impacts.

The following chemicals were detected in game fish fillets collected from the North of Pier 8 Aquatic DU: total DDT, arsenic, chromium, lead, mercury, and selenium. Only lead, mercury, and selenium exceeded the comparison criteria; a comparison criterion value for chromium in tissue is not available. Therefore, chromium, lead, selenium, and mercury were retained for further evaluation of extent of impacts.

8.1.4.8 Aquatic - Finger Piers

Arsenic in surface water in the Aquatic - Finger Piers DU was retained for further evaluation of extent of impacts. Arsenic was detected at concentrations of 1.11 µg/L and 1.17 µg/L in the two surface water samples collected, which is two orders of magnitude greater than the comparison criteria (0.018 µg/L).

Of the SVOCs detected in the sediment replicates, only cPAHs exceeded its respective screening criterion and was retained for further evaluation of extent of impacts. Total PCBs were reported at estimated concentrations ranging from 0.0024 to 0.0040 J mg/kg. Total PCBs were also reported in all replicates at estimated concentrations greater than the reference and comparison criteria; therefore, total PCBs were retained for further evaluation of extent of impacts. The following inorganic constituents were detected in all replicates analyzed: antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, vanadium, and zinc. Only mercury exceeded the

comparison criterion; therefore, it was retained for further evaluation of extent of impacts.

The following chemicals were detected in clam tissue collected from the Finger Piers aquatic DU: total DDT, dieldrin, arsenic, chromium, lead, mercury, and selenium. Lead and selenium exceeded the comparison criteria; a comparison criterion value for chromium in tissue is not available. Therefore, only chromium, lead, and selenium were retained for further evaluation of extent of impacts.

The following chemicals were detected in forage fish tissue collected from the Finger Piers aquatic DU: fluoranthene, pyrene, total DDT, dieldrin, dioxins/furans (as 2,3,7,8-TCDD TEQ), arsenic, chromium, lead, mercury, and selenium. Lead, mercury, and selenium exceeded the comparison criteria; a comparison criterion value for chromium in tissue is not available. Therefore, only chromium, lead, mercury, and selenium were retained for further evaluation of extent of impacts.

The following chemicals were detected in the fish fillets collected from the Finger Piers aquatic DU: total DDT, dioxins/furans (as 2,3,7,8-TCDD TEQ), arsenic, chromium, lead, mercury, and selenium. Mercury and selenium exceeded comparison criteria; a comparison criterion for chromium in tissue is not available. Therefore, only chromium, mercury, and selenium were retained for further evaluation of extent of impacts.

8.1.4.9 Aquatic - Near Landfill

Arsenic was the only chemical retained for further evaluation in surface water in the Aquatic - Near Landfill DU. Arsenic was detected at a concentration of 1.02 µg/L at two orders of magnitude greater than the comparison criterion (0.018 µg/L).

Carcinogenic PAHs exceeded comparison criterion in five of the seven replicates, but detections were of the same magnitude as the screening criterion. Total PCBs were also reported in all replicates at estimated concentrations greater than the reference and comparison criteria. Total PCBs were reported at estimated concentrations ranging from 0.0035 to 0.0043 J mg/kg. Dioxins/furans concentrations, reported as 2,3,7,8-TCDD TEQ, exceeded the comparison criterion value of 0.0091 mg/kg for mammals exposed to sediment. The following inorganics were detected in all replicates analyzed from the Near Landfill aquatic DU: antimony, arsenic, cadmium, chromium, lead, mercury, nickel, silver, and zinc. With the exception of mercury, none of the sediment inorganic analytical results exceeded comparison criteria. Therefore, mercury, cPAHs, total PCBs, and dioxins/furans were retained for further evaluation of extent of impacts in surface sediments from the Aquatic - Near Landfill DU.

The following chemicals were detected in clam tissue collected from the Near Landfill aquatic DU: fluoranthene, pyrene, total DDT, dieldrin, dioxins/furans (as 2,3,7,8-TCDD TEQ), arsenic, chromium, lead, mercury, and selenium. Lead, mercury, and selenium exceeded the comparison criteria; comparison criterion for chromium in

tissue is not available. Therefore, only chromium, lead, mercury, and selenium were retained for further evaluation of extent of impacts.

The following chemicals were detected in forage fish tissue collected from the Near Landfill aquatic DU: fluoranthene, pyrene, total DDT, alpha-chlordane, dieldrin, hexachlorobenzene, arsenic, chromium, lead, mercury, and selenium. Lead, mercury, and selenium exceeded the comparison criteria; comparison criterion for chromium in tissue is not available. Therefore, only chromium, lead, mercury, and selenium were retained for further evaluation of extent of impacts.

The following chemicals were detected in fish fillets collected from the Near Landfill aquatic DU: total DDT, dioxins/furans (as 2,3,7,8-TCDD TEQ), arsenic, chromium, lead, mercury, and selenium. Dioxins/furans were reported at a concentration of 9.7×10^{-7} mg/kg. Lead, mercury, and selenium exceeded the comparison criteria; comparison criterion for chromium in tissue is not available. Therefore, only chromium, lead, mercury, and selenium were retained for further evaluation of extent of impacts.

An objective of the RI was to evaluate near shore sediments adjacent to the landfill to determine the success of the landfill removal action as a containment action that eliminates the landfill as a possible current or continuing source of dioxins/furans to near-shore sediments. Previous studies indicated the release of dioxins/furans from the landfill could have occurred, and a removal action was completed in 2006 to address the release. Comparisons of 2008 RI data to historical data collected before the 2006 action were used to evaluate the success of the removal action.

Data evaluated were concentrations of 2,3,7,8 TCDD and the TEQ as 2,3,7,8 TCDD from near-shore surface sediment samples collected in 1997, and core samples collected in 1999, from along perimeter of the landfill. These historic, pre-removal data were compared to the mean concentration of 2,3,7,8 TCDD in surface sediment samples collected from the Near Landfill during the 2008 RI, and 2,3,7,8-TCDD TEQ mean concentrations in the seven analyses of the IS from the Aquatic-Near Landfill DU. The detailed comparison concluded that the 2008 post removal concentrations are less than historical values before the removal action. In addition, the 2008 data showed similar mean concentrations of TCDD TEQ in the 2008 Near Landfill DU sediments as those from the Aquatic-Reference Area. These data suggest that concentrations of dioxins/furans in surface sediments do not reflect the higher concentrations found historically in sediment samples near the landfill. RI data are entirely consistent with the conclusion that TCDD TEQ in sediments near the landfill is typical for sediments elsewhere in Cathlamet Bay. The surface sediment data show no indication of current or continuing source of dioxins/furans that could be attributed to the landfill or to past DoD activity.

8.1.5 Fate and Transport Processes

This section summarizes the conclusions from the fate and transport evaluation. The summary is presented by upland (terrestrial) and aquatic DUs.

Upland Decision Units

The most important fate and transport mechanisms for the terrestrial areas are adsorption and biodegradation, with some volatilization playing a role for the light hydrocarbons (TPH-G and BTEX compounds). AVGAS and diesel components that are resistant to (or not subject to) biodegradation and that tend to partition onto the soil are the components which have remained at the DU, including PAHs, dioxins/furans, lead, TPH-D, and TPH-O. Other components, which are more mobile or biodegradable, are not as prevalent in the soil, or are not detectable in the system. These compounds include VOCs such as BTEX, EDB, and TPH-G. Where LNAPL remains (UST Site No. 1 and Fire Training Area), aqueous concentrations of diesel-related components tend to be higher within the groundwater because of partitioning from the free product. The LNAPL also maintains anaerobic conditions, which tends to limit biodegradation of the hydrocarbons and TEL.

Aquatic Decision Units

The fate and transport within the aquatic DUs tend to be controlled by the behavior of the sediments. The Study Area is within the Columbia River estuary, and estuaries tend to be environments dominated by sediment deposition, partially because of the effect of varying salinity gradients. Additionally, the finger piers within the Study Area reduce the Columbia River's scouring effect and create a lower energy environment favoring greater sediment deposition. Active sedimentation tends to bury the impacted sediments beneath non-impacted sediments, which removes them from the system unless dredging is conducted or they are otherwise disturbed. The concentrations of AVGAS and diesel fuel components and metals are higher within the buried sediments of the aquatic DUs when compared to the Reference Area, suggesting that some releases have occurred in the past. Deposition of fine-grained sediment high in organic carbon content tends to sorb organic chemicals and reduce the bioavailability to ecological receptors. The reducing conditions within the buried sediments tend to preserve the PAHs and hydrocarbons because of the absence of aerobic biodegradation. The Columbia River also continuously flushes affected water downstream of the Study Area.

8.1.6 Conclusions of the Risk Assessments

This section summarizes the conclusions from the HHRA and the ecological evaluations. The summaries are divided by upland and aquatic DUs.

8.1.6.1 Human Health Risk Assessment

The HHRA provides a quantitative estimate of cancer risk and health hazard associated with COPCs at the Study Area under current and future anticipated land-use conditions. The methods and procedures followed are consistent with current ODEQ and EPA guidance for HHRAs.

Because of the CERCLA exemption for petroleum hydrocarbons, fuels would not be addressed within risk assessments based on CERCLA regulations. However, per

RCRA the State of Oregon does not follow this exclusion and petroleum hydrocarbons were addressed per ODEQ risk assessment guidance.

To appropriately assess possible exposure and risk related to petroleum hydrocarbons, characterization of risks in this assessment followed a dual track. For four DUs (i.e., AST, UST Site No. 1, Refueling Pit 3, and UST Site No. 4), petroleum hydrocarbons were assessed separately following CERCLA requirements and applicable standards per RCRA. RCRA requirements. For the remaining DUs, where DoD did not store or use petroleum and fuel, risks are assessed only for the CERCLA guidance. These DUs are the former Incinerator, the Fire Training Area, and the aquatic DUs. For these CERCLA DUs, risks are characterized only using the CERCLA process, and petroleum hydrocarbons are addressed only through consideration of individual chemicals associated with petroleum discharged from past DoD activity. Thus, the risk characterization is presented and summarized to distinguish between CERCLA and ODEQ processes.

The following summary is presented based on the human health risk evaluations for the upland and aquatic DUs.

Upland Decision Units

Considering all scenarios evaluated for current land use, no upper-bound excess cancer risk estimates exceeded the ODEQ ELCR of 1×10^{-5} for exposure to multiple carcinogens and thus all estimates fall within or below the EPA target cancer risk range of 10^{-4} to 10^{-6}.

In addition, all of the calculated noncancer HIs for current scenarios are below the ODEQ and EPA threshold of 1. These results support the conclusion that COPCs identified in soil and groundwater at AST, UST Site No. 1, Refueling Pit 3, UST Site No.4, Incinerator Building and Fire Training Area DUs are not likely to cause adverse health effects for any human receptors that currently use upland areas of the TPMS.

Considering all scenarios evaluated for future land-use, calculated upper-range excess cancer risks exceed ODEQ threshold for ELCR of $1 \times 10^{-5,}$ and are within the EPA target cancer risk range of 10^{-4} to 10^{-6}, for consumption of groundwater as drinking water at UST Site No. 1(future resident $1x10^{-4}$), Refueling Pit 3 (future worker $3x10^{-5}$), and Fire Training Area (future worker $7x10^{-5}$) DUs. Noncancer HIs exceed the ODEQ and EPA threshold HI of 1 for future indoor workers at UST Site No. 1 with an HI = 3, and Refueling Pit 3 with an HI = 7, and future residents at UST Site No. 1 (HI = 12).

Carcinogenic risks for upland DUs are; (1) almost entirely (+90%) from exposure to arsenic in groundwater (UST Site No. 1 and Refueling Pit 3), which appears to be present only at background levels and is below state and federal drinking water standard and (2) based on hypothetical future use of groundwater as a potable water supply. Thus, cancer risks are unlikely to be related to past DoD activity in the Study Area, and are unlikely to be realized via installation of drinking water wells in the

future. Future potable use of groundwater is unlikely because a high quality municipal water supply is readily available and serves the vicinity.

One exception occurs at the Fire Training Area DU. Vinyl chloride-related cancer risk from consumption of groundwater at this DU is 3×10^{-5}, which exceeds the ODEQ ELCR and is within the EPA target cancer risk range of 10^{-4} to 10^{-6}. Vinyl chloride is likely to be related to past DoD activity from use of chlorinated solvents, such as PCE and TCE, during fire training exercises. Both of these solvents degrade to vinyl chloride when oxygen concentrations are sufficiently low. Total risk from consumption of groundwater at the Fire Training Area is 7×10^{-5}, with arsenic being the other major contributor. As discussed, arsenic is likely present only at background concentrations.

At UST Site No. 1 and Refueling Pit 3, non-cancer hazards are associated with gasoline and diesel range petroleum hydrocarbons in groundwater which are likely to be DoD related. Small contributions to non-cancer hazards are made by arsenic and manganese, but concentrations of both these inorganic constituents are consistent with local or ambient background rather than historical DoD activities. Because non-cancer hazards are based on hypothetical future use of groundwater as a potable water supply, hazards are unlikely to be realized because groundwater is not a foreseeable drinking water resource. Future potable use of groundwater is unlikely because a high quality municipal water supply is readily available and serves the Study Area and vicinity.

Aquatic Decision Units

For current and future land-use scenarios, upper-range excess cancer risks to recreational users are below or within the EPA target risk range of 10^{-6} to 10^{-4}. The highest risk value was for the recreational adolescents at North of Pier 8 DU of $2\text{x}10^{-6}$. In addition, all of the computed HIs for the recreational user scenarios are below 1. Recreational users of the shoreline at TPMS are unlikely to experience significant exposure.

Upper-bound cancer risks for the angler scenario for the North of Pier 8 and Near Landfill DUs are 1×10^{-4}, at the upper end of the EPA target risk range of 10^{-6} to 10^{-4}. The upper-bound cancer risk for the angler scenario for the Finger Piers DU is 2×10^{-4}, which exceeds the upper bound of the EPA target risk range of 10^{-6} to 10^{-4}. These calculated cancer risks are almost entirely due to consumption of fish caught from aquatic DUs, as opposed to direct contact with sediment and surface water.

Risks from exposure to arsenic in fish make up the majority of total excess cancer risk: 78% at the Near Landfill DU, 85% at Finger Piers DU, and 96% at North of Pier 8 DU. Risks from dioxins/furans in fish tissue make up the rest of the calculated cancer risk. Additionally, the noncancer HI exceeds the regulatory threshold of 1 at the Finger Piers DU. Arsenic and dioxins/furans are the noncancer hazard drivers at the Finger Piers DU.

Quantitative risk estimates are uncertain because the most appropriate target species for anglers could not be collected, and sculpin were used as a surrogate. Multiple line-of-evidence approach, however, indicates that the sculpin data can be used in comparative fashion, along with other Study Area, Cathlamet Bay, and Lower Columbia River data, to support conclusions concerning fish consumption. These lines of evidence demonstrate that arsenic and dioxins/furans in surface sediment and fish tissues at the aquatic DUs most likely reflect typical ambient concentrations from sediment moving downstream to TPMS, and are not related to past DoD activities. They are, thus, likely to be attributable to upstream sources. Certainly many upstream sources exist that could be important sources of dioxins/furans, such as storm water discharges, the lower Willamette River, and agricultural runoff.

Multiple Lines of Evidence

A multiple lines of evidence approach was used (**Section 6.5.4**) to evaluate chemical concentrations in fish and sediment in the aquatic DUs. Arsenic and 2,3,7,8-TCDD TEQ were selected for the evaluations based on the frequency of detection and potential for toxic effects. As discussed in **Section 6.5.4.2**, other inorganic constituents were detected in sediment, but, in general, analytical results were consistent with the conclusion that Reference Area and aquatic DU concentrations of inorganic constituents are similar and that no signature related to the releases from the landfill or past DoD activities is obvious from a detailed evaluation of sediment data.

The first line of evidence evaluated arsenic concentrations in surface sediment. Mean arsenic concentrations in sediment are at or below the regional default background concentration of 7 mg/kg (ODEQ 2007). This indicates that arsenic concentrations in surface sediment in the aquatic DUs reflect typical background concentrations from the state, and are not related to past DoD activities in the Study Area.

The second line of evidence used is the mean concentration of 2,3,7,8-TCDD TEQ in surface sediment, which is higher at the Reference Area than at the Near Landfill DU, although dioxins/furans were not detected in fish fillet from the Reference Area. Third, dioxin/furan concentrations present in surface sediment at the Near Landfill DU are significantly lower than historical levels.

As the third line of evidence, the concentrations of 2,3,7,8-TCDD and 2,3,7,8-TCDF in fish fillets collected from Tongue Point are similar to those collected from other nearby sites along the lower Columbia River and lower than those from regional values (i.e., upriver in Cathlamet Bay and upriver portions of Lewis and Clark NWR). The 2,3,7,8-TCDD TEQ concentrations found in fish fillet at aquatic DUs are in the lower range of concentrations found in the lower Columbia River near the Study Area.

These lines of evidence demonstrate that arsenic and dioxins/furans in surface sediment and fish tissues in aquatic DUs most likely reflect ambient concentrations in the lower Columbia River Basin and are not related to releases from the landfill or past DoD activities. They may be attributable to other upstream source areas because

the Columbia River receives surface water runoff and storm water discharges from various industrial and agricultural areas upstream. The Finger Pier area receives aerial dispersion and stormwater discharges associated with the current industrial use of the facility. In addition, near shore sediment could receive petroleum and PAHs released from fueling of the ship currently used for training at the Job Corp Center.

8.1.6.2 Baseline Ecological Risk Assessment

The results of the BERA are summarized here, by DU. Results are described as risk estimates by media type and ecological receptor group of concern.

Upland Decision Units

Incinerator Building, Refueling Pit 3, UST Site No. 1, UST Site No. 4

The Incinerator Building, Refueling Pit 3, and UST Site No. 1 provide little or no suitable habitat for ecological receptors. UST Site No. 4 provides a very small amount of marginally suitable habitat for some receptors, but the degree of soil contamination at this location is low. No chemicals for which ecological screening values are available were measured at concentrations associated with unacceptable risk. Although petroleum hydrocarbons are not designated hazardous constituents within the CERCLA regulations, they are considered hazardous by ODEQ and were evaluated for ecological effects. Four classes of petroleum hydrocarbons were detected in UST Site No. 4 soils. Maximum detected concentrations of these compounds did not exceed the surrogate SLVs that were used as adapted Washington State Department of Ecology.

AST Fuel Storage Area

Petroleum hydrocarbons were detected in surface soils measured as TPH-D and TPH-O. Comparisons of detected concentrations of these compounds to surrogate SLVs show that maximum detected concentrations of TPH-D (2,400 mg/kg) and TPH-O (7,300 mg/kg) exceed the surrogate SLVs. A maximum HQ of 12 for the diesel range was estimated using the surrogate SLVs. Although the maximum HQ is greater than the threshold of 1.0, the localized presence of petroleum does not represent significant threat to ecological receptors. Use of these conclusions for cleanup decision making should include other factors and be based in part with consideration of the small size of the AST DU (0.34 acre), the extensive higher quality habitat within and adjacent to theAST DU (including the Tongue Point Eagle Sanctuary and Lewis and Clark National Wildlife Refuge), and the relatively low risk estimates (HQs) for soil-associated receptors. For further consideration is the expectation that lead in soils is less bioavailable than that used in laboratory studies from which ecological screening values are commonly derived. Conclusions for other CPECs are briefly summarized in the following bullets.

- Soils at the AST Fuel Storage Area contain lead at concentrations exceeding conservative thresholds associated with phytotoxicity (i.e., toxicity to plants).

- Soils at the AST Fuel Storage Area contain lead at concentrations unlikely to adversely affect soil invertebrates, represented by earthworms.

- Soils at the AST Fuel Storage Area contain lead at concentrations that may adversely affect individual omnivorous avian receptors with small foraging ranges (represented by American robin).

- Soils at the AST Fuel Storage Area contain lead at concentrations unlikely to affect (1) populations of omnivorous avian receptors with small foraging ranges, (2) small omnivorous mammals (represented by deer mouse), or (3) small vermivorous mammals (represented by short-tailed shrew).

Aquatic Decision Units

Petroleum hydrocarbons were detected in sediment samples from the Aquatic DUs and in nearshore discrete samples. These compounds are not designated hazardous constituents within the CERCLA regulations, but are considered hazardous by ODEQ and per guidance were evaluated for ecological effects. Surrogate SLVs for petroleum hydrocarbons in sediment were compared to detected concentrations of TPH-G (gasoline range hydrocarbons), TPH-D (diesel range hydrocarbons), and TPH-O (oil range hydrocarbons). The results of these comparisons indicating that sediment associated ecological receptors such as benthic macroinvertebrates are unlikely to be exposed to harmful concentrations of petroleum hydrocarbons at these locations. Conclusions for other CPECs are briefly summarized in the following bullets.

- Several CPECs in sediment are associated with HQs exceeding the 1.0 threshold (based on protection of benthic invertebrates), but no HQ exceeds 5 and in most cases the DU HQs are similar to the Reference Area HQs.

- Barium in surface water at all locations (including reference) is associated with HQs exceeding the 1.0 threshold (based on protection of aquatic life, which includes a wide range of salmonid and non-salmonid fish as well as water column invertebrates). However, considerable uncertainty is associated with these HQs based on sparse ecotoxicity data for barium. Finally, all DU HQs for barium in surface water are similar to those of the Reference Area (all HQs for the DU and reference range from 6.4 to 7.3).

- Total DDT concentrations in sediments for the Aquatic DUs and Reference Areas are associated with HQs slightly exceeding the 1.0 threshold for individual small piscivorous avian receptors with small foraging ranges (represented by belted kingfisher). These HQs range from 1.3 to 1.4 for site and Reference Areas. All other HQs for total DDT remain below 1.0 (populations of kingfisher and individuals and populations of other receptors).

- Mercury concentrations in sediments for the Aquatic DUs and Reference Areas are associated with one or more HQs exceeding the 1.0 threshold for piscivorous avian receptors (represented by great blue heron and belted kingfisher). These HQs range

from <1 to 2.3 for heron populations and from 1.3 to 4.5 for heron individuals. For kingfisher, HQs range from 3.1 to 7.6 (populations) and from 6.2 to 15.2 (individuals). In all cases, the HQs for the Near Landfill DU slightly exceed those of the Reference Area; the North of Pier 8 and Finger Pier DU HQs are slightly below those of the Reference Area.

- Total DDT and mercury concentrations in the Aquatic DUs and Reference Area sediments are not associated with HQs exceeding 1.0 for bald eagle (populations or individuals) or mink (populations or individuals).

PCBs in sediments and biota were a concern with regard to the past remedial actions associated with the landfill closure. Although PCBs were not detected above tissue-residue reporting limits in whole body fish and soft tissue clams taken from any of the aquatic DUs, a discussion of PCBs in the sediments of the aquatic DUs is included here. Where detected, mean concentrations of Aroclor 1254 in aquatic DU sediments ranged from 3.2 ug/kg (Finger Pier DU) to 54 ug/kg (Refueling Pit 3, discrete nearshore samples). Mean concentrations for the North of Pier 8 DU and FTA discrete nearshore samples equaled 4.0 and 13.5 ug/kg, respectively. These values were compared to the SET proposed by Meador (2000) for evaluating adverse effects in juvenile salmonid fish exposed to PCBs in sediment. Using the Aquatic DU mean TOC, the associated SETs for populations and individuals is 150 ug/kg and 75 ug/kg dw, respectively. The highest average Aroclor 1254 concentration (54 ug/kg, at the Refueling Pit 3 nearshore discrete sampling location) is below the most protective PCB SET of 75 ug/kg dw, based on the one percent average TOC content of aquatic DU sediments. These comparisons suggest that salmonid fish populations and individuals are unlikely to experience adverse sublethal effects due to PCB exposures associated with aquatic DU sediments.

8.2 Conclusions

The HHRA performed as part of this RI determined that existing conditions are protective of current and future receptors within the Study Area. The chemicals present at the Study Area pose no threat to human receptors because the chemical responsible for the greatest percentage of the low level of risk is arsenic, which occurs at concentrations less than or similar to naturally occurring concentrations.

For future indoor workers, vinyl chloride-related risks from consumption of groundwater at the Fire Training Area DU are 3×10^{-5}, which exceeds the ODEQ ELCR, and are within EPA's management range. Vinyl chloride is likely to be related in part to past DoD activity from use of chlorinated solvents, such as PCE and TCE, during fire training exercises. Both of these chlorinated ethenes may degrade to vinyl chloride. Total risk from consumption of groundwater at the Fire Training Area is 7×10^{-5}, with arsenic being the other major contributor. As discussed, arsenic is likely present only at background concentrations. Given a cancer, risk above $1 \times 10^{-5}$and the exceedance of regulatory criteria groundwater at the Fire Training Area DU could restrict the future potable use of groundwater at this DU. The RI documents that groundwater samples had concentrations of vinyl chloride that exceed the Federal

Maximum Contaminant Level of 2 ug/L (Found at: *http://water.epa.gov/drink/contaminants/index.cfm#Primary*). In addition, the groundwater sample concentrations exceed the 2 ug/L "Reference Level" per OAR 40 Groundwater Quality Protection (Found at: *http://www.deq.state.or.us/wq/rules/div040/tables.pdf*).

The presence of LNAPL in specific wells at UST Site No. 1 and Fire Training Area DUs does not present a quantifiable human health or ecological risk. Although the investigation data show that the transport pathway is not complete for migration of LNAPL to surface water and sediment in Cathlamet Bay, the potential of future migration because of extreme precipitation or tidal events is possible. Petroleum hydrocarbons as LNAPL represent a source with future potential to migrate to adjacent surface water and sediment.

Evaluations were completed of surficial near shore sediments of the Finger Pier DU and Landfill DU to determine if the DoD related releases from the landfill are a current or continuing source of dioxins/furans to near-shore sediments. Evaluations conclude that sediments show no indication of current or continuing source of dioxins/furans that could be attributed to past DoD activity.

Risk management decisions will be based on the site history, previous response actions, and comparisons to chemical and risk based regulatory criteria that are identified in this RI. The FS will address the CERCLA DUs carried forward as summarized above, for identification and evaluation of remedial alternatives to achieve risk-based goals, and will review preliminary ARARs to determine compliance with environmental laws. As appropriate, the non-CERCLA DUs will proceed with a cleanup process following applicable policy and standards.

Section 9
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