Remedial Investigation Report

Boeing Renton Plant
Renton, Washington

Submitted to:

The Boeing Company
Boeing Shared Services Group
Energy and Environmental Affairs

10 August 2001

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WO 3709-066-003-4500

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LIST OF ACRONYMS

ac-ft/yr	acre-feet per year
AOC	area of concern
APA	aquifer protection area
ARARs	applicable or relevant and appropriate requirements
ASFLs	Applicable State and Federal Laws
ASTM	American Society of Testing and Materials
BCAG	Boeing Commercial Airplane Group
BEP	bis-(2-ethylhexyl)phthalate
bgs	below ground surface
BML	Bryn-Mawr-Lakeridge
BTEX	benzene, toluene, ethylbenzene, and xylene
CAP	Corrective Action Plan
CFR	Code of Federal Regulations
cm/s	centimeters per second
CSU	container storage unit
DCE	dichloroethene
DQOs	Data Quality Objectives
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
EPH	extractable petroleum hydrocarbons
Facility	Boeing Renton Plant
FS	feasibility study
gpm	gallons per minute
HPAHs	heavy polycyclic aromatic hydrocarbons
IA	Interim Action
KCDNR	King County Department of Natural Resources
lb/ft^3	pounds per cubic foot
MEK	methylethylketone
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MTCA	Model Toxics Control Act (Washington State)

LIST OF ACRONYMS *(Continued)*

NGVD	National Geodetic Vertical Datum
Order	Agreed Order
OSHA	Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
PCE	tetrachloroethene, perchloroethylene
PCLs	preliminary cleanup levels
POC	point of compliance
PQL	practical quantitation limit
QAPjP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RFA	RCRA facility assessment
RI	Remedial Investigation
SAIC	Science Applications International Corporation
SL	screening level
SVOCs	Semivolatile Organic Compounds
SWMU	solid waste management unit
TCE	trichloroethene
TEF	toxicity equivalency factor
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TPH-D	diesel-range total petroleum hydrocarbons
TPH-G	gasoline-range total petroleum hydrocarbons
TPH-Jet-A	Jet-A fuel-range total petroleum hydrocarbons
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
USACOE	U.S. Army Corps of Engineers
USGS	U.S. Geologic Survey
UST	underground storage tank
VC	vinyl chloride
VOC	volatile organic compound
VPH	volatile petroleum hydrocarbons
VSI	visual site inspection

LIST OF ACRONYMS *(Continued)*

WAC	Washington Administrative Code
WESTON	Roy F. Weston, Inc.

EXECUTIVE SUMMARY

This Remedial Investigation (RI) report documents the investigation of potentially contaminated subsurface soil and groundwater at the Boeing Renton Plant. The work was performed by Roy F. Weston, Inc. (WESTON®) following the requirements stipulated in the 10 October 1997 Agreed Order issued to The Boeing Company (Boeing) by Washington State Department of Ecology (Ecology). This report consolidates information from previous interim reports as well as results from the final tier of the three-tiered approach for the RI.

PURPOSE AND APPROACH

The RI focused on 39 solid waste management units (SWMUs) and areas of concern (AOCs) identified in the Order where contamination of soil and groundwater was either historically known or could potentially occur. Investigative activities at each unit were conducted to: (1) determine whether a release of hazardous substances may have occurred from the SWMUs/AOCs, (2) adequately characterize the nature and extent of released hazardous substances, and (3) identify human and ecological receptors and exposure pathways. Using applicable federal and state regulations, preliminary cleanup levels were developed to compare with unit-specific hazardous substance concentrations, providing the basis for development of cleanup action alternatives which will occur for all SWMUs/AOCs recommended for Feasibility Study (FS).

As required by the Agreed Order, this report presents remedial investigation results, which were obtained in accordance with the adopted amendments (February 2001) to the Model Toxics Control Act (Chapter 173-340 WAC). The report contains the following Facility-specific information: physical characteristics (Section 2), conceptual site model (Section 3), preliminary cleanup levels (Section 4), analytical data and observations of the SWMUs/AOCs (Section 5), and recommendations for units to be further studied during the FS (Section 6).

PHYSICAL CHARACTERISTICS OF THE FACILITY

The physical characteristics of the Facility provide the foundation for the conceptual site model, with associated exposure pathways, and establish the framework for determining FS fate and transport processes. The results of fate and transport analysis will be used to evaluate the protectiveness of future cleanup actions and remediation levels.

Facility Setting

The Facility is located at the south end of Lake Washington within the Renton city limits. Boeing manufactures the 737 and 757 models of commercial airplanes, including parts preparation, mechanical assembly, coating operations, testing, and support operations associated with the final assembly of airplanes. Throughout its developed history, the Facility has been used principally for industrial purposes, which first began in 1941 as a U.S. Government Air Force seaplane facility and later expanded for commercial aircraft, with Boeing acquiring the property in 1962.

The Facility, almost entirely developed with buildings and paved surfaces, encompasses approximately 277 acres, of which Boeing owns approximately 232 acres and leases the remaining 45 acres from the City of Renton. The Boeing property is bounded to the north by Lake Washington, and crossed by the Cedar River in the western portion of the Plant. Three leased portions of the Facility are located on the Renton Municipal Airport. Two parcels are adjacent to the west side of the airstrip and one on the east side of the airstrip.

Facility Geology

Because the Facility was developed on a plain formed by the ancestral Cedar and Black rivers, its underlying geology is characterized by an alluvial sequence, comprised of silt, sand and gravel with interbedded peat. The area of the Facility and adjacent land was filled and graded to provide a usable land surface for development. Hydraulically placed fill, consisting mostly of medium- to coarse-grained silty sand with variable amounts of fine- to coarse-grained gravel, was observed from the surface to 15 feet below ground surface (bgs). Lithologic units underlying the fill in descending sequence, consist of silty sand, silt with sand and clay, peat, and interbedded silty sand and clayey silt. Ubiquitous peat and organic matter was observed in soil borings, indicative of a depositional environment during ancient fluctuations in lake and river levels.

Site Hydrological Model

The following key points of the hydrological model of the Facility provide the foundation for contaminant migration analysis, fate and transport modeling, and alternatives development in the forthcoming Feasibility Study:

- Average annual precipitation ranges from approximately 35 to 40 inches (SeaTac Airport Oct. 1948-Sept. 1996). Infiltration on the Facility is extremely low given the predominant surface cover (i.e., pavement and buildings).
- The Facility rests on hydraulically placed fill overlying a prograding alluvial fan deposited into lacustrine deposits associated with Lake Washington and is largely shoreward of the former Lake Washington shoreline. The alluvial and delta sediments of the Cedar River were deposited in a complex inter-layering with the fine-grained deposits of Lake Washington.
- Prograding alluvial fans deposited into lacustrine environments result in one of the most complex of stratigraphic sequences. The sequence contains numerous discontinuities. The discontinuities have a direct impact on groundwater flow and hazardous constituent transport. The fine-grained stratum inhibits both vertical and horizontal transport.
- The high organic carbon content of the peat layers provides for a highly adsorbent stratum for mobile constituents and limits transport. The presence of discontinuities affects the potential interconnectivity of contaminated groundwater to current and future sources of drinking water.
- Groundwater in Holocene Alluvium discharges to surface water and as such the Facility is located in an area of regional groundwater discharge and associated upward vertical hydraulic gradients.

- The groundwater flow direction in the Cedar River hydrologic basin is variable and fluctuates locally depending on municipal extraction wells, and the seasonal variability of the level of the Cedar River Waterway and Lake Washington.
- The general direction of the groundwater in Renton is radial from the mouth of the Cedar River valley toward the Cedar River Waterway and Lake Washington. This portion of the basin is a groundwater discharge zone.
- Groundwater conditions beneath the Facility are influenced primarily by fluctuations within the Cedar River Waterway and Lake Washington, and upland recharge of the Cedar River Aquifer.
- No groundwater production wells are located on or adjacent to the Facility, and there are restrictions or institutional controls in place that prevent the use of groundwater beneath the Facility for water supply.
- No part of the Facility falls within the City of Renton's Aquifer Protection Area (APA). At its closest point, the Facility lies 700 feet northwest (hydraulically downgradient) of the APA boundary.
- Fifteen water supply wells were identified within one mile of the Facility, but the hydrogeologic characteristics of the area indicate it is unlikely that any of the wells will draw groundwater from underneath the Facility because: all of the wells are upgradient of the Facility, or isolated in a different aquifer or in the case of wells west and northeast of the Facility are at elevations over 100 feet higher than the Facility.
- The high organic material content of the Holocene Alluvium has an effect on groundwater geochemistry. Decomposition byproducts, organic acids and gases, result in locally acidic conditions creating reducing conditions. These naturally reducing conditions result in locally low dissolved oxygen content, pH, and elevated dissolved metals concentrations (arsenic, iron, manganese, etc.).

SITE CONCEPTUAL MODEL

The conceptual site model provides a general framework of the Facility, identifying potential or suspected sources of hazardous substances, types and concentrations of hazardous substances, potentially contaminated media, and potential exposure pathways and receptors.

Potential Sources

The processes historically associated with the SWMUs/AOCs investigated under the Agreed Order can generally be classified under one of the following general manufacturing processes:

- Metal finishing and cleaning operations
- Steam cleaning activities
- Chemical storage for painting operations
- Fuel storage
- Compressed air generation
- Waste storage

These potential sources include a variety of containment areas, product storage tanks, waste holding tanks, and waste management areas, many of which were constructed below floor grade.

Detected Hazardous Substances

Hazardous substances detected in soil during the RI include only a limited number of chemical classes: chlorinated and aromatic volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs, which include polycyclic aromatic hydrocarbons), petroleum hydrocarbons, and inorganic constituents (i.e., metals).

Hazardous substances detected in groundwater during the RI generally comprise a smaller subset of the analytes detected in soil. Although a similar number of VOCs and petroleum hydrocarbons were detected in each media, the number of SVOCs and metals detected in groundwater was approximately half of the number of these contaminants detected in soil.

Volatile Organic Compounds (VOCs)

Of the chlorinated VOCs detected in soil, the most common (i.e., detected in more than 5 samples) were carbon tetrachloride, chloroform, cis-1,2-dichloroethene (cis-1,2-DCE), methylene chloride, tetrachloroethene (PCE), trans-1,2-dichloroethene (trans-1,2-DCE), trichloroethene (TCE), and vinyl chloride. The most common aromatic VOCs detected in soil and groundwater were benzene, toluene, ethylbenzene, and xylenes (BTEX).

Of the fifteen chlorinated VOCs detected in groundwater, the most common included PCE, TCE, their degradation products, cis-1,2-dichloroethene and vinyl chloride, chlorobenzene, 1,1-dichloroethane (1,1-DCE), chloroform, and trans-1,2-DCE. Note that this group is similar to that found in soil.

Polycyclic Aromatic Hydrocarbons (PAHs)

Of the 16 PAHs detected in soil, 14 PAHs were commonly found, including all seven of the carcinogenic PAHs (benzo[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene).

Of the six PAHs detected in the groundwater samples, only one of the carcinogenic PAHs (chrysene) was present.

Petroleum Hydrocarbons

The petroleum hydrocarbons detected during the RI included gasoline-, diesel-, jet fuel-A-, and motor oil-range petroleum hydrocarbons. All four of these petroleum hydrocarbon groups were detected in both soil and groundwater during the RI.

Inorganics

Soil samples showed the presence of 13 metal constituents, the most common of which were antimony, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc. Of the six dissolved metals detected in groundwater, the most common included antimony, arsenic, and zinc.

Migration Processes of Hazardous Substances

Based on the Facility characteristics, migration is expected to be significant only for chlorinated solvents (i.e., TCE), BTEX, and perhaps, the branched and cyclic alkanes. The HPAHs and inorganics are expected to be relatively immobile due to their strong binding affinity to soil, low water solubility, and low vapor pressure.

The predominant release mechanism for BTEX, and TCE and its degradation by-products is most likely leaching to groundwater and migration down gradient with groundwater flow to Lake Washington and/or the Cedar River Waterway. Adsorption and retardation are relatively low; therefore, eventual off-site migration of contaminated groundwater is possible if elevated concentrations of hazardous substances are left untreated. A secondary VOC release mechanism is partitioning to soil gas and evaporation to the atmosphere, but this is probably significant only for areas of shallow soil contamination. Discharge of VOCs in shallow groundwater to the surface water bodies adjacent to the site is the primary pathway for VOCs migrating to surface water.

Receptor and Pathways Analysis

Future Site Development

For the purpose of this conceptual site model, it is assumed that the Facility will retain its industrial character and that any future development will be consistent with the current zoning and land use regulations. Similarly, land use restrictions of the surrounding properties are assumed to be consistent with current regulations.

Identified Complete Pathways

Complete exposure pathways enable hazardous substances to either directly or indirectly contact human or ecological receptors through the exposure routes and are further evaluated based on the magnitude of exposure. High potential exposure pathways pose potentially significant risks to receptors due to more direct contact and greater probability of contact with the receptors, whereas low potential exposure pathways are more tenuous and will result in lower potential for exposure leading to risk.

Identified complete pathways for site contaminants include the following potential exposures:

- High potential for exposure to temporary construction workers via ingestion, dermal contact, and inhalation (particulate and volatile emissions) of hazardous substances in on-site soil;
- Low potential for exposure to temporary construction workers via dermal contact and inhalation of hazardous substance in groundwater;
- Low potential for exposure to residents/water supply consumers via ingestion, dermal contact and inhalation (of volatile organics during showering or washing) of hazardous substances in groundwater discharging to surface water;
- Low potential for exposure to fishers via ingestion of hazardous substances in groundwater discharging to surface water and bioaccumulating in aquatic biota;
- Low potential for exposure to recreational users via ingestion and dermal contact from hazardous substances in groundwater discharging to surface water;
- High potential for exposure to ecological receptors (small aquatic mammals, benthos, and fish) via ingestion and dermal contact of hazardous substances in groundwater discharging to surface water;
- Low potential for exposure to ecological receptors (piscivorous birds and raptors) via ingestion and dermal contact of hazardous substances in groundwater discharging to surface water.
- Low potential for exposure to ecological receptors (small aquatic mammals, benthos, fish, piscivorous birds and raptors) via ingestion of hazardous substances in groundwater discharging to surface water and bioaccumulating in aquatic biota.

PRELIMINARY CLEANUP LEVELS

Identification of Preliminary Cleanup Levels

The process for identifying preliminary cleanup levels (PCLs) for soil and groundwater at the Facility is consistent with the requirements outlined in MTCA (WAC 173-340-700) and incorporates the adopted amendments to MTCA (February 2001). The approach used to establish PCLs involved three steps. The first step is to identify the nature of the contamination in relationship to the conceptual site model. The second step overlays the Applicable State and Federal Laws (ASFLs) on the conceptual site model to tailor the regulatory requirements to the Facility-specific conditions and identify those requirements pertinent to the Facility. The final step includes comparing the numerical values from potential ASFLs to each other. The lowest value for each constituent was selected for the PCL in order to achieve protective values. Table ES-1 depicts the exposure pathway criteria and the regulatory provisions used in selecting the PCLs. Final cleanup levels and point of compliance will be revisited in the feasibility study and cleanup action plan.

Point of Compliance

Point of compliance (POC) means the point or points where cleanup levels will be attained (WAC 173-340-200). For evaluating hazardous substances detected in soil and/or groundwater during the RI, a standard point of compliance (i.e., at the location of potentially affected soil and groundwater throughout the Facility) is utilized. To assess whether a SWMU or AOC requires further consideration in the FS, the hazardous substances present at the units will be compared to the PCLs for each constituent. SWMUs and AOCs will not be evaluated in the FS if the concentrations of the substances are below PCLs at the standard POC.

INVESTIGATION RESULTS AND RECOMMENDATIONS

The remedial investigation was conducted in three tiers. The tiers were used only as a means of phasing investigations; the results were not used to screen out or eliminate any SWMUs or AOCs from the RI process. Tier 1 examined the historical documentation during the units’ operation and, in some cases, during closure activities, to determine whether conclusive evidence existed that demonstrated a release of hazardous substances had or had not occurred. Tier 2 was the preliminary subsurface assessment during which soil and groundwater samples were collected and analyzed for the constituents of concern; the analytical results were compared to conservative screening levels (SLs) to determine whether a release of hazardous substances may have occurred. Tier 3 provided a detailed subsurface investigation of those units in which a release was identified in Tier 2. Interim Action units identified in the Agreed Order were also incorporated into the RI process in Tier 3. The information obtained from Tier 3 was used to assess the nature and extent of the release, as well as unit-specific characteristics affecting fate and transport mechanisms.

The analytical and physical data obtained during each tier of investigation have been consolidated and evaluated to determine whether hazardous substances are present in the soil and groundwater that may threaten human health or the environment as determined by the PCLs.

SWMUs and AOCs in which concentrations of hazardous substances exceed the PCLs at the standard points of compliance are recommended for further examination under the Feasibility Study. Table ES-2 summarizes the results of the RI and presents recommendations for which SWMUs and AOCs should be further examined during the FS process. The units recommended for FS examination are SWMU-168, SWMU-172 and -174, SWMU-179, the 4-78/79 SWMU/AOC Group, the Former Fuel Farm Group, AOCs-001 through -003, AOC-004, AOC-060, and AOC-090. Figure ES-1 illustrates soil concentrations exceeding PCLs for those units recommended for Feasibility Study. Figure ES-2 illustrates groundwater concentrations exceeding PCLs for units recommended for Feasibility Study.

Units not recommended for FS examination are SWMUs-001 and -002, AOCs-005 through -011, AOC-012, AOCs-034 and -035, AOC-042, AOC-049, AOCs-050 through -052, AOC-074, and AOC-091.

CONSIDERATIONS FOR THE FEASIBILITY STUDY

Model Remedies

MTCA presumes that model remedies may be selected “to streamline and accelerate the selection of cleanup actions that protect human health and the environment” (WAC 173-340-390[1]). Circumstances at the Facility, related to common types of contamination and media, may be considered for model remedies (e.g., diesel fuel in soil) in the FS Work Plan. Should Ecology determine that the circumstances at the Facility warrant a model remedy, the components of the model remedy could be selected as the cleanup action or portion of the cleanup action, without feasibility study or a disproportionate cost analysis (WAC 173-340-390[3]). However, public notice and participation is required when a model remedy is proposed as the cleanup action or a portion of the cleanup action (WAC 173-34—390[4]).

Points of Compliance

The applicability of a conditional POC for groundwater will be evaluated during the FS. The conditional POC could include the Facility boundary and/or as close as technically possible to the point where groundwater flows into surface water (WAC 173-340-720[8][d]). The FS will include fate and transport modeling to predict the concentration of hazardous substances at the conditional POC. This modeling will consider natural processes that attenuate concentrations based on site-specific mitigating factors. Mitigating factors include partitioning, dispersion, adsorption, and degradation. SWMU/AOC-specific cleanup standards will be determined through completion of this effort.

SECTION 1

INTRODUCTION

This Remedial Investigation (RI) report has been prepared in compliance with the requirements of the Agreed Order (Order) issued by the Washington State Department of Ecology (Ecology) to The Boeing Company (Boeing) under the Revised Code of Washington (RCW) 70.105D.050(1) and Washington Administrative Code (WAC) 173-340-350. The Order (No. DE 97HZ-N233), which became effective 10 October 1997, specifies activities necessary to evaluate or correct actual or potential threats to human health and the environment resulting from the release or potential release of hazardous substances from or at the Boeing Commercial Airplane Group (BCAG)—Renton Plant (Facility). The Facility location is shown on Figure 1-1.

As required by the Order, the report presents remedial investigation results which were obtained in accordance with the Model Toxics Control Act (MTCA) (Chapter 173-340 WAC)[1] This report represents a consolidation of previously submitted interim reports, as well as the results and assessment of the Tier 3 investigation effort. The Ecology-approved scope of work for the RI program was presented in the *RI Work Plan* (WESTON 1998) and corresponding addenda (WESTON 1999a, 2000a,b,c).

This report does not incorporate the Order-directed activities associated with past discharges from selected stormwater outfalls (OF-003, OF-004, and OF-010 through OF-016) or catch basin material upstream of designated stormwater outfalls (OF-001, OF-002, and OF-005). The results and conclusions from these specific RI activities were submitted to Ecology under separate cover in the *Outfall, Shoreline, and Nearshore Sediment Sampling Report* (WESTON 1999b) and *Selected Stormwater Catch Basin Sampling Report* (WESTON 1999c).

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[1] All references and citations and references to MTCA refer to the adopted amendments, released February 2001 (Ecology 2001).

1.1 STATEMENT OF PURPOSE

After the Order became effective in 1997, Boeing contracted Roy F. Weston, Inc. (WESTON®) to investigate, consistent with MTCA, the subsurface soil and hydrogeological regime at the Facility, as well as to determine the chemical nature, extent (horizontal and vertical), and the direction and rate of migration of hazardous substances released from the Facility's solid waste management units (SWMUs) and areas of concern (AOCs). The investigation was focused on the SWMUs and AOCs identified in the Order under Attachment 2 ("Where Action is Needed") and Attachment 3 ("Where Action is On-Going"). SWMUs and AOCs identified in Attachment 4 ("Where No Action is Anticipated") have been excluded from the RI program per the Order. Two additional AOCs (AOC-090 and AOC-091) were identified after approval of the RI Work Plan and incorporated into the investigation.

Targeted toward the specific SWMUs and AOCs identified in Attachments 2 and 3 of the Order, the purpose of the RI was multileveled and included the following:

- Evaluate the possibility of hazardous substance releases.
- Characterize the hydrogeologic regime.
- Identify and characterize potential hazardous substance impacts to soil and groundwater.
- Characterize the nature and extent, and rate and direction of hazardous substance migration.
- Identify potential human and ecological receptors of released hazardous substances.
- Support the development and analyses of cleanup action alternatives .

Information gathered from the investigations will form the basis for selecting the SWMUs and AOCs that will be addressed in the Feasibility Study (FS). The FS will consist of a FS work plan, implementation of the work plan and preparation of a FS report. The FS will evaluate the technical, environmental and human health considerations, and the financial costs associated with remedial option(s) proposed for the SWMUs and AOCs identified in the RI. The FS report will contain a recommendation for one or more remedial options based on the FS evaluation of current conditions, technical, human health and environmental receptors, cost estimate and restoration time frame [WAC 173-340-350(8)(b)(c)].

1.2 RI IMPLEMENTATION

1.2.1 Primary Project Tasks

Supporting the multileveled purpose of the RI, five primary tasks were identified:

- Determination of actual or potential releases.
- Characterization of the chemical and physical environment.
- Identification of human and environmental receptors and pathways.
- Selection of preliminary cleanup levels to compare to concentrations identified in soil and groundwater.
- Recommendation of areas to be included in the FS Work Plan.

Information regarding each of the units is summarized in Tables 1-1 and 1-2, and their general location at the Facility is shown on Figure 1-2. Section 5 provides a detailed description of each SWMU/AOC and the unit-specific findings. For those units where evidence of a release was found, the nature and extent of the SWMU/AOC-specific hazardous substances and the relevant physical setting, including human and environmental receptors and pathways, were identified.

1.2.2 Project Phasing of the Release Determination and Chemical and Physical Characterization

Consistent with the Order, a phased approach was implemented in three tiers. This phased approach was used to ensure that all units were thoroughly investigated. This approach was not used to screen units out of the RI. When maintained throughout the RI, this approach allowed the investigators to address any data gaps identified in subsequent tiers of the investigation. The compiled conclusions of Tiers 1 and 2, and the results of the Tier 3 detailed investigation are documented in subsequent sections of this RI Report. A chronological summary of the primary events associated with the RI is presented in Table 1-3. Activities completed under the three tiers in the RI are described below:

Tier 1

Tier 1 activities evaluated historical information regarding the six SWMUs and 19 AOCs listed in Attachment 2 of the Order (see Table 1-1). The purpose of the Tier 1 evaluation was to determine if further subsurface investigation of each SWMU and AOC was warranted given information available on each unit's operation and closure. Historical information was examined for sampling results, closure documents, maintenance records, and site investigation reports. The unit's history, construction, subsurface characteristics, associated chemical constituents, and historical laboratory results were reviewed to assess if releases may have occurred or chemical concentrations remain above the screening levels (SLs), developed in the *RI Work Plan* (WESTON 1998a) and approved by Ecology. Screening levels are chemical-specific concentrations that can be present in soil and groundwater that were deemed by Ecology to be protective of human health and the environment, based on applicable state and federal regulations at the time the RI Work Plan was approved. The Tier 1 results were presented in the RI Work Plan. Because the Tier 1 evaluation did not conclusively determine that releases of hazardous substances had not occurred or constituents were no longer present above SLs, all units from the Order were further investigated in Tier 2. Interim Action units (Attachment 3 to the Order) were not evaluated in Tier 1 because action was ongoing at these units.

Tier 2

Tier 2 was the preliminary subsurface assessment of the six (6) SWMUs and nineteen (19) AOCs listed in Attachment 2 of the Order. The purpose of the Tier 2 Assessment was to determine if a hazardous substances release occurred during past operations. A release was indicated when hazardous substances were detected in soil or groundwater at concentrations above the SLs. The results of this investigation are documented in the *Tier 2 Assessment Report* (WESTON 1999d).

Tier 2 field activities were conducted from 17 May 1999 to 6 June 1999 and primarily consisted of soil and groundwater sample collection from push-probe locations as well as existing and newly installed groundwater monitoring wells. Samples were analyzed for constituents related to the historical processes of the SWMU or AOC and the associated degradation products of these constituents.

Analytical data were reviewed to determine if any of the samples exceeded the SLs, and if so, exceedances were evaluated for significance, relationship to a SWMU or AOC, and likelihood of a release at or from the Facility. Units with detected concentrations in soil or groundwater above SLs that were statistically insignificant or related to background concentrations did not require further subsurface investigation under Tier 3 activities but were not removed from the RI. The following units were not subjected to further field investigations in Tier 3:

- SWMU-168 (Building 5-50)
- SWMU-179 (Building 4-76)
- AOCs-005 through –011 (Building 4-44)
- AOC-012 (Building 4-45)
- AOC-034 and AOC-035 (Building 4-41)
- AOC-042 (Building 10-81)
- AOC-074 (Apron D)

The remaining SWMUs/AOCs were identified in Tier 2 investigations as having soil and/or groundwater samples containing target or nontarget analyte concentrations significantly above the SLs. These units were further evaluated in Tier 3 to fill data gaps and included the following:

- SWMU-001 and SWMU-002 (Building 4-21)
- SWMU-172 and SWMU-174 (Building 5-09 and 5-08)
- AOC-001, AOC-002 and AOC-003 (Building 4-81)
- AOC-004 (Building 4-21)
- AOC-050 through AOC-052 (Building 10-52)

Although petroleum hydrocarbons were not detected in the Tier 2 groundwater samples from AOC-050 through AOC-052, Ecology required that additional quarterly groundwater monitoring be conducted as specified in the Agreed Order and the data incorporated into the RI report.

Tier 3

The purpose of the Tier 3 detailed investigation was to obtain sufficient unit-specific information to comply with the requirements of the Order for identifying units for inclusion into the Feasibility Study. The Tier 3 program characterized the extent of hazardous substances in soil and groundwater at each unit listed in the Order. A physical characterization of the geologic and hydrogeologic conditions of the Facility was also conducted. Field activities included a groundwater and surface water interaction study, groundwater well slug tests, aquifer pumping tests, and groundwater level monitoring. Potential human and environmental receptors and pathways were identified for impacted SWMUs and AOCs.

As described in the RI Work Plan, in addition to the units that were carried forward from Tier 2, the following interim action SWMUs and AOCs listed in Attachment 3 of the Order were incorporated into the RI process in Tier 3:

- 4-78/79 SWMU/AOC Group (SWMU-181, AOC-013, AOC-014, AOC-015, AOC-026, AOC-037 and AOC-054)
- Former Fuel Farm AOC Group (AOC-046, AOC-047 and AOC-048)
- AOC-049 (Building 5-50)
- AOC-060 (Building 4-42)

Table 1-2 provides a brief description of these units. AOC-049 was not investigated for data gaps during Tier 3 because total petroleum hydrocarbon (TPH) concentrations in the groundwater have not exceeded MTCA Method A (1.0 milligrams per liter [mg/L]) since 1996 and the volatile organic compounds (VOCs) detected in the groundwater were evaluated as part of SWMU-172 and SWMU-174.

AOC-090 and AOC-091

Based on conditions discovered during construction activities at the Facility, the following units were added to the remedial investigation after submission of the Tier 2 Report:

- AOC-090 (Building 4-65 Yard)

- AOC-091 (Building 4-21, Column G-6 Elevator)

Additional information, including the results of the soil and groundwater sampling conducted at these two areas are presented in Sections 5.20 and 5.21 of this report. These two units were added to the Attachment 2 list of the Order (Table 1-1).

1.2.3 Identification of Human and Environmental Receptors and Pathways

Information assimilated during the RI was used to physically characterize the Facility, leading to the development of a site conceptual model. This model provides a conceptual understanding of the Facility by identifying potential or suspected sources of hazardous substances, contaminated media, and exposure pathways and receptors. This model is the foundation for selecting preliminary cleanup levels and will be the basis for fate and transport modeling to be evaluated in the FS.

1.2.4 Selection of Preliminary Cleanup Levels

Preliminary cleanup levels are numerical concentrations selected to compare with hazardous substance concentrations in soil and groundwater at SWMUs and AOCs in order to identify which SWMUs and AOCs require further analysis in the feasibility study process. Selection of preliminary cleanup levels was based on the actual or potential exposure pathways and receptors identified in the site conceptual model. The preliminary cleanup levels were the lowest of promulgated numerical standards potentially appropriate for the exposure pathways and receptors established in the site conceptual model.

These highly restrictive preliminary cleanup levels ensure that any unit that is not recommended for feasibility study is protective of human health and the environment. The potential applicability and appropriateness of these preliminary cleanup levels will be evaluated in alternatives development in the FS. This evaluation will take into consideration the cleanup levels' applicability in light of the physical site conditions and site conceptual model through fate and transport analysis. Proposed cleanup actions will be developed in the FS that will establish appropriate and protective cleanup levels and/or remediation levels for approval by Ecology.

1.2.5 Recommendation of Areas to be Addressed in the FS Work Plan

After comparing the preliminary cleanup levels to conditions at SWMUs and AOCs, some units were identified and recommended for feasibility study while others were not. All the units evaluated in the RI will be discussed in the FS Work Plan. Units that are not recommended for further evaluation in the FS will be identified in the FS Work Plan and proposed as candidates for no further action under the Order. A draft FS Work Plan, submitted to Ecology following approval of the RI report will discuss the units recommended for evaluation in the FS; the methods to be used in evaluating the technical, environmental and human health, and financial considerations associated with remedial options for each unit; and a proposed schedule for FS activities.

1.3 REPORT ORGANIZATION

The RI Report is organized into seven sections and a companion set of appendices:

- Section 1—Introduction. This section presents the purpose and objectives of the work plan and describes the organization of the document.
- Section 2—Physical Characteristics of the Facility. This section presents a description of the Facility's background and environmental setting.
- Section 3—Conceptual Site Model. This section provides a conceptual understanding of the Facility and identifies potential or suspected sources of hazardous substances, potentially contaminated media, and actual or potential exposure pathways and receptors.
- Section 4—Preliminary Cleanup Levels. This section presents the preliminary cleanup levels for the Facility and the applicable state and federal laws.
- Section 5—SWMU/AOC Remedial Investigation Results. This section details all RI field investigation activities conducted at each SWMU and AOC, reviews the physical characteristics of the units, presents the nature and extent of hazardous substances, and compares the results to the preliminary cleanup levels.

- Section 6—Conclusions and Recommendations. This section reviews the results of the RI and recommends units for the Feasibility Study.
- Section 7—References.

SECTION 2

PHYSICAL CHARACTERISTICS OF THE FACILITY

2.1 INTRODUCTION

The physical characteristics of the Facility are the single most important factor in predicting the transport and fate of hazardous constituents in the environment, and in determining exposure pathways. This section discusses the RI findings regarding the physical characteristics of the Facility as specified by the Order. Not only do these physical characteristics provide the foundation for the conceptual site model and associated potential exposure pathways, they also present input parameters for Feasibility Study fate and transport modeling and for evaluation of the protectiveness of future cleanup actions and remediation levels.

The future alternatives evaluation in the Feasibility Study will use these characteristics as a starting point to reevaluate the preliminary cleanup levels (see Section 4) used for screening purposes in this RI. The findings presented here should therefore be considered in the context of their role within the FS evaluation framework. The following subsections describe the Facility setting, environmental compliance history, land use, and regional and site-specific hydrogeology and hydrology.

2.2 FACILITY SETTING

2.2.1 Location and Description of the Boeing Renton Plant

The Boeing Renton Plant is located at the south end of Lake Washington within the Renton city limits, as depicted on Figure 1-1. BCAG manufactures the 737 and 757 models of commercial airplanes, including parts preparation, mechanical assembly, coating operations, testing, and support operations associated with the final assembly of airplanes.

The Facility encompasses approximately 277 acres, of which Boeing owns approximately 232 acres and leases the remaining 45 acres from the City of Renton. The Facility is bounded on the north by Lake Washington and is crossed by the Cedar River on the western portion of the Plant. Three leased portions of the Facility are located on the Renton Municipal Airport. Two parcels are adjacent to the west side of the airstrip and one on the east side of the airstrip.

The Facility use is principally industrial and is almost entirely developed with buildings and asphalt- or concrete-paved surfacing (Figure 2-1) and meets the MTCA definition for industrial properties (WAC 173-340-200). The ground surface elevation within the Facility ranges from approximately 18 to 27 feet above the National Geodetic Vertical Datum 1929 (NGVD 1929).

2.2.2 Climate

Mild temperatures and a pronounced rainy season typical of the Puget Sound region characterize the climate at the Facility, with average winter daytime high temperatures in the 40s (degrees Fahrenheit) and the nighttime temperatures in the 30s. Summer daytime high temperatures average in the 70s, with nighttime lows in the 50s. Extreme temperatures usually are of short duration. The dry season is centered on July and August, with the rainy season extending from October to March. Average annual precipitation ranges from approximately 35 to 40 inches (SeaTac Airport Oct. 1948-Sept. 1996).

2.2.3 Ecological Setting of Cedar River-Lake Washington

The Facility is located along the banks of the Cedar River Waterway at the south end of Lake Washington, which includes approximately 1,300 feet of lake shoreline and approximately 1.1 miles of the lower Cedar River Waterway. The Cedar River Waterway is the last segment of the Cedar River basin. The Cedar River basin receives 75 percent of its runoff from the Cascades. Regulated by dams, the Cedar River is partially diverted near Landsburg (over 15 miles upstream of the Facility) for domestic water supply. Lake Washington is the principal freshwater receiving body from the Cedar River Waterway, which provides at least 50 percent of the lake’s inflow.

Sediment characteristics in the Cedar River Waterway are variable along its reach, but are typified by over 50 percent cobble and gravel, with the remainder consisting of sands with little silt and organic detritus. The waterway along the Facility has been channelized and armored up to 60 percent of its length on at least one bank. The Facility's lake shoreline is composed of variable materials including fill, riprap, concrete walls, metal sheet piling and natural soils/sediment.

The Cedar River/Lake Washington system includes salmonid habitat for sockeye, coho, and chinook salmon, and steelhead trout populations. The Cedar River also provides habitat for populations of pygmy whitefish and bull trout. Aquatic and terrestrial birds also frequent the waterway with gulls, dabbling ducks, and Canada geese commonly observed, and occasional sightings of bald eagles and great blue and green herons. Mammals such as beaver and river otter have also been observed. Benthic and epibenthic invertebrates reside within the river and lake sediments of the system. Recreational activities include fishing, swimming, water skiing, and boating at the River Park (Figure 2-5) and lakeshore (King County 1995).

The Cedar River has been designated "water quality limited" due to sporadic exceedance of the state water quality standard for fecal coliform, most likely caused by upstream sources of livestock and human wastes (e.g., malfunctioning septic systems) (King County 1995). The City of Renton also has a stormwater outfall that discharges to the Cedar River Waterway near the west end of North 6th Street.

2.3 FACILITY BACKGROUND

The Facility is located on property that was selected by the U.S. Government in 1941 for an Air Force seaplane facility. That year, construction was initiated on a 95-acre parcel of the property that was originally a marsh. A 5,000-foot runway was constructed in 1945 west of the original parcel on land reclaimed from Lake Washington, which later became the City of Renton Municipal Airport. In 1947, the U.S. Government phased out aircraft production. In 1955, Boeing resumed aircraft production at the site and, in 1962; Boeing purchased the original 95 acres from the Air Force. Currently, Boeing owns approximately 232 acres and leases approximately 45 acres from the City of Renton.

On 8 August 1980, Boeing notified the U.S. Environmental Protection Agency (EPA) Region X of its dangerous waste management activities at the Facility, and the EPA assigned them generator identification number WAD009262171. On 18 November 1980, Boeing filed the original Resource Conservation and Recovery Act (RCRA) Part A permit application for the storage of dangerous wastes in a container storage unit (CSU) at Building 4-78 and in dangerous waste tanks at the Facility. In May 1990, a visual site inspection (VSI) was performed as part of a RCRA Facility Assessment (RFA) by Science Applications International Corporation (SAIC) on behalf of EPA, Region X. Ecology had previously approved closure of all tanks covered in the original Part A permit application. In December 1997, the above-grade portions of the existing Building 4-78 CSU were closed in accordance with the Ecology-approved plan. Currently, the Facility does not store hazardous wastes for more than 90 days.

On 4 November 1994, Ecology obtained authorization from EPA Region X to implement RCRA corrective action requirements using an enforceable order or decree pursuant to MTCA regulations, which are specified in Chapter 173-340 WAC. Therefore, Boeing and Ecology signed the Order, which became effective on 10 October 1997.

2.4 LAND USE

Figures 2-2 through 2-5 show the location of industrial, commercial, residential, and public use properties in relationship to the Facility, based on information obtained from a City of Renton zoning map (dated 2 August 1996).

Industrial—The Facility and a portion of land surrounding it are zoned for industrial use (Figure 2-2). The PACCAR truck plant located southeast of the Facility (at the southeast corner of North 8th Street and Garden Avenue North) is the largest adjacent parcel of industrial zoned property (approximately 82 acres). Approximately 48 acres of industrial property is located east of the Facility at the northeast corner of North 8th Street and Garden Avenue North. Three smaller parcels (each less than 15 acres) zoned for industrial use are also located within 0.5 mile south of the Facility boundary. A small portion of Boeing's property near North 6th Street and Park Avenue North is zoned commercial.

Commercial and Commercial/Residential—Land zoned for mixed use commercial and commercial/residential includes small areas west and south of Renton Municipal Airport, within

0.25 mile of the properties leased by BCAG (Figure 2-3). Small parcels are located within 0.25 mile of the Facility along Park Avenue North. These commercial properties are near Boeing office buildings such as Building 10-20 (Figure 2-1). Additional small parcels are also located within 1 mile to the south and east of the of the Facility boundary. A parcel northeast and abutting the Facility was recently rezoned from industrial to commercial.

Residential—The closest residential-zoned properties are located south of North 6th Street, south of BCAG Building 10-20 (Figure 2-4). Residential properties are also located within 0.25 mile west and south of the Renton Municipal Airport. Property located east of Interstate 405 (within 0.5 mile of the Facility boundary) is also zoned as primarily residential.

Public Use—Public use areas include land reserved for municipal and/or recreational purposes. The largest public use area located near the Facility is the Renton Municipal Airport (Figure 2-5). In addition, Cedar River Trail Park is located adjacent to the Facility, along the east side of the Cedar River Waterway, and extends north to Lake Washington. Cedar River Park and Liberty Park are located at the intersection of Interstate 405 and the Maple Valley Highway, approximately 0.7 mile south-southeast of the Facility boundary. Coulon Beach Park is also located on Lake Washington, approximately 0.25 mile northeast of the Facility boundary. Water sport activities, including fishing, boating, and water skiing, occur on Lake Washington.

2.5 GEOLOGY

2.5.1 Regional Geology

The Facility is located within the Puget Sound basin; a major north-south trending topographical and structural depression, extending north to the Canadian Border and south to Oregon, and extending east to the Cascade Range and west to the Olympic Mountains. The basin is a slightly curved, convex-eastward basin created by subsidence of the Juan de Fuca Plate beneath western Washington. Sediment filling the basin is the result of numerous southward incursions of continental ice from Canada into the basin during the Pleistocene Age (1.8 million years ago). At least five major and several lesser glacial advances are recorded. In the central Puget Sound basin, each incursion is characterized by a complex sequence of lacustrine deposits, advance and recessional outwash, glaciomarine drift, and till (Galster and Laprade 1991).

Details regarding the bedrock beneath the Quaternary fill are sparse and have been derived mostly from gravity and magnetic data, several deep borings, projection of surface exposures along the flanks of the basin, and several bedrock outcrops (Galster and Laprade 1991). Figure 2-6 presents the stratigraphy of Tertiary and Quarternary deposits in the area. These deposits consist of folded and faulted Tertiary (Eocene to Oligocene) marine and estuarine sedimentary deposits together with basalt, andesite, volcaniclastic rocks, and coal-bearing sedimentary rocks, which are mainly found along the Cascade flank of the basin east and south of Seattle.

2.5.2 Local Geology

North-south trending elongate ridges and drift uplands dominate the local geology in the vicinity of the Facility. The uplands are separated by large glacial age troughs that are now occupied by large lakes (Lake Washington), tidal waters or have been alluviated by streams (Cedar River) that inherited the troughs following the most recent retreat of glacial ice from the Renton area. The Facility occupies a position in the southern end of the Lake Washington trough at its confluence with the northern end of the Green River trough (Galster and Laprade 1991). The geology at the confluence of these two troughs is dominated by a post-glacial alluviation by the Cedar River. The Cedar River discharge deposited an alluvial fan and prograding deltaic complex into the troughs, isolated Lake Washington, and alluviated the northern end of the Green River trough. Figure 2-7 illustrates a generalized geologic cross-section through the Facility and the relationship between the alluviated trough and drift uplands.

The stratigraphic complexity of the Holocene to Recent Alluvium that comprises the Cedar River alluvial fan and prograding deltaic complex is well understood because it has been exploited for municipal water supply use (CH2M Hill 1988a,b, 1989; City of Renton 1999; Hart Crowser 1989; Shannon and Wilson 1979, 1994; RH2 1989; and RH2 and Pacific Groundwater Group 1989). A representative geologic cross section is presented in Figure 2-8, its location shown on

Figure 2-9. The geologic section illustrates the progressive fining (both horizontal and vertical upwards) sequence with distance from the mouth of the Cedar River.

Coarse-grained sand and gravel deposits are present at the mouth of the Cedar River. These coarse deposits at the valley mouth are also referred to as the Downtown Aquifer (City of Renton 1999). (See Section 2.6.2.2 for a discussion on groundwater use and extraction wells.) Beyond the lateral extent of the coarse deposits, the alluvial and deltaic deposits of the Cedar River were deposited in a complex inter-layering with the fine-grained deposits of Lake Washington. The Holocene Alluvial deposits become progressively finer grained in a radial outward direction, grading from sand and gravel to silty sand. Ultimately, silts and layers of peat, indicative of lake-type deposits, are encountered. The highly productive sand, gravel and cobble deposits commonly associated with the Downtown Aquifer excludes the less productive lacustrine deposits associated with Lake Washington (CH2M Hill 1988b).

The Facility rests on the less productive lacustrine deposits (Figure 2-8) associated with Lake Washington and is largely outboard of the former Lake Washington shoreline (Figure 2-9). This fact is supported by deep borings that encountered the fine-grained lacustrine and peaty deposits beneath the Facility (Shannon and Wilson 1979, 1994; and Hart Crowser 1989). This unproductive stratigraphy is not included in the definition of the Downtown Aquifer.

Prograding alluvial fans deposited into lacustrine environments result in one of the most complex of stratigraphic sequences. All sedimentary beds deposited in this sequence are controlled by the laws of physics and are discontinuous (Scruton 1960). The numerous discontinuities have a direct impact on groundwater flow and hazardous constituent transport. The fine-grained stratum inhibits both vertical and horizontal transport. The high organic carbon content of the peaty layers provides for a highly adsorbent stratum for mobile constituents and limits transport. The presence of discontinuities affects the potential interconnectivity of contaminated groundwater to current and future sources of drinking water.

2.5.3 Site Geology

The Facility is located at the terminus of the Cedar River valley, which was formed by post-glacial erosion and partially filled by post-glacial and non-glacial sediments. Following the last glacial retreat, the ancestral Cedar and Black rivers eroded a channel into the glacial drift plain and deposited a sequence (approximately 100 feet thick) of alluvial sediments. The alluvial sequence is comprised of sand and gravel with interbedded peaty silt beds (CH2M Hill 1988).

The Facility and City of Renton were developed on the alluvial plain formed by the ancestral Cedar and Black rivers. From 1911 to 1916 the construction of the Lake Washington Ship Canal and the Chittenden Locks (in Ballard) produced major changes to Lake Washington and surrounding areas. The completion of the canal and locks in 1916 resulted in a drop in the lake level of approximately 8 to 10 feet, which redefined the lake shoreline shown in Figure 2-9. In addition to lowering the lake level, the channel of the Black River, which was the original natural outlet for Lake Washington, was filled along almost its entire length in 1917. During this same period, the Cedar River was diverted from the Black River into a waterway discharging into the southern end of the lake (Figure 2-9). The diversion of the Cedar River into Lake Washington via the Cedar River Waterway provides a steady source of freshwater to Lake Washington and sustains the operation of the Chittenden Locks (Chrzastowski 1983).

The lowering of Lake Washington and the rechannelization of the Cedar River resulted in significant changes in the southern lakeshore. The area of the Facility and adjacent lands were filled and graded to provide a usable land surface for development. Much of this fill was hydraulically placed sand and silt.

Based on the *Tier 2* (WESTON 1999d) and Tier 3 site investigations, two distinctive subsurface geological units, the Fill Unit and the Alluvium Unit, have been identified underlying the Facility. Figure 2-10 shows a generalized stratigraphic column of these units.

2.5.3.1 Fill Unit

The uppermost geological unit underlying the Facility is the Fill Unit (Figure 2-10). The Fill Unit was hydraulically placed along the new shoreline of Lake Washington after the lake level was lowered in order to provide suitable land area for development. During the Tier 2 and Tier 3 investigations, fill was encountered throughout the Facility at depths ranging from 0 to 15 feet below ground surface (bgs) and consisted mostly of greenish-brown, medium- to coarse-grained silty sands with variable amounts of fine to very coarse gravel. Other types of soil debris such as construction debris and refuse (i.e., asphalt, glass, paper) were observed locally within this unit.

2.5.3.2 Alluvium Unit

Beneath the hydraulically placed fill, interbedded sand and silt deposited by the ancestral Black and Cedar rivers was encountered (Figure 2-10). Alluvium has been found as shallow as 2 feet bgs and consisted mostly of greenish-gray silts and sands with minor amounts of clay and gravel interbedded with greenish-gray, medium- to coarse-grained sand with silt and variable amounts of gravel and local peat deposits. Based on the Tier 2, Tier 3, and other subsurface investigations, four distinct sedimentary facies have been identified within the alluvium beneath the Facility. Listed in descending order (shallow to deep) and illustrated in Figure 2-10, these four facies consisted of the following:

- Silty sand
- Silt with sand and clay
- Peat
- Interbedded silty-sand and clayey-silt

The thickness of the sand beds encountered at the site typically ranged from 5 to 20 feet and consisted of fine- to medium-grained greenish-gray sand with variable amounts of silt and occasional traces of clay. Thin gravel stringers (1 inch or less) were common within the sand. The sand gradually became coarser with depth and had a subangular character.

The silt layers usually ranged from 3 to 25 feet and consisted of greenish-gray silt with very fine-grained sand and some clay. With typically low to medium plasticity, the silt occasionally graded into silty clay as clay content surpassed the silt in layers of 2-foot thickness or less.

Several peat beds (typically less than 5 feet thick) were observed at different horizons during the subsurface investigations conducted at the site. A shallow peat bed (15 to 20-feet bgs) was encountered at groundwater monitoring wells GW049, GW050, GW051, and GW052 (AOC-001 and AOC-002) in the northeast portion of the Facility.

Two additional peat beds were observed in the deeper borings associated with AOC-090. The uppermost peat layer was located approximately 24 feet bgs. A second and deeper peat layer was observed at 28 to 34 feet bgs. Both peat horizons were less that 2 feet thick and may represent historical changes in the lake levels or changes in the depositional environment as the Cedar and Black river channels meandered through the area.

The nature of the deposits below the second peat layer changes as thin interbedded beds of sand and silt, typically less than 1.5-feet thick, were observed in contrast to the layers (several feet thick) of the shallower sands and silt. These deposits may represent ancient seasonal flooding events on the ancestral Cedar and Black river's floodplain.

The total thickness of the alluvium beneath the Facility is not known, but is expected to be greater than 100 feet. Geologic cross-sections N-S and E-W (Figures 2-11, 2-12 and 2-13) illustrate the typically fine-grained, laterally discontinuous, and interbedded nature of the near surface stratigraphy of Holocene Alluvium beneath the Facility. Section 5 of this report contains detailed cross-sections of the individual SWMUs/AOCs that better represent the heterogeneity of these deposits beneath each SWMU and AOC.

2.6 HYDROLOGY AND REGIONAL HYDROGEOLOGY

2.6.1 Surface Water Hydrology

The Facility is bordered by two surface water hydrological units: Lake Washington to the north and 1.1 miles of the Cedar River Waterway to the west. The Cedar River Waterway is the last segment of the river basin prior to reaching Lake Washington. The waterway was constructed in 1917 when the Cedar River was diverted into Lake Washington.

The Cedar River basin receives 75 percent of its runoff from the Cascade Range, and is divided into an upper and lower section by the Landsburg Dam located over 15 miles upstream of the Facility. At the Landsburg Dam, a portion of the Cedar River flow is diverted for domestic water supply. Sediment characteristics in the Cedar River Waterway are variable along its reach, but are typified by over 50 percent cobble and gravel, with the remainder consisting of sands with little silt and organic detritus.

During 1999, the U.S. Army Corp of Engineers (USACOE) constructed floodwalls and earthen levees for flood control along the Cedar River Waterway from the Logan Avenue North bridge to the mouth of the Cedar River. The concrete floodwalls (maximum height of approximately 10 feet above grade) were constructed above interlocking steel sheet piles driven to a minimum depth of 21 feet bgs. Figure 2-11 shows the location of the sheet piling installed along the Cedar River Waterway. Earthen levees were constructed in areas where the sheet piling was not installed.

The Cedar River's discharge rate within the City of Renton is monitored by the U.S. Geological Survey (USGS) at the Renton gauging station (Station Number 12119000). This station is located approximately 2,000 feet upstream of the Logan Avenue bridge near the Bronson Way North bridge. Gauging station data collected from January 1987 through September 1999 (Figure 2-14) indicate summer discharge rates ranging from less than 200 cubic feet per second (cfs) to occasional peak flows exceeding 4,000 cfs, with an average rate of approximately 700 cfs. The maximum flow rate during this 12-year period was approximately 8,000 cfs, and the stage at this gauging location ranged from 7.3 to 16.4 feet above a datum of 15.2 feet NGVD 1929.

Lake Washington is the principal freshwater receiving body from the Cedar River Waterway, which provides at least 50 percent of the lake's inflow. Lake Washington is the largest lake in Washington west of the Cascade Range. The lake has a total water area of approximately 28 square miles and a total shoreline length of approximately 71.5 miles (Chrzastowski 1983).

2.6.2 Regional Hydrogeology

Groundwater in the Puget Sound Region is obtained mostly from the Pleistocene unconsolidated sedimentary rocks of glacial origin collectively called the glacial-drift aquifer. This aquifer is composed chiefly of glacial outwash and the more permeable units within the glacial till prevalent in the region (Evans and Jensen 1996). Because of the variability in the composition of these deposits, the water-yielding capacities of this aquifer vary greatly. However, coarser layers can yield up to 10,000 gallons per minute (gpm).

Smaller hydrologic basins exist locally within the glacial-drift aquifer. The Facility lies at the northwest extent of the Cedar River hydrologic basin that includes the sand, silt, and gravels of Holocene alluvium deposited along the ancestral Cedar and Black rivers. Four distinct geologic and hydrostratigraphic units have been identified within the basin (Evans and Jensen 1996):

- Recessional outwash and Holocene Alluvium comprise the uppermost aquifer in the basin, which is believed to extend to approximately 60 feet bgs.
- A non-water-bearing till unit (Vashon age) typically underlies the alluvium, although it is not present in the vicinity of the City of Renton.
- Underlying the till is the advance/recessional alluvium, which, except for the modern alluvium previously described, is the uppermost aquifer in the basin and extends to approximately 150 feet bgs.
- Underlying the advance/recessional alluvium is another non-water-bearing unit consisting of glaciolacustrine deposits of silt and clay.

Below the four units listed above, several deep water-bearing units are present at depths between approximately 200 feet bgs and bedrock. The depth to bedrock below the Cedar River valley is typically greater than 350 feet bgs.

2.6.2.1 Hydrostratigraphy and Flow

Locally, the regional hydrostratigraphic interactions are simplified as represented in Figure 2-16. Upland groundwater-bearing units provide recharge to the Holocene Alluvium. The Holocene Alluvium rests on non-groundwater-bearing drift and bedrock. Groundwater in the Holocene Alluvium discharges to surface water. Hence, the Facility is located in an area of regional groundwater discharge and associated upward vertical hydraulic gradients.

The groundwater flow direction and hydraulic gradients in the Cedar River hydrologic basin are variable and fluctuate locally, depending on the location with respect to municipal groundwater production wells and the seasonal variability of the level of the Cedar River Waterway and Lake Washington. However, the general direction of groundwater flow from the mouth of the Cedar River valley is radial toward the Cedar River Waterway and Lake Washington. A conceptual model of the hydrologic features associated with the Facility is depicted by cross-sections A-A' (Figure 2-16) and B-B' (Figure 2-17), the locations of which are shown on Figure 2-15. This portion of the basin is a groundwater discharge zone. Figure 2-18 presents groundwater flow directions in a portion of the basin.

2.6.2.2 Groundwater Use, Production Wells and Aquifer Properties

Most of potable water at the Facility and in the City of Renton is obtained from groundwater; however, no production wells are located on or adjacent to the Facility. The City of Renton obtains groundwater from two well fields. Seven extraction wells are located within 1 mile of the Facility, including RW-1, RW-2, RW-3, RW-5A, EW-3, PW-8, and PW-9 (Table 2-1) (Map ID numbers 1 through 7). Of these, five production wells (RW-1, RW-2, RW-3, PW-8, PW-9) are located near the intersection of Interstate 405 and the Maple Valley Highway, approximately 0.5 to 0.7 mile south-southeast (i.e., hydraulically upgradient) of the Facility boundary. Ecology allocates 14,809 acre-feet per year (ac-ft/yr) of water to be drawn from the well field, equivalent to roughly 9,181 gpm (City of Renton 1999). Pumping rates for the individual wells range from 800 (PW-9) to 3,500 gpm (PW-8). The downtown wells are screened within the Cedar River Aquifer at intervals of roughly 50 to 105 feet bgs. Wells RW-5A and EW-3 are not normally operated by the City of Renton (Carolyn Boatsman, City of Renton, personal communication).

The City's second well field is located in the Maplewood Golf Course, approximately 2.2 miles southeast of the Facility boundary. Two wells (PW-11 and PW-17) are screened from 284 to 344 feet bgs with a production capacity of 1,500 to 2,500 gpm. The wells appear to produce water from glacial sediment older than the Cedar River Aquifer.

The City of Renton has defined the boundaries for an Aquifer Protection Area (APA) based on the capture zone of their groundwater recovery wells and their city limits. None of the properties leased or owned by the BCAG falls within the APA, as presented in Figure 2-15. The closest

BCAG property to the APA is the southwest corner of the Facility, located approximately 700 feet northwest and hydraulically downgradient of the APA boundary.

A search was performed to identify additional active and inactive water wells within a 1-mile radius of the Facility. The search radius included the areas designated as Township 23N, Range 5E, Sections 4 through 9 and 16 through 20, and Range 4E, Sections 1, 12, and 13 on USGS topographic maps. In addition to the seven City of Renton wells discussed above, and based on information obtained from Ecology, the Bryn Mawr-Lakeridge Water District, the King County Department of Health, and the USGS, 15 wells were identified within the designated area (Figure 2-19). Information pertaining to these wells is provided in Table 2-1.

The Bryn Mawr-Lakeridge Water District reported that it owns six wells within the search radius, all of which are located within the same 80-acre parcel of Section 12, Range 4E, to the west of the Facility (Figure 2-19). Three of these wells are currently operating; they are identified in Table 2-1 as BML-5, BML-6, and BML-7. BML-6 and BML-7 reportedly operate intermittently at pumping rates ranging from 0 to 67 gpm. BML-5 is an artesian well approximately 15 feet deep that operates on a float system; the normal extraction rate is roughly 30 gpm. The other three wells are reportedly no longer used.

The King County Department of Health reported the existence of nearly 30 wells within the 1-mile radius in which the present conditions are unknown . According to USGS records, all but seven of these are reported destroyed (Lane, Ron, USGS, personal communication, 20 October 2000). No additional information was available in USGS records regarding the seven remaining wells. Based on known location and ownership information, five likely belong to the Bryn Mawr-Lakeridge (BML) group discussed above, including the three inoperative wells. The information available on these wells implies that the depths of the inoperative wells likely range from 150 to 160 feet bgs (Map ID number 11, 12, and 13 on Table 2-1). The other two wells are those identified as belonging to “Mr. James Banker” (Map ID number 14) and “Puget Western” (Map ID number 15) on Table 2-1. The exact locations of these two wells are unknown.

The hydrogeologic characteristics of the area indicate it is unlikely that any of the 15 wells identified within the search radius will draw groundwater from underneath the Facility or will be affected by conditions there. Evidence for the protection of these wells is as follows:

- Hydraulic Gradient: Hydraulic gradients calculated from three sets of site-wide groundwater elevation data (9 June 1999, 31 March 2000, and 7 September 2000) show that groundwater flow in the site vicinity is directed seasonally toward the Cedar River or Lake Washington. All 15 wells mentioned above are upgradient of the Facility.
- Cedar River Hydraulic Divide: The Cedar River acts as a hydraulic divide that essentially isolates potentially contaminated Facility groundwater on one side of the river from that on the other side. Since the majority of the Facility property is located to the east of the Cedar River, wells located to the west (including the six BML wells, the James Banker well, and Puget Western well) are hydraulically segregated from the main portion of the Facility.
- Elevation: The BML wells to the west and the well to the northeast of the Facility (RW-5A) are located among the hills bordering the City of Renton at elevations of approximately 236 to 350 ft. In comparison, the surface elevations of the Facility property are between approximately 18 and 27 feet (NGVD 29). Based on screened interval information, the total depths of all but three surrounding wells (BML-6, BML-7, and RW-5A) are at elevations over 100 feet higher than the Facility, within the formations comprising the hills.
- Aquifer: In addition to being located hydraulically upgradient of the Facility property, RW-5A is isolated from site conditions because it draws from a different aquifer than those present beneath the Facility.
- Aquifer Protection Areas: The City of Renton has defined the boundaries for APA based on the capture zone of their groundwater recovery wells and the city limits. None of the properties owned or leased by the BCAG falls within the APA. The southwest corner of the Facility is the closest point to the APA; it lies 700 feet northwest (hydraulically downgradient) of the APA boundary (Figure 2-15).

2.7 SITE HYDROGEOLOGY

The Facility is generally located downgradient of the Cedar River Aquifer. The Cedar River Aquifer is defined as the highly productive sand, gravel and cobble deposits of the Cedar River valley and deposits west of the valley mouth. The northwest portion of the Cedar River Aquifer that includes the coarse deposits at the valley mouth is also referred to as the Downtown Aquifer (City of Renton 1999). The northwestern extent of the Cedar River Aquifer is located near the southern portion of the Facility boundary (Figure 2-18), and represented as the sand and gravel portion of the delta illustrated in the cross section on Figure 2-8.

Beyond the lateral extent of the Cedar River Aquifer (Figure 2-18), the alluvial and delta sediments of the Cedar River were deposited in a complex inter-layering with the fine-grained deposits of Lake Washington. The Cedar River valley deposits become progressively finer grained in a radial outward direction, grading from sand and gravel to silty sand. Ultimately, silts and layers of peat, indicative of lake-type deposits, are encountered. The highly productive sand, gravel and cobble deposits commonly associated with the Cedar River Aquifer, excludes the less productive lacustrine deposits associated with Lake Washington (CH2M Hill 1988b).

The Facility rests on the less productive lacustrine deposits associated with Lake Washington and is largely shoreward of the former Lake Washington shoreline (Figure 2-9). This fact is supported by deep borings that encountered the fine-grained lacustrine and peaty deposits beneath the Facility (Shannon and Wilson 1979, 1994; and Hart Crowser 1989). This unproductive stratigraphy is not included in the definition of the Downtown Aquifer is because it is not technically or economically viable for a municipal drinking water source.

The distance between the Facility and the Downtown Aquifer extraction wells varies (see Figure 2-18). The closest distance between an affected groundwater plume and an extraction well is about 3,000 feet. The extraction wells are located upgradient of the Facility, and screened in a deeper water-bearing zone than the shallow, unproductive lacustrine deposits present beneath the Facility.

2.7.1 Hydrostratigraphy and Flow

The geology beneath the Facility consists primarily of the Holocene alluvium interbedded sand, silt, and clay deposited by the Cedar River, Black River and Lake Washington. The coarser water-bearing portions of these deposits, primarily consisting of fine to coarse sand, comprise the uppermost alluvium unit of the Downtown Aquifer as described in the previous section. The sand units are locally separated into various water-bearing horizons by less permeable layers of silt and clay. Shallow groundwater is under unconfined water table conditions, whereas deeper groundwater units are generally under semiconfined to confined conditions.

Groundwater conditions beneath the Facility are influenced primarily by fluctuations within the Cedar River Waterway and Lake Washington, and upland recharge of the Cedar River Aquifer. The lake level is lowered by the USACOE approximately 2 feet during the winter months to reduce shoreline storm damage and allow storage of peak stormwater runoff. The twice-yearly lake level changes affect the groundwater regime near the lake, and to a lesser degree, within the Cedar River Waterway. Water levels within the Cedar River Waterway vary seasonally with high flows occurring during the winter and spring and low flows during the late summer and fall.

The water table at the Facility is relatively shallow, ranging from approximately 2 feet bgs near Lake Washington's shoreline (in the northern area of the site) down to 11 feet bgs west of the Cedar River Waterway (near the southwest portion of the site). Water levels vary seasonally by 1 foot or more. The seasonal difference in groundwater elevations can exceed 2 feet during years of flooding or drought.

The groundwater flow direction beneath the Facility is variable and fluctuates locally. Investigations conducted at the Facility indicate that the groundwater flow direction generally varies from west to north (Figure 2-20) toward the Cedar River Waterway and Lake Washington. The hydraulic gradient across the Facility varies with an average gradient of 0.002 foot per foot (ft/ft). The groundwater flow direction and hydraulic gradient fluctuate depending on the location within the Facility and the seasonal variability of the level of the Cedar River Waterway and Lake Washington. A conceptual model of the hydrologic features associated with the

Facility is depicted by cross-sections A-A’ (Figure 2-16) and B-B’ (Figure 2-17), the locations of which are shown on Figure 2-15.

2.7.2 Groundwater Elevations, Gradient and Groundwater/Surface Water Interactions

This section presents the results of groundwater flow evaluations in the shallow aquifer beneath the Renton Facility. Groundwater elevations, flow directions, and horizontal and vertical gradients were determined from the results of RI groundwater elevation studies. A discussion of the groundwater and surface water interaction study is also included in this section.

2.7.2.1 Groundwater Elevations

Groundwater elevation data were collected from selected monitoring wells on 9 June 1999, 31 March 2000, and 7 September 2000 (Table 2-2). The seasonal variation in water levels observed in a particular hydrogeologic unit depends upon a complex variety of factors including the amount of recharge, the porosity and permeability, the topography, the depth of water table, and the proximity to recharge and discharge areas. The horizontal flow direction and gradient for the shallow aquifer was interpreted from groundwater elevation data and contour maps generated from water level studies. Groundwater elevation contours based on the 1999 and 2000 groundwater elevation data are shown in Figures 2-20, 2-21, and 2-22.

The water table at the Facility is relatively shallow, ranging from approximately 2 feet bgs near the Lake Washington shoreline (in the northern area of the Facility) down to 11 feet bgs west of the Cedar River Waterway (near the southwest portion of the Facility).

Groundwater elevations recorded in wells completed in the shallow sand aquifer ranged from 14.16 to 20.34 feet during June 1999 measurements; from 13.75 to 22.08 feet during March 2000 measurements; and from 11.91 to 21.57 in September 2000. Water levels in wells generally dropped between the March and September 2000 measurements. The largest water level change recorded was 3.66 feet in well GW065, but the average change was 0.94 feet.

2.7.2.2 Horizontal Gradients

Hydraulic gradient, defined as the change in groundwater elevation with distance, is a key parameter governing the direction and rate of groundwater flow and contaminant migration. Horizontal gradients were calculated using groundwater elevations for 80 well pairs completed in the shallow aquifer unit. Horizontal gradients were calculated using the following equation:

$$i_h = dh/dl$$

where : i_h = horizontal gradient (feet/feet)
dh = difference in groundwater elevation (feet)
dl = horizontal distance between wells (feet)

The horizontal gradient calculations are provided in Appendix B.

Calculated horizontal gradients observed in the shallow wells ranged from 0 to 0.015, with an average of 0.002. In general, horizontal gradients at the site are relatively flat. The steepest gradients are evident in the shallow aquifer in the vicinity of the Former Fuel Farm and the shallowest gradients are present in the vicinity of Lake Washington.

2.7.2.3 Vertical Gradients

Vertical gradients were calculated for 10 well pairs, and were calculated using the following equation:

$$i_v = dh/dl$$

where: i_v = vertical gradient (feet/feet)
dh = difference in groundwater elevation (feet)
dl = vertical difference between the midpoint of well screen (feet)

The vertical gradient calculations are provided in Appendix B.

Vertical gradients between shallow and deep wells typically were upward reflecting the fact that the Facility is located in an area of regional discharge. Calculated vertical gradients between the shallow and deep wells ranged from less than 0.001 to 0.024 with a mean of 0.009, and were generally one and as much as two orders of magnitude greater than the calculated mean horizontal gradients, indicating that gradients are greater for vertical groundwater flow than for the horizontal component of groundwater flow.

2.7.2.4 Groundwater-Surface Water Interaction Study

Continuous groundwater and surface water measurements were performed in the Cedar River Waterway and selected monitoring wells in May 2000. The purpose of the measurements was to assess the potential hydraulic connection between shallow groundwater and adjacent surface water bodies.

Sheet piling is installed to a minimum depth of 21 feet bgs along the Cedar River Waterway in the vicinity of SWMU-172, but is not present along the river in the area of AOC-060 (Figure 2-11). Water level data from these two areas were collected to evaluate the effectiveness of the sheet piling to reduce groundwater and surface water interaction.

Pressure transducers were installed in selected monitoring wells adjacent to the Cedar River Waterway as shown on Figure 2-23. Wells selected for the groundwater and surface water interaction monitoring study included:

- GW147, GW150 and GW160 (AOC-060, Building 4-42)
- GW136 and GW152 (SWMU-172, Building 5-09)

Wells GW136 and GW152 are located downstream of the Logan Street gauge and upstream of the Apron D gauge. These wells are also located upgradient of a sheet pile hydraulic barrier placed by the USACOE along the west bank of the waterway. Wells GW147, GW150 and GW160 are located downstream of the Apron D gauge.

To enable surface water measurements to be recorded, two stilling wells or gauges were installed within the Cedar River and one was installed in Lake Washington. Of the stilling wells within the Cedar River, one was attached to the northern abutment of the Logan Avenue bridge and the other was attached to the eastern abutment of the Boeing Apron D bridge (see Figure 2-23). The Facility stilling well for Lake Washington was installed on a bulkhead north of Building 4-41.

Water levels were recorded in the monitoring wells and the Logan Street stilling wells using individual pressure transducer/data logger units with rated resolution of 0.001 foot. Water levels in the Apron D and Lake Washington stilling gauges were monitored with data logger/pressure transducer units with a rated resolution of 0.01 foot. All locations were surveyed relative to NGVD 1929. Data loggers recorded measurements at 20-minute intervals at these locations from 1 May to 1 June 2000. Hourly barometric pressure data for Boeing Field was obtained from the National Weather Service. During this time, fluctuations in the river level at the USGS Cedar River at Renton station were monitored via the Internet. The water elevation recorded in the monitoring wells and stilling gauges is presented in Appendix B.1.

Water levels in the Cedar River Waterway, as recorded in the stilling gauges, generally declined during the monitoring period. Water levels at the Logan Street stilling gauge ranged from 18.83 to 18.47, a variation of 0.36 foot, and at the Apron D stilling gauge ranged from 15.56 to 15.16 feet, a change of 0.4 feet. During the monitoring period, water levels in Lake Washington varied by 0.23 feet at the Facility stilling well and varied by 0.3 feet at the USACOE Ballard gauge.

Water levels in the Cedar River Waterway as recorded at Logan Street were about 3 feet higher than water levels at the Apron D bridge. The difference between water levels at the Apron D bridge and those at Lake Washington was generally less than 0.2 feet. The water level variations recorded at the Logan Street stilling gauge did not mirror those recorded at the Apron D bridge. The general water level patterns were expected to be similar at these gauges. The reason for the dissimilar patterns is not clear, but may result from resolution limitations of the water level monitoring equipment used at the Apron D gauge. Another possible explanation is that water levels variations at the Apron D stilling well are modified as the river flows into and interacts with Lake Washington.

Water levels in the monitoring wells varied by about 0.2 to 0.4 foot during the monitoring period. The relationship between water levels in the individual wells and the Cedar River as recorded at the Logan Street gauge are shown in Figures 2-24 through 2-28. Graphs showing the comparison of water levels between the wells, Cedar River, Lake Washington, and barometric pressure are provided in Appendix B.1.

The following conclusions can be drawn from the groundwater-surface water interaction study:

- Shallow groundwater at the Facility is hydraulically connected to the Cedar River Waterway. The relative influence of the waterway varies depending primarily on the permeability of the formation, distance from the waterway, and location of recharge zones and hydraulic barriers.
- Water level variations in GW136 (Figure 2-23) closely match those observed in Cedar River Waterway as recorded at the Logan Street gauge. The close relation of water levels in GW136 to those recorded at the Logan Street gauge indicates that the formation is not hydraulically isolated from the Cedar River Waterway and that the sheet pile barrier does not act to hydraulically isolate the Cedar River Waterway from shallow groundwater beneath the Facility. Although the variation observed in shallow groundwater levels can be attributed to variations of stage and flow in the waterway, the relationship is complex and other factors such as precipitation, aquifer properties, and pavement modify groundwater hydraulics.
- Variations in recharge appear to have an impact on local groundwater elevations and the direction and magnitude of groundwater flow. Since gradients are relatively shallow, small variations in recharge can have an impact on groundwater gradients and flow direction.

2.7.3 Aquifer Properties

This section discusses the results of the investigations that evaluated the hydraulic properties of the hydrogeologic units at the Facility. The principal hydraulic property of interest is hydraulic conductivity, which is a measure of the ability of geologic materials to transmit water. Estimates of hydraulic conductivity are needed to understand the rate of groundwater flow. During the RI, the hydraulic conductivity of the aquifer was estimated using a combination of grain-size analysis, vertical permeability tests, slug tests, and pumping tests. In addition to hydraulic properties, the results of porosity, dissolved oxygen, total organic carbon and density analyses are presented below.

2.7.3.1 Grain-Size Analysis

Grain-size analysis was used to classify soil samples and provide estimates of hydraulic conductivity using the Hazen Method (Vukovic and Soro 1992). Grain-size analysis was completed on four soil samples collected during the RI. Historic grain-size data (WESTON 1993) from four soil samples were also evaluated. All the grain-size analysis was performed using American Society of Testing and Materials (ASTM) Method D-422. Plots of the gradation curves are presented in Appendix B.5.

The Hazen method uses the grain size at which 10 percent by weight of the soil particles are finer, and applies an empirical relationship of

$$K = Ad_{10}^{2}$$

where: K = the hydraulic conductivity (centimeters per second [cm/s])
A = the constant of proportionality equal to 1 for uniformly graded sands
d_{10} = the particle diameter (in millimeters) corresponding to the grain size at which 10 percent by weight of particles in a sample is finer.

Grain-size results are presented in Table 2-3. Most of the samples classify as silt with several samples described as fine sand with silt. Hydraulic conductivity values as determined from grain-size data ranged from 2.3×10^{-6} to 8.1×10^{-3} cm/s. The hydraulic conductivities calculated from the grain size-analysis result correlated well with the lithology observed in the samples.

2.7.3.2 Vertical Permeability Tests

Two historical soil samples were collected for vertical permeability testing (WESTON 1993). The samples were collected using Shelby tubes pushed with a drill rig and submitted for laboratory analysis using ASTM Method D5084-90. The soil samples were classified as silts. The results of vertical permeability testing are presented in Table 2-3. The vertical permeability results were 2×10^{-7} and 3×10^{-6} cm/s for the two samples. These results correlate well with the observed lithology (Terzaghi and Peck 1967).

2.7.3.3 Slug Tests

Slug tests were performed in 34 wells as shown in Figure 2-29. The slug test calculations are presented in Appendix B.3, and the results are summarized in Table 2-4. The slug test data were analyzed using the Bouwer and Rice (1976) method. This method provides relatively consistent estimates of aquifer hydraulic properties when used with scientific judgment (Bouwer 1989). The range of hydraulic conductivities from slug testing is presented in Figure 2-30.

The hydraulic conductivity values from the rising and falling tests from the same well were within the same order of magnitude.

The Bouwer and Rice slug test method was developed as a rising head test, but can be used to evaluate falling head data provided that the equilibrium water level is above the screened or open section of the borehole (Bouwer 1989). In wells screened close to or across the water table, some error can be introduced due to variations of the initial displacement from the slug rod as a result of changes in the effective length of the screen through which water flows into/out of the well during a test. Bouwer (1989) concluded that the falling head test can overestimate the hydraulic conductivity compared to the rising head test in cases where the water level is below the top of the screen. The range of hydraulic conductivities based on slug testing indicated that water-bearing materials are very heterogeneous and the ability to transmit groundwater can vary greatly. Duplicate slug tests were conducted in seven wells as a control to assess the reproducibility of slug test results. In general, the duplicate slug tests yielded results with a similar order of magnitude. The geometric means of the hydraulic conductivities were calculated for shallow and deep wells and are summarized below.

Well Interval	Number of Wells	Hydraulic Conductivity		
		Minimum	Maximum	Geometric Mean
Shallow	29	0.00005 cm/s (0.13 ft/d)	0.03 cm/s (80 ft/d)	0.0013 cm/s (3.6 ft/d)
Deep	5	0.0004 cm/s (1 ft/d)	0.01 cm/s (38 ft/d)	0.0038 cm/s (10.7 ft/d)

The calculated hydraulic conductivities are within the range typical for silt and sand (Freeze and Cherry 1979).

The geometric mean for deep wells was greater than shallow wells but within a factor of three.

2.7.3.4 Pumping Test

An aquifer pumping test was conducted in August 2000 in the vicinity of Buildings 4-78/79. The objective of the pumping test was to determine the hydraulic properties of the aquifer. The test results were used to determine (1) hydraulic properties of the aquifer; (2) aquifer yield potential within the contaminated area; and (3) aerial extent of the aquifer pumping test influence. The pumping test methodology, test data, drawdown curves, and distance-drawn plots are presented in Appendix B.4.

The pumping test was conducted using the existing groundwater extraction and treatment system. The treatment system consists of extraction wells GW042 and GW151 (Figure 2-31). Groundwater from the extraction wells is routed to an air stripper to remove volatile organic constituents. Treated water is discharged via piping to the sanitary sewer for disposal by King County Department of Natural Resources (KCDNR).

2.7.3.4.1 Pumping Test Data Analysis

Pumping test analysis consists of taking the pumping well discharge rate and drawdown data from monitoring wells at known distances from the pumping well, substituting these measurements into an appropriate well-flow equation, and calculating the hydraulic characteristics of the aquifer. The well-flow equations are based on various theoretical models assumed to represent the characteristics of real aquifer systems. Ideally, to identify an aquifer system, its drawdown behavior is compared with that of various theoretical models. The model and hence the well-flow equation that compares best with the real system is then selected for the calculation of the hydraulic characteristics.

Pumping test data were analyzed with the AquiferWin32 (version 1.44) program, using the Theis type curve solution and Cooper-Jacob straight-line solution. The pumping test data were also analyzed using the Jacob's straight-line method applied to distance drawdown. Descriptions of these methods are found in Kruseman and deRidder (1991).

2.7.3.4.2 Pumping Test Results

Radius of Influence

The influence resulting from the well GW151 pumping test is clearly visible in the hydrographs for all of the observation wells. During this test, the extraction rate from well GW151 was 40 gallons per minute (gpm). The drawdown in each of the observations was recorded at 4,000 minutes (2.8 days) and the distance of the observation wells from the pumping well was as follows:

Observation Well Number	Distance (ft) to Pumping Well	Drawdown (ft)
GW030	115	0.23
GW031	65	0.23
GW033	45	0.6
GW034	17	0.34
GW039	90	0.17
GW041	144	0.44
GW042	144	0.44
GW151	Pumping Well	0.6
GW154	413	0.06

The radius of influence recorded during the pumping test was greater than 400 feet. The recorded drawdown at GW154 (413 feet from the pumping well) was 0.06 foot or less than an inch.

Aquifer Parameters

The calculated transmissivity, hydraulic conductivity, and storage values are summarized in Table 2-5. Generally, the data from the pumping test on a log-log plot provided a poor match to the theoretical Theis curve. The aquifer parameters were made based on fitting the observed drawdown data with the latter portion of the Theis type curve. The curve indicates that the aquifer is leaky, with contribution from above and below the well screen.

Hydraulic conductivities were calculated by dividing the transmissivity for an aquifer thickness of 20 feet. The hydraulic conductivities using the Theis method ranged from 0.14 to 0.6 cm/s. The calculated hydraulic conductivities are consistent with coarse sand to fine gravel. A hydraulic conductivity of 68 cm/s was calculated from GW039, a value typical of aquifers consisting of coarse gravels and boulders. The value from GW039 was considered to be an extreme outlier and not a reliable measure of the permeability of the sand aquifer. There was general agreement in hydraulic conductivity values for the same data sets calculated using the Theis method and the Jacob distance-drawdown method. The hydraulic conductivity calculated using the distance-drawdown method was 1×10^{-1} cm/s (Appendix B.4).

The calculated storage coefficient values for the observation wells (Table 2-5) ranged from 2×10^{-1} to 5×10^{-6}. The storage coefficient values were less than 2.5×10^{-2}, except for 2.3×10^{-1} calculated for well GW033. Low storage coefficient values are generally consistent with confined aquifers (less than 5×10^{-3}) rather than unconfined aquifers (greater than 1×10^{-1}). The data from this pump test indicates that in this area of the Facility the groundwater bearing zone behaves like a leaky confined aquifer.

2.7.3.4.3 Discussion of Pumping Tests Results

Aquifer Anisotropy

The standard assumption used in aquifer analysis is that the aquifer is isotropic (i.e., that the hydraulic conductivity is the same in all directions). Most aquifers, however, are anisotropic and hydraulic conductivity varies spatially. A range of hydraulic conductivities was observed in the RI aquifer tests, indicating that significant vertical and horizontal variation in hydraulic conductivities is present in the aquifer.

Barometric Pressure Effects

Changes in atmospheric pressure can affect water levels in wells. Barometric pressure effects were generally not observed in the drawdown data collected during the pumping test. Therefore, no corrections to the pumping test data were warranted to compensate for barometric pressure variations.

Deviations from the Theis Type Curve

Deviations from the ideal Theis curve were noted in all the observation wells during the pumping test. The deviations were noted as significant flattening of the drawdown curve in the late pumping data. Comparing the observed drawdown data with the ideal Theis curve can lead to overestimates of the permeability of a formation. The observed flattening of the drawdown curve is attributed to one or more of the following factors: (1) presence of recharge boundaries, (2) partial penetration of the aquifer by the pumping well, or (3) leakage of water through the confining layers. Pumping test data cannot be used to distinguish which factors are involved.

Comparison with Historical Pumping Test Data

In 1993 a short-term pumping test was conducted shortly after construction of the extraction system (WESTON 1993). The pumping duration was only 8 hours and drawdown was recorded from 22 observation wells. The drawdown data were analyzed using the Theis method for confined aquifers. Because of the short duration of the test, the observed drawdown curve was matched to the early part of the theoretical Theis curve. Inspection of the drawdown curve on log-log plots indicates that steady-state conditions were not achieved and that the data generally had a good match to the early part of the Theis curve. The calculated hydraulic conductivities, assuming an aquifer thickness of 20 feet, ranged from 0.105 to 0.216 cm/s, which is consistent with the results of the August 2000 pumping test provided in this report.

Comparison with RI Slug Test Data

The hydraulic conductivity values calculated from the 1993 and 2000 pumping tests are one to two orders of magnitude greater than the hydraulic conductivity values calculated from the RI slug tests. Slug tests are a generally accepted tool for estimating the hydraulic properties of a formation. Because slug tests can be conducted rapidly with good repeatability, they are used to measure the spatial variability in the permeability of an aquifer, which was a major goal of using slug tests in the RI. A pumping test is generally considered to be a more reliable estimator than a slug test of the overall hydraulic properties of a formation. A slug test measures the hydraulic properties of a formation within several feet of the screen, whereas the pumping test can measure as far as 100 to 1,000 feet from the pumping well.

A significant limitation of slug tests is that they are extremely sensitive to the condition of the well. Factors such construction methods, well development, screen, and sand pack conditions can greatly influence the slug tests. The presence of material plugging the screen (i.e., silt, biofilms, or products of biochemical actions) that inhibits the free exchange of water across the screen can lead to significant underestimates of hydraulic conductivity. The condition of the well cannot be easily evaluated in the field. The slug tests were conducted on wells that were constructed as long ago as 10 years to only a few months prior to conducting the tests. For wells with obstructions on their screens, the hydraulic conductivity estimate from a slug test can easily be in error by an order of magnitude or more. The hydraulic conductivity estimates obtained from the RI slug tests should be considered to represent a lower estimate of the conductivity of the formation surrounding the well screen.

Comparison of Pumping Test Result with "Textbook" Values of Hydraulic Conductivity

The range of hydraulic conductivity values observed in various soil and rock types is provided in the published literature (Freeze and Cherry 1979). The observed range for clean sand is 10^{-1} to 10^{-3} cm/s and silt is 10^{-7} to 10^{-3} cm/s. The higher the silt content, the lower the hydraulic conductivity of sand. Although the hydraulic conductivity estimates from the pumping test are in the upper range for clean sand, the sands at the Facility contain varying amounts of silt and are interbedded with silt lenses and interbeds of varying thickness and lateral extent. The presence of significant silt content will greatly reduce the permeability of sand. The hydraulic conductivity estimates obtained from the pumping tests should be considered to represent an upper estimate of the hydraulic conductivity of the formation in the area where the test was conducted. The calculated hydraulic conductivity values from the pumping test should not be considered representative of the entire Facility.

2.7.3.4.4 Pumping Test Summary

The data from the RI pumping test were analyzed using the Theis and Copper-Jacob methods for confined aquifers. The calculated hydraulic conductivities from the pumping test are in the range of 0.1 to 0.6 cm/sec. These calculated hydraulic conductivity values are greater than the upper range of hydraulic conductivities reported for aquifers with similar grain size. The drawdown curves suggest that several processes (i.e., leakage and recharge boundaries), which cannot be properly quantified, were present during pumping test. During the pumping test, well GW151 maintained an extraction rate of 40 gpm for approximately 2.8 days. Analysis of the cone of depression from this pumping test indicates that the maximum radius of influence ranged from approximately 400 to 450 feet from well GW151.

The hydraulic conductivity values from the pumping tests were also greater than the hydraulic conductivities calculated from the slug tests. The hydraulic conductivity values calculated from the pumping test should not be considered representative of the entire Facility. The range of hydraulic conductivities indicates that both vertical and horizontal variations in hydraulic conductivity are present in the aquifer. The high hydraulic conductivity observed in the pump test is not consistent with slug tests, grain size analysis, and vertical hydraulic conductivity testing because the area in the vicinity of the pump test has been highly disturbed by construction and remediation activities. These activities have included the excavation of large quantities of natural soil and replacement with clean granular structural fill. This condition provides groundwater from above the groundwater zone where the pumping well is screened. Secondly, the discontinuous nature of silt beds beneath the Facility suggest a contribution of flow beneath this leaky confined zone in which the pump test was conducted. Lastly, the groundwater zone tested does contain some highly permeable, localized interbeds of clean gravel with high permeability. This pump test-derived hydraulic conductivity is only applicable to the portion of the Facility in the vicinity of the pump test.

2.7.3.5 Total Porosity and Density

Three soil samples were analyzed for dry bulk density and total porosity (Table 2-3). The dry bulk density ranged from 79 to 120 pounds per cubic foot (lb/ft^3). Total porosity ranged from 0.33 to 0.42.

2.7.3.6 Total Organic Carbon

Eighteen soil samples were analyzed for total organic carbon (TOC) using the procedure described in Plumb (1981) (Table 2-6). TOC is the fraction of the soil matrix comprised of organic carbon, which is an important parameter in the development of distribution coefficients (K_d) used in fate and transport analysis. TOC ranged from 0.06 to 6.4 percent with an average of 1.25 percent. A site-wide TOC of 0.81 was approved by Ecology (B. Meang, certified letter dated 31 May 2001) as representative of site conditions [WAC 173-340-747(5)(b)(i)] for use in calculating cleanup standards (Appendix D).

2.7.3.7 Chemical Properties

The geochemical characteristics of Western Washington's alluvial deltas prograding into lacustrine environments are similar. The groundwater is fresh reflecting moderate to heavy precipitation and generally low in soluble salts, a result of the regional geology. The most dominant characteristic is the high content of organic detritus carried in the stream's sediment load and deposition of peat associated with the receiving surface water bodies. The high organic material content of the deltaic sediments has a locally dramatic effect on geochemistry. Decomposition byproducts, organic acids, and gases result locally in acidic conditions creating reducing conditions. These reducing conditions result in locally naturally low dissolved oxygen content and elevated dissolved metals concentrations (As, Fe, Mg, etc.).

Another important characteristic of the organic detritus and peat is their ability to retard the mobility of certain constituents in groundwater. This topic will be further evaluated in the Feasibility Study under fate and transport freshwater analysis.

2.7.3.7.1 Dissolved Oxygen, pH and Redox Potential

Dissolved oxygen is a field parameter measured during groundwater sampling. The natural trend of dissolved oxygen is depletion in the groundwater system as water moves away from the atmosphere and as the residence time of water in the aquifer increases. The oxidation of organic material (natural or manmade) can also reduce dissolved oxygen values. It was measured in the field using a YSI 600 XL flow-through cell with a YSI dissolved oxygen probe or equivalent. The concentration of dissolved oxygen in water in contact with air is a function of temperature. Dissolved oxygen in groundwater is generally under 10 mg/L. The dissolved oxygen concentrations recorded during groundwater sampling at the Facility ranged from 0.16 to 5.48 milligrams per liter (mg/L). The lowest dissolved oxygen concentrations were measured in the deep (screen interval 25 to 35 feet bgs) wells at AOC-090 (Table 2-7).

Low concentrations of oxygen are usually correlated with a chemically reducing environment, while high concentrations indicate a chemically oxidizing environment. The average pH (6.34) of groundwater under the Facility is slightly acidic (pH ranged from 5.3 to 8.18). The range in Redox potential (-197 to 372 mV) reflects the nature of locally reducing conditions within the alluvium beneath the Facility.

2.7.3.7.2 Dissolved Metals

Naturally elevated dissolved arsenic, manganese, and iron concentrations were detected in groundwater beneath the Facility. Dissolved arsenic was detected in monitoring wells at concentrations ranging from 0.001 to 0.049 mg/L. These concentrations are within the range of ambient arsenic concentrations detected in the Puget Sound region (San Juan, Charles, Department of Ecology personal communication, 7 September 1999; Washington State Department of Health 1999).

Similar concentrations are present in shallow groundwater-bearing strata at PACCAR. The PACCAR site is located upgradient of the Boeing Facility, as shown in Figure C-1 (Appendix C.1). Dissolved arsenic concentrations of 0.005 to 0.035 mg/L have been detected in shallow wells (screen interval less than 25 feet in depth). These shallow wells are located off the Facility on property between the Facility and the western boundary of the PACCAR site (Hart

Crowser 1989, 1999, 2000). Dissolved arsenic concentrations detected at Boeing and downgradient from PACCAR were evaluated by performing a two-sample t-test using SYSTAT©, version 7.0 (Appendix C.1). The t-test showed no significant difference at the 95 percent confidence level ($\alpha = 0.05$) between sample means of groundwater arsenic concentrations from the Facility groundwater and wells that are located downgradient of PACCAR.

Naturally elevated iron and manganese concentrations that are above the groundwater quality criteria listed in Chapter 173-200 WAC have also been detected in the shallow groundwater beneath the Facility. Groundwater samples collected from wells associated with the 4-78/79 SWMU/AOC Group contained total iron as high as 32.3 mg/L, which is over 100 times the groundwater quality criteria of 0.30 mg/L. Manganese concentrations were also detected in this area at 1.39 mg/L, over 25 times the groundwater quality criteria of 0.05 mg/L.

By comparison, data provided by the City of Renton from the highly productive Downtown Aquifer showed a maximum iron concentration of 0.15 mg/L in samples collected from their water supply wells. Manganese was not detected in any of the water supply well samples collected by the City.

The naturally elevated metals present in the fine-grained, organic-rich portions of the Cedar River Delta are the result of natural processes and have been observed elsewhere in Holocene Alluvial deposits Green River Valley (Washington State Department of Health 1999)**.**

2.8 SITE HYDROLOGIC MODEL

This section summarizes the key points of the hydrologic model of the Facility. The following provides the foundation for contaminant migration analysis, fate and transport modeling, and alternatives development in the forthcoming Feasibility Study:

Facility Characteristics

- Facility use is principally industrial, is almost entirely developed with buildings and asphalt- or concrete-paved surfacing, and meets the MTCA definition of industrial property.
- Average annual precipitation ranges from approximately 35 to 40 inches. Infiltration on the Facility is extremely low due to impervious surfaces.
- The Facility is located along the banks of the Cedar River Waterway and at the south end of Lake Washington. The Cedar River has been designated "water quality limited" due to sporadic excursions above the state water quality standard for fecal coliform.
- The Facility rests on hydraulically placed fill overlying a prograding alluvial fan deposited into lacustrine deposits associated with Lake Washington and is largely shoreward of the former Lake Washington shoreline. The alluvial and delta sediments of the Cedar River were deposited in a complex inter-layering with the fine-grained deposits of Lake Washington.

Geologic and Hydrogeologic Characteristics

- Prograding alluvial fans deposited into lacustrine environments result in one of the most complex stratigraphic sequences. The sequence contains numerous discontinuities. The discontinuities impact groundwater flow and hazardous constituent transport. The fine-grained stratum inhibits both groundwater flow and vertical and horizontal transport.
  - The dry density ranged from 79 to 120 lb/ft^3.
  - Total porosity ranged from 0.33 to 0.42.
  - TOC ranged from 0.06 to 6.4 percent with an average value of 1.25 percent.
  - Hydraulic conductivity values as determined from grain-size data range from 2.3 x 10^{-6} to 8.1 x 10^{-3} cm/s.
  - The vertical permeability results were 2 x 10^{-7} and 3 x 10^{-6} cm/s.

  - — The calculated hydraulic conductivities from slug tests are within the range typical for silt and sand (5 x 10^{-5} to 1 x 10^{-2} cm/s).
  - — The calculated hydraulic conductivities from the pumping test are in the range of 0.1 to 0.6 cm/sec and reflect the large volumes of clean granular fill placed in the pumping zone during construction and remedial activities that results in a leaky confined aquifer and do not represent site-wide hydraulic conductivities.

- The high organic carbon content of the peaty layers provides for a highly adsorbent stratum for mobile constituents and limits transport. The presence of discontinuities affects the potential interconnectivity of contaminated groundwater to current and future sources of drinking water.

<u>Groundwater Flow and Discharge</u>

- Groundwater in Holocene Alluvium discharges to surface water and as such the Facility is located in an area of regional groundwater discharge and associated upward vertical hydraulic gradients.
- The groundwater flow direction in the Cedar River hydrologic basin is variable and fluctuates locally in Renton depending on municipal well extraction rates, and the seasonal variability of the level of the Cedar River Waterway and Lake Washington.
- The general direction of the groundwater in Renton is radial from the mouth of the Cedar River Valley toward the Cedar River Waterway and Lake Washington. Hydraulic gradients show that groundwater flow in the site vicinity is directed seasonally toward the Cedar River or Lake Washington. This portion of the basin is a groundwater discharge zone.
- Groundwater conditions beneath the Facility are influenced primarily by fluctuations within the Cedar River Waterway and Lake Washington, and upland recharge of the Cedar River Aquifer.
  - — The water table at the Facility is relatively shallow ranging from approximately 2 feet to 11 feet and varies seasonally by 1 foot or more.

  - The groundwater flow direction beneath the Facility flows toward Lake Washington and the Cedar River Waterway.
  - Horizontal gradients at the Facility are relatively flat. Calculated horizontal gradients observed in the shallow wells ranged from 0 to 0.015, with an average of 0.002.
  - Vertical gradients between shallow and deep wells typically were upward. Calculated vertical gradients between the shallow and deep wells ranged from less than 0.001 to 0.024, and were generally one and as much as two orders of magnitude greater than the calculated mean horizontal gradients.
  - Shallow groundwater at the Facility is hydraulically connected to the Cedar River Waterway.
  - The sheet pile barrier between the Facility and the Cedar River does not hydraulically isolate the Cedar River Waterway from shallow groundwater.
  - The Cedar River Waterway is a controlling influence for shallow groundwater.

<u>Relationship to Water Supply</u>

- No groundwater production wells are located on or adjacent to the Facility, and there are institutional controls in place that prevent the use of groundwater beneath the Facility for water supply.
- No part of the Facility falls within the City of Renton's APA. At its closest point, the Facility lies 700 feet northwest (hydraulically downgradient) of the APA boundary.
- Fifteen water supply wells were identified within one mile of the Facility, but the hydrogeologic characteristics of the area indicate it is unlikely that any of the wells will draw groundwater from underneath the Facility or will be affected by conditions there for the following reasons:
  - All of the water supply wells are upgradient of the Facility.
  - The Cedar River and Cedar River Waterway act as a hydraulic divide that essentially isolates shallow groundwater from one side to the other. Since the majority of the

  Facility property is located to the east of the Cedar River Waterway, water supply wells located to the west are hydraulically segregated from the main portion of the Facility.

  - Wells west and northeast of the Facility are at elevations over 100 feet higher than the Facility.
  - In addition to being located hydraulically upgradient of the Facility property, water supply well RW-5A is isolated from the Facility because it draws from a different aquifer than those present beneath the Facility.
  - The Facility is generally located downgradient of the Cedar River Aquifer.

<u>Geochemistry</u>

- The high organic material content of the Holocene Alluvium has an effect on groundwater geochemistry. Decomposition byproducts, organic acids and gases, result in locally acidic conditions creating reducing conditions.
  - The dissolved oxygen concentrations recorded during groundwater sampling at the Facility ranged from 0.16 to 5.48 mg/L.
  - The average pH (6.34) of groundwater under the Facility is slightly acidic (pH ranged from 5.3 to 8.18). The range in Redox potential (-197 to 372 mV) reflects the nature of locally reducing conditions within the alluvium beneath the Facility.
  - These reducing conditions result in locally naturally low dissolved oxygen content, and pH, and naturally elevated dissolved metals concentrations (As, Fe, Mg, etc.).

SECTION 3

CONCEPTUAL SITE MODEL

The conceptual site model outlines a general framework of the Facility, identifying potential or suspected sources of hazardous substances, types and concentrations of hazardous substances, potentially contaminated media, and potential exposure pathways and receptors. This section updates and expands the conceptual site model for the Facility, initially presented in Subsection 2.4 of the *RI Work Plan* (WESTON 1998a) and later refined in the *Tier 3 Detailed Investigation Addendum* (WESTON 2000). This model reflects current conditions and possible future development in assessing exposure pathways. All complete exposure pathways have been considered while examining risks to human health or the environment and determining preliminary cleanup levels. Details of the sources and transport mechanisms, in addition to pathways, exposure routes, and receptors are presented in the updated model.

In addition, this section summarizes the chemical properties of hazardous substances detected during the RI. To determine if these constituents could potentially impact receptors related to the Facility, this RI report evaluates the primary physical and chemical processes that influence contaminant migration.

The specific elements of the conceptual site model, discussed in the following subsections, are as follows:

- Potential sources
- Detected hazardous substance and properties
- Pathway and receptor analysis
    - Release mechanisms
    - Exposure media and routes
    - Potential receptors
    - Exposure pathways

3.1 POTENTIAL SOURCES

The processes historically associated SWMUs/AOCs addressed in the RI and IA can generally be classified under one of the following general manufacturing processes:

- Metal finishing and cleaning operations
- Steam-cleaning activities
- Chemical storage for painting operations
- Fuel storage
- Compressed air generation
- Waste storage

SWMUs and AOCs identified in the Order under Attachments 2 and 3 were investigated as potential sources of hazardous substances in environmental media at the Facility. These potential sources include a variety of containment areas, product storage tanks, waste holding tanks, and waste management areas, many of which were constructed below floor grade. A brief description of the former activities conducted at each unit is provided in Tables 1-1 and 1-2. Detailed information on each SWMU and AOC is included in Section 5.

3.2 DETECTED HAZARDOUS SUBSTANCES AND PROPERTIES

This section provides a general overview of the types and properties of hazardous substances detected and identified as potential contaminants of concern at the Facility. As presented in the *RI Work Plan* (WESTON 1998a), concentrations of hazardous substances detected in environmental media during the RI were compared to SLs to determine whether a release may have occurred from SWMUs or AOCs. The SLs were conservatively derived values from relevant and appropriate regulations in effect at the time the RI Work Plan was approved, establishing a threshold for the permissible risk posed to human or environmental receptors. As part of this RI, preliminary cleanup levels (PCLs) were developed using the adopted amendments to MTCA (Ecology 2001)[1]. For some constituents, the PCLs have lower concentrations than SLs, resulting in an expanded list of relevant hazardous substances as compared to the RI Work Plan.

Hazardous substances detected in soil during the RI include only a limited number of chemical classes, as shown in Table 3-1: chlorinated and aromatic volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), which include polycyclic aromatic hydrocarbons (PAHs), petroleum hydrocarbons, and inorganic constituents (i.e., metals).

Hazardous substances detected in groundwater during the RI generally comprise a smaller subset of the analytes detected in soil, as shown in Table 3-2. Although a similar number of VOCs and petroleum hydrocarbons were detected in each media, the number of SVOCs and metals detected in groundwater was approximately half of the number of these contaminants detected in soil. Note that this comparison is based on the number of dissolved metals detected in groundwater.

3.2.1 Volatile Organic Compounds

VOCs detected in soil and groundwater included both chlorinated and aromatic compounds. Of the 16 total chlorinated compounds detected in soil, the most common (i.e., detected in more than five samples) are carbon tetrachloride, chloroform, cis-1,2-dichloroethene (cis-1,2-DCE), methylene chloride, tetrachloroethene (PCE), trans-1,2-dichloroethene (trans-1,2-DCE), trichloroethene (TCE), and vinyl chloride.

Of the 15 chlorinated VOCs detected in groundwater, the most common included PCE, TCE, cis-1,2-DCE and vinyl chloride, chlorobenzene, 1,1-dichloroethane (1,1-DCA), chloroform, and trans-1,2-DCE. Note that this group is similar to that found in soil.

Chlorinated solvents such as PCE, TCE, methylene chloride, chloroform, and carbon tetrachloride have been extensively used as paint strippers, cleaning solvents, and degreasers.

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[1] The development of the PCLs is discussed in Section 4. Groundwater PCLs are presented in Table 4-3 and soil PCLs are presented in Table 4-4.

While both cis-1,2-DCE and vinyl chloride were often detected, there is no evidence these compounds were used at the Facility because concentrations were generally lower than found for PCE and TCE. It is most likely that they were present as minor constituents in the technical grade PCE and TCE commonly used in industrial degreasing operations (VonderHaar, el al. 1994) or resulted from the stepwise anaerobic biodegradation of PCE and TCE. VonderHaar also indicates that commercial PCE and TCE typically contain a wide range (approximately 2 to 3 percent) of other chlorinated organics including the dichloroethanes detected in samples from the Facility.

PCE and TCE are volatile liquids at room temperature with densities (1.62 g/cm^3 and 1.46 g/cm^3, respectively) greater than water.

3.2.1.1 Aromatic VOCs

The most common (i.e., detected in more than five samples) aromatic VOCs detected in soil and groundwater were benzene, toluene, ethylbenzene, and xylenes (BTEX). The BTEX compounds are major components of gasoline, composing approximately 30 to 40 percent by volume, and minor components of Jet-A and Number 2 diesel fuels (~ 0.5 to 1 percent). In addition, aromatic hydrocarbons are major components of lacquers, oil-based paints and paint thinners.

BTEX compounds are relatively mobile in the environment, exhibiting moderate vapor pressures and solubility. These hazardous substances, especially benzene, tend to undergo rapid biodegradation under aerobic conditions to initially produce phenols and, ultimately, carbon dioxide.

3.2.2 Semivolatile Organic Compounds

Semivolatile organics detected in soil included sixteen PAHs and six additional compounds (including bis[2-ethylhexyl]phthalate). A total of six PAHs and three additional compounds (also including bis[2-ethylhexyl]phthalate) were detected in groundwater.

3.2.2.1 Polycyclic Aromatic Hydrocarbons

Sixteen PAHs were detected in soil. Of these, fourteen PAHs were commonly found, including all seven of the carcinogenic PAHs (benzo[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene). Of the six PAHs detected in the groundwater samples, only two of the carcinogenic PAHs (pyrene and chrysene) were present.

Structurally, PAHs comprise of two or more planar, fused benzene rings. PAHs are ubiquitous in urban environments. They are formed by incomplete combustion of organic matter. PAHs occur naturally in crude oil and, hence, are present in all petroleum products including gasoline, fuel oils, and lubricating oils. In addition, PAHs are a present in roadway runoff due to oil crankcase leaks and deposition of diesel exhaust. PAHs at the Facility are most likely associated with petroleum hydrocarbons from releases of fuel and lubricating oil.

Due to their high molecular weight and structure, PAHs are relatively immobile in the environment, having low volatility and very limited solubility. They have high soil organic carbon partition coefficients and therefore, preferentially bind tightly to soil.

3.2.2.2 Bis-(2-ethylhexyl)phthalate

Bis-(2-ethylhexyl)phthalate (BEP) is ubiquitous in the environment. Historically, it has been used extensively as a plasticizer in polyvinyl chloride and other plastics. Due to its superior properties, it was the plasticizer of choice for most plastics. Typically BEP concentrations in plastics ranged from 15 to 30 percent. BEP had extensive use in paints and other coatings, adding both gloss and flexibility to prevent chipping and cracking. BEP is also used in high performance vacuum pump oil.

While BEP is slightly soluble in water, it is relatively immobile in the environment due to its high organic carbon partition coefficient.

3.2.3 Petroleum Hydrocarbons

The petroleum hydrocarbons detected during the RI included gasoline, diesel, jet fuel-A, and motor oil range petroleum hydrocarbons. All four of these petroleum hydrocarbon groups were detected in both soil and groundwater during the RI.

Petroleum hydrocarbon fuels and lubricating oils are mixtures of hundreds of individual compounds. Fuel and lubricating oil ranges are defined primarily by their boiling point ranges, which are influenced by the molecular weight and number of carbon atoms in the individual compounds. Jet-A fuel (kerosene-range hydrocarbons), Number 2 diesel fuel, and lubricating oil contain primarily straight-chain hydrocarbons with smaller amounts of branched, cyclic, and polycyclic aromatic hydrocarbons. Jet-A fuel is the light fraction (kerosene range) of Number 2 diesel fuel and is made up mainly of C_{10} to C_{16} straight-chain hydrocarbons. Number 2 diesel fuel primarily contains C_{10} to C_{24} straight-chain hydrocarbons with most compounds falling in the C_{14} to C_{18} range. Lubricating oil typically contains C_{24} to C_{36} straight-chain hydrocarbons with organic and inorganic additives to enhance oxidation stability and viscosity performance.

Straight-chain petroleum hydrocarbons that make up the bulk of fuel and lubricating oils degrade relatively quickly in the environment under aerobic conditions, initially forming organic acids and eventually degrading to carbon dioxide.

Gasoline consists primarily of aromatic, cyclic, and branched chain hydrocarbons ranging from C_4 to C_{12}. BTEX compounds are major components of gasoline comprising approximately 30 to 40 percent by volume with lower concentrations of other aromatics such as styrene and trimethylbenzenes. All gasoline components are relatively mobile in the environment exhibiting moderate vapor pressures and solubility. The aromatic compounds, especially benzene, tend to undergo fairly rapid biodegradation under aerobic conditions to initially produce phenols and, ultimately, carbon dioxide while the branched and cyclic alkanes are more resistant to degradation.

3.2.4 Inorganics

Soil samples showed the presence of 13 inorganic constituents, the most common of which included antimony, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc. Of the six dissolved metals detected in groundwater, the most common included antimony, arsenic, and zinc.

Metals have a wide range of potential sources since they have many industrial uses and occur naturally in the environment. Potential industrial sources of metals at the Facility are metal fabrication operations and paint pigments. Historically, white lead oxide was used in paint pigments while smaller amounts of cadmium and copper oxides have been used as paint colorants. Chromium compounds have been used as metal corrosion inhibitors.

Metal compounds exhibit a wide range of solubilities depending upon the chemical species present (i.e., oxidation state and associated ions present), and water pH and redox potential. If elevated metal concentrations at the Facility were a result of paint and/or metal debris disposal, it is anticipated that they would be primarily in the form of metal oxides and hydroxides or in the elemental state alloyed with other metals. In either case, solubilities would be negligible and little or no migration is expected. This is borne out by the observation that, of the metals detected above the soil SLs, only arsenic was detected in groundwater above its screening threshold. Dissolved metal species, for the most part, exhibit only moderate mobility since they tend to adsorb to soil particles within the saturated zone.

The presence of arsenic in groundwater is more likely due to anaerobic conditions rather than a Facility release. Under oxidizing conditions, arsenic is typically present in the saturated zone adsorbed to iron (III) minerals, primarily complex hydrous iron oxides and hydroxides. If organics such as organic-rich soil and peat are present in the subsurface, dissolved oxygen is consumed during the biodegradation of these materials and groundwater conditions can become reducing. When this occurs, iron(III) compounds in the aquifer are reduced to soluble iron(II) species, which dissolve and release adsorbed arsenic. Detected arsenic concentrations are attributed to natural sources based on: the observation of widespread deposition of peat across the Facility; consistency of observed elevated concentrations of arsenic, iron, and manganese on- and off-site; and a lack of known on-site sources.

3.3 PATHWAY AND RECEPTOR ANALYSIS

The pathway and receptor analysis examines the release mechanisms from the potential primary sources of hazardous substances to secondary and tertiary sources, the exposure media and routes, the exposure pathways, and the potential receptors. This analysis, expanded and updated from earlier versions furnished in the *RI Work Plan* (WESTON 1998a) and *Tier 3 Detailed Investigation Addendum* (WESTON 2000b), is depicted in Figure 3-1 and discussed below.

3.3.1 Release Mechanisms

Release mechanisms are those processes by which hazardous substances may potentially be transferred from the potential primary sources (i.e., SWMUs and AOCs as discussed in Section 3.1) to affected media, principally soil and groundwater, and possibly surface water and sediment in Lake Washington or catch basin material. The conceptual site model, illustrated in Figure 3-1, identifies those mechanisms and pathways by which hazardous substances may travel should a release from a SWMU/AOC have occurred.

The primary potential release mechanism of concern at the Facility is associated with releases from containment structures of each SWMU and AOC (i.e., tanks, sumps, etc.). Other release mechanisms (i.e., secondary and tertiary) are processes that transfer hazardous substances from the location of primary release to other environmental media and receptors. The conceptual site model depicts potential transport pathways through which contaminants may migrate should a release have occurred. Secondary release mechanisms at the Facility include the following:

- Leaching and infiltration from soil into groundwater;
- Discharge of groundwater into surface water; and
- Uptake by aquatic organisms in surface water.

Release mechanisms identified in the RI Work Plan and Tier 3 Detailed Investigation Addendum that have been deleted in the updated model include surface water runoff/direct discharge to sediment and surface water and resuspension/deposition of sediment from groundwater discharge to surface water. Details regarding these release mechanisms, along with rationale for excluding them from the site conceptual model are provided below.

Water Runoff/Direct Discharge to Sediment and Surface Water

> As a result of the catch basin sampling program, conducted in accordance with the *RI Work Plan* (WESTON 1998a), surface water runoff/direct discharge to sediment and surface water in the catch basins was deleted from the conceptual site model as a primary release mechanism. The results of this sampling program were presented in the *Selected Stormwater Catch Basin Sampling Report* (WESTON 1999c). This release mechanism was deleted because Boeing operates the Facility under a general stormwater permit (Permit Number SO3-000232), and has comprehensive hazardous waste management and hazardous material management programs. The stormwater catch basins associated with the Facility are periodically cleaned in accordance with the Facility's maintenance procedures.

Resuspension/Deposition of Sediment

> The tertiary release mechanism of sediment resuspension/deposition has also been deleted because it has not been observed to occur during the RI program through either visual examination or sampling data. Sediment sampling was conducted in accordance with Appendix I of the *RI Work Plan* (WESTON 1998a) in which samples were collected from Lake Washington adjacent to outfalls along the shoreline and at nearshore locations. The results of this sampling effort are presented in the *Outfall, Shoreline, and Nearshore Sediment Investigation Report* (WESTON 1999b). Although no regulatory standards have been established for freshwater sediment, the analytical data showed an irregular distribution and low concentrations of PAHs, inconsistent with releases from the Facility. Moreover, available data suggest the presence of hazardous substances in the sediment offshore of the Facility is likely related to nearby off-site sources (e.g., the Shuffleton steam plant). Therefore, this release mechanism has been eliminated from the conceptual site model.

3.3.2 Exposure Media and Routes

The exposure media are the environmental media through which human or ecological receptors could be exposed to hazardous substances. As depicted in Figure 3-1, the exposure media affected by potentially released hazardous substances at the Facility include on-site soil, groundwater, surface water, and aquatic biota in the Cedar River Waterway and/or Lake Washington. Accordingly, the applicable exposure routes for the corresponding media at the Facility are confined to the following:

Exposure Media	Exposure Routes
On-Site Soil	— Ingestion — Dermal Contact — Inhalation of Particulates — Inhalation of Volatile Emissions
Groundwater	— Ingestion — Dermal Contact — Inhalation of Volatile Emissions
Surface Water	— Ingestion — Dermal Contact — Inhalation of Volatile Emissions
Aquatic Biota	— Ingestion

Exposure routes refer to the means by which human or environmental receptors are exposed to hazardous substances. Ingestion and dermal contact with surface water in addition to ingestion by aquatic organisms are the major routes of exposure through which human and ecological receptors may potentially contact contaminated media from the Facility.

3.3.3 Potential Receptors

Receptors are the human or ecological populations that may be potentially exposed to hazardous substances, considering current and credible future Facility land use. Determining receptors includes characterizing the exposure setting with respect to the general physical characteristics of the Facility and the characteristics of the populations on or near the Facility. Receptor populations are identified with respect to those characteristics that influence exposure, such as location relative to the site, activity patterns, and the presence of sensitive subpopulations.

3.3.3.1 Future Site Development Scenario

For the purpose of this conceptual site model, it is assumed that the Facility will retain its industrial character and that any future development will be consistent with the current zoning and land use regulations.

3.3.3.2 Potentially Applicable Receptors

The potential human receptors applicable to the Facility are as follows:

- Industrial Worker—Facility employees.
- Temporary Construction Workers—Personnel temporarily engaged at the Facility during non-routine maintenance or construction activities.
- Residents and Water Supply Consumers—Residents of the immediately surrounding community and individuals consuming privately or municipally supplied water.
- Fishers—Recreational, commercial, and tribal subsistence fishing.
- Recreational Users—Users of the adjacent water bodies and parks, such as swimmers, water skiers, etc.

The potential ecological receptors applicable to the Facility are as follows:

- Small Aquatic Mammals—Riparian mammals (e.g., beaver and river otters).
- Benthos—Invertebrates residing within the sediment of Lake Washington or the Cedar River Waterway, to include shellfish.
- Fish—Resident or migrating populations, including sockeye, coho, and chinook salmon, pygmy whitefish, bull trout and steelhead trout.
- Piscivorous Birds—Resident or migratory fish-eating bird populations to include ducks and herons.
- Raptors—Bald eagles.

- Terrestrial—While the proposed amendments to MTCA require consideration of terrestrial plants and animals that may be potentially exposed to hazardous substances at certain sites, the Facility can qualify for an exclusion under WAC 173-340-7491(1)(b) given the significant coverage by pavement and buildings, which provide "physical barriers that prevent plants or wildlife from being exposed to soil contamination."

3.3.4 Exposure Pathways

Exposure pathways are the paths that hazardous substances take or could take from a source to an exposed human or ecological receptor (WAC 173-340-200). An exposure pathway describes the mechanisms, media, and routes by which receptors are exposed or have the potential to be exposed to hazardous substances at or originating from primary potential sources (i.e., SWMUs/AOCs) and secondary or tertiary sources. In the context of the Renton Facility's conceptual site model, the exposure pathways represent the intersections of the exposure routes with the receptors, depicted as nodes in Figure 3-1.

Determining the potential impacts of hazardous substances on the receptors depends on whether the exposure pathways are incomplete or complete. Incomplete exposure pathways physically prevent the contaminated media from coming into contact with the receptors. Complete pathways, on the other hand, allow hazardous substances to either directly or indirectly contact the receptors through the exposure routes and are further evaluated based on the magnitude of exposure. High potential exposure pathways pose potentially significant risks to receptors due to more direct contact and greater probability of contact with the receptors, whereas low potential exposure pathways are more tenuous and will result in lower potential for exposure leading to risk.

3.3.4.1 Complete Exposure Pathways

An exposure pathway is complete if there is (1) a source or a hazardous substance release from a source, (2) an exposure medium in which contact can occur, and (3) an exposure route by which contact can occur (EPA 1989). For the purpose of this report, hazardous substance releases from SWMUs/AOCs are presumed, limiting the pathway analysis to the exposure media and routes. Expanding on the approach provided in the *RI Work Plan* (WESTON 1998a) and the *Tier 3*

Work Plan Addendum (WESTON 2000b), all complete exposure pathways will be considered under this RI in determining the preliminary cleanup levels. Those pathways identified as being low potential may be further examined during the FS for the development and evaluation of remedial alternatives. The complete exposure pathways for human and ecological receptors are as follows:

Human Receptors—

- Temporary Construction Workers
    - High potential exposure pathways identified for temporary construction workers include direct contact via ingestion, dermal contact, or inhalation of hazardous substances in on-site soil during temporary construction activities. Examples of such exposures include possible contact with soil during excavation work.
    - Low potential exposure pathways temporarily identified for construction worker include dermal contact and inhalation of hazardous substances in groundwater during construction activities. These exposures are considered to be of low potential because excavations are dewatered prior to a worker entering the excavation. Accordingly, only incidental dermal contact with the groundwater is anticipated during the dewatering effort and while work is conducted within the excavation. In addition, although ancillary volatilization of hazardous substances in groundwater seepage within the excavation is likely, risks posed to temporary construction workers would not contribute more significantly than volatilization of hazardous substances in soil. This additional contribution would easily be mitigated by obligatory confined-space entry procedures (e.g., positive forced-air ventilation of the excavation, worker personal protection equipment), thereby reducing the worker exposure. Therefore, while hazardous substances in groundwater represent a complete exposure pathway to temporary construction workers, the potential of such exposures through dermal contact and inhalation remains low.
- Resident/Water Supply Consumer—Low potential exposure pathways are assumed to exist for water supply consumers for surface water diversions as domestic water supply, although there are currently no such potential uses from either groundwater under the

Facility or surface water. Under this exposure scenario, surface water near the Facility from either Lake Washington or the Cedar River Waterway theoretically could be diverted as a water supply source. The exposure routes assumed are ingestion, dermal contact, and inhalation. These exposure pathways are considered low potential because of the regulatory restrictions on diverting surface water, the junior status accorded new appropriations, and the obligatory minimum in-stream flow requirements.

Pursuant to Chapters 90.22 and 90.54 RCW, Ecology has determined that additional diversions from the Lake Washington drainage system, which includes the Cedar River, would deplete in-stream flows and lake levels required to support the users (Chapter 173-508 WAC). Consequently, lakes and streams contributing to the Lake Washington system have been closed by Ecology to further consumptive appropriations, with the exclusion of the Cedar River (WAC 173-508-030). For the Cedar River, Ecology has established minimum in-stream flows that must be maintained throughout the year (WAC 173-508-060). Data from a USGS gauging station (No. 12119000, Figure 2-13) indicate in-stream flows during the summer and autumn are maintained at or near the minimum in-stream flow rates of 130 to 200 cfs. Given the aforementioned conditions, the probability of surface water diversions from either Lake Washington or the Cedar River Waterway is low, reflecting the low potential exposure pathway selection.

- Recreational Users—Low potential exposure pathways via ingestion and dermal contact with hazardous substances in surface water are assumed for recreational users. Should any hazardous substances from the SWMU/AOCs at the Facility be transported via groundwater to the Cedar River Waterway or Lake Washington, recreational users of those water bodies may be exposed to site-related constituents. The extent of these exposures will depend on the amount of constituents transferred to the water bodies as well as the conditions of the surface water.
- Fishers—Recreational, commercial, and tribal fishers possess a low potential exposure with hazardous substances via ingestion of aquatic biota. Fish consumption was determined to be a low potential pathway because the risks posed to fishers through this pathway is tenuous, given the exposure scenario and nature of potential hazardous substances.

Recreational fishers and tribal subsistence fishers provide the greatest opportunity under this scenario because there is no commercial fishing within Lake Washington, except for crayfish. The recreational and tribal fishery in Lake Washington is based primarily on sockeye salmon, bass, and perch. These fish are mid- to upper water-column dwellers that feed on plankton or juvenile fishes. Sockeye salmon reside in Lake Washington as juveniles and then spend years in the ocean while maturing to full size; potential hazardous substance body burdens are largely a function of exposure that occurs in the ocean. The degree to which these fish spend time or feed in Lake Washington upon their return to spawn, and therefore their potential for accumulating chemical contaminants found in Lake Washington, is inconsequential in comparison to the exposure they receive in the ocean. Moreover, water quality in both Lake Washington and the Cedar River is not degraded and is classified as AA or Lake Class under WAC 173-201A-140. Therefore, surface water exposure of fish such as bass and perch that reside in Lake Washington throughout their lives is considered inconsequential.

In addition, human fish consumption is considered a low potential exposure pathway because volatile organic compounds are not taken up into fish tissue. Of the chemicals detected in groundwater at the Facility, VOCs are the primary hazardous substances that could discharge to surface water due to their mobility in groundwater and prevalence. Other chemicals are not likely to be discharged due either to their low prevalence and/or low mobility in groundwater. The ability for VOCs to bioaccumulate in fish is minimized by two mechanisms. First, VOCs generally degrade too rapidly in the water column to undergo bioaccumulation in aquatic organisms. The primary mode of VOC degradation is volatilization, with additional biodegradation in the aerobic systems found in lakes and rivers.

Second, VOCs exhibit a poor ability to be absorbed by fish tissue, as quantified by its low octanol-water partitioning coefficient and low bioconcentration factors. The octanol-water partitioning coefficient measures the tendency of a chemical to partition into the organisms’ lipid, while bioconcentration factors reflect the degree to which chemicals partition from water into organisms’ tissue. Low bioconcentration factors (i.e., factors at or below one) indicate a low potential to bioaccumulate. In addition, target recreational fish will not acquire volatile constituents from plankton or those fish on which they prey because VOCs do not bioconcentrate in these lower organisms.

Ecological Receptors—Because the Facility itself is covered with pavement and buildings, ecological receptors associated with the Facility are limited to the aquatic environment. Identified complete pathways are discussed below.

- Small Aquatic Mammals, Benthos, and Fish—High potential exposure pathways via ingestion and dermal contact with hazardous substances in surface water are assumed for small aquatic mammals, benthos, and fish. Should any hazardous substances from the SWMU/AOCs at the Facility be transported via groundwater to the Cedar River Waterway or Lake Washington, the organisms that reside in or adjacent to those water bodies may be exposed to site-related hazardous substances. The extent of these exposures will depend on the amount of constituents transferred to the water bodies as well as the conditions of the surface water in these water bodies.

  Ingestion of hazardous substances by aquatic mammals, benthos, and fish via aquatic biota is assumed to be a low potential exposure pathway. The low potential for this pathway is due to the rapid degradation of VOC (the primary hazardous substances in the Facility groundwater) and their low potential for bioaccumulation, as discussed under fishers above.

- Piscivorous Birds and Raptors—Exposure pathways to piscivorous (fish-eating) birds or raptors are considered low potential pathways via ingestion and dermal contact with hazardous substances in surface water and ingestion of aquatic biota. Direct exposure of these birds to hazardous substances in surface water is irregular because of the range to which these birds travel in comparison to the limited extent of the potentially impacted media. In addition, exposure of hazardous substances from ingestion or bioaccumulation by consuming aquatic organisms or small aquatic mammals is a low potential pathway for the reasons discussed under fishers above.

3.3.4.2 Incomplete Exposure Pathways

The U.S. Environmental Protection Agency's (1989) *Risk Assessment Guidance* establishes three nonexclusive conditions for determining whether an exposure pathway is incomplete:

1. The exposure resulting from the pathway is much less than that from another pathway involving the same medium;
2. The potential magnitude of exposure from a pathway is low; or
3. The probability of the exposure occurring is very low and the risks associated with the occurrence are not high.

Consequentially, incomplete exposure pathways will not be used in determining the potentially applicable cleanup levels. Incomplete exposure pathways identified for the Facility are discussed below.

Human Receptors

- Industrial Worker—Incomplete pathways exist for Boeing employees and plant workers for all exposure media and routes. Exposure pathways of dermal contact and ingestion are incomplete given the low potential magnitude of exposure to hazardous substances in on-site soil via these pathways. As discussed in Section 2, the Facility is at least 90 percent covered by buildings and pavement forming an effective barrier between the workers and the hazardous substances. Moreover, hazardous substances in the soil, where encountered, were almost exclusively found at depths exceeding 2 feet bgs (refer to the investigation results presented in Section 5), which further obstructs potential contact.

  Indoor or ambient air at the Facility is considered an incomplete pathway because of the low potential magnitude of exposure and the very low probability of exposure occurring. The predominant surface coverage and the depth of hazardous substances in subsurface soil inhibit constituent volatilization and particulate suspension in air. The Facility currently employs appropriate engineering controls and monitoring prior to allowing workers to enter utility vaults, manholes, or other enclosures where air emissions may collect, and during invasive work in potentially impacted media. Such potential exposures occur infrequently and are subject to applicable Occupational Safety and Health Administration (OSHA) compliant requirements (29 CFR 1910.146, Confined Space Entry) to ensure adequate worker protection. Open excavations for maintenance or Facility improvement may temporarily release hazardous substance from impacted soil, but these occurrences are infrequent and of short duration; these conditions produce a very low probability of exposure. Such exposures would be characterized by lower concentrations of hazardous substances than those exposures to temporary construction workers taking part in excavation-related projects, as discussed in Section 4.3.3.1 above. Moreover, VOCs or gasoline/diesel-range hydrocarbons were never encountered in soil within 1-foot of a building foundation or floor-slab [WAC 173-340-745(5)(c)(iv)(A)(I)], resulting in a low potential magnitude of indoor air inhalation from volatile emissions.

MTCA presumes that the hazardous substances in soil pose a greater risk of exposure to human receptors by way of a soil-to-groundwater pathway than to site workers resulting from air vapors [WAC 173-340-745(5)(c)(iv)(A)][2]. Because the soil-to-groundwater pathway will be used to determine soil cleanup levels (refer to Section 4.3.2), the numerical values derived under WAC 173-340-747 are compared the values computed under Method C Industrial [WAC 173-340-745(5)]. Accordingly, the soil vapor pathway is incomplete

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[2] WAC 173-340-745(5)(c)(iv)(A) provides in part, "[t]he soil to vapor pathway shall be evaluated whenever the proposed changes to the standard Method C would result in a significantly higher soil cleanup level than would be calculated without the proposed changes. The soil to vapor pathway shall also be evaluated whenever one of the methods specified in WAC 173-340-747(5) through (9) is used to derive a soil concentration that is protective of groundwater and that concentration is significantly higher than a concentration derived under the method specified in WAC 173-340-747(4)." (emphasis added). Note that WAC 173-340-747(4) is being used in this RI to derive soil concentrations protective of groundwater, and therefore the second provision of the quoted section is not operative.

because the Method C Industrial values are "significantly higher" than the soil-to-groundwater pathway values.[3]

- Temporary Construction Worker—Incomplete pathways exist for ingestion of groundwater and all exposure routes associated with surface water and aquatic biota to temporary construction workers. Although these workers would be expected to enter into excavations, the probability of an exposure by ingestion is very low and the risk associated with such an occurrence is not high. Common construction practice requires excavations to be dewatered prior to a worker's entry. Therefore, at most, only incidental ingestion would be possible from pore water seepage, and then only in very small quantities. Such exposures would also occur very infrequently and for short (i.e., instantaneous) durations.

  Surface water exposures are incomplete pathways because the probability of exposure to construction workers is very low and the risk associated with such an occurrence is not high. Construction workers would only be exposed to surface water if offshore or near-shore construction were to occur at or adjacent to the Facility. Such work would occur from a waterborne platform or shoreline.

- Resident/Water Supply Consumer—Incomplete pathways exist for all exposure routes associated with on-site soil and groundwater to local residents and water supply consumers. There exists a very low probability of exposure to residents from hazardous substances in on-site soil, and the risks associated with such occurrences are not high given the restricted access to the Facility. Security fencing surrounds the Facility and guards are posted at each entrance as well as roam the perimeter of the Facility to prevent trespassing. Public exposure at the Facility is very unlikely due to the extensive industrial use of the site and access restrictions (i.e., security fencing, posted guards, etc.). Resident exposure to

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[3] Refer to Section 4.3 and Table 4-4 for a comparison of these values. The soil cleanup levels derived using the Modified Method C Industrial values [WAC 173-340-745(5)(c)] are not significantly higher than the standard Method C Industrial values [WAC 173-340-745(5)(b)], presented in the MTCA CLARC II update (Ecology 1996); both sets of values are typically within an order of magnitude of each other with the modified values typically lower than the standard values. Soil-to-groundwater values were derived using WAC 173-340-747(4) (Section 4.3.2).

hazardous substances from inhalation similarly represents an incomplete pathway for the same rationale discussed under industrial workers above. Off-site residents may be exposed to airborne contaminants during excavation activities near the perimeters of the Facility. However, such exposures would be characterized by lower concentrations of constituents than those exposures to on-site workers taking part in excavation-related projects, as discussed in Section 3.3.4.1 above.

Exposure to hazardous substances in groundwater beneath the Facility represents an incomplete pathway because the potential magnitude for such exposure is low. This magnitude is measured by considering the likelihood of groundwater consumption from beneath the Facility, and the physical and regulatory limitation to withdrawing groundwater. First, the Facility and local community are currently served by public water supply wells through the City of Renton (refer to Section 2.6.2.2). Second, groundwater beneath the Facility and contiguous to the Facility's perimeter is not a current source of drinking water (refer to Section 2.6.2.2). Third, Boeing's institutional controls prevent installation of water supply wells on the Facility. Fourth, the Facility is down gradient of municipal water supply wells and a groundwater-flow divide separates the Facility from the zone of influence of the municipal wells (refer to Section 2.6.3). Finally, it is "highly improbable" that Ecology would grant a water supply well servicing more than one domestic residence within the City of Renton (telephone conversation with Steve Hirschey, Ecology, Water Resources Program, 12 January 2001). A single resident domestic well would be permitted by Ecology so long as it is greater than 100 feet from a known contaminated source (WAC 173-160-171) and maintains withdrawals less than 5,000 gallons per day (RCW 90.44.050). The cone of depression associated with that withdrawal rate is less than 50 feet across, which is too small to affect potentially contaminated groundwater on the Facility.

- Fishers—Incomplete pathways exist for all exposure routes associated with on-site soil and groundwater to fishers. There exists a very low probability of exposure to fishers from hazardous substances in on-site soil, and the risks associated with such occurrences are not high given the restricted access to the Facility. The rationale for this determination is discussed under residents above.

Exposure to fishers from hazardous substances in surface water are incomplete because such exposures are much less than that posed to recreational users for the same media and exposure routes, which are complete exposure pathways. Recreational exposure pathways are discussed in Section 3.3.4.1 above.

- Recreational—Incomplete pathways exist for all exposure routes associated with on-site soil and groundwater to recreational users. There exists a very low probability of exposure to recreational users from hazardous substances in on-site soil or groundwater, and the risks associated with such occurrences are not high given the restricted access to the Facility. The rationale for this determination is discussed under residents above.

  An incomplete pathway exists for exposures by inhalation of hazardous substances via surface water because the probability of such an exposure occurring is very low and the risks associated with the occurrence are not high. Hazardous substances in groundwater will be significantly diluted and dispersed when discharging to surface water. These occurrences will result in very low concentration exposures to recreational users, particularly when considering the infrequency of potential contact with the recreational user.

Ecological Receptors

- Small Aquatic Mammals—Incomplete pathways exist for all exposure routes associated with on-site soil and groundwater to small aquatic mammals. There exists a very low probability of exposure to such mammals from hazardous substances in either media, and the risks associated with such occurrences are not high given their behavioral patterns. Aquatic mammals tend to burrow into riparian banks, typically no deeper than 18-inches. However, only a small portion of the Facility’s perimeter is undeveloped riparian soil suitable for such habitat, and are distant from SWMUs or AOCs.[4] Moreover, hazardous substances, when encountered in on-site soil, were found in the industrial areas of the Facility and at depths typically exceeding 2 feet below ground surface. Similarly, exposures to small aquatic mammals resulting from the groundwater pathways are incomplete because the depth to groundwater is at least 2 feet bgs near the shoreline except for the point at which the groundwater discharges into Lake Washington. Under these limited circumstances, the potential magnitude of such exposures is considered low or at least equal to surface water exposure.

- Benthos and Fish—Incomplete pathways exist for all exposure routes associated with on-site soil and groundwater to benthos and fish. These organisms are physically separated from and may not exist in these media.
- Piscivorous Birds and Raptors—Incomplete pathways exist for all exposure routes associated with on-site soil and groundwater to raptors and other fish-eating birds. There exists a very low probability of exposure to such birds from hazardous substances in either media, and the risks associated with such occurrences are not high given their behavioral patterns. Neither piscivorous birds nor raptors burrow or establish nesting habitat below ground surface, thereby eliminating the likelihood of encountering hazardous substances in on-site soil or groundwater.
- Terrestrial—Incomplete pathways exist for all exposure routes associated with all exposure media to terrestrial plants and animals. MTCA excludes from terrestrial ecological evaluation those sites that are covered by buildings and pavement, which prevents exposure to plants and wildlife [WAC 173-340-7491(1)(b)].The Facility is at least 90-percent

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[4] Refer to Figure 2-1. The only riparian areas contiguous with the Facility are along the Northwest property boundary. Approximately 300 feet of shoreline near the former boathouse lies under walkways and a small boat slip. Another 150 feet of shoreline lies directly east of the former seaplane ramps, which becomes the Washington State Department of Natural Resources (DNR) property where the shoreline crosses the inner harbor line. In addition, significant portions of the Cedar River Waterway were armored by the Corps of Engineers in 1999, removing habitat for aquatic mammals within these areas (Section 2.6).

covered with pavement and buildings (Figure 2-1); SWMUs and AOCs discussed in this RI Report are completely covered[5]. These covers provide an effective barrier for exposure to terrestrial plants and animals.

3.4 SUMMARY OF THE CONCEPTUAL SITE MODEL

Based on the site characteristics and topography (see Section 3.2), migration is expected to be significant only for chlorinated solvents (such as TCE), BTEX, and perhaps, the branched and cyclic alkanes. The HPAHs and inorganics are expected to be relatively immobile due to their strong binding affinity to soil, low water solubility, and low vapor pressure.

The predominant release mechanism for BTEX and TCE and its degradation by-products is most likely soil leaching to groundwater and migration down gradient with groundwater flow to Lake Washington and the Cedar River Waterway. Adsorption and retardation are relatively low; therefore, eventual off-site migration of contaminated groundwater is possible if left untreated in areas with elevated concentrations. A secondary VOC release mechanism is partitioning to soil gas and evaporation to the atmosphere, but this is probably insignificant except in areas of shallow soil contamination. Discharge of VOCs in shallow groundwater to the surface water bodies adjacent to the site is the primary pathway for VOCs migrating to surface water.

Identified complete pathways for site contaminants include the following potential exposures:

- High potential for exposure to temporary construction workers via ingestion, dermal contact, and inhalation (particulate and volatile emissions) of hazardous substances in on-site soil.
- Low potential for exposure to temporary construction workers via dermal contact and inhalation of hazardous substance in groundwater.

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[5] One sample location on a vegetative strip near AOC-090 (sample station PP056) contained elevated concentrations of gasoline-range petroleum hydrocarbons at the 2-4 foot bgs interval.

- Low potential for exposure to water supply consumers via ingestion, dermal contact and inhalation (of volatile organics during showering or washing) of hazardous substances in groundwater discharging to surface water. These exposure pathways are considered low potential because of the regulatory restrictions on diverting surface water and obligatory minimum in-stream flow requirements.
- Low potential for exposure to fishers via ingestion of hazardous substances in groundwater discharging to surface water and bioaccumulating in aquatic biota. Low potential for exposure to recreational users via ingestion and dermal contact from hazardous substances in groundwater discharging to surface water.
- High potential with low risks for exposure to aquatic ecological receptors (small aquatic mammals, benthos, and fish) via ingestion and dermal contact of hazardous substances in groundwater discharging to surface water.
- Low potential for exposure to aquatic and fish-eating ecological receptors (small aquatic mammals, benthos, fish, piscivorous birds and raptors) via ingestion of aquatic biota that have accumulated hazardous substances from groundwater discharging to surface water.
- Low potential for exposure to aquatic and fish-eating ecological receptors (piscivorous birds and raptors) via ingestion and dermal contact of hazardous substances in groundwater discharging to surface water.

SECTION 4

PRELIMINARY CLEANUP LEVELS

4.1 IDENTIFICATION OF CLEANUP LEVELS

This section provides an overview of the process in which preliminary cleanup levels (PCLs) for soil and groundwater were developed for the SWMUs and AOCs at the Facility. This process is consistent with the requirements outlined in MTCA (WAC 173-340-700) and incorporates the adopted amendments to the MTCA (February 2001). Regulatory citations that reference MTCA (WAC 173-340) are from the adopted amendments to the MTCA (Ecology 2001).

A cleanup level is defined in MTCA as the concentration of a hazardous substance in an environmental medium that is determined to be protective of human health and the environment under specified exposure conditions (WAC 173-340-200). Cleanup levels are distinguishable from the cleanup standards. Cleanup standards specify the cleanup level and the point(s) of compliance (i.e., specific location) where the cleanup level shall be attained.

In addition, cleanup levels differ from remediation levels, which are developed in the FS and approved in a Corrective Action Plan (CAP). A remediation level is a concentration (or other method of identification such as physical appearance or location) of a hazardous substance in an environmental medium above which a particular cleanup action component will be required as part of the overall cleanup action at a site (WAC 173-340-200). Cleanup action means any remedial action taken at a site to stabilize, treat, or remove a hazardous substance, accounting for cleanup action components (e.g., treatment technologies, containment, institutional or engineering controls, etc.) that, individually or in combination, achieve a cleanup action (WAC 173-340-200). The actual degree of cleanup may vary from site to site and will be determined through the FS. If selected in accordance with applicable MTCA provisions, a cleanup action that includes remediation levels is considered to be protective of human health and the environment (WAC 173-340-355).

PCLs are identified in this RI for the particular hazardous substances at the Facility and the specific SWMUs/AOCs or pathways. PCLs are used in this RI to assess whether identified releases may pose a potential threat to human life or the environment. SWMUs and AOCs with chemical concentrations detected above the PCLs will be recommended for further evaluation in the FS. If chemical concentrations are not detected above the PCLs, these SWMUs and AOCs will not be recommended for further evaluation in the FS. The PCLs do not include factors such as engineering and institutional controls that could enable less restrictive CLs that would also be protective to human life or the environment. These factors will be fully evaluated as part of the FS and may be a component of remediation level development in the CAP. Therefore, PCLs have been determined only for the particular hazardous substances detected at the specific SWMUs/AOCs during the RI.

4.1.1 Approach

The approach used to establish PCLs involved three steps. The first step is to identify the nature of the contamination, which includes the potentially contaminated media, the current and potential pathways of exposure, the current and potential receptors, and the current and potential land and resource uses [WAC 173-340-700(5)]. These elements were evaluated for the Facility-specific condition, as reflected in the conceptual site model presented in Section 3.

The second step overlays the Applicable State and Federal Laws (ASFLs) on the conceptual site model [WAC 173-340-700(6)]. The purpose of this step is to tailor the regulatory requirements to the Facility-specific conditions and identify those requirements pertinent to the Facility. Preliminary ASFLs were furnished in the *Tier 3 Detailed Investigation Addendum* (WESTON 2000b). Subsections 4.2 and 4.5 of this report update the list of preliminary ASFLs.

The final step includes comparing the numerical values from potential ASFLs to each other. The lowest value for each constituent was selected for the PCL to ensure the value is sufficiently protective for the identified exposure pathways and receptors. For those potential ASFLs in which numerical values were not available for the identified exposure pathway and receptor (e.g., recreational exposure), a value was calculated using the risk assessment procedures provided in WAC 173-340-708. Section 4.3 provides a detailed discussion of the PCL selection process.

Inherent to this approach is the cleanup levels are met at the point of compliance, which is defined as the "cleanup standard" in accordance with WAC 173-340-700(7). A detailed discussion of the proposed points of compliance is provided in Section 4.4.

4.2 POTENTIAL APPLICABLE STATE AND FEDERAL LAWS (ASFLs)

This section discusses the potentially applicable state and federal laws for the Boeing Renton Facility. These requirements are similar to the "ARARs" (applicable or relevant and appropriate requirements) approach under federal law. This evaluation is a refinement of the preliminary ARARs identified in the *Tier 3 Detailed Investigation Addendum* (WESTON 2000b).

4.2.1 ASFLs Defined

Section 173-340-360(2) of the Model Toxics Control Act (MTCA) requires Facility cleanup actions to comply with all applicable state and federal laws. "Applicable state and federal laws" means all legally applicable requirements and those requirements that the department determines, based on the criteria in WAC 173-340-710(3), are relevant and appropriate requirements.

Legally applicable requirements include those cleanup levels, standards of control, and other environmental protection requirements, criteria, or limitations adopted under state or federal law that specifically address a hazardous substance, cleanup action, location, or other circumstances at the site (WAC 173-340-200).

Relevant and appropriate requirements include those cleanup levels, standards of control, and other environmental requirements, criteria, or limitations established under state or federal law that, while not legally applicable to the hazardous substance, cleanup action, location, or other circumstance at a site, address problems or situations sufficiently similar to those encountered at the site that their use is well suited to the particular site (WAC 173-340-200). WAC 173-340-710 through 173-340-760 identify several requirements Ecology considers relevant and appropriate for establishing cleanup levels.

MTCA requires the cleanup levels to be “at least as stringent as all applicable state and federal laws.” In addition to establishing minimum requirements for cleanup levels, applicable state and federal laws may also impose certain technical and procedural requirements for performing cleanup actions.

ASFL Categories

In general, ASFLs can be grouped into the following categories:

- Chemical-specific requirements
- Action-specific requirements
- Location-specific requirements

Chemical-specific requirements are health- or risk-based numerical values or methods that, when applied to the Facility-specific conditions, enable selection of the preliminary cleanup levels. PCLs establish the acceptable concentration of a hazardous substance that may be found in or discharged to the ambient environment. If a hazardous substance has more than one such requirement, the most stringent will generally be selected.

Action- and location-specific requirements influence the character and nature of the cleanup standard, cleanup action, and/or remediation level. These ASFLs are discussed in Section 4.5.

4.2.2 Identification and Evaluation of ASFLs

As mentioned above, a list of potential chemical-specific ASFLs is used to establish the preliminary cleanup levels. PCLs serve to identify those SWMUs and AOCs where releases may pose an unacceptable risk to human health or the environment and, later during the FS, to focus the development of alternatives on cleanup technologies that can achieve the remediation goals, thereby limiting the number of alternatives to be considered in the detailed cleanup action analysis.

At the beginning of the FS process, location- and action-specific ASFLs are preliminarily identified. When the detailed analysis of cleanup actions is completed, all action-specific ASFLs are tailored to each alternative before a comparison of alternatives begins. The preliminary

ASFLs provided in this section are based in part on the RI results. The ASFLs will be refined further in the FS based on Ecology's recommendations.

The chemical-specific ASFLs were evaluated during RI for the development of the PCLs and are discussed below. The remaining ASFLs are dependant on the cleanup action alternatives to be assessed during the FS, and are discussed in Section 4.5.

4.2.2.1 Chemical-Specific ASFLs

Health-based, chemical-specific ASFLs pertinent to the constituents of concern are primarily derived from federal and state health and environmental regulations. Table 4-1 summarizes chemical-specific ASFLs for the constituents at the Facility and evaluates whether these standards are potentially applicable to the Facility.

4.3 SELECTION OF PRELIMINARY CLEANUP LEVELS

PCLs were selected during the RI for hazardous substances detected in soil and groundwater. These PCLs are protective of human health and the environment under the potential exposure scenarios discussed in the conceptual site model (Section 3). Human receptors with complete groundwater exposure pathways include temporary construction workers, surface water supply consumers, fishers and recreational users. Ecological receptors with complete groundwater exposure pathways include small aquatic mammals, benthic organisms, fish, piscivorous birds and raptors.

The PCLs were derived using two methods. First, values were obtained directly from ASFLs when the furnished regulatory levels were based on exposure scenarios consistent with the Facility conditions and were sufficiently protective. Second, values were calculated using the risk assessment procedures provided under WAC 173-340-708 for the relevant exposure scenario. For constituents in which both methods yielded a value, each value was compared, and the most restrictive value for the constituent was selected as the PCL. In some cases, the most restrictive value was less than natural background levels or the practical quantitation limit (PQL).

In those situations, the PCL was established at the concentration equal to the PQL or the natural background concentration, which ever is higher [WAC 173-340-700(6)(d)].

For each of the complete exposure pathways identified in the conceptual site model (Section 3.3.4.1), Table 4-2 summarizes the exposure pathway criteria and associated regulations used to develop the groundwater and soil PCLs. The numerical values for complete groundwater and soil exposure pathways are presented in Tables 4-3 and 4-4, respectively. Numerical values are listed for the chemical constituents detected in groundwater and soil during the RI. Additional information regarding the development of the PCLs is presented in Appendix D.

4.3.1 Groundwater Preliminary Cleanup Levels

Groundwater PCLs were established by identifying receptors that may directly or indirectly come into contact with groundwater; that is, the receptors exposed under the complete exposure pathways discussed in Section 3.3.4.1. Table 4-3 presents values protective of each complete exposure pathway for groundwater, as well as the selected groundwater PCL. The process outlined for selection of the groundwater PCLs is in accordance with MTCA Method B for surface water (WAC 173-340-730) and groundwater (WAC 173-340-720), as described below.

Applicable State and Federal Laws

ASFLs used in the development of the groundwater PCLs include:

- Washington Water Quality Criteria (WAC 173-201A)
- Federal Water Quality Criteria (40 CFR 131)
- MTCA Method B (WAC 173-340-720 and 173-340-730)

These ASFLs were selected because they are sufficiently protective of human health and the environment and are suitable for the complete exposure pathways identified in the conceptual site model (Section 3). The exposure pathway criteria and associated regulations used to develop the groundwater PCLs are summarized on Table 4-2 and are further discussed below.

Environmental Effects

Values for ecological receptors were obtained exclusively from concentrations furnished in ASFLs, as cited in MTCA (WAC 173-340-730). Washington State regulations included *Water Quality Standards for Surface Waters of the State of Washington* (Chapter 173-201A WAC). Applicable federal regulations included *Water Quality Standards* (40 CFR 131) under the Clean Water Act. For both state and federal regulations, both acute and chronic criteria for protection of aquatic organisms were considered. These values are estimated to result in no adverse effects on the protection and propagation of aquatic life.

Human Health Protection

For human receptors, groundwater PCLs were developed for the following complete exposure pathways:

- Protection of surface water that is classified as suitable for domestic water supply. Levels are protective of water supply consumers via ingestion and inhalation and dermal contact (during showing and washing).
- Protection of recreational users from dermal contact with surface water and incidental ingestion of surface water while swimming in the Cedar River Waterway or Lake Washington.
- Protection of fishers who ingest fish from Lake Washington or the Cedar River Waterway.
- Protection of temporary construction workers from dermal contact or inhalation of volatile emissions from groundwater.

Regulations used to evaluate cleanup levels for the pathways included MTCA Method B surface water cleanup standards. Primary risk assessment guidance used to evaluate the surface water pathway included MTCA (Ecology 2001), *EPA Risk Assessment Guidance for Superfund (RAGS) Part A* (EPA 1989), and the *EPA Exposure Factors Handbook* (EPA 1997a). Refer to Appendix D for a detailed discussion of the risk assessment and exposure parameters.

Values protective of surface water classified as suitable for domestic water supply, as required by WAC 173-340-730(3)(b)(iv), were derived using the methods specified in WAC 173-340-720(4). The default values for the receptors (i.e., average body weight, drinking water ingestion rate) were utilized. Chemical specific factors (i.e., reference dose, carcinogenic potency factor) were selected using the sources identified in WAC 173-340-708. Additional information is included in this section under "Drinking Water Considerations."

Exposure to surface water was assumed to occur during recreational contact activities such as swimming. Modifications to the standard Method B values were necessary to ensure sufficient protection against exposure to these receptors. The recreational user was considered to be a 7 to 18 year old youth, and an exposure duration of 10 years was used (EPA 1995) with an exposure frequency of 12 days per year (1 event per month) (EPA 1997a). The recreational user was assumed to be swimming for approximately 1 hour per event (EPA 1997a). The body weight calculated for the recreational user was determined to be 47 kilograms based on the average body weight of boys and girls between the ages of 7 and 18 (EPA 1997a). A target cancer risk of 1 x 10^{-6} and a target hazard quotient of 1 were used to calculate the risk-based values. The lower of the two integrated oral/dermal values is shown on Table 4-3.

Values protective of fish ingestion by humans were calculated using the MTCA Method B equations provided in WAC 173-340-730(3)(b). The default values for the receptors (i.e., average body weight, fish consumption rate) were utilized. Chemical-specific factors (i.e., reference dose, bioconcentration factor) were selected using the literature sources identified in WAC 173-340-708.

Groundwater PCLs protective of temporary construction workers via dermal contact and inhalation were addressed by the values calculated for water supply consumers. The exposure frequency and duration for a temporary construction worker is well below those assumed for a water supply consumer.

Drinking Water Considerations

As previously discussed in Section 3.3.4.1, groundwater beneath the Facility discharges to surface water (Cedar River Waterway and Lake Washington), which theoretically could be diverted as a water supply source. Although this is a low potential exposure pathway, values protective of surface water classified as suitable for domestic water supply were derived using the methods specified in WAC 173-340-720(4).

4.3.2 Soil Preliminary Cleanup Levels

The Facility meets the criteria of an industrial property as specified in WAC 173-340-745. Soil cleanup levels were established by identifying receptors that may directly or indirectly be exposed to hazardous substances released to the soil, and therefore the receptors exposed under the complete exposure pathways discussed in Section 3.3.4.1. Table 4-4 presents the values protective of each complete exposure pathway for soil as well as the selected soil PCL. The process outlined for selection of the soil PCLs is in general accordance with MTCA Method C for industrial soil (WAC 173-340-745) and ensures relevant receptors are sufficiently protected, as described below.

<u>Applicable State and Federal Laws</u>

ASFLs used in the development of the soil PCLs include:

- MTCA Method C Industrial (WAC 173-340-745)
- MTCA soil concentrations for groundwater protection (WAC 173-340-747)

These ASFLs were selected because they are sufficiently protective of human health and are suitable for the complete exposure pathways identified in the conceptual site model (Section 3). Ecological ASFLs were not included because the Facility is covered with pavement and buildings, and these receptors would not be directly exposed to soil containing hazardous substances. If MTCA Method C Industrial cleanup levels are employed for Facility cleanup, an institutional control will be attached to the Facility after cleanup. The cleanup level criteria and associated regulations used to develop the soil PCLs are summarized on Table 4-2 and are further discussed below.

Environmental Protection

Because the Facility is covered with pavement and buildings, ecological receptors would not be directly exposed to soil containing hazardous substance(s) released from a source. Therefore the Facility would qualify for an exclusion from a terrestrial ecological evaluation under WAC 173-340-7491.

Soil concentrations that will not cause groundwater concentrations to exceed the groundwater PCLs protective of ecological receptors were also evaluated. The evaluation for groundwater protection was also completed for human receptors and is discussed below.

Human Health Protection

For human receptors, soil PCLs were developed for the following complete exposure pathways:

- Protection of temporary construction worker from soil via ingestion, dermal contact, and inhalation.
- Protection of groundwater from soil concentrations that potentially could cause an exceedance of the groundwater PCLs.

Values protective of temporary construction workers were derived using the MTCA Modified Method C Industrial equations provided in WAC 173-340-745(5)(b)(iii) that account for concurrent exposure due to ingestion and dermal contact with soil. Input parameters modified to reflect the temporary construction worker scenario included exposure frequency, and the soil ingestion rate. These parameters were modified to address the specific exposures potentially posed to the temporary construction worker and ensure PCLs are sufficiently protective of these receptors. For the purpose of the RI only, the default exposure duration value for an industrial worker (20 years) was used for the temporary construction worker scenario. As further discussed in Appendix D (Section D.2.1), an exposure duration of 1 year is commonly used to calculate soil cleanup levels protective of temporary construction workers, therefore the 20 year exposure duration value is conservative. Conversely, PCLs based either on the standard Method C Industrial [WAC 173-340-745(5)] or allowable modifications to Method C Industrial [WAC 173-340-745(5)(c)] account for lower exposure levels than are appropriate for temporary construction workers. Chemical specific factors (i.e., reference dose, carcinogenic potency factor) were selected using the literature sources identified in WAC 173-340-708.

As discussed in Section 3.3.4.2, MTCA presumes that the hazardous substances in soil typically pose a greater risk of exposure to human receptors by way of a soil-to-groundwater pathway than to site workers resulting from air vapors [WAC 173-340-745(5)(c)(iv)(A)]. Because soil PCLs protective of groundwater were derived under WAC 173-340-747(4), a separate calculation to evaluate the potential exposure of temporary construction workers due to inhalation is not required under Method C Industrial [WAC 173-340-745(5)].

Groundwater Protection

Soil values reflecting the requirement to protect groundwater, specifically Method C cleanup levels under WAC 173-340-745(5)(b)(iii)(A), were also derived. The soil PCLs were calculated using the fixed parameter, three-phase partitioning model outlined in WAC 173-340-747(4). As selected in Section 4.3.1, the groundwater PCLs protective of the human and ecological receptors were used as an input parameter. Default values for dilution factor, dry soil bulk density, and water- and air-filled porosity were utilized. Distribution coefficients (Kd) and Henry's law constants were obtained using the methods specified in WAC 173-340-747(4). The parameters used to derive soil PCLs protective of groundwater are provided in Appendix D.

4.4 POINT OF COMPLIANCE

Point of compliance (POC) means the point or points where cleanup levels established in accordance with WAC 173-340-720 through 173-340-760 shall be attained. This term includes both standard and conditional points of compliance (WAC 173-340-200).

For groundwater, the standard POC is defined as any location throughout the site from the uppermost level of the saturated zone extending vertically to the lowest most depth that could be potentially affected by the site. Conditional POCs for groundwater are subject to Ecology approval but could include such points as the property boundary or where groundwater discharges to surface water [WAC 173-340-720(8)].

For soil, the standard POC is dependent on the exposure pathway as described in WAC 173-340-740(6). For soil cleanup levels based on the protection of groundwater, MTCA specifies that the standard POC shall be established throughout the site. For soil cleanup levels based on direct contact by human or ecological receptors, the standard POC shall be established from the ground surface to 15 feet below the ground surface. For cleanup actions that involve containment of hazardous substances, the rules specify that soil cleanup levels will typically not be met within the containment.

A conditional POC for soil is available based on ecological considerations. For sites with institutional controls to prevent excavation of deeper soil, a conditional POC may be set at the biologically active zone. The depth of this zone is assumed by Ecology to be 6 feet, but Ecology may approve shallower depths depending on site-specific conditions [WAC 173-340-7490(4)].

For evaluating hazardous substances detected in soil and/or groundwater during the RI, a standard point of compliance is considered to be protective of human health and the environment. To assess whether a SWMU or AOC requires further consideration in the FS, the hazardous substances present at the units will be compared to the PCLs for each constituent. SWMUs and AOCs will not be evaluated in the FS if the concentrations of the substances are below PCLs at the standard POC.

During the FS, the applicability of one or more conditional POCs will be evaluated. A conditional POC for groundwater could include the Facility boundary and/or as close as technically possible to the point where groundwater flows into surface water. The FS will include fate and transport modeling to predict the concentration of hazardous substances at the conditional POC. This modeling will consider natural processes that attenuate concentrations based on site-specific mitigating factors. Mitigating factors include partitioning, dispersion, adsorption, and degradation. SWMU/AOC-specific cleanup standards will be determined through completion of this effort.

4.5 ASFLS TO BE EVALUATED IN THE FEASIBILITY STUDY

In addition to the chemical-specific ASFLs used to select the PCLs, action- and location-specific ASFLs, as well as other items to be considered (i.e., regulatory guidance), will be evaluated during the FS. These ASFLs are dependent on the cleanup action alternatives to be assessed during the FS.

4.5.1 Action-Specific ASFLs

Performance, design, and other action-specific requirements set restrictions on particular activities related to the management of hazardous substances. These requirements are not triggered by the specific chemicals present at a site, but are instead triggered by site characterization activities and cleanup actions. Potential action-specific ASFLs are technology-based performance standards such as the best available technology standard of the Federal Water Pollution Control Act. Other examples include Dangerous Waste Regulations (Chapter 173-303 WAC) concerning treatment, storage, and disposal standards and Clean Water Act (CWA) pre-treatment standards for discharges to publicly owned treatment works. The selection of action-specific ASFLs will be further refined during the FS based on applicable general response actions.

Table 4-5 presents the potential action-specific ASFLs for each medium (i.e., soil, groundwater, surface water, and air), and Table 4-6 lists the potential action-specific ARARs for construction-derived wastes at the Facility.

4.5.2 Location-Specific ASFLs

Location-specific ASFLs are statutes or regulations that set restrictions on activities or limits on constituent levels solely because of location (e.g., within a floodplain, wetland, historic place, or sensitive ecosystem or habitat). The potential location-specific ASFLs are presented in Table 4-7.

4.5.3 Potential Items To Be Considered

Potential items to be considered, such as regulatory guidance, are presented in Table 4-8.

4.5.4 Applicability of ASFLs to the Final Remedy

All cleanup actions are required by MTCA to comply with applicable state and federal laws. Moreover, a cleanup action must comply with the most stringent requirement, which then ensures attainment of all other ASFLs. MTCA requires that the remedies selected must attain ASFLs and be protective of human health and the environment.

Once a preferred cleanup action is formally selected, all chemical-, location-, and action-specific ASFLs will be identified. If it is found that the most suitable cleanup action does not meet an ASFL, MTCA provides for variances or waivers of ASFLs if the substantive conditions of the regulation are met (WAC 173-304-710). In all such cases, cleanup actions shall be protective of human health and the environment.

SECTION 5

SWMU/AOC REMEDIAL INVESTIGATION RESULTS

5.1 INVESTIGATION METHODOLOGY

As described in Section 1.2, the remedial investigation was conducted under Ecology approval in three mutually inclusive and dependant tiers: Tier 1 examined the historical documentation during the units' operation and, in some cases, during closure activities, to determine whether conclusive evidence existed that demonstrated a release of hazardous substances had not occurred. Tier 2 was the preliminary subsurface assessment during which soil and groundwater samples were collected and analyzed for the constituents of concern. The analytical results were compared to conservative screening levels to determine whether a release of hazardous substances may have occurred. Tier 3 provided a detailed investigation of those units in which a release was identified in Tier 2. Interim Action units were also incorporated into the RI process in Tier 3. The information obtained from the Tier 3 investigation was used to assess the nature and extent of the release, as well as unit-specific characteristics affecting fate and transport mechanisms.

The analytical and physical data obtained during each tier of investigation have been evaluated to determine whether hazardous substances are present in the soil and groundwater that threaten human health or the environment. In turn, this information will enable Boeing to develop and evaluate cleanup actions under the feasibility study process.

Sections 5.3 through 5.20 recount the investigations conducted at each of the SWMUs and AOCs. Each section also provides a synopsis of the unit's hydrogeologic characteristics and defines the nature and extent of hazardous substances in the soil and groundwater. Conclusions and recommendations for each unit are based on a comparison of the analytical results to the preliminary cleanup levels, as well as other factors that could potentially affect the identified pathways and receptors.

Tables summarizing the detected constituents in soil and/or groundwater associated with each unit are provided in the unit-specific subsection. Detected values exceeding the PCLs are shaded except for total metals concentrations detected in push-probe groundwater samples. Dissolved metals samples are more representative because push probes cannot be sufficiently developed to provide low turbidity water samples [WAC 173-340-720(9)(b)]. Figures provided in each subsection include a plan view showing the location of the SWMU/AOCs and associated monitoring wells and push-probes. A lithologic cross-section for each unit was developed from push probes and borings. Facility-wide groundwater elevation measurements collected on 9 June 1999, 31 March 2000 and 7 September 2000 were used to develop groundwater contour maps for each SWMU/AOC. Figures showing sampling locations and concentrations above the PCLs were created for each SWMU or AOC unit, as applicable. Separate figures were created for soil and groundwater at each SWMU/AOC, provided that concentrations higher than the PCLs occurred in both media. Figures were not created for media at a SWMU/AOC with no values above the PCLs.

Detailed investigative methods and results are provided in the following appendices:

- Appendix E: Summaries the Tier 3 field activities and provides a general discussion of field procedures conducted during the RI.
- Appendix F: Contains boring and well construction logs for the push-probes, borings and monitoring wells completed during the RI.
- Appendix G: Includes field data sheets such as groundwater sampling records as well as graphs of the groundwater quality parameters measured during the purging of the Tier 3 push-probes and monitoring wells.
- Appendix H: Includes the laboratory results and statistical summary of data collected during 1999 and 2000 for each area sampled. Laboratory data in this appendix were compared to the PCLs, and all detections above the PCLs were shaded.
- Appendix I: Contains copies of the validated laboratory reports for each Tier 3 SWMU/AOC as well as an evaluation of the overall data quality for soil and groundwater analyses conducted during the RI process.

5.2 DATA QUALITY OBJECTIVES

Media-specific analytical data quality objectives (DQOs) were developed following Ecology's *Guidelines and Specifications for Preparing Quality Assurance Project Plans* (Ecology 1991), as presented in the QAPjP in the *Remedial Investigation Work Plan* (WESTON 1998a), to ensure that data quality would be sufficient to achieve project objectives. Specifically, DQOs were established and assessed for the following parameters:

- Analytical methods
- Analytical precision
- Analytical accuracy
- Representativeness
- Comparability
- Completeness

All analytical data underwent a complete validation review to ensure the results were valid, legally defensible, intercomparable, and of acceptable quality. Validation of data followed the quality control specifications outlined in *Laboratory Data Functional Guidelines for Evaluating Organic Analytes* (EPA OSWER 9240.1-05-01, February 1994a) and *Laboratory Data Functional Guidelines for Evaluating Inorganic Analytes* (EPA OSWER 9240.1-05, February 1994b) modified to address project-specific criteria. All data generated through the Analytical Resource, Inc. laboratory underwent validation by WESTON. Tier 3 data validation memoranda and laboratory reports for soil and water analyses are presented in Appendix I. Data that have been included in previously submitted documents are not duplicated in this appendix. Appendix I also includes a discussion of the overall data quality for all the sampling events documented in this report.

Data were of high quality and, with few exceptions, met DQOs established for the project. The Tier 3 results presented in this report and companion interim data reports used all validated data, including analytes with concentrations or detection limits qualified as estimated due to minor exceedances of quality control criteria or qualified because reported sample concentrations were lower than the practical quantitation limit. Data for individual samples and analytes that were rejected during the validation process were not used for any purposes because it was not possible to determine the presence or absence of these analytes.

5.3 SWMU-001 AND SWMU-002: FORMER SUMPS SRE-2228 AND SRE-2229 (BUILDING 4-21)

SRE-2228 and SRE-2229 were sumps located near the southwest corner of Building 4-21. SRE-2228 was a 100-gallon polyethylene sump that managed rinsewater from nitric and chromic acid baths associated with a plating line. SRE-2229 was a 34-gallon concrete sump used to collect spills that occurred in the main containment area beneath the finish floor of this plating line. Both sumps were installed in the late 1970s and removed in 1991. Additional information regarding these SWMUs is included in Appendix A.

A site assessment performed in 1994 confirmed elevated metals concentrations in the subsurface soil in the areas of the former sumps. Soil in these areas was excavated as part of an independent remedial action. The location of the former sumps and the extent of the soil excavated are shown on Figure 5-1. The analytical results of compliance samples indicated that the soil exceeding MTCA cleanup levels had been removed. Ecology issued a statement that the soil in the area of the former sumps at Building 4-21 was remediated. Groundwater samples were not analyzed during the site assessment or independent remedial action.

Investigation Conducted

During the Tier 2 Assessment at SWMU-001 and SWMU-002 groundwater samples were collected upgradient and downgradient of the former sumps to evaluate if metals concentrations indicative of a release are present. The scope of work performed during Tier 2 included:

- Installation of three wells (GW154, GW155 and GW158).
- Collection of groundwater samples from one upgradient (GW158) and three downgradient wells (GW154, GW155, and existing well GW021).
- Analysis of groundwater samples for total cyanide and total and dissolved priority pollutant metals.

Tier 2 groundwater sample results indicated that arsenic was the only constituent exceeding SLs at these SWMUs, but that the arsenic concentrations compare to concentrations commonly detected in the Puget Sound region. However, groundwater elevations obtained during Tier 2 suggested a more northwesterly flow direction than assumed for the monitoring well placement.

Based on these results, the scope of work for the Tier 3 investigation included:

- Collection of groundwater samples from one upgradient (GW158) and three downgradient wells (GW021, GW154, and GW155), and from a push-probe sampling point (PP060) located directly downgradient (northwest) of SWMU-002 (Figure 5-1).
- Analysis of groundwater samples for dissolved priority pollutant metals.

Hydrogeologic Characteristics

The general stratigraphy beneath this area is shown in cross-section A-A’ (Figures 5-1A and 5-1B). Fill consisted of greenish-brown sand with silt and gravel (Figure 5-1B). Alluvium encountered below the fill was composed of greenish-gray sand with silt and occasional lenses of gravel and clayey silt (Figure 5-1B). The contact between the fill and alluvium appeared to become shallower toward the east. Soil samples collected from the three groundwater monitoring well borings and the push-probe advanced at SWMU-001 and SWMU-002 indicate that the hydraulic fill material extended to depths ranging from 5.5 to approximately 10 feet bgs.

Groundwater in this area is approximately 4 to 5 feet bgs, as measured in wells GW021, GW154, GW155, and GW158 (Table 2-2). Seasonal variations in groundwater elevations (9 June 1999, 31 March 2000, and 7 September 2000) were within 0.91 feet for the four wells in this area. Groundwater in this area generally flows to the west-northwest toward the Cedar River Waterway and Lake Washington at a gradient generally ranging from 0.001 to 0.007 (Figures 5-1C, 5-1D, and 5-1E). However, groundwater at some wells in the vicinity of these SWMUs appears to be affected by the extraction system located at the 4-78/79 Building, thus explaining the southerly groundwater flow direction south of this AOC (Figures 2-20 to 2-22).

A slug test was conducted in monitoring well GW154 located in the vicinity of the 4-45 Building at SWMU-001 and SWMU-002. As discussed in Section 2.9, the results of the slug test indicated that the hydraulic conductivity of groundwater in this area is approximately 2.8×10^{-4} cm/s.

Nature and Extent of Releases

Total and dissolved metals were detected in the groundwater samples collected during the Tier 2 and Tier 3 investigations at SWMU-001 and -002. As shown on Table 5-1A and Figure 5-1F, all samples except one collected from GW021 in June 1999 contained arsenic concentrations above the 1 µg/L PCL. The maximum concentration (49 µg/L) was detected in the groundwater sample from PP060, the sampling point added to assess the dissolved metals concentrations in the groundwater immediately downgradient of SWMU-002. All detected total and dissolved arsenic concentrations are within the range of arsenic concentrations in the Puget Sound region discussed previously in Section 2.7.3.7.2.

Conclusions and Recommendations

The objective of the RI at SWMU-001 and SWMU-002 was to determine if the previously remediated release to soil from these units had impacted groundwater. In addition to the one upgradient and three downgradient wells sampled during the Tier 2 assessment, the Tier 3 investigation included groundwater sampling from a push-probe located immediately downgradient (northwest) of SWMU-002. The groundwater samples from these five locations were analyzed for priority pollutant metals. The analytical results indicated that concentrations of total and dissolved arsenic were above the PCL but within the range of ambient concentrations found in the Puget Sound region.

Therefore, based on the analytical results, inclusion of SWMU-001 and SWMU-002 in the Feasibility Study is not recommended.

5.4 SWMU-168: FORMER UST URE-31 (BUILDING 5-50)

URE-31 was a 10,000-gallon concrete underground storage tank (UST) located near the northeast corner of Building 5-50. The UST was installed in 1979 to collect solvent waste generated in the building and was removed in September 1985. The location of the former UST is indicated by the limits of the former excavation shown in Figure 5-2. No information was available pertaining to releases from this unit. Additional information regarding this SWMU is included in Appendix A.

Investigation Conducted

The Tier 2 objective at SWMU-168 was to determine if a release from the UST had occurred. The scope of work performed during Tier 2 included:

- Collection of 12 soil and eight groundwater samples from four push-probe locations (PP001, PP002, PP003, and PP004).
- Analysis of soil and groundwater samples for volatile organic compounds (VOCs).

All VOC concentrations detected in the Tier 2 soil samples were below the SLs. Of the eight groundwater samples analyzed, only one sample contained VOC concentrations above the SLs. Vinyl chloride was detected in PP003 at 14 feet bgs at 2.1 µg/L, which slightly exceeded the SL of 2.0 µg/L. PP003 was located in close proximity and slightly upgradient of the former UST. Vinyl chloride was not detected in any of the other soil or groundwater samples analyzed. In light of this, and because the minor SL exceedance was within the accuracy of the laboratory analysis, no further evaluation was considered warranted at SWMU-168. The unit was not included in the Tier 3 Detailed Investigation.

Hydrogeologic Characteristics

The general stratigraphy beneath this area is shown in cross-section B-B’ (Figures 5-2A and 5-2B). Boring logs from the four push-probes advanced at this SWMU during the Tier 2 investigation indicate that the fill extended to depths ranging from approximately 5 to 7 feet bgs (Appendix F). This contact was deeper in push-probe PP001 (approximately 10 to 14 feet bgs) possibly because that area was the location of the former UST. The fill consisted of fine- to medium-grained reddish- to greenish-brown sand with silt and gravel. Alluvium beneath the fill consisted of interbedded greenish-gray clayey silt with gravelly and silty sand (Figure 5-2B).

Groundwater at this SWMU was approximately 5 feet bgs during Tier 2 drilling activities (Appendix F). However, groundwater as measured at GW079 during the three Facility-wide groundwater monitoring events (9 June 1999, 31 March 2000, and 7 September 2000) was typically deeper in this area, ranging from 7.26 to 8.41 feet bgs (Table 2-2). Seasonal variations observed in well GW079 during the three Facility-wide groundwater monitoring events were 1.15 feet or less. As presented in Figures 5-2C (June 1999), 5-2D (March 2000), and 5-2E (September 2000), groundwater consistently flows to the northeast toward the Cedar River Waterway. The range in average gradient is from 0.001 (March 2000) to 0.006 (June 1999).

Slug tests were conducted on nearby wells GW080, GW081, GW152, GW153, GW171, and GW173 of SWMU-172 and SWMU-174. Due to the proximity of these wells to the SWMU-168 investigation area, the data obtained can be used as an indicator of groundwater conditions at SWMU-168. As discussed in Section 2.9, the results of the slug tests indicated that the hydraulic conductivity of groundwater in this vicinity ranged from 4.6×10^{-5} to 4.2×10^{-3} cm/s.

Nature and Extent of Releases

Twelve soil and eight groundwater samples were collected from push-probes PP001 through PP004 during the Tier 2 investigation. All of the samples collected were analyzed for VOCs. As shown in Tables 5-2A and 5-2B, VOCs were detected in samples from both media.

Table 5-2A and Figure 5-2F summarize the concentrations of VOCs detected in the soil samples. Only one VOC, methylene chloride, was detected in soils at concentrations above the PCLs. Methylene chloride was detected at 73 µg/kg at a depth of 2 to 4 feet in PP001, and at 30 µg/kg at a depth of 5 to 7 feet in PP002. The PCL for methylene chloride is 27 µg/kg. The remaining concentrations of detected VOCs in soils did not exceed their corresponding PCLs.

Table 5-2B and Figure 5-2G summarize the concentrations of detected VOCs in the groundwater samples. In the groundwater sample collected from a depth of 14 foot bgs in PP003, vinyl chloride was detected at a concentration of 2.1 µg/L. This concentration is slightly above the PCL of 2 µg/L. The remaining concentrations of VOCs did not exceed their corresponding PCLs.

Conclusions and Recommendations

The objective of the Remedial Investigation at SWMU-168 was to determine if a release from the former UST had occurred. The analytical results for the samples collected during the Tier 2 assessment indicated that only one VOC (methylene chloride) was present in the soil at three probe locations (PP001, PP002, and PP003) at concentrations above the PCLs. Vinyl chloride was also detected in groundwater from PP003 at a concentration just exceeding the PCL.

Based on the detection of methylene chloride in soil and vinyl chloride in groundwater, at concentrations above the PCLs, inclusion of SWMU-168 in the Feasibility Study is recommended.

5.5 SWMU-172 AND SWMU-174: FORMER USTs URE-66 (BUILDING 5-09) AND URE-73 (BUILDING 5-08)

URE-66 and URE-73 were former USTs used to collect steam cleaning wastewater from Buildings 5-09 and 5-08, respectively (Figure 5-3). URE-66 was a 155-gallon concrete tank installed in 1963, and URE-73 was a 120-gallon concrete tank installed in 1957. Following removal of both USTs in 1987, approximately 37 cubic yards of soil were excavated. Although selected VOCs and semivolatile organic compounds (SVOCs) were detected, only PCE was detected slightly above SLs in any of the verification soil samples collected following UST removal. Additional information regarding these SWMUs is included in Appendix A.

Interim action activities at AOC-049 (former URE-030, Building 5-50), located north and generally downgradient of SWMU-172 and SWMU-174, have included quarterly groundwater sampling of four wells (GW080, GW081, GW082, and GW136) (Figure 5-3). Groundwater sampling activities were initiated at AOC-049 following the removal of URE-30, a 25,000-gallon diesel UST. In addition to diesel-range TPH, the wells have also been analyzed for VOCs, which are more likely attributable to SWMU-172 and SWMU-174 than former URE-30.

Investigation Conducted

The Tier 2 objective at SWMU-172 and SWMU-174 was to evaluate the concentration of previously detected constituents to determine if significant concentrations of these compounds were present in the soil and groundwater. The scope of work performed during Tier 2 included:

- The installation of two wells (GW152 and GW153).
- Collection of 16 soil and nine groundwater samples from four push-probes (PP005, PP006, PP007, PP008) and the two wells.
- Analysis of soil and groundwater samples for VOCs, selected SVOCs, and total and dissolved priority pollutant metals.

Tier 2 analytical results indicated that further evaluation of VOCs in soil and groundwater was warranted because concentrations of selected constituents exceeded the SLs. In addition, groundwater sampling activities associated with AOC-049 (Interim Action), indicated that VOCs were detected above the SL in well GW082, located downgradient of SWMU-172 and SWMU-174.

Based on these findings, the Tier 3 scope of work for these SWMUs included:

- The installation of one upgradient (GW171) and two downgradient (GW172 and GW173) wells.
- Collection of seven soil and 14 groundwater samples from three new push-probe locations (PP061, PP062, and PP063) and 10 wells (GW080 through GW084, GW152, GW153, and GW171 through GW173).
- Analysis of four soil and 14 groundwater samples for VOCs.
- Analysis of three soil samples for geotechnical parameters including TOC, bulk dry density, particle size distribution, and total porosity.

The groundwater monitoring conducted as part of the SWMU-172 and SWMU-174 investigation was also associated with AOC-049.

Hydrogeologic Characteristics

The general stratigraphy beneath this area is shown on cross-section C-C’ (Figures 5-3A and 5-3B). Fill encountered in this area was generally coarser than areas in the north end of the plant and consisted of greenish- to reddish-brown sand with silt and coarse gravel. As shown on the boring log, buried debris (glass, paper, and bricks) was also encountered during drilling at approximately 5 feet bgs in PP061 (Figure 5-3B and Appendix F). Alluvium consisted of interbedded greenish-gray silty clay, clayey silt, and fine- to medium-grained silty sand with occasional gravelly lenses (Figure 5-3B). Boring logs from the seven push-probes and five groundwater monitoring wells advanced during the Tier 2 and 3 investigations indicated that the contact between fill materials and alluvium ranged from approximately 5 to 15 feet bgs (Appendix F).

During drilling, groundwater was encountered at approximately 9 to 9.5 feet bgs (Appendix F). The formation in this area has a low permeability; therefore, the water table was characterized only by moist soils. Groundwater as measured at GW080, GW081, GW152, GW153, GW171, and GW173 during the three Facility-wide groundwater monitoring events (9 June 1999, 31 March 2000, and 7 September 2000) ranged between 8 to 10.7 feet bgs, with a maximum seasonal variation of 1.45 feet (Table 2-2). As presented on Figures 5-3C (June 1999), 5-3D (March 2000), and 5-3E (September 2000), groundwater generally flows to the northeast, toward the Cedar River Waterway. The range in average gradients is from 0.003 (June 1999) to 0.006 (September 2000).

Slug tests were conducted in monitoring wells GW080, GW081, GW152, GW153, GW171, and GW173 located in the vicinity of SWMU-172 and SWMU-174. As previously discussed in Section 2.9, the results of the slug tests indicated that the hydraulic conductivity of groundwater in the area ranges from 4.6×10^{-5} to 4.2×10^{-3} cm/s.

Nature and Extent of Releases

The soil analytical results for the 23 soil samples collected during the Tier 2 and 3 investigations are included in Table 5-3A. Concentrations detected above the PCLs in soil are shown on Figure 5-3F. Results from the 23 groundwater samples collected during the Tier 2 and Tier 3 investigations, as well as the 1999 quarterly VOC sampling results of wells GW080, GW081, and GW082 from AOC-049, are presented in Table 5-3B. Concentrations detected above the PCLs in groundwater are shown on Figure 5-3G.

Soil

VOCs, SVOCs, and metals were detected in the soil samples collected from SWMU-172 and SWMU-174 during the Tier 2 and Tier 3 investigations.

VOCs detected above the PCLs included PCE, TCE, benzene, and methylene chloride. PCE was detected above the PCL of 48 µg/kg in eight soil samples from six locations. PCE concentrations above the PCL ranged from 70 to 5,900 µg/kg, with the maximum concentration detected in the 2 feet bgs sample from PP006. TCE concentrations above the PCL of 54 µg/kg were detected in only two samples at concentrations of 61 µg/kg (2- to 4-foot bgs sample from PP061) and 400 µg/kg (2- to 4- foot bgs sample from PP006). Benzene was detected above the

PCL (14 µg/kg) only in the 2 feet bgs sample from PP006, at a concentration of 1,200 µg/kg. The one detection of methylene chloride at a concentration above the PCL (27 µg/kg) occurred in the 2- to 4-foot bgs sample from PP008. The distribution of constituent concentrations exceeding the PCLs in soil is illustrated in Figure 5-3F.

The analytical results indicate that in the vicinity of SWMU-172, VOC concentrations above the PCL in soil are limited to within 15 feet of the surface. Concentrations above the PCL were detected in sample intervals ranging from 2 to 10.5 feet bgs at sampling points at least 45 feet to the east (PP061), 15 feet to the north (GW152), 70 feet to the south (PP062), and 10 feet to the southwest (PP005). VOC concentrations in samples collected from 15 feet bgs in the vicinity of SWMU-172 (GW152 and PP005) were below PCLs.

In the vicinity of SWMU-174, analytical results indicate the presence of VOC concentrations above the PCL within 9 feet of the surface at the sampling point 15 to the east (PP008). VOC concentrations in samples collected from PP007, located closest to the former SWMU location, were below PCLs.

SVOC concentrations in soil were not detected above the PCLs in any of the samples collected during the RI.

The inorganic constituents antimony, copper, selenium, thallium, and zinc exceeded the PCL in one or more soil samples collected during the Tier 2 investigation. Concentrations of antimony above the PCL (5.786 mg/kg) were limited to the vicinity of SWMU-174. Antimony occurred at estimated concentrations of 7 mg/kg in the 2 feet bgs samples from PP005, PP008, and GW153, and at an estimated concentration of 6 mg/kg in the 8.5 feet bgs sample from GW153. Selenium concentrations above the PCL (5.2 mg/kg) were detected in samples near both of the SWMUs in PP006, GW152, PP007, and GW153, at concentrations ranging from 7 mg/kg to 8 mg/kg. Copper and zinc concentrations above the PCLs were limited to the vicinity of SWMU-172. Copper was detected at concentrations exceeding the PCL (0.011 mg/kg) in PP005 (61.4 mg/kg at 2 feet bgs), PP006 (41.6 mg/kg at 2 feet bgs), and in GW152 (37.7 mg/kg at 8.5 feet bgs). Thallium was detected above the PCL (5 mg/kg) in the 8.5 feet bgs sample of GW152 (6 mg/kg).

Zinc was detected at a concentration above the PCL (0.1 mg/kg) in PP006 (217 mg/kg at 2 feet bgs).

Analytical results indicate that metals concentrations exceeding the PCLs extend east, north, and southwest of SWMU-172. The eastern extent is defined by PP061, located 45 feet east of the SWMU. The northern extent beyond GW152 is not fully defined with respect to the PCLs, but is likely limited based on the relatively low concentrations in samples from that location. The southwestern extent is also not fully defined. The vertical extent of metals concentrations above the PCLs near SWMU-172 is limited to within 15 feet bgs to the north and east, and at least 17 feet bgs to the southwest. The analytical results indicated that metals concentrations exceeding the PCLs extend to the north and east from SWMU-174. The northern and eastern extent of metal concentrations are not fully defined with respect to the PCLs, but are likely limited based on the relatively low concentrations detected. Vertically, metals concentrations above the PCLs near SWMU-174 are seen to extend to at least 15 feet bgs in the immediate vicinity of the unit, but are limited to within 9 feet bgs to the east. Because antimony results were not reported for the 15 feet bgs sample from GW153, the vertical extent to the north of the unit is uncertain, but based on concentrations reported, is likely limited to within 15 feet bgs.

Groundwater

VOCs, bis(2-ethylhexyl)phthalate, and metals were detected in selected groundwater samples associated with SWMU-172 and SWMU-174 (Table 5-3B). VOCs were the only constituents that significantly exceeded the RI SLs in the groundwater samples collected during Tier 2. Low concentrations of dissolved arsenic were also detected during Tier 2, but these concentrations were within the range of ambient arsenic concentrations in the Puget Sound region discussed previously in Section 2.7.3.7.2. Based on Tier 2 analytical results, the Tier 3 groundwater samples from SWMU-172 and SWMU-174 were analyzed for VOCs.

In addition to the RI Tier 2 and Tier 3 sampling events, monitoring wells GW080, GW081, and GW082 have undergone quarterly groundwater sampling. Table 5-3B presents the results of all detected constituents in samples collected from January 1999 through August 2000 (Tier 3). VOC concentrations exceeding PCLs included 1,1-dichloroethene (1,1-DCE), benzene, chloromethane, cis-1,2-DCE, methylene chloride, PCE, TCE, and vinyl chloride. Maximum concentrations of these constituents detected over the sampling period were: 3.8 µg/kg for 1,1-DCE, 2,500 µg/kg for cis-1,2-DCE, and 1900 µg/kg for TCE, each detected in the August 2000 sample from PP061; 1.7 µg/kg for benzene, an estimated concentration of 16 µg/kg for chloromethane, and 12 µg/kg for methylene chloride, each detected in the June 1999 sample from GW082; 300 µg/kg for PCE, detected in the May 1999 sample from PP006 (12 feet bgs); and 34 µg/kg for vinyl chloride, detected in the August 2000 sample from GW172.

The SVOC bis(2-ethylhexyl)phthalate was detected above the PCL (1.8 µg/L) in groundwater samples from GW152, PP005 and PP007 at concentrations ranging from 2.4 to 3.6 µg/L. No other detections of SVOC concentrations above the PCLs occurred during the RI.

VOCs were detected at concentrations above the PCLs in GW082, GW083, GW152, GW153, GW172, GW173, PP005, PP006, PP007, PP008, PP061, and PP062. Based on these analytical results, the extent of concentrations exceeding the PCLs may be defined by GW171 to the south, GW084 to the west, and GW080/GW081 to the north. The eastward extent toward the Cedar River is not fully defined with respect to the PCLs.

Total metals concentrations in groundwater detected above the PCLs included arsenic, chromium, copper and lead in the June 1999 sample from GW152, and arsenic in the June 1999 sample from GW153. These total metals concentrations were detected slightly above their respective PCLs. Dissolved arsenic concentrations above the PCL (1 µg/kg) were detected in groundwater samples from PP006 and PP007 in May 1999; concentrations in these samples were reported as 0.002 mg/L (estimated) in PP006 and 0.002 mg/L in PP007.

Conclusions and Recommendations

In the course of the 1999 through August 2000 sampling period, 20 soil samples were collected at SWMU-172 and SWMU-174 and analyzed for VOCs, SVOCs and metals. Several VOCs and several metals were detected at concentrations above the PCLs.

Based on the soil analytical results, VOC concentrations exceeding the PCLs in the vicinity of SWMU-172 appear to extend to at least 45 feet to the east, 15 feet to the north, 70 feet to the south, and 10 feet to the southwest. The data suggests the vertical extent of these constituents with concentrations above the PCLs is limited to within 15 feet of the surface.

The soil analytical results indicated that VOC concentrations exceeding the PCLs in the vicinity of SWMU-174 extend at least 15 feet to the east of the unit. Vertically, concentrations above the PCLs are limited to within 9 feet bgs to the east.

Thirty-two groundwater samples were collected at SWMU-172 and SWMU-174 over the period of 1999 through August 2000. Analyses included VOCs, SVOCs, and metals. VOCs were detected at concentrations above the PCLs in several samples collected over this period. One SVOC [bis(2-ethylhexyl)phthalate], four total metals (arsenic, chromium, copper and lead), and one dissolved metal (arsenic) were detected at concentrations exceeding the PCLs. Based on the analytical results, the extent of groundwater impact in the area is confined an area delineated by GW171 to the south, GW084 to the west, and GW080/GW081 to the north; the extent toward the east is not fully defined with respect to the PCLs.

Based on the analytical results, SWMU-172 and SWMU-174 is recommended for inclusion in the Feasibility Study.

5.6 SWMU-179: FORMER CONDENSATE BLOWDOWN CISTERN (BUILDING 4-76)

The former cistern located in Building 4-76 (Figure 5-4) received blowdown condensate from an air compressor that contained low concentrations of oil. The cistern was constructed of concrete walls with a gravel floor; the installation date is not known. The cistern's walls were removed in November 1990, and soil was excavated to a depth of approximately 5 feet. TPH and nickel concentrations above the SL were detected in the soil samples collected from the excavation after soil removal. Additional soil was not removed due to the potential for damaging the Building 4-63 foundation and floor slab. Groundwater sampled from a well point driven in the cistern prior to closure was analyzed for TPH; no concentrations were detected. Additional information regarding this SWMU is included in Appendix A.

Investigation Conducted

The Tier 2 sampling objective at SWMU-179 was to evaluate the current concentration of previously detected constituents to determine if significant concentrations of these compounds were present in the soil and groundwater. The scope of work performed during Tier 2 included:

- Installation of one well (GW157).
- Collection of six soil and three groundwater samples from two push-probes (PP009 and PP010) and one well (GW157).
- Analysis of soil and groundwater samples for polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), diesel- and motor oil-range total petroleum hydrocarbons (TPH), and total and dissolved priority pollutant metals.

Laboratory results of the soil and groundwater samples indicate PAH and PCB concentrations were not detected and TPH concentrations did not exceed the SL. Only one soil sample was slightly above the SL for chromium, which was considered the natural background concentration for soil in the Puget Sound region (Ecology 1994). This chromium concentration is below the MTCA Method A cleanup level (Ecology 1996). Nickel concentrations were detected slightly above the SL, although these values were below the natural background concentration for soil in the Puget Sound region (Ecology 1994).

Total and dissolved arsenic were the only constituents that exceeded the SL in the groundwater samples analyzed, although detected concentrations were within the range commonly detected in the Puget Sound region and in wells located upgradient of the Facility. Therefore, these concentrations were not considered indicative of a release. SWMU-179 was not included in the Tier 3 Detailed Investigation.

Hydrogeologic Characteristics

The general stratigraphy beneath this area is shown in cross-section D-D’ (Figures 5-4A and 5-4B). Fill observed in this area consisted of greenish-brown fine- to medium-grained sand with silt and gravel ranging to 2.5 to 5 feet bgs. Alluvium encountered below the fill consisted of light brown clayey silt with fine-grained sand grading into greenish-brown fine-grained sand with silt (Figure 5-4B). Boring logs from the two push-probes and the groundwater monitoring well advanced at this SWMU during the Tier 2 investigation indicated that the hydraulic fill materials extended only 2 feet bgs (Appendix F).

Groundwater was encountered at approximately 5 feet bgs during drilling (Appendix F). Groundwater as measured at GW157 during the three Facility-wide groundwater monitoring events (9 June 1999, 31 March 2000, and 7 September 2000) ranged between 7.09 to 7.49 feet bgs (Table 2-2). Seasonal water table variations observed in groundwater levels in this well were less than 0.4 foot bgs. As presented on Figures 5-4C, 5-4D, and 5-4E, groundwater generally flows to the west-northwest, toward the Cedar River Waterway. The gradient of the groundwater flow remains fairly constant at approximately 0.004.

Nature and Extent of Releases

Six soil and three groundwater samples from well GW157 and push-probes PP009 and PP010 were collected during the Tier 2 investigation and analyzed for PAHs, PCBs, diesel- and motor oil-range TPH, and total and dissolved priority pollutant metals.

As shown on Table 5-4A and Figure 5-4F, motor oil-range TPH and selected metals were the only constituents that were detected in soil. With the exception of chromium, copper and selenium all of the detected concentrations were below the PCLs. Chromium was detected at a concentration of 54 mg/kg and copper was detected at a concentration of 39.7 mg/kg at the 2 feet bgs soil sample collected at PP010. Selenium was detected at a concentration of 8 and 6 mg/kg at the 2 feet bgs soil sample collected at PP009 and the 5 feet bgs sample collected at GW157 respectively. The concentrations detected for these constituents are slightly above the PCL.

Table 5-4B and Figure 5-4G summarize the concentrations of detected constituents in the three groundwater samples collected. Diesel-range hydrocarbons and total and dissolved priority pollutant metals were detected in the samples collected. From these, diesel range TPH at a concentration of 1 mg/L and arsenic at concentrations ranging from 0.006 to 0.013 mg/L were the only detected constituents in concentrations above the PCL.

Conclusions and Recommendations

The objective of the RI at SWMU-179 was to evaluate the concentrations of previously detected constituents in the soil and groundwater. Soil and groundwater samples were collected adjacent to this unit and analyzed for PAHs, PCBs, metals, and diesel- and motor-oil range TPH. Analytical results indicated that copper and selenium in soil and diesel-range TPH and arsenic in groundwater were detected in concentrations only slightly above their respective PCLs. As discussed in Sections 2 and 3, naturally elevated arsenic concentrations in the area are not indicative of a release from the Facility. However, the presence of selenium in soil above the PCL indicates the detected concentrations are not protective of groundwater and might be indicative of a release. In addition, the presence of diesel in groundwater above the PCL may also be indicative of a release.

Based on the results of the Remedial Investigation, inclusion of SWMU-179 in the Feasibility Study is recommended.

5.7 BUILDING 4-78/79 SWMU/AOC GROUP: SWMU-181, AOC-013, AOC-014, AOC-015, AOC-026, AOC-037, AND AOC-054

The SWMU/AOC group in the vicinity of Building 4-78/79 includes a former dangerous waste storage area (SWMU-181), four former gasoline USTs (URE-17, -23, -24 and -54) and two former MEK USTs (URE-18 and -25). The former locations of these units are shown on Figure 5-5. A general description of each unit is provided below:

- SWMU-181: Building 4-78 Former Dangerous Wastes Storage Area—This SWMU was used for the accumulation of dangerous wastes brought from other areas of the Facility. Wastes typically stored at SWMU-181 included solvents, spent petroleum products, and sludges. Historical data from investigations in the vicinity of SWMU-181 (GTI 1989) indicate releases of VOCs, SVOCs, and TPH to groundwater.

- AOC-013: Former URE-17—This 1,000-gallon steel tank was used to store gasoline. The UST was removed in September 1985 after Norton Corrosion detected a potential release. During the removal operation of URE-017 and nearby URE-024, approximately 50 gallons of free-phase gasoline were recovered (Landau 1987). Soil and groundwater samples collected in the vicinity of this former UST in 1989 detected VOCs and TPH concentrations.

- AOC-14: Former URE-18—This 10,000-gallon steel tank was used to store MEK. Approximately 290 cubic yards of soil were excavated following the tank's removal in 1987 Landau 1987). VOCs, MEK, and TPH were detected in groundwater in the vicinity. These constituents were not detected in soil near the former tank (GTI 1989).

- AOC-015: Former URE-24—This 4,000-gallon steel tank was used to store gasoline. The tank was removed in September 1985 (Landau 1987). BTEX, TPH, MEK, and VOCs were detected in groundwater in the vicinity. Soil samples collected near the former tank were analyzed for BTEX, TPH, and MEK; none of the analytes were detected (GTI 1989).

- AOC-026: Former URE-54—This 1,000 gallon steel tank was used to store gasoline. During the removal of the tank in 1985, six holes were noted in the bottom of the UST and free product was observed on water present in the excavation. An unspecified quantity of contaminated soil was excavated, and the floating hydrocarbons were removed. No soil or groundwater samples were collected. Dissolved-phase benzene was detected in groundwater adjacent to this former UST (GTI 1989). TCE, benzene, and vinyl chloride were detected in groundwater in the vicinity of this AOC (WESTON 1997a).

- AOC-037: URE-25—This 500-gallon steel tank was used to store MEK. URE-25 was removed in September 1987. Laboratory analyses of soil verification samples collected in 1993 were below RCRA Subpart S action limits (WESTON 1993). TCE, benzene, and vinyl chloride were detected in groundwater in the vicinity of this AOC (WESTON 1997a).
- AOC-054: URE-23—This 10,000-gallon steel tank was used to store gasoline. During removal of URE-23 in April 1989, gasoline was observed in the soil and on groundwater samples. Approximately 200 cubic yards of soil were excavated (Landau 1989). Soil and groundwater sampling revealed detectable concentrations of BTEX, TPH, and VOCs (GTI 1989; WESTON 1993b).

Sampling conducted in 1989 detected VOCs above the PCLs in soil and groundwater in the vicinity of the former USTs (GTI 1989). Additional information on these units is included in Appendix A.

The interaction of historical releases from units within the Building 4-78/79 SWMU/AOC Group and hydrogeological conditions at the site have resulted in a commingled subsurface contaminant condition beneath and surrounding this vicinity.

Ongoing Interim Action

The interim action at the Building 4-78/79 SWMU/AOC group was initiated following the closure of former USTs URE-17, -18, -23, -24, -25, and -54 and consists of extracting groundwater from wells GW042 and GW151 (Figure 5-5A). The extracted groundwater is then treated via a low-profile air stripper and discharged to King County Department of Natural Resource's (KCDNR's) wastewater treatment facility. The primary objectives of the interim action are to prevent the off-site migration of VOCs and TPH-G and to reduce groundwater concentrations of those constituents.

The scope of work performed at this SWMU/AOC group included:

- Continued biannual groundwater sampling of 13 wells (GW022, GW024, GW030, GW031, GW033, GW034, GW035, GW038, GW039, GW040, GW041, and GW143), including the addition of GW132 to the monitoring network.
- Analysis of the groundwater samples for VOCs and gasoline-range TPH.

Hydrogeologic Characteristics

The general stratigraphy beneath this area is shown in cross-section E-E' (Figures 5-5A and 5-5B). Hydraulic fill materials consisted of brown sandy gravel, to brown fine- to medium-grained sand with silt and gravel. Alluvium consisted of interbedded greenish-gray silt, greenish-gray silty clay, grayish-green sand, and grayish-green sandy gravel. Boring logs from groundwater monitoring wells GW022, GW024, GW030, GW031, GW033, GW034, GW035, GW038, GW039, GW040, GW041, and GW143 indicated that the contact between hydraulic fill materials and alluvium ranged from 2 to 5 feet bgs (Appendix F).

Groundwater as measured in monitoring wells GW022, GW028, GW030, GW031, GW033, GW035, GW036, GW038, GW039, GW041, GW042, GW132, GW133, and/or GW143 during the three Facility-wide groundwater measurement events (9 June 1999, 31 March 2000, and 7 September 2000) ranged between 3.79 to 6.56 feet bgs (Table 2-2). Variations in the groundwater elevations measured at these 13 wells during the three monitoring events ranged from 0.08 to 0.97 feet bgs (Table 2-2). Contour maps constructed for the area indicate a cone of depression due to extraction wells GW042 and GW151 (Figures 5-5C, 5-5D, and 5-5E). Effects from the extraction system are seen throughout the area as far as well GW021, which is associated with the SWMU-001 and SWMU-002. The maps indicate that the cone of depression created by the system wells keeps groundwater in the area from migrating toward Lake Washington or the Cedar River (Figures 5-5C, 5-5D, and 5-5E). Outside the extraction system influence area, groundwater flows to the west-northwest toward the Cedar River Waterway and Lake Washington (Figures 2-20 through 2-22).

Slug tests were conducted in wells GW031, GW033, GW034, GW035, GW036, GW037, GW038, GW040, GW041, and GW143. As discussed in Section 2.9, the results of the slug tests indicated that the hydraulic conductivity of groundwater in the area ranges from 7.3×10^{-5} to 1.8×10^{-2} cm/s.

Nature and Extent of Releases

The analytical results of groundwater sampling at the Building 4/78-79 SWMU/AOC Group indicate that VOCs and gasoline-range TPH (TPH-G) are present in the groundwater. The concentrations detected over the previous three biannual groundwater monitoring events (June 1999 to June 2000) are summarized in Table 5-5A.

As shown on Table 5-5A and Figure 5-5F, 1,1-dichloroethene, benzene, cis-1,2-dichloroethene, TCE, vinyl chloride, and TPH-G were detected at concentrations exceeding the PCLs. The VOC 1,1-dichloroethene was detected slightly above its PCL of 1 µg/L in only one groundwater sample from monitoring well GW033 in June 1999 at a concentration of 1.9 µg/L. However, there were no detections of this constituent during the following two biannual sampling events.

Benzene was detected above its PCL value (1 µg/L) in 11 groundwater samples collected from the monitoring wells GW031, GW038, GW039, GW040, and GW041 at concentrations ranging from 8.4 to 280 µg/L (Figure 5-5F). The highest concentration was detected on June 1999 at GW031 downgradient from GW151, one of the pumping wells. Benzene concentrations decreased during the following two biannual sampling events conducted on this well. However, results were highly variable in the other wells where benzene was detected (Table 5-5A). For example, while benzene concentrations in GW038 and GW041 dropped from 150 µg/L (June 1999) and 8.4 µg/L (December 1999) to non-detect within 6 months respectively, benzene remained above the PCL in GW031, GW039, and GW040.

There were only two occasions where concentrations of cis-1,2-dichloroethene was above its PCL value of 80 µg/L. The concentrations were detected in monitoring wells GW033 (estimated value of 160 µg/L) and GW034 (89 µg/L) in June and December 1999, respectively (Figure 5-5D). In both wells concentrations decreased in the following biannual sampling events to non-detect concentrations or significantly below the PCL.

TCE was detected above its PCL value of 2.7 µg/L in three groundwater samples collected from the monitoring wells GW030 and GW033 in June 1999, and GW034 in May 1999. In all three wells TCE concentrations decreased to non-detect levels in the following biannual sampling event.

Vinyl chloride was detected above its PCL value of 2 µg/L in 3 samples collected from groundwater monitoring wells GW033 (June 1999) and GW034 (May 1999 and June 2000). The June 1999 sample from well GW033 contained an estimated vinyl chloride concentration of 72 µg/L and decreased to non-detect levels in the following biannual sampling event. The December 1999 sample from well GW034 contained a vinyl chloride concentration of 35 µg/L and decreased to 3.8 µg/L in the June 2000 biannual sampling event.

Concentrations above the PCL for TPH-G (Table 5-5A, Figure 5-5D) were detected in one groundwater sample collected from GW039 (0.95 mg/L; June 2000) and three groundwater samples collected from GW040 during the June 1999 (1.9 mg/L), December 1999 (0.92 mg/L), and June 2000 (3.3 mg/L) sampling events. All other detected concentrations were below the PCLs.

Conclusions and Recommendations

The results of the biannual groundwater sampling at the Building 4/78-79 SWMU/AOC Group indicate that VOC and TPH-G concentrations are present in the groundwater. VOCs such as 1,1-dichloroethene, benzene, cis-1,2-dichloroethene, TCE, and vinyl chloride, and TPH-G were detected above the PCLs during the previous three biannual groundwater monitoring events (June 1999 to June 2000). Concentrations of 1,1-dichloroethene, cis-1,2-dichloroethene, and TCE decreased to non-detect values or significantly below the PCLs from their onset in 1999 to the last biannual event conducted in June 2000. With the exception of GW038 and GW041, where benzene concentrations dropped dramatically from June 1999 to December 1999, concentrations of benzene, vinyl chloride, and TPH-G remain at concentrations above their respective PCLs.

Beyond the influence of the Building 4-78/79 groundwater extraction system, natural groundwater flow is generally toward the northwest. Groundwater samples from downgradient wells GW132 and GW143 did not contain concentrations above the PCLs and PQLs, respectively. These results indicate that the existing groundwater extraction system is prohibiting northwesterly migration of VOCs and TPH-G present in the groundwater at this SWMU/AOC Group.

Based on the information obtained during the RI, Building 4-78/79 SWMU/AOC Group is recommended for inclusion in the Feasibility Study.

5.8 FORMER FUEL FARM AOC GROUP, AOC-046, AOC-047, AND AOC-048: FORMER USTs URE-033, URE-034, AND URE-035

The Former Fuel Farm consisted of four USTs (URE-033 through URE-036) located near the south end of Renton Municipal Airport, about 200 feet southeast of Building 5-02 (Figure 5-6). The USTs were installed in 1956 and 1957, and removed during closure activities at the Former Fuel Farm in 1993 (Burlington Environmental 1994a). One UST (URE-036), used for waste fuel and hydraulic fluid storage, was closed in place in 1987 (Hart Crowser 1988). This tank was closed under an Ecology-approved closure plan in 1994 (Burlington Environmental 1994b), and Ecology approved the closure certification. Residual petroleum hydrocarbons remaining in soil associated with three former fuel storage tanks, URE-033, -034, and -035, were identified in the Order as AOC- 046, -047 and -048, respectively. URE-033, -034, and –035 were steel tanks used to store jet fuel. URE-033 and –034 had capacities of 50,000 gallons; URE-035 had a capacity of 12,000 gallons. Additional information regarding these tanks is included in Appendix A.

Soil sampling (WESTON 1994) performed in 1994 assessed the lateral and vertical extent of TPH-impacted soil. The total volume of soil above MTCA Method A was estimated to be approximately 4,400 cubic yards. An evaluation of chromatograms from Former Fuel Farm soil samples suggests the presence of Jet-A petroleum products and not diesel- or gasoline-range TPH (WESTON 1994).

Ongoing Interim Action

The interim action at the Former Fuel Farm AOC group was initiated in May 1995 following the closure and removal of URE-033 through URE-036. The interim action includes an air sparging and bioventing system designed to enhance bioremediation of the Jet-A fuel present in the subsurface. The cleanup objective for the interim action is for residual impacted soil to be reduced to the MTCA Interim TPH Policy Standards (Ecology Publication No. ECY 97-600) or prevailing MTCA provisions.

The performance monitoring program for the Former Fuel Farm AOC group primarily consists of biannual soil and groundwater sampling, as well as periodic inspections of the equipment and operational systems. Soil analyses conducted during recent sampling events have included TPH, PAHs, volatile petroleum hydrocarbons (VPH), and extractable petroleum hydrocarbons (EPH). Groundwater samples have also been analyzed for diesel- and Jet-A-range TPH.

The scope of work for the Tier 3 monitoring included:

- Collection of 10 groundwater samples from two monitoring wells (GW101 and GW102), and from eight push-probe locations (PP401, PP405, PP420, PP427, PP429, PP430, PP431, and PP433).
- Collection of four soil samples from four push-probe locations (PP401, PP405, PP420, PP427).
- Analysis of groundwater samples for diesel- and Jet-A-range TPH.
- Analysis of soil samples for diesel- and Jet-A range TPH, VPH, EPH, PAHs, and TOC.

The monitoring results for the Former Fuel Farm are included in the following subsections.

Hydrogeologic Characteristics

The general stratigraphy beneath this area is shown in cross-section F-F’ (Figures 5-6A and 5-6B). Hydraulic fill encountered in this area consisted of brown to reddish-brown fine-grained sand with silt and gravel. Alluvium consisted of medium- to coarse-grained greenish-gray sand with silt (Figure 5-6B). Boring logs from wells GW101 and GW102, as well as selected push-probes sampled at this AOC, indicate that the contact between hydraulic fill and *in situ* alluvium ranged from 5 to 10.5 feet bgs (Appendix F). The fill/alluvium contact in the two monitoring wells was observed at approximately 5 feet bgs, while the contact in the push-probes was observed at approximately 9 to 10.5 feet bgs (Appendix F). The differences observed in the elevation of the fill might be a result of the location of the wells and the push-probes in relation to the former UST excavation conducted in the area during the early 1990s (Figure 5-6). The wells are located outside the limits of the excavation, and the push-probes are located within the excavation area.

During drilling, groundwater was typically encountered at approximately 8 to 11 feet bgs (Appendix F). Groundwater, as measured in monitoring wells GW101 and GW102 during the three Facility-wide groundwater measurement events (9 June 1999, 31 March 2000, and 7 September 2000), ranged between 8.52 to 11.75 feet (Table 2-2). Seasonal groundwater level variations observed at these wells during the three monitoring events were approximately 1.5 feet (Table 2-9). As presented in Figures 5-6C, 5-6D, and 5-6E, groundwater in this area generally flows to the north toward the Cedar River at an average gradient of about 0.004.

Slug tests were conducted in wells GW101 and GW102 within the Former Fuel Farm AOC Group area. As discussed in Section 2.9, the results of the slug tests indicated that the hydraulic conductivity of the groundwater in the area ranged from 1.7×10^{-3} to 6.9×10^{-3} cm/s.

Nature and Extent of Releases

The analytical results of the IA and Tier 3 soil and groundwater samples collected indicate that detectable concentrations of VOCs, SVOCs, and TPH are present in the soil, and detectable concentrations of TPH are present in the groundwater.

Soil

Soil samples from PP401, PP405, PP420, and PP427 collected during IA biannual sampling (WESTON 1999j, 2000d) and the Tier 3 investigation were analyzed for VOCs, SVOCs, diesel- (TPH-D) plus Jet-A fuel-range (TPH-Jet-A) petroleum hydrocarbons, as well as EPH and VPH. The concentrations of constituents detected in soil samples during the three IA sampling rounds prior to the Tier 3 sampling event (June 1999 to June 2000) and the Tier 3 event (August 2000) are summarized in Table 5-6A.

VOCs, SVOCs, TPH, and EPH and VPH compounds were detected in the soil samples. As shown on Table 5-6A, concentrations of benzene, 2-methylnaphthalene, TPH-D, and TPH-Jet-A exceeded the PCLs in one or more samples. The spatial distribution of soil concentrations above the PCLs is shown in Figure 5-6F.

Benzene concentrations were detected above the PCL of 14 µg/kg in PP401, PP405, and PP420 during the 16 December 1999 to 3 January 2000 sampling rounds (Figure 5-6F). Concentrations in these soil samples ranged from 510 to 7,200 µg/kg, with the highest concentration detected in PP420. 2-Methylnaphthalene was detected above the PCL during one or more sampling events in all four push probes. The concentrations of 2-methylnaphthalene exceeding the PCL of 1,496 µg/kg ranged from 2,200 to 20,000 µg/kg.

TPH concentrations above the PCLs (2,000 mg/kg each for TPH-D and TPH-Jet-A) were detected in soil samples collected from PP401, PP420, and PP427 on 17 June 1999, and from PP420 during the June and August 2000 sampling events. The TPH constituents exceeding the PCLs during the June 1999 sampling event were tentatively identified as TPH-Jet-A in each of the three samples, with concentrations ranging from 2,300 mg/kg in PP401 to 5,900 mg/kg in PP427. TPH-D was detected above the PCL in PP427 at a concentration of 6,700 mg/kg (June 1999), and in PP420 at an estimated concentration of 3,600 mg/kg (June 2000) and 2,400 mg/kg (August 2000). The TPH signatures on most of the sample chromatographs do not exactly match either TPH-D or TPH-Jet-A standards, indicating that the hydrocarbons present in the soil have weathered. This often resulted in qualification of the concentrations as tentative identifications (N). The TPH ranges detected in the soil samples collected over the monitoring period were generally considered to reflect severely weathered Jet-A fuel.

Groundwater

Groundwater samples were collected from GW101, GW102, PP401, PP405, PP420, PP427, and PP430 through PP433 during IA biannual sampling and/or the Tier 3 investigation. Analyses included diesel (TPH-D) and Jet-A fuel-range (TPH-Jet-A) petroleum hydrocarbons. The concentrations of constituents detected in groundwater during the three IA sampling rounds prior to the Tier 3 sampling event (June 1999 to June 2000) and the Tier 3 event (August 2000) are summarized in Table 5-6B.

As shown in Table 5-6B, detectable concentrations of TPH, identified as either TPH-Jet-A or TPH-D, are present in the groundwater. TPH concentrations have been reported above the PCLs (0.5 mg/L each for TPH-Jet-A and TPH-D) in samples from PP401, PP405, PP420, PP427, and

PP430. The spatial distribution of constituent concentrations above the PCL in groundwater samples is shown in Figure 5-6G. TPH-Jet-A concentrations above the PCL ranged from an estimated 1.4 mg/L detected in PP420 (June 2000) to 11 mg/L detected in PP405 (June 1999). TPH-D concentrations above the PCL ranged from 1.4 mg/L detected in PP420 (June 1999) to 7.3 mg/L detected in PP430 (August 2000). As with the soil analyses, chromatographs for most of the groundwater samples do not match well with the standard TPH-D or Jet-A signatures, and several of the concentrations are qualified as tentative identifications (N). The hydrocarbon ranges detected in most groundwater samples are believed to reflect the presence of highly weathered Jet-A fuel.

TPH concentrations, as either TPH-D or TPH-Jet-A, were not detected in any of the samples collected from GW101, GW102, PP429, PP431, and PP433.

Conclusions and Recommendations

During the IA and Tier 3 sampling activities at the Former Fuel Farm, concentrations of benzene, 2-methylnaphthalene, and diesel- and Jet-A-range TPH were detected above the PCLs in selected soil samples. Concentrations as high as an estimated 7,200 µg/kg of benzene (PCL of 14 µg/kg), 20,000 µg/kg of 2-methylnaphthalene (PCL of 1,496 µg/kg), 5,900 mg/kg of TPH-Jet-A (PCL of 2,000 mg/kg), and 6,700 mg/kg of TPH-D (PCL of 2,000 mg/kg) were detected.

In groundwater, TPH-Jet-A concentrations detected above the PCL of 0.5 mg/L ranged from an estimated 1.4 mg/L to an estimated 17 mg/L. TPH-D concentrations detected above the PCL of 0.5 mg/L ranged from 1.4 to 7.3 mg/L.

Based on the results of the RI, the Former Fuel Farm AOC Group is recommended for inclusion in the Feasibility Study.

5.9 AOC-001, AOC-002, AND AOC-003: FORMER USTs URE-01, URE-02, AND URE-03 (BUILDING 4-81)

These three former USTs were installed in 1980 and were used to store MEK and toluene. The former USTs were located west of Building 4-81, as shown on Figure 5-7. Each tank was constructed of steel within a cylindrical concrete vault for secondary containment and had a capacity of 500 gallons.

Following the removal of these USTs in July 1986, toluene concentrations were detected in the water found between each tank and concrete vault. A total of 130 cubic yards of soil was removed from the URE-01 and URE-02 excavation area, and 74 cubic yards of soil was removed from the URE-03 excavation. Approximately 4,600 gallons of water were pumped from the URE-01 and URE-02 excavation, and 3,600 gallons of water were pumped from the URE-03 excavation. Toluene and vinyl chloride were detected in groundwater samples collected in the area adjacent to URE-01 and URE-02. Groundwater samples from the area adjacent to former URE-03 did not contain detectable concentrations of solvents. Additional information regarding these AOCs is included in Appendix A.

Investigation Conducted

The Tier 2 objective at AOC-001, AOC-002, and AOC-003 was to determine if previously detected constituents were present in the soil and groundwater. The scope of work performed during Tier 2 included:

- Collection of 18 soil and six groundwater samples from six push-probes (PP011 through PP016).
- Analysis of soil and groundwater samples for VOCs.

Analytical results indicated that VOC concentrations were well below the SL in the soil samples analyzed. TCE, PCE, and vinyl chloride were detected above the SL in groundwater; however, these compounds were not reportedly stored in the former USTs and are considered non-target analytes.

To confirm the presence of these compounds in groundwater, the Tier 3 scope of work for AOC-001, AOC-002, and AOC-003 included:

- The collection of three soil and three groundwater samples from three new push-probes (PP064, PP065 and PP066).
- The redevelopment and collection of four groundwater samples from existing wells GW049 through GW052.
- Analysis of the three soil samples for TOC and particle size distribution.
- Analysis of the seven groundwater samples for VOCs.

Hydrogeologic Characteristics

The general stratigraphy beneath this area is shown in cross-section G-G' (Figures 5-7A and 5-7B). Fill materials consisted of greenish-brown fine- to medium-grained sand with silt and gravel. Beneath the fill, alluvium consisted of greenish-gray clayey silt to silty clay with a high content of organic matter represented by wood fragments and roots. Boring logs from the nine push-probes advanced during the Tier 2 and Tier 3 subsurface investigations indicated that the depth of the contact between hydraulic fill materials and alluvium ranged from approximately 6 to 10 feet bgs (Appendix F). Boring logs from monitoring wells GW049, GW050, GW051, and GW052 indicated the presence of a clayey peat layer directly underlying the fill (Appendix F). The occurrence of the peat layer was slightly deeper than the depth the push-probes were advanced during the Tier 2 and 3 investigations. It is possible that the shallow push-probes only reached the very top of this peat layer represented by the silty clay with high organic content observed in PP013, PP014, PP015, and PP016 before it graded into the peat layer described in the deeper wells.

During drilling, groundwater was encountered at approximately 3 to 4 feet bgs (Appendix F). However, groundwater as measured in monitoring wells GW049, GW050, GW051, and GW052 during the three Facility-wide groundwater measurement events (9 June 1999, 31 March 2000, and 7 September 2000) ranged from 1.4 to 3.2 feet bgs (Table 2-2). Seasonal variations in groundwater elevations as measured during the three monitoring events ranged from 0.35 to

0.64. As presented in Figures 5-7C, 5-7D, and 5-7E, groundwater flows to the northwest toward Lake Washington at an average gradient of approximately 0.001.

Slug test were conducted in wells GW049, GW050, GW051, and GW052 in the vicinity of AOC-001, AOC-002, and AOC-003. As discussed in Section 2.9, the results of the slug tests indicated that the hydraulic conductivity of groundwater in the area ranged from 1.4×10^{-3} to 5.0×10^{-3} cm/s.

Nature and Extent of Releases

Eighteen soil samples were collected from six push-probes collected during the Tier 2 investigation and analyzed for selected VOCs including BTEX. Three soil samples collected from PP064 through PP066 during the Tier 3 investigation were analyzed for selected physical parameters (i.e., TOC and grain- size distribution). A total of 13 groundwater samples from monitoring wells GW049 through GW052, and push-probes PP011 through PP016 and PP064 through PP066 were collected during both investigations. The groundwater samples were analyzed for selected VOCs including BTEX constituents. Analytical results from the soil samples and the groundwater samples are presented in Tables 5-7A and 5-7B, respectively.

Soil

As shown in Table 5-7A and Figure 5-7F, several VOCs were detected in the soil samples collected. Of these constituents, only TCE was detected at concentrations above the 54 μg/kg PCL in three of the 18 soil samples collected from the push-probes. TCE concentrations above the PCL ranged from 66 to 330 μg/kg. The maximum TCE concentration was detected near the surface in the 2 feet bgs sample collected from push-probe PP011 located approximately 5 feet downgradient from AOC-001. However, as illustrated in Figure 5-7F, the distribution of TCE in soil throughout the AOC-001, AOC-002, and AOC-003 appeared to be highly variable**.** The next to highest concentrations were observed at the 9.5 feet bgs samples collected at both PP015 (89 μg/kg) and PP016 (66 μg/kg) downgradient and crossgradient from AOC-003.

Groundwater

As presented in Table 5-7B and Figure 5-7G, VOC constituents were detected in the 13 groundwater samples collected during the Tier 2 and Tier 3 investigations. Of these constituents, PCE, TCE, and vinyl chloride were the only VOCs detected at concentrations above the PCLs (Figure 5-7G). PCE was detected above its PCL of 1 μg/kg only in one groundwater sample collected from push-probe PP016 at a concentration of 8.3 μg/L. TCE was also detected above its PCL (2.7 μg/kg) only in push-probe PP011 at a concentration of 23 μg/L. Vinyl chloride was detected above its PCL (2 μg/kg) in groundwater samples from push-probes PP016 and PP066 and monitoring well GW049 at concentrations ranging from 4.9 μg/L. to 9.3 μg/L respectively. The highest vinyl chloride groundwater concentration was detected at GW049 located approximately 140 feet downgradient from AOC-001.

Conclusions and Recommendations

The objective of the RI at AOC-001, AOC-002, and AOC-003 was to evaluate the presence of selected VOCs that were reportedly stored in the former USTs or previously detected in the soil or groundwater. The analytical results from 18 soil and six groundwater samples collected during the Tier 2 Assessment indicated VOC concentrations were well below the SL in the soil samples analyzed. Non-target analytes TCE, PCE, and vinyl chloride were detected in the Tier 2 groundwater samples. The Tier 3 investigation in these areas included the analysis of seven additional groundwater samples for VOCs. The analytical results of the RI sampling indicated that TCE in both soil and groundwater and PCE and vinyl chloride in groundwater above the PCLs are present in AOC-001 through AOC-003.

Based on these results, inclusion of AOC-001, AOC-002, and AOC-003 in the Feasibility Study is recommended.

5.10 AOC-004: FORMER UST URE-04 (BUILDING 4-21)

Former URE-04 was a 250-gallon steel UST located adjacent to the east side of Building 4-21 (Figure 5-8). The UST was used for the storage of gasoline and likely contained leaded gasoline prior to the mid-1970s. The installation date for the tank is unknown. During the removal of the tank in December 1986, a thin layer of floating product (gasoline) was observed on the water in the excavation. Information available at the time did not indicate if gasoline-impacted soil was removed from this excavation. Additional information regarding this AOC is included in Appendix A.

Investigation Conducted

The sampling objective at AOC-004 was to determine the concentrations of previously detected constituents in the soil and groundwater. The scope of work performed during Tier 2 included:

- Collection of nine soil and three groundwater samples from three push-probes (PP017, PP018, and PP019).
- Analysis of soil and groundwater samples for VOCs, gasoline-range TPH, and total and dissolved lead.

Some Tier 2 soil samples from AOC-004 exceeded SLs for BTEX, TPH-G, and lead. The highest lead concentration in soil (85 mg/kg) exceeded the SL (background concentration for soil in the Puget Sound region), but was well below the MTCA Method A Cleanup level of 250 mg/kg. Benzene and total lead concentrations exceeded the SL in two of the three groundwater samples analyzed. The groundwater sample from the downgradient location (PP019) did not contain detectable benzene concentrations, and total lead concentrations were below the SL. Dissolved lead concentrations were not detected in any of the groundwater samples. The difference in total and dissolved lead results is due to suspended solids in the unfiltered samples. Since soil lead concentrations did not exceed the MTCA Method A Cleanup level, and dissolved lead was not detected in groundwater, lead was not considered a constituent of concern for the Tier 3 investigation at this unit.

To further evaluate the nature and extent of BTEX concentrations in the soil and groundwater, the Tier 3 scope of work in this area included:

- Collection of five soil samples from two push-probes (PP067 and PP068) and one new well (GW174).
- Collection of one groundwater sample from GW174.
- Analysis of four push-probe soil samples and the groundwater sample for BTEX.
- Analysis of one soil sample from the new well boring for geotechnical parameters including TOC, bulk dry density, particle-size distribution, and total porosity.

Hydrogeologic Characteristics

The general stratigraphy beneath this area is shown in cross-section H-H' (Figures 5-8A and 5-8B). Fill at this AOC consisted of brown fine- to medium-grained sand with silt and gravel. Alluvium beneath the fill consisted of greenish-gray fine-grained sand with silt. At PP068, the contact between the fill and alluvium was approximately 3 feet shallower than the rest of the push-probes advanced in the area. A silty clay lens was observed below the contact with the fill materials and overlying the silty sand in PP068 (Figure 5-8B). Boring logs from the five push-probes and the groundwater monitoring well completed during the Tier 2 and Tier 3 investigations indicated that hydraulic fill extended to approximately 5 feet bgs (Appendix F).

Groundwater was encountered during drilling at approximately 4 to 6 feet bgs (Appendix F). The well installed during the Tier 3 field effort, GW174, is the only groundwater monitoring well near this AOC (Figure 5-8). This well was measured only during the 7 September 2000 Facility-wide groundwater monitoring event. Groundwater at GW174 was measured at 4.28 feet bgs during this event (Table 2-9). Based on the groundwater elevation contours from the June 1999 (Figure 2-20), March 2000 (Figure 2-21), and September 2000 (Figure 2-22) monitoring events, the seasonal variation was approximately one foot. As presented in Figures 5-8C, 5-8D, and 5-8E, groundwater measurements during all three Facility-wide events indicate that groundwater in this area flows toward the northwest. The range in average gradient is from flat

(June 1999) to 0.002 (September 2000). Based on the information from the maps, the gradient flattens during the dry summer months and steepens during the winter rainy season as expected.

A slug test was conducted in well GW174 within AOC-004. As discussed in Section 2.9, the results of the slug tests indicated that the hydraulic conductivity of groundwater as measured from this well was 1.2 x 10^{-3} cm/s.

Nature and Extent of Releases

Thirteen soil and four groundwater samples were collected from push-probes PP017 through PP019, PP067, and PP068, and monitoring well GW174. Chemical analyses included BTEX, TPH-G, and lead. Some samples were also analyzed for gasoline-related VOCs.

As shown in Table 5-8A, VOCs, and TPH-G were detected in selected soil samples. Of the detected constituents, concentrations of benzene, ethylbenzene, toluene, acetone, and gasoline-range TPH (TPH-G) were detected in soil above the PCLs. As shown on Figure 5-8F, the soil concentrations exceeding the PCLs were detected in two samples. The 5-foot bgs sample from PP018 contained a tentatively identified concentration of TPH-G (42 mg/kg) in soil above the PCL. All other soil concentrations above the PCLs were detected in the 2-foot bgs sample from PP017 (the sample location closest to the former UST). Benzene was detected in this sample at a concentration of 7,000 µg/kg, ethylbenzene at 44,000 µg/kg, toluene at 56,000 µg/kg, acetone at 23,000 µg/kg, and TPH-G was detected at an estimated concentration of 1,200 mg/kg.

Soil sample results indicate that VOC and TPH-G concentrations detected above the PCL appear to occur within 10 feet of the former UST location. Laboratory results of the samples collected indicate the vertical extent of these constituents is less than 10 feet bgs (Figure 5-8F).

Table 5-8B and Figure 5-8G summarize the constituents detected in the three groundwater samples. Benzene concentrations above the 1 µg/kg PCL were detected in the groundwater samples from 7 feet bgs at PP017 (29 µg/kg) and from 10 feet bgs at PP018 (13 µg/kg). The TPH-G concentration detected from the 7 feet bgs groundwater sample at PP017 (0.93 µg/kg) exceeded the benzene-dependant PCL of 0.8 µg/kg. Although total lead concentrations were detected in each of the groundwater samples, dissolved lead concentrations were not detected in any of the groundwater samples analyzed.

Groundwater sample results indicate that benzene concentrations decreased from 29 µg/kg to 13 µg/kg within 10 feet south of the former UST location, indicating that the total extent of concentrations above the PCL is likely limited to approximately 20 feet south of the former tank. Analytical results indicate that TPH-G concentrations decreased to below the PCL within 10 feet of the former UST location.

Conclusions and Recommendations

The soil analytical results indicate that VOCs, TPH-G, and total lead were detected in selected samples. Of the constituents detected, benzene, ethylbenzene, toluene, acetone, and TPH-G were detected in soils at concentrations above the PCLs. Soil concentrations above the PCLs were limited to within approximately 10 feet south of the former UST, and to depths less than 10 feet bgs.

Groundwater analytical results indicate that VOCs, TPH-G, and total lead were detected in one or more samples. Benzene concentrations above the PCL are likely limited to within 20 feet south of the former UST, and TPH-G concentrations above the PCL are limited to within 10 feet south of the former tank.

Based on the analytical results, AOC-004 is recommended for inclusion in the Feasibility Study.

5.11 AOC-005 THROUGH AOC-011: FORMER USTs URE-09 THROUGH URE-15 (BUILDING 4-44)

These seven former USTs were installed in 1944 within a common concrete vault adjacent to the south side of Building 4-44 (Figure 5-9). Each UST was a 12,000-gallon steel tank used to store diesel fuel. During removal of the USTs in October 1985, oily water was found between the tanks and the concrete vault. Available information from the time of the removal did not indicate if any soil or groundwater had been remediated from the tank area. Additional information regarding these AOCs is included in Appendix A.

Investigation Conducted

The Tier 2 objective at AOC-005 through AOC-011 was to evaluate if a release from the former USTs and concrete vault had occurred. The scope of work performed included:

- Collection of 27 soil and three groundwater samples from nine push-probes (PP020 through PP028) and one well (GW154).
- Analysis of soil and groundwater samples for PAHs and diesel-range TPH.

Soil samples from AOC-005 through AOC-011 detected carcinogenic PAHs and TPH as motor oil at concentrations greater than the SL. None of the deeper soil samples (12 to 14 feet bgs) contained PAHs or petroleum hydrocarbons at concentrations greater than the SLs. The highest TPH concentration detected in the soil samples collected from AOC-005 through AOC-011 (620 mg/kg) was less than the proposed Method A cleanup level of 2,000 mg/kg (Ecology 2000). A toxicity equivalency factor (TEF) was used to convert concentrations of carcinogenic PAHs to an equivalent concentration of benzo(a)pyrene. The highest carcinogenic PAH concentrations were calculated to a total benzo(a)pyrene equivalent concentration of 529 µg/kg, which is below the soil PCL of 15,700 µg/kg.

Of the three groundwater samples analyzed, no PAHs or petroleum hydrocarbons were detected above the RI SLs. Because the detected PAH and TPH soil concentrations were below the proposed MTCA Method A cleanup levels, and groundwater concentrations did not exceed RI SLs, this area was not included in the Tier 3 Detailed Investigation.

Hydrogeologic Characteristics

The general stratigraphy beneath the AOCs is shown in cross-section I-I' (Figures 5-9A and 5-9B). Boring logs from the nine push-probes and the groundwater monitoring well advanced during the Tier 2 subsurface investigation indicated that fill materials extended to depths exceeding 14 feet bgs (Appendix F). Since most of the push-probes advanced during the Tier 2 investigation were located within the former UST area excavated in the 1990s, the location of the contact between the fill materials and alluvium do not represent standard subsurface conditions for this area. The lithology observed in PP023, PP028, and GW154 is more representative of the subsurface conditions since these push-probes were located outside the limits of the former excavation. In these locations, the contact between the fill and alluvium was observed approximately between 4 to 8 feet bgs. Fill consisted of fine- to medium-grained, greenish-brown sand with silt and gravel. Beneath the fill, alluvium of medium- to coarse-grained, greenish-gray sand with silt and gravel was observed (Figure 5-9B).

Groundwater at the time of drilling was encountered at approximately 5 feet bgs (Appendix F). As measured in nearby monitoring wells GW009, GW010, GW021, GW147, GW149, GW150, GW154, GW155, and GW158 during the three Facility-wide groundwater measurement events (9 June 1999, 31 March 2000, and 7 September 2000), groundwater depths ranged between 3.5 and 5.2 feet bgs (Table 2-2). Seasonal variations in groundwater elevations measured during the three monitoring events were within 0.96 foot.

Groundwater in this area generally flows to the west-northwest toward the Cedar River Waterway and Lake Washington at a gradient ranging from approximately 0.001 to 0.005 (Figures 5-9C, 5-9D, and 5-9E). However, groundwater elevations at some of these wells appear to be affected by the extraction system located at Building 4-78/79 located south of this AOC (Figures 2-20 through 2-22).

A slug test was conducted in monitoring well GW154. As discussed in Section 2.9, the results of the slug test indicated that the hydraulic conductivity of groundwater in this area was approximately 2.8×10^{-4} cm/s.

Nature and Extent of Releases

Twenty-seven soil samples (push-probes PP020 through PP028) and three groundwater samples (push-probes PP020 and PP021, well GW154) were collected during the Tier 2 investigation and were analyzed for PAHs and diesel- and motor oil-range TPH.

Table 5-9A summarizes the concentrations of PAH and motor oil-range TPH constituents detected in the soil samples. None of the 27 soil samples contained constituent concentrations above the PCL.

Table 5-9B summarizes the concentrations of detected constituents in groundwater. Petroleum hydrocarbons were not detected in any of the groundwater samples. Although PAHs were detected in the groundwater samples from PP020 and PP021, concentrations were below the PCLs.

Conclusions and Recommendations

Soil and groundwater samples from AOC-005 through AOC-011 were analyzed for PAHs and diesel- and motor-oil TPH. None of the soil or groundwater samples contained PAHs or petroleum hydrocarbons at concentrations greater than the PCLs.

Petroleum hydrocarbons were not detected in any of the three groundwater samples. PAHs were detected only in the groundwater samples from PP020 and PP021 at concentrations below the PCLs.

Based on the analytical results, AOC-005 through AOC-011 are not recommended for inclusion in the Feasibility Study.

5.12 AOC-012: FORMER UST URE-16 (BUILDING 4-45)

Former UST URE-016 was installed in 1980 adjacent to the west side of Building 4-45 (Figure 5-10). The 500-gallon steel tank was used to store MEK. There was no information available from the time of the removal in 1987 to indicate if a release had occurred from this UST. Additional information regarding this AOC is provided in Appendix A.

Investigation Conducted

The Tier 2 sampling objective at AOC-012 was to evaluate if a release from the former UST had occurred. The scope of work performed included:

- Collection of nine soil and three groundwater samples from three push-probes (PP029 through PP031).
- Analysis of soil and groundwater samples for MEK and selected VOCs.

The analytical results indicated that none of the detected soil concentrations were above the SL and no detections in groundwater were present. Based on this information, AOC-012 was not included in the Tier 3 Investigation.

Hydrogeologic Characteristics

The general stratigraphy beneath this area is shown in cross-section J-J’ (Figures 5-10A and 5-10B). Fill consisted of reddish- to greenish-brown fine- to medium-grained sand with silt with occasional clay. Alluvium beneath the fill consisted of greenish-gray medium- to coarse-grained sand with silt and gravel (Figure 5-10B). Boring logs from the three push-probes advanced in this area during the Tier 2 investigation indicated that the fill extended to approximately 4 to 5 feet bgs (Appendix F).

Groundwater during drilling was encountered at approximately 5.5 feet bgs (Appendix F). As measured in monitoring wells GW009, GW010, GW021, GW147, GW149, GW150, GW154, GW155, and GW158 during the three Facility-wide groundwater measurement events (9 June 1999, 31 March 2000, and 7 September 2000), groundwater depths ranged between

3.5 to 5.2 feet (Table 2-2). Typically, seasonal variations observed on groundwater levels in these nearby wells were within 0.53 foot or less.

Groundwater in this area generally flows to the west-southwest toward the Cedar River Waterway at a slightly varying gradient of 0.002 (June 1999 and September 2000) to 0.001 (March 2000) (Figures 5-10C, 5-10D, and 5-10E). The extraction system located at Building 4-78/79 is the reason for the southwesterly groundwater flow direction at this AOC.

A slug test was conducted in monitoring well GW154 located near the northeast corner of Building 4-45. As discussed in Section 2.9, the results of the slug test indicated that the hydraulic conductivity of groundwater in this area was approximately 2.8 x 10^{-4} cm/s.

Nature and Extent of Releases

Nine soil and three groundwater samples collected from push-probes PP029, PP030 and PP031 during the Tier 2 investigation were analyzed for MEK (2-butanone). The laboratory also included non-target VOCs that were detected in some samples.

Table 5-10A summarizes the constituents detected in the soil samples. Although MEK and selected VOCs were detected in one or more soil samples, all the detected concentrations were below the PCLs.

Table 5-10B summarizes the analytical results for the three groundwater samples. As shown in the table, no MEK or other VOCs were detected.

Conclusions and Recommendations

The soil and groundwater samples at AOC-012 were analyzed for selected VOCs including MEK. The concentrations of all constituents detected in the soil samples were below their respective PCLs and no constituents were detected in groundwater.

Based on the RI results, AOC-012 is not recommended for inclusion in the Feasibility Study.

5.13 AOC-034 AND AOC-035: FORMER USTs URE-07 AND URE-08 (BUILDING 4-41)

These two former USTs were installed in 1980 adjacent to the south side of Building 4-41 (Figure 5-11). Both tanks were 500-gallon steel USTs designed for storage of a MEK and toluene mixture, but were reportedly never used. Following the removal of the USTs in September 1987, volatile organic vapors up to 500 parts per million (ppm) were detected (using a HNu) in the northwest corner of the excavation. The field readings increased northward away from the tanks. Field readings of 120 to 140 ppm were detected in fill materials between the two USTs. Additional information regarding these AOCs is included in Appendix A.

Investigation Conducted

The Tier 2 sampling objective at AOC-034 and AOC-035 was to evaluate if a release from the former USTs had occurred. The scope of work performed included:

- Collection of 12 soil and four groundwater samples from four push-probes (PP032 through PP035).
- Analysis of soil and groundwater samples for MEK, toluene, and selected VOCs.

The target analytes for AOC-034 and AOC-035 were MEK and toluene. Vinyl chloride, a non-target analyte, was detected at 5.2 µg/kg in one of the 12 soil samples analyzed (PP032 at 5 feet bgs). Although the detected concentration in this sample was slightly greater than the SL (2.3 µg/kg; MTCA Method B 100 times Groundwater Cleanup Level), this value was well below the MTCA Method B Cleanup Level of 526 µg/kg. None of the remaining soil and groundwater samples contained VOC concentrations above the SL. The vinyl chloride concentration above the SL in one soil sample was not considered to warrant further investigation. Therefore, this area was not included in the Tier 3 Detailed Investigation.

Hydrogeologic Characteristics

The general stratigraphy beneath this area is shown in cross-section K-K’ (Figures 5-11A and 5-11B). Fill consisted of reddish- to greenish-brown fine- to medium-grained sand with silt and gravel with occasional clay. Alluvium beneath the fill consisted of greenish-gray medium- to coarse-grained sand with silt and gravel and greenish-gray very fine-grained sand with silt (Figure 5-11B). Soil samples collected from the four push-probes advanced at AOC-034 and AOC-035 during the Tier 2 investigation indicated that fill materials extended to approximately 6 to 9 feet bgs (Appendix F).

Groundwater during drilling was encountered approximately at 5 to 5.5 feet bgs (Appendix F). As measured in nearby monitoring wells GW005, GW006, and GW007 during the three Facility-wide groundwater measurement events (9 June 1999, 31 March 2000, and 7 September 2000), groundwater depths ranged between 2.42 to 4.41 feet bgs (Table 2-2). Seasonal variations observed in groundwater elevations in these nearby wells were less than 0.86 foot. As presented in Figures 5-11C, 5-11D and 5-11E, groundwater in this area generally flows to the west-northwest towards the Cedar River Waterway and Lake Washington at a gradient of less than 0.001.

Nature and Extent of Releases

Twelve soil and four groundwater samples were collected from push-probes PP032 through PP035 during the Tier 2 investigation, and were analyzed for toluene and MEK. Laboratory analysis also detected non-target VOCs in some samples.

Table 5-11A summarizes the concentrations of detected constituents in soil samples. MEK and VOCs were detected in several soil samples, however, none of the detected constituents exceeded their respective PCLs.

Table 5-11B summarizes the concentrations of detected constituents in groundwater samples. Of the four groundwater samples collected, only one sample (PP032) detected vinyl chloride (1.8 µg/L). However, this concentration fell below the PCL of 2 µg/L. There were no other constituents detected.

Conclusions and Recommendations

None of the soil and groundwater samples collected at AOC-034 and AOC-035 contained VOCs at concentrations above the PCLs.

Based on the results of the RI, AOC-034 and AOC-035 are not recommended for inclusion in the Feasibility Study.

5.14 AOC-042: FORMER UST URE-45 (BUILDING 10-81)

Former URE-045 was located adjacent to the east side of Building 10-81 (Figure 5-12). This 550-gallon steel UST was installed in 1975 to store diesel fuel. The tank was removed in October 1987. A soil sample collected near the tank prior to its removal contained 430 mg/kg TPH as oil and grease. During the soil excavation activities, soil with elevated HNu readings was removed from the excavation. Additional information regarding AOC-042 is included in Appendix A.

Investigation Conducted

The Tier 2 sampling objective at AOC-042 was to evaluate if concentrations of previously detected constituents were present. The scope of work performed included:

- Collection of nine soil and three groundwater samples from three push-probes (PP036 through PP038).
- Analysis of soil and groundwater samples for PAHs and diesel-range TPH.

Shallow soil samples from AOC-042 exceeded RI SLs for chrysene and/or TPH as motor oil. The highest TPH concentration detected in the Tier 2 soil samples was estimated at 1,000 mg/kg (WESTON 1999d). The proposed changes to the MTCA Cleanup Regulation (Ecology 1998) state that the Method A cleanup level for unrestricted land uses is 2,000 mg/kg for motor oil-range TPH. As proposed by Ecology and recommended by the EPA (EPA 1993), a toxicity equivalency factor (TEF) was used to convert concentrations of carcinogenic PAHs to an equivalent concentration of benzo(a)pyrene. The values from the sample with the highest carcinogenic PAH concentrations were calculated to have a total benzo(a)pyrene equivalent concentration equaling 56 µg/kg. This value is well below the soil PCL of 15,700 µg/kg.

Groundwater samples collected from this AOC did not contain PAH or TPH concentrations above SLs. Since the detected PAH and TPH concentrations were below the proposed MTCA Method A cleanup levels, no further investigation of this AOC was considered warranted. AOC-042 was not included in the Tier 3 Detailed Investigation.

Hydrogeologic Characteristics

The general stratigraphy beneath this AOC is shown in cross-section L-L' (Figures 5-12A and 5-12B). Fill consisted of fine- to medium-grained, greenish- to reddish-brown sand with silt and gravel. Beneath the fill, alluvium consisted of greenish-gray clayey silt interbedded with medium- to coarse-grained, greenish-gray sand with silt and gravel. Boring logs from the three push-probes advanced during the Tier 2 investigation indicated the contact between the fill and alluvium ranged from approximately 3.5 feet at PP038, to approximately 6 feet at PP037, and to beyond 13 feet, the maximum depth reached in PP036 (Appendix F). Push-probe PP036 was advanced within the former cistern excavation, which may account for the depth of the contact. In addition, the presence of a large water main branching from Building 10-81 near locations PP037 and PP038 can account for the 3-foot difference between this contact in PP036 and in PP037 and PP038 (Figure 5-12B).

Groundwater at the time of drilling was encountered at approximately 6 to 7 feet bgs in this area (Appendix F). Groundwater, as measured the nearest monitoring well (GW058) during the three Facility-wide groundwater monitoring events (9 June 1999, 31 March 2000, and 7 September 2000), ranged between 8.06 to 9.11 feet bgs (Table 2-2). Seasonal variations in groundwater elevations measured during the three monitoring events at GW058 were approximately 1 foot. Groundwater at this AOC generally flows to the west-northwest toward the Cedar River Waterway. The gradient varies from 0.002 (June 1999 and September 2000) to 0.003 (March 2000) as shown in Figures 5-12C, 5-12D, and 5-12E.

Nature and Extent of Releases

Nine soil and three groundwater samples were collected from push-probes PP036, PP037, and PP038 during the Tier 2 investigation and were analyzed for PAHs and total petroleum hydrocarbons as diesel and motor oil.

As shown on Table 5-12A, PAHs and motor oil-range petroleum hydrocarbons were detected in several soil samples from the three push-probe locations. However, no PAHs were detected in the soil samples above the PCLs. Although motor oil was detected in several soil samples, none were above the PCL of 2,000 mg/kg.

Table 5-12B summarizes the analytical results for groundwater. Of the PAH and TPH constituents analyzed no detected constituents were above the PCL.

Conclusions and Recommendations

Soil and groundwater samples were analyzed for PAHs and total petroleum hydrocarbons as diesel and motor oil. No soil or groundwater samples contained constituents at concentrations above the PCLs.

Based on the results of the RI, AOC-042 is not recommended for inclusion in the Feasibility Study.

5.15 AOC-049: URE-30 (BUILDING 5-50)

URE-30 was a 25,000-gallon steel UST used to store diesel fuel for the operation of a boiler. The tank was installed in 1950 near the southeast corner of Building 5-50 and Door #9 (Figure 5-13). The UST was removed in April 1993 (SECOR 1993), and a new UST was installed in the same excavation. Additional information regarding this tank is included in Appendix A.

Investigation Conducted

The interim action at AOC-049 (Building 5-50) was initiated following the closure of URE-030. The primary objective of the interim action was to reduce the TPH concentrations detected in the groundwater to the MTCA Method A cleanup standard of 1.0 mg/L, as established by Washington Department of Ecology prior to the February 2001 release of the MTCA adopted amendments. The MTCA adopted amendments (Ecology 2001) reduced the Method A groundwater cleanup level to 0.5 mg/L for diesel-range TPH. The performance monitoring program for AOC-049 (Building 5-50) included quarterly groundwater sampling of four monitoring wells (GW080, GW081, GW082, GW136) for TPH-D (Figure 5-13).

As discussed in the *December 1999 Performance Monitoring Report* (WESTON 2000d), TPH-D levels in wells GW080, GW081, and GW136 have remained below the 1.0 mg/L criterion previously set by MTCA Method A since 1996. The diesel-range TPH concentrations detected in well GW082 have exceeded the MTCA Method A criterion, but the chromatograms of these samples do not match diesel. The chromatographic response in the diesel range may represent petroleum-based solvents.

Although URE-030 only contained diesel fuel, VOCs have been historically detected in well GW082. Because well GW082 is hydraulically upgradient of AOC-049 and TPH-D concentrations in the remaining wells have not exceeded 1.0 mg/L since 1996, AOC-049 is not a likely source of the detected constituents. SWMU-172 and SWMU-174, two former USTs that stored steam cleaning wastewater, are two potential sources of VOCs that are under evaluation. As shown on Figure 5-13, these SWMUs are located within 100 feet and generally upgradient of well GW082.

As likewise discussed in Section 2.1.1, the VOC concentrations detected in GW082 will be further evaluated as part of the SWMU-172 and SWMU-174 investigation. Therefore, no additional groundwater monitoring at AOC-049 was conducted under Tier 3.

Hydrogeologic Characteristics

The general stratigraphy beneath this area is shown in cross-section M-M' (Figures 5-13A and 5-13B). Fill encountered at this AOC was also coarser than areas in the north end of the plant and consisted of brown to reddish-brown fine- to coarse-grained sand with silt and gravel. Alluvium consisted of interbedded dark grayish-brown fine-grained sand with silt, medium gray silt and clay, and black gravel and coarse-grained black sand. Boring logs from monitoring wells GW080, GW081, GW082, GW083, GW084, and GW136 indicated the contact between fill materials and alluvium was deeper in this area of the Facility, ranging from 10 to 15 feet bgs (Appendix F).

During drilling, groundwater was encountered at approximately 8 to 9 feet bgs (Appendix F). As measured at GW080, GW081, GW082, GW084, and GW136 during the three Facility-wide groundwater measurement events conducted (9 June 1999, 31 March 2000, and 7 September 2000) groundwater depths ranged between 7 to 10.6 feet bgs (Table 2-2). Seasonal variations of groundwater elevations were typically 1.5 feet bgs (Table 2-2). However, one monitoring well, GW136, showed seasonal variations as high as 4.39 feet bgs (Table 2-2). As presented in Figures 5-13C, 5-13D, and 5-13E, groundwater in this area generally flows to the northeast toward the Cedar River Waterway at an average gradient of approximately 0.004.

Slug tests were conducted in monitoring wells GW080, GW081, GW152, GW153, GW171, and GW173 located in the vicinity of AOC-049. As discussed in Section 2.9, the results of the slug tests indicated that the hydraulic conductivity of groundwater in the area ranged from 4.6×10^{-5} to 4.2×10^{-3} cm/s.

Nature and Extent of Releases

Groundwater samples collected from wells GW080, GW081, GW082, and GW136 were analyzed for VOCs and/or diesel-range petroleum hydrocarbons (TPH-D). The detected concentrations from the six rounds of quarterly groundwater monitoring collected between March 1999 to August 2000 are summarized in Table 5-13A and Figure 5-13F. TPH-D was detected at concentrations above the PCL of 0.5 mg/L in GW082 over the March 1999 to March 2000 monitoring period. The TPH-D concentrations ranged from 0.71 to 3 mg/kg. TPH-D was not detected in the well during the June 2000 monitoring event. A marked decrease in TPH-D concentrations occurred in the well since the September 1999 sampling event. The decrease may be the result of degradation and/or a silica gel cleanup method used since December 1999 to remove naturally occurring organic matter from samples in the lab. Previous laboratory analyses may have had higher TPH concentrations due to presence of natural organic matter. TPH-D was not detected above the PCLs in any of the other wells.

Up to five VOCs were detected at concentrations exceeding PCLs during four sampling events in GW082. Benzene was detected above the PCL of 1 µg/L during the June 1999 sampling event at a concentration of 1.7 µg/L. Chloromethane was detected above its PCL (3.37 µg/L) during the June 1999 sampling event at an estimated concentration of 16 µg/L. Methylene chloride was detected above its PCL of 4.7 µg/L during the June 1999 sampling event at a concentration of 12 µg/L. Tetrachloroethene (PCE) was detected during the March through September 1999 and August 2000 sampling events at 5.6 to 6.5 µg/L. The PCL for PCE is 1 µg/L. Trichloroethylene (TCE) was detected above its PCL (2.7 µg/L) during the March through September 1999 sampling events at 4.4 to 11 µg/L. No VOCs were detected above the PCLs in any of the other wells.

Conclusions and Recommendations

The results of quarterly groundwater monitoring conducted since March 1999 at AOC-049 indicate that TPH-D and select VOC concentrations in samples from GW082 were the only constituent detected above the PCLs. However, because this well is located upgradient of the former UST URE-30, the detected concentrations are likely related to conditions at SWMU-172 and SWMU-174. Chromatograms from GW082 have not matched diesel and may be the result of weathered solvents in the diesel range. Furthermore, a marked decrease in TPH-D concentrations has occurred in the well since the September 1999 sampling event. The decrease may be the result of degradation and/or a silica gel cleanup method used since December 1999 to remove naturally occurring organic matter from samples in the lab. Previous laboratory analyses may have had higher TPH concentrations due to presence of natural organic matter.

Based on the analytical results of the quarterly groundwater sampling at AOC-049, this AOC is not recommended for inclusion in the Feasibility Study. VOCs detected above the PCLs in GW082 will be further evaluated in the FS as part of SWMU-172 and SWMU-174.

5.16 AOC-050, AOC-051, AND AOC-052: FORMER USTs URE-38, -39, AND -40 (BUILDING 10-52)

Former USTs URE-38, URE-39, and URE-40 stored fuel oil (diesel) to provide backup fuel for boilers located inside the Building 10-52 Boiler/Mechanical Room (Figure 5-14). The USTs were installed in 1957. Each was constructed of steel and had a capacity of 25,000 gallons. During the removal of the USTs in August, 1992, petroleum hydrocarbon-impacted soil was observed and excavated to the extent feasible. Groundwater monitoring conducted in the vicinity of the former USTs since June 1993 did not detect TPH-D concentrations exceeding the SL. Data from quarterly groundwater monitoring conducted by WESTON (December 1997 to March 1999) prior to Tier 2 is included in three monitoring reports (WESTON 1998b; WESTON 1999f,g). Additional information regarding AOC-050, AOC-051 and AOC-052 is included in Appendix A.

Investigation Conducted

The Tier 2 objective at AOC-050, AOC-051 and AOC-052 was to evaluate potential impacts to groundwater from residual TPH concentrations in soil. The scope of work performed included:

- The installation of one additional groundwater monitoring well (GW156) in the area of abandoned well 10-52-MW2, as recommended by Ecology.
- Collection of groundwater samples from the new monitoring well (GW156) and four existing monitoring wells (GW059 through GW062).
- Analysis of groundwater samples for diesel- and motor oil-range TPH.

None of the groundwater samples collected from AOC-050, AOC-051 and AOC-052 in the Tier 2 investigation contained detectable concentrations of diesel- and motor oil-range TPH. Quarterly monitoring conducted since Tier 2 indicated that TPH-D levels in groundwater remained below the detection limit (WESTON 1999g; WESTON 2000f,g,h). However, Ecology requested that additional quarterly groundwater monitoring be conducted at these AOCs during the Tier 3 investigation. The Tier 3 scope of work at these AOCs included:

- Collection of groundwater samples from GW059 through GW062, and GW156.
- Analysis of groundwater samples for diesel-range TPH.

Hydrogeologic Characteristics

The general stratigraphy beneath this area is shown in cross-section N-N’ (Figures 5-14A and 5 14B). Fill consisted of fine- to medium-grained, greenish-brown sand with some silt and some gravel (Figure 5-14B). Beneath the fill, alluvium consisted mostly of greenish-brown clay to silty clay interbedded with fine- to medium-grained, greenish-gray sand with silt, clay, and peat lenses (Figure 5-14B). Boring logs from the groundwater monitoring well GW156 installed during the Tier 2 investigation and existing wells GW059, GW060, GW061, and GW062 show the contact between the fill and alluvium to range from approximately 5 to 7 feet bgs (Appendix F).

Groundwater at the time of drilling was encountered at approximately 5.5 feet bgs. However, groundwater depths measured at GW059 and GW156 during the three Facility-wide groundwater measurement events (9 June 1999, 31 March 2000, and 7 September 2000) ranged from 4.7 to 6.2 feet bgs (Table 2-2). The amount of utilities and the location of the current UST pit in between these wells may account for the water level differences in these wells (Figure 5-14). Seasonal variations observed in groundwater elevations as measured during the three monitoring events in these wells was approximately 0.56 feet bgs (Table 2-2).

Figures 5-14C through 5-14E present groundwater elevation contours during the three Facility-wide groundwater events conducted at AOC-050, AOC-051, and AOC-052. The site-wide groundwater measurements collected in June 1999 present the groundwater flow direction towards the northwest. However groundwater flow during the 31 March and 7 September 2000 events is towards the west-southwest. Historical measurements collected during quarterly groundwater sampling events indicate that groundwater in the area typically flows toward the northwest to west as presented on the June 1999 map. Over the course of March 1999 to June 2000 quarterly monitoring, groundwater flow directions were observed to be toward the northwest in March 1999, September 1999, December 1999, and March 2000 (WESTON 1999g; WESTON 2000e,f), and to the west in June 1999 (WESTON 1999h). This is the groundwater flow pattern more typically observed at these AOCs and is illustrated by the contour map shown in Figure 5-14F. This contour map was based on measurements collected during the 1 March 2000 quarterly sampling event. Based on this information, the range in average gradient for these AOCs is 0.001 (June 1999) to 0.005 (1 March 2000).

A slug test was conducted in monitoring well GW059 located in the vicinity if this AOC group. As discussed in Section 2.9 and based on the results of the slug test conducted in this well, the hydraulic conductivity of groundwater in this area was 3.8×10^{-3} cm/s.

Nature and Extent of Releases

During previous quarterly monitoring, the Tier 2 sampling event and subsequent quarterly monitoring, groundwater samples collected from wells GW059 through GW062 and GW156 were analyzed for diesel- range TPH (the Tier 2 samples, collected in June of 1999, were also analyzed for motor oil-range TPH). The analytical results for these quarterly monitoring events are summarized in Table 5-14A.

As shown in the table, petroleum hydrocarbons concentrations were not detected in any of the groundwater samples analyzed.

Conclusions and Recommendations

The objective of the Remedial Investigation at AOC-050, AOC-051 and AOC-052 was to evaluate potential impacts to groundwater from residual TPH concentrations in soil. Petroleum hydrocarbon concentrations were not detected above the PCLs in any of the groundwater samples collected during the Tier 2 Assessment or subsequent quarterly monitoring.

Based on these results, inclusion of AOC-050, AOC-051 and AOC-052 in the Feasibility Study is not recommended.

5.17 AOC-060: FORMER VAPOR DEGREASER (BUILDING 4-42)

The former vapor degreaser in the southern portion of Building 4-42 was used primarily for metal parts cleaning with TCE (Figure 5-15). Secondary containment for the former vapor degreaser consisted of sumps SRE-2345, -2346, -2347 and -2348; the locations of which are presented in Figure 5-15. The sumps were constructed in 1942. SRE-2345, the main sump, was constructed of concrete and had a capacity of approximately 6,000 gallons. Three smaller sumps, SRE-2346, -2347 and -2348, extended below the base of SRE-2345. SRE-2346 was a steel sump with a 20-gallon capacity. Sumps SRE-2347 and SRE-2348 were constructed of concrete and had capacities of 13 and 18 gallons, respectively. The sumps were removed in December 1993. Additional information regarding these sumps is included in Appendix A. Results from assessment activities conducted since December 1993 have detected the presence of VOCs in soil and groundwater in the vicinity of the degreaser (SECOR 1994).

Investigation Conducted

The interim action at AOC-060 was initiated following the closure of the Building 4-42 vapor degreaser, and consists of quarterly groundwater monitoring. The primary objective of the interim action was to monitor the groundwater VOC concentrations to verify that the VOC plume remains stable and that monitoring wells adjacent to the Cedar River Waterway (GW159 and GW160) do not contain VOC concentrations above applicable surface water quality criteria.

The quarterly monitoring at this unit includes:

- The collection of groundwater samples from 13 monitoring wells (GW009 through GW015, GW147 through GW150, GW159 and GW160).
- The analysis of the groundwater samples for VOCs.

Monitoring at AOC-060 has been performed by WESTON since June 1997. Details are included in the *Interim Action Quarterly Performance Monitoring reports, Volumes I through IV* (WESTON 1997b,c; WESTON 1998c,d,e,f,g; WESTON 1999i,j,k; WESTON 2000d,i,j).

Hydrogeologic Characteristics

The general stratigraphy beneath this area is shown in cross-section O-O’ (Figures 5-15A and 5-15B). This cross-section shows that the depth of the hydraulic fill beneath the pavement generally increases toward the Cedar River or to the west (Figure 5-15B). Fill consists of light brown to brown sand with variable amounts of silt and gravel (Figure 5-15B). Alluvium generally consists of interbeds of gray silty sand, gray clayey silt, and gray sandy silt (Figure 5-15B). Boring logs from wells GW009, GW010, GW012, GW013, GW014, GW015, GW018 (replaced by GW150), GW020 (replaced by GW149), GW134 (replaced by GW159), GW135 (replaced by GW160), GW147, and GW148 indicated the contact between fill materials and alluvium ranged from approximately 3 to 7 feet (Appendix F).

As measured at wells GW009, GW010, GW012, GW014, GW147, GW149, GW150, GW159, and GW160 during the three Facility-wide groundwater monitoring events (9 June 1999, 31 March 2000, and 7 September 2000), groundwater depths ranged from 3.5 to 6.4 feet bgs (Table 2-2). Typically, seasonal variations were within 0.91 foot in the monitoring wells associated with this AOC.

As shown in Figures 5-15C (June 1999), 5-15D (March 2000), and 5-15E (September 2000), groundwater in the vicinity of AOC-060 generally flows to the northwest towards the Cedar River Waterway. Groundwater elevations in wells GW159 and GW160 located adjacent to the Cedar River are typically slightly higher than GW149 and GW150. Factors that could contribute to the higher groundwater elevations include: 1) perched groundwater above a localized, less-permeable soil layer; 2) increased surface water infiltration (precipitation, irrigation) through the unpaved surface within Cedar River Trail Park; and 3) influence from the Cedar River Waterway. The average gradient, as presented on the Facility-wide maps for this area, is typically 0.00, as the gradient remains pretty flat throughout the year. A steeper gradient is also observed east-southeast of the unit. The change in gradient south of the unit, as well as the lack of seasonal variation in the gradient through the unit, may be a result of the influence in groundwater resulting from the operation of the nearby 4-78/79 groundwater extraction system.

Slug tests were conducted in the monitoring wells GW010, GW011, GW147, GW150, GW154, and GW160 located in the vicinity of AOC-060. As discussed in Section 2.9, the results of the slug tests indicated that the hydraulic conductivity of groundwater ranged from 1×10^{-3} to 2.8×10^{-2} cm/s.

Nature and Extent of Releases

Analytical results of groundwater sampling at AOC-060 indicate that detectable concentrations of VOCs are present in the groundwater. The detected concentrations from the previous seven quarters (March 1999 to September 2000) of monitoring are summarized in Table 5-15A and Figure 5-15F. As shown on this table, vinyl chloride, cis-1,2-Dichloroethene (cis-1,2-DCE), and TCE have exceeded the PCLs at AOC-060. Seven of the 13 wells (GW009, GW012, GW014, GW147, GW149, GW150, and GW160) sampled during the previous seven quarters contained vinyl chloride concentrations above the PCL (2 µg/L); two (GW009 and GW012) have contained cis-1,2-DCE concentrations above the PCL (80 µg/L), and one (GW147) has contained TCE concentrations above the PCL (2.7 µg/L).

Since 1999, the maximum vinyl chloride concentration (660 µg/L) was detected in GW009 in June 2000. The September 2000 sampling results indicate that GW014, GW150, GW147, and GW009 were the only wells with constituent concentrations exceeding the PCLs, specifically, vinyl chloride concentrations of 2.8 µg/L, 16 µg/L, 19 µg/L, and 200 µg/L, respectively (Figure 5-15F).

The two wells (GW009 and GW012) in which cis-1,2-DCE concentrations have exceeded the PCL are within approximately 20 feet of the former degreaser unit. Cis-1,2-DCE concentrations were above the PCL in GW012 in quarterly samples from March, June, and July 1999, and in March 2000, at concentrations ranging from 97 µg/L to 180 µg/L. Cis-1,2-DCE was also above the PCL in the sample collected from GW009 in June 2000, at an estimated concentration of 92 µg/L. Detected concentrations of cis-1,2-DCE were below the PCL in all AOC-060 samples collected in September 2000.

The only well in which TCE has exceeded the PCL concentration (GW147) is approximately 90 feet southeast of the former degreaser unit. TCE concentrations above the TCL in GW147 were detected in quarterly groundwater samples from March and December 1999, and in June 2000 at concentrations ranging from 3.2 µg/L to 3.8 µg/L. Detected TCE concentrations in GW147 were below the PCL in the groundwater sample collected in September 2000.

The wells (GW009, GW012, GW014, GW147, GW149, GW150, and GW160) that have contained VOC concentrations above the PCLs over the 1999-2000 monitoring period are shallow wells with a screened interval of 3 to 15 feet bgs. Except for one incidence of vinyl chloride detection in GW011 (1.2 µg/l on 14 June 2000), no VOCs have been detected in the three intermediate wells (GW011, GW013 and GW015; screened at 29 to 39 feet bgs) located in the vicinity of the former degreaser, which indicates that the VOC plume is confined to the shallow wells. Analytical data from September 2000 indicated that vinyl chloride was the only constituent present at AOC-060 at concentrations above the PCL. Concentrations decreased to 2.8 µg/L or less within 50 feet to the north (GW014) and southeast (GW010), and were not detectable within approximately 170 feet (GW159 and GW160) to the west (downgradient) of the former degreaser. The eastern extent of the plume is likely limited by the westerly direction of groundwater flow.

Conclusions and Recommendations

Results of the groundwater analyses for VOCs during the previous seven quarters (March 1999 to September 2000) indicate that vinyl chloride, cis-1,2-DCE, and TCE concentrations have been present above the PCLs. Of the 13 wells sampled during this period, seven have at times contained vinyl chloride concentrations above PCL, with the maximum vinyl chloride concentration (660 µg/L) detected in GW009 in June 2000. September 2000 sampling results indicated that the maximum vinyl chloride concentration decreased to 200 µg/L (GW009). Two of the seven wells with vinyl chloride concentrations above the PCLs have contained concentrations of cis-1,2-DCE above the PCL; the maximum concentration (180 µg/L) was detected in GW012 in June and August, 1999. These two wells are located within approximately 20 feet of the former degreaser. Concentrations of cis-1,2-DCE detected during the September 2000 sampling event were below the PCL.

With the exception of one minor detection of vinyl chloride (1.2 µg/L in GW011), VOCs have not been detected in the three deep wells (GW011, GW013 and GW015; screened at 29 to 39 feet bgs) located in the vicinity of the former degreaser, indicating that the VOC plume is confined to shallow wells (screened intervals of 3 to 15 feet bgs). The September 2000 data indicate that the lateral extent of VOC (vinyl chloride) concentrations exceeding the PCL is limited to within 170 feet of the former vapor degreaser.

Based on the analytical results, inclusion of AOC-060 in the Feasibility study is recommended.

5.18 AOC-074: APRON D, IN THE AREA OF THE FORMER CITY OF RENTON SANITARY SEWAGE TREATMENT PLANT

Apron D, located south of Building 4-64, is used by Boeing for aircraft pre-flight checks. It was also the former location of the City of Renton sanitary sewage treatment plant. The location of Apron D is shown on Figure 5-16.

Soil and groundwater samples were collected from Apron D area prior to the Tier 2 Assessment. The results of metals analyses on soil samples collected in 1992 indicated that none contained metal concentrations above the SLs. Therefore, no additional soil samples were collected during the Tier 2 Assessment. Quarterly groundwater monitoring was conducted at Apron D from September 1997 to March 1999 using two upgradient monitoring wells (GW064 and GW065) and three downgradient monitoring wells (GW144 through GW146). The results are documented in three groundwater monitoring reports (WESTON 1998h; WESTON 1999l,m).

Investigation Conducted

The objective of the Tier 2 Assessment at AOC-074 was to collect groundwater samples upgradient and downgradient of Apron D to evaluate if metals concentrations indicative of a release are present. The scope of work performed included:

- Collection of groundwater samples from two upgradient (GW064 and GW065) and three downgradient wells (GW144 through GW146).
- Analysis of groundwater samples for total and dissolved priority pollutant metals.

Groundwater laboratory results indicated that total cadmium and total and dissolved arsenic were the only constituents that exceeded the SL. Although total cadmium concentrations were detected slightly above the SL in three of the five groundwater samples analyzed, dissolved cadmium concentrations were not detected in any of the samples. The difference in total and dissolved results are likely due to suspended solids in the unfiltered samples. Turbidity levels in the unfiltered AOC-074 well samples were generally higher than levels observed in other wells at the Renton facility. Arsenic was detected in the groundwater at concentrations commonly detected in the Puget Sound region and wells located upgradient of the Boeing Renton Plant.

Furthermore, arsenic and cadmium are not associated with the activities conducted by Boeing (i.e., pre-flight testing) at this AOC. Based on these findings, AOC-074 was not included in the Tier 3 Detailed Investigation.

Hydrogeologic Characteristics

The general stratigraphy beneath this area is shown in cross-section P-P' (Figures 5-16A and 5-16B). Fill in this area consisted of olive brown medium-grained sand with gravel grading into dark grayish-brown sandy silt (Figure 5-16B). Alluvium consisted of interbedded greenish-gray sandy silt and dark gray fine-grained silty sand (Figure 5-16B). Boring logs from existing wells GW064, GW065, GW144, GW145, and GW146 indicated the contact between fill and alluvium ranged from approximately 2.5 to 4 feet bgs (Appendix F).

During installation of these wells, groundwater was encountered at approximately 6 to 6.5 feet bgs. Groundwater as measured at these five wells during the three Facility-wide groundwater monitoring events (9 June 1999, 31 March 2000, and 7 September 2000) ranged from 4.27 to 8.91 feet bgs (Table 2-2). The shallowest water table was observed in GW065 where slight artesian conditions have been observed in the past and groundwater is typically higher than in the rest of the wells in the vicinity, thus appearing as a mound in groundwater contour maps (Figures 5-16C, 5-16D, and 5-16E). Seasonal variations on groundwater levels as measured during the three monitoring events ranged from 0.42 to 3.66 feet bgs. The highest seasonal variation was also observed in GW065 (3.66) where the mounding effect is observed. Groundwater in this area consistently flows to the west-northwest toward the Cedar River Waterway at a variable gradient of 0.005 (June 1999 and September 2000) to 0.008 (March 2000). This groundwater behavior is shown in Figures 5-16C, 5-16D, and 5-16E.

A slug test was conducted in monitoring well GW065 located at AOC-074. As discussed in Section 2.9 and based on the results of the slug test in this well, hydraulic conductivity of groundwater in the area was 7.2×10^{-5} cm/s.

Nature and Extent of Releases

Previous results from the September 1997 to December 1998 quarterly monitoring indicate that detected dissolved metals concentrations did not exceed the PCLs (WESTON 1998h; WESTON 1999l,m). In 1999, two rounds of groundwater samples (March and June) were collected from wells GW064, GW065, GW144, GW145 and GW146 and were analyzed for total and dissolved priority pollutant metals. Table 5-16A and Figure 5-16F summarize the constituents detected in the groundwater samples. All concentrations were below the PCLs with the exception of total and dissolved arsenic and total cadmium. Arsenic concentrations in groundwater above the PCL (0.001 mg/L) were detected in the five monitoring wells sampled during these two sampling rounds. Total arsenic concentrations ranged from 0.004 to 0.039 mg/L. Dissolved arsenic concentrations in these wells ranged from 0.005 to 0.038 mg/L. Total cadmium concentrations ranged from less than 0.002 to 0.007 mg/L in the two upgradient wells and from less than 0.002 to 0.019 mg/L in the three downgradient wells. Total cadmium in both upgradient and downgradient wells exceeded the PCL of 0.002 mg/L. Dissolved cadmium concentrations were not detected above the reporting limit in any of these monitoring wells.

The total cadmium results from the upgradient and downgradient wells were compared statistically to determine if there is a significant difference across Apron D. A two-sample t-test was performed using SYSTAT©, Version 9 (Appendix C.2). The results from this test showed that the upgradient and downgradient monitoring well sample means are not significantly different at the 95 percent confidence level ($\alpha = 0.05$). This comparison indicates that Apron D does not contribute to the measured total cadmium concentrations.

Conclusions and Recommendations

The objective of the Remedial Investigation at AOC-074 was to evaluate metals concentrations in groundwater upgradient and downgradient of Apron D to determine if evidence of a release was present. Seven rounds of groundwater sampling have been conducted since September 1997, and with the exception of total and dissolved arsenic and total cadmium, all detected metals concentrations have been below the PCLs. As discussed in Sections 2 and 3, naturally elevated dissolved arsenic concentrations in the area are not indicative of a release from the

Facility. Upgradient and downgradient monitoring results for total cadmium indicate that no release has occurred. These total cadmium results likely are the result of naturally occurring cadmium being detected in turbid groundwater samples; as evidenced by cadmium not being detected in the dissolved results. Therefore, the total cadmium results detected in groundwater are not indicative of a release at or from the Facility.

Based on these results, inclusion of AOC-074 in the Feasibility Study is not recommended.

5.19 AOC-090: UNKNOWN RELEASE (BUILDING 4-65 YARD)

AOC-090 and Building 4-65, the Boeing Renton Gate D-30 Guard House, is located near the southwest corner of Building 4-64 as depicted in Figure 5-17. During the installation of an underground fire protection water line and fire hydrant in July 1999, approximately 40 cubic yards of soil was excavated to a depth of approximately 6 feet bgs. Laboratory analysis of soil samples collected from the stockpiled soil indicated elevated concentrations of selected VOCs (TCE and carbon tetrachloride) and TPH in the gasoline, diesel and oil ranges. The source of the elevated concentrations is unknown.

Investigation Conducted

A preliminary investigation performed in the Building 4-65 yard in December 1999 consisted of the following:

- The collection of 48 soil samples from 12 push-probe locations (PP039 through PP050), and the collection of eight groundwater samples from four push-probe locations (PP039, PP043, PP045 and PP046).
- Analysis of the soil and groundwater samples for VOCs, gasoline-range TPH (TPH-G), and diesel- and motor oil-range TPH (TPH-D extended).

Following review of the elevated VOC and TPH laboratory results, soil samples from several sample stations were subsequently analyzed for SVOCs, PCBs, and metals.

The results of the December 1999 sampling indicated the highest VOC and TPH soil concentrations were detected in push-probes located just north of the fence, within a 4-foot wide strip of asphalt paving that is adjoined on the north side by concrete paving. This asphalt paving strip may have historically been unpaved. PCBs were not detected in the soil samples analyzed and were not further evaluated during the Tier 3 investigation. Several SVOCs and priority pollutant metals were detected at concentrations exceeding the RI SLs. However, due to the fact that a limited number of analytes exceeded their SLs, and the SLs were generally only exceeded slightly, SVOCs and priority pollutant metals were also not further evaluated during Tier 3. The results of the December 1999 investigation were documented in *Building 4-65 Yard Sampling Report (AOC-090)* (WESTON 2000k).

The purpose of the Tier 3 sampling at AOC-090 was to characterize the nature and extent of VOC and TPH constituents in the soil and groundwater in the area. The scope of work included:

- The installation of five pairs of groundwater monitoring wells (GW161 and GW162, GW163 and GW164, GW165 and GW166, GW167 and GW168, GW169 and GW170).
- The collection of 49 soil samples from nine push-probe locations (PP051 through PP059) and three groundwater monitoring well borings (GW161, GW167, and GW169).
- The collection of 11 groundwater samples from one push-probe (PP058) and 10 monitoring well locations.
- The analysis of 44 soil samples and 11 groundwater samples for VOCs, and gasoline-, diesel-, and oil-range TPH. Additional soil samples were also analyzed for bulk dry density, total organic carbon, particle size distribution (i.e., grain size analysis), and total porosity.
- The measurement of groundwater depths from the 10 monitoring wells to evaluate groundwater flow direction and gradient.

The 10 new wells at AOC-090 were installed as five sets of shallow and deep wells (Figure 5-17). One of each set (GW162, GW164, GW166, GW168 and GW170) was installed to a depth of 14 feet bgs (screen interval from 4 to 14 feet bgs), while the other (GW161, GW163, GW165, GW167 and GW169) was installed to a depth of 35 feet bgs (screen interval from 25 to 35 feet bgs). A detailed discussion of the investigation at this unit is presented in the *AOC-090 Interim Report* (WESTON 2000l).

Hydrogeologic Characteristics

The general stratigraphy beneath this area is shown on cross-section Q-Q’ (Figures 5-17A and 5-17B). Fill consisted of brown to reddish-brown fine- to medium-grained sand with silt and gravel (Figure 5-17B). Alluvium beneath the fill consisted of interbedded reddish-brown to greenish-gray fine-grained sand with silt and variable amounts of clay and reddish-brown to greenish-gray clayey silt, and peat layers (Figure 5-17B). Boring logs from the 21 push-probes and 10 groundwater monitoring wells advanced/installed during the AOC-090 preliminary and Tier 3 investigations indicated that fill extended from approximately 2.5 to 7 feet bgs (Appendix F).

Groundwater at time of drilling was estimated at 4 to 5.5 feet bgs (Appendix F). Groundwater levels were measured on 18 August 2000 in the 10 wells installed at AOC-090 (GW161 to GW170) (WESTON 2000l) and on 7 September 2000 in the five shallow monitoring wells (GW162, GW164, GW166, GW168, and GW170). Both monitoring events indicated that groundwater depths ranged from approximately 5.4 to 7.1 feet bgs (Table 2-2). Since the wells associated with AOC-090 were installed in July 2000, seasonal variations in the area were estimated by nearby wells GW064, GW065, GW144, GW145 and GW146 from AOC-074, and GW157 from SWMU-179. Groundwater levels obtained from these wells during the three Facility-wide groundwater monitoring events (9 June 1999, 31 March 2000, and 7 September 2000) indicated that groundwater depths ranged between 4.27 to 8.91 feet bgs (Table 2-2). The maximum seasonal variation in groundwater elevation was 3.66 feet for these wells.

Inferred groundwater elevation contours obtained from the Facility-wide groundwater monitoring events conducted in 9 June 1999 (Figure 5-17C) and 31 March 2000 (Figure 5-17D), in addition to actual groundwater measurements obtained on 7 September 2000 (Figure 5-17E) from the five shallow monitoring wells (GW162, GW164, GW166, GW168, and GW170) indicate that shallow groundwater in this area generally flows to the west toward the Cedar River Waterway. The range in average gradient observed from these figures is from 0.001 (June 1999 and September 2000) to 0.003 (March 2000), and as expected is typically flatter during the drier summer season. These results are similar to the 18 August 2000 measurements obtained from these shallow wells, which indicated the groundwater flow direction was toward the northwest, with a groundwater gradient of approximately 0.0005 (WESTON 2000l).

As shown on Figure 5-17F, measurements from the five deep wells (GW161, GW163, GW165, GW167 and GW169) on 18 August 2000 indicated that the groundwater flow direction is toward the southwest, with a groundwater gradient of approximately 0.002. The groundwater elevation in each of the five deep wells on 18 August 2000 was 0.28 to 0.5 feet higher than the adjacent shallow well (WESTON 2000l). These measurements indicate that the groundwater flows upward with a vertical gradient ranging from 0.013 to 0.024.

Slug tests were conducted in monitoring wells GW065, GW169, and GW170 located in the vicinity of AOC-090. The results of the slug tests indicated that the hydraulic conductivity of groundwater in the area ranged from 7.2 x 10^{-5} to 7.2 x 10^{-4} cm/s.

Nature and Extent of Releases

Ninety-two soil samples and 19 groundwater samples were analyzed from AOC-090 in the preliminary (December 1999) and Tier 3 investigations. Analytical results of the soil samples collected are presented in Tables 5-17A through 5-17C. Analytical results of the groundwater samples collected are presented in Tables 5-17D and 5-17E. Figures 5-17G through 5-17L show the locations of soil and groundwater samples that exceeded PCLs.

Soil

Selected soil samples from AOC-090 were analyzed for VOCs, TPH, SVOCs, PCBs, and metals. As discussed below, VOCs, TPH, SVOCs, and metals were detected in selected soil samples. PCBs were not detected in any of the soil samples analyzed as documented in the *Building 4-65 Yard Sampling Report* (WESTON 2000k).

VOCs

Of the 92 soil samples analyzed, 37 soil samples collected from the push-probes and monitoring wells contained one or more VOCs at concentrations above the PCLs (Tables 5-17A and 5-17B). These VOCs included 1,1,2-trichloroethane, 1,1-dichloroethene, benzene, carbon tetrachloride, chloroform, cis-1,2-DCE, methylene chloride, PCE, toluene, TCE, and vinyl chloride. The 5-foot sample from PP047 contained the highest overall concentrations of 1,1-dichloroethene (an estimated 69 µg/kg), benzene (an estimated 120 µg/kg), carbon tetrachloride (520,000 µg/kg), chloroform (35,000 µg/kg), methylene chloride (38,000 µg/kg), and toluene (67,000 µg/kg). The 5-foot sample from PP054 contained the highest overall concentrations of PCE (17,000 µg/kg), and TCE (870,000 µg/kg). The highest concentration of cis-1,2-dichloroethene (24,000 µg/kg) was detected in the 2-foot sample from PP055. The highest concentration of vinyl chloride (an estimated 380 µg/kg) was detected in the 5-foot sample from PP045. The 3-foot soil sample from PP047 had the only concentration of 1,1,2-TCE (an estimated 130 µg/kg) above the PCL.

As shown on Figure 5-17G, the highest soil VOC concentrations above their respective PCLs are located in the vicinity of PP045, PP047, PP048, PP053, PP054 and PP055. VOC concentrations in soil generally decrease as you move outward from this cluster of push-probes. Of the southernmost push-probes (PP056, PP057, PP058, and PP059), only PP058 contained VOC concentrations above the PCLs. At PP058, TCE was the only VOC detected in soil above the PCL. At this push-probe, TCE (110 µg/kg) was detected slightly above the PCL (54 µg/kg). These results suggest the extent of VOC contamination above the PCLs may not extend underneath North 6th Street. Soil data from PP040 and PP041 suggests that soil with concentrations above the PCLs may extend beneath the 4-64 Building.

The analytical results from GW167 and GW169 suggest that the vertical extent of VOC in soil above the PCLs is less than 20 feet bgs.

TPH

Twenty-five of the 92 soil samples analyzed contained TPH concentrations above the PCLs (Tables 5-17A and 5-17B). Samples with TPH concentrations above the PCLs include those collected from PP041, PP045, PP047, PP048, and PP052 through PP058. The standard chromatographic patterns for gasoline, diesel, and motor oil did not match well with the chromatograms for the soil samples collected. Review of the sample chromatograms suggested the presence of weathered gasoline or solvents in the gasoline range, and a mixture of kerosene (Jet-A fuel) and lubricating, mineral or hydraulic oil. The highest TPH concentrations were detected in samples from PP047. The 3-foot soil sample contained the highest gasoline-range TPH (10,000 mg/kg), and the 5-foot sample contained the highest diesel-range TPH concentration (19,000 mg/kg) and motor oil-range TPH concentration (21,000 mg/kg). None of the soil samples collected at a depth greater than 10 feet bgs contained TPH concentrations above the PCLs.

As shown on Figure 5-17H, the lateral extent of TPH concentrations above the PCLs is generally defined by soil samples collected from PP040, PP042, PP044, PP049, PP051, and PP059. Due to utilities, the lateral extent of TPH concentrations was not defined with respect to the PCLs south of PP056, PP057 and PP058, and may extend beneath N. 6th Street. Figure 5-17H also shows that the vertical extent of TPH concentrations above the PCLs is less than 15 feet bgs.

SVOCs

Soil samples from the preliminary investigation were analyzed for SVOCs (Table 5-17C). As shown on Figure 5-17I, SVOCs present at concentrations above the PCLs included 2-methylnaphthalene, isophorone, and phenanthrene. Concentrations of 2-methylnaphthalene above the PCL were detected only at the 5 feet and 9.5 feet bgs samples collected from PP047 at concentrations of 4,000 and 1,500 µg/kg respectively. Isophorone was above the PCL only in the 1-foot bgs sample collected in PP048 at a concentration of 12,000 µg/kg. Phenanthrene was detected above the PCL only in one soil sample from PP047 (5 feet bgs) at a concentration of 5,500 µg/kg.

Based on the limited number of concentrations detected, SVOCs were not considered constituents of concern for the Tier 3 investigation.

Metals

Twelve soil samples from the preliminary investigation were analyzed for priority pollutant metals (Table 5-17C). Concentrations of one or more metals were detected above the PCLs in each of the 12 soil samples analyzed from PP045, PP047, and PP048. As shown on Figure 5-17J, the highest concentration of each of the metals detected above the PCLs are antimony (estimated at 16 mg/kg); arsenic (8 mg/kg); cadmium (10.3 mg/kg); chromium (51.9 mg/kg); copper (69.9 mg/kg); and silver (1.2 mg/kg). Because the concentrations were only slightly above RI SLs, metals were not considered constituents of concern for the Tier 3 investigation.

Groundwater

Groundwater samples from AOC-090 were analyzed for VOCs and TPH. As discussed below, several VOCs and TPH fractions were detected above their respective PCLs in selected groundwater samples.

VOCs

Tables 5-17D and 5-17E present the VOC data for the 19 groundwater samples analyzed during the preliminary and Tier 3 investigations. Maximum VOC concentrations detected above the PCL during these two investigations included 1,1-dichloroethene (estimated at 11 µg/L), acetone (2,800 µg/L), benzene (12 µg/L), carbon tetrachloride (2,000 µg/L), chloroform (5,100 µg/L), cis-1,2-dichloroethene (6,600 µg/L), methylene chloride (120 µg/L), PCE (28 µg/L), TCE (13,000 µg/L) and vinyl chloride (2,200 µg/L). These concentrations were detected in the groundwater samples collected from GW168 at 8.5 feet bgs, and from PP045 at 5.5 feet bgs and 11.5 feet bgs (Figure 5-17K). The groundwater sample collected from the deeper well adjacent to GW168 (GW167 at 30 feet bgs) also contained concentrations above the PCLs of carbon tetrachloride (110 µg/L), chloroform (150 µg/L), and TCE (500 µg/L). Additional VOCs detected slightly above the PCLs in the deeper wells included vinyl chloride (2.7 µg/L) detected in the groundwater sample collected at approximately 30 feet bgs from GW161 and chloroform (7.9 µg/L), which was tentatively identified in GW165 at approximately 29 feet bgs. Groundwater samples from the upgradient deep well (GW169) and shallow well (GW170) did not contain VOC concentrations above the PCL.

TPH

Tables 5-17D and 5-17E and Figure 5-17L present the TPH data for the 19 groundwater samples analyzed for the preliminary and Tier 3 investigations. Of all the groundwater samples analyzed for TPH, only the samples from PP045 (12 mg/L at 5.5 feet bgs and 2.2 mg/L at 11.5 feet bgs), GW167 (1.6 mg/L at 30 feet) and GW168 (19 mg/L at 8.5 feet bgs) contained gasoline-range TPH concentrations above the PCL of 0.8 mg/L for TPH-G with detectable benzene concentrations. The groundwater samples collected from GW168 at 8.5 feet bgs and PP045 collected at 5.5 feet bgs were the only samples that contained diesel-range hydrocarbons above the PCL at concentrations of 0.56 mg/L and 170 mg/L respectively. The groundwater sample collected from PP045 at 5.5 feet bgs (190 mg/L) was the only sample that contained motor oil-range TPH concentrations above the PCLs.

The standard chromatographic patterns for gasoline, diesel, and motor oil did not match well with the chromatograms for the groundwater samples collected. Review of the sample chromatograms suggested the presence of weathered gasoline or solvents in the gasoline range, and a mixture of kerosene (Jet-A fuel) and lubricating, mineral or hydraulic oil. As shown in Figure 5-17L, the lateral extent of TPH concentrations in groundwater exceeding PCLs is limited to the area adjacent to PP045, GW167 and GW168. None of the remaining eight wells or four push-probes sampled contained TPH concentrations above the PCL.

Conclusions and Recommendations

The results of the investigations conducted at AOC-090 indicate that selected VOCs, SVOCs, metals and TPH were detected in soil at concentrations above the PCLs. The lateral extent of VOC concentrations above the PCLs is generally defined by soil samples collected from PP040, PP041, PP043, PP049, PP051, PP056, PP057, PP058, and PP059 and may not extend south underneath N. 6th Street. Soil analytical results indicate the vertical extent of VOC concentrations above the PCLs is within 20 feet bgs. The highest concentrations of SVOCs and metals were detected in soil samples collected from PP045, PP047, and from PP048. The highest TPH concentration in soil was detected in PP047. Due to subsurface utilities located in North 6th Street, the southern lateral extent of TPH was not fully defined with respect to the PCLs and may extend beneath the roadway.

Groundwater analytical results indicated that 1,1-dichloroethene, acetone, benzene, carbon tetrachloride, chloroform, cis-1,2-dichloroethene, methylene chloride, PCE, TCE, vinyl chloride, and TPH were the constituents detected at concentrations above the PCLs. The highest concentrations of these constituents were detected in GW168 and PP045.

Based on the results of the Remedial Investigation, inclusion of AOC-090 in the Feasibility Study is recommended.

5.20 AOC-091: COLUMN G-6 ELEVATOR (BUILDING 4-20)

The elevator is located at column G-6 near the center of Building 4-20 (Figure 5-18). The elevator vault is constructed of concrete, and the base of the vault is approximately 4.5 feet below the main floor of the building. A steel-lined hydraulic ram shaft extends from the concrete base of the vault to approximately 22 feet below the base. The hydraulic ram is contained within a steel outer casing, which is believed to be open at its bottom. Staining of the concrete surface of the vault floor was observed; the stains are considered most likely to be hydraulic oil from the normal operation of the elevator.

Investigation Conducted

Preliminary soil and groundwater sampling was conducted by WESTON on 27 April 2000 to assess and characterize the potential impacts of elevator operations on soil and groundwater. The scope of work of the initial investigation included:

- Collection of 13 soil samples and four groundwater samples from four push-probe locations (HP001 through HP004).
- The analysis of the samples for PCBs and diesel- and motor oil-TPH.

Laboratory analyses detected PCBs in the groundwater, and hydraulic oil-range petroleum hydrocarbons in the soil and groundwater. The groundwater results from the 27 April 2000 sampling event may have been the result of cross-contamination due to the presence of accumulated groundwater in the vault and the observed staining on the concrete floor. The results of this investigation were presented in the *Building 4-20, Column G-6 Elevator, Soil and Groundwater Sampling Report* (WESTON 2000m).

Additional sampling at AOC-091 was conducted on 19 September 2000 to evaluate the nature and extent of PCB and TPH in soil and groundwater near the elevator vault. As detailed in *Addendum 4 of the RI WP* (WESTON 2000c) the scope of work included:

- Collection of four soil samples and four groundwater samples from four push-probe locations (PP069 through PP072).

- The analysis of the samples for PCBs and diesel- and oil-range TPH.

Push-probes PP069 through PP072 were located on the main floor of Building 4-20 to avoid potential sample cross-contamination due to groundwater within the elevator vault.

Hydrogeologic Characteristics

The general stratigraphy beneath this area is shown on cross-section R-R' (Figures 5-18A and 5-18B). Fill consisted of fine- to medium-grained brown to reddish-brown sand with silt. Alluvium beneath the fill consisted of fine- to medium-grained greenish-gray sand with silt. Boring logs form the eight push-probes advanced at the AOC-091 during the preliminary and Tier 3 investigations indicated that fill materials extended to approximately 3.5 to 4 feet bgs (Appendix F).

Groundwater at the time of drilling during the Tier 3 investigation was encountered at approximately 4 feet bgs (Appendix F). During the preliminary investigation, however, groundwater at the time of drilling is assumed to have been higher, due to the season (December) and the fact that water was observed flowing from the borings onto the floor of the elevator shaft. Groundwater levels as measured from nearby wells GW006, GW007, GW052, GW154, and GW174 during the three Facility-wide groundwater monitoring events (6 June 1999, 31 March 2000, and 7 September 2000) indicated that groundwater in the area typically ranges between 2.42 to 4.85 feet bgs (Table 2-2). Seasonal variations observed on groundwater as measured during the three monitoring events for these wells were within 0.86 foot bgs (Table 2-2). Monitoring well GW174 was excluded in the seasonal variations calculation since it was recently installed and only one groundwater measurement exist from this well. Groundwater in this area consistently flows to the northwest toward Lake Washington at an average gradient ranging from approximately 0.001 to 0.005 (Figures 5-18C, 5-18D, and 5-18E).

Slug tests were not conducted in any nearby wells therefore, no hydraulic conductivity data are available for these AOC.

Nature and Extent of Releases

Seventeen soil and eight groundwater samples were collected from eight push-probes (HP001 through HP004, and PP069 through PP072) at AOC-091. All samples were analyzed for PCBs and diesel (TPH-D) and motor oil-range petroleum hydrocarbons.

Table 5-18A presents a summary of the soil sample analytical results. As shown on the table, no PCB concentrations were detected above the quantitation limits. TPH-D and motor oil were detected in some of the samples, but all detected concentrations were below the PCLs.

Table 5-18B and Figure 5-18F presents a summary of the groundwater analytical results. As shown on the table, PCBs (Aroclor 1242), TPH-D, and motor oil concentrations were above the PCLs in some samples. PCB concentrations above the PCL (1 µg/L) ranged from 1.5 to 2.7 µg/L in HP001, HP002, and HP003. TPH-D and motor oil concentrations above the PCL (0.5 mg/L) were detected in HP001 through HP004. Detected TPH-D concentrations ranged from 7.8 to 18 mg/L, and detected motor oil concentrations ranged from 11 to 31 mg/L. All concentrations above the PCLs were detected in samples collected from directly within the elevator vault. Due to the presence of accumulated water within the vault and the observed presence of hydraulic oil staining of the concrete surface, the detected constituents are not representative of actual groundwater conditions beneath the elevator vault due to potential cross contamination at the time of sampling. No constituent concentrations were detected in samples collected from outside the vault (PP069 through PP072).

Conclusions and Recommendations

The results of the soil analyses at AOC-091 indicate that no PCB concentrations were detected above the quantitation limits, and TPH-D and motor oil concentrations were below the PCLs. No constituent concentrations were detected in groundwater samples collected from outside the vault (PP069 through PP072).

PCBs and TPH were not detected in any of the downgradient soil and groundwater samples. WESTON believes that the groundwater results collected from inside the elevator vault do not accurately reflect the underlying groundwater quality. Due to the presence of accumulated groundwater in the vault and the observed hydraulic oil staining of the concrete surface, the concentrations of constituents detected were the likely consequence of cross-contamination at the time of the sampling.

Based on these results, AOC-091 is not recommended for inclusion in the Feasibility Study.

SECTION 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

This section summarizes results of the SWMU/AOC-specific investigations provided in Section 5. SWMUs/AOCs that are recommended for feasibility study, and those SWMUs/AOCs that are not recommended for feasibility study are discussed below. The SWMUs/AOCs recommended for feasibility studies are categorized for like hazardous substances to aid in feasibility study planning. This section also discusses key considerations for the FS work plan.

6.1.1 SWMUs/AOCs Recommended for Feasibility Study

SWMUs and AOCs are recommended for feasibility study if concentrations of hazardous substances exceed the preliminary cleanup levels at the standard point of compliance [WAC 173-340-350(8)(a)] as discussed in Section 4.4. Table 6-1 contains a list of SWMUs/AOCs recommended for feasibility study based on the nature and extent of hazardous substances present. The nature, extent and justification for inclusion of these SWMUs/AOCs is summarized below.

SWMU-168: Former UST URE-31 (Building 5-50)

Nature

The analytical results for the samples collected during the Tier 2 assessment indicated that one VOC (methylene chloride) was present in the soil at three probe locations (PP001, PP002, and PP003) at concentrations above the PCLs.

Vinyl chloride was detected in groundwater from PP003 at a concentration at the PCL.

Extent

Soil concentrations of methylene chloride above the PCL was detected within backfill in the former UST excavation and to extend at least approximately 20 feet to the east and 5 feet to the south. Vertically, concentrations of methylene chloride above the PCL appears to be limited to within 7 feet of the ground surface.

Vinyl chloride was detected above the PCL in groundwater collected from PP003, which was located approximately 5 feet south of the former UST. However, vinyl chloride is likely limited to the immediate vicinity of the UST excavation, since vinyl chloride was not detected in probe PP002 (located 15 feet downgradient of the former UST).

Justification for Feasibility Study

SWMU-168 is recommended for Feasibility Study because soil and groundwater have hazardous constituents above PCLs. The nature and extent of chlorinated solvents in soil and their potential to impact groundwater will be evaluated in the FS.

SWMU-172 and SWMU-174: Former USTs URE-66 (Building 5-09) and URE-73 (Building 5-08)

Nature

Soil samples collected at SWMU-172 and SWMU-174 were analyzed for VOCs, SVOCs and metals. Several VOCs and several metals were detected at concentrations above the PCLs.

Groundwater samples contained several VOCs, one SVOC and four metals at concentrations above the PCLs. VOCs were detected above the groundwater PCLs at 12 of the 17 locations sampled. Bis(2-ethylhexyl)phthalate was detected (3.6 µg/L) at one location slightly above the PCL (1.8 µg/L). Four total metals (arsenic, chromium, copper and lead) and one dissolved metal (arsenic) were detected above the PCLs. Although arsenic slightly exceeded the PCL in four groundwater samples, the concentrations were within the typical background range.

Extent

In the vicinity of SWMU-172, VOC and SVOC soil concentrations above the PCLs extend to at least 45 feet to the east, 15 feet to the north, 70 feet to the south, and 10 feet to the southwest. Vertically, concentrations of these constituents above the PCLs occur within 15 feet of the surface.

Soil VOC concentrations above the PCLs in the vicinity of SWMU-174 extend at least 15 feet to the east of the unit. Vertically, concentrations above the PCLs are limited to within 9 feet bgs to the east.

Based on the analytical results, the extent of groundwater above the PCLs in the area is confined an area delineated by GW171 to the south, GW084 to the west, and GW080/GW081 to the north; the extent toward the east is not fully defined.

Justification for Feasibility Study

SWMU-172 and SWMU-174 are recommended for inclusion in the Feasibility Study because soil and groundwater contain hazardous substances above PCLs. A release of hazardous substances to soil has impacted groundwater quality, and the eastward extent is not fully defined with respect to the PCLs. The FS is necessary to evaluate remedial action alternatives.

SWMU-179: Former Condensate Blowdown Cistern (Building 4-76)

Nature

Soil and groundwater samples were collected adjacent to this unit and analyzed for PAHs, PCBs, metals, and diesel- and motor-oil range TPH.

Of the soil samples analyzed, only chromium, copper and selenium were detected at concentrations slightly above their respective PCLs.

Groundwater results indicated that diesel-range TPH and arsenic in groundwater were detected in concentrations only slightly above their respective PCLs. As discussed in Sections 2 and 3 naturally elevated arsenic concentrations in the area are not indicative of a release from the Facility.

Extent

In the vicinity of SWMU-179, soil concentrations of chromium, copper and selenium exceeding the PCLs extend at least approximately 2 feet to the north, 5 feet to the west, and 9 feet to the southwest. Vertically, concentrations of these two metals above PCLs are likely limited to within 7 feet of the ground surface. However, soil samples were not collected from depths below 7 feet so the vertical extent of selenium in soil at GW157 is not fully defined, with respect to PCLs.

TPH was detected above the PCL in groundwater collected from the push-probe located approximately 2 feet north of the SWMU (PP009). However, TPH appears to be limited to the immediate vicinity of the unit based on the results from downgradient push-probe PP010. In this probe (located approximately 5 feet west of the SWMU), TPH was not detected.

Justification for Feasibility Study

SWMU-179 is recommended for Feasibility Study because hazardous substances are present in soil and groundwater above PCLs. Fate and transport modeling is necessary to evaluate whether the existing concentrations are likely protective at a conditional point of compliance.

Building 4-78/79 SWMU/AOC Group: SWMU-181, AOC-013, AOC-014, AOC-015, AOC-026, AOC-037, and AOC-054

Nature

The results of the biannual groundwater sampling at the Building 4/78-79 SWMU/AOC Group indicate that VOC and TPH-G concentrations are present in the groundwater. Five VOCs (1,1-dichloroethene, benzene, cis-1, 2-dichloroethene, TCE, and vinyl chloride) and TPH-G were detected above the PCLs during the previous three biannual groundwater monitoring events (June 1999 to June 2000). Concentrations of 1,1-dichloroethene, cis-1, 2-dichloroethene, and TCE decreased to non-detect values or significantly below the PCLs from the June 1999 sampling event to the biannual event conducted in June 2000. With the exception of GW038 and GW041, where benzene concentrations significantly decreased from June 1999 to December 1999, concentrations of benzene, vinyl chloride, and TPH-G remain above their respective PCLs.

Extent

Beyond the influence of the Building 4-78/79 groundwater extraction system, natural groundwater flow is generally toward the northwest. Groundwater samples from downgradient wells GW132 and GW143 did not contain concentrations above the PCLs and PQLs, respectively. These results indicate that the existing groundwater extraction system is prohibiting northwesterly migration of VOCs and TPH-G present in the groundwater at this SWMU/AOC Group. The plume is stabilized within the zone of capture of the existing groundwater extraction system.

Justification for Feasibility Study

The Building 4-78/79 SWMU/AOC Group is recommended for inclusion in the Feasibility Study because chlorinated solvents are present in soil and groundwater above PCLs. The Feasibility Study will evaluate continued operation of the existing extraction system as compared to other cleanup action alternatives.

Former Fuel Farm AOC Group, AOC-046, AOC-047, and AOC-048: Former USTs URE-033, URE-034, and URE-035

Nature

During the IA and Tier 3 sampling activities at the Former Fuel Farm, concentrations of benzene, 2-methylnaphthalene, and diesel- and Jet-A-range TPH were detected above the PCLs in selected soil samples.

In groundwater, TPH-Jet-A concentrations detected above the PCL of 0.5 mg/L ranged from an estimated 1.4 mg/L to an estimated 17.0 mg/L. TPH-D concentrations detected above the PCL of 0.5 mg/L ranged from 1.4 to 7.30 mg/L.

Extent

The constituents exceeding the PCLs in soil (diesel and Jet-A-range TPH, benzene, and 2-methylnaphthalene) were detected at locations within the boundaries of the former fuel farm area and to the north and northeast. All locations were within the boundaries of the existing air sparging and bioventing system, which encompasses an area of approximately 200 by 300 feet. Vertically, the constituents exceeding the PCLs exist within 12 feet of the ground surface (the approximate depth of the water table at the time of sampling).

The constituents above the PCLs in groundwater (diesel and Jet-A-range TPH) were detected at the same general locations where constituents exceeding the PCLs were detected in soil. In addition, diesel-range TPH was detected above the PCL in a push-probe (PP430) located approximately 40 feet downgradient of the *in situ* remediation system. No other probes were installed downgradient of PP430. These results indicate that groundwater contaminated with TPH above the PCLs is present within the boundaries of the remediation system and at locations downgradient. However, the downgradient extent of the TPH contamination is not defined.

Justification for Feasibility Study

Although the remediation system at the Former Fuel Farm AOC Group has made substantial progress, soil and groundwater concentrations above the PCLs are present at selected locations.

AOC-001, AOC-002, and AOC-003: Former USTs URE-01, URE-02, and URE-03 (Building 4-81)

Nature

The objective of the RI at AOC-001, AOC-002, and AOC-003 was to evaluate the presence of selected VOCs (MEK and toluene) that were reportedly stored in the former USTs. Non-target analytes TCE, PCE, and vinyl chloride were detected in the Tier 2 groundwater samples. The analytical results of the RI sampling indicated that TCE in both soil and groundwater and PCE and vinyl chloride in groundwater above the PCLs are present in AOC-001 through AOC-003.

Extent

At AOC-001 and AOC-002, soil containing TCE above the PCL is present 20 feet north of the former USTs at a depth of 2 feet. The vertical and horizontal extent of TCE in soil is not fully defined.

At AOC-003, TCE above the PCL in soil extends at least approximately 30 feet north of the former UST. Vertically, TCE above the PCL was detected both near the ground surface (2 to 4 feet bgs) and in the deepest samples collected (9.5 to 11.5 feet bgs).

TCE in groundwater at a concentration above the PCL was detected in a push-probe located approximately 20 feet downgradient of AOC-001 and AOC-002. TCE in excess of the PCL was not detected in GW049 and PP066, both located approximately 100 feet downgradient of the former USTs.

This data indicates that the plume of TCE contamination in the vicinity of AOC-001 and AOC-002 is limited. Vinyl chloride was detected above the PCL in groundwater collected from downgradient locations PP066 and GW049. Vinyl chloride (at a concentration below the PCL) was detected in only one of the four groundwater samples collected near the former USTs (from PP011, PP012, PP013, and GW050). This data suggests that AOC-001 and AOC-002 are not the source of the vinyl chloride.

At AOC-003 TCE and vinyl chloride were detected at concentrations above the PCLs in groundwater sampled from PP016 located approximately 20 feet north (crossgradient) of the former UST. The downgradient extent of TCE and vinyl chloride is defined by PP015 located approximately 300 feet downgradient of AOC-003 and PP016. VOCs were not detected above PCLs in the groundwater sample from PP065.

Justification for Feasibility Study

AOC-001, AOC-002, and AOC-003 are recommended for Feasibility Study because hazardous substances are present in soil and groundwater above PCLs.

During the Feasibility Study, the influence of natural degradation processes to reduce the VOC concentrations detected above the PCLs. The applicability of a conditional point(s) of compliance for these AOCs will also be assessed. The effectiveness of natural degradation will be compared to other cleanup action alternatives.

AOC-004: Former UST URE-04 (Building 4-21)

Nature

Thirteen soil and four groundwater samples were collected at AOC-004 and analyzed for TPH-G, gasoline-related VOCs including BTEX, and lead.

The soil analytical results indicate acetone, benzene, ethylbenzene, toluene and TPH-G were detected at concentrations above the PCLs. Benzene and TPH-G were detected in groundwater.

Extent

Concentrations of hazardous substances in soil above the PCLs were limited to within approximately ten feet south of the former UST, and to depths less than 10 feet bgs.

Groundwater analytical results indicate that benzene concentrations above the PCL are likely limited to within 20 feet south of the former UST, and TPH-G concentrations above the PCL are limited to within 10 feet south of the former tank.

Justification for Feasibility Study

AOC-004 is recommended for inclusion in the Feasibility Study because hazardous substances are present in soil and groundwater above PCLs. The nature of constituents and their limited extent suggest this unit is a potential candidate for a model remedy.

AOC-060: Former Vapor Degreaser (Building 4-42)

Nature

Groundwater analyses for VOCs during the previous seven quarters (March 1999 to September 2000) indicate that vinyl chloride, cis-1,2-DCE and TCE concentrations have been detected above the PCLs. The maximum vinyl chloride concentration (660 µg/L) was detected in GW009 in June 2000. September 2000 sampling results indicated that the maximum vinyl chloride concentration may have decreased to 200 µg/L (GW009). The maximum concentration of cis-1,2-DCE (180 µg/L) was detected in GW012 in June and August, 1999. These two wells are located within approximately 20 feet of the former degreaser. Concentrations of cis-1,2-DCE detected during the September 2000 sampling event were below the PCL. TCE was detected in GW147 above the PCL.

Extent

With the exception of one minor detection of vinyl chloride (1.2 µg/L in GW011), VOCs have not been detected in the three deep wells (GW011, GW013 and GW015) located in the vicinity of the former degreaser, indicating that the VOC plume is confined to shallow wells. The September 2000 data indicates that the lateral extent of VOC (vinyl chloride) concentrations above the PCL is limited to within 170 feet of the former vapor degreaser.

Justification for Feasibility Study

AOC-060 is recommended for Feasibility Study because hazardous substances are present in groundwater above PCLs.

The Feasibility Study will evaluate the influence of natural degradation processes to reduce the VOC concentrations detected above the PCLs. The applicability of a conditional point(s) of compliance for these AOCs will also be assessed. The effectiveness of natural degradation will be compared to other cleanup action alternatives.

AOC-090: Unknown Release (Building 4-65 Yard)

Nature

The results of the investigations conducted at AOC-090 indicate that selected VOCs, SVOCs, metals and TPH were detected in soil at concentrations above the PCLs. The highest concentrations of SVOCs and metals were detected in soil samples collected from PP045, PP047, and from PP048. The highest TPH concentration was detected in PP047.

Groundwater analytical results indicated that selected VOCs (1,1-dichloroethene, acetone, benzene, carbon tetrachloride, chloroform, cis-1,2-dichloroethene, methylene chloride, PCE, TCE and vinyl chloride) and TPH were the constituents detected at concentrations above the PCLs. The highest concentrations of these constituents were detected in GW168 and PP045.

Extent

At AOC-090, concentrations of VOCs in soil exceeding the PCLs were detected in an area consisting of an approximately 120 feet long section of parking lot between Building 4-64 and N. 6th Street. The width of the impacted parking area is approximately 50 feet. Explorations were not conducted to the north of this area beneath Building 4-64 and to the south beneath N. 6th Street. Based on the exploration results in the parking lot, it is possible that VOCs-impacted soil extends north and/or south beneath these areas. Data suggests the vertical extent of VOCs in soil above the PCL is limited to within 20 feet of the ground surface.

TPH, SVOCs, and metals contamination in soil above the PCLs was detected in an approximately 30-foot by 50-foot area located within the VOCs-impacted area described above. Based on the results from samples collected from the southern edge of this area, TPH, SVOCs, and metals contamination may extend southward beneath N. 6th Street. Vertically, concentrations of these constituents above the PCLs appears to be limited to within 15 feet of the ground surface.

Concentrations of VOCs in groundwater exceeding the PCLs were detected in samples generally collected from within the area of VOC-impacted soil. Locations where VOCs concentrations exceeded the PCLs include push-probes and wells located at the downgradient boundary of the impacted area. No wells or probes were installed further downgradient of these locations, so no data exists that would aid in further defining the downgradient extent of the contaminant plume.

TPH concentrations in groundwater exceeding the PCLs were detected in samples collected from within the area of TPH-impacted soils, but were not detected at the downgradient sampling points. From this data, it appears that TPH in groundwater is limited to the area of impacted soil.

Justification for Feasibility Study

AOC-090 is recommended for Feasibility Study because of the range of hazardous substances in soil and groundwater are present above PCLs. The complications presented by existing infrastructure dictate a range of alternatives be analyzed to meet MTCA requirements for remedy selection.

6.1.2 SWMUs/AOCs Not Recommended for Feasibility Study

If concentrations of hazardous substances do not exceed the preliminary cleanup level at the standard point of compliance, no further action is considered necessary at the SWMU or AOC [WAC 173-340-350(8)(a)]. Table 6-2 contains a list of SWMUs/AOCs not recommended for feasibility study.

SWMU-001 and SWMU-002: Former Sumps SRE-2228 and SRE-2229 (Building 4-21)

The objective of the RI at SWMU-001 and SWMU-002 was to determine if the previously remediated release to soil from these units had impacted groundwater. The groundwater samples from these SWMUs were analyzed for priority pollutant metals. Although arsenic concentrations were above the PCL, concentrations were within the range of concentrations found in the Puget Sound region, and therefore are not indicative of a release from the Facility.

SWMU-001 and SWMU-002 are not recommended for feasibility study.

AOC-005 through AOC-011: Former USTs URE-09 through URE-15 (Building 4-44)

Soil and groundwater samples from AOC-005 through AOC-011 were analyzed for PAHs and diesel- and motor-oil TPH. None of the soil or groundwater samples contained PAHs or petroleum hydrocarbons at concentrations greater than the PCLs.

AOC-005 through AOC-011 are not recommended for feasibility study.

AOC-012: Former UST URE-16 (Building 4-45)

The soil and groundwater samples at AOC-012 were analyzed for selected VOCs including MEK. The concentrations of all constituents detected in the soil samples were below their respective PCLs and no constituents were detected in groundwater.

AOC-012 is not recommended for feasibility study.

AOC-034 and AOC-035: Former USTs URE-07 and URE-08 (Building 4-41)

None of the soil and groundwater samples collected at AOC-034 and AOC-035 contained VOCs at concentrations above the PCLs.

AOC-034 and AOC-035 are not recommended for feasibility study.

AOC-042: Former UST URE-45 (Building 10-81)

Soil and groundwater samples were analyzed for PAHs and total petroleum hydrocarbons as diesel and motor oil. Concentrations above the PCLs were not detected in soil or groundwater.

AOC-042 is not recommended for feasibility study.

AOC-049: URE-30 (Building 5-50)

The results of quarterly groundwater monitoring conducted since March 1999 at AOC-049 indicate that TPH-D and select VOC concentrations in samples from GW082 were the only constituent concentrations detected above the PCLs. However, because this well is located upgradient of the former UST URE-30, the detected concentrations are likely related to conditions at SWMU-172 and SWMU-174. Chromatograms from GW082 have not matched diesel and may be the result of weathered solvents in the diesel range (e.g., stoddard solvents). Further, a marked decrease in TPH-D concentrations has occurred in the well since the September 1999 sampling event. The decrease may be the result of degradation and/or a silica gel cleanup method used since December 1999 to remove naturally occurring organic matter from samples in the lab. Previous laboratory analyses may have had higher TPH concentrations due to presence of natural organic matter.

AOC-049 is not recommended for feasibility study. VOCs detected above the PCLs in GW082 will be further evaluated in the FS as part of SWMU–172 and SWMU-174.

AOC-050, AOC-051, and AOC-052: Former USTs URE-38, -39, and -40 (Building 10-52)

The objective of the Remedial Investigation at AOC-050, AOC-051 and AOC-052 was to evaluate potential impacts to groundwater from residual TPH concentrations in soil. Petroleum hydrocarbon concentrations were not detected above the PCLs in any of the groundwater samples collected during the Tier 2 Assessment or subsequent quarterly monitoring for a period of 2 years.

AOC-050, AOC-051 and AOC-052 are not recommended for feasibility study.

AOC-074: Apron D, in the Area of the Former City of Renton Sanitary Sewage Treatment Plant

The objective of the Remedial Investigation at AOC-074 was to evaluate metals concentrations in groundwater upgradient and downgradient of Apron D to determine if evidence of a release is present. Seven rounds of groundwater sampling have been conducted since September 1997, and with the exception of total and dissolved arsenic and total cadmium, all detected metals concentrations have been below the PCLs. Although arsenic concentrations were above the PCL, concentrations were within the range of concentrations found in the Puget Sound region, and therefore are not indicative of a release from the Facility. Total cadmium concentrations were also above the PCL. However, dissolved cadmium was not detected in any of these monitoring wells. This indicates that these total cadmium concentrations are likely the result of naturally occurring cadmium being detected in turbid groundwater samples. To further evaluate these total cadmium results, a two-sample t-test was performed using the total cadmium results to determine if there was a statistical significance. This statistical test showed that the upgradient and downgradient monitoring well results are not significantly different at the 95 percent confidence level. Therefore, based on the dissolved cadmium concentrations being non-detect and the t-test not showing a statistical significance, there has not been a release at or from the Facility.

AOC-074 is not recommended for feasibility study.

AOC-091: Column G-6 Elevator (Building 4-20)

The results of the soil analyses at AOC-091 indicate that no PCB concentrations were detected above the quantitation limits, and TPH-D and motor oil concentrations were below the PCLs. No constituent concentrations were detected in groundwater samples collected from outside the vault (PP069 through PP072).

PCBs and TPH were not detected in any of the downgradient soil and groundwater samples. The groundwater results collected from inside the elevator vault do not accurately reflect the underlying groundwater quality. Due to the presence of accumulated groundwater in the vault and the observed hydraulic oil staining of the concrete surface, of the vault concentrations of constituents detected were the likely influence at the time of the sampling.

AOC-091 is not recommended for feasibility study.

6.1.3 Hazardous Substance Categories at SWMUs/AOCs Recommended for Feasibility Study

The type of hazardous substances detected at the SWMUs and AOCs recommended for Feasibility Study (Table 6-1) will be a primary factor when evaluating cleanup action alternatives during the FS. Hazardous substance categories detected at these SWMUs and AOCs include one or more of the following: chlorinated and aromatic VOCs, SVOCs, metals and petroleum hydrocarbons. Table 6-3 summarizes the hazardous substance categories detected above the PCLs at SWMUs and AOCs recommended for feasibility study.

6.2 FEASIBILITY STUDY WORK PLAN CONSIDERATIONS

6.2.1 Model Remedies

MTCA presumes that model remedies may be selected “to streamline and accelerate the selection of cleanup actions that protect human health and the environment” [WAC 173-340-390(1)]. Circumstances at the Facility related to common types of contamination and media should be considered for model remedies (e.g., diesel fuel in soil) in the FS Work Plan. Should Ecology determine that the circumstances at the Facility warrant a model remedy, the components of the model remedy could be selected as the cleanup action or component of the action, without a Feasibility Study or a disproportionate cost analysis [WAC 173-340-390(3)].

6.2.2 Fate and Transport Processes

The FS Work Plan will consider fate and transport processes to examine the cleanup levels for magnitude of risk posed to human and ecological receptors via exposure pathway migration. The primary fate and transport processes that influence hazardous substance concentrations and migration include:

- Dissolution and partitioning to groundwater.
- Adsorption to soil.
- Volatilization.
- Degradation.

Organic constituents can undergo all of the processes listed above while inorganics are susceptible only to adsorption and leaching. Physical and chemical properties that influence the processes listed above are functions of the compound’s molecular weight and chemical structure and include solubility, organic carbon-water partition coefficient (K_{oc}), and air-water (Henry’s Gas Law) partition coefficient (H). In general, adsorption increases with increasing molecular weight while solubility, degradation rates, and volatility decrease.

6.2.3 Points of Compliance

During the FS, the applicability of conditional POCs will be evaluated. A conditional POC for groundwater could include the Facility boundary and/or as close as technically possible to the point where groundwater flows into surface water [WAC 173-340-720(8)(d)]. The FS will include fate and transport modeling to predict the concentration of hazardous substances at the conditional POC. This modeling will consider natural processes that attenuate concentrations based on site-specific mitigating factors. Mitigating factors include partitioning, dispersion, adsorption, and degradation. SWMU/AOC-specific cleanup standards will be determined through completion of this effort.

SECTION 7

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