Remedial Investigation Report for the Harbor Oil Site

Prepared for the Voluntary Group
for the Harbor Oil Site RI/FS
FINAL

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AND
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Acronyms

ACDP	Air Contaminant Discharge Permit
AMSL	above mean sea level
AOC	Administrative Settlement Agreement and Order on Consent for Remedial Investigation/Feasibility Study
AST	aboveground storage tank
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	ambient water quality criteria
BAF	bioaccumulation factor
bgs	below ground surface
BHC	benzene hexachloride
BOD	biochemical oxygen demand
Bridgewater	Bridgewater Group, Inc.
BSAF	biota-sediment accumulation factor
C	Celsius
CEC	Coles Environmental Consulting
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Chempro	Chempro of Oregon
COC	contaminant of concern
COD	chemical oxygen demand
COI	contaminant of interest
COPC	contaminant of potential concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CSM	conceptual site model
CSP	concrete sewer pipe
CU1	Confining Unit 1
CU2	Confining Unit 2
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DEQ	Oregon Department of Environmental Quality
dh/dl	hydraulic gradient
DO	dissolved oxygen
DQO	data quality objective
dw	dry weight
Eco-SSL	ecological soil screening level
EMRI	Energy & Materials Recovery, Inc.
EPA	US Environmental Protection Agency
EPC	exposure point concentration

ERA	ecological risk assessment
F	Fahrenheit
f_{oc}	fraction of organic carbon
FOIA	Freedom of Information Act
GC	gas chromatography
gpm	gallons per minute
GPS	global positioning system
HHRA	human health risk assessment
HI	hazard index
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
HQ	hazard quotient
ID	identification
IDW	investigation-derived waste
J qualifier	estimated concentration
K	horizontal hydraulic conductivity
K_d	soil-water partition coefficient
K_{oc}	organic carbon-normalized partition coefficient
K_{ow}	octanol-water partition coefficient
LOAEL	lowest-observed-adverse-effects level
LNAPL	light non-aqueous phase liquid
LPAH	low-molecular-weight polycyclic aromatic hydrocarbon
MAO	Mutual Agreement and Order
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
msl	mean sea level
NAPL	non-aqueous phase liquid
NOAEL	no-observed-adverse-effect level
NPDES	National Pollutant Discharge Elimination System
NRMP	Natural Resources Management Plan
NTU	nephelometric turbidity unit
OAR	Oregon Administrative Rule
ORNL	Oak Ridge National Laboratory
PA	preliminary assessment
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	perchloroethylene
PEN 1	Peninsula Drainage District No. 1
PM	particulate matter
ppt	parts per thousand
PVC	polyvinyl chloride
Q qualifier	estimated concentration
QAPP	quality assurance project plan

QA/QC	quality assurance/quality control
R	retardation factor
RAO	remedial action objective
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RfD	reference dose
RFO	refined fuel oil
RI/FS	remedial investigation/feasibility study
RL	Reporting limit
RME	reasonable maximum exposure
ROC	receptor of concern
RSL	regional screening level
RZA	Rittenhouse-Zeman and Associates
SF	slope factor
SGA	Sand and Gravel Aquifer
SI	site investigation
SOW	statement of work
SPCC	spill prevention, control, and countermeasure
SVOC	semivolatile organic compound
TAL	target analyte list
TCA	trichloroethane
TCE	trichloroethylene
TEC	threshold effects concentration
TEL	threshold effects levels
TEQ	toxic equivalent
TGA	Troutdale Gravel Aquifer
TLC	thin-layer chromatography
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TPH-Dx	total petroleum hydrocarbons – diesel and oil extractable
TPH-G	total petroleum hydrocarbons – gasoline
TPH-HCID	total petroleum hydrocarbons – hydrocarbon identification
TRV	toxicity reference value
TSA	Troutdale Sandstone Aquifer
TSS	total suspended solid
U qualifier	not detected at given concentration
UCL	upper confidence limit on the mean
v	horizontal pore velocity of groundwater
VOC	volatile organic compound
Windward	Windward Environmental LLC
ww	wet weight

EXECUTIVE SUMMARY

On May 31, 2007, the Voluntary Group for the Harbor Oil Remedial Investigation/Feasibility Study (RI/FS) entered into an Administrative Settlement Agreement and Order on Consent for the RI/FS (AOC) with the US Environmental Protection Agency (EPA) for the Harbor Oil Superfund Site (Site) in Portland, Oregon. The AOC statement of work requires that the Voluntary Group perform an RI. The objective of the RI is to gather sufficient information to support informed risk management decisions regarding the remedy for the Site. In particular, sufficient information must be collected for the characterization of the nature and extent of contamination, determination of potential migration pathways, verification of the preliminary CSMs, and evaluation of risks to human health and ecological receptors.

This RI includes sections on site description and history, Study Area investigations, physical characteristics of the Study Area, the nature and extent of contamination, the conceptual site model (CSM), the baseline risk assessments, and the summary and conclusions of the RI. Each of these sections is briefly summarized below.

ES.1 Site Description and History

The Site encompasses the Harbor Oil facility (Facility), the adjacent wetlands to the south and west of the Facility, and Force Lake. The term Study Area refers to the areas sampled as part of the RI, which includes the areas that make up the Site, as well as a portion of North Lake. The following provide a brief overview of the Study Area, which is shown in Figure ES-1:

- The Facility is an approximately 4.1-ac parcel of land located in an industrial area of north Portland. The Study Area is approximately 19 acres. Until recently, most of the Facility was unpaved and covered with gravel. However, during the fall of 2011, the majority of the Facility (all areas except for the western-most portion) was paved with asphalt.
- Harbor Oil, Inc., ceased doing business on the property in 1999. Energy & Materials Recovery, Inc. (EMRI), currently operates the Facility for the treatment and processing of used oil, fuels, and oily water.
- Stormwater from the Facility is collected and treated onsite near the southwest Facility boundary. Treated stormwater is discharged to the wetlands under a National Pollutant Discharge Elimination System (NPDES) Industrial Stormwater Discharge Permit. A soil berm, which extends along the southwest and northwest Facility boundaries, is intended to prevent Facility stormwater runoff from flowing into the adjacent wetlands.

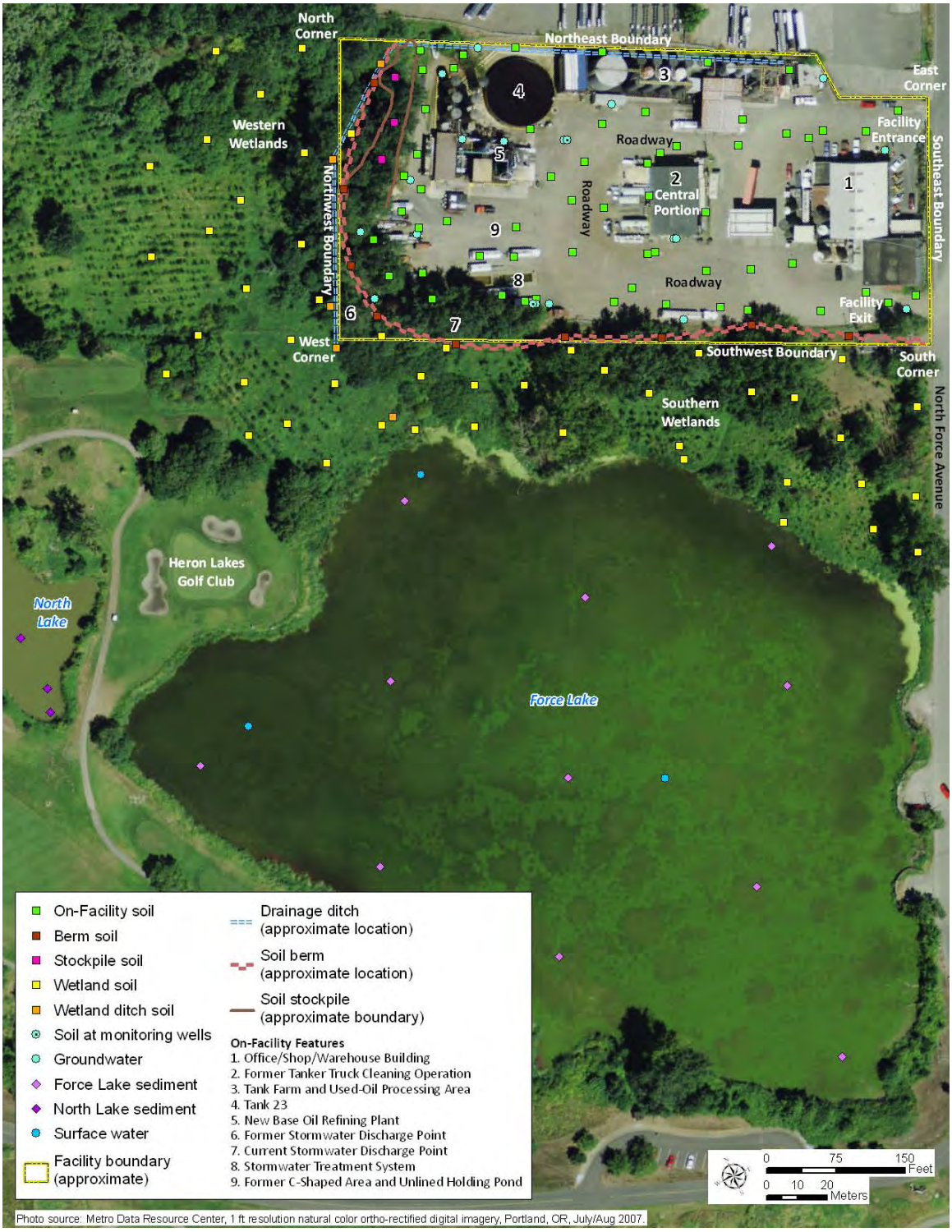


Figure ES-1. Facility Features, Area Descriptions, and RI Sampling Locations

Key points regarding the Facility history that are potentially most relevant to the distribution of chemicals at the Study Area are listed below:

- **Cattle truck and tanker truck cleaning operations**: Truck cleaning operations began in the 1950s and continued until 1994.
- **Road oiling for dust suppression:** There is evidence to suggest that the Facility road was oiled in the early 1970s and mid-1980s.
- **Oil treatment and processing activities:** Oil recycling activities began at the Facility in 1961 by Empire Industries. EMRI currently treats and processes used oil, oily water, and other water at the Facility.
- **1979 Facility fire:** A fire destroyed the Facility in 1979 and reportedly resulted in releases to the adjacent wetlands and Force Lake. After the fire, a soil berm was constructed to prevent direct stormwater flow or other releases into the wetlands, and the Facility was expanded and reconstructed.
- **Stormwater drainage patterns:** During early operations at the Facility, stormwater and industrial wastewater likely drained to sumps and holding ponds located along the southwest Facility boundary (which may have extended into what is now considered the wetlands) and in the western portion of the Facility with overflows into the adjacent wetlands. In the 1970s, a drainage ditch that discharged Facility stormwater to the wetlands was constructed along the northeast Facility boundary. The ditch remained open until 2002 when it was filled. The current stormwater treatment system collects all Facility stormwater and discharges under an NPDES permit to the wetlands southwest of the Facility.

Multiple field investigations have been conducted at the Facility, adjacent wetland areas, and Force Lake since 1988. The data from one sampling event (Ecology and Environment 2001) were considered acceptable for use in the RI. Data from seven other historical sampling events did not meet data quality objectives (DQOs) and were unsuitable for use.

ES.2 Study Area Investigation

All investigation activities were completed in accordance with the EPA-approved *Remedial Investigation/Feasibility Study Work Plan for the Harbor Oil Site* (Bridgewater et al. 2008b), hereafter referred to as the RI/FS Work Plan.

The RI site characterization was conducted in two phases. Phase 1 sampling was conducted in April-May 2008, and Phase 2 was completed in March-April 2009. These sampling events included the following activities:

- Collection of surface or subsurface soil samples at 61 locations at the Facility (including 9 soil berm and 3 soil stockpile locations)

- Collection of wetland and ditch soil samples at 52 surface and 10 subsurface locations
- Collection of surface sediment samples at 11 locations in Force Lake, subsurface sediment samples at 3 locations in Force Lake, and surface sediment samples at 3 locations in North Lake
- Collection of surface water samples at 3 locations in Force Lake
- Installation of 8 new monitoring wells followed by the collection of groundwater samples from the 8 new wells, 7 existing monitoring wells, and the plant well
- Aquifer slug testing at 9 monitoring well locations
- Collection of monthly groundwater and lake elevations between May 2008 and April 2009
- Completion of a fish population survey in Force Lake in April 2009 to obtain information on the types of fish present in the lake and estimate the abundance and sizes of these fish

ES.3 Physical Characteristics of the Study Area

The physical characteristics of the Study Area include:

- **Surface features:** The Facility is relatively flat with a slight slope from northeast to southwest, toward the wetlands and Force Lake.
- **Meteorology:** The Study Area is in a temperate marine climate characterized by wet winters and dry summers. The average annual amount of precipitation (primarily as rain) is 37 in.; the average annual temperature is 54 °F.
- **Surface water hydrology:** The Study Area is located within the Columbia River floodplain, an area with numerous wetlands and small lakes. Force Lake is approximately 12 ac in size and has an average depth of 2.5 ft. Inflows and outflows from the Force Lake are limited, and thus Force Lake acts as a settling basin.
- **Geology:** One non-native (i.e., fill) layer and several native lithologic layers are present beneath the Study Area.
- **Hydrogeology:** Three distinct groundwater zones, separated by saturated silt deposits, are located beneath the Facility: a shallow saturated zone, an intermediate saturated zone, and a deep saturated zone. Depth to uppermost groundwater beneath the Facility (shallow saturated zone) ranges from less than 1 ft to approximately 6 ft below ground surface (bgs), depending on location and the time of year. Groundwater flow is to the southwest for the shallow zone, to the west or southwest for the intermediate zone, and alternates between northwest and southwest for the deep zone. Shallow groundwater flows towards and discharges to Force Lake.

- **Demography and land use:** The current and likely future land use of the Facility is industrial, particularly given its designation as an Industrial Sanctuary by the City of Portland. The current and likely future land use designation of the wetlands and Force Lake is open space, indicating that these areas will continue to be used for recreation and as habitat for ecological receptors.
- **Ecology:** The Study Area is located within the Peninsula Drainage District No. 1 Natural Resources Management Plan (NRMP) area and provides habitat for numerous birds and several species of mammals.

ES.4 Nature and Extent of Contamination

Chemicals and chemical groups known to be of interest at the Study Area based on the results of the risk assessments or because of past or present industrial activities at the Facility are discussed in detail in the RI. These chemicals or chemical groups included total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAHs), petroleum-associated volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs), metals, dichlorodiphenyltrichloroethanes (DDTs), and chlorinated solvents. A summary of the data for these chemicals is presented in Table ES-1 for surface soil and sediment and in Table ES-2 for groundwater and surface water.

Table ES-1. Summary of Concentrations for Select Chemicals in Surface Soil and Sediment Samples

Chemical	Unit	Concentration or TEQ Range (Mean Concentration or TEQ)[a]			Area(s) with the Highest Detected Concentrations
		Facility Soil[b]	Wetland Soil[b]	Force Lake Sediment[b]	
TPH, PAH, and Petroleum-Associated VOCs					
TPH – gasoline range	mg/kg dw	5.6 U – 3,800 (260) DF = 62%	9.4 U – 58 U (nc) DF = 4%	7.7 U – 80 U (nc) DF = 9%	central portion of the Facility near the former tanker truck cleaning operation
TPH – diesel range	mg/kg dw	8.0 – 13,000 (1,700) DF = 100%	7.4 U – 4,000 (400) DF = 90%	16 – 270 (98) DF = 100%	central portion of the Facility near the former tanker truck cleaning operation and along the nearby southwest boundary of the Facility
TPH – motor oil range	mg/kg dw	38 – 12,000 (2,200) DF = 100%	15 U – 6,600 (1,200) DF = 94%	130 – 2,000 (760) DF = 100%	
Total TPH	mg/kg dw	46 – 25,000 (4,100) DF = 100%	15 U – 9,300 (1,500) DF = 94%	150 – 2,300 (840) DF = 100%	
cPAH TEQ	µg/kg dw	14.0 – 4,900 (565) DF = 93%	38.0 – 5,200 (438) DF = 96%	11.6 – 118 (61.9) DF = 100%	central portion of the Facility near the former tanker truck cleaning operation and tank farm, and in one sample collected from the soil berm in the west corner of the Facility
Total PAHs	µg/kg dw	36 J – 360,000 (13,000) DF = 98%	200 J – 28,190 J (3,000) DF = 98%	104 – 1,060 (560) DF = 100%	
Benzene	µg/kg dw	1.0 U – 6,400 (140) DF = 38%	1.6 U – 56 (6) DF = 51%	1.1 U – 8.2 U (nc) DF = 0%	central portion of the Facility near the tank farm
PCBs					
Total PCBs	µg/kg dw	4.9 J – 32,000 (2,000) DF = 80%	32 U – 4,200 (400) DF = 62%	32 U – 131 (80) DF = 64%	east corner of the Facility near the Facility entrance, in the central portion of the Facility near the former tanker truck cleaning operation, and along the U-shaped roadway that extends from the Facility entrance around the former truck cleaning operation area
Metals					
Arsenic	mg/kg dw	0.7 – 20.6 J (3) DF = 100%	1.5 – 53.1 (9) DF = 100%	2.6 – 7 (6) DF = 100%	west corner of the Facility, the area of the former unlined holding pond/C-shaped area, and the former drainage ditch to the west of the Facility
Chromium	mg/kg dw	4.0 – 63 (20) DF = 100%	6.6 – 149 (30) DF = 100%	7.7 – 34 (30) DF = 100%	west corner of the Facility and the former drainage ditch to the west of the Facility

Table ES-1. Summary of Concentrations for Select Chemicals in Surface Soil and Sediment Samples (cont.)

Chemical	Unit	Concentration or TEQ Range (Mean Concentration or TEQ)[a]			Area(s) with the Highest Detected Concentrations
		Facility Soil[b]	Wetland Soil[b]	Force Lake Sediment[b]	
Copper	mg/kg dw	9.23 – 1,070 (100) DF = 100%	10.3 – 162 (60) DF = 100%	16.2 – 72 (53) DF = 100%	west corner of the Facility and the area of the former unlined holding pond/C-shaped area
Mercury	mg/kg dw	0.03 – 6.69 (0.2) DF = 45%	0.06 – 0.4 (0.2) DF = 90%	0.06 U – 0.3 U (nc) DF = 9%	the area of the former unlined holding pond/C-shaped area
Zinc	mg/kg dw	35 – 718 J (200) DF = 100%	37 – 748 (230) DF = 100%	80 – 229 (200) DF = 100%	west corner of the Facility, the area of the former unlined holding pond/C-shaped area, the former drainage ditch to the west of the Facility, and the area near the current and former stormwater treatment system discharge points near the southwest corner of the Facility
DDTs					
Total DDTs	µg/kg dw	0.6 U – 78,000 J (8,000) DF = 95%	2.7 J – 46,000 (3,000) DF = 98%	22 J – 250 (160) DF = 100%	central portion of the Facility near the former truck cleaning operation, in the C-shaped area to the west of the former truck cleaning operation, and along the southwest boundary of the Facility
Chlorinated Solvents					
TCE	µg/kg dw	1.0 U – 2,400 (66) DF = 11%	1.5 U – 15 U (nc) DF = 5%	1.1 U – 8.2 U (nc) DF = 0%	central portion of the Facility near the former truck cleaning operations

[a] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values. Means were not calculated if the detection frequency was less than 10% or if fewer than three samples had detected concentrations.

[b] Facility surface soil samples were collected immediately below the gravel layer from depths of 0 to 5 ft bgs (0.5- to 1.5-ft sampling intervals for a given sample). Wetland surface soil samples were collected from 0 to 0.5 ft bgs. Lake surface sediment samples were collected from 0 to 4 in. below the mudline.

bgs – below ground surface
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
DF – detection frequency
dw – dry weight
J – estimated concentration
nc – not calculated
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RL – reporting limit
TCE – trichloroethene
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons
U – not detected at given concentration (concentration shown is the RL)
VOC – volatile organic compound

Table ES-2. Summary of Concentrations for Select Chemicals in Groundwater and Lake Surface Water Samples

Chemical	Unit	Water Concentration or TEQ Range (Mean Concentration or TEQ)[a]			Area(s) with the Highest Detected Concentrations
		Groundwater (Shallow)	Groundwater (Intermediate and Deep)	Force Lake Surface Water	
TPH, PAH, and Petroleum-Associated VOCs (unfiltered)					
TPH – gasoline range	mg/L	0.25 U – 0.81 (0.22) DF = 23%	0.25 U (nc) DF = 0%	not analyzed	near the tank farm and the former C-shaped area
TPH – diesel range	mg/L	0.25 U – 0.26 J (nc) DF = 0%	0.25 U (nc) DF = 0%	0.25 U (nc) DF = 0%	detected in only one groundwater sample (from well A-18 near the former C-shaped area)
TPH – motor oil range	mg/L	0.5 U (nc) DF = 0%	0.50 U (nc) DF = 0%	0.50 U (nc) DF = 0%	not detected
Total TPH	mg/L	0.27 – 1.07 J (0.33) DF = 23%	0.50 U (nc) DF = 0%	0.50 U (nc) DF = 0%	near the tank farm and the former C-shaped area)
cPAH TEQ	µg/L	0.0910 U – 1.50 U (nc) DF = 0%	0.0910 U – 1.40 U (nc) DF = 0%	0.0910 U (nc) DF = 0%	not detected
Total PAHs	µg/L	0.10 – 6.3 (1) DF = 43%	0.10 U – 3.8 U (nc) DF = 0%	0.10 U (nc) DF = 0%	near the Facility exit and in the area of the base oil refining plant
Benzene	µg/L	0.20 U – 140 (6) DF = 29%	1.0 U (nc) DF = 0%	1.0 U (nc) DF = 0%	near the tank farm
PCBs (filtered)					
Total PCBs	µg/L	0.10 U – 0.96 U (nc) DF = 0%	0.10 U – 0.92 U (nc) DF = 0%	0.10 U (nc) DF = 0%	not detected
Metals (filtered)					
Arsenic	mg/L	0.8 – 32.2 (10) DF = 100%	0.2 U – 6.3 (3.4) DF = 80%	0.9 – 1.0 (1) DF = 100%	near the tank farm
Chromium	mg/L	5 U (nc) DF = 0%	5 U (nc) DF = 0%	5 U (nc) DF = 0%	not detected
Copper	mg/L	2 U – 5 (nc) DF = 0%	2 U (nc) DF = 0%	2 U – 4 (nc) DF = 33%	low variability in concentrations

Table ES-2. Summary of Concentrations for Select Chemicals in Groundwater and Lake Surface Water Samples (cont.)

Chemical	Unit	Water Concentration or TEQ Range (Mean Concentration or TEQ)[a]			Area(s) with the Highest Detected Concentrations
		Groundwater (Shallow)	Groundwater (Intermediate and Deep)	Force Lake Surface Water	
Mercury	mg/L	0.1 U (nc) DF = 9%	0.1 U (nc) DF = 0%	0.1 U (nc) DF = 0%	not detected
Zinc	mg/L	10 U – 80 (nc) DF = 9%	10 U – 9,870 (nc) DF = 20%	10 U (nc) DF = 0%	plant well (PW-01), located in the east corner of the Facility
DDTs (unfiltered)					
Total DDTs	µg/L	0.0071 J – 0.24 J (0.030) DF = 43%	0.01 U – 0.048 (0.015) DF = 50%	0.010 U (nc) DF = 0%	detected in shallow groundwater samples in some of the areas where DDT concentrations in soil samples were highest (the exit driveway and along the southwest boundary of the Facility)
Chlorinated Solvents (unfiltered)					
TCE	µg/L	0.20 U – 1.0 U (nc) DF = 0%	1.0 U – 6.1 (nc) DF = 17%	1.0 U (nc) DF = 0%	detected only in the plant well (PW-01), located in the east corner of the Facility

[a] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values. Means were not calculated if the detection frequency was less than 10% or if fewer than three samples had detected concentrations.

[b] The depth of shallow groundwater wells ranged from 10 to 20 ft bgs, the depth of intermediate wells ranged from 48 to 50 ft bgs, and the depth of the deep well was 97 ft bgs. Lake surface water samples were collected from 1 ft below the water surface.

bgs – below ground surface
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
DF – detection frequency
J – estimated concentration
LNAPL – light non-aqueous phase liquid
nc – not calculated
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RL – reporting limit
TCE – trichloroethene
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons
U – not detected at given concentration (concentration shown is the RL)
VOC – volatile organic compound
ww – wet weight

Key findings of the nature and extent evaluation are summarized below:

- Chemical concentrations were generally highest at the Facility, with the exception of some metals for which the highest concentrations were in the wetlands near the west corner of the Facility. The locations with the highest concentrations (which were generally greater than screening levels) varied by chemical:
    - The highest cPAH TEQs were detected in the central portion of the Facility (near the tank farm and former truck cleaning operation) and in one sample from the soil berm in the west corner of the Facility.
    - TPH concentrations were highest near the former truck cleaning operation and along the southwest boundary of the Facility.
    - The highest total PCB concentrations were detected near the Facility entrance, in the central portion of the Facility, and along the Facility roadway.
    - The highest total DDT concentrations were detected in the central portion of the Facility, in the former C-shaped area where the unlined holding pond was located, and along the southwest boundary of the Facility and wetlands where historical ponds and sumps that received drainage from the truck wash were located.
    - The highest concentrations of arsenic (and other metals) were detected in the west corner of the Facility, near the C-shaped area where the unlined holding pond was located and in the former drainage ditch.
- In most cases, concentrations were highest in surface soil samples (both at the Facility and in the wetlands), except in areas where historical holding ponds or sumps were known to have been located. In these areas, concentrations were sometimes highest in intermediate soil samples but lower in deep soil samples, indicating that the extent of the highest concentrations was limited.
- Patterns of chemical concentrations in the wetlands are consistent with former drainage patterns at the Facility as well as the location of historical sumps and holding ponds along the southwest Facility boundary (which may have extended into what is now considered the wetlands).
- In general, detected concentrations of chemical were limited to shallow groundwater, with detected concentrations low relative to screening levels and of limited lateral extent. Detections of metals, dichlorodiphenyldichloroethane (DDD), six VOCs, and one semivolatile organic compound (SVOC) in intermediate or deep well samples were likely attributable to non-Facility-related sources because detections were located upgradient of Facility operations or, with regard to DDD, to a possible well seal breach

or drilling-induced drag-down of contaminated soil into the screen interval at the MW-2i/B-4 well cluster location.

- A thin layer (0.1 ft) of LNAPL was collected from well GA-30 in 2008; only trace thicknesses (0.01 to 0.02 ft) have been observed in this well during follow-up monitoring. Trace thicknesses of LNAPL (0.01 ft or less) have been observed in two of the precautionary (i.e., never used) extraction wells. Thus, the presence of LNAPL is localized and constrained to a small portion of the Facility. No LNAPL has been observed in wells located along the downgradient boundary of the Facility.
- Chemical concentrations in Force Lake sediment and surface water were generally low relative to concentrations in Facility or wetland soils and were mostly lower than screening levels or, for metals, background concentrations. The background concentrations of metals were as cited by the Oregon Department of Environmental Quality (DEQ) (2002, 2007a), which provides both soil and sediment regional background concentrations (see Section 2.8). No lateral concentration gradients were apparent in lake sediments (i.e., concentrations were not higher in the north end of the lake, which is nearer to the Facility). Concentrations in Force Lake surface sediment were higher than those in Force Lake subsurface sediment.
- With the exception of metals, chemical concentrations in North Lake sediment were typically lower than those in Force Lake sediment. In most cases, concentrations of metals in North Lake sediment were similar to those in Force Lake and to background concentrations. These results indicate that there is minimal transport of chemicals from Force Lake.

The comparison of chemical concentrations with conservative screening levels (and background concentrations for metals) indicated that higher chemical concentrations were generally bounded both vertically and laterally. Chemicals have been adequately delineated, and the available data met the DQOs identified in the RI/FS Work Plan (Bridgewater et al. 2008b).

ES.5 Conceptual Site Model

This section discusses the CSM for the Study Area as it relates to fate and transport processes that affect the distribution of chemicals at the Study Area. A summary of the key components of the CSM is provided below:

- Known or suspected sources of chemicals at the Facility and in the adjacent wetlands that appear to be associated with historical industrial operations at the Facility
- Known or suspected mechanisms for the release of chemicals to Facility soils, which include discharges from the former truck cleaning operations, spillage of petroleum products stored or

handled at the Facility, application of used oils at the Facility roadway for dust suppression, release of oils and other materials present at the Facility during the 1979 Facility fire, and the overflow or discharge of oily rinsate/stormwater from sumps or an unlined pond formerly located in the southwestern portion of the Facility

The primary migration pathway for chemicals appears to be historical direct discharge and transport via stormwater runoff. Chemicals were likely bound to soil particles that were transported in surface water runoff from the areas of spillage or discharge to low-lying areas historically located to the south and west. Over the course of operations, these low-lying areas included existing wetlands and Force Lake to the south of the Facility, as well as areas of the existing Facility that were lower in elevation at the time but were subsequently filled to match the existing grade. This fill history resulted in chemical impacts in deeper soils in certain areas relative to other portions of the Facility.

Facility physical and operational modifications such as the termination of truck cleaning operations, installation of a stormwater collection and treatment system, and the placement of a hard-packed gravel and pavement cover throughout the Facility have mitigated the primary migration pathway (direct discharge and stormwater runoff). Other potential pathways (future erosion of soils, groundwater migration, sediment transport, and volatilization to air) were not found to be pathways of likely significance.

Future land uses in the Study Area are not anticipated to change from those currently established, and thus the conceptual model for the Study Area in terms of migration and exposures is not expected to change.

ES.6 Baseline Risk Assessments

ES.6.1 Human Health Risk Assessment

The baseline HHRA presents human health risk estimates associated with potential exposures to chemicals in soil, lake sediment, lake water, groundwater, and fish caught in Force Lake. The exposure scenarios and assumptions assessed in the HHRA are consistent with a reasonable maximum level of exposure, and thus, although uncertain, risk estimates are intended to be health protective for individuals (EPA 1989).

The following scenarios were evaluated in the HHRA to assess risks to workers at the Facility:

- **Industrial (construction/trenching) worker reasonable maximum exposure (RME) scenario:** evaluated risks to current and future workers involved in construction or excavation work conducted outdoors at the Facility

- **Future outdoor worker RME scenario:** evaluated risks to future outdoor workers in the event that different operations or activities are conducted at the Facility and/or that the surficial gravel fill material and pavement that currently cover most of the Facility are removed
- **Industrial/commercial worker vapor intrusion scenario:** evaluated risks to current and future workers performing routine activities inside buildings at the Facility

The following scenarios were evaluated in the HHRA to assess risks to recreational users and fish consumers in the non-Facility portions of the Study Area:

- **Force Lake recreational user RME scenario:** evaluated risks to current and future recreational users during recreation-associated activities at Force Lake and in the surrounding wetlands, including bird watching, remote-control boating, or golf ball retrieval
- **Force Lake fish consumer RME scenario:** evaluated risks to current and future fish consumers based on the consumption of fish caught in Force Lake

Table ES-3 summarizes the total excess cancer risk and overall hazard index (HI) for each of the scenarios evaluated in the HHRA. When applicable, these risk estimates are the combined risks across the relevant exposure media. All excess cancer risk estimates were within EPA's target risk range of 10-6 to 10-4. The overall HIs (i.e., sum of non-cancer HQs for all contaminants of potential concern (COPCs) across all endpoints) were less than or equal to 1 for all scenarios except the Force Lake fish consumer RME scenario (Table ES-3). However, when endpoint-specific HIs (e.g., developmental or nervous system endpoints) were calculated for this scenario, no endpoint-specific HIs were greater than 1.

Table ES-3. Summary of Total Excess Cancer Risks and Non-Cancer HIs

Scenario	Total Excess Cancer Risk	Overall HI[a]
Industrial (construction/trenching) worker RME scenario (cumulative risk across media)	3×10^{-6}	1
Future outdoor worker RME scenario	2×10^{-5}	0.6
Industrial/commercial worker vapor intrusion scenario	9×10^{-7}	ne[b]
Force Lake recreational user RME scenario (cumulative risk across media)	1×10^{-5}	0.4[c]
Force Lake fish consumer RME scenario	2×10^{-5}	3 (endpoint-specific HIs were less than or equal to 1)[c, d]

[a] The overall HI is equal to the sum of HQs across multiple exposure pathways, endpoints, and/or target organs.

[b] Risks for this scenario were calculated based on a comparison of Study Area concentrations with vapor intrusion screening levels, which are based on the more stringent of the cancer or non-cancer risks (i.e., whichever one results in lower

screening levels). For this scenario, screening levels for all COPCs were based on cancer risks, and thus it was not possible to calculate non-cancer risks.

[c] The overall HI is based on children 0 to 6 years of age. This HI is higher than HIs for the integrated 0-to-30 year age group and for older age groups (i.e., 7 to 16 years and 17 to 30 years), and thus is typically used for risk management decisions.

[d] The overall HI for this scenario was equal to 3. Because this value was greater than 1, endpoint-specific HIs were calculated per EPA guidance (1989). No endpoint-specific HIs were greater than 1 (see Section 5.3.5 of the HHRA [Appendix I] for details).

COPC – contaminant of potential concern
HI – hazard index
HQ – hazard quotient
ne – not evaluated
RME – reasonable maximum exposure

In addition to the scenarios shown in Table ES-3, a screening-level assessment was conducted to estimate risks based on the exposure of hypothetical future residents to contamination in the Study Area. Based on a comparison of concentrations with regional screening levels (RSLs) (EPA 2009c), total excess cancer risks would likely be greater than the upper end of EPA's target risk range (10^{-4}), and HQs for some chemicals would likely be greater than 1, indicating that risks would have to be further assessed in the future if the area were to be developed for residential use. Because the City of Portland has designated the Facility as an Industrial Sanctuary, and the non-Facility portions of the Study Area are zoned as open space within an NRMP area, future residential development in the Study Area is unlikely.

Based on the results of the HHRA, arsenic, carcinogenic PAH (cPAH) toxic equivalent (TEQ), total PCBs, total DDTs, and TPH-gasoline (aliphatic) were identified as contaminants of concern (COCs) (i.e., COPCs with risk estimates greater than 10^{-6}). No COPCs had HQs greater than 1. These COPCs contributed the majority of risk to the total risk for each exposure scenario. Together, these five COCs contributed 95% or more to the total excess cancer risk (other COPCs made up less than 5% of the total risk). For those scenarios with the highest risks (i.e., those greater than 1×10^{-5}), the percent contribution by COPC was as follows:

- **Future outdoor worker RME scenario based on exposure to Facility soil:** The total excess cancer risk of 2×10^{-5} was made up of 30% arsenic, 17% cPAH TEQ, 26% total PCBs, 9% total DDTs, 13% TPH-gasoline (aliphatic), and 5% other COPCs.
- **Force Lake fish consumer RME scenario:** The total excess cancer risk of 2×10^{-5} was made up of 37% arsenic, 53% total PCBs, and 11% total DDTs.

To further evaluate risks for COCs in the HHRA, risk estimates were calculated based on regional background or reference area concentrations. Although background concentrations have been recommended for metals by DEQ, similar recommendations are unavailable for organic compounds (DDTs, cPAH TEQ, and PCBs). For these organic compounds, concentrations from reference areas (urban areas within the vicinity of the Study Area) were used for comparison with Study Area concentrations. Background risk estimates for arsenic were

similar to those based on Study Area concentrations for most exposure scenarios, indicating that background concentrations of arsenic are an important consideration. With one exception, risk estimates based on reference area concentrations were lower than Study Area risk estimates for cPAH TEQ, total PCBs, and total DDTs for all scenarios. The exception was for the Force Lake recreational user based on exposure to wetland soil: cPAH TEQs from reference areas were slightly higher than or similar to those at the Study Area. No background or reference area concentrations were available for TPHs.

ES.6.2 Ecological Risk Assessment

The baseline ERA presents risk estimates for benthic invertebrates, terrestrial invertebrates, fish, and wildlife species that may be exposed directly to chemicals in wetland soil, Force Lake surface sediment, Force Lake surface water, and to aquatic or terrestrial biota through their diet. Conservative assumptions, such as the use of the lowest toxicity values and the use of upper confidence limit on the mean (UCL) concentrations for estimating exposure, were used in an attempt to ensure that risk estimates, although uncertain, were protective of ecological receptors.

The following receptors of concern (ROCs) representing various feeding guilds were selected:

- **Invertebrates:** aquatic benthic invertebrate community and wetland invertebrate community
- **Fish:** brown bullhead (omnivorous fish) and pumpkinseed (invertivorous fish)
- **Birds:** ruddy duck (invertivorous bird), great blue heron (piscivorous bird), and red-tailed hawk (higher-trophic-level carnivorous bird)
- **Mammals:** shrew (invertivorous mammal) and Eastern cottontail (herbivorous mammal)

Table ES-4 provides a summary of HQs for all receptor of concern (ROC)-COPC pairs with effects-based HQs greater than 1.0. Table ES-4 also presents HQs based on background (for metals) or reference area (for organic compounds) concentrations[1] for comparison with those based on Study Area concentrations.

[1] See notes on background concentrations in Section ES.6-1. The term reference area is used instead of background for organic compounds because no specific background concentrations that are representative of anthropogenic background have been selected or approved by EPA.

Table ES-4. COPCs and ROCs with LOAEL-Based HQs Greater than 1.0

COPC	Matrix	NOAEL-Based HQ	LOAEL-Based HQ	Background or Reference Area LOAEL-Based HQ[a]
Aquatic Benthic Invertebrate Community				
DDD	surface sediment	**2.4 – 17**[b]	1.0 **– 7.2**[c]	0.072 – 0.79[c]
DDE	surface sediment	**6.4 – 110**[b]	**1.3 – 22**[c]	1.0 – **1.5**[c]
Terrestrial Invertebrate Community				
Chromium	wetland soil	**3.3 – 75**[d]		**21**[d]
Copper	wetland soil	0.21 – **25**[d]		0.72[d]
Zinc	wetland soil	0.31 – **6.2**[d]		0.72[d]
Total HPAHs	wetland soil	0.0056 **– 3.2**[d]		0.003 – 0.022[d]
Fish – Pumpkinseed				
Copper	diet	**3.5**	**1.8**	0.30
Fish – Brown Bullhead				
Copper	diet	**2.1**	**1.1**	0.18
Birds – Red-Tailed Hawk				
Total DDTs	diet	**5.8**	**1.2**	0.020 – 0.47
Mammals – Eastern Cottontail				
Mercury	diet	**5.9**	**1.2**	0.54
Mammals – Shrew				
Mercury	diet	**65**	**13**	**5.7 – 15**
Total DDTs	diet	**9.2**	**8.5**	0.053 – 0.41

[a] Background and reference area concentrations and sources are discussed in Section 2.8 and in Attachment 4 of the ERA (Appendix J). Concentrations for metals are representative of background concentrations, and concentrations for organic compounds are representative of reference area concentrations.

[b] HQs were developed based on a comparison with a TEL or a TEC.

[c] HQs were developed based on a comparison with a PEL or a PEC; total DDT concentrations were less than the total DDT PEL/PEC.

[e] HQs were developed based on a comparison with soil screening levels.

COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effect level
NOAEL – no-observed-adverse-effect level
PEC – probable effects concentration
PEL – probable effects level
ROC – receptor of concern
TEC – threshold effects concentration
TEL – threshold effects level
TRV – toxicity reference value

Bold identifies HQs greater than 1.0.

Lowest-observed-adverse-effects level (LOAEL)-based HQs were greater than 1.0 for chromium, copper, zinc, mercury, DDTs, and total HPAHs for at least one receptor (Table ES-4). LOAEL-based HQs were greater than 5 for DDE (aquatic invertebrates), DDD (aquatic invertebrates), chromium (terrestrial invertebrates), copper (terrestrial invertebrates), total DDTs (shrew), and zinc (terrestrial invertebrates). LOAEL-based HQs were also

greater than 5 for mercury (shrew), but mercury concentrations were within the range of DEQ background concentrations.

Key uncertainties in these risk estimates include: the terrestrial invertebrate screening levels; the observation of earthworms in areas with higher concentrations of metals (which may indicate that invertebrate screening levels are overly protective for the Study Area); and the bioavailability of DDTs in lake sediment (the total organic carbon [TOC] was high in sediment, likely limiting the potential for toxicological effects).

ES.7 Conclusions and RAOs

This section presents a synthesis of pathway, nature and extent, and risk information for the Facility, groundwater, wetlands, and Force Lake in order to help inform EPA's risk management decisions in each part of the Study Area in concert with the preliminary remedial action objectives (RAOs).

ES.7.1 Facility Soil

Key findings for Facility soil are summarized below:

- Patterns of chemical concentrations are consistent with what is known regarding historical uses and releases at the Facility; ongoing activities appear to be controlled (surface water runoff is collected, treated, and monitored under an NPDES permit).
- In the HHRA, risks associated with current and future activities at the Facility were within EPA's target risk range 10^{-4} to 10^{-6} (3×10^{-6} for the industrial [construction/trenching] worker and 2×10^{-5} for the future outdoor worker). HQs were less than or equal to 1.
- In the HHRA, risks based on exposure to Facility soil were assessed as part of the screening assessment for hypothetical future residents. Based on the results of this analysis (i.e., calculation of risks using the published screening levels), the total excess cancer risks would likely be greater than the upper end of EPA's target risk range (10^{-4}) and HQs for some chemicals would likely be greater than 1. However, as discussed in Section 3.6, the current and expected future land use of the Study Area does not include residential use or development.

ES.7.2 Groundwater

Key findings for Facility groundwater are summarized below:

- In the HHRA, risks associated with potential current exposures to groundwater were less than 10^{-6}. HQs were less than 1.
- The majority of chemicals detected in groundwater were in samples collected from shallow wells; concentrations of detected chemicals were low relative to screening levels.

- Chlorinated solvents were detected in groundwater in only two wells: deep well PW-01 and shallow well GA-34, both of which are located in the east corner of the Facility. The identified chlorinated solvents appear to be attributable to upgradient or documented regional impacts and are not attributable to releases from the Facility.
- DDD was detected in shallow groundwater samples in some of the areas where DDD concentrations in soil samples were highest. The mobility of DDD is low, and DDD is not expected to migrate off of the Facility in groundwater to Force Lake. In addition, DDD was detected in deeper groundwater samples at a single well cluster location in the south-central portion of the Facility. With regard to the deeper DDD detections, and given the low mobility of DDD as demonstrated by calculations using the estimated retardation factor, it is suspected that the deeper presence is likely attributable to drilling artifacts or to a breach in the seals of the wells in this cluster and is not the result of vertical migration through natural processes.
- A thin layer of LNAPL was observed in one well and trace amounts were observed in two wells. Thus, LNAPL is not a significant component at the Facility, and its presence is localized and constrained to a small portion of the Facility.
- Chemicals in groundwater that are related to the Facility do not appear to be widespread or to be migrating off the Facility.
- In the HHRA, risks based on exposure to groundwater were assessed as part of the screening assessment for hypothetical future residents. Based on the results of this screening assessment (i.e., calculation of risks using the published screening levels), the total excess cancer risks would likely be greater than the upper end of EPA's target risk range (10^{-4}), and HQs for some chemicals would likely be greater than 1. However, the current and expected future land use of the Study Area does not include residential use or development.

In addition, it should be noted that five chemicals were detected in groundwater samples at concentrations greater than the MCL. These MCL exceedances are summarized below by chemical:

- **Benzene (1 of 28 samples > MCL):** Detected at a concentration greater than the MCL of 5 µg/L in one sample (140 µg/L in the sample collected from location MW-4s in 2008). In 2009, benzene was detected at a concentration of 2.9 µg/L (which is less than the MCL) at the same location.
- **Arsenic (12 of 27 [filtered] and 16 of 34 [unfiltered] samples > MCL):** Detected at concentrations greater than the MCL of 10 µg/L in 12 of 27 filtered water samples and in 16 of 34 water samples (maximum detected concentrations were equal to 32.2 and 31.6 µg/L for filtered and unfiltered water samples, respectively). Concentrations were greater than the MCL or non-

zero maximum contaminant level goal (MCLG) by factors ranging from 1.1 to 3.2. Similar concentrations of arsenic were detected in groundwater across the Facility, including shallow groundwater at the upgradient property boundary near the northeastern corner of the Facility (arsenic concentrations in samples from well GA-34 were approximately 19 µg/L (for both filtered and unfiltered water samples). These results suggest that arsenic concentrations detected at the Facility may not be site-related.

- **TCE (1 of 28 samples > MCL):** Detected at a concentration above the MCL of 5 µg/L in one sample (6.1 µg/L in the sample from location PW-01 in 2000). TCE was not detected in the sample collected at PW-01 in 2008, and the well was not sampled in 2009.
- **Chlorobenzene (1 of 28 samples > MCL):** Detected at a concentration above the MCL of 100 µg/L in one sample (130 µg/L in the sample collected from location GA-34 in 2009).
- **Lead (1 of 28 samples > MCL):** Detected at a concentration greater than the MCL of 15 µg/L in one sample (19.6 µg/L in the sample collected from location A-18 in 2000). Lead was not detected in samples collected from this well in 2008 or 2009.

ES.7.3 Wetland Soil

Key findings for wetland soil are summarized below.

- Patterns of chemical concentrations are consistent with drainage patterns at the Facility as well as the location of historical sumps and holding ponds along the southwest Facility boundary (which may have extended into what is now considered the wetlands). The migration of chemicals from the Facility into the wetlands now appears to be controlled.
- In the HHRA, risks associated with current activities in the wetlands were within EPA's target risk range of 10^{-4} to 10^{-6} for recreational users (9×10^{-6}). HQs were less than 1.
- In the ERA, dietary effects-based HQs were greater than 1 for red-tailed hawk (total DDTs), Eastern cottontail (mercury), and shrew (total DDTs). All other HQs were less than 1 or within background or reference area ranges.
- Wetland soil concentrations were greater than invertebrate screening levels (e.g., for earthworms) for chromium, copper, zinc, and HPAHs. However, earthworms were frequently observed during field sampling, including in those areas with higher concentrations of these chemicals.

- In the HHRA, risks based on exposure to wetland soil were assessed as part of the screening assessment for hypothetical future residents. Based on the results of this screening assessment (i.e., calculation of risks using the published screening levels), the total excess cancer risks would likely be greater than the upper end of EPA's target risk range (10^{-4}), and HQs for some chemicals would likely be greater than 1. However, the current and expected future land use of the Study Area does not include residential use or development.

ES.7.4 Force Lake Sediment and Surface Water

Key findings for Force Lake sediment and surface water are summarized below:

- No lateral concentration gradients were apparent in lake sediment; mean concentrations were less than those at the Facility or in wetland soil and declined with sediment depth.
- With the exception of metals, concentrations in North Lake sediment were generally lower than those in Force Lake sediment. In most cases, concentrations of metals in sediment were similar to those in Force Lake and to background concentrations. In addition, chemical concentrations in Force Lake surface water were low or non-detect. These results indicate that there is minimal transport of chemicals from Force Lake.
- In the HHRA, risks associated with current activities at Force Lake were less than or equal to 10^{-6} for recreational users. HQs were less than 1. Risks were within EPA's target risk range of 10^{-4} to 10^{-6} for current exposure via fish consumption (2×10^{-5}). HQs and endpoint-specific HIs were less than or equal to 1.
- In the ERA, dietary effects-based HQs were greater than 1 only for pumpkinseed and brown bullhead for both copper.
- Sediment concentrations were greater than effects-based screening levels for benthic invertebrates for DDD and DDE; total DDT concentrations were less than the effects-based screening level. TOC in the sediment was relatively high, which would limit site-specific bioavailability and toxicity.
- In the ERA, no refined COPCs were identified for surface water; therefore, no risks to the ecological receptors from exposure to surface water are expected.

ES.7.5 Preliminary RAOs

Preliminary RAOs were provided in Appendix D of the Work Plan (Bridgewater et al. 2008b). Consistent with EPA guidance (EPA 1988), the preliminary RAOs are media-specific goals for protecting human health and the environment at the Study Area.

The preliminary RAOs were evaluated based on the site-specific environmental information gathered during the RI and on the findings of the HHRA and ERA. They appear to be inclusive and relevant for the assessment and management of current and future risks for the Study Area. The preliminary RAOs, as defined in the work plan for the RI/FS (Bridgewater et al. 2008b), were as follows:

- Control or eliminate ongoing sources of contamination, or other Study Area COCs, to groundwater, surface water, and sediment
- Reduce or eliminate human and ecological exposure to any Study Area-related contaminated media that may lead to potential current or future unacceptable risk

One additional RAO was added to control exposure to chemicals in wetland soil that may result in unacceptable risk to human health. The full list of RAOs, along with a discussion of the relevant findings from the RI, HHRA, and ERA, is provided in Table 7-9.

Based on the results of the RI and baseline risk assessments, EPA will make risk management decisions for the Study Area and will determine whether risks are unacceptable. As discussed in EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988), if the baseline risk assessments determine that risks are acceptable for humans and ecological receptors, the conclusions of the risk assessments and RI may serve as the primary means of documenting this decision. EPA guidance (1991b) states that action is generally not warranted when carcinogenic risks are less than 10^{-4}, non-carcinogenic risks are less than a HQ of 1, and maximum contaminant levels (MCLs) and non-zero MCLGs are not exceeded. This guidance also indicates that risk assessments should characterize uncertainties when determining whether risks to human health or the environment are unacceptable (EPA 1991b).

Below is a summary of the results of the RI and baseline risk assessments relative to EPA guidance:

- Carcinogenic risks for current and future RME scenarios in the HHRA were less than 10^{-4}, the upper level of EPA's target risk range, which is typically used by EPA for risk management decisions (EPA 1991b).
- Non-cancer HQs for individual COPCs and endpoint-specific HIs were less than or equal to 1 for all RME scenarios.
- For ecological receptors HQs were less than 1.0 or were less than or similar to background or reference area concentrations, with the exception of two COPCs for wildlife (mercury and total DDTs), one COPC for fish (copper), and four COPCs for terrestrial invertebrates (chromium, copper, zinc, and total HPAHs). Uncertainty exists regarding the likelihood that these COPCs would result in unacceptable population-level risks.

- Detected concentrations in groundwater were greater than the MCL or non-zero MCLG for 12 of 27 dissolved water arsenic samples and 16 of 34 total water arsenic samples (approximately 45% of samples), as well as for 1 of 28 samples each for lead, benzene, chlorobenzene, and trichloroethene. However, the groundwater at the Study Area is not currently used as drinking water, and this is not expected to change in the future.

A screening assessment for hypothetical future residents conducted as part of the HHRA indicated that total excess cancer risks would be greater than the upper end of EPA's target risk range (10^{-4}) and non-cancer HQs for some chemicals would be greater than 1. The results of this assessment indicate that if the land use designation were to change, additional analyses would be needed. It should be noted that future residential land use is unlikely at the Study Area based on current and expected future land use designations (industrial at the Facility or open space in the wetlands). In addition, as noted in EPA guidance (EPA 1991b), the NCP states that "the assumption of future residential land use may not be justifiable if the probability that the site will support residential use in the future is small."

EPA will carefully evaluate the information presented in this RI relative to the RAOs for the Study Area to determine what next steps, if any, are necessary.

1.0 INTRODUCTION

1.1 Purpose of Report

On May 31, 2007, Portland General Electric Company, Bonneville Power Administration, Avista Corporation, NorthWestern Corporation, Union Oil Company of California, and Waste Management Disposal Services of Oregon, Inc. (which together comprise the Voluntary Group for the Harbor Oil Site RI/FS [Voluntary Group]), entered into an AOC, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Docket No.CERCLA-10-2007-0106, with the EPA for the Harbor Oil Superfund Site (Site) in Portland, Oregon. In accordance with the AOC, the Site encompasses the Harbor Oil facility (Facility), an approximately 4.1-ac parcel of property located at 11535 N Force Avenue, the adjacent wetland to the south and west of the Facility, and Force Lake. The AOC statement of work (SOW) required that the Voluntary Group prepare an RI/FS work plan. The *Remedial Investigation/Feasibility Study Work Plan for the Harbor Oil Site* (Bridgewater et al. 2008b), hereafter referred to as the RI/FS Work Plan, was completed in March 2008.

The site characterization was conducted in two phases. Areas sampled included the Site, as defined above, and a portion of North Lake. Collectively, the areas studied are referred to as the Study Area in this document. Phase 1 sampling was conducted in April and May 2008, and included the collection of surface and subsurface soil samples at the Facility and in the adjacent wetlands; installation of monitoring wells and collection of groundwater samples; and collection of lake surface water and sediment samples. Phase 2 sampling was conducted in March and April 2009, and included the collection of additional surface and subsurface soil samples at the Facility and in the wetlands; collection of another round of groundwater samples; and collection of subsurface lake sediment samples. Monthly groundwater and lake elevations were collected between May 2008 and April 2009.

This document is the RI report for the Site. The objective of the RI was to gather sufficient information regarding the Site to support informed risk management decisions regarding the remedy for the Site. In particular, sufficient information had to be collected in order to characterize site conditions, describe of the nature and extent of contamination, and assess risks to humans and ecological receptors. The RI report was prepared by Bridgewater Group, Inc. (Bridgewater); Windward Environmental LLC (Windward); GeoDesign, Inc.; and Hahn and Associates, Inc., for the Voluntary Group.

1.2 Report Organization

This RI report was prepared in accordance with the EPA-approved RI/FS Work Plan (Bridgewater et al. 2008b) and EPA RI/FS guidance (EPA, 1988). The report is organized to follow the outline provided in EPA RI/FS guidance and includes the following sections:

Section 1.0 Introduction

Section 2.0 Study Area Investigation

Section 3.0 Physical Characteristics of the Study Area

Section 4.0 Nature and Extent of Contamination

Section 5.0 Conceptual Site Model

Section 6.0 Baseline Risk Assessments

Section 7.0 Summary and Conclusions

Section 8.0 References

Appendices to the RI report include:

A Aerial Photographs

B Remedial Investigation Database

C Field Forms, Field Notes, and Chain-of-Custody Forms

D Boring Logs

E Sample Location Tables

F Well Construction Diagrams

G Slug Test Results

H Force Lake Fish Survey Memorandum

I Human Health Risk Assessment

J Ecological Risk Assessment

K Golder Associates Figures

L Groundwater Elevation Maps and Hydrographs

M Data Validation

N Data Management

O Laboratory Report Forms

1.3 Site Background

1.3.1 Site Description

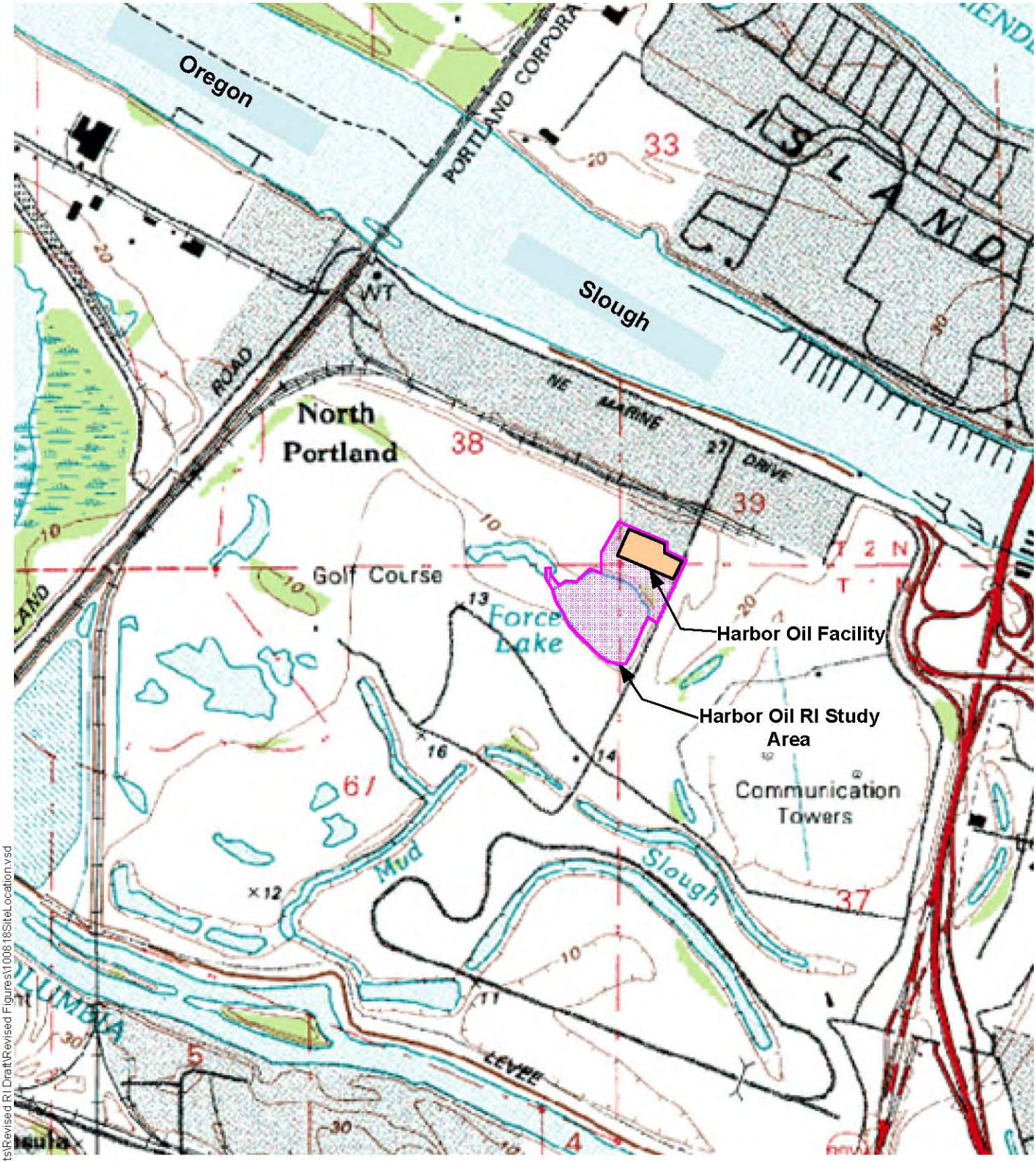
1.3.1.1 Site Location

The Site is located in north Portland, Multnomah County, Oregon. The Site is located in an industrial area of north Portland, south of Marine Drive and west of Interstate 5 (Figure 1-1).

The Oregon Slough (Figure 1-1), a side channel to the Columbia River, is located to the north of Marine Drive. The Heron Lakes Golf Club, which includes the Great Blue and Greenback Golf Courses, is located to the south of the Site.

The Site is located in Township 2 North, Range 1 East of Section 33 of the Willamette Meridian. According to Ecology and Environment (2001), the Site is located at latitude 45°36’24.5” N and longitude 122°40’59.47” W.

In accordance with the AOC, the Site encompasses the Facility, an approximately 4.1-ac parcel of property located at 11535 N Force Avenue (bounded by North Force Avenue to the east and by the Bulk Transportation facility to the north), the adjacent wetland to the south and west of the Facility and Force Lake. The term Study Area is used to refer to the entire sampled area, which includes the areas listed as part of the Site as well as a portion of North Lake. Figure 1-2 shows the location of the Facility and Force Lake; the wetlands are located to the northwest and southwest of the Facility. This figure also shows the approximately 19-acre Study Area, where soil, groundwater, sediment and surface water samples were collected during the RI.



Source: Force Lake, USGS Portland (OR,WA) Topo Map from TopoZone

N

0.5 Mile

Approximate Scale

Figure 1-1
Location Map
Harbor Oil Study Area

BRIDGEWATER GROUP, INC.

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Wind Ward environmental LLC

N E S W

0 100 200 Feet

0 25 50 Meters

Figure 1-2. Harbor Oil Study Area

Prepared by CEH, 08/20/2010; MAP #4348; W:\Projects\Harbor Oil\Data\GIS\R1

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

1.3.1.2 Facility Description and Conditions

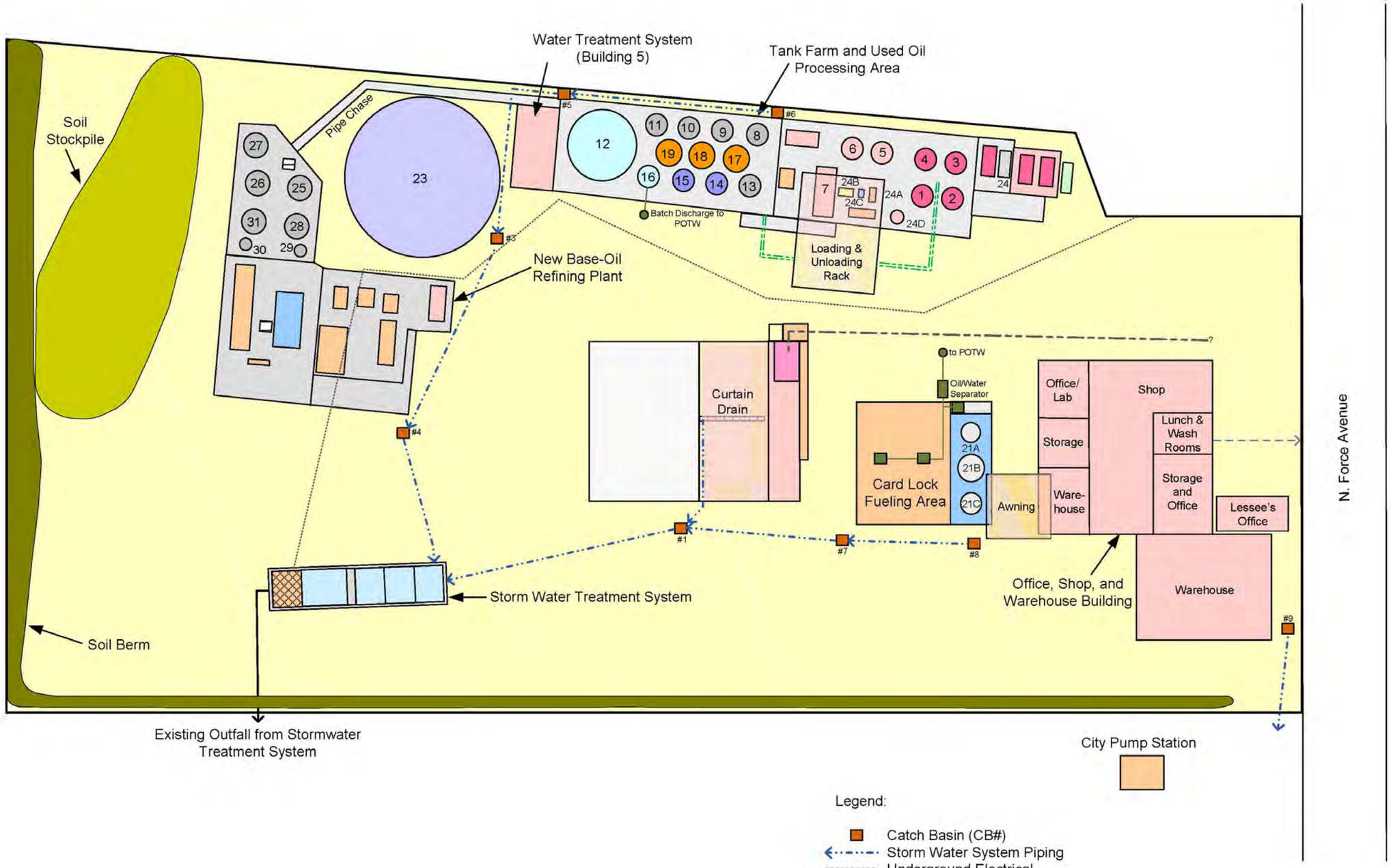
According to Coles Environmental Consulting (CEC) (2002), EMRI, currently operates a treatment and processing plant at the Facility for used oil, oily water, and other water. In 2005, EMRI processed 3.3 million gallons of raw used oil. EMRI took over the operation on October 1, 1999, after Harbor Oil, Inc., ceased doing business on the property. Under both Harbor Oil and EMRI, the Facility has processed various types of oil, off-specification fuels, and oily waters to produce refined fuel oil (RFO).

Figure 1-3 shows current features at the Facility, most of which until recently, was unpaved and covered with gravel. However, during the fall of 2011, the majority of the Facility (all areas except for the western-most portion) was paved with asphalt. The August 2011 aerial photograph included in Appendix A depicts the current extent of asphalt pavement at the Facility. EMRI's office/shop/warehouse building is located on the southeast side of the Facility, near the main entrance along N Force Avenue. As of early 2010, a portion of this building was also used by Wevco Biodiesel Products LLC for the manufacture of biodiesel. Another portion of the building is occupied by an asphalt coating business, Phoenix Asphalt. Immediately to the northwest of the building is a card lock fueling operation, which was also operated by a tenant. The locations of known underground utilities at the Facility, including underground electric, stormwater, sanitary, and fuel lines, are shown on Figure 1-3.

A tank farm and used oil processing area is located along the northeast side of the Facility. Used oil is delivered at a covered unloading rack located immediately southwest of the processing area and is stored in the tank farm. It is heated and then processed (i.e., filtered, dehydrated and blended) to produce RFO. The locations of all known underground petroleum piping at the Facility (limited to the south-central portion of the tank farm and processing area) are shown on Figure 1-3. According to D. Coles (2010c), no information concerning leak or tightness testing that may have been done on the product line or the tanks is available.

To the northwest of the tank farm and processing area is a large steel tank referred to as Tank 23. Wastewater from the RFO process was historically discharged to Tank 12 (located at the northwest end of the tank farm and used oil processing area) for storage and then to Tank 23 for treatment.

The RFO is further processed in a new base oil refining plant (constructed in 2003), which is located to the west of the tank farm and used oil processing area. A variety of petroleum products are produced by the new base oil refining plant. Soils excavated during the construction of the new base oil plant were stockpiled at the Facility to the northwest of the plant (Figure 1-3).



Source: Coles Environmental Consulting, Inc., Energy & Materials Recovery, Inc. Site Diagram (Formerly Harbor Oil, Inc.), April 2009.

Figure 1-3
Current Facility Features
Harbor Oil Facility

BRIDGEWATER GROUP, INC.

C:\Userdata\Document\Harbor Oil\Reports\Revised RI Draft\Revised Figures\100826 Site Features.vsd

A stormwater treatment system, which includes an oil-water separator, is located near the southwest side of the Facility. Catch basins are used to collect stormwater and convey it to the stormwater treatment system. Figure 1-3 illustrates the location of underground piping from the catch basins to the treatment system based on information provided by D. Coles (2007). According to D. Coles, piping was initially installed by 1984 at the same time as the installation of the treatment system. Additional piping was installed in 2002 when EMRI closed off the drainage ditch that ran along the northeastern property boundary and installed the two catch basins located in the area immediately north of the tank farm, and in 2006, when the catch basins near the card lock facility were installed. According to D. Coles, the system is in good condition. Treated stormwater is discharged to the wetlands at a point southwest of the Facility, under a NPDES Industrial Stormwater Discharge Permit 1200-COLS issued by the Oregon Department of Environmental Quality (DEQ). Based on DEQ file information, EMRI is required to sample stormwater four times per year, at least 14 calendar days apart. Two of the sampling events are to occur prior to December 31 each year and the remaining two are to occur between January 1 and June 30. The samples are collected at the point of discharge to the wetland and are analyzed for biochemical oxygen demand (BOD), oil and grease, pH, total phosphorus, total suspended solids (TSS), copper, lead, zinc, and *Escherichia coli*. Section 1.3.2 summarizes information found in DEQ's water quality file related to NPDES permit violations and unpermitted discharges.

A soil berm extends along the southwest and northwest sides of the Facility (Figure 1-3); the berm is intended to prevent stormwater runoff from flowing into the adjacent wetlands (Figure 1-2). Facility history information indicates that the soil berm was constructed shortly after a 1979 fire at the Facility.

According to D. Coles (2007a), the soil berm is approximately 2 to 3 ft high and 5 to 6 ft wide at its base. The soil berm is intact, covered with sparse vegetation, and there are no known areas of substantial erosion. The soil berm is effective in preventing stormwater runoff from discharging into the adjacent wetlands.

An open area to the northwest of the new base oil refining plant and stormwater treatment system is used for storage of vehicles, equipment, and materials.

A tanker truck cleaning operation was previously located in the central portion of the Facility; the western portion of the area where the former tanker truck cleaning operation was located is currently leased to the asphalt coating business and the eastern portion is used for vehicle and equipment storage.

1.3.2 Facility History

This section provides a summary of information on Facility history from CEC (2002), Ecology and Environment (2001), Golder Associates (1990), and historical aerial photos, as well as information gathered as part of a review of State of Oregon air quality, water quality, hazardous waste, and

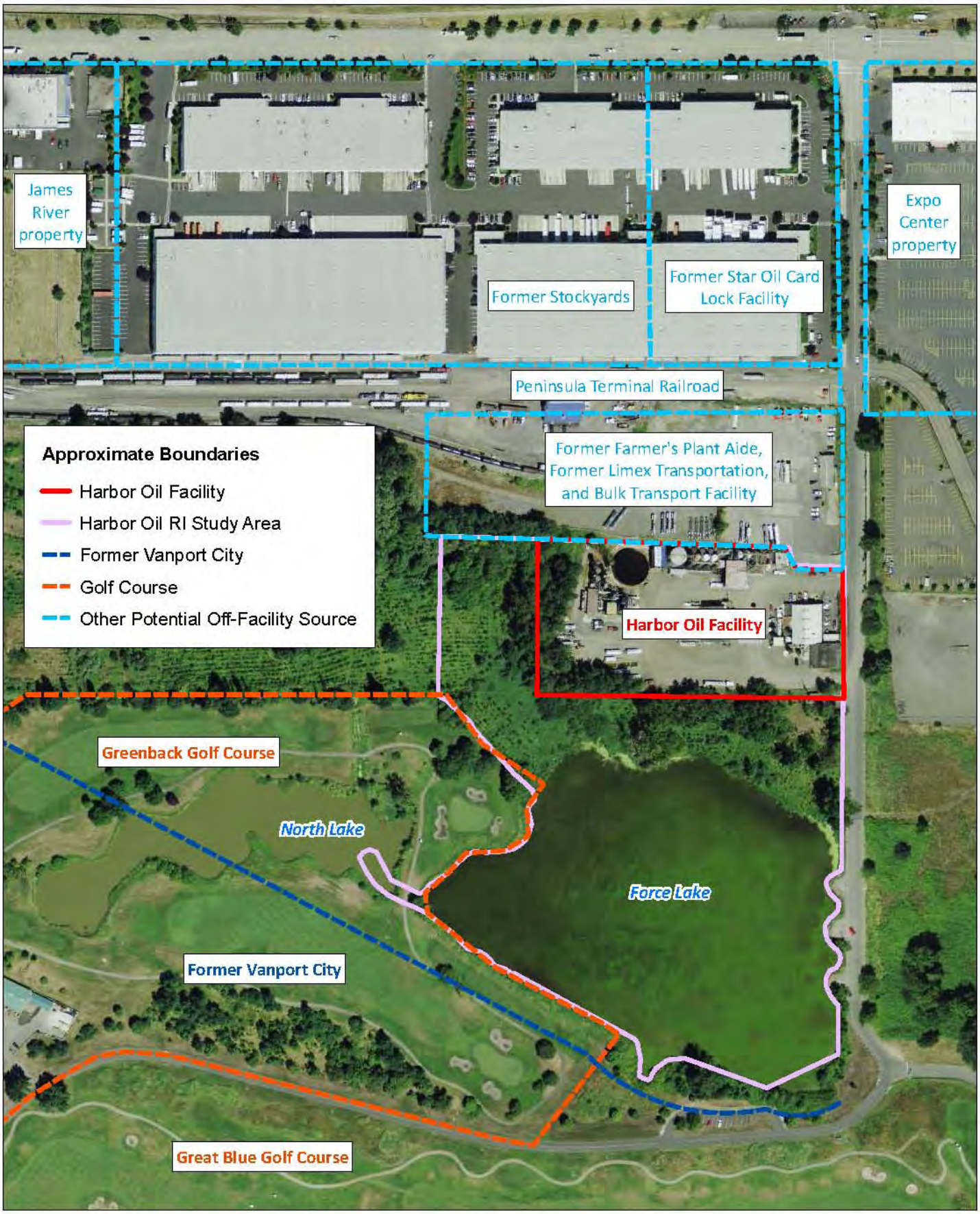
cleanup files. The file review information was gathered as required by the SOW to support preparation of the RI/FS Work Plan (Bridgewater et al. 2008b).

1.3.2.1 1940s

Based on a 1948 aerial photograph taken after the May 1948 Vanport flood, the area that is now the location of the Facility was essentially undeveloped in the late 1940s.[2] Piles of unknown materials were present at the Facility. The only other feature was a railroad spur that ran southward from what is now the Peninsula Terminal Railroad switching yard (Figure 1-4). The rail spur ran parallel to and west of Force Avenue to about the location of the current office/shop/warehouse building.

The 1948 flood destroyed Vanport City, Oregon, which was located to the southwest of Force Lake (Figure 1-4 and photograph in Appendix A). Vanport City was originally constructed in 1942 to house workers at shipyards located in Portland and in Vancouver, Washington. By the end of 1943, nearly 40,000 people lived in Vanport City. After World War II, it provided housing for returning servicemen and their families.

[2] The aerial photographs referenced in Section 1.3.2 are presented in CEC (2002) or are included in Appendix A.



Wind Ward environmental LLC

0 200 400 Feet

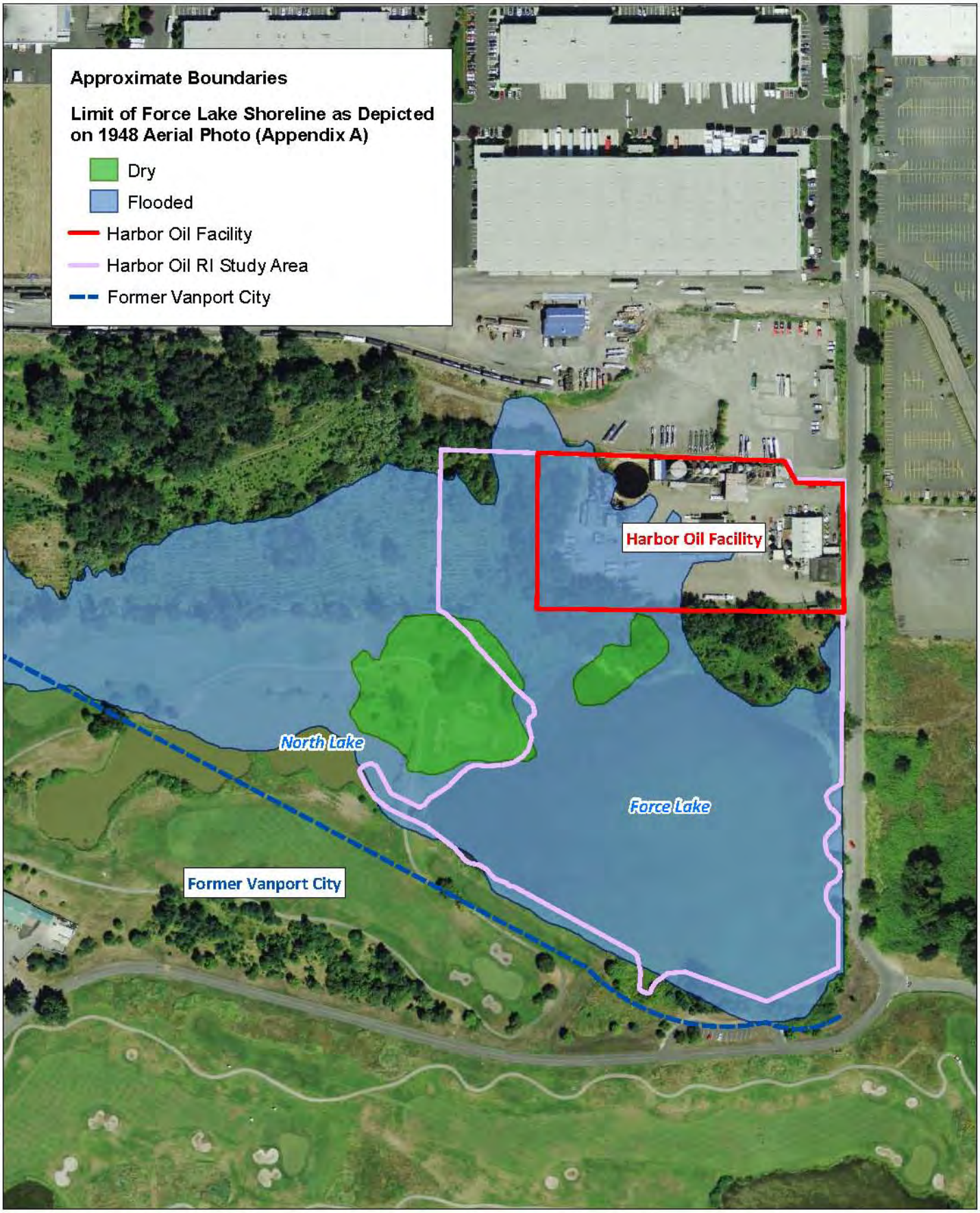
0 50 100 Meters

Figure 1-4. Potential Off-Facility Sources

Prepared by CEH, 08/19/2010; MAP #4317; W:\Projects\Harbor Oil\Data\GIS\R1

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

A 1948 aerial photograph (Appendix A) shows the topography of the Facility when flood waters covered the southern and western portions of the Facility; these areas were historically lowlands compared with the northern and eastern portions of the property. Thus, it is expected that site surface water drainage during this timeframe would have flowed from the upland areas in the north and east to the lowland areas in the south and west. The photograph also depicts vegetated areas to the south and southwest of the current Facility boundary that were above Force Lake at flood stage, providing an overall indication of topographic highs and lows in the area. Figure 1-5 shows the extent of the floodwaters depicted on the 1948 photograph as overlain on a recent aerial photograph of the Facility and surrounding Study Area. As described below, the low area identified in the 1948 photograph was subsequently filled in several stages and brought to grade with the remainder of the Facility, According to D. Coles (2010a), the property was incrementally filled in a general east to west direction as operations expanded.



Wind Ward environmental LLC

N E S W

0 200 400 Feet

0 50 100 Meters

Figure 1-5. Force Lake Shoreline – 1948 Post-Vanport City Flood

Prepared by CEH, 08/19/2010; MAP #4344; W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

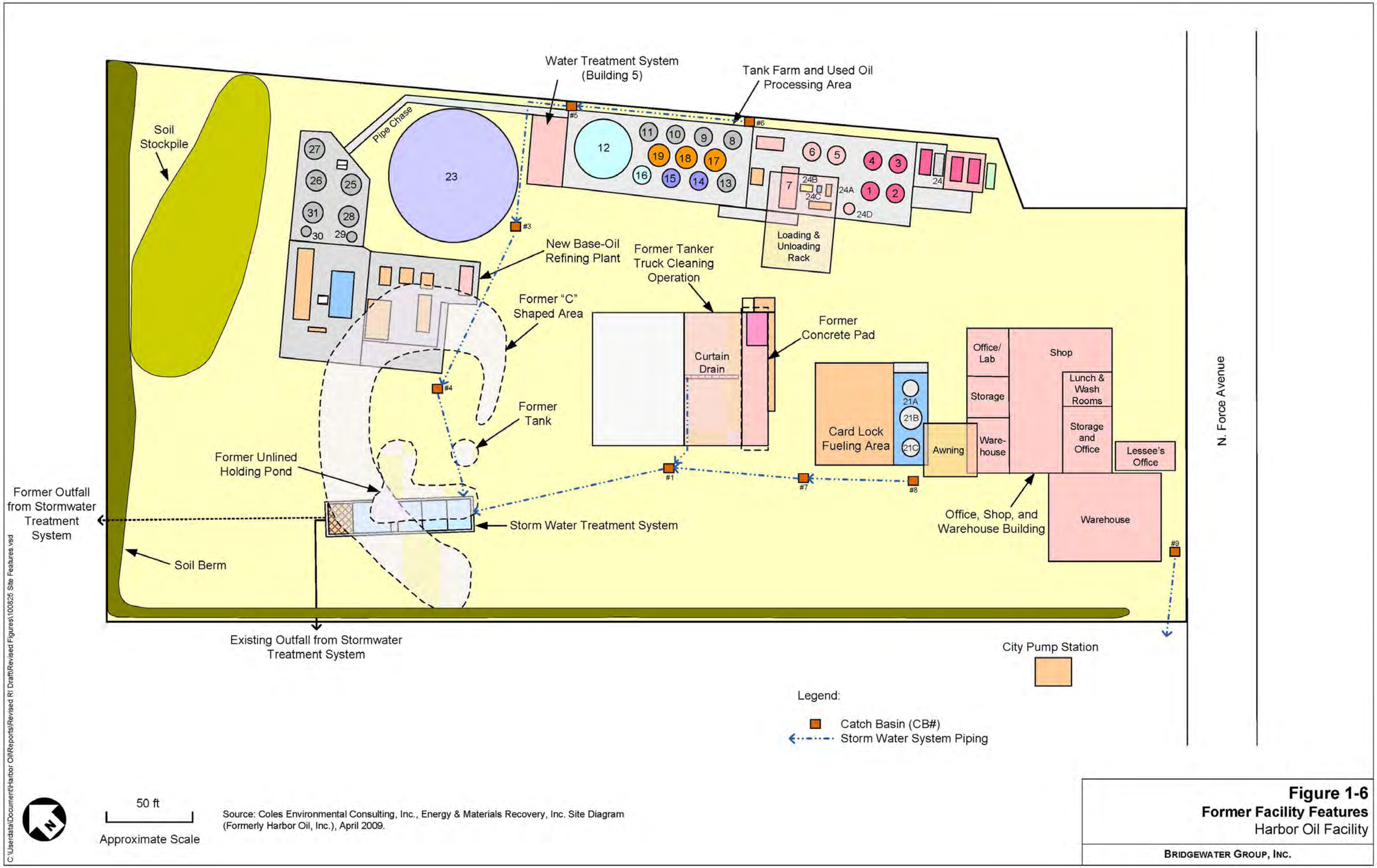
1.3.2.2 1950s

A 1956 aerial photograph indicates that the railroad spur was no longer present at that time (Appendix A). A portion of the current office/shop/warehouse building was present, and the aerial photograph shows what appear to be tanker trucks and a concrete slab located in the area where the former tanker truck cleaning operation was later located. As discussed below, this concrete slab may have been the “cement washing basin” observed by DEQ in 1973 where cattle and tanker trucks were cleaned. Figure 1-6 shows the approximate location of the concrete slab and other former facility features.

CEC (2002) discusses a C-shaped area of apparent “dumped material” that was located to the southwest of Tank 23 in the area where the new base oil refining plant and current stormwater treatment system are located (Figure 1-6 and Appendix A [1956 photograph]). CEC (2002) suggests that the C-shaped area could have been fill material or the outline of a berm for a retention pond.

According to CEC (2002), EMRI indicated that during the 1950s, the Facility may have been occupied by a dust suppression service that used asphalt blended with lignite (waste paper mill liquor). Used oil was apparently added to thin the mixture.

The portion of the Facility that was presumably filled to current grade (and developed with structures) appears to have been limited to the eastern portion of the Facility (similar to the 1948 photograph). The C-shaped material was placed on the lower, as of yet unfilled, portion of the property.



Source: Coles Environmental Consulting, Inc., Energy & Materials Recovery, Inc. Site Diagram (Formerly Harbor Oil, Inc.), April 2009.

Figure 1-6
Former Facility Features
Harbor Oil Facility

BRIDGEWATER GROUP, INC.

C:\Userdata\Document\Harbor Oil\Reports\Revised RI Draft\Revised Figures\100825 Site Features.vsd

1.3.2.3 1960s

According to Ecology and Environment (2001), Empire Industries, Inc., started oil recycling activities at the Facility in 1961. Harbor Distributing (type of business unknown) and Industrial Cleaning Systems (truck cleaning) also operated at the Facility at this time (CEC 2002).

The *Site Assessment Program Strategy Recommendation, Harbor Oil, Inc.* (DEQ 1995), hereafter referred to as the DEQ Strategy Recommendation, which DEQ prepared for the Facility, refers to a pond with oil-stained soil that was filled sometime before 1964. The location of the pond was not identified in the DEQ Strategy Recommendation (1995).

Aerial photographs from 1964 and 1966 show that development during this time frame was restricted to the southeastern half of the Facility. The office/shop/warehouse building and concrete slab were present during these years. It appears that the C-shaped area identified in CEC (2002) was also present during these years, with no apparent additional filling, although the 1966 aerial photograph is of poor quality, making interpretation difficult.

1.3.2.4 1970s

A 1972 aerial photograph (CEC 2002) shows that key facility features at that time were limited to the office/shop/warehouse building and concrete pad. Numerous trailers or tanks were located around the perimeter of the Facility, which was developed only as far west as the location of the current stormwater treatment system. A comparison of the 1966 and 1973 aerial photographs (Appendix A) suggests that the filling and working of soils extended westward during this time frame along the southern portion of the Facility to the location of the current stormwater treatment system. An upright tank was located in the location of the C-shaped area (Figure 1-6). Also visible in the 1972 photograph is a drainage ditch that starts at the north property line, approximately 250 ft northwest of N Force Avenue. The drainage ditch runs along the northeastern border and then follows the northwestern border through the wetlands. The current relationship between the drainage ditch and Facility is not obvious from the aerial photograph because fill may have been placed on the adjacent property to the north, particularly when a stormwater retention pond located immediately north of Tank 23 was filled sometime prior to 1987. The adjacent property is now several ft higher than the Facility.

1.3.2.4.1 1973 DEQ Site Visit

According to Ecology and Environment (2001), DEQ conducted a site visit in May 1973 in response to a complaint that oil was flowing off the Facility into the adjacent wetlands and Force Lake. Apparently, at that time Empire Industries repaired, stored, and cleaned trucks. Both cattle trucks and oil tankers were cleaned on a “cement washing basin” that had a curb and apron. The basin drained to an open ditch (likely the drainage ditch that was located on the northeast side of the Facility), which discharged into the wetlands. An October 16, 1979, DEQ memorandum (1979) stated that 90% of Empire Industries’ operation was washing cattle trucks. Approximately 10% of its operation was washing the inside and

outside of oil tankers. Empire Industries also had two large storage tanks for oil. Animal waste was stockpiled on the ground, as was sawdust that was being used for oil cleanup (DEQ 1973). DEQ observed that the entire yard had been oiled for dust control.

1.3.2.4.2 1974 Oil Release

In March 1974, DEQ investigated a release of oil that reportedly spread across approximately 2 ac of wetland and created a sheen on Force Lake. A DEQ report, *Investigation of Fish Kill at Force Lake, West Delta Park, Multnomah County on March 19, 1974* (DEQ 1974a), stated that during the investigation, DEQ observed a thin film of oil on Force Lake, and that thick oil (fresh and decomposed) had accumulated on the shoreline. The source was determined to be an approximately 80-by-100-yard work area used by Industrial Cleaning Systems to clean tanker trucks. Along the south edge of the work area were several small sumps filled with oil and water, which drained toward Force Lake. Based on the DEQ file information, these sumps were probably excavated unlined sumps that were not part of the later truck washing system that used trichloroethylene (TCE) (i.e., Detrex system). As discussed below, the work area was filled with sand and gravel after Chempro of Oregon (Chempro) started its operations. The location of these two sumps is unknown. Just west and slightly north of the work area was a large sump (15 by 50 ft) filled with oil and water that drained toward the wetlands. Large piles of sawdust and wood chips were distributed around the area. These materials were used to soak up oil. DEQ observed dead bullhead catfish and goldfish in Force Lake, along with a dead duck and coot.

Examination of aerial photographs from 1973 and 1977 (Appendix A) did not reveal conclusive evidence of the existence or location of the sumps identified in DEQ's March 1974 report.

An April 12, 1974, letter from Empire Industries (1974) stated that oil residue in the wetlands came from 10 to 12 years of truck cleaning operations. The letter also stated that dried grasses were not discolored by oil but by manure from the adjoining Farmer's Plant Aide or Stockyards properties. In 1974, Empire Industries placed 1,146 cubic yards of rock fill in the area between the work area and Force Lake to provide containment for wash water. Empire Industries planned to install a skimmer system in the drainage ditch to remove oil residue, and then remove contaminated soil from the drainage ditch and surrounding area.

A July 17, 1974, DEQ letter (1974b) indicated that Empire Industries had implemented a program to clean up oils and contaminated soils in the wetlands. The scope of the program implemented by Empire Industries was not described in the DEQ letter.

1.3.2.4.3 Chempro Operations

Chempro is believed to have started its operations in the mid-1970s. During this time, the Facility was owned by Canal Capital Corp. (aka United Stockyards Corp.). After Chempro started its operations, it filled the work area (where cattle trucks and oil tankers were cleaned) with sand and gravel (DEQ 1979).

According to a January 7, 1975, letter (DEQ 1975), DEQ noted that a wall surrounding the truck unloading rack (referred to in the letter as the "transfer area") had not been completed and there was evidence of discharges into the drainage ditch along the northeast side of the Facility.

In 1977, Chempro installed the "plant well," a 100-ft-deep water supply well located near the northeast corner of the office/shop/warehouse building. The use(s) of this well between 1977 and 1990 is uncertain.

1.3.2.4.4 Chempro Changes to Stormwater Management System

To address the March 1974 oil release (Section 1.3.2.4.2), DEQ ordered Chempro to make improvements to its stormwater management system. Chempro made the improvements in 1975, at which time DEQ issued an NPDES Waste Discharge Permit (File No. 16045) on October 10, 1975. The permit allowed Chempro to discharge to the "North Ditch of Force Lake" until 1977, after which discharges were to go to the City of Portland sewer system. The permit contained discharge limits for oil and grease (10 mg/L monthly average and 15 mg/L daily maximum), suspended solids (50 mg/L), and pH (6.5 to 8.5).

DEQ received a complaint in November 1978 that Chempro was discharging oily wastes into the wetlands (DEQ 1988c). DEQ found that oily and water wastes went to a large holding tank in 1978 and were then sold as a dust suppressant. Oil sludge was hauled to Arlington.

In 1978, DEQ found that the sewer system hookup had not been completed as required by the 1975 permit. Chempro had an oil-water separator on order and was coordinating with the City of Portland before installing it.

1.3.2.4.5 1979 Fire

In October 1979, a major fire destroyed the Chempro facility. The heat of the fire reportedly destroyed at least five 20,000-gallon storage tanks, resulting in the release of used oils and lesser volumes of waste paints. These materials flowed to the west and south across the Facility and into the wetlands and Force Lake (DEQ 1995).

1.3.2.5 1980s

CEC (2002) discusses a 1980 aerial photograph (Appendix A) that was taken after the fire. Based on this photograph, the office/shop/warehouse building had been expanded, the tank farm and used oil processing area had been rebuilt, and Tank 23 had been constructed. In addition, a new structure had been constructed in the area where the concrete pad was located. As discussed below, this structure housed the tanker truck cleaning operation (i.e., Detrex system).

According to Ecology and Environment (2001), the Facility was re-graded and covered with gravel when the Facility was rebuilt. A 1984 aerial photograph (Appendix A) indicates that the filling of the lowland areas on the western portion of the Facility occurred between 1977 and 1984, likely as a part of the regrading activities subsequent to the 1979 fire. This filling and regrading work brought the Facility to its present topographic expression. An unlined holding pond was constructed in the southwest corner of the Facility to serve as an oil-water separator (Figure 1-6). The

far northwestern portion of the Facility remained undeveloped. An earthen berm was constructed around the northwest and southwest sides of the Facility, apparently from soil impacted by releases caused by the fire.

1.3.2.5.1 1980 EPA Site Inspection

A March 13, 1980, memorandum (EPA 1980) described the results of a February 29, 1980, EPA site inspection. The memorandum stated that Chempro, which was headquartered in Seattle, Washington, collected waste oils from various sources including service stations. The oils were screened and filtered prior to resale to industrial customers. Some oils were used for road oiling. Chempro also collected solvents and thinners, which were shipped to Resource Recovery for reprocessing. Non-recoverable thinners and solvents were shipped to Masterwash in Vancouver, British Columbia, for use as fuel supplements. Chempro also accepted oily wastewater and some liquid chemicals from various sources. It did not knowingly accept or handle PCBs (EPA 1980).

The waste generated from operations at the Facility consisted of oily sludges from tank bottoms, oily sludges from screening and reprocessing, and asphalt sludges from the tanker truck cleaning operation. Sludges were put into barrels and stored at the Facility until they were transported to Arlington, Oregon.

Surface runoff was directed to the unlined holding pond. When the pond filled up, the water under the surface of floating oil was pumped off the Facility to a “swamp on the exposition center property.” The EPA memorandum does not identify the exact location of the discharge point of water from the holding pond. It is likely that the swamp referenced by EPA refers to the wetlands adjacent to the Facility. Truck washings were collected in a sump that was vacuumed out and pumped into one the storage tanks.

According to a DEQ Hazardous Waste/Used Oil Processor Compliance Evaluation Inspection Report (DEQ 2000d), Chempro submitted a Part A permit application for hazardous waste storage to EPA in November 1980. DEQ subsequently issued hazardous waste collection site license number HWC5 (a state-issued hazardous waste storage permit) to Chempro on April 23, 1981 (DEQ 1996a). The license expired on May 1, 1983. The inspection report stated that DEQ records indicated that Harbor Oil removed all hazardous waste in storage prior to the expiration of the license.

1.3.2.5.2 1983 NPDES Permit

Chempro changed its name to Harbor Oil, Inc., on September 23, 1983, and merged with Harbor Oil, Inc. (a Washington corporation) on October 31, 1985.

On December 5, 1983, DEQ issued an NPDES Waste Discharge General Permit 1300-J to Harbor Oil. The permit covered treated stormwater runoff from bulk petroleum storage, transfer, formulation, and packaging facilities. The permit contained a 10 mg/L monthly average and 15 mg/L daily maximum oil and grease discharge limit. It required that stormwater be collected and treated through an oil-water separator.

By 1984, Harbor Oil had installed a new oil-water separator (i.e., the current stormwater treatment system), which initially discharged into the drainage ditch near the west corner of the Facility. This system is visible in a 1984 aerial photograph (Appendix A).

1.3.2.5.3 EPA 1984 and 1985 Preliminary Assessment/Site Investigation

EPA conducted a preliminary assessment (PA) of the Facility in June 1984, followed by a site investigation (SI) in 1985. As part of the SI, water in the stormwater treatment system was sampled and found to contain TCE.

1.3.2.5.4 1984 Air Contaminant Discharge Permit

On July 3, 1984, DEQ issued an Air Contaminant Discharge Permit (ACDP) No. 26-3021 to Harbor Oil. The permit established emission limits for opacity, particulates, odors, and fugitive dusts.

1.3.2.5.5 Harbor Oil Operations

According to Golder Associates (1990), Harbor Oil transported, collected, and refined used oils and asphalt and marketed virgin oils. Materials were accepted from Washington, Oregon, Idaho, and western Montana. Active operations at the time included recycling waste oils for resale to industrial burners, and re-blending oils to meet client specifications. DEQ also listed Harbor Oil as a dust suppressant provider. Active facilities during this time included the tank farm and used oil processing area, a surge tank for collection and storage of separated water, the stormwater treatment system, a waste drum storage area, and the tanker truck cleaning operation.

On December 2, 1986, DEQ issued an NPDES Waste Discharge General Permit 1300-J to Harbor Oil.

According to a February 4, 1988 spill prevention, control, and countermeasure (SPCC) plan prepared for Harbor Oil, the Facility was bermed with an earthen dike that was approximately 2 ft high (HMS Environmental Inc. 1988). Runoff drained to the southwest toward the stormwater treatment system. Stormwater collected in the treatment system was pumped to a nearby pond just west of the property line. The location of this pond was not identified in the SPCC plan. The “heated tank area” contained seven 20,000-gallon tanks with concrete containment. The truck loading and unloading rack area had a roof, was paved, and had two sump drains to collect spills and transfer them to the stormwater treatment system. A 4,000-gallon aboveground storage tank (AST) was located in a concrete secondary containment outside the boiler house. The oil storage area consisted of one 210,000-gallon tank and eight 20,000 gallon tanks with concrete containment. A 320,000-gallon “water tank” (i.e., Tank 23) did not have secondary containment and was used to store water recovered from the oil recycling operation. A 6,000-gallon vertical gasoline AST, a 20,000-gallon vertical diesel AST, and a 275-gallon gas tank were located in a concrete containment in the truck fuel tank area.

1.3.2.5.6 1988 DEQ Site Inspection and Follow-Up Sampling Activities

A March 14, 1988, DEQ memorandum (1988b) discusses observations made during a site inspection, including the potential for wash water from the tanker truck cleaning operation to go to the stormwater treatment system.

DEQ subsequently observed and confirmed that the tanker truck cleaning operation discharged to the wetlands via the stormwater treatment system (DEQ 1988c). At that time, the tanker truck cleaning operation (Detrex system) consisted of a TCE distillation unit and storage tank located on a raised concrete pad adjacent to the cleaning area. Used TCE and truck wastes were pumped into the storage tank and then into the distillation unit for reprocessing. TCE still bottoms and sludge from the distillation process were drummed and shipped off the Facility to Baron-Blakeslee in Portland for treatment.

The DEQ water quality file presented EPA Method 8270 analytical results for a sample collected on June 28, 1988 from the “bottom of the oil-water separator” (i.e., stormwater treatment system). The sample was analyzed by the DEQ laboratory. No acid-base/neutral compounds were detected. DDD, dichlorodiphenyltrichloroethane (DDT), and dichlorodiphenyldichloroethylene (DDE) were also not detected. The sample contained detectable concentrations of trans-1,2-dichloroethylene (trans-1,2-dichloroethylene) (~2.8 mg/L), 1,1,1-trichloroethane (1,1,1-trichloroethane) (0.001 mg/L), TCE (0.035 mg/L), benzene (0.003 mg/L), toluene (0.002 mg/L), and chlorobenzene (0.004 mg/L).

A sample collected from the “drain trench at the truck cleaning area” (i.e., curtain drain) contained no detectable concentrations of acid-base/neutral compounds but did contain detectable concentrations of TCE (70 mg/L), trans-1,2-dichloroethylene (6.1 mg/L), 1,1,1-trichloroethane (0.7 mg/L) and 1,1,2,2-tetrachloroethylene (0.5 mg/L).

A sample of the water layer collected from the “large oil-water tank” (i.e., Tank 23) contained detectable concentrations of phenol (1.9 mg/L), 2-methylphenol (1.3 mg/L) and 4-methylphenol (4.3 mg/L). Note that at the time these samples were collected, the stormwater treatment system discharged to the drainage ditch through a pipe located at the west corner of the property.

1.3.2.5.7 1988 NPDES Permit

On July 21, 1988, DEQ issued NPDES Waste Discharge Permit 1300-J to Harbor Oil. The permit covered the following:

- Treated stormwater runoff
- Groundwater dewatering discharges
- Water bottoms from facilities storing, transferring, formulating and/or packaging bulk petroleum products or vegetable oils; motor pools; and other facilities with oily discharges controlled by DEQ-approved oil-water separators

The monthly average oil and grease discharge limit in the permit was 10 mg/L, with a 15-mg/L daily maximum.

In August 1988, DEQ proposed to revoke Harbor Oil's stormwater discharge permit because pollutants from the tanker truck cleaning operation were entering the stormwater treatment system, which was not designed to treat them (Ecology and Environment 2001). Harbor Oil subsequently settled with DEQ and agreed to a June 1989 Stipulation and Consent Agreement (No. WQ-WQ-NWR-89-28) that allowed Harbor Oil to continue discharging stormwater to the wetlands if process wastewater was discharged to the sanitary sewer. In addition, Harbor Oil agreed to collect and pre-treat waste water from the tanker truck cleaning operation.

According to the Agreement, most of the Facility stormwater went directly to the stormwater treatment system. Some stormwater flowed into an oil collection sump located at the truck loading and unloading rack, and was then transferred to Tank 23. Wastewater or oil bottoms from the bulk used oil storage tanks were also pumped to Tank 23. When the liquid level in Tank 23 reached capacity, some of the wastewater was transferred to a flocculation tank for further polishing and then released to a storm drain that flowed to the stormwater treatment system. The settled solids in the flocculation tank were returned to Tank 23.

According to a December 12, 1988, DEQ memorandum (DEQ 1988a), discharges from the flocculation tank started in 1985. Also according to the memorandum, a 4,600-gallon AST was installed at the tanker truck cleaning operation to store truck wash water. DEQ observed that there was a storm drain located just south of the tanker truck cleaning operation that could have received spills during filling or off-loading of the wash water tank. The storm drain was connected to the stormwater treatment system.

1.3.2.5.8 Property Acquisition by Waste Management Disposal Services of Oregon

Waste Management Disposal Services of Oregon, Inc. acquired the Facility on January 31, 1989, from Canal Capital Corp.

1.3.2.6 1990s

1.3.2.6.1 Facility Wastewater Treatment System

In August 1990, Harbor Oil installed a wastewater treatment system to comply with City of Portland sanitary sewer discharge requirements and to comply with the DEQ consent order. The system was designed to treat wastewater from waste oil processing and provide pre-treatment before discharge to the City of Portland sanitary sewer system. Prior to the installation of this system, wastewater from waste oil processing was stored and treated in Tank 23 and then further treated through flocculation in Building 5 before being released to the stormwater treatment system (Figure 1-3). After August 1990, stormwater runoff flowed directly to the stormwater treatment system.

The wastewater treatment system was described in *A Condensed Process General Description, Oil/Wastewater Treatment Facility* (Advanced Treatment Systems 1993), which stated that a concrete drip containment pad collected spills that occurred during the transfer of oil and oily wastewaters from tanker trucks to a 4,000-gallon screened sump tank. The pad also collected water used to wash down trucks following

the discharge of their oily wastewater. The contents in the sump were pumped into either Tank 7 or Tank 15, or in rare cases into Tank 23. Tank 23 was only used when the water contained little oil. Oily water pumped to Tank 7 was heated to separate most of the oil from the water; following separation, the water was pumped to Tank 15. The floating oil was pumped to the oil processor for further refinement. After Tank 15 was at least half full, its contents would be pumped into the flocculator tank, where it was mixed with caustic soda and ferric chloride to form a sludge containing organic compounds and metals. The supernatant water was pumped to an oily water treatment system that included oil removal, particle filtration, and activated carbon, and was then stored in Tank 16; the sludge was pumped into a sludge tank for further separation (through settling) and treatment (through evaporation).

The Advanced Treatment Systems document (1993) indicated that Tank 23 provided active bioremediation of sediment sludges through aeration, circulation, mechanical oil skimming, periodic addition of bacteria, and maintenance of nutrients. Water was pumped from Tank 23 for additional physical treatment (i.e., flocculation) in a tank located in Building 5. The treated water was then pumped to Tank 16 where it was tested prior to discharge to the City of Portland sewer system.

The document (Advanced Treatment Systems 1993) also discussed the Detrex tanker truck-cleaning system. The Detrex system was used to clean the internal surfaces of trucks. The tanker truck-cleaning operation included a diesel-fired heater, which was used to heat a storage tank containing TCE and water. The TCE/steam mixture was used to clean tanker trucks. The spent cleaning solution was drained onto a concrete pad where it was collected in a curtain drain and pumped back to the heated storage tank. The truck cleaning operation was a closed-loop, stand-alone process that was not physically connected to the Facility wastewater treatment system.

The Advanced Treatment Systems document (1993) included a laboratory report for a sample collected from Activated Carbon Bed No. 1, in the Facility wastewater treatment system. The sample contained acenaphthene, benzene, 1,1,1-trichloroethane, 1,1-dichloroethane (1,1-dichloroethane), 2-chlorophenol, 2,4-dimethylphenol, ethylbenzene, phenol, bis(2-ethylhexyl) phthalate, butyl benzyl phthalate, di-n-butyl phthalate, diethyl phthalate, dimethyl phthalate, acenaphthylene, anthracene, fluorene, phenanthrene, tetrachloroethylene, perchloroethylene (PCE), toluene, TCE, and vinyl chloride. The document stated that any TCE found in the wastewater treatment system's activated carbon filters came from its ubiquitous nature in numerous oils and oily wastewaters processed at the Facility, not from the Detrex system.

1.3.2.6.2 Water Supply Well

In 1990, the plant well was being used to provide the water supply for emergency fire control; it was not being used as a potable water supply. The use(s) of this well between 1977 and 1990 is uncertain.

1.3.2.6.3 1991 Facility Conditions

A 1991 color infrared aerial photograph (CEC 2002) of the Facility shows the tank farm and used oil processing area with what appears to be secondary containment, as well as the covered truck loading and unloading rack. The current stormwater treatment system was in place. The far northwestern end of the Facility was still undeveloped.

1.3.2.6.4 1992 DEQ RCRA Inspection

A DEQ Resource Conservation and Recovery Act (RCRA) inspection conducted in June 1992 found an oily substance on the ground that Harbor Oil stated was lignin that was being used as a dust suppressant (DEQ 1995). DEQ determined that the Facility generated one 55-gallon drum per month of F001 hazardous waste (TCE sludge); however, because there were 170 drums (contents unspecified) at the Facility during the visit, Harbor Oil was listed as a RCRA large-quantity generator. Two of the drums were open, and at least one drum had leaked. DEQ cited Harbor Oil for storage of hazardous waste without a permit, failure to make hazardous waste determinations, and failure to retain Land Disposal Restriction forms. DEQ assessed a civil penalty of $10,777 for these violations, which Harbor Oil paid in May 1993.

1.3.2.6.5 Cessation of Dust Suppression Business and Tanker Truck Cleaning

The dust suppression business ceased operating in 1993. According to CEC (2002), the tanker truck cleaning operation ceased in 1994.

1.3.2.6.6 Stormwater Sampling

DEQ's water quality file contained stormwater sampling results submitted by Harbor Oil to DEQ between 1994 and 1999. During that period, stormwater samples were analyzed for pH, TSS, oil and grease, chemical oxygen demand (COD), total phosphorus, TOC, arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc.

1.3.2.6.7 1994 DEQ Site Inspection

A June 30, 1994 DEQ inspection report stated that Harbor Oil was processing used oil by blending and cooking (DEQ 1994). Used oil was stored in four tanks heated by two natural gas-fired boilers. Harbor Oil also had one oil-fired boiler for the Detrex system. Incoming raw materials consisted of approximately 80% used motor oil and 20% oil containing less than 50 mg/kg PCBs that was tested and separated by concentration. Oil with PCB concentrations above 8 mg/kg was stored for shipment to Ash Grove Cement. Oil with PCB concentrations below 8 mg/kg was blended by Harbor Oil into product, which contained less than 0.5 mg/kg PCBs. Harbor Oil burned some of the product in the onsite oil-fired boiler.

1.3.2.6.8 1994 Sampling of North Drainage Ditch

In August and September 1994, at the request of Jordan Schnitzer Properties, Golder Associates sampled soil from the drainage ditch, and installed and sampled a shallow monitoring well near the drainage ditch (DEQ 1995). Soil samples collected at 40-ft intervals (horizontal spacing) along the ditch at depths of between 0.5 and 1 ft contained diesel and heavy oil at concentrations ranging from 1,400 to 11,000 mg/kg. The DEQ Strategy Recommendation (1995) discussed this sampling effort but did

not mention whether the soil samples were analyzed for analytes other than diesel and heavy oil.

1.3.2.6.9 1994 Limex Diesel Release

According to the DEQ Strategy Recommendation (1995), 50 to 150 gallons of diesel were released in November 1994 by Limex Transportation, Inc., from a faulty valve on a 300-gallon AST located on the adjacent Limex property, located north of the Facility. The diesel flowed into the drainage ditch between the Limex property and the Facility, entering the wetlands. Cleanup involved product recovery and some soil removal from the most heavily impacted wetland areas. DEQ suspended soil removal activities after determining that an oily layer 16 in. below the surface represented pre-existing conditions. The DEQ Strategy Recommendation (1995) did not specify where the soil removal activities were conducted.

1.3.2.6.10 Property Sale to Harbor Oil

Waste Management Disposal Services of Oregon sold the property to Harbor Oil, Inc. on December 14, 1994.

1.3.2.6.11 1995 DEQ Notification of Site Listing

In June of 1995, DEQ notified owners and operators of the Facility of the agency's proposal to place the property on its "Confirmed Release List" and "Inventory List."

1.3.2.6.12 1996 Mutual Agreement and Order

In 1996, Harbor Oil proposed to install an off-gas/steam condensation system to reduce volatile organic and halogenated organic emissions produced from waste oil reprocessing operations. The proposal was in response to Mutual Agreement and Order (MAO) No. AQP-NWR-96-206 between DEQ and Harbor Oil. The MAO was issued because DEQ had received periodic complaints of strong, acrid odors (fugitive emissions) from the Facility. The odors were documented by DEQ on December 11, 1995, and February 14, 1996 (DEQ 1996c). The MAO required Harbor Oil to:

- Install controls adequate to abate nuisance conditions resulting from the heating of used oils or cease heating used fuel oils
- Limit production to 5.9 million gallons of used fuel oil and/or gasoline in calendar year 1996 unless satisfactory controls were installed
- Limit emissions from the re-refining Facility to no more than 9.9 tons per calendar year of any hazardous air pollutant or 24.9 tons per calendar year of any combination of hazardous air pollutants
- Submit a final control strategy to DEQ by August 29, 1996

Analyses of incoming raw waste oil and RFO indicated that they contained detectable concentrations of benzene, sec-butylbenzene, ethylbenzene, isopropylbenzene, p-isopropyltoluene, naphthalene, n-propylbenzene, toluene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, xylenes, methylene chloride,

1,1,1-trichloroethane, TCE, and PCE. The incoming raw waste oil and RFO were not analyzed for PCBs.

1.3.2.6.13 1996 DEQ Site Inspection

A 1996 DEQ inspection report (DEQ 1996c) discussed the February 14, 1996, odor. It also described the Facility processes, which included the blending and cooking of used oil that was placed in four vented, heated tanks to evaporate water. The tanks were heated by two natural gas-fired boilers, which had the capacity to burn oil as a backup fuel. In the process of evaporating water from used oil, VOCs and possibly some hazardous air pollutants were also evaporated. At the time, the heating oil tank vents were uncontrolled. Harbor Oil also had a diesel storage tank and diesel-fired boiler for the Detrex system. The raw material received by Harbor Oil was mainly used motor oil, although they did receive and process some oil containing less than 50 mg/kg PCBs. The 1996 DEQ inspection report did not include any analytical results to substantiate that PCB concentrations were less than 50 mg/kg. The report states that "Harbor Oil's raw materials consist of mostly used motor oil. They do receive and process some PCB-contaminated oil (< 50 mg/kg)."

According to the report, the Facility also used two heated storage tanks, Tank 23, the stormwater treatment system, six 20,000-gallon oil storage tanks, two 20,000-gallon wastewater tanks, one 205,000-gallon finished oil tank, one 20,000-gallon truck fuel storage tank (for shipment off the Facility), and one truck fuel tank for use at the Facility.

1.3.2.6.14 1996 RCRA Inspection

According to DEQ's updated Strategy Recommendation (DEQ 1998b), a November 1996 RCRA inspection found that Harbor Oil received and processed used oil, off-specification fuels, and oily or petroleum-contaminated wastewater. The Facility also managed a limited quantity of used oil filters and waste antifreeze containers.

On November 19, 1996, DEQ sent Harbor Oil a notice of noncompliance for violations of Oregon's hazardous waste and used oil management regulations (DEQ 1996b), based on its November 8, 1996, DEQ inspection. At that time, Harbor Oil was a Conditionally Exempt Small Quantity Hazardous Waste Generator. Violations included:

- Storage of hazardous wastes at an un-permitted facility (specifically, Harbor Oil stored wastes from the tanker truck cleaning operation for longer than 90 days after it was generated)
- Failure to correctly file annual hazardous waste generator reports (reports were not filed for shipments made in 1992 and 1993)
- Failure to correctly develop a contingency plan designed to address potential facility releases as required under 40 CFR 279.52(b), as adopted in Oregon Administrative Rule (OAR) 340-100-002
- Failure to develop an analysis plan for used oil management

The inspection results were summarized in DEQ's November 8, 1996 Hazardous Waste/Used Oil Processor Compliance Evaluation Inspection

report (DEQ 1996a). By December 1996, Harbor Oil had taken actions to correct the violations (Harbor Oil 1996b).

A 1996 Emergency Preparedness and Contingency Plan prepared by Harbor Oil stated that the Facility stored and used the following materials: used oil, oily wastewater, used oil vapor-recovery condensate, diesel fuel, mineral spirits (laboratory solvent), toluene (laboratory stock), caustic soda, ferric chloride, antifreeze (ethylene glycol), mixed fuels (gasoline, diesel, etc.), propane (forklift fuel), oxygen (welding tanks), and acetylene (welding tanks) (Harbor Oil 1996a). Attached to the plan was a used oil and petroleum-contaminated water analysis plan, which stated that used oil was tested for total metals (arsenic, cadmium, chromium, and lead), total halogen content, PCBs, and sulfur content. Wastewater was tested for pH, ammonia, oil and grease, total metals (cadmium, chromium, nickel, and lead), flash point, and chlorinated hydrocarbons.

A 1998 aerial photograph (Appendix A) suggests facility features at that time were very similar to those that existed in 1991.

1.3.2.6.15 1998 DEQ Site Inspection

DEQ conducted a site inspection on March 19, 1998 (DEQ 1998a). Issues of concern identified during the site inspection included:

- The combustion of condensate collected from the heating tanks, which would require quantification of metals and halogen concentrations in the condensate
- The approach used to calculate air emissions
- Vapors exiting the cable outlets on cooking tanks
- Dust/fugitive emissions from truck traffic

1.3.2.6.16 EMRI Operations

EMRI took over the operation on October 1, 1999 after Harbor Oil ceased doing business on the property. That same year, DEQ issued NPDES Industrial Stormwater Discharge Permit 1200-COLS to EMRI for the stormwater treatment system.

On December 30, 1999, EMRI submitted an application to transfer ACDP No. 26-3021 from Harbor Oil effective January 1, 2000.

Under its air quality permit, EMRI indicated that it processed 1.9 million gallons of raw used oil in 1999; the report did not contain information on the actual halogen content of used oil held for processing (estimated to be about 700 mg/kg), or the PCB, metal, or halogen content of reprocessed fuel burned at the Facility.

1.3.2.7 2000 to Present

A January 27, 2000, DEQ air quality file memorandum (DEQ 2000b) discussed the numerous odor complaints that had been received by DEQ, and noted that none had been received since EMRI took over the operation. The memorandum indicated that the prior owner had failed to complete all monitoring and reporting requirements set forth in ACDP No. 26-3021. The memorandum stated that the permit set limits on the metal, PCB, and halogen content of reprocessed fuels burned at the Facility,

allowing less than 2 mg/kg PCBs and less than 1,000 mg/kg total halogens. The memorandum stated that EMRI wanted to burn oil that contained PCBs up to the allowable regulatory limit of 49 mg/kg (off-specification fuel) and increase the total halogen limit to 4,000 mg/kg.

1.3.2.7.1 2000 DEQ Site Inspection

A DEQ Northwest Region Multi-Media Checklist in the DEQ air quality file for a September 27, 2000, SI (DEQ 2000c) included the following issues and observations:

- Opacity issue, potentially as a result of startup
- Stains in the northwest corner of the truck loading and unloading rack area
- Stained soil near the northwest corner of the pad where drums were being stored outside the containment pad, with leaks from the drums being the apparent source of contamination
- Clor-D-Tect® kits and excess plastics in the FPI kiln. DEQ had concerns regarding solid waste incineration and potential releases of mercury and cadmium

In October 2000, DEQ issued a notice of non-compliance (DEQ 2000a) to the Facility for: 1) storage of drums outside the containment pad, and 2) a gap between the wall and pad along part of the south side of the used oil processing area. DEQ requested that the contaminated soil be removed and properly disposed, the gap be sealed, and a plan be submitted to prevent future releases from escaping the loading area. DEQ's findings were documented in a September 27, 2000, used oil processor inspection report (DEQ 2000d). EMRI objected to each of DEQ's requested actions in a November 27, 2000, letter to DEQ (EMRI 2000). Based on the file information, it appears that EMRI did not remove the contaminated soils.

1.3.2.7.2 ACDP Reporting

In its 2000 annual report for ACDP Permit No. 26-3021, EMRI reported that it processed 4.5 million gallons of raw used oil with a halogen content of 200 mg/kg. Maximum PCB and metal concentrations in reprocessed fuel burned at the Facility were PCBs (6.38 mg/kg) and lead (0.5 mg/kg). Cadmium, arsenic, chromium, and total halogens were not detected.

Laboratory data in the DEQ air quality file indicated that in 2001 and 2002, PCBs were present in fuel oil stored in Tank 24 at concentrations ranging from less than the detection limit of 5 mg/kg to 6.2 mg/kg. PCBs were not detected in "incoming used oil" during that time. In 2001, incoming oil contained detectable concentrations of lead (8 to 37 mg/kg), cadmium (0.2 to 0.4 mg/kg), chromium (0.6 to 1.2 mg/kg), and total halogens (200 to 600 mg/kg). In 2001, the product in Tank 24 contained lead (0.5 to 2.2 mg/kg), cadmium (not detected to 0.06 mg/kg), chromium (not detected to 0.24 mg/kg), and total halogens (not detected to 3,700 mg/kg).

Under ACDP Permit No. 26-3021, EMRI submitted its 2002 Annual Air Quality Report stating that it processed 7.2 million gallons of raw used oil that had a halogen content ranging from 200 to 500 mg/kg. Reprocessed

fuel burned at the Facility contained detectable concentrations of cadmium (0.02 mg/kg), lead (19 mg/kg), chromium (0.3 mg/kg), and total halogens (100 mg/kg). PCBs were not detected.

In 2003, 3.6 million gallons of raw used oil were processed, and 49,000 gallons of oil with less than 50 mg/kg PCBs were blended into off-specification use fuels.

EMRI's 2005 annual report issued under its ACDP stated that it processed 3.3 million gallons of raw used oil.

1.3.2.7.3 Stormwater Sampling

Between 2000 and 2006, EMRI reported exceedances of permit benchmark values for one or more of the following analytes in samples collected from the stormwater treatment system discharge: total phosphorus, TSS, *E. coli*, lead, copper, oil and grease, and BOD. During this time, stormwater discharge samples collected by EMRI were analyzed for these seven analytes and zinc.

In 2000, EMRI collected samples from the portion of the drainage ditch that ran along the northeast side of the Facility. The sampling results indicated that lead and *E. coli* were migrating onto the Facility from a source or sources located off the Facility (CEC 2000). At the time the samples were collected, drainage entered this portion of the ditch from topographically higher properties immediately adjacent to and north of the Facility (e.g., Former Farmer's Plant Aide, Former Limex Transportation, and Bulk Transportation facilities and Peninsula Terminal Railroad). The drainage would have flowed down the ditch along the northeast and northwest sides of the Facility and discharged into the wetlands near the southwest corner of the Facility; the drainage would not have discharged into the current storm water treatment system. As discussed below, this drainage pattern changed in 2002 when EMRI closed off the portion of the drainage ditch that ran along the northeast side of the Facility and instead installed catch basins connected to the current storm water treatment system.

On August 20, 2001, the City of Portland notified EMRI that it was in violation of its stormwater permit because it failed to collect a sufficient number of samples for the year July 1, 2000, through June 30, 2001.

1.3.2.7.4 Resolution of Used Oil and Hazardous Waste Compliance Issues

On November 2, 2001, DEQ stated that all operations at the Facility (Fuel Processors, Inc.; EMRI; the Oil Re-Refining Co.; and Harbor Oil) were in compliance with the facility management plan and the used oil and hazardous waste regulations and statutes (DEQ 2001b). All alleged violations cited in Notices of Noncompliance or Notices of Assessment of Civil Penalty issued by DEQ had been resolved. The letter references MAO No. WMC/HW-NWR-99-207.

1.3.2.7.5 New Base Oil Refining Plant Construction

EMRI constructed the new base oil refining plant in the northwestern portion of the Facility in 2003. The construction of the new plant required that soils be excavated from within the plant footprint. These soils are

currently stockpiled northwest of the base oil refining plant, near the northern corner of the property (Figure 1-6).

According to D. Coles (2010b), who oversaw the excavation and stockpiling of soil during the construction of the base oil plant, evidence of oil impacts was apparent. As the soil was being excavated, zones of "clean" soil (with minor or no visual indication of impact) were observed interspersed with layers or lenses of soil that had dark staining and a petroleum odor or that appeared to be saturated with oil. Coles indicated that these layers or lenses might typically be on the order of 1 inch thick by several feet in length and were not continuous over the area of excavation but instead were patchy and were interspersed with soils with no or less substantial evidence of impact. In addition, field notes related to soil sampling conducted as part of the construction (2010b), noted the presence of an oily sawdust layer, as well as the presence of coal fragments and miscellaneous debris.

According to D. Coles (2010b), wells EW-1 through EW-3 (Section 2.0) were installed within granular backfilled foundation support pits or electrical pits coincident with the new base oil refining plant construction. Specifically, these wells were reportedly installed within the existing construction-related pits based on the recognition that pits filled with granular material extending beneath the water table within the oil plant area would make excellent LNAPL collection points and that it would be remiss to not plan ahead for the removal of any potential accumulated LNAPL.

As described in Section 2.3.1.3, the presence of more than trace levels of LNAPL has never been identified in wells EW-1 through EW-3, and for that reason, they have never been used. The function of wells EW-1 through EW-3 remains entirely precautionary.

1.3.2.7.6 Drainage Ditch Modification

According to D. Coles (Coles 2007b), EMRI closed off the drainage ditch that ran along the northeastern property boundary in approximately 2002. Since that time, stormwater from this area has been captured by catch basins and conveyed to the current stormwater treatment system; it no longer flows from this area into the wetlands northwest and southwest of the Facility (CEC 2002).

1.3.2.7.7 National Priorities List Listing

The Harbor Oil Site was placed on the National Priorities List on September 29, 2003.

1.3.2.7.8 2003 ACDP

DEQ issued ACDP No. 26-3021 on October 24, 2003. The permit allowed the use of fuel containing arsenic (5 to 10 mg/kg), cadmium (2 to 4 mg/kg), chromium (10 to 20 mg/kg), lead (100 to 300 mg/kg), PCBs (2 to 49 mg/kg), and total halogens (1,000 to 4,000 mg/kg). It established plant emission limits for particulate matter (PM), PM_{10}, sulfur dioxide (SO_2), nitrogen oxides (NO_X), carbon dioxide (CO_2), and VOCs. It prohibited the processing or evaporation of any wastewater with a total halogen content greater than 1,000 mg/kg and total VOC content greater than 1,000 mg/kg.

According to the DEQ air quality file, between 2001 and 2006 DEQ received numerous complaints regarding odors potentially coming from the Facility.

1.3.2.7.9 2004 ATSDR Public Health Assessment

In 2004, the Agency for Toxic Substances and Disease Registry (ATSDR) issued a public health assessment for the Facility (ATSDR 2004a). The assessment concluded that:

- Exposure to chemicals found in the drainage area and wetlands adjacent to Force Lake represented a complete exposure pathway. Exposure to this area was not anticipated to result in adverse health effects. However, the existing data for this area were limited in sample number and geographic location.
- The level of contamination in fish tissue and information regarding populations that may consume fish from Force Lake was unknown, which limited the ability to completely characterize the risks to human health.
- Soils, groundwater, ambient air, soil vapor and surface water pathways from Facility were considered to be potential exposure pathways because of the lack of data for these pathways.
- Based on the existing environmental data, the Superfund Health Investigation and Education program considered the Study Area to be a no apparent public health hazard.

1.3.2.7.10 2004 Facility Operations

A 2004 Emergency Preparedness and Contingency Plan prepared by EMRI (2004) indicated that materials handled by the Facility included: used oil-asphalt, oily wastewater, used oil vapor recovery condensate, diesel fuel, mineral spirits (laboratory solvent), toluene (laboratory stock), caustic soda, antifreeze (ethylene glycol), mixed fuels (gasoline, diesel, etc.), propane (forklift fuel), oxygen (welding tanks), acetylene (welding tanks), boiler chemicals (Scalex, sodium sulfate, oxygen scavenger), water treatment chemicals (lime, soda ash, magnesium sulfate, magnesium oxide, sodium bicarbonate, and aluminum sulfate), water-based paints, oil-based paints, shop chemicals (WD-40 lubricant, penetrating oils, rust penetrants, never seize lubricants, cutting oils, and corrosion inhibitors and cleaners), carbon, and concrete sealers.

1.3.2.7.11 2005 Updated SPCC

In January 2005, EMRI submitted an updated SPCC plan for the Facility (EMRI 2005).

1.3.2.7.12 2006 DEQ Site Inspection

According to information in DEQ's hazardous waste file for the Facility, DEQ performed a site inspection on June 22, 2006, and returned to collect oil and water samples from Tank 23 on July 4, 2006 (DEQ 2006a). DEQ did not discover any hazardous waste regulation violations, but did request that EMRI create policies and guidance documents for crack repair and for the elimination of standing water in secondary containments. DEQ observed cracks and a small hole in the secondary containment around the oil cooker units that required repair. DEQ also

had concerns about the contents of Tank 23. These concerns prompted DEQ to return to the Facility on July 5, 2006, to collect samples from Tank 23 to determine if oil and water in the tank contained any hazardous chemicals and if EMRI could put the oil and water through their process. The samples collected by DEQ were analyzed for VOCs, SVOCs, PCBs, pesticides, toxicity characteristic leaching procedure metals, total halogenated organics, and pH. According to DEQ's July 5, 2006, site inspection report (DEQ 2006a) and subsequent letter to EMRI (DEQ 2006b), no listed hazardous chemicals were detected in the EMRI samples and DEQ decided to allow EMRI to put the oil and water through their re-refining process. DEQ also requested that EMRI prepare a sampling plan for testing sludges in the bottom of Tank 23.

1.3.2.7.13 Wevco Biodiesel Operation

In July 2006, Wevco Biodiesel notified DEQ of its intent to construct a process to convert fats and oils and greases into alternative food grade oil that would be blended with 20% of EMRI's 100N oil. The operation was to be located in the warehouse and awning area, and was projected to produce 250,000 to 300,000 gallons per month. DEQ issued air quality permit No. 26-0148 for the operation. A Notice of Approved Construction Completion was submitted to DEQ on September 1, 2006.

1.3.2.7.14 2006 NPDES Permit

According to information in DEQ's water quality file for the Facility, the current NPDES permit was issued on October 5, 2006.

On March 20, 2007, EMRI submitted a written action plan (EMRI 2007b) under their 1200-COLS permit as a result of elevated total phosphorus and TSS levels. The written action plan stated that EMRI was in the process of implementing corrective actions, including the potential use of an alternative cooling tower corrosion inhibitor and anti-algae/fungus treatment chemicals that have lower phosphorus contents. The cooling tower corrosion inhibitor and treatment chemicals were identified in EMRI's January 19, 2007, written storm water action plan (EMRI 2007a), along with runoff from truck washing operations conducted on the adjacent Bulk Transportation property.

1.3.2.7.15 Tank 23 Contents Characterization

In mid-2007, EMRI agreed with EPA to characterize the contents of Tank 23 under a separate AOC. On August 16, 2007, EMRI collected samples from four locations in Tank 23 following the procedures described in a work plan prepared by CEC (2007c). The Voluntary Group observed sample collection activities and collected split samples for analysis.

The sampling approach and analytical results for the samples, including the analytical results for the Voluntary Group split samples, were submitted to EPA in a letter report prepared by CEC (CEC 2007b). The sludge samples were analyzed for VOCs, SVOCs, PCBs, pesticides, herbicides, TPH, metals, and pH. As reported by CEC (2007b), sludge in the tank (estimated at 250,000 gallons) was found to contain approximately 2% gasoline-range TPH and approximately 21% combined diesel- and oil-range TPH. In addition, total PCBs (15.4 mg/kg) and total

chlorinated VOCs (372 mg/kg), as well as varying concentrations of PAHs, phthalates, phenols, and metals were identified in the sludge. No organochlorine pesticides or chlorinated herbicides were detected in the sludge.

In 2008, EMRI removed oil, water, and sludge from Tank 23 and transported them to the Fuel Processors facility for treatment. Some of the sludge material was taken to Coffin Buttes Landfill located near Corvallis, Oregon. Once the tank was empty, it was scraped and pressure washed, and the side of the tank was cut open for access (CEC 2008). EPA issued a notice of completion for the work on November 13, 2008 (EPA 2008).

1.3.2.7.16 2009 Facility Fire

On July 24, 2009, a fire occurred at the Facility while workers were refueling a tank that provided fuel for a burner in the northeastern corner of the used oil processing area. Fire crews were able to quickly contain the fire, which was burning the foam insulation around the tanks in this area, and were able to prevent the fire from spreading and igniting other nearby fuels. No structural damage was reported to the tanks, and there was no evidence of a release of oil or oily water to areas beyond the secondary containment of the tank farm (Salem News 2009; GeoDesign 2009; LeCocq 2009).

1.3.3 Historical Investigations

Between 1990 and 2007, when the Voluntary Group entered into the AOC, the following investigations had been conducted in the vicinity of the Study Area:

- 1990 SI and preliminary remediation plan for Portland Stockyards by Golder Associates (1990).
- 1997 surface water and sediment sampling of Force Lake by the City of Portland (City of Portland 1997)
- 2001 Harbor Oil Site PA/SI by EPA (Ecology and Environment 2001)
- 2003 soil sampling by CEC (2007b)
- 2006 City of Portland Heron Lakes Golf Club water quality sampling (Goodling 2007)

Other earlier investigations (e.g., Sweet-Edwards/EMCON 1988) are not discussed in this evaluation of historical SIs because of their incomplete documentation and uncertain data quality.

EMRI's work plan for the characterization of the contents of Tank 23 discussed various water, oil, and sludge sampling events that occurred between 1988 and 2006 (CEC 2007c). This sampling event characterized the sludge present in Tank 23 (Section 1.3.2.7.5) but is not relevant for characterizing Study Area conditions.

Figure 1-7 illustrates the locations where pre-RI soil and surface water samples were collected on the Facility. Figure 1-8 illustrates the locations

where pre-RI wetland soil and surface water samples were collected outside of the Facility but within the Study Area. Note that the City of Portland did not identify the specific locations where sediment and surface water samples were collected in Force Lake (City of Portland 1997). Figure 1-9 shows the locations of pre-RI groundwater monitoring wells, extraction wells, and the plant well located on the Facility.

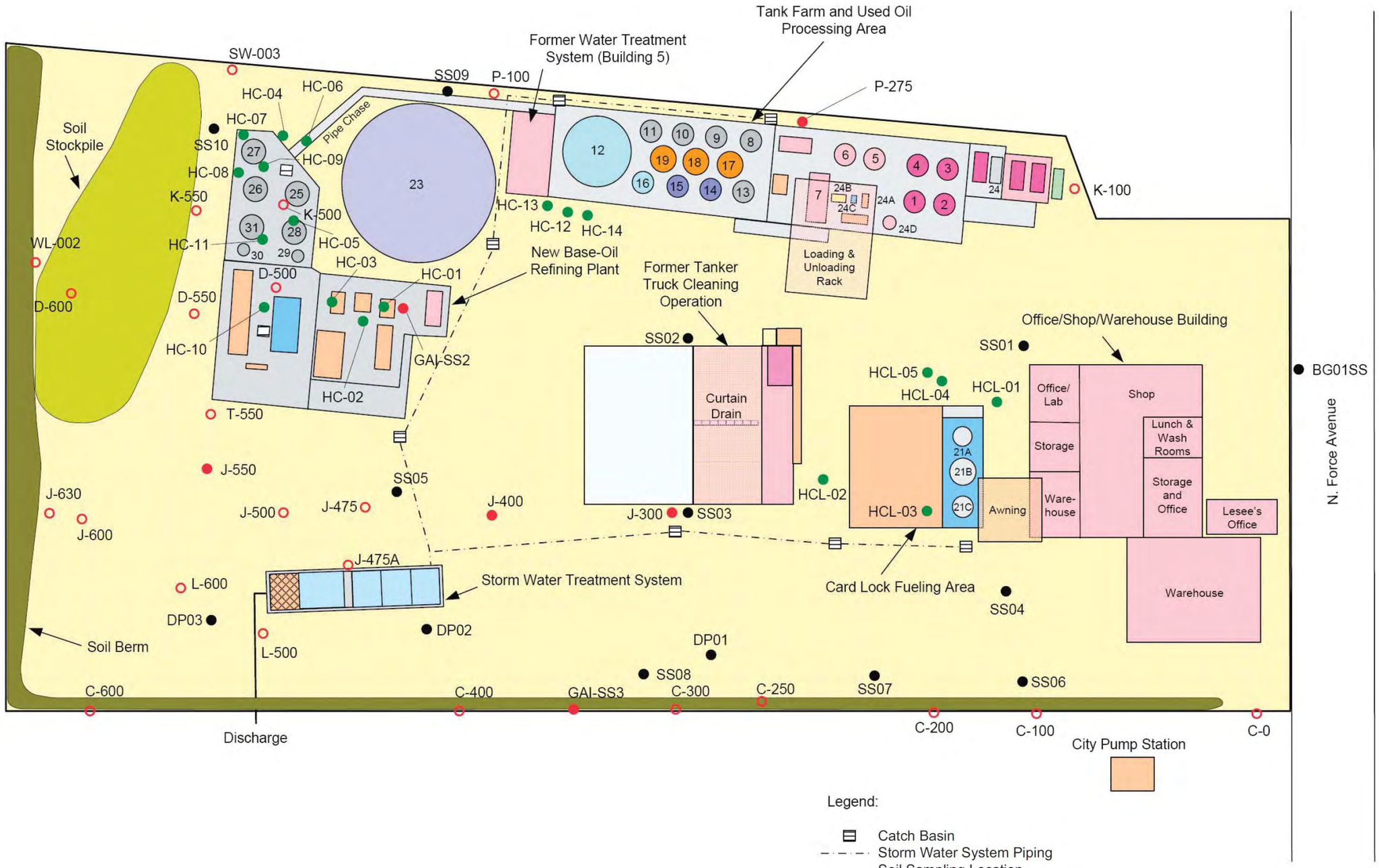
1.3.3.1 1990 Portland Stockyards Site Investigation

The 1990 Portland Stockyards SI included the collection of samples on the Facility, in the wetlands, and on a number of nearby properties (e.g., the former Portland Livestock Auction, Inc. [Stockyards], Peninsula Terminal Railroad, Star Oil, and Former Farmer's Plant Aide/Former Limex Transportation/Bulk Transportation facility) (Golder Associates 1990). With the exception of the deep regional groundwater investigations completed by Golder Associates in 1990 (Golder Associates 1990), this section summarizes the samples that were collected on the Facility and in the adjacent wetlands as part of this investigation.

Surface soil samples were collected at two locations: P-100 and P-275. Subsurface soil samples were typically collected at depths of 2.0 or 2.5 ft bgs and/or 5.0 or 6.0 ft bgs at 14 locations: P-275, K-550, D-550A, D-550B, K-500, J-550, J-600, J-630, J-650, C-0, J-400, J-475, L-500, T-550, WL-001 and WL-002 (see Figure 1-7). Deeper subsurface soil samples were collected at depths of 10 and/or 15 ft bgs at 10 locations: D-550B, K-500, J-550, K-600, J-630, J-650, J-300, J-400, J-475, and T-550. A total of 39 soil samples were analyzed in a field laboratory using gas chromatography (GC) for benzene, toluene, m,p-xylenes (and ethylbenzene), o-xylene, 1,1-dichloroethylene, trans-1,2-dichloroethylene, 1,1,1-trichloroethane, TCE, PCE, and 1,3-dichlorobenzene, and using thin-layer chromatography (TLC) for TPH. Ten of the subsurface soil samples were analyzed in the Close Analytical Support Facility in Redmond, Washington for total lead, chromium, and cadmium. Two surface soil samples (GAI-SS2 and GAI-SS3) and one subsurface soil sample (J-550 at 5.0 ft bgs) were submitted for fixed laboratory analysis of the EPA target analyte list (TAL) of inorganics. Soil samples collected from location J-300 (at a depth of 10.0 ft bgs) and from J-550 (at a depth of 5.0 ft bgs) were submitted for fixed laboratory analysis of organic compounds, including VOCs, SVOCs, pesticides, PCBs, metals and TPH.

Soil samples were collected in the wetlands west of the Facility, typically at depths of 0.0, 2.5, and 5.0 ft bgs, at 10 locations: M-150, M-300, M-450, M-600, N-150, N-300, N-600, O-000, O-100 and O-200 (Figure 1-8). A total of 29 wetland soil samples were analyzed in a field laboratory for benzene, toluene, m,p-xylenes (and ethylbenzene), o-xylene, 1,1-dichloroethylene, trans-1,2-dichloroethylene, 1,1,1-trichloroethane, TCE, PCE, and 1,3-dichlorobenzene, and TPH.

Surface water samples were also collected at six locations. Two samples were collected in the drainage ditch at the same locations as soil samples P-100 and P-275 (Figure 1-7). Three samples were collected in the wetlands to the west of the Facility (SW-003, J-650-SW, and stormwater treatment system discharge). One sample was collected from the



Source: Coles Environmental Consulting, Inc., Energy & Materials Recovery, Inc. Site Diagram (Formerly Harbor Oil, Inc.), March 2005.

Figure 1-7
Historical On-Facility Soil and Surface Water Sampling Locations
Harbor Oil Site

BRIDGEWATER GROUP, INC.

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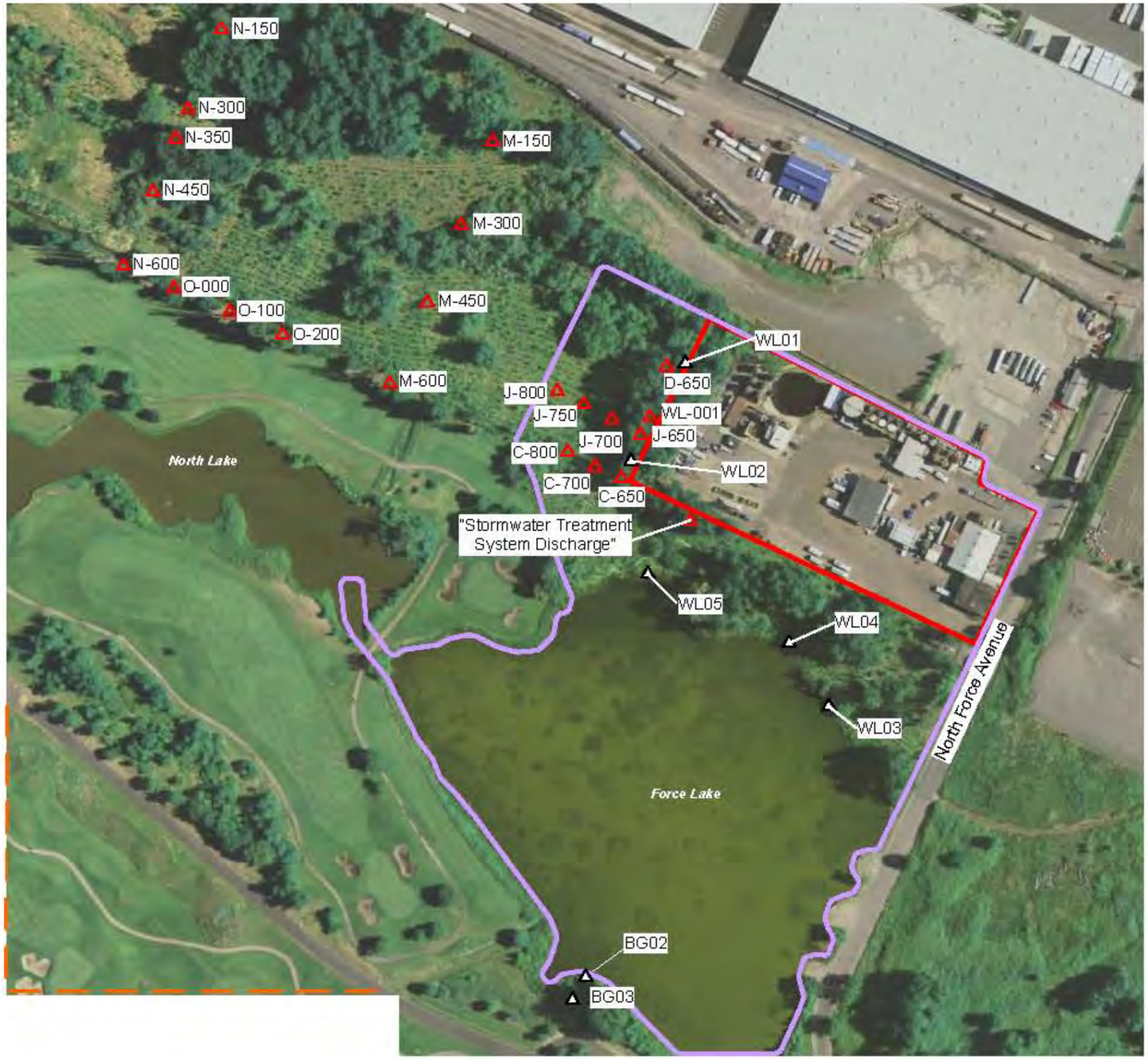


Legend:

Offsite Sampling Locations

- Golder (1990)
- E&E (2001)
- Harbor Oil Facility Boundary
- Harbor Oil RI Study Area Boundary

Note: Force Lake sediment sample (S-1) and water sample (W-1) collected in 1997 are not shown because sampling locations were not identified by the COP.

200 Feet

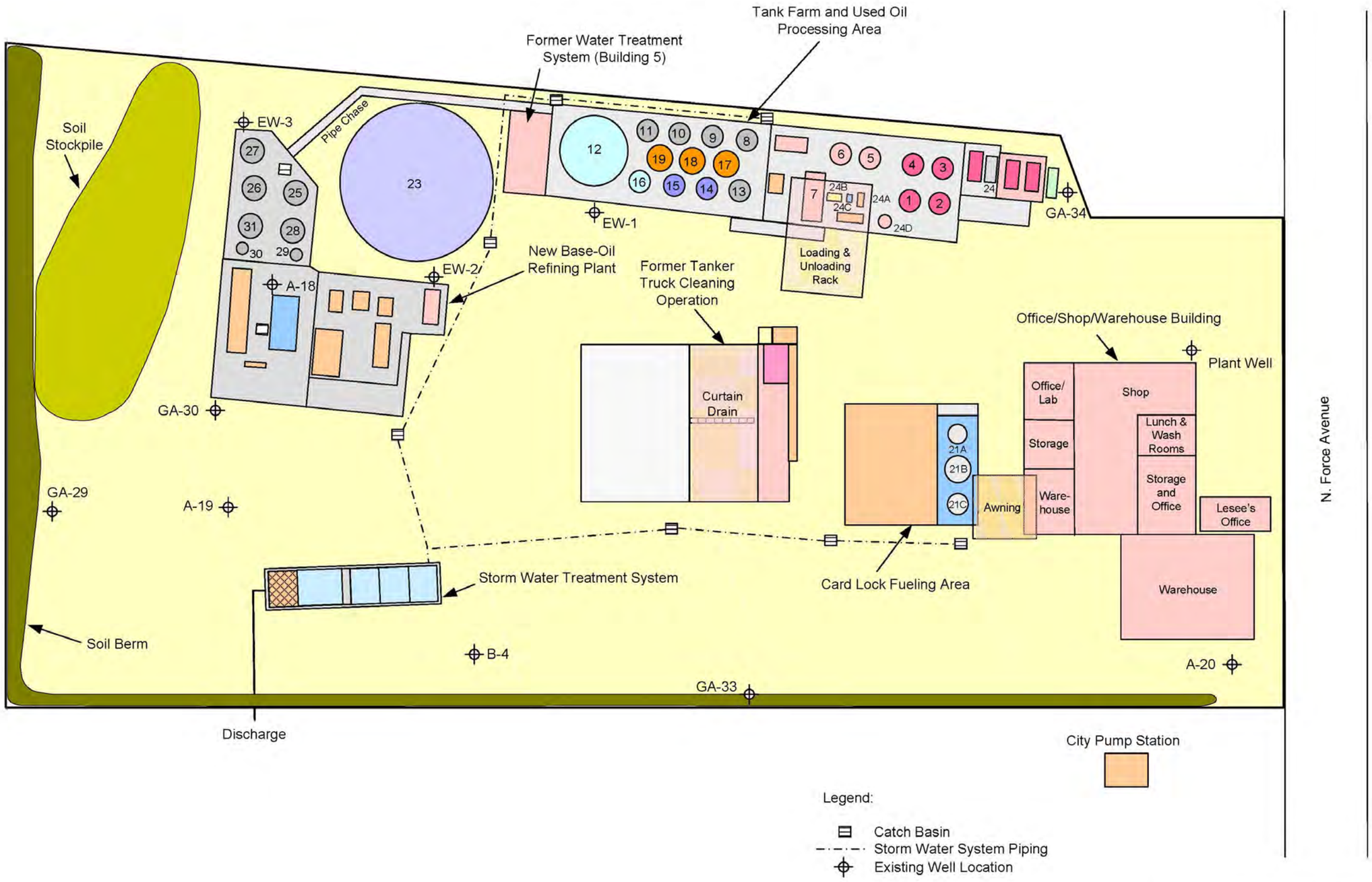
Approximate Scale

Figure 1-8

Historical Off-Facility Soil and Surface Water Sampling Locations

Harbor Oil Study Area

BRIDGEWATER GROUP, INC.



Source: Coles Environmental Consulting, Inc., Energy & Materials Recovery, Inc. Site Diagram (Formerly Harbor Oil, Inc.), March 2005.

Figure 1-9
On-Facility (Pre-RI) Well Locations
Harbor Oil Site

BRIDGEWATER GROUP, INC.

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stormwater treatment system. Three surface water samples were also collected further to the west in the wetlands at locations N-600, O-100 and O-200 (Figure 1-8). They were analyzed in the field laboratory using GC for benzene, toluene, m,p-xylenes (and ethylbenzene), o-xylene, 1,1-dichloroethylene, trans-1,2-dichloroethylene, 1,1,1-trichloroethane, TCE, PCE, and 1,3-dichlorobenzene, and using TLC for TPH.

Surface water samples were also collected at six locations. Two samples were collected in the drainage ditch at the same locations as soil samples P-100 and P-275 (Figure 1-7). Three samples were collected in the wetlands to the west of the Facility (SW-003, J-650-SW, and stormwater treatment system discharge). One sample was collected from the stormwater treatment system. Three surface water samples were also collected further to the west in the wetlands at locations N-600, O-100 and O-200 (Figure 1-8). They were analyzed in the field laboratory using GC for benzene, toluene, m,p-xylenes (and ethylbenzene), o-xylene, 1,1-dichloroethylene, trans-1,2-dichloroethylene, 1,1,1-trichloroethane, TCE, PCE, and 1,3-dichlorobenzene, and using TLC for TPH.

Four groundwater monitoring wells already existed at the Harbor Oil Facility when the 1990 investigation was conducted: A-18, A-19, A-20, and B-4 (Figure 1-9). The “A” wells ranged in depth from 10 to 20 ft. Well B-2 was 91.5 ft deep. Golder Associates installed four additional wells on the Facility: GA-29, GA-30, GA-33 and GA-34 (Golder Associates 1990). All four of these wells were 16.5 ft deep.

Following well installation and development, groundwater samples were collected from all of the newly installed wells and from selected previously installed monitoring wells. Groundwater samples collected from GA-30, A-18 and B-4 were analyzed for TAL inorganics. Groundwater samples collected from GA-29, GA-30, GA-34, A-18, A-19, A-20, and B-4 and the plant well were analyzed in the field laboratory. Groundwater samples collected from A-18, GA-30, and B-4 were analyzed in the fixed laboratory for VOCs and SVOCs.

Analytical testing results of the samples referenced above, collected on or adjacent to the Study Area as part of the 1990 Portland Stockyards SI, have previously been summarized and compared with DEQ and EPA screening levels in the RI/FS Work Plan (Bridgewater et al. 2008b). As described in Section 1.3.4, these data were used to identify data gaps and to assist in the RI study design, but were not deemed to be of sufficient quality to be used in the RI.

It should be noted that pesticides, including DDT, were commonly used at livestock yards for vector and insect control, which was often accomplished by dusting, spraying, or dipping the livestock. As described in Section 4.6, elevated concentrations of DDT and its metabolites (e.g., DDD) have been identified in soil and groundwater at portions of the Harbor Oil Facility, with the greatest concentrations proximate to historical drainage leading from the former livestock truck-cleaning operations area.

Although the presence and distribution of DDT proximate to the former truck wash area is consistent with a source that could be related to the entrainment of DDT in rinse water, review of available historical

information and investigation work at the Portland Stockyards property identified no discussion concerning the use of DDT. Furthermore, no testing results for pesticides at the Portland Stockyards or the adjacent Peninsula Terminal Railroad property (livestock loading/unloading) property have been identified inasmuch as these chemicals were not identified by Golder Associates as contaminants of interest (COIs) for those properties.

DEQ reviewed the results of the 1990 Portland Stockyards SI (Golder Associates 1990), and in February 1992 added the stockyards property to the Confirmed Release List. A priority evaluation of the property was completed in November 1996. Further investigation was recommended by DEQ as a result of the priority evaluation, although the priority for further action was designated as "low." No additional actions by DEQ are known to have occurred since the completion of the priority evaluation in 1996 based on review of the DEQ project files for the property.

1.3.3.2 Regional Deep Groundwater Investigation

An investigation of regional chlorinated solvent impacts on deep groundwater was conducted as a component of the overall investigatory activities related to the Portland Stockyards as described in Section 1.3.3.1. This focused evaluation was conducted by Golder Associates as a result of the identification of TCE and PCE in groundwater samples collected from the Portland Stockyards' production well and other deep wells on or near the Portland Stockyards property.

Specifically, and as documented in the 1990 Portland Stockyards SI (Golder Associates 1990, 1991b), TCE and PCE were identified in deep zone groundwater (Pleistocene gravels, usually greater than 100 ft bgs) in samples collected from both the Harbor Oil supply well (PW-01) and the Portland Stockyards supply well.

Further investigation related to the presence of TCE and PCE in deep groundwater was documented in the report titled *Oregon Waste Systems Deep Groundwater Sampling in the Vicinity of the Portland Stockyards Property* (Golder Associates 1991a***).*** This additional investigation included a well survey and subsequent deep-zone groundwater sample collection at supply wells W-5 (125 ft deep) and W-6 (86 ft deep) at the Heron Lakes Golf Club and at a supply well (166 ft deep) located at the nearby Exposition Center property. In addition, sampling results for the James River Corporation property well No.2 (163 ft deep) were identified and reported.

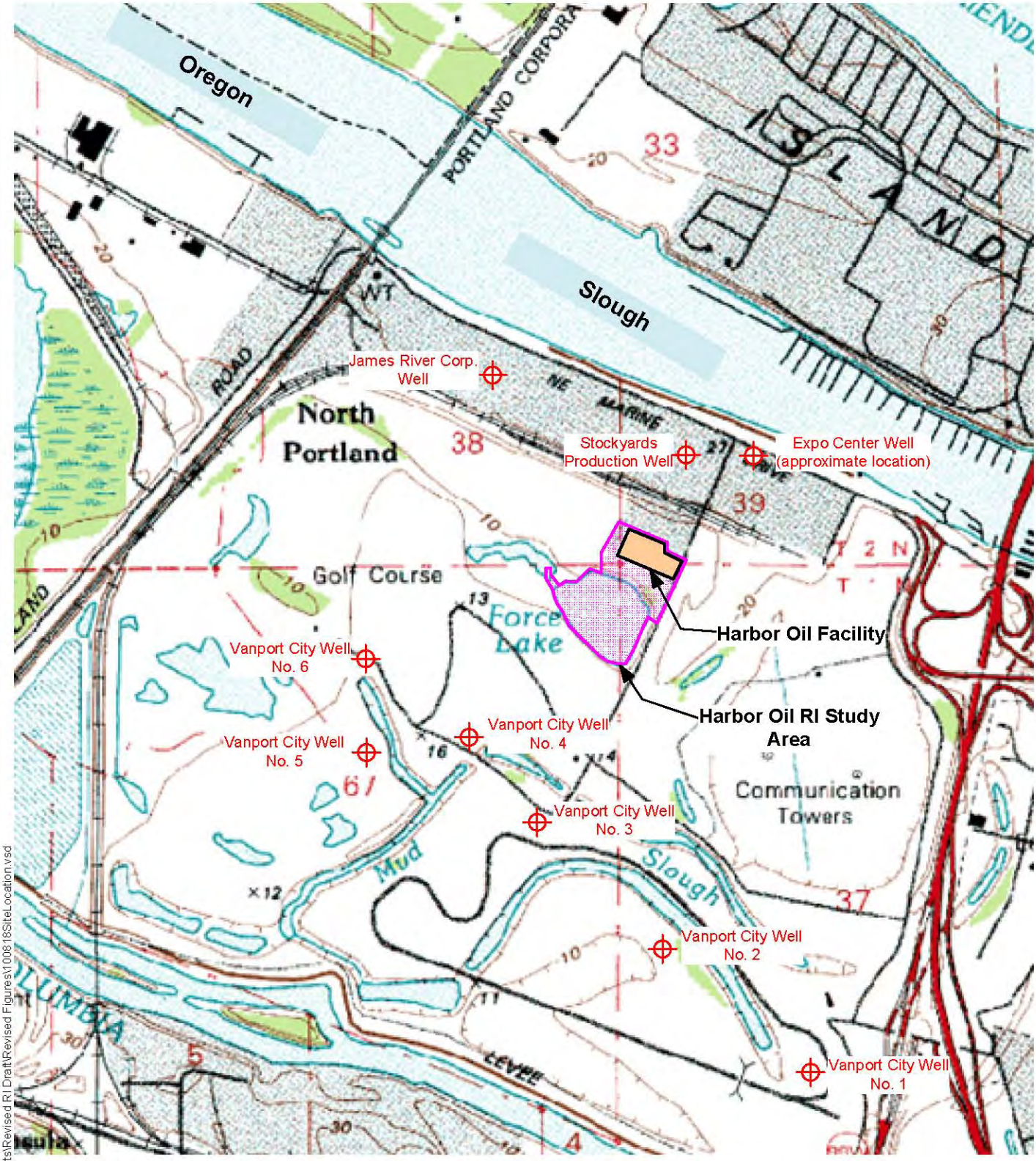
As summarized in Golder Associates (1990, 1991a), testing of groundwater samples collected from the wells described above identified TCE and PCE concentrations within the deep groundwater zone that were relatively uniform across the area (usually between 1 and 20 µg/L). Table 1-1 summarizes TCE and PCE concentrations in groundwater as reported by Golder Associates(1991a, b), as well as more recent data for the Harbor Oil production well. All of the off-site well locations identified in Table 1-1 are shown on Figure 1-10.

Table 1-1. Summary of Historical Regional Deep Supply Well Sampling Results for TCE and PCE

Well Location	Sampling Date	Depth (ft)	Concentration (µg/L)	
			TCE	PCE
Vanport City Well No. 5	1990	125	20	1 U
Vanport City Well No. 6	1990	86	13	1 U
Exposition Center	1990	166	9	4
James River Corporation	1989	163	7.1	20
Portland Stockyards Well	1990	215	9	6
PW-01 (Harbor Oil)	2000	97	6.1	4.2

Source: Golder Associates (1991a) and CEC (2002)
PCE – perchloroethylene
TCE – trichloroethene
U – not detected at given concentration (concentration shown is the reporting limit)

As the data suggest, and as concluded by Golder Associates (1991a), the sampling results are indicative of relatively low-level regional PCE and TCE impacts on the regional aquifer (deep groundwater zone). DEQ reviewed the information as summarized in the Golder Associates reports (1990, 1991a) and added the Portland Stockyards property to the Confirmed Release List in 1992. DEQ also recommended further investigation as an outcome of a priority evaluation. The priority for further action at the property was designated by DEQ as “low,” and there is no record in DEQ files that subsequent investigations have been requested by the agency.



Sources: Force Lake, USGS Portland (OR,WA) Topo Map from TopoZone. Well locations from Golder (1990).
Note: Four more supply wells may be located on the James River Corporation facility; their locations are unknown.

N

0.5 Mile

Approximate Scale

Figure 1-10
Off-Facility Well Locations
Harbor Oil Study Area

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1.3.3.3 1997 Force Lake Sampling

As part of the development of the Peninsula Drainage District No. 1 (PEN 1) Natural Resources Management Plan (NRMP) (City of Portland 1997), the City of Portland collected a water (W-1) and a sediment (S-1) sample from Force Lake. The City of Portland also collected a water sample (W-2) and a sediment sample (S-2) from the intersection of the Midwestern Slough and Forebay Slough, and a water sample (W-3) from the northwest corner of the Forebay Slough near the road crossing (Figure 1-11). Sediment samples S-1 and S-2 were composite samples. The City of Portland report did not identify where the grab samples used to form sample S-1 were collected in Force Lake. As described in Section 1.3.4, these data were used to identify data gaps and to assist in the RI study design, but were not deemed to be of sufficient quality to be used in the RI.

The samples were analyzed for general chemistry, ammonia, total solids, total dissolved solids, TSS, total coliform, COD, BOD, TOC, oil and grease, TPH, VOCs, metals (total and toxicity characteristic leaching procedure), pesticides and PCBs, herbicides, and SVOCs.

The samples were collected on January 2, 1992, except for the VOC sediment sample, which was collected on February 6, 1992.

The following summarizes the results for the water samples:

- Oil & grease was detected at a concentration of 0.18 mg/L in sample W-1. Samples W-2 and W-3 contained 0.17 and 0.08 mg/L, respectively, of oil and grease.
- TPH was not detected in samples W-1, W-2, or W-3 using Method 418.1 at a detection limit of 0.04 mg/L.
- The following metals were detected in sample W-1: copper (0.011 mg/L), iron (0.816 mg/L), lead (0.126 mg/L) and zinc (0.019 mg/L); arsenic, chromium, mercury, and nickel were not detected in sample W-1. Sample W-2 contained detectable concentrations of copper (0.016 mg/L), iron (1.21 mg/L) and zinc (0.020 mg/L). Sample W-3 contained detectable concentrations of copper (0.015 mg/L), iron (0.746 mg/L), nickel (0.051 mg/L), and zinc (0.026 mg/L).
- No herbicides, pesticides, or PCBs were detected in sample W-1, except lindane (gamma-BHC, 0.04 µg/L). A higher lindane concentration (0.06 µg/L) was detected in sample W-2. Lindane was not detected in sample W-3 at a detection limit of 0.003 µg/L.
- No VOCs or SVOCs were detected in any of the water samples.

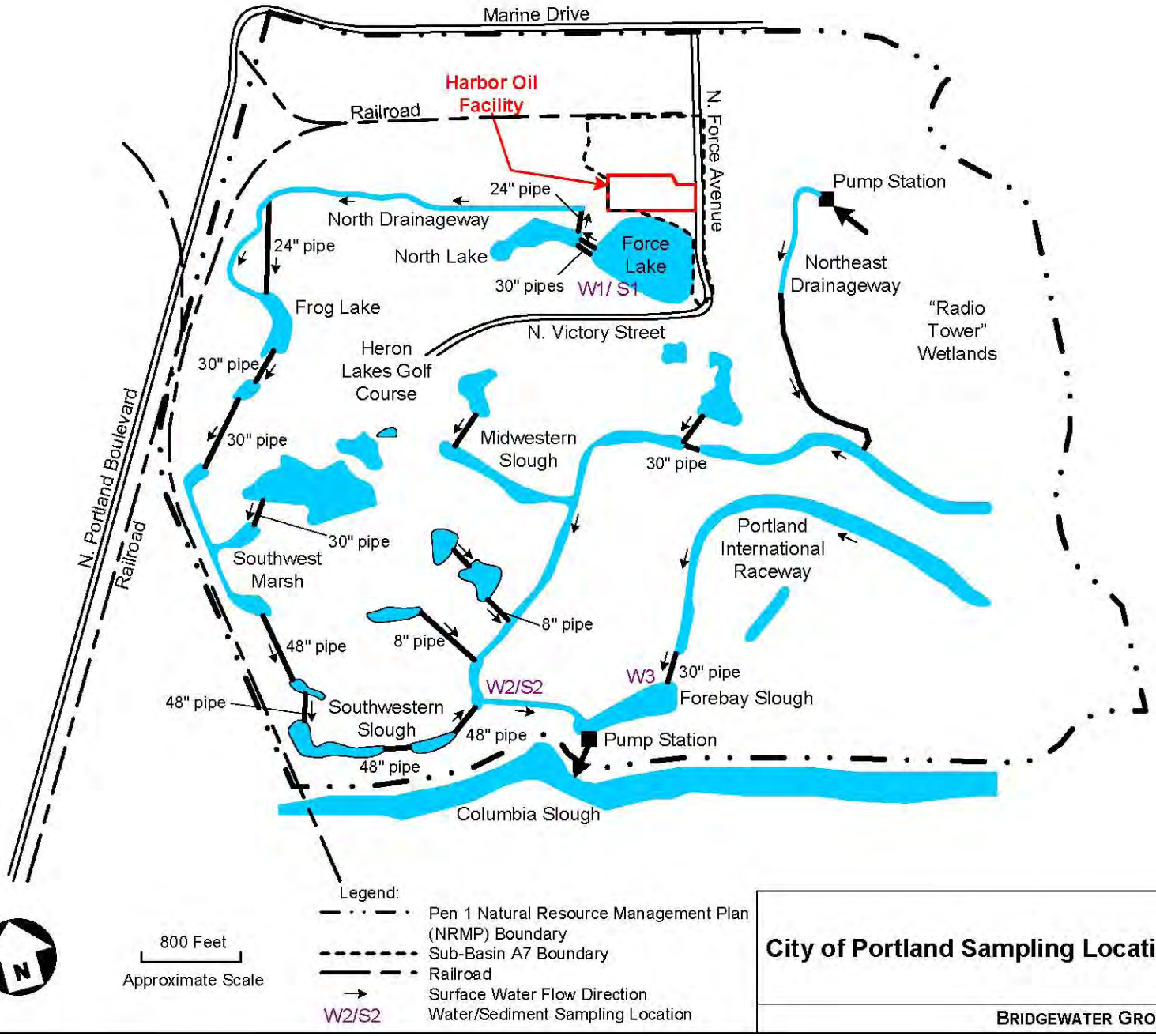

Figure 1-11
City of Portland Sampling Locations in PEN 1 NRMP Area
Harbor Oil Study Area

BRIDGEWATER GROUP, INC.

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The following summarizes the results for the sediment samples:

- Oil & grease was detected in sample S-1 at a concentration of 120 mg/kg, compared to 11 mg/kg detected in sample S-2.
- TPH was detected in sample S-1, using Method 418.1 at a concentration of 180 mg/kg, compared to 10 mg/kg in sample S-2.
- Arsenic (4.1 mg/kg), chromium (6.7 mg/kg), copper (106 mg/kg), iron (15,500 mg/kg), lead (18,600 mg/kg), nickel (11.7 mg/kg), zinc (173 mg/kg) were detected in sample S-1; no mercury was detected. Sample S-2 contained detectable concentrations of arsenic (2.91 mg/kg), chromium (15.0 mg/kg), copper (19.6 mg/kg), iron (11,100 mg/kg), nickel (14.6 mg/kg), and zinc (83.9 mg/kg); lead and mercury were not detected.
- No herbicides, pesticides, or PCBs were detected in sample S-1, except 4,4′-DDD (100 µg/kg); DDD was not detected in sample S-2.
- No VOCs were detected in sample S-1; sample S-2 was not analyzed for VOCs. Sample S-1 not analyzed for SVOCs; and no SVOCs were detected in sample S-2.

1.3.3.4 2000 EPA Site Inspection

In July and August 2000, surface soil, subsurface soil, wetland soil, groundwater, and product samples were collected by EPA as part of its PA/SI (Ecology and Environment 2001).

Fifteen surface soil samples (DP01SS through DP03SS and SS01SS through SS10SS), including two samples that were referred to as “background” samples (BG01SS and BG03SS), were collected from the Study Area (Figures 1-7 and 1-8). Sample BG03SS may or may not be representative of “background” conditions because it was collected on the Heron Lakes Golf Club. As discussed below, pesticides were historically used at the Heron Lakes Golf Club and the City of Portland placed fill material south of Force Lake. In addition, as discussed below, DDT was historically used at Vanport City, which was located south of Force Lake.

The surface soil samples from the Facility were collected at depths of 12 to 26 in. bgs below the approximately 12-in. layer of hard-packed gravel.

Ten subsurface soil samples, including two background samples, were collected at locations DP01 through DP03 and BG01. The samples were collected at locations co-located with samples DP01SS, DP02SS, DP03SS, and BG01SS (Figure 1-7).

Six soil samples were collected from the wetlands south of the Facility at depths of 0 to 6 in. bgs. EPA refers to these samples as “Force Lake sediment” samples even though some of them were collected from the wetlands rather than within the lake. The samples were collected at locations WL01SD through WS05SD and BG02SD (Figure 1-8). Note that background sample BG02SD was collected from the Heron Lakes Golf Club. It may or may not be representative “background” conditions for the reasons mentioned above.

Groundwater samples were collected from monitoring wells (GA-29, GA-33, GA-34, A-18, A-19 and A-20) and the plant well (Figure 1-9). EPA sampled the plant well to represent "background" conditions; the plant well was screened deeper than most of the other wells that EPA sampled. A light non-aqueous phase liquid (LNAPL) sample was collected from monitoring well GA-30.

Some soil, groundwater and LNAPL samples were analyzed for TAL metals, pesticides, PCBs, SVOCs, TOC, TPH and VOCs.

A number of pesticides were detected in the LNAPL sample, including: alpha-BHC (110 JK µg/kg), alpha chlordane (61 JK µg/kg), beta-BHC (130 JK µg/kg), dieldrin (150 µg/kg), endosulfan sulfate (210 µg/kg), endrin aldehyde (160 µg/kg), gamma chlordane (87JK µg/kg), and heptachlor epoxide (61 JK µg/kg). PCBs were also detected as Aroclor 1242 (9,600 µg/kg) and Aroclor 1254 (5,300 JK µg/kg).

Analytical testing results of the soil and groundwater samples referenced above, collected at the Study Area as part of the 2000 EPA SI and submitted to an offsite fixed laboratory, have previously been summarized and described in the RI/FS Work Plan (Bridgewater et al. 2008b). As described in Section 1.3.4, these data were deemed to be of sufficient quality to be used in the RI and in the baseline risk assessments. Therefore, these historical data are included in the RI database (Appendix B) and discussed in Section 4.0.

1.3.3.5 2003 CEC Soil Sampling

Between February 1 and April 17, 2003, CEC collected a total of 19 soil samples in several locations as part of the new base oil plant construction and card lock fueling area projects (CEC 2007a). Sampling locations are shown on Figure 1-7. Depths of the soil samples ranged from 1.0 to 7.0 ft bgs. Samples were analyzed for diesel- and oil-range TPH and PCBs.

Eleven soil samples were collected at sampling locations HC-01 through HC-11 in the area where the new base oil plant was to be constructed in order to evaluate TPH- and PCB-contaminated soil prior to construction. The excavation depth was approximately 6 ft (until clean material had been reached). The excavated material is now stockpiled to the west of the new plant. Samples were collected from various locations within the excavations (e.g., bottom, sidewalls).

The samples from HC-04 and HC-07 had concentrations approximately one order of magnitude above those of other samples at the facility (154,125 mg/kg TPH and 1.18 mg/kg PCBs at HC-04; and 173,800 mg/kg TPH and 13.6 mg/kg PCBs at HC-07). All other HC-series samples had chemical concentrations that were the same order of magnitude as those in other Facility soil samples. Based on a review of Dave Coles's field notes (CEC 2007a), samples HC-04 and HC-07 were biased samples intended to characterize a thin zone of "black, plastic-like asphalt" (HC-07) and an "oily sawdust layer" (HC-04), which were not observed at surrounding locations. It should also be noted that nearby samples HC-06, HC-08, and HC-09 (which were collected within 10 ft of HC-04

and HC-07) were not similarly impacted (based both field notes and analytical results).

Three soil samples were collected from locations HC-12 through HC-14 to the southwest of the tank farm and used oil processing area, where new electrical equipment was installed in a vault. The samples were collected at depths ranging from 2 to 5.5 ft bgs. TPH concentrations for these samples ranged from non-detect (HC-14 at 5.5 ft bgs) to 13,360 mg/kg (HC-12 at 3.5 ft bgs). The concentration of PCBs in the HC-14 sample was 0.622 mg/kg,

Five soil samples were collected from locations HCL-01 through HCL-05 near the card lock fueling area. Sample HCL-01 was collected from a pipe trench near the laboratory for the card lock fueling area. Sample HCL-02 was collected as a composite sample from a soil stockpile generated during trench excavation. Sample HCL-03 was collected from a caisson hole near the south corner of the card lock fueling area awning. Samples HCL-04 and HCL-05 were collected from the area where an oil-water separator had been installed. The samples were collected at depths ranging from 1.5 to 6 ft bgs. TPH concentrations in these samples ranged from non-detect (HC-04 at 1.5 ft bgs) to 6,117 mg/kg (HCL-02). The PCB concentration in the HCL-02 sample was 0.0802 mg/kg.

Analytical results for the samples referenced above have previously been summarized and compared with DEQ and EPA screening levels in the RI/FS Work Plan (Bridgewater et al. 2008b). Although the Coles's data (CEC 2007a) could not be used in the RI because they did not meet minimum DQOs (as described in Section 1.3.4), these data were used to guide the selection of RI sampling locations (i.e., to ensure that samples would be collected in the same vicinity). Specifically, samples SL-30, SL-31, and SL-38 were collected from this area to refine the understanding of chemical concentrations and distributions. Note that the area beneath the concrete at the base oil plant was backfilled with clean fill (basalt) and thus was not, and could not, be re-sampled.

RI sample SL-31 was collected immediately adjacent to the base oil plant foundation, approximately 10 ft to the northeast of HC-07 and 10 ft to the north of HC-04. The boring log for SL-31 does not identify the black plastic-like asphalt layer identified at HC-07 or the sawdust layer identified at HC-04; instead, a "slight odor from 4.0 to 7.0 ft" was described. The boring log for sample SL-30, which was located approximately 15 ft north of HC-07, reported conditions similar to those for SL-31, noting a "slight odor at 6 ft."

Based on the available information from RI sampling, chemical concentrations and environmental conditions represented by the HC-04 and HC-07 samples from the 2003 Coles's data (CEC 2007a) are not representative of current conditions in the area where these samples were collected. The RI data adequately describe overall soil conditions at the northern portion of the Facility without the incorporation of the unvalidated 2003 Coles's data.

1.3.3.6 2006 Heron Lakes Golf Club Water Quality Sampling

According to J. Goodling (2007), the City of Portland Parks Department collects water samples from Force Lake (just before it discharges into the culverts that connect it to North Lake) and from the Southwestern Slough (where it exits the southern boundary of the Heron Lakes Golf Club) to compare the quality of surface water entering and leaving the Heron Lakes Golf Club. Samples have been collected twice per year since 2001 and have been analyzed for indicators of nutrient runoff and pesticides that had been applied to the golf course during the prior 6 months. The most recent results provided by J. Goodling were for samples collected on October 10, 2006. Table 1-2 summarizes the analytical results for the water samples collected from Force Lake, including field parameters measured during sample collection.

The only pesticide that has been detected in Force Lake water since 2001 was Clopyralid (Confront®) (0.42 µg/L on October 20, 2003).

Table 1-2. October 10, 2006, Heron Lakes Golf Club Water Quality Sampling Results

Parameter	Unit	Force Lake	Southwestern Slough
Field			
pH	unitless	8.22	8.50
Specific conductance	µS/cm	281	253
DO	mg/L	12.77	7.18
Laboratory			
Orthophosphate-phosphorus	mg/L	0.24	0.04
Nitrate-nitrogen	mg/L	0.1 U	0.3
Clopyralid (Confront®)	µg/L	0.08 U	0.08 U
Fludioxanil (Medallion)	µg/L	0.03 U	0.03 U
Glyphosate (Roundup®)	µg/L	10 U	10 U
Propiconazole (Banner)	µg/L	0.12 U	0.12 U
Triadimefon (Bayleton)	µg/L	0.6 U	0.6 U

Source: Goodling (2007)
DO – dissolved oxygen
U – not detected at given concentration (concentration shown is the reporting limit)

1.3.4 Evaluation of Historical Data Quality

This section summarizes the methods and results of a data quality screen that was conducted as part of the DQO process to determine whether historical data were acceptable for use in the RI, as presented in the *Remedial Investigation/Feasibility Study: Risk Assessment Scoping Memorandum for the Harbor Oil Site* (Windward and Bridgewater 2008a), hereafter referred to as the Risk Assessment Scoping Memorandum. This data quality screen ensured that data used in the RI and risk assessments were of adequate quality.

Multiple field investigations at the Facility, adjacent wetland areas, and Force Lake have been conducted since 1988 (Table 1-3). Data from these historical studies were considered for use in the RI dataset if acceptable laboratory methods were used and sufficient analytical and field documentation was available. Data were considered to be unacceptable for use in the RI dataset if field screening methods were used or if insufficient analytical and field documentation was available. Dataset acceptability was evaluated based on the criteria established in the RI/FS Work Plan (Bridgewater et al. 2008b), as discussed in Section 1.3.4.1.

1.3.4.1 Criteria for Historical Data Screen

Specific criteria were used to evaluate chemistry data collected during previous (i.e., pre-RI) sampling events to determine their acceptability for use in the RI and risk assessments. All new data collected through the RI process outlined in the RI/FS Work Plan (Bridgewater et al. 2008b) met these criteria through compliance with the methods detailed in the quality assurance project plan (QAPP).

The criteria for chemistry data use in the RI for all purposes were as follows:

- Hard copy or original electronic copy of data report must be available.
- Field coordinates must be available.
- Data must have been collected using acceptable sampling methods.
- Sample depth must be identified.
- Sample type must be clearly identified.
- Analytical methods must be identified and acceptable.
- Quality assurance/quality control (QA/QC) information must be available.
- Data validation qualifiers must be present, or derivable from laboratory qualifiers or QA information and must be applied in a manner consistent with EPA functional guidelines (EPA 1999, 2002e). For non-detected results, detection limits and appropriate qualifiers must be provided.
- Data reports should contain laboratory-generated forms (often called Form Is) with the results for each sample.
- Documentation supporting the dataset, including the analytical raw data, chain-of-custody forms, and sample handling descriptions, should be available for future reference, confirmation, and/or reproducibility by a third party.

Table 1-3. Datasets Reviewed for Data Quality and Documentation for the Harbor Oil RI

Year	Sampling Event	Data Summary
2001 to 2006	Heron Lakes Golf Club water quality sampling performed by the City of Portland (unpublished)	Samples have been collected twice per year since 2001 and analyzed for indicators of nutrient runoff and pesticides(only one year of data was provided to the Voluntary Group)
2003	Soil analysis results for the 2003 excavations required for the construction of the EMRI base oil refining plant (Coles 2007)	19 subsurface soil samples were analyzed for TPH-Dx and PCBs
2000	Harbor Oil PA/SI (Ecology and Environment 2001)	15 surface soil samples, 10 subsurface soil samples, 6 Force Lake sediment samples,[a] 7 groundwater samples, and 1 LNAPL sample were analyzed for TPH-HCID, TPH-G, TPH-Dx, metals, VOCs, SVOCs, PCBs, and pesticides
2000	Preliminary risk assessment problem formulation (Coles 2002)	4 surface soil samples, 1 wetland soil sample, and 3 groundwater samples were analyzed for TPH-HCID, TPH-G, TPH-Dx, lead, magnesium, VOCs, SVOCs, and PCBs
1992	PEN 1 NRMP (City of Portland 1997)	1 Force Lake surface water sample and 1 Force Lake sediment sample were analyzed for TPH (range not reported), metals, VOCs, SVOCs, PCBs, pesticides, and herbicides
1990	Portland Stockyards SI and preliminary remediation plan (Golder Associates 1990)	2 surface soil samples, 9 subsurface soil samples, 3 wetland soil samples, and 3 groundwater samples were analyzed for metals
1990	Black & Veatch and RZA stockyards site assessment (RZA 1990, as cited in Golder Associates 1990)	39 soil vapor samples at Merit Truck Stop, Star Oil, Harbor Oil, Rod's Truck Repair, and Stockyards facility were analyzed for VOCs; unspecified testing relating to underground storage tanks was conducted at Merit Truck Stop and the Star Oil facility
1988	Sweet-Edwards/EMCON environmental audit, field investigation, and remedial alternatives assessment (Sweet-Edwards/EMCON 1988, as cited in Golder Associates 1990)	19 shallow borings, 17 surface soil samples, and an unspecified number of groundwater samples collected at Rod's Truck Repair, Harbor Oil, Merit Truck Stop, and Farmers Plant Aid were analyzed for VOCs, PCBs, diesel, and gasoline

[a] The six samples designated as Force Lake sediment samples in the 2000 sampling event were characterized as wetland soil samples in the RI and risk assessments based on the sample locations and descriptions. In addition, one of these six samples was collected on the south side of Force Lake as a "background sample." However, because of the proximity of this sample to the golf course, this sample may not represent background concentrations. Thus, only five of these samples were appropriate for use in the RI and risk assessments.

EMRI – Energy & Material Recovery, Inc.
LNAPL – light non-aqueous phase liquid
NRMP – natural resources management plan
PA – preliminary assessment
PCB – polychlorinated biphenyl
PEN 1 – Peninsula Drainage District No. 1
RI – remedial investigation
RZA – Rittenhouse-Zeman and Associates
SI – site investigation
SVOC – semivolatile organic compound
TPH – total petroleum hydrocarbons
TPH-Dx – total petroleum hydrocarbons –diesel and oil extractable
TPH-G – total petroleum hydrocarbons – gasoline
TPH-HCID – total petroleum hydrocarbons – hydrocarbon identification
VOC – volatile organic compound

Although EPA has not established definitive guidelines specifying the level of data validation required for CERCLA, EPA Order 5360.1 and Office of Solid Waste and Emergency Response Directive 9355.9-01 (EPA 1993) require environmental measurements to be of known quality, verifiable, and defensible. For a dataset to be used for decision making, EPA's information quality guidelines (2002b) require that a historical dataset be of known quality and legally defensible and have undergone the same level of scrutiny and review as any other environmental data generated internally or externally by or for EPA.

1.3.4.2 Historical Data Screen Results

The results of the data screen are presented in Table 1-4. The data from one sampling event (Ecology and Environment 2001) were considered acceptable for use. Data from seven sampling events did not meet minimum DQOs and were determined to be unsuitable for use. These seven sampling events are listed in Table 1-4 with the rationale for their exclusion.

Table 1-4. Results of Data Screen of Historical Datasets

Sampling Year	Sampling Event	Available Documentation	Acceptability for All Uses in the RI	Rationale for Exclusion
2001 to 2006	Heron Lakes Golf Club water quality sampling conducted by the City of Portland 2006 (unpublished)	Laboratory reports provided by J Goodling to S Brown.	unacceptable	Minimum DQOs were not met; data report and supporting documentation were not available.
2003	soil analysis results for the 2003 excavations required for the construction of the EMRI base oil refining plant (Coles 2007)	Field notes, chain-of-custody forms, and laboratory report forms.	unacceptable	Minimum DQOs were not met; data report and data validation report were not available.
2000	Harbor Oil PA/site inspection (Ecology and Environment 2001)	Sampling and quality assurance plan, data report, data validation memoranda, laboratory report forms; raw data and chain-of-custody forms on file with EPA, Ecology and Environment, and/or MEL.	acceptable	Dataset was acceptable.
2000	preliminary risk assessment problem formulation (Coles 2002)	Laboratory report forms; some QA/QC information; sampling methods, sample depths, and coordinates not provided.	unacceptable	Minimum DQOs were not met; data were unvalidated; raw data were unavailable; uncertainty exists regarding sampling locations, methods, and depths.
1992	PEN 1 NRMP (City of Portland 1997)	Incomplete data report; copies of laboratory report forms and QA/QC information are not available; sampling methods, locations, and depths not provided.	unacceptable	Minimum DQOs were not met; laboratory report forms and QA/QC information were unavailable; uncertainty exists regarding sampling locations, methods, and depths.
1990	Portland Stockyards SI and preliminary remediation plan (Golder Associates 1990)	Data report.	unacceptable	Minimum DQOs were not met; laboratory report forms and QA/QC information were unavailable.
1990	Black & Veatch and RZA stockyards site assessment (RZA 1990, as cited in Golder Associates 1990)	Incomplete documentation and uncertain data quality.	unacceptable	Minimum DQOs were not met; data report and supportive documentation were not available.
1988	Sweet-Edwards/EMCON environmental audit, field Investigation, and remedial alternatives assessment (Sweet-Edwards/EMCON 1988, as cited in Golder Associates 1990)	Incomplete documentation and uncertain data quality.	unacceptable	Minimum DQOs were not met; data report and supportive documentation were not available.

DQO – data quality objective
EMRI – Energy & Material Recovery, Inc.
EPA – US Environmental Protection Agency
MEL – Manchester Environmental Laboratory
NRMP – natural resources management plan
PA – preliminary assessment
PEN 1 – Peninsula Drainage District No. 1
QA/QC – quality assurance/quality control
RI – remedial investigation
RZA – Rittenhouse-Zeman and Associates
SI – site investigation
SVOC – semivolatile organic compound
VOC – volatile organic compound

2.0 STUDY AREA INVESTIGATION

This section describes field activities conducted at the Study Area as part of the RI. A complete dataset with analytical results is provided as Appendix B.

The site characterization was conducted in two phases. Phase 1 sampling was conducted in April and May 2008 and included the collection of surface soil samples on the Facility and in the adjacent wetlands, installation of monitoring wells and collection of groundwater samples, and collection of lake surface water and sediment samples. Phase 2 sampling was conducted in March and April 2009 and included the collection of additional surface and subsurface soil samples on the Facility and in the wetlands, collection of an additional round of groundwater samples, and collection of subsurface lake sediment samples. Monthly groundwater and lake elevations were collected between May 2008 and April 2009.

Figure 2-1 shows the locations where all Phase 1 and 2 soil and sediment were collected; Figure 2-2 shows the locations where all Phase 1 and 2 groundwater and surface water samples were collected. These figures also show sampling locations from the Ecology and Environment preliminary site assessment/site inspection (2001), which was the only historical sampling event determined to be acceptable for use in the RI (Section 1.3.4). Note that surface soil samples were collected from the Facility just beneath the packed gravel cover, where present.

The RI was conducted in accordance with the DQO process developed by EPA as outlined in the document *Guidance for the Data Quality Objectives Process* (EPA 2000) and in the updated DQO guidance (EPA 2006). The DQO process is used to clarify study objectives in order to develop an appropriate data collection design to support decision making (EPA 2000, 2006). The seven-step DQO process developed by EPA was applied to identify field collection efforts needed to complete the RI/FS. Tables 30 through 33 in the RI/FS Work Plan (Bridgewater et al. 2008b) describe the seven-step DQO process that was used to define the objectives of the proposed sampling in order to support the following study objectives presented in the RI/FS Work Plan:

- Evaluate ecological risks
- Evaluate human health risks
- Characterize the nature and extent of contamination[3]
- Define the physical characteristics and hydrological system

[3] It should be noted that dioxins/furans were not analyzed in samples collected from the Harbor Oil Study Area (and were not considered to be a contaminant of interest) because according to EPA's 1980 SI (1980), Chempro did not accept or handle PCBs at the Facility. This inspection was conducted in February 1980 (several months after the October 1979 fire), and thus there is no information to indicate that PCBs were present at the time of this fire.

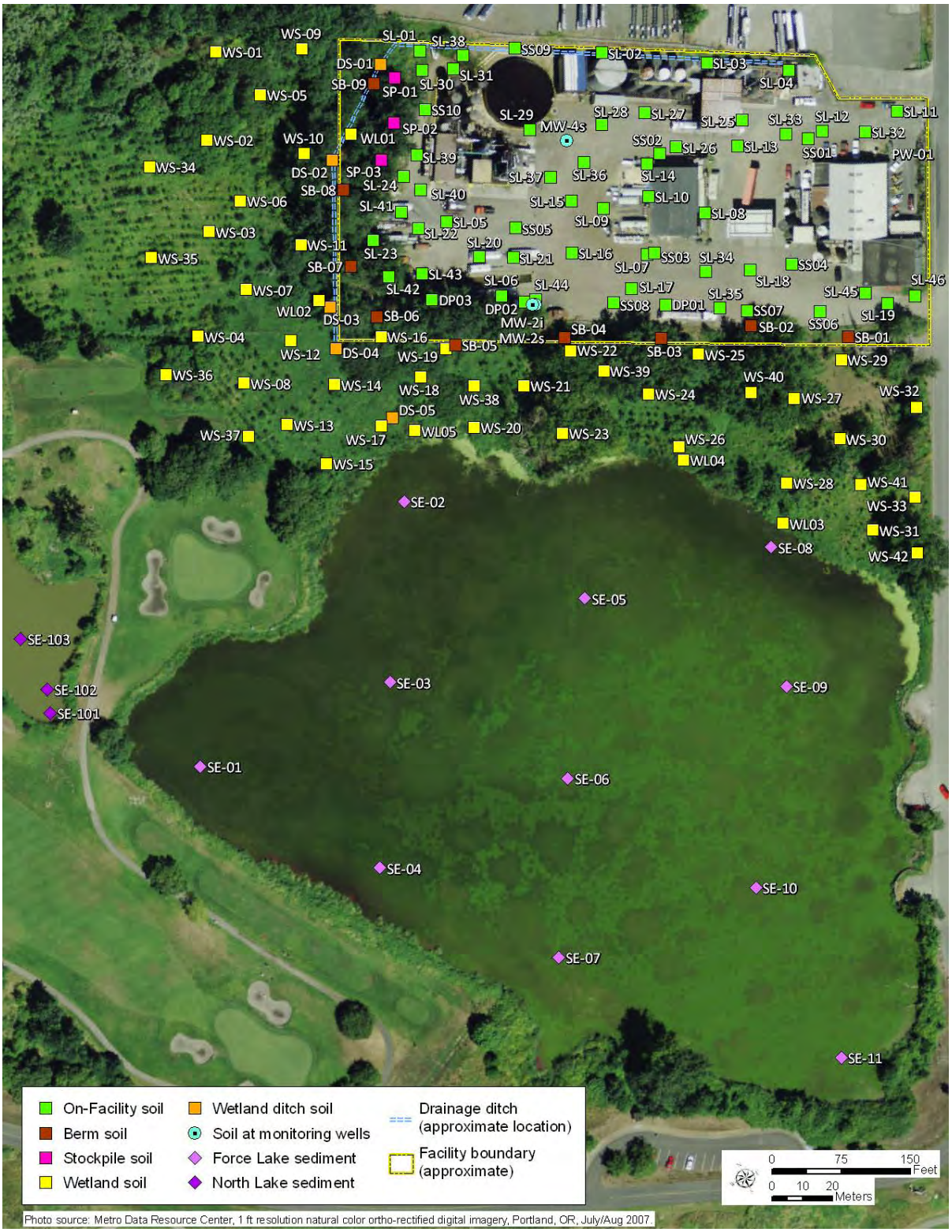


Figure 2-1. RI Soil and Lake Sediment Sampling Locations

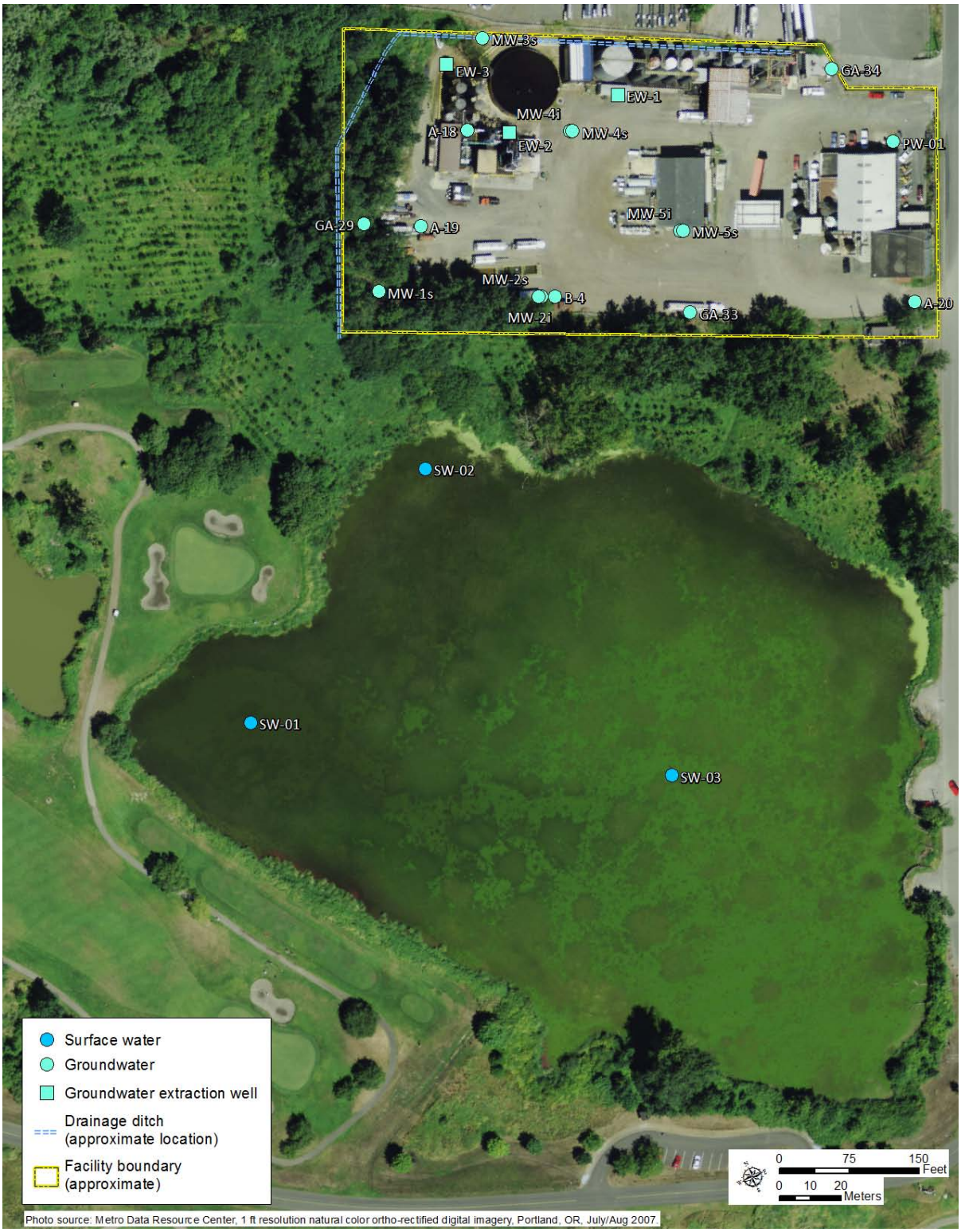


Figure 2-2. RI Groundwater Sampling, Surface Water Sampling, and Extraction Well Locations

These four elements are consistent with the general preliminary RAOs described in the SOW. As stated in the DQO tables, if unacceptable risks to humans or ecological receptors are determined, remedial alternatives will be evaluated in the FS. Step 7 of the DQO process provides a summary of the data needed to support the RI/FS.

In addition to clarifying study objectives, a data quality screen was conducted as part of the DQO process to provide all parties with a common benchmark for determining data acceptability (i.e., identifying which data could be used to estimate risks and develop risk-based goals). This data quality screen ensured that data were of a quality adequate to characterize the problems and decisions identified in the DQO process (Steps 1 and 2 of the DQO process identified in Tables 30 through 33). Data quality screening results for the historical data were presented in Section 1.3.4.

The RI/FS Work Plan (Bridgewater et al. 2008b) discussed the data gaps that were identified and the sampling design that was implemented to meet the following primary objectives defined in the SOW:

- Characterize the physical system of the Study Area by evaluating migration pathways including fluxes and rates through zones of migration.
- Determine the nature and extent of contamination at the Facility and for contaminants of potential concern (COPCs) in adjacent wetlands, Force Lake, and, if needed, downstream surface water bodies that received Facility-impacted discharges from Force Lake.
- Characterize any NAPL in soil or groundwater within the Study Area.
- Verify the preliminary CSM.
- Evaluate the human health and ecological risks posed by COPCs for all appropriate pathways and receptors.

Copies of the field logbooks, protocol modification forms, and field logs are provided in Appendix C.

The following subsections summarize the methodologies used to collect the samples, present the final sampling locations, and describe any deviations from the QAPP (Bridgewater et al. 2008a).

The field activities were conducted, with a few minor deviations, in accordance with the QAPP, and are briefly described in Sections 2.1 to 2.7.

2.1 Surface Features

All sampling locations were identified and documented using a global positioning system (GPS) unit with sub-meter accuracy.

A survey was completed on May 9, 2008 to determine the horizontal and vertical position of all Facility monitoring wells, Facility extraction wells, the Facility production well, the Force Lake observation point, and invert

elevations of the culverts located in Force Lake. The survey was completed by a professional land surveyor registered in Oregon. Each position was recorded relative to the State Plane (Oregon North) projection and City of Portland elevation datum. Each monitoring well elevation was recorded at the ground surface elevation and the well-specific groundwater measurement point (top of casing), which was located either below surface grade or above surface grade.

The May 2008 survey also included selected Facility features including property corners, building corners, concrete structures, catch basins, and ground surface elevations.

2.2 Facility Soil and Vadose Zone Investigations

Phase 1 field sampling activities were conducted from April 24 through May 2, 2008. The field sampling activities included the collection of soil samples from hand-auger and direct-push borings at 43 locations.

Phase 2 field sampling activities were conducted from April 6 through 9, 2009, at the Facility. The field sampling activities included the collection of 35 samples from hand-auger and direct-push borings at 15 locations.

For both phases of investigation, all onsite boreholes were filled with hydrated bentonite chips after the samples collected (according to the QAPP (Bridgewater et al. 2008a)), and an asphalt patch was placed in areas paved with asphalt to restore surface conditions. Soil sampling locations were documented, photographed, and logged with GPS equipment in accordance with the QAPP. Soil sampling and aquifer testing equipment was decontaminated between each location, and investigation-derived waste (IDW) was stored onsite, in accordance with the QAPP. Laboratory analytical results for IDW water and solids were submitted to Waste Management for purposes of profiling the IDW for permitted offsite land disposal or treatment. Waste Management transported drums containing IDW water and solids to their facility in Arlington, Oregon, on May 11, 2009.

The use of the term “surface” soil in this report is consistent with its use in the RI/FS Work Plan (Bridgewater et al. 2008b) (i.e., “surface” soil samples were collected just below the gravel fill layer, if present). Target “surface” soil sampling depths were identified in the RI/FS Work Plan based on limited information regarding the thickness of the gravel fill layer. When the actual thickness of the gravel fill layer deviated from the expected depth, the surface soil sample depth was revised accordingly.

The terms “intermediate” and “deep” soil are used to refer to the upper and lower subsurface samples, respectively, collected on the Facility. Most of the upper subsurface soils were collected between 4 and 6 ft bgs, consistent with the RI/FS Work Plan (Bridgewater et al. 2008b); although at some locations, samples were collected just above or below this interval based on field indicators (see Appendix D). Similarly, most of the lower subsurface samples were collected between 8 and 10 ft bgs, consistent with the RI/FS Work Plan.

The depth to groundwater at the time the soil samples were collected was not considered because the depth varies seasonally. Specifically, a review of

historical depth to groundwater data for the Study Area (see Section 2.3.1.3) indicated that uppermost groundwater ranged in depth from less than 1 ft bgs to approximately 6 ft bgs, depending on location and time of year. Thus, the surface and upper subsurface (e.g., "intermediate") sampling depths across the site may be within the vadose zone during portions of the year, while the lower subsurface (e.g., "deep") sampling depths would be expected to be below the water table year-round. Upland boring logs indicate where saturated conditions were encountered during field sampling (Appendix D).

2.2.1 Phase 1

Figure 2-1 shows the 43 locations where soil samples were collected on the Facility during the Phase 1 field sampling activities. Location information (Oregon State Plane coordinates) as well as latitude and longitude for all soil sampling locations are tabulated in Appendix E. Soil samples were collected at 17 locations (i.e., SB-01 to SB-09, SP-01 to SP-03, SL-01 to SL-04, and SL-11) using a hand auger, and at 25 locations (i.e., SL-05 to SL-10, SL-12 to SL-28, SL-30, and SL-31) using direct-push drilling equipment. Because of angle-boring limitations of the direct-push drilling equipment, soil samples were collected from a single angle-boring beneath Tank 23 (sample location SL-29) using a Rotosonic drill rig at a 45-degree angle.

Soil samples were collected from locations consistent with the QAPP (Bridgewater et al. 2008a), with the following exceptions:

- Direct-push drilling attempts at SL-11 indicated that the area was located over reinforced concrete covered by asphalt. Because of refusal, the location was moved approximately 12 ft northeast, and the soil sample was collected with a hand auger instead of the direct-push equipment due to the presence of a subsurface natural gas line. EPA approved the revised location.
- SL-26 was originally located inside the tank farm and used oil processing area inside the unloading and loading rack concrete containment. It was relocated approximately 24 ft southwest just outside the unloading and loading rack to avoid compromising the concrete containment. EPA approved the revised location.

Hand-auger soil samples were collected from the depths designated in the QAPP, with one exception. At SL-11, the hand-auger soil sample was collected at 0.5 to 1.5 ft bgs. This depth interval was sampled instead of the designated sampling interval of 0.0 to 1.0 ft bgs because of differences in the surface conditions at the new location. None of the deviations discussed affected the sampling objectives.

Soil samples from direct-push borings were usually collected at the intervals designated in the QAPP; however, some soil sample depths were altered slightly from those specified in the QAPP based on the actual fill thickness encountered in the field and based on field screening results. As detailed on the boring logs (Appendix D), sampling intervals ranged from 0.0 to 5.0 ft bgs for SL-11 to SL-19, from 0.5 to 10.0 ft bgs for SL-01 to SL-10, and from 0.0 to 10.25 ft bgs for SL-20 to SL-31. None of the deviations discussed affected the sampling objectives.

In order to provide sufficient soil volume for QA/QC samples, it was necessary to collect samples from several closely spaced borings. One hand-auger boring provided sufficient soil volume to fill the laboratory-supplied sample containers for a standard sample; two hand-auger borings were necessary at soil-sampling locations where additional QA/QC samples (i.e., splits or replicates) were collected in accordance with QAPP. The stainless steel hand auger had a 1-ft-long, 3-in.-diameter barrel with open sides. At the direct-push locations, three direct-push borings were necessary to collect a standard sample at the selected interval; five to six direct-push borings were necessary at soil sampling locations where additional QA/QC samples were collected in accordance with the QAPP.

The additional hand-auger borings completed at QA/QC locations were installed within 1 ft of the original hand-auger location. The direct-push borings were, on average, installed in a 1-to-1.5-square-foot (ft^2) area for the three-boring clusters and in a 2-to-3-ft^2area for the five- or six-boring clusters. The replicate soil sample was collected approximately 3 ft from the original soil sampling location, with the three replicate borings located within a 1 to 1.5-ft^2 area of the original replicate boring.

Additional soil samples were collected during the installation of monitoring wells MW-2s, MW-2i, and MW4s based on field screening results (see Appendix D).

Observations of soil sample characteristics and field-screening results were recorded on the soil sample collection forms, which are provided in Appendix C.

2.2.2 Phase 2

Figure 2-1 shows the locations where soil samples were collected on the Facility during the Phase 2 field sampling activities. Soil samples were collected at fifteen locations (i.e., SL-32 to SL-46) using direct-push drilling equipment. Location information (Oregon State Plane coordinates) as well as latitude and longitude for all soil sampling locations are presented in Appendix E. Soil samples were collected from locations consistent with the QAPP (Bridgewater et al. 2008a).

Soil samples from direct-push borings were usually collected at the intervals designated in the Response to EPA Comments on the Preliminary Site Characterization Report, which was provided to the Voluntary Group on September 18, 2008 (Windward et al. 2008b). An additional soil sample was collected at SL-37 (2.0 to 4.0 ft bgs), based on field screening results from this interval. As detailed on the boring logs (Appendix D), soil sampling intervals ranged from 1.0 to 2.0 ft bgs for SL-32, SL-33, SL-45 and SL-46; from 1.0 to 10.0 ft bgs for SL-34 to SL-37, SL-41, SL-42 and SL-43; from 4.0 to 6.0 ft bgs for SL-38, SL-39 and SL-40; and from 16.0 to 22.0 ft bgs for SL-44.

In order to provide sufficient soil volume for QA/QC samples, it was necessary to collect samples from several closely spaced borings. At the direct-push locations, three direct-push borings were necessary to collect a standard sample at the selected interval; five to six direct-push borings were necessary at soil sampling locations where additional QA/QC samples were

collected in accordance with the QAPP. At SL-44, two additional cores were required due to limited recovery percentages.

The direct-push borings were, on average, installed in a 1-to 1.5-ft^2 area for the three-boring clusters and in a 2- to3-ft^2area for the five- or six-boring clusters. The replicate soil sample was collected approximately 3 ft from the original soil sampling location, with the three replicate borings located within a 1- to 1.5-ft^2 area of the original replicate boring.

Observations of soil sample characteristics and field-screening results were recorded on the soil sample collection forms and boring logs, which are provided in Appendix D.

2.3 Facility Groundwater Investigations

Phase 1 field sampling activities were conducted from April 17 to May 2, 2008, and included the development/rehabilitation of monitoring wells, the collection of groundwater samples, the completion of aquifer slug tests, and the collection of water-level measurements. Phase 2 field sampling activities were conducted from March 30 to April 3, 2009, and included the collection of groundwater samples.

2.3.1 Phase 1

Phase 1 Facility groundwater field sampling activities were initiated on April 17, 2008. The field sampling activities consisted of the following:

- Development of eight existing monitoring wells, including rehabilitation of four of the eight existing monitoring well monuments and concrete pads
- Installation and development of eight new monitoring wells
- Collection of groundwater samples from the 16 existing and new monitoring wells and the plant well
- Completion of aquifer slug tests at nine of the existing and new monitoring wells
- Collection of water level measurements from the 16 existing and new monitoring wells, and from three existing precautionary extraction wells (e.g., EW-1) that were installed by EMRI, for potential future use as product recovery wells. Wells that pre-date the RI are shown on Figure 1-9; the full well network (i.e., existing and new wells) is shown on Figure 2-2).

2.3.1.1 Facility Monitoring Well Installation

Eight new monitoring wells (i.e., MW-1s, MW-2s, MW-2i, MW-3s, MW-4s, MW-4i, MW-5s and MW-5i) were installed on the Facility from May 2 to May 6, 2008 (Figure 2-2). Five new shallow wells (i.e., MW-1s, MW-2s, MW-3s, MW-4s, and MW-5s) were installed at depths ranging from 12.5 to 15 ft bgs. Three new intermediate wells (i.e., MW-2i, MW-4i, and MW-5i) were installed at depths ranging from 48 to 49.5 bgs.

Each well consisted of 2-in.-diameter polyvinyl chloride (PVC) schedule 40 casing with a 10-ft-long screen (slot size 10 or 0.01-in. openings), which was flush-mounted and installed with a Rotosonic SRO 71 drill rig using 6.25-in.-diameter casing. The 10-ft-long screen was installed at the bottom of each boring. The filter pack, consisting of 10/20 silica sand, was placed in the annular space around the screen from the bottom of the well to approximately 0.5 ft above the screen in shallow monitoring wells and approximately 2 ft above the screen in intermediate monitoring wells. The remaining annular space was filled to approximately 1 to 1.5 ft bgs with 3/8-in. hydrated bentonite chips. The final 1 to 1.5 ft of annular space was filled with a grout mixture consisting of Portland cement, sand, and bentonite (1 ft of grout at wells with smaller concrete pads with limited or no truck traffic and 1.5 ft of grout at wells with truck-proof concrete pads). Flush-mounted outer casings were set in the concrete pads installed at each well. New water-tight lockable well caps were installed on each well, with new Sherwood monuments bolted to the outer flush-mounted casing ring. Well identifications were stamped into the metal ring at each well. The wells were located, designed, constructed, and installed in accordance with the QAPP (Bridgewater et al. 2008a). The location coordinates for the new and existing groundwater monitoring wells, the Facility plant well (PW-01), and the extraction wells are provided in Appendix E. Table 2-1 summarizes well construction information for the new and existing monitoring wells and for the plant well. Well construction diagrams for Facility wells are included in Appendix F.

Table 2-1. Well Construction Details for On-Facility Wells

Well ID	Year Installed	Casing Material	Nominal Casing Dia. (in.)	Casing Elevation (ft AMSL)	Ground Surface Elevation (ft AMSL)	Total Depth (ft bgs)	Screen Interval (ft bgs)	Filter Pack Interval (ft bgs)	Seal Interval (ft bgs)
New RI Monitoring Wells[a]									
MW-1s	2008	PVC	2	13.07	13.5	13.5	3.5 – 13.5	3.0 – 13.5	0.0 – 3.0
MW-2s	2008	PVC	2	12.42	12.7	15.5	5.5 – 15.5	5.0 – 15.5	0.0 – 5.0
MW-2i	2008	PVC	2	12.38	12.7	48	38.0 – 48.0	35.0 – 48.0	0.0 – 35.0
MW-3s	2008	PVC	2	14.6	14.9	12.5	2.5 – 12.5	2.0 – 12.5	0.0 – 2.0
MW-4s	2008	PVC	2	12.79	13.1	13	3.0 – 13.0	2.5 – 13.0	0.0 – 2.5
MW-4i	2008	PVC	2	12.85	13.1	49.5	39.5 – 49.5	37.5 – 49.5	0.0 – 37.5
MW-5s	2008	PVC	2	12.01	12.3	13.5	3.5 – 13.5	3.0 – 13.5	0.0 – 3.0
MW-5i	2008	PVC	2	11.98	12.3	50	40.0 – 50.0	38.0 – 50.0	0.0 – 38.0
Existing Monitoring Wells[b]									
A-18	1989?	PVC	2	13.48	13.7	10.5	5.5 – 10.5	4.5 – 10.5	0.0 – 4.5
A-19	1989?	PVC	2	13.34	13.6	20.5	10.5 – 20.5	9.5 – 20.5	0.0 – 9.5
A-20	1989?	PVC	2	13.14	13.4	20.5	10.5 – 20.5	9.5 – 20.5	0.0 – 9.5
B-4	1989?	PVC	2	12.74	13	94.5	84.5 – 94.5	unknown	unknown
GA-29	1990	PVC	2	13.14	13.4	15.5	5.5 – 15.5	4.5 – 15.5	0.0 – 4.5
GA-30	1990	PVC	2	13.43	13.6	14	4.0 – 14.0	3.0 – 14.0	0.0 – 3.0
GA-33	1990	PVC	2	12.29	12.5	15	5.0 – 15.0	4.0 – 15.0	0.0 – 4.0
GA-34	1990	PVC	2	14.1	14.3	14.5	4.5 – 14.5	3.5 – 14.5	0.0 – 3.5
EW-1	2003	PVC	4	13.32	13.6	8.25	1.6 – 8.25	1.6 – 8.25	0.0-1.6
EW-2	2003	PVC	4	13.49	13.8	6.4	2.3 – 6.4	2.3 – 6.4	0.0 – 2.3
EW-3	2003	PVC	4	17.14	14.2	5.2	2.0 – 5.2	2.0 – 5.2	0.0 – 2.0
Plant Wells[c]									
PW-01	1977	steel	4	13.79	13.8	97	na	na	0 – 30

[a] New RI monitoring wells MW-1s, MW-2s/2i, MW-3s, MW-4s/4i and MW-5s/5i installed by GeoDesign.

[b] Existing monitoring wells A-18, A-19, A-20 and B-4 were presumably installed by Black and Veatch during a 1989 study based on available information; however, this work was never reported and documentation is not sufficient to verify. Monitoring wells GA-29, GA-30, GA-33 and GA-34 installed by Golder Associates. Extraction wells EW-1, EW-2 and EW-3 installed by CEC.

[c] Plant well PW-1 installed by Chempro.

AMSL – above mean sea level
bgs – below ground surface
CEC – Coles Environmental Consulting
Chempro – Chempro of Oregon
ID – identification
na – not available
PVC – polyvinyl chloride
RI – remedial investigation

2.3.1.2 Water Level and Free Product Measurements

In accordance with the QAPP (Bridgewater et al. 2008a), water level measurements were initially collected from the new and existing monitoring wells and from Force Lake between May 12 and May 15, 2008, during Phase 1 groundwater sampling. A complete round of water level measurements was collected from the 16 existing and new monitoring wells, the three extraction wells, and Force Lake on June 9, 2008. After that, monthly water levels and free product measurements were collected between June 2008 and April 2009. Because the sanitary seal limited access to the plant well, water level measurements were not taken at this well.

Water level measurements in the extraction wells were not included in the QAPP because even though the extraction wells were screened in the shallow groundwater zone, EMRI did not provide well construction information for these wells. Water levels were measured in the extraction wells to further characterize shallow groundwater zone elevations near the new base oil plant.

Water level and product thickness measurements were made in each well in accordance with the QAPP. A summary of water level and product thickness measurements is presented in Table 2-2. The shaded cells in Table 2-2 identify the dates on which groundwater elevations were below the top of the screen.

Floating free product (i.e., LNAPL) was present in monitoring well GA-30. Product thickness was measured during each water level monitoring event.

When the water level was consistently above the top of the well screen, it was not possible to definitively identify the presence or magnitude of LNAPL on the water column at that location because LNAPL, which floats on the groundwater surface, would have consistently been above the screen interval of the well. The evaluation of the presence of LNAPL presented below takes this circumstance into consideration, and for ease of reference, Table 2-2 includes shading where measured water levels were below the top of the well screen.

As is indicated in Table 2-2, groundwater elevations in MW-1s have consistently been below the well screen and no free product has been observed. As groundwater elevations declined during the summer and fall of 2008, water levels in five of the shallow monitoring wells and the three precautionary extraction wells (MW-1s, MW-2s, MW-3s, GA-29, GA-30, EW-1, EW-2, and EW-3) were below the tops of their screens.

Table 2-2. Summary of Groundwater Elevation and Free-Product Thickness Measurements

Date	Measuring Point Elevation (ft AMSL)[a]	Screened Interval Elevation (ft AMSL)[a]	Depth to Water (ft)	Groundwater Elevation (ft AMSL)[b]	Free Product Thickness (ft)
MW-1s					
05/15/08	13.07	0.5 to 10.5	3.80	9.27	na
06/09/08			3.76	9.31	na
07/09/08			4.86	8.21	na
08/11/08			5.93	7.14	na
09/10/08			6.42	6.65	na
10/10/08			5.58	7.49	na
11/10/08			4.93	8.14	na
12/08/08			4.37	8.70	na
01/12/09			3.78	9.29	na
02/14/09			3.94	9.13	na
03/11/09			3.89	9.18	na
04/27/09			3.77	9.30	na
MW-2s					
05/14/08	12.42	-0.3 to 9.7	2.83	9.59	na
06/09/08			2.25	10.17	na
07/09/08			2.68	9.74	na
08/11/08			3.75	8.67	na
09/10/08			4.09	8.33	na
10/10/08			3.35	9.07	na
11/10/08			2.00	10.42	na
12/08/08			2.13	10.29	na
01/12/09			1.96	10.46	na
02/14/09			2.89	9.53	na
03/11/09			2.32	10.10	na
04/27/09			2.81	9.61	na
MW-2i					
05/14/08	12.38	-35.3 to -25.3	2.24	10.14	na
06/09/08			0.99	11.39	na
07/09/08			1.20	11.18	na
08/11/08			2.68	9.70	na
09/10/08			3.32	9.06	na
10/10/08			3.98	8.40	na
11/10/08			3.76	8.62	na
12/08/08			3.46	8.92	na
01/12/09			2.65	9.73	na
02/14/09			2.24	10.14	na
03/11/09			2.73	9.65	na
04/27/09			2.14	10.24	na
MW-3s					
05/14/08	14.60	2.4 to 12.4	1.48	13.12	na
06/09/08			1.01	13.59	na
07/09/08			1.60	13.00	na
08/11/08			2.08	12.52	na
09/10/08			2.32	12.28	na

Table 2-2. Summary of Groundwater Elevation and Free-Product Thickness Measurements (cont.)

Date	Measuring Point Elevation (ft AMSL)[a]	Screened Interval Elevation (ft AMSL)[a]	Depth to Water (ft)	Groundwater Elevation (ft AMSL)[b]	Free Product Thickness (ft)
10/10/08			2.26	12.34	na
11/10/08			1.61	12.99	na
12/08/08			1.66	12.94	na
01/12/09			0.92	13.68	na
02/14/09			1.30	13.30	na
03/11/09			1.21	13.39	na
04/27/09			1.40	13.20	na
MW-4s					
05/15/08			0.97	11.82	na
06/09/08			0.78	12.01	na
07/09/08			1.03	11.76	na
08/11/08			1.67	11.12	na
09/10/08			1.67	11.12	na
10/10/08	12.79	0.6 to 10.6	1.41	11.38	na
11/10/08			0.82	11.97	na
12/08/08			1.00	11.79	na
01/12/09			0.59	12.20	na
02/14/09			0.87	11.92	na
03/11/09			0.88	11.91	na
04/27/09			0.93	11.86	na
MW-4i					
05/15/08			2.48	10.37	na
06/09/08			1.20	11.65	na
07/09/08			1.49	11.36	na
08/11/08			3.02	9.83	na
09/10/08			3.67	9.18	na
10/10/08	12.85	-35.9 to -25.9	4.34	8.51	na
11/10/08			4.15	8.70	na
12/08/08			3.86	8.99	na
01/12/09			2.88	9.97	na
02/14/09			2.63	10.22	na
03/11/09			3.10	9.75	na
04/27/09			2.44	10.41	na
MW-5s					
05/15/08			0.60	11.41	na
06/09/08			0.44	11.57	na
07/09/08			0.78	11.23	na
08/11/08			1.31	10.70	na
09/10/08			1.39	10.62	na
10/10/08	12.01	-0.7 to 9.3	1.05	10.96	na
11/10/08			0.55	11.46	na
12/08/08			0.71	11.30	na
01/12/09			0.26	11.75	na
02/14/09			0.45	11.56	na
03/11/09			0.41	11.60	na

Table 2-2. Summary of Groundwater Elevation and Free-Product Thickness Measurements (cont.)

Date	Measuring Point Elevation (ft AMSL)[a]	Screened Interval Elevation (ft AMSL)[a]	Depth to Water (ft)	Groundwater Elevation (ft AMSL)[b]	Free Product Thickness (ft)
04/27/09			0.47	11.54	na
MW-5i					
05/15/08	11.98	-37.2 to -27.2	1.36	10.62	na
06/09/08			0.33	11.65	na
07/09/08			0.51	11.47	na
08/11/08			1.98	10.00	na
09/10/08			2.57	9.41	na
10/10/08			3.23	8.75	na
11/10/08			3.03	8.95	na
12/08/08			2.75	9.23	na
01/12/09			1.90	10.08	na
02/14/09			1.52	10.46	na
03/11/09			1.98	10.00	na
04/27/09			1.43	10.55	na
A-18					
05/16/08	13.48	3.7 to 8.7	1.73	11.75	na
06/09/08			1.51	11.97	na
07/09/08			1.94	11.54	na
08/11/08			2.68	10.80	na
09/10/08			2.67	10.81	na
10/10/08			2.52	10.96	na
11/10/08			1.70	11.78	na
12/08/08			1.85	11.63	na
01/12/09			1.14	12.34	na
02/14/09			1.63	11.85	na
03/11/09			1.54	11.94	na
04/27/09			1.69	11.79	na
A-19					
05/13/08	13.34	-6.4 to 3.6	3.05	10.29	na
06/09/08			2.80	10.54	na
07/09/08			3.44	9.90	na
08/11/08			4.57	8.77	na
09/10/08			4.78	8.56	na
10/10/08			3.87	9.47	na
11/10/08			3.25	10.09	na
12/08/08			3.08	10.26	na
01/12/09			2.50	10.84	na
02/14/09			2.88	10.46	na
03/11/09			2.85	10.49	na
04/27/09			2.89	10.45	na

Table 2-2. Summary of Groundwater Elevation and Free-Product Thickness Measurements (cont.)

Date	Measuring Point Elevation (ft AMSL)[a]	Screened Interval Elevation (ft AMSL)[a]	Depth to Water (ft)	Groundwater Elevation (ft AMSL)[b]	Free Product Thickness (ft)
A-20					
05/13/08	13.14	-6.6 to 3.4	0.98	12.16	na
06/09/08			0.91	12.23	na
07/09/08			1.57	11.57	na
08/11/08			2.27	10.87	na
09/10/08			2.53	10.61	na
10/10/08			2.00	11.14	na
11/10/08			1.36	11.78	na
12/08/08			1.43	11.71	na
01/12/09			0.57	12.57	na
02/14/09			1.09	12.05	na
03/11/09			0.72	12.42	na
04/27/09			1.01	12.13	na
B-4					
05/13/08	12.74	-81.1 to -71.1	2.59	10.15	na
06/09/08			0.92	11.82	na
07/09/08			1.15	11.59	na
08/11/08			2.90	9.84	na
09/10/08			3.73	9.01	na
10/10/08			4.50	8.24	na
11/10/08			4.43	8.31	na
12/08/08			4.23	8.51	na
01/12/09			3.14	9.60	na
02/14/09			2.90	9.84	na
03/11/09			3.41	9.33	na
04/27/09			2.62	10.12	na
GA-29					
05/13/08	13.14	-1.6 to 8.4	3.56	9.58	na
06/09/08			3.36	9.78	na
07/09/08			4.41	8.73	na
08/11/08			5.65	7.49	na
09/10/08			6.14	7.00	na
10/10/08			5.48	7.66	na
11/10/08			4.50	8.64	na
12/08/08			4.01	9.13	na
01/12/09			2.96	10.18	na
02/14/09			3.47	9.67	na
03/11/09			3.40	9.74	na
04/27/09			3.41	9.73	na

Table 2-2. Summary of Groundwater Elevation and Free-Product Thickness Measurements (cont.)

Date	Measuring Point Elevation (ft AMSL)[a]	Screened Interval Elevation (ft AMSL)[a]	Depth to Water (ft)	Groundwater Elevation (ft AMSL)[b]	Free Product Thickness (ft)
GA-30					
05/16/08	13.43	-0.4 to 9.6	2.68	10.84[c]	0.10
06/09/08			2.39	11.06[c]	0.02
07/09/08			3.19	10.26[c]	0.02
08/11/08			4.12	9.32[c]	0.01
09/10/08			4.32	9.13[c]	0.02
10/10/08			3.87	9.58[c]	0.02
11/10/08			3.03	10.41[c]	0.01
12/08/08			2.93	10.52[c]	0.02
01/12/09			2.11	11.32[c]	trace
02/14/09			2.54	10.91[c]	0.02
03/11/09			2.45	10.99[c]	0.01
04/27/09			2.49	10.94[c]	trace
GA-33					
05/12/08	12.29	-2.5 to 7.5	1.72	10.57	na
06/09/08			1.69	10.60	na
07/09/08			2.31	9.98	na
08/11/08			2.96	9.33	na
09/10/08			3.09	9.20	na
10/10/08			2.43	9.86	na
11/10/08			1.76	10.53	na
12/08/08			1.80	10.49	na
01/12/09			1.39	10.90	na
02/14/09			1.64	10.65	na
03/11/09			1.55	10.74	na
04/27/09			1.72	10.57	na
GA-34					
05/12/08	14.10	0.3 to 10.3	0.95	13.15	na
06/09/08			0.81	13.29	na
07/09/08			1.28	12.82	na
08/11/08			1.82	12.28	na
09/10/08			1.97	12.13	na
10/10/08			1.79	12.31	na
11/10/08			1.32	12.78	na
12/08/08			1.56	12.54	na
01/12/09			0.50	13.60	na
02/14/09			0.86	13.24	na
03/11/09			0.83	13.27	na
04/27/09			0.96	13.14	na

Table 2-2. Summary of Groundwater Elevation and Free-Product Thickness Measurements (cont.)

Date	Measuring Point Elevation (ft AMSL)[a]	Screened Interval Elevation (ft AMSL)[a]	Depth to Water (ft)	Groundwater Elevation (ft AMSL)[b]	Free Product Thickness (ft)
EW-1					
06/09/08	13.32	5.2 to 11.9	0.63	12.69	na
07/09/08			1.00	12.32	na
08/11/08			1.71	11.63[c]	0.02
09/10/08			1.74	11.59[c]	0.01
10/10/08			0.93	12.40[c]	0.01
11/10/08			0.51	12.81[c]	trace
12/08/08			0.76	12.56[c]	trace
01/12/09			0.25	13.07[c]	trace
02/14/09			0.70	12.62[c]	trace
03/11/09			0.70	12.62[c]	trace
04/27/09			0.82	12.50[c]	trace
EW-2					
06/09/08	13.49	7.4 to 11.5	1.67	11.82	na
07/09/08			na[d]	na[d]	na
08/11/08			2.53	10.96	na
09/10/08			2.45	11.04	na
10/10/08			2.34	11.15	na
11/10/08			1.63	11.86	na
12/08/08			1.78	11.71	na
01/12/09			1.44	12.05	na
02/14/09			1.67	11.82	na
03/11/09			1.66	11.83	na
04/27/09			1.77	11.72	na
EW-3					
06/09/08	17.14	9.0 to 12.0	4.87	12.27	na
07/09/08			5.41	11.73	na
08/11/08			6.04	11.11[c]	0.01
09/10/08			6.02	11.13[c]	0.01
10/10/08			5.91	11.23	na
11/10/08			4.83	12.32[c]	0.01
12/08/08			5.08	12.06[c]	trace
01/12/09			4.34	12.80[c]	trace
02/14/09			4.93	12.21[c]	trace
03/11/09			4.77	12.37[c]	trace
04/27/09			5.13	12.01[c]	trace
PW-01					
Date unknown	13.79	na[d]	na[d]	na[d]	na[d]

Table 2-2. Summary of Groundwater Elevation and Free-Product Thickness Measurements (cont.)

Date	Measuring Point Elevation (ft AMSL)[a]	Screened Interval Elevation (ft AMSL)[a]	Depth to Water (ft)	Groundwater Elevation (ft AMSL)[b]	Free Product Thickness (ft)
Force Lake					
05/13/08	12.15	na	2.81	9.34	na
05/14/08			2.90	9.25	na
06/09/08			2.87	9.28	na
07/09/08			3.33	8.82	na
08/11/08			3.89	8.26	na
09/10/08			4.12	8.03	na
10/10/08			4.18	7.97	na
11/10/08			3.88	8.27	na
12/08/08			3.49	8.66	na
01/12/09			3.08	9.07	na
02/14/09			3.11	9.04	na
03/11/09			3.10	9.05	na
04/27/09			2.90	9.25	na

Note: Shaded cells indentify the dates on which groundwater elevations were below the top of the screen.

[a] All measuring point elevations were professionally surveyed on May 9, 2008, by Thurston and Associates, Inc. Reported elevations are AMSL, City of Portland Elevation Datum.

[b] Groundwater elevations calculated using measuring point elevations and depth-to-water measurements.

[c] Free product (LNAPL) was measured. A specific gravity of 0.85 was assumed for calculating the corrected groundwater elevation.

[d] Depth-to-water measurement was not obtained because of access limitations.

AMSL – above mean sea level
ID – identification
LNAPL – light non-aqueous phase liquid
na – not applicable

Consistent with historical observations, free product has been observed in well GA-30. As noted on the April 18, 2008, well development log, the free product observed in well GA-30 was described as being a "viscous oil – black and thick." Note that prior to collecting the LNAPL sample from GA-30, there was a 0.10-ft-thick layer of product observed in the well. Six months after removing LNAPL from the well during Phase 1 sampling, the product thickness was observed to be 0.01 to 0.02 ft. In addition, no LNAPL was observed in downgradient shallow monitoring wells GA-29 or MW-1s (which had water levels below the top of screen). Furthermore, a review of the field screening results as reported on the soil boring logs and the field sampling descriptions for these wells and for surrounding borings did not identify the presence of oil product in soils.

The observed "thick and viscous" nature of the LNAPL as observed at well GA-30, the inability to gain entry into surrounding wells or re-entry into well GA-30, and the absence of LNAPL in surrounding borings would suggest that LNAPL is of limited extent and mobility potential. These findings are indicative of a limited source zone.

Monitoring results indicate that only minor amounts of LNAPL are present and that the LNAPL is localized in extent and is constrained on the Facility; no LNAPL has been observed in shallow monitoring wells MW-1s and MW-2s located along the downgradient boundary of the Facility or in shallow monitoring wells GA-29, located in the southwest corner of the Facility.

2.3.1.3 Facility Groundwater Sampling

During Phase 1, a total of 17 wells (16 monitoring wells and the plant well) were sampled from May 12 to May 16, 2008. The 16 monitoring wells consisted of 8 existing monitoring wells (i.e., A-18, A-19, A-20, GA-29, GA-30, GA-33, GA-34, and B-4) and 8 new monitoring wells (i.e., MW-1, MW-2s, MW-2i, MW-3s, MW-4s, MW-4i, MW-5s, and MW-5i). The only deviation from the QAPP during groundwater sampling was during the collection of a groundwater sample from PW-01. At this well, there was limited access because the submersible pump column and sanitary seal had been bolted to the top of casing. This well was purged prior to sampling by operating the down-hole pump for 15 minutes at approximately 45 gallons per minute (gpm) until approximately 675 gallons, or approximately three casing volumes, had been removed from the well. The well was then sampled using a peristaltic pump and 0.25-in.-diameter disposable Teflon® tubing placed approximately 15 ft bgs into the casing.

The remaining 16 wells were purged and sampled using low-flow techniques and a GeoTech peristaltic pump with 0.25-in.-diameter, disposable Teflon® tubing placed near or slightly above the center of each well screen until drawdown levels and water quality parameters had stabilized, in accordance with the QAPP (Bridgewater et al. 2008a). Water quality measurements were recorded using a calibrated YSI 556 MPS multi-parameter meter and a Hach turbidimeter.

Each well was purged at varying rates between 151 milliliters per minute (ml/min) and 442 ml/min. The selected rate was based on each well's

ability to stabilize without excessive (greater than approximately 0.33 ft) drawdown. Several wells, including A-19, B-4, GA-29, MW-2s, MW-4s, MW-5s, and MW-5i, had stable water quality parameter measurements, although drawdown exceeded the 0.33-ft target value. In these instances, the peristaltic pump was operating at the lowest possible setting.

The only well that did not stabilize, based on turbidity readings, was A-20. The first purging attempt revealed that there was relatively high turbidity and intermittent gas bubbling, consistent with what one would observe when opening a well that is under positive pressure. The gas did not have any odor. The second purging attempt (one day after the first) revealed similarly high turbidity and gas bubbling. Therefore, the groundwater sample was collected from this well without stabilized parameters. Gas did not appear to be entrained in the groundwater sample.

Table 2-3 provides a summary of stabilized water quality measurement data obtained during groundwater sampling.

2.3.1.4 Facility Well Development and Well Monument Rehabilitation

Seven of the eight existing monitoring wells and eight new monitoring wells were developed at the Facility (Figure 2-2) in accordance with the procedures described in the QAPP (Bridgewater et al. 2008a). As noted above, at the plant well (i.e., PW-01), the pump prevented sufficient access for the development equipment. GA-30 was not redeveloped because of the presence of LNAPL. The remaining 15 monitoring wells displayed adequate recovery after well development and appeared suitable for water-level measurements and groundwater sampling (although a sample was collected from A-20 without stabilized parameters as discussed in Section 2.3.1.4).

Four existing well monuments (i.e., A-19, GA-29, GA-30, and GA-34) were rehabilitated. The wells had various degrees of damage to the concrete pad and flush-mounted cover; however, none of these wells appeared to have damaged well casings or well seals. Each expandable well cap appeared water-tight (when initially removed for well development). Boart Longyear, under GeoDesign's supervision, removed the old concrete pads, flush-mounted outer casings, and monuments at all of the wells. A new Sherwood aluminum monument and a flush-mounted outer casing were installed at each well and secured with a new truck-proof concrete pad at monitoring wells A-19, GA-29, and GA-30 and with a regular pad at monitoring well GA-34 (which is located in an area that has no truck access). As added protection from stormwater runoff, 2-in.-diameter PVC risers were added to the existing PVC casings in each of the four wells.

Table 2-3. Stabilized Water Quality Measurement Data for Groundwater Samples Collected During Phase 1

Well ID	Date/Time	Temperature (°C)	DO (mg/L)	pH	Oxidation-Reduction Potential (mV)	Conductivity (µS/cm)	Turbidity (NTU)
GW-MW1s	05.15.08/1115	11.6	0.07	6.69	-54.2	479	1.6
GW300[a]	15.15.08/1130	na	na	na	na	na	na
GW-MW2s	05.14.08/1530	13.6	0.47	6.61	-46.7	1823	6.9
GW-MW2i[b]	05.14.08/1015	13.8	0.15	6.91	-135.4	979	3.2
GW-MW3s[b]	05.14.08/0815	12.5	0.21	6.57	-139.1	1,386	1.4
GW-MW4s	05.15.08/1430	16.1	0.15	6.91	-136.5	957	2.9
GW-MW4i	05.15.08/1600	15.7	0.14	7.42	-130.1	828	2.2
GW-MW5s[b]	05.15.08/0830	14.8	0.23	6.58	-82.1	1,012	2.5
GW-MW5i	05.15.08/0745	15.0	0.15	6.74	-134.4	890	1.9
GW-A18	05.15.08/0930	15.1	0.15	6.71	-130.9	893	3.0
GW-A19	05.13.08/1315	12.3	0.31	6.43	-98.6	1,858	5.8
GW-A20[c]	05.13.08/0815	12.7	0.20	6.42	-76.1	649	265
GW-B4	05.13.08/1500	13.2	0.33	6.88	-128.7	1,439	4.1
GW-GA29	05.13.08/1030	10.8	0.23	6.31	-36.7	757	1.1
GW-GA30[d]	05.16.08/1100[d]	na	na	na	na	na	na
GW-GA33	05.12.08/1445	12.0	0.22	6.53	-98.7	883	0.8
GW-GA34	05.12.08/1215	13.5	0.26	6.63	-91.5	632	1.4
GW-PW01[b]	05.14.08/1330	14.6	2.03[e]	7.53	16.7	354	1.8

[a] Replicate groundwater sample at MW-1s.

[b] EPA split samples were collected at these locations.

[c] Groundwater sample collected despite turbidity readings above 10 NTUs, as discussed in Section 2.3.1.4.

[d] Groundwater sample was not collected because of the presence of free product in GA-30. A sample of the free product (LNAPL-GA30) was collected.

[e] May not reflect actual aquifer condition because of the purging method, as discussed in Section 2.3.1.4.

C – Celsius
DO– dissolved oxygen
EPA – US Environmental Protection Agency
ID – identification
LNAPL – light non-aqueous phase liquid
na – not available
NTU – nephelometric turbidity unit

2.3.1.5 Aquifer Slug Testing

Aquifer slug tests were conducted on nine monitoring wells (MW-1s, MW-2s, MW-3s, MW-4s, MW-4i, MW-5i, GA-29, GA-34, and B-4) on May 22 and 23, 2008. The aquifer slug tests were conducted in accordance with the QAPP (Bridgewater et al. 2008a), except that each well was tested using only slug removal instead of slug injection and removal. This deviation was necessary because of the following field conditions:

- The water level in each intermediate and shallow well was approximately 1 to 3 ft bgs. These conditions would have provided approximately 0.16 gallons per foot or a slug of 0.32 gallon per well (averaging 2 ft of casing between the water table and ground surface).
- An injected slug of that size (i.e., 0.33 gallon) would have imposed only a minor, although measurable, amount of stress on the well, resulting in limited data from the slug test.
- Slug injection could have resulted in "over slugging" and the spilling of water over the top of the casing, invalidating the test.
- If the water level in any of the shallow wells was below the screened interval (i.e., greater than 3 ft bgs), the injection of a slug could have caused water to enter the screen above the water table, infiltrating the vadose zone (also invalidating the test).

As was discussed in Section 2.1.6 of the *Preliminary Site Characterization Report for the Harbor Oil Site* (Windward et al. 2008a), hereafter referred to as the Preliminary Site Characterization Report, the only slug test that could be performed on the shallow and intermediate monitoring wells was a “slug-out/rising head” test. Pre-test water levels were between 1 and 3 ft bgs. Table 2-4 lists pre-test water levels and screen elevations for the monitoring wells where slug tests were performed. Given the slug volume, the instantaneous rise in head for a “slug-in/falling head” test would have been approximately 4.3 ft and would have over-spilled the well casing. EPA approved this revision to the slug testing method specified in the QAPP.

Also, the water levels in the two intermediate wells where slug tests were performed (MW-4i and MW-5i) were not within the screened intervals of the intermediate wells; the screens for these intermediate wells were located far below the pre-test groundwater elevations (see Table 2-4). The only shallow or intermediate well where the pre-test water level elevation was within the screen was MW-1s.

Table 2-4. Slug Testing Pre-Test Water Levels

Monitoring Well	Screen Interval Elevation (ft AMSL)	Pre-Test Groundwater Elevation (ft AMSL)	Relationship of Groundwater Elevation to Screen Interval
MW-1s	0.48 to 10.48	9.13	within
MW-2s	-0.34 to 9.66	9.73	above
MW-3s	2.36 to 12.36	13.22	above
MW-4s	0.58 to 10.58	11.93	above
MW-4i	-35.88 to -25.88	11.06	above
MW-5i	-37.23 to -27.23	10.80	above
B-4	-81.05 to -71.05	10.80	above
GA-29	-1.55 to 8.45	9.74	above
GA-34	0.26 to 10.26	13.23	above

AMSL– above mean sea level

EPA approved a revision to the slug testing method specified in the QAPP. The revised procedure for slug testing was as follows:

- Water levels were measured prior to slug test implementation over an approximate 20-minute period until the water level was stable and equilibrated with the atmosphere.
- A 1.91-in.-diameter, 5-ft-long slug with weighted PVC sand-filled casing was lowered into each of the shallow wells (MW-1s, MW-2s, MW-3s, MW-4s, GA-29, and GA-34). At the intermediate and deep wells (MW-4i, MW-5i, and B-4), a 1.91-in.-diameter, 10-ft-long slug with weighted PVC sand-filled casing was lowered into each well.
- The slug remained in the well until the water level stabilized. The slug was then immediately removed from the well (within approximately 5 to 10 seconds), and the water level was measured frequently during the first minutes of the test (every 5 to 10 seconds), then more slowly (every 20 to 30 seconds, then every 1 to 5 minutes) for the remainder of the test until the water rebounded back to within 90 to 95% of the static level.

Given this deviation, slug tests were conducted on six shallow groundwater monitoring wells (MW-1s, MW-2s, MW-3s, MW-4s, GA-29 and GA-34), rather than the three wells identified in the QAPP (GA-29, GS-34 and MW-5s); MW1s, MW-2s, MW-3s and MW-4s were substituted for MW-5s to obtain hydraulic conductivity information over more of the Facility. Consistent with the QAPP, slug tests were conducted on two intermediate monitoring wells; a slug test was performed on MW-4i rather than MW-2i because the recovery at MW-2s was very slow and subsequent pre-test static water level at MW-2i would have been suspect. Also, a slug test was performed on deep monitoring well B-4 to obtain hydraulic conductivity information for the deep zone.

The time required for tested wells to rebound to within 90 to 95% of the static water level ranged from 27 seconds (MW-1s) to 86 minutes (MW-2s). Drawdown in the shallow monitoring wells ranged from 2.78 to 3.54 ft, excluding MW-1s. Recovery was so rapid in MW-1s that the first water level measurement, approximately 12 seconds after the slug was removed, was only 0.15 ft from the original static level. Drawdown in the two intermediate monitoring wells (MW-4i, MW-5i) and on deep monitoring well (B-4) ranged from 3.32 to 7.80 ft. Each well, with the exception of MW-1s, was adequately stressed by the removal of the slug to obtain the necessary data to calculate the hydraulic conductivity. Slug testing data and analyses summaries are presented in Appendix G. The calculated hydraulic conductivities from the May 2008 slug testing activities are described in Section 3.5.2.3.1.

2.3.2 Phase 2

During Phase 2, 14 monitoring wells were sampled from March 30, 2009 to April 3, 2009. The14 monitoring wells consisted of the previously installed monitoring wells (i.e., A-18, A-19, A-20, GA-29, GA-30, GA-33, GA-34, and B-4) and a subset of the new monitoring wells installed during Phase 1 (i.e., MW-1s, MW-2s, MW-2i, MW-3s, MW-4s and MW-5s).

Monitoring wells were purged and sampled using low-flow techniques and a GeoTech peristaltic pump with 0.25-in.-diameter, disposable Teflon® tubing placed near or slightly above the center of each well screen until drawdown levels and water quality parameters had stabilized, in accordance with the QAPP (Bridgewater et al. 2008a). Water quality measurements were recorded using a calibrated YSI 556 MPS multi-parameter meter and a Hach turbidimeter.

Each well was purged at varying rates between 114 ml/min and 284 ml/min. The selected rate was based on each well's ability to stabilize without excessive (greater than approximately 0.33 ft) drawdown. Several wells, including A-18, A-19, A-20, B-4, GA-29, MW-2s and MW-5s had stable water quality parameter measurements, although drawdown exceeded the approximate 0.33-ft target value. In these instances, the peristaltic pump was operating at the lowest possible setting.

Similar to the observations noted during Phase 1 groundwater sampling (Section 2.3.1), the only well that did not stabilize during Phase 2 sampling, based on turbidity readings, was A-20. Purging revealed that there was relatively high turbidity and intermittent gas bubbling, consistent with what one would observe when opening a well that is under positive pressure. The gas did not have any odor. Therefore, the groundwater sample was collected from this well without stabilized parameters. Gas did not appear to be entrained in the groundwater sample.

A subset of the oxidation-reduction potential (ORP) readings collected on April 2, 2009 (from MW-3s, A-18, and GA-29) appeared to vary significantly in comparison to the Phase I readings; several iterations of calibration for ORP were subsequently conducted on the multi-parameter meter. The stabilization criteria for ORP were realized in these wells in

accordance with the QAPP (Bridgewater et al. 2008a); however, the numerical value for ORP in these wells may not reflect actual values.

Table 2-5 provides a summary of stabilized water quality measurement data obtained during Phase 2 groundwater sampling.

Table 2-5. Stabilized Water Quality Measurement Data for Groundwater Samples Collected During Phase 2

Well ID	Date/Time	Temperature (°C)	DO (mg/L)	pH	Oxidation-Reduction Potential (mV)	Conductivity (µS/cm)	Turbidity (NTU)
GW-MW1s	04.01.09/1230	8.3	0.26	6.57	43.9	1,100	1.0
GW301[a]	04.01.09/1300	na	na	na	na	na	na
GW-MW2s	03.31.09/1030	10.3	0.30	6.97	-112.5	1,573	9.0
GW-MW2i	03.31.09/1330	12.7	0.31	7.34	-105.8	875	1.6
GW-MW3s	04.02.09/1200	10.6	0.26	6.29	520.1[c]	795	4.1
GW-MW4s	03.31.09/0815	10.5	0.42	6.87	-121.5	1,253	9.4
GW-MW5s	04.01.09/1000	9.7	0.22	6.91	-110.1	1,093	4.0
GW-A18	04.02.09/1500	10.3	0.30	6.55	715.0[c]	557	0.9
GW-A19	04.01.09/1530	10.6	0.34	6.26	-41.9	1,191	5.2
GW-A20[b]	03.30.09/1245	11.8	0.28	6.70	-70.1	574	116.3
GW-B4	03.31.09/1500	12.1	0.47	7.49	-133.1	1,478	4.3
GW-GA29	04.02.09/0930	9.4	0.42	6.04	398.1[c]	230	1.8
GW-GA30[d]	04.03.09/0830[c]	na	na	na	na	na	na
GW-GA33	03.30.09/1545	10.5	0.22	6.92	-121.8	868	2.6
GW-GA34	03.30.09/1015	10.9	0.42	6.92	-104.8	684	0.6

[a] Replicate groundwater sample at MW-1s.

[b] Groundwater sample collected despite turbidity readings above 10 NTUs, as discussed in Section 2.3.2.

[c] Numerical values of Oxidation-Reduction Potential (ORP) readings collected at this well were considered suspect and may represent field meter error, as discussed in Section 2.3.2. Stabilization criteria were realized in accordance with the QAPP.

[d] Groundwater sample was not collected because of the presence of free product in GA-30. A sample of the free product (LNAPL-GA30) was collected, but not analyzed (previously characterized).

C – Celsius
DO– dissolved oxygen
LNAPL – light non-aqueous phase liquid
na – not available
NTU – nephelometric turbidity unit

2.4 Wetland Soil Investigations

Sediment surface (0 to 6 in. bgs) and subsurface (6 to 12 in. and 24 to 36 in. bgs) samples were collected as part of the Phase 1 and Phase 2 sampling events, as discussed in the following subsections.

It should be noted that although the areas to the west and south of the Facility are referred to as wetlands throughout this document, the extent of the saturated, marshy area did not cover the entire wetland area during field sampling. In some areas, standing water was present at the sampling locations; in other areas, the subsurface soil samples were not saturated. Both sampling events occurred during the spring and similar saturated areas were observed. It is expected that the extent of the saturated area varies seasonally.

2.4.1 Phase 1

During Phase 1, surface and subsurface soil samples were collected from the wetlands adjacent to the Facility on April 23 and 24, 2008. The wetland sampling locations were accessed from either North Force Avenue or from the southwestern corner of the Facility.

2.4.1.1 Wetland Surface Soil

Thirty-eight surface soil samples (0 to 6 in. bgs) were collected from the wetlands area on April 23 and 24, 2008 (Figure 2-1). In accordance with the QAPP (Bridgewater et al. 2008a), surface soil samples were collected from the upper 6 in. with a decontaminated stainless steel spoon and bowl. A stainless steel spoon was not used to collect wetland soil samples at stations WS-17, WS-18, and WS-20 because the stations were inundated with approximately 6 to 12 in. of water. Instead, soil samples were collected with a decontaminated stainless steel hand auger. At each location, overlying vegetation and debris were removed before the sample was collected. Samples were processed in the field at the sampling location. After all sampling containers had been filled, extra material was returned to the sampling location.

Coordinates for the wetland surface soil samples are provided in Appendix E. One soil target station, WS-33, was relocated because the location at the target coordinates was on top of a small soil mound. After consultation with the EPA oversight representative, the sampling location was moved approximately 5 ft to the southeast of the target location to better characterize soils near the ditch located next to North Force Avenue (Figure 2-1); this deviation did not affect the objectives of this sample. Observations of soil sample characteristics were recorded on the surface sediment collection forms provided in Appendix C.

2.4.1.2 Wetland Subsurface Soil

Six subsurface wetland soil samples (WS-19, DS-03, WS-26, DS-02, and DS-05, and WS-06) were collected on April 23 and 24, 2008, using a hand auger (Figure 2-1). Subsurface soil samples (6 to 12 in. and 24 to 36 in. bgs) were collected at wetland locations as indicated in the QAPP

(Bridgewater et al. 2008a), with the exception of DS-03. This location was moved approximately 10 ft northwest because of continued refusal at the target location caused by cobbles and riprap located just below the surface.

The hand auger borings were advanced to the sampling depths described in the QAPP. Two hand-auger borings provided sufficient soil volume for a standard sample; three to four hand-auger borings were necessary when additional QA/QC samples (i.e., splits or replicates) were collected. Standard hand-auger sampling locations were within 1 ft of the original hand-auger location. Replicate subsurface soil samples were collected approximately 3 ft from the original subsurface soil sampling location. Coordinates for the subsurface soil samples are presented in Appendix E.

2.4.2 Phase 2

During Phase 2, surface and subsurface soil samples were collected from the wetlands adjacent to the Facility on April 7 and 8, 2009, as specified in the Response to EPA recommendations for Phase 2 sampling (Bridgewater et al. 2008c). The wetland sampling locations were accessed from either North Force Avenue or from the southwestern corner of the Facility.

2.4.2.1 Wetland Surface Soil

To further characterize the spatial extent of contamination in the wetlands, nine surface soil samples (0 to 6 in. bgs) were collected from the wetlands area on April 7, 2009 (i.e., WS-34 through WS-42; Figure 2-1). Locations WS-34 through WS-37 were collected in the northern portion of the wetlands to further characterize the spatial extent of chemical concentrations in the western and southwestern portions of the wetlands. Locations WS-38 through WS-42 were collected to refine the spatial extent of chemical concentrations in the wetlands in areas specified by EPA.[4]

In accordance with the QAPP (Bridgewater et al. 2008a), surface soil samples were collected from the upper 6 in. with a decontaminated stainless steel spoon and bowl, with one exception. Location WS-38 was inundated with approximately 6 in. of water, and thus it was necessary to use a decontaminated stainless steel hand auger to collect this sample. At each location, overlying vegetation and debris were removed before the sample was collected. Samples were processed in the field at the sampling location. After all sampling containers had been filled, extra material was returned to the sampling location.

[4] Specifically, samples were collected at WS-38 north of Phase 1 location WS-20 and west of WS-21; at WS-39 between Phase 1 locations WS-21 and WS-25 and north of WS-24; at WS-40 between WS-25 and WS-27; at WS-41 between WS-28, WS-30, WS-31 and WS-33; and at WS-42 south of WS-31 and WS-33.

With three exceptions, all samples were collected at the locations specified in the Response to EPA recommendations for Phase 2 sampling (Bridgewater et al. 2008c). The three exceptions were:

- **WS-36:** The targeted coordinates for location WS-36 were located on an elevated area, which was likely elevated as the result of fill used to construct the golf course. To better capture the intent of this location, the sample was collected approximately 15 ft from the target coordinates.
- **WS-37:** The targeted coordinates for location WS-37 were on the edge of the golf course green. This sample was moved approximately 10 ft away from the green to better capture the intent of this sample.
- **WS-42:** The target coordinates for location WS-42 were located directly between two large trees where no soil was available to collect a sample. The relocation of this sample approximately 5 ft from the target coordinates did not alter the intent of this sample.

All other wetland surface samples were collected as specified in the Response to EPA recommendations for Phase 2 sampling (Bridgewater et al. 2008c).

2.4.2.2 Wetland Subsurface Soil

To further characterize the vertical extent of contamination in the wetlands, four subsurface wetland soil samples (6 to 12 in. and 24 to 36 in. bgs) were collected on April 8, 2009 (Figure 2-1), at locations where surface soil samples were collected during the Phase 1 sampling event. Locations WS-20, WS-21, and WS-25 were sampled between the Facility and Force Lake, while location WS-11 was sampled to the west of the Facility.

All subsurface soil samples were collected at wetland locations as specified in the Response to EPA recommendations for Phase 2 sampling (Bridgewater et al. 2008c). The hand auger sampling procedures described for Phase 1 (Section 2.4.1.2) were the same for the Phase 2 samples. A minor modification to this procedure was made for only one location: at location WS-25, a shovel was used to collect the lower sampling interval (24 to 36 in. bgs) because of dense gravel starting at approximately 10 in. bgs. This modification did not alter the intent of this sample.

2.5 Lake Surface Water Investigation

During Phase 1 field activities, surface water samples were collected from Force Lake on April 21 and 22, 2008. Sampling locations in Force Lake were accessed using a canoe that was launched from the parking area on the eastern side of the lake (near North Force Avenue).

Three surface water samples, and one field duplicate sample, were collected (Figure 2-2). In accordance with the QAPP (Bridgewater et al. 2008a), water samples were collected approximately 1 ft below the water

surface using a decontaminated 5-L Niskin bottle sampler that was manually deployed from a canoe. Two to three water grabs were necessary to fill the required volume of sample containers needed by the laboratory for analysis. Samples were processed in the canoe at the location where the samples were collected so that extra water could be discarded at the sampling location.

In addition to surface water samples, *in situ* water quality measurements were collected at the three sampling locations from 1 ft below the water surface. Temperature, dissolved oxygen (DO), salinity, and conductivity were measured using a YSI meter. Water hardness was measured using a LaMotte water hardness kit. Sampling location coordinates are provided in Appendix E. Table 2-6 presents the *in situ* water quality results.

Table 2-6. *In Situ* Water Quality Data for the Three Water Samples Collected During Phase 1

Sample ID	Temperature (°C)	DO (mg/L)	Salinity (ppt)	Conductivity (mS/cm)	Hardness (mg/L)
SW-01	10.0	5.59	0.2	275.5	880
SW-02	10.4	6.34	0.2	274.8	444
SW-03[a]	11.1	6.31	0.2	283.0	460

[a] The water quality measurements at SW-03 also apply to the duplicate samples (SW-300) collected at this location.

C – Celsius

DO – dissolved oxygen

ID – identification

ppt – parts per thousand

2.6 Lake Sediment Investigations

Sediment samples were collected as part of the Phase 1 and Phase 2 sampling events, as discussed below.

2.6.1 Phase 1

During Phase 1 field activities, sediment samples were collected from Force Lake and North Lake on April 21 and 22, 2008. Sampling locations in Force Lake were accessed using a canoe that was launched from the parking area on the eastern side of the lake (near North Force Avenue). The canoe was portaged from Force Lake to access the sampling locations in North Lake.

Eleven surface sediment samples (and one field duplicate sample) were collected from Force Lake, and three surface sediment samples were collected from North Lake on April 21 and April 22, 2008 (Figure 2-1). In accordance with the QAPP (Bridgewater et al. 2008a), surface sediment samples were collected using a decontaminated 0.02-m^2 Ekman grab sampler that was manually deployed from a canoe. Grab samples were rejected if less than 8 cm (just over 3 in.) of sediment were penetrated by the Ekman sampler. For most sediment samples, only one grab was

necessary to obtain sufficient volume to fill the sample containers needed by the laboratory for analysis. Additional grab samples were necessary at locations where replicate or split samples were collected. Samples were processed in the canoe at the sampling location so that extra sediment could be discarded at the sampling location.

Force Lake sediment sampling location SE-08 was relocated approximately 20 ft away from the shoreline because the substrate at the target location adjacent to the shore was obstructed by root debris. Multiple grab attempts in the vicinity were unsuccessful at obtaining acceptable sediment recovery, and sufficient sediment volume could not be collected. It should be noted that the initial target coordinates were based on the Force Lake sampling grid, and were not intended to target a particular source. After the sample was collected, EPA was consulted to ensure that this relocation was acceptable. EPA approved the relocation of the sampling station, and thus the sample was retained and sent to the laboratory.

Lake sediment target station SE-101 was also relocated approximately 20 ft away from the target location (Figure 2-1). Multiple grab attempts at the target location were unsuccessful because the rocky substrate prevented acceptable sediment recovery and the collection of sufficient sample volume. The EPA oversight representative approved the relocation of the sampling station, and the new location met the sampling objectives.

Because of the high water content of the lake sediment samples, the standard procedures for VOC sample collection (EPA Method 5035A) were slightly modified. For lake sediment samples, a decontaminated stainless steel spoon was used to collect sediment from the Ekman sampler to fill the pre-set EasyDraw Syringe®. Caution was used to minimize disturbance to the sediment that could have resulted in the evaporative loss of VOCs. The EPA oversight representative was informed of the issue and approved the modification to the standard procedures.

Coordinates for the surface sediment samples and observations of gross sediment sample characteristics (recorded on the surface sediment collection forms) are provided in Appendix C.

2.6.2 Phase 2

During Phase 2 field activities, subsurface sediment samples were collected from Force Lake on April 8, 2009, using a vibracore sediment core sampler. Sampling locations in Force Lake were accessed using the Ross Island Sampler launched from the parking area on the eastern side of the lake (near North Force Avenue). The original plan to hand-collect sediment cores in Force Lake from a small drift boat (attempted on April 6, 2009) was unsuccessful because of consolidated sediment starting approximately 1 ft below the mudline in Force Lake.

Subsurface sediment samples were collected at three locations in Force Lake at two depth intervals (1 to 3 ft, and if feasible, 3 to 5 ft). The

rationale for selecting these three sampling locations was as follows (Bridgewater et al. 2008c):

- Locations SE-03 and SE-05 were sampled to provide data for locations on either side of the point where the drainage ditch discharges into Force Lake and where stormwater drains into the lake from the area around wetland soil sample locations WS-20, WS-21, and WS-25. Location SE-02 was not sampled because although it was closer to the entry point for the drainage ditch, it would have been difficult to sample because of the shallow water depth and relatively hard lake bottom substrate observed during Phase 1 sampling.
- Location SE-10 (in the southeast portion of the lake) was sampled to provide spatial coverage for the rest of the lake.

For each core, the vertical profile was visually logged for major and minor contacts (i.e., regions in the core where sediment characteristics noticeably changed), and photographs of each core were taken before sampling. Sediment descriptions were recorded on a core processing log (Appendix C).

A tiered approach was used to analyze subsurface sediment samples. Specifically, the upper subsurface samples collected from the 1-to-3-ft depth interval were analyzed for the same analytes as the Phase 1 surface sediment samples (i.e., metals, TPH, PAHs, organochlorine pesticides, PCBs, VOCs, moisture, grain size, and TOC). The 3-to-5-ft samples were archived until the results of the 1-to-3-ft samples were available.

In June 2009, the upper subsurface sediment sample results were submitted to EPA along with a recommendation that the lower subsurface samples not be analyzed because very few chemicals were detected in the upper subsurface samples. With one exception, no detected concentrations were above regional background levels for metals or sediment screening levels for organic compounds. 4.4′-DDE was detected in one of the three samples at a concentration of 4.5 µg/kg dw, which slightly exceeded its ecological screening level (3.2 µg/kg dw). EPA agreed that the analysis of the lower subsurface samples was not necessary.

2.7 Ecological Investigations

Two surveys of fish in Force Lake have been conducted, as discussed in this section.

2.7.1 Historical Evaluation of Force Lake Fishery

An evaluation of the Force Lake fishery was conducted by Fishman Environmental (1989) to determine the potential for the development of a warm-water fishery. Fish were collected in the fall of 1988 and in the spring of 1989, as summarized in Table 2-7. For comparison, this table

also presents the results of the 2009 fish survey (Windward 2009b), which is discussed in Section 2.7.2.

The majority of the fish caught in Force Lake during the Fishman study were small mosquitofish and juvenile sunfish, less than 2 cm (less than 1 in.) in length. Fish of this size class are usually not consumed by humans. Some of the carp, brown bullhead, and sunfish (bluegill and pumpkinseed) that were collected from the lake as part of the Fishman study were of sizes that could potentially be kept by anglers for consumption.

Based on the results of the study, Fishman characterized Force Lake as a self-sustained bullhead fishery and a stunted bluegill fishery because the bluegill captured were less than 5 cm (approximately 2 in.) in length. The Fishman study did not investigate the fishing rates of local anglers, but noted that conclusions regarding the fishery health were based on current fishing rates at that time (late 1980s).

2.7.2 Force Lake Fish Survey

A survey of the fish population in Force Lake was conducted on Tuesday, April 7, 2009 to obtain information on the types of fish present in the lake and estimate the abundance and sizes of these fish. This section provides a brief summary of this effort. Additional information, including a summary of survey methods and catch records and a discussion of results, is provided in Appendix H.

The survey was conducted in accordance with the fish survey sampling design memorandum approved by EPA (Windward 2009a). The survey objectives were met using a range of fish collection methods, including electrofishing, minnow traps, and a fyke net to ensure a more complete picture of the fish population in Force Lake.

Approximately 86% of the fish in Force Lake collected as part of the 2009 survey were small (76 of the 88 fish collected were 14 cm (5.5 in.) in length or less). Only 12 fish (all carp) greater than this size were caught, 10 of which were in the 15 to 20 cm range (approximately 6 to 8 in.), and 2 of which were in the 21-to-25-cm range (approximately 8 to 10 in.). In addition, one or two larger carp were observed but not captured.

Table 2-7. Summary of Fish Collected During Force Lake Fish Population Surveys

Fish Species	Number of Fish Collected (Fish Size Range)							
	August 5, 1988[a]			March 13, 1989[a]		April 7, 2009[b]		
	Electrofishing	Beach Seine	Trap	Beach Seine	Trap	Electrofishing	Fyke Net	Minnow Traps
Small or Juvenile Fish (5 cm or Less in Length)								
Mosquitofish	>1,000 (<2 cm)	>1,000 (<2 cm)	nc	1 (4 cm)	nc	nc[c]	nc[c]	nc[c]
Unidentified juvenile sunfish	150 to 200 (<2 cm)	>1,000 (<2 cm)	nc	25 (2.6 to 5.4 cm)	nc	nc (not targeted)	nc (not targeted)	nc (not targeted)
Bluegill	nc	21 (2.5 to 4.4 cm)	nc	nc	nc	nc (not targeted)	nc (not targeted)	nc (not targeted)
Fish Greater than 5 cm in Length								
Goldfish	2 (7.8 to 11.4 cm)	6 (5.9 to 9.5 cm)	nc	1 (8.3 cm)	nc	nc	nc	nc
Bluegill	1 (14 cm)	nc	nc	nc	nc	nc	nc	nc
Pumpkinseed	5 (8.7 to 11.1 cm)	2 (11.5 to 12.3 cm)	nc	nc	nc	1 (8.4 cm)	32 (7.6 to 10.3 cm)	nc
Brown bullhead	1 (15 cm)	14 (5.5 to 25 cm)	nc	2 (7.4 to 8.3 cm)	1 (26 cm)	nc	1 (6.7 cm)	nc
Carp	1 (39 cm)	nc	1 (30 cm)	2 (35 to 45.7 cm)	nc	6 (16.5 to 21.8 cm)	47 (6.4 to 17.6 cm)	1 (12.5 cm)

[a] Fishman (1989).

[b] Windward (2009b).

[c] According to the Multnomah County Vector Control, mosquitofish were historically released in lakes in late spring/early summer to help control mosquito populations. However, since the mid-1990s, mosquitofish are no longer released into water bodies such as Force Lake where they might escape into other water bodies and thus their presence in Force Lake was not expected (Windward 2009b).

nc – none collected

These results are consistent with the expected population of a small, shallow lake with no riparian cover, such as Force Lake. In lakes of this type, the fishery is often stunted, meaning that most of the fish are small in size because of the high competition for food and the lack of large predator fish. Only carp (all less than 22 cm [approximately 8.5 in.]), pumpkinseed (all less than 12 cm [approximately 4.7 in.]), and one small brown bullhead (6.7 cm [approximately 2.6 in.]) were caught, none of which are native to the region. No game fish (e.g., trout or bass) were observed during the survey. The 2009 survey results are consistent with the results of the Fishman study conducted in the late 1980s (Fishman 1989), during which a similarly low number of larger fish were caught (Section 2.7.1). Note that the survey methods used during the 1988/1989 Fishman study (1989) and the 2009 survey (Windward 2009b) were different. The methods employed as part of the Fishman study included

electrofishing, beach seine, and traps; the 2009 survey methods included electrofishing, fyke nets, and minnow traps. These methods are not expected to be sufficiently different to significantly impact catch results.

The change in the bullhead population since the 1988/1989 Fishman study to the 2009 survey may indicate either a change in the Force Lake habitat and/or that the lake was stocked with bullhead in the past. Jesse Goodling, Heron Lakes Golf Course Superintendent, noted that since 1986, when he started working at the golf course, the water level in Force Lake during at least two different years was low enough to expose part of the lake bottom, typically at the end of a hot, dry summer. The last time this happened (4 or 5 years ago), Mr. Goodling recalled seeing a number of dead fish floating in the lake, possibly because of an algae bloom, which would depress oxygen levels in Force Lake. This type of event could have been responsible for altering the fish species present in Force Lake.[5]

The results of the 2009 survey indicate that there is a small population of carp in Force Lake and a stunted pumpkinseed fishery. Calculations done as part of the HHRA indicated that the assumed adult fish consumption rate in the risk assessment would require the annual consumption of 5 to 10 times the number of fish observed during the 2009 Force Lake survey (Windward 2009b). In addition, public access to Force Lake is limited because three sides of the lake are bordered by wetlands or the Heron Lakes Golf Club. Anglers can only access the lake along the east side (North Force Avenue) and at the southern corner of the lake. This information indicates that Force Lake could not support a significant and sustained level of fishing.

[5] Information provided to Stu Brown (Bridgewater) by Jesse Goodling in July 2009.

2.8 Background and Reference Area Concentrations

EPA guidance discusses two types of background concentrations, natural background and anthropogenic background. Natural background is defined as “naturally occurring substances present in the environment in forms that have not been influenced by human activity.” Anthropogenic background is defined as “natural and human-made substances present in the environment as a result of human activities (not specifically related to the CERCLA site in question)” (EPA 2002a).

This section discusses background concentrations for metals that are available from DEQ (DEQ 2002) and reference area concentrations for organic compounds. The term reference area is used instead of background for organic compounds because no specific background concentrations that are representative of anthropogenic background have been selected or approved by EPA. Instead, concentrations from reference areas (urban areas within the vicinity of the Study Area) are presented for comparison with Study Area concentrations.

Background or reference area concentrations are discussed for contaminants determined to be either COCs in the baseline human health risk assessment (HHRA) or have effects-based hazard quotients (HQs) greater than 1.0 in the ecological risk assessment (ERA) and for which background or reference area concentrations were less than Study Area concentrations (Appendices I and J, respectively).

2.8.1 Metals

Based on the HHRA and ERA, five metals (arsenic, chromium, copper, mercury, and zinc) were determined to be either COCs in the HHRA or have effects-based HQs greater than 1.0 in the ERA and for which background concentrations were less than Study Area concentrations.

Background metals concentrations were based on values reported in DEQ’s *Memorandum from the Toxicology Workgroup to DEQ Cleanup Program Managers Regarding Default Background Concentrations for Metals* (DEQ 2002) and in DEQ’s Guidance for assessing bioaccumulative COCs in sediment (DEQ 2007a). DEQ (2007a) provides both soil and freshwater sediment background concentrations available for use in the Portland region. When multiple values were available, a range of values was presented in this RI.

Background values for soil and freshwater sediment for the five metals are presented in Table 2-8.

Table 2-8. Background Concentrations for Metals

Contaminant	Background Concentration (mg/kg dw)		Source
	Soil	Freshwater Sediment	
Arsenic	7	7 to 7.9	DEQ (2002) and DEQ (2007a)[a]
Chromium	42	30	DEQ (2002)
Copper	36	12	DEQ (2002)
Mercury	0.07	0.07 to 0.2	DEQ (2002) and DEQ (2007a)[a]
Zinc	86	53	DEQ (2002)

[a] A range of sediment concentrations was presented for some metals because values presented in DEQ-recommended background sources are different.

DEQ – Oregon Department of Environmental Quality

dw – dry weight

The background values presented in Table 2-8 were used in the risk assessments and in this RI to provide context for contaminant concentrations at the Study Area.

2.8.2 Total DDTs

Reference area concentrations for total DDTs in sediment and soil were available from several sources located near the Study area. These DDT concentrations were used to derive an estimate of the expected ambient concentrations near the Study Area.

- A range of DDD, DDE, and total DDT concentrations were reported in DEQ's Columbia Slough Sediment Project (2005), which represents calculated baseline maxima concentrations meant to reflect the upper end of the range of sediment concentrations throughout the slough that are not associated with a particular source.
- A range of concentrations of 4,4′-DDD, 4,4′-DDE, and total DDTs were reported for five samples collected at the Radio Tower Site as part of the preliminary soil investigation for that site (URS 2000). The highest concentration (355 µg/kg ww for total DDTs) was substantially higher than the next highest concentration (55 µg/kg ww for total DDTs). The relative difference in concentrations was similar for DDEs and DDTs. However, because of the patchy nature of DDT concentrations in the region and because there was no indication that the maximum concentration was linked to a specific source, all five samples were included as reference area concentrations in this RI.

DDT concentrations across the two sources discussed above were used to represent a range of possible reference sediment and soil concentrations that might be expected within the Study Area for each of the DDT COPCs identified in the risk assessments: 2,4′-DDD, 4,4′-DDD, 4,4′-DDE, and total DDTs. Table 2-9 presents the range of COPC

concentrations reported in the two sources. Specific background concentrations for DDTs have not been established by EPA or DEQ.

Table 2-9. Summary of DDT Reference Area Concentrations in Sediment

DDT COPC	Range of Concentrations (µg/kg dw)	
	Columbia Slough (Sediment)[a]	Radio Tower (Soil)[b]
2,4′-DDD	6.1 – 6.7[c]	5[e] – 15[f]
4,4′-DDD	6.1 – 6.7[c]	5[e] – 15
4,4′-DDE	7 – 9.8[d]	5[e] – 110
Total DDTs	16 – 19	15[e] – 355

[a] DEQ (2005)
[b] URS (2000)
[c] Concentrations for 2,4′-DDD and 4,4′-DDD are based on reported DDD concentration.
[d] Concentration for 4,4′-DDE is based on reported DDE concentration.
[e] The low end of this range is equal to the RL.
[f] Concentration for 2,4′-DDD is based on 4,4′-DDD concentration.

COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
DEQ – Oregon Department of Environmental Quality
dw – dry weight
RL – reporting limit

In addition to the soil and sediment DDT concentrations discussed above, a Freedom of Information Act (FOIA) file review was conducted to provide additional information regarding DDT concentrations in the north Portland area. The FOIA file review was conducted at the EPA Region 10 Superfund Records Center in Seattle, Washington, on February 17 and 19, 2010. Files for eight sites were reviewed for information about DDTs in soil or sediment; relevant data are presented for three sites[6] (Table 2-10). The table includes only the most recent sampling data (i.e., historical sampling data were not included if newer data were available).

At sites with DDT information, concentrations of DDD, DDE, and DDT ranged from less than 1 µg/kg dw[7] to 100 µg/kg dw in surface soil (with the exception of some surface soil samples collected from the 1610 Pier 99 Street/Schooner Creek Boat Works facility [concentrations were as high as 2,700 µg/kg dw]), from non-detect to 310 µg/kg dw in subsurface soil, and from non-detect to 140 µg/kg dw in sediment.

[6] No DDT information was provided for Diversified Marine, Redi-Strip of Oregon, James River, and Lacamas Lab sites. In general, pesticides are not of concern at these sites according to EPA records and the DEQ Environmental Cleanup Site Information database (DEQ 2010). In addition, DDT information for the Rhône-Poulenc/Stauffer Chemical Company facility was not included because this facility was known to process DDTs and had concentrations up to 3,100,000 µg/kg dw.

[7] Units are assumed to be dry weight, although source documents did not specify this in every case.

Table 2-10. Summary of DDT Data from FOIA File Review

Facility Information	Year	Media Type	Concentrations in Soil or Sediment (µg/kg)[a]			Other Information	Source
			DDD	DDE	DDT		
Merit USA Inc. (approximately 1 mile northwest of the Study Area)							
Petroleum product refinery	2002	surface soil	2 – 3.3	0.86 JQ – 1.3	1.9 – 4.4		EPA (2002c)
	2002	subsurface soil	34 – 310	nd – 58	nd – 14		
	2002	sediment	13 – 140	3.9 – 20	10 – 51	collected from onsite wetland	
	2002	sediment	nd	nd	nd	collected from Smith Lake	
	2002	surface soil	5.1	23	100	referred to as “background” in source document	
	2002	subsurface soil	5.1	100	210	referred to as “background” in source document	
	2002	sediment	nd	nd	nd	referred to as “background” in source document	
City of Portland Saint John’s Landfill (approximately 2.5 to 3 miles northwest of the Study Area)							
Former general-purpose municipal landfill now undergoing restoration (Waste from a pesticide manufacturing facility was disposed in the landfill from 1958 to 1962.)	not reported	sediment	0.7 – 3.8	0.813 – 21.3	3		EPA (2010a); Oregon Metro (2010)
1610 Pier 99 Street/Schooner Creek Boat Works (approximately 0.5 mile east of the Study Area)							
Boat building, boat repair, and machine shop since late 1930s	2008	surface soil	0.28 JQ – 2,700	0.74 JQ – 58	4.3 U – 370		Ecology and Environment (2009)
	2008	surface soil	0.39 JQ	3.4 U	1.2 JQ	one sample collected on the property but outside of the area of operations; referred to as a “background sample”	
	2008	sediment	nd	nd	nd	sediment collected from the facility dock area	
	2008	sediment	nd	nd	nd	sediment collected from the Columbia River approximately 50 to 200 ft from the facility docks	
	2008	sediment	nd	nd	nd	five samples collected from upstream of the facility and referred to as “background samples”	

[a] Units are assumed to be dry weight, although source documents did not specify this in every case.

bgs – below ground surface
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
FOIA – Freedom of Information Act
J – estimated concentration
nd – not detected (RL not provided)
Q –estimated concentration (because below the contract-required quantitation limit)
U – not detected at given concentration

2.8.3 PAHs

Reference area concentrations for PAHs in sediment and soil were available as follows:

- A range of PAH sediment concentrations as reported for DEQ's Columbia Slough Sediment Project (2005), which represents calculated baseline maxima concentrations meant to reflect the upper end of the range of sediment concentrations throughout the slough that are not associated with a particular source.
- A range of PAH soil concentrations reported for individual PAHs from five samples taken at the Radio Tower Site (URS 2000).

A range of PAH concentrations across the above two sources was used to represent reference area sediment and soil PAH concentrations at the Study Area for each PAH. Table 2-11 presents the range of PAH concentrations reported in the two sources. Specific background concentrations for PAHs have not been established by EPA or DEQ.

Table 2-11. Summary of PAH Reference Area Concentrations in Sediment and Soil

PAH	Range of Concentrations (µg/kg dw)	
	Columbia Slough (Sediment)[a]	Radio Tower Site (Soil)[b]
Benzo(a)anthracene	72 – 87	4.5 – 33
Benzo(a)pyrene	90 – 100	5.3 – 39
Chrysene	103 – 129	6.7 – 51
Fluoranthene	132 – 144	7.3 – 53
Phenanthrene	80 – 88	14 – 25
Pyrene	196 – 196	68 –427[c]
Total PAHs	1,073 – 1,078	na

[a] DEQ (2005)
[b] URS (2000)
[c] Non-detected values were treated as one-half the reporting limits for calculating sums.
DEQ – Oregon Department of Environmental Quality
dw – dry weight
na – not available
PAH – polycyclic aromatic hydrocarbon

2.8.4 PCBs

Reference area concentrations for total PCBs are available from one source, DEQ's Columbia Slough Sediment Project (2005). A range of 23 to 24 µg/kg dw (Aroclor 1254) was calculated from the data, which represents calculated baseline maxima concentrations meant to reflect the upper end of the range of sediment concentrations throughout the slough that are not associated with a particular source. This range was used to represent reference area sediment and soil total PCB concentrations for comparison to Harbor Oil data (no soil-specific values were available). Total PCBs were not analyzed in the samples collected from the Radio Tower Site. Specific background concentrations for total PCBs have not been established by EPA or DEQ.

3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This section presents a summary of the current physical characteristics of the Study Area, including the surface features, meteorology, hydrology, geology, hydrogeology, demography, and ecology.

3.1 Surface Features

Based on Figure 2-2 from the *Site Investigation and Preliminary Remediation Plan for Portland Stockyards* (Golder Associates 1990), the land surface of the Facility is relatively flat with a slight slope from northeast to southwest toward the wetlands. A soil berm along the northwest and southwest sides of the Facility prevents runoff from flowing into the wetlands. Figure 2-2 from Golder Associates (1990), as well as other figures from Golder Associates (1990) referenced later in this section, are presented in Appendix K.

3.2 Meteorology

The Portland area has a temperate marine climate characterized by wet winters and dry summers. According to information provided by NOAA (2010), precipitation, temperature, and wind data for the Portland area are as follows:

Precipitation	
Average annual	37 in. (mostly rain)
Average wettest month	6.1 in. (December)
Average driest month	0.6 in. (July)
Temperature	
Average annual	54 °F
Average coldest month	40 °F (January)
Average warmest month	69 °F (August)
Wind	
Average wind speed	7.9 miles per hour
Prevailing direction	East-southeast

3.3 Surface-Water Hydrology

According to the PEN 1 NRMP (City of Portland 1997), the PEN 1 drainage area is approximately 900 ac in size and is located within the Columbia River floodplain. The area was diked and drained in the early 1900s. Over time, the area has been filled to create housing sites and roads, develop the Portland International Raceway and Heron Lakes Golf Club, and to store surplus soil from other projects. The perimeter of the PEN 1 NRMP area is surrounded by a levee to protect the area from flooding by the Willamette and Columbia Rivers. All runoff generated within the area is pumped over the levee into the Columbia Slough.

Given its floodplain setting, hydrologic resources in the vicinity of the Facility include: wetlands the southwest and northwest, the “radio tower” wetlands to the southeast, Force Lake, numerous small lakes within the Heron Lakes Golf Club, and a network of sloughs, ditches, and culverts (Figure 1-11).

3.3.1 Force Lake Drainage Basin

There are only two known point discharges into Force Lake. According to J. Goodling (2007), a catch basin drains a small area along the east side of N Force Avenue, just north of its intersection with N Victory Boulevard. Stormwater captured in this catch basin is conveyed beneath N Force Avenue and discharged into Force Lake. In addition, an underdrain for one of the greens on the Greenback Golf Club drains to the lake.

All of the other discharges to Force Lake are nonpoint source discharges of stormwater. According to the PEN 1 NRMP (City of Portland 1997), Force Lake is located within drainage sub-basin A-7, which includes the Facility, properties between the Facility and the Peninsula Terminal Railroad, properties west of N Force Avenue, properties east of N Force Avenue and south of the Peninsula Terminal Railroad, and the wetlands between the Facility and Force Lake (see Figure 1-11). All of the surface water runoff south of an east-west trending topographic divide[8] that represents the northeast boundary of sub-basin A-7 drains southward toward Force Lake. In addition, the portion of the Heron Lakes Greenback Course that borders the south and west sides of Force Lake also drain into Force Lake. There are no other known surface water inflows to Force Lake.

The current stormwater treatment system located on the Facility does not discharge directly into Force Lake; it discharges into the wetlands near just south of the Facility (Figure 1-3).

During golf course construction in 1969 and 1970, the narrow west end of Force Lake was bisected by fill material to create another small lake (presumably North Lake) (DEQ 1974a). The preceding is confirmed by review of available aerial photographs of the area for 1966 and 1973 (Appendix A). The 1966 aerial photograph shows Force Lake to be one

[8] The east-west topographic divide is located north of the Site by the railroad tracks, approximately halfway between the Site and N. Marine Drive.

contiguous surface water body with what is now known as North Lake. The 1973 aerial photograph depicts the lake area after golf course construction is complete. As depicted in the 1973 photograph, the former single water body had been separated into two separate water bodies (i.e., North Lake and Force Lake) by the newly constructed golf course. As depicted in the 1948 aerial photograph (Appendix A) and on Figure 1-5, the area where the golf course was extended to create the two separate lakes was historically at a relatively high elevation as indicated by the limits of the flood waters at the time the aerial photograph was taken. The configuration of North Lake and Force Lake remains relatively unchanged as shown in aerial photographs between 1973 to the present (Appendix A).

3.3.2 Force Lake Hydraulics

According to the NRMP (City of Portland 1997), the estimated drainage area to Force Lake is 17 ac and the estimated peak flow into Force Lake during a 5-year frequency storm event is 9 cubic ft per second.

Force Lake is 590 to 890 ft in diameter and has a surface area of about 12 ac (City of Portland 1997). The estimated storage volume of the lake is about 30 acre-feet. Based on these parameters and on observations during Phase 1 and 2 sampling, the average depth of Force Lake is 2.5 ft.

The NRMP indicates that outflow volumes from Force Lake are much less than inflow volumes, and are minimal for storm events less than a 2-year event. This is due the fact that outflows from Force Lake are controlled by two, 30-in. concrete sewer pipes (CSPs) located on the west side of the lake, which have an invert elevation of about 0.8 ft higher than the water levels in other downstream water bodies located in what is referred to as the upper “A” sub-basin. The upper “A” sub-basin includes Force Lake, North Lake, the North Drainageway, Frog Lake, and an unnamed lake (see Figure 1-11). The 30-in. corrugated metal pipe (CMP) that connects the unnamed lake to the Southwest Marsh hydraulically separates the upper “A” sub-basin and controls upstream water levels everywhere except in Force Lake. Thus, until water in Force Lake rises to the elevation of the pipe invert for the two, 30-in. CSPs, no outflow occurs from the lake. According to Mr. Goodling, Force Lake discharges to North Lake about 9 or 10 months per year.

Because of the hydraulic control on outflows from Force Lake, the NRMP (City of Portland 1997) indicates that pollutants conveyed to Force Lake by runoff from sub-basin A-7 and the Heron Lakes Greenback Golf Club will remain in Force Lake and not be transported downstream. This conclusion is supported by the findings of the RI, which indicate generally low concentrations of chemicals in North Lake sediments and few detections of chemicals in Force Lake surface water.

The water elevation in Force Lake is controlled by the invert elevation of the pipes that connect Force Lake to North Lake. This hydraulic control limits the flow of water from Force Lake. Because inflows and outflows from the Lake are limited, the water velocity or current is small (i.e., the lake is a quiescent water body that behaves like a settling basin) and

suspended solids that enter the lake tend to settle to the bottom, rather than being transported downstream. Chemicals entering the lake will tend to remain because of the lake hydraulics, the tendency for solids to settle, and the fact that most of the chemicals that have been detected above screening levels have a tendency to adsorb to solids that will settle. As discussed in Section 4.0, sediment samples collected in North Lake confirm that contamination in Force Lake does not appear to have migrated to North Lake.

3.3.3 Downstream Surface Water Bodies

Force Lake discharges to North Lake, which also receives runoff from the Heron Lakes Greenback Course. North Lake discharges to the North Drainageway via a ditch and 24-in. culvert. The North Drainageway flows to the west through a wetland area and heron rookery, and then flows to the south near the northwest corner of the Greenback Course (Figure 1-11). It is at this point that drainage from the area between the levee and the railroad tracks apparently enters the North Drainageway, and where the North Drainageway flows into a 24-in. culvert that flows to the south into Frog Lake. According to J. Goodling, the 24-in. culvert has settled and is partially clogged. To overcome this problem, the City of Portland extended the North Drainageway to the west to connect to Frog Lake in approximately 1995 (Goodling 2007).

From Frog Lake, water flows to the south through a 30-in. culvert to a smaller unnamed lake and then through another 30-in. culvert, where it enters the Southwest Marsh. According to the NRMP (City of Portland 1997), the invert elevation for the second culvert controls upstream hydraulics, likely indicating that water only flows in the Southwest Marsh once upstream water levels are high enough to reach the invert for the culvert that discharges from Frog Lake.

From the Southwest Marsh, surface water flows to the south through several culverts and another unnamed lake to the Southwest Slough and then flows to the east to Forebay Slough where it is pumped over the levee into the Columbia Slough at a pumping station as shown on Figure 1-11. Because this pumping station only moves surface water from the north side of the levee to the south side of the levee, it is not expected to influence the groundwater flow regime in the Study Area.

Southwest Marsh receives runoff from a series of lakes located in the west central portion of the Heron Lakes Golf Club. Prior to entering Forebay Slough, surface water from Southwest Slough combines with surface water drainage from the central portion of the Heron Lakes Golf Club that collects in various unnamed lakes and Midwestern Slough. Note that Forebay Slough also receives runoff from the Portland International Raceway, which is located in the southeastern portion of the PEN 1 NRMP area, as well as runoff from the Northeast Drainageway, located east of the Facility. As shown on Figure 1-11 and documented in the PEN 1 NRMP (City of Portland 1997), the Northeast Drainageway receives runoff from the Excel Communications property via a small pumping station that moves surface water over the dike that separates the property from the drainageway. As with the larger surface water

pumping station described for the Forebay Slough, the Northeast Drainageway pumping station is not expected to influence the groundwater flow regime in the Study Area.

Mr. Goodling indicated that he had worked at the Heron Lakes Golf Club since 1986 and that the drainage system had not changed over that time, other than the extension of the North Drainageway to Frog Lake.

3.4 Geology

3.4.1 Regional Geology

The Study Area is located in the central part of the Portland Basin physiographic province, which is bounded by the Tualatin Mountains to the west and south and the Cascade Range to the east and north. The Study Area is located along the southern bank of the Columbia River floodplain, east of the confluence with the Willamette River (Figure 1-1).

The geologic history of the Portland Basin is described by Trimble (1957, 1963), Burns et al. (1998), and Beeson et al. (1991). A basin formed from basalt of the Columbia River Basalt Group that flowed from the northeast corner of Oregon down the ancestral Columbia River 14 to 16 million years ago and solidified in the area. Afterward, the basin was faulted and pulled apart causing the middle part to sink and the edges to uplift to form the Tualatin Mountains to the south and west and the Cascade Mountains to the north and east. Concurrent with this structural deformation, over a 12-million-year period ending about two million years ago the basin filled with up to 1,500 ft of ancestral Columbia River sediments (gravels, sands, silts, and clays) that comprise the Troutdale Formation (coarse-grained facies) and Sandy River Mudstone (fine-grained facies). Volcanic vents formed throughout the eastern part of the basin and erupted basaltic Boring Lavas during a period starting two million years ago and ending approximately 260,000 years ago. Between approximately 12,700 to 15,300 years ago, numerous catastrophic floods caused by glacial ice dam breaks in Montana inundated the Portland Basin with flood water up to an elevation over 400 ft, and after the water receded, silt deposits up to 100 ft thick were windblown onto surrounding slopes of the Tualatin Mountains forming the Portland Hills Silt Formation.

The regional stratigraphy, listed from the surface down, is as follows:

- **Poorly Consolidated Silt and Sand Alluvium:** Holocene to Pleistocene age Columbia River and catastrophic flood deposits composed of discontinuous layers of silts, silty sands, and sands that are approximately 120 ft[9] thick in the Study Area vicinity (Beeson et al. 1991; Madin 1990).
- **Troutdale Formation:** Pleistocene, Pliocene, and upper Miocene age fluvial coarse-grained deposits of the ancestral Columbia River that are composed of poorly to moderately consolidated,

[9] Logs of wells near the Study Area indicate the sand and silt extend to a depth of 130 to 135 feet bgs.

poorly graded, and sub-rounded to rounded sand and gravel with occasional cobbles. Well logs indicate the Troutdale Formation extends to approximately 300 ft bgs in the vicinity of the Study Area. The maximum thickness of the Troutdale Formation is over 600 ft and possibly up to 1,500 ft in the East Portland Well field study area (Hoffstetter 1984).

- **Sandy River Mudstone:** Miocene to Pleistocene age (1 to 5 million years old) fluvial and lacustrine fine-grained deposits of the ancestral Columbia River (Madin 1990) composed of silt and clay with some sand deposited in a broad delta in the Portland-Vancouver region. The mudstones extend beyond 980 ft bgs according to one well log in the vicinity of the Study Area, giving a combined thickness with the Troutdale Formation of approximately 1,100 ft in this area (Swanson et al. 1993).
- **Columbia River Basalt Group:** Miocene age (23 to 5 million years old) layered basalt flows that individually range in thickness from approximately 10 to 150 ft and comprises a total thickness of 100 ft to about 800 ft. The Columbia River Basalt Group is considered the geologic basement unit for this area.

3.4.2 Local Geology

Local geologic conditions described in this section are primarily based on the lithology recorded on numerous shallow (i.e., approximately 10 ft bgs) direct-push boring logs and deeper (i.e., approximately 50 ft bgs) boring logs for intermediate monitoring wells MW-2i, MW-4i, and MW-5i (see Appendix D). In addition, two boring logs presented by Redmond and Associates (2002) were used to evaluate local geologic conditions. Geologic conditions below a depth of approximately 50 ft bgs were based on lithologic information for the plant well and cross sections prepared by Golder Associates (1990) (see Appendix K).

One non-native (i.e., fill) lithologic layer and native lithologic layers are present on the Facility, as presented in the geologic cross sections (Figures 3-1 through 3-4). The native lithologic layers are consistent with a fluvial depositional environment of predominantly low energy,[10] as indicated by the high percentage of silts and clays in most of the soil samples. Occasionally, the fluvial depositional environment changed to moderate energy,[11] as indicated by the fine- to medium-grained sand layers detected in some of the soil samples. The components of and conditions within the non-native and native distinct lithologic layers are described below:

- **Approximately 0 to 3 ft bgs:** Fill, primarily rock fragments and gravel, silty/sandy matrix, trace to little brick fragments, pieces of wood or cobbles, poorly sorted, medium dense, moist.

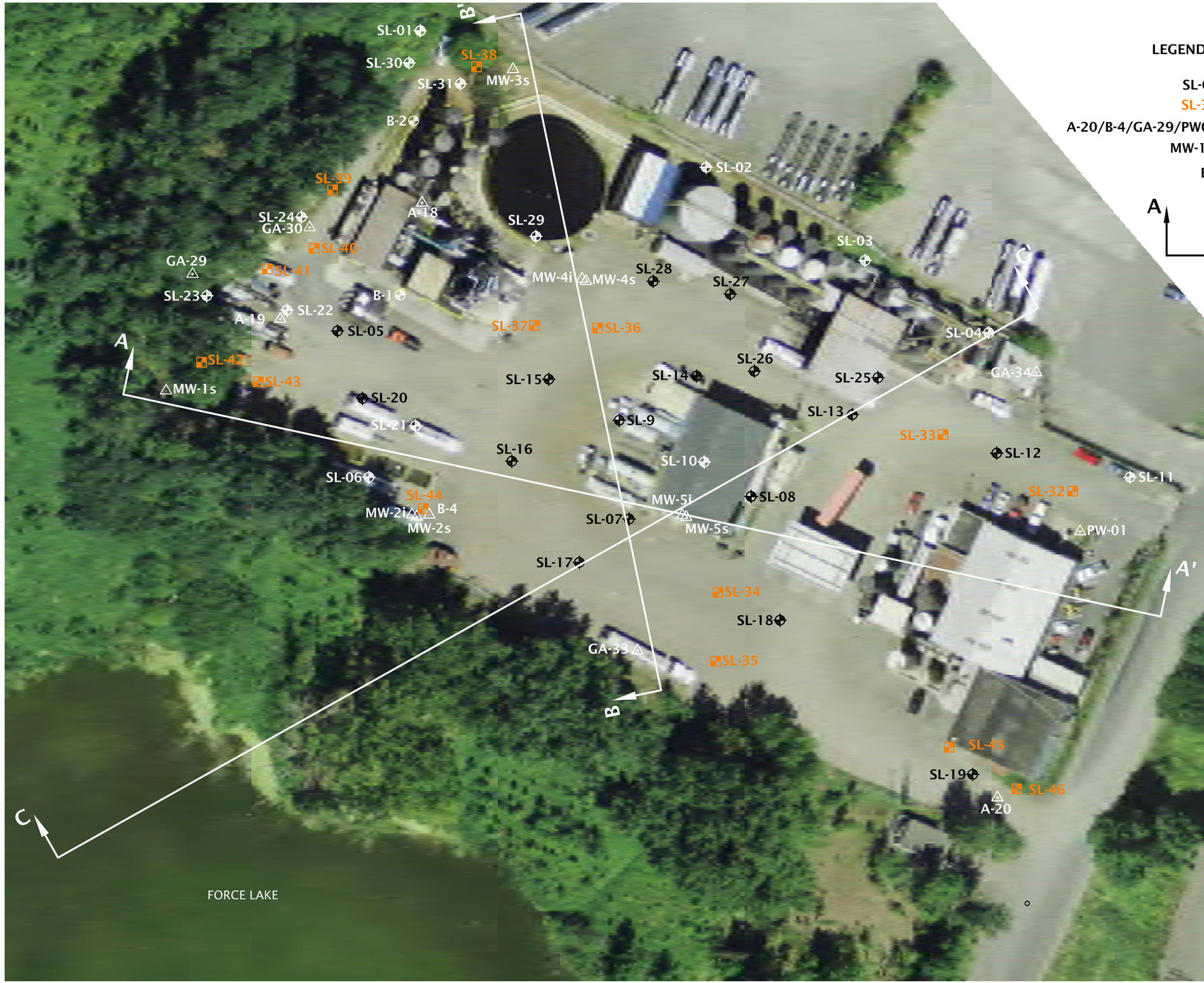
[10] Sediment deposited in lacustrine environments, swamps, marshes, deltas and lagoons.

[11] Sediments deposited in outwash plains, alluvial fans, along coasts and shorelines, and by rivers and streams by flooding and meltwater from snow and glaciers.

- **Approximately 3 to 8 ft bgs:** Very fine- to fine-grained sand, moderately sorted (some micro-stratification), trace silt, very loose to loose, gray, wet.
- **Approximately 8 to 37 ft bgs:** Silt, some clay, trace sand, moderate plasticity, olive gray to light gray to gray brown, soft to medium stiff, moist.
- **Approximately 37 to 48 ft bgs:** Fine- to medium-grained sand, trace silt, poorly graded, gray, loose to medium dense, wet.
- **Approximately 48 to 50 ft bgs:** Silt, some clay, trace sand, moderate plasticity, light gray brown to gray, soft to medium stiff, moist to wet.

Surface and subsurface soil conditions observed during Phase 1 and Phase 2 soil sampling activities, coupled with evaluation of the aerial photography of the property and field reconnaissance observations indicate that approximately 82% of the Facility ground surface was covered by packed gravel or structures at the time of the investigation. Since that time (in the fall of 2011), the majority of the Facility was paved with asphalt. Areas of the Facility that do not have a gravel or asphalt-paved surface include the following:

- The northern ditch area, which also includes a vegetated area in the vicinity of MW-3s, SL-31 and SL-38. It should be noted that gravel fill materials were observed beneath the topsoil cover layer in SL-31, SL-38 and MW-3s (Figure 2-1).
- The western margin of the site, which includes the soil stockpile area and adjacent portion of the wetland area, the western portion of the perimeter soil berm, and non-graveled areas observed near SL-42, MW-1s, and GA-29 (Figure 2-1).
- The southern site boundary and associated perimeter soil berm and wetland area (Figure 2-1).
- A portion of the eastern site boundary, adjacent to Force Avenue (Figure 2-1).



LEGEND:

SL-01	PHASE I SOIL SAMPLING LOCATION
SL-32	PHASE II SOIL SAMPLING LOCATION
A-20/B-4/GA-29/PW01	EXISTING WELL LOCATION
MW-1s	NEW WELL LOCATION
B-1	REDMOND AND ASSOCIATES BORING LOCATION (2002)
A A'	CROSS SECTION

N

0 60 120

(SCALE IN FEET)

SITE PLAN BASED ON SURVEY DATA PROVIDED BY THURSTON & ASSOCIATES, MAY 2008

SITE PLAN AND CROSS-SECTION LOCATIONS

FIGURE 3-1

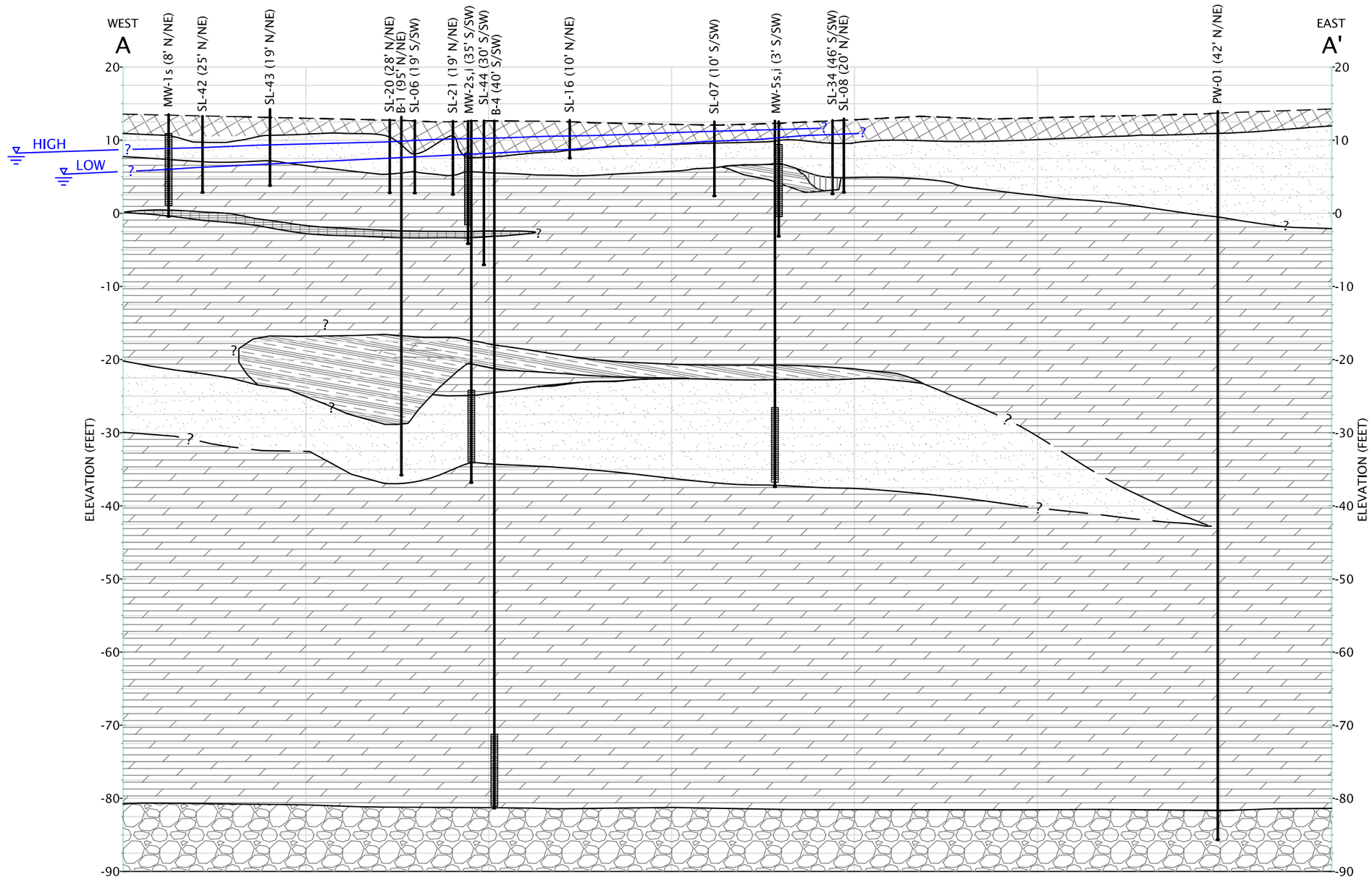
HARBOR OIL SITE
PORTLAND, OR

BWGROUP-1-01-07

JUNE 2010

GEODESIGN INC
15575 SW Sequoia Parkway - Suite 100
Portland OR 97224
Off 503.968.8787 Fax 503.968.3068

Printed By: cdavis | Print Date: 6/23/2010 2:08:40 PM
File Name: J:\A-D\BWGroup\BWGroup-1\BWGroup-1-01\BWGroup-1-01-07\Figures\CAD\BWGroup-1-07-SP_CS01.dwg | Layout: FIGURE 3-1



LEGEND:

- FILL: GRAVEL, SAND, SILT (GP)
- POORLY GRADED SAND, TRACE SILT (SP)
- CLAYEY SILT; SILT WITH CLAY (MH)
- SILT (ML)
- SILTY SAND (SM)
- CONSOLIDATED COBBLES, GRAVEL, SAND & SILT (TROUTDALE FORMATION)
- GRAVEL, SILT, ORGANICS
- INFERRED WATER TABLE ELEVATION

NOTE:

HIGH AND LOW WATER TABLE ELEVATION INFERRED FROM MONITORING WELLS MW-1s, MW-2s AND MW-5s. HIGH ELEVATIONS REFLECT JANUARY 2009 DATA AND LOW ELEVATIONS REFLECT SEPTEMBER 2008 DATA.

0 60 120
(SCALE IN FEET)

CROSS SECTION A-A'

HARBOR OIL SITE
PORTLAND, OR

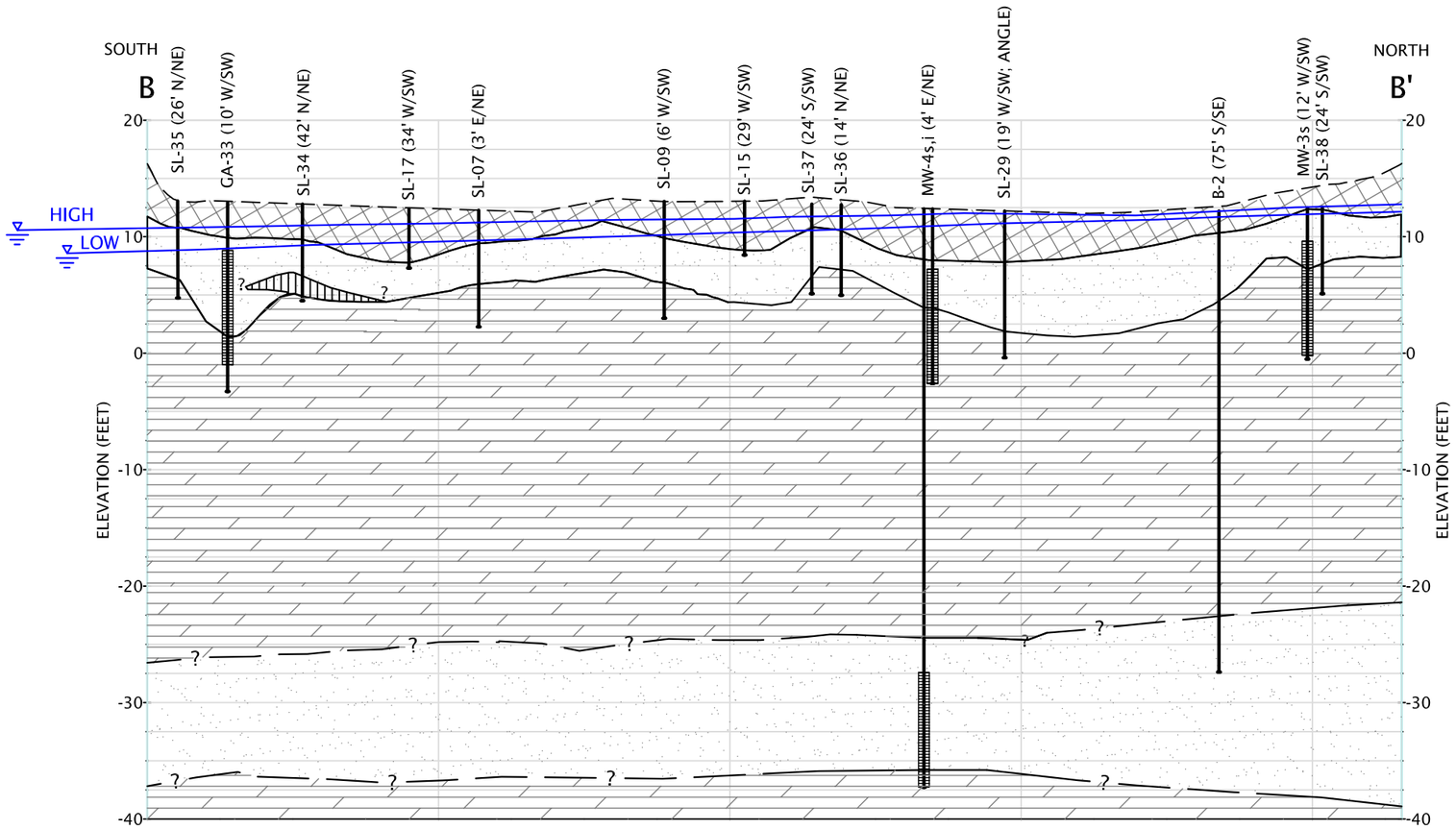
FIGURE 3-2

BWGROUP-1-01-07

JUNE 2010

GEODESIGN INC
15575 SW Sequoia Parkway - Suite 100
Portland OR 97224
Off 503.968.8787 Fax 503.968.3068

Printed By: cdavis | Print Date: 6/23/2010 2:08:14 PM
File Name: J:\A-D\BWGroup\BWGroup-1\BWGroup-1-01\BWGroup-1-01-07\Figures\CAD\BWGroup-1-07-SP_CS01.dwg | Layout: FIGURE 3-2



LEGEND:

- FILL: GRAVEL, SAND, SILT (GP)
- POORLY GRADED SAND, TRACE SILT (SP)
- CLAYEY SILT; SILT WITH CLAY (MH)
- SILT (ML)
- INFERRED WATER TABLE ELEVATION

NOTE:

HIGH AND LOW WATER TABLE ELEVATION INFERRED FROM MONITORING WELLS GA-33, MW-4s AND MW-3s. HIGH ELEVATIONS REFLECT JANUARY 2009 DATA AND LOW ELEVATIONS REFLECT SEPTEMBER 2008 DATA.

0 50 100
(SCALE IN FEET)

CROSS SECTION B-B'

HARBOR OIL SITE
PORTLAND, OR

FIGURE 3-3

BWGROUP-1-01-07

JUNE 2010

GEODESIGN INC
15575 SW Sequoia Parkway - Suite 100
Portland OR 97224
Off 503.968.8787 Fax 503.968.3068

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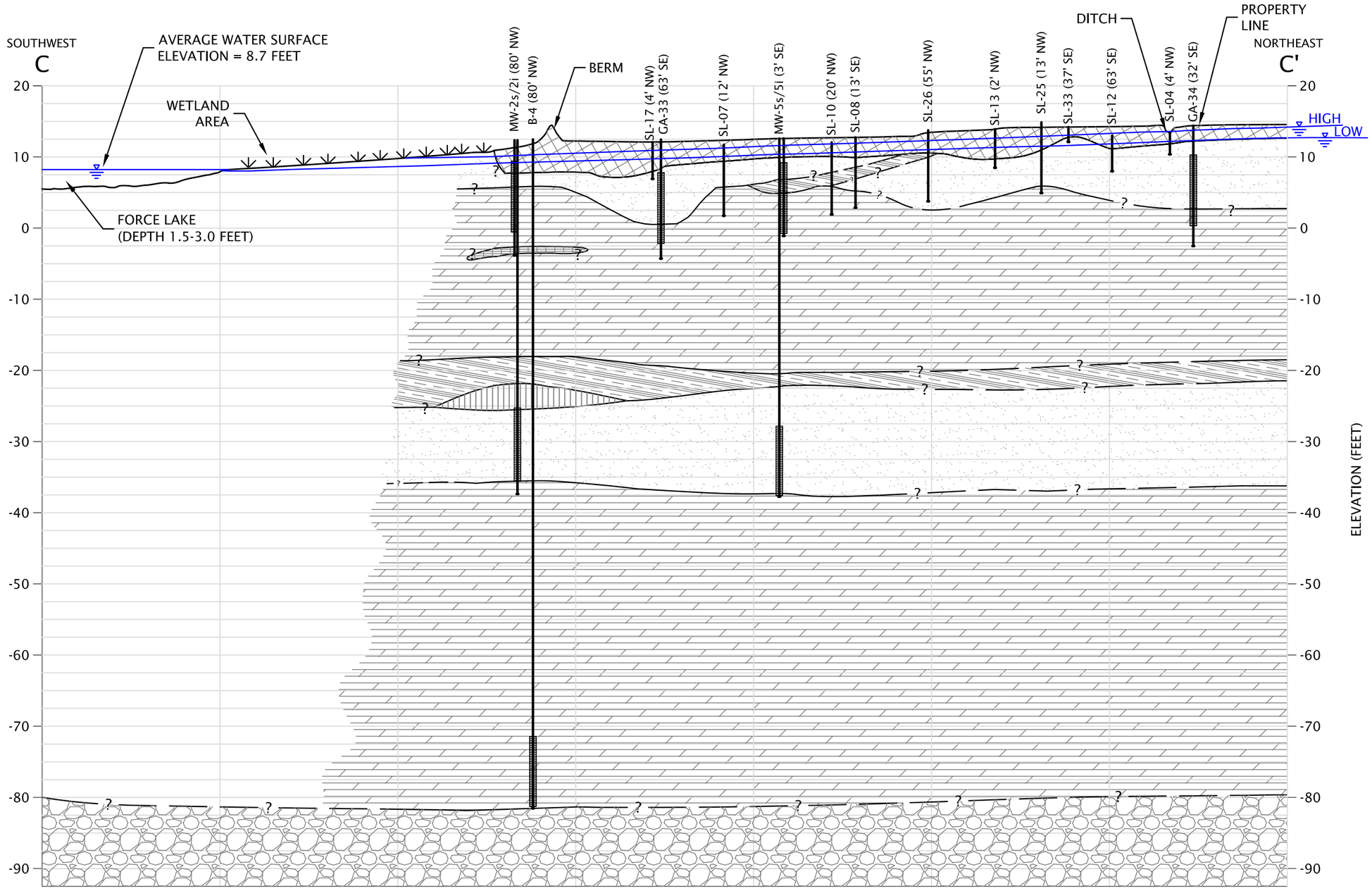
File Name: J:\A-D\BWGroup\BWGroup-1\BWGroup-1-01\BWGroup-1-01-07\Figures\CAD\BWGroup-1-07-SP_CS01.dwg | Layout: FIGURE 3-3



LEGEND:

- FILL: GRAVEL, SAND, SILT (GP)
- POORLY GRADED SAND, TRACE SILT (SP)
- CLAYEY SILT; SILT WITH CLAY (MH)
- SILT (ML)
- SILTY SAND (SM)
- CONSOLIDATED COBBLES, GRAVEL, SAND & SILT (TROUTDALE FORMATION)
- GRAVEL, SILT, ORGANICS
- INFERRED WATER TABLE ELEVATION

NOTE:

HIGH AND LOW WATER TABLE ELEVATION INFERRED FROM MONITORING WELLS MW-2s, GA-33, MW-5s AND GA-34. HIGH ELEVATIONS REFLECT JANUARY 2009 DATA AND LOW ELEVATIONS REFLECT SEPTEMBER 2008 DATA.

0 60 120
(SCALE IN FEET)

FIGURE 3-4

CROSS SECTION C-C'

HARBOR OIL SITE
PORTLAND, OR

BWGROUP-1-01-07

JUNE 2010

GEODESIGN INC
15575 SW Sequoia Parkway - Suite 100
Portland OR 97224
Off 503.968.8787 Fax 503.968.3068

Printed By: cdavis | Print Date: 6/24/2010 12:16:44 PM
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3.5 Hydrogeology

3.5.1 Regional Hydrogeology

The Study Area is located in the lowlands of PEN 1, the perimeter of which is a levee intended to protect the lands in PEN 1 from high water in the Columbia River and Willamette River (City of Portland 1997). PEN 1 and the Study Area are located within the alluvial floodplain of the Columbia River, bounded by the Oregon Slough channel of the Columbia River approximately 0.23 mile to the north and the Columbia Slough approximately 0.8 mile to the south (Figure 1-1). The Columbia Slough extends 18 miles from Fairview Lake on the east to the Willamette River at Kelley Point Park on the west. There are three sections or reaches of the Columbia Slough. The reach near the Study Area is the Lower Slough, the western reach.

Six distinct hydrogeologic units, described below, have been mapped regionally in the alluvial flood plain of the Columbia River in the Portland Basin (Hoffstetter 1984; Morgan and McFarland 1996a; Hartford and McFarland 1989). The inclusion of descriptions of these hydrogeologic units in this section does not infer that all six units underlie the Study Area.

Unconsolidated Sedimentary Aquifer: Referred to as the Overbank Deposits by Hoffstetter (1984), this aquifer consists mostly of catastrophic flood deposits of silt, clayey silt, and sand. Thickness is variable but is 65 ft thick at the western edge of the East Portland Well Field study area. The Unconsolidated Sedimentary Aquifer thickens to the north from Sandy Boulevard to the Columbia River. The horizontal hydraulic conductivity in the Unconsolidated Sedimentary Aquifer is 175 ft/day (Morgan and McFarland 1996b). A spring 1988 groundwater level of -2.2 ft mean sea level (msl) was measured in a well near the Columbia Slough south of the Study Area (Morgan and McFarland 1996a). A +1-ft change in water level was noted in this well between measurements taken in 1988 and 1989.

Troutdale Formation Hydrogeologic Units: Three major aquifers (Troutdale Gravel Aquifer [TGA], Troutdale Sandstone Aquifer [TSA], and Sand and Gravel Aquifer [SGA]) and two major aquitards (Confining Unit 1 [CU1] and Confining Unit 2 [CU2]) have been delineated within the Troutdale Formation as follows:

Troutdale Gravel Aquifer: Referred to as the Columbia River Sand Aquifer by Hofftstetter (1984), this aquifer consists of late Pleistocene and Holocene medium quartzose sand occasionally layered with silt, clay, and basalt, andesite, dacite, and quartzsite gravel zones that fill a Pleistocene Columbia River valley. The TGA attains a maximum thickness of approximately 400 ft; the TGA is approximately 195 ft thick at the western edge of the East Portland Well Field study area, not far from the Study Area. According to Ecology and Environment (2000), most municipal wells have been completed in this aquifer; the upper part of the TGA has been weathered to clay to form a discontinuous confining layer, but this

confining layer has not been confirmed in the Study Area vicinity. The horizontal hydraulic conductivity for the TGA ranges from about 7 to 16 ft/day (Morgan and McFarland 1996).

Troutdale Sandstone Aquifer: According to Hoffstetter (1984), the TSA consists of a relatively uniform deposit of conglomerate and vitric sand and sandstone that extends throughout a large portion of the Portland Basin. A thin layer of silt separates the depositional mode of the aquifer into an Upper Unit (approximately 60 ft thick) consisting of fluvial vitric sand and sandstone and a Lower Unit (approximately 35 ft thick) consisting of fluvial-lacustrine conglomerate. Well yields for the TSA are 1,000 to 2,000 gpm.

Sand and Gravel Aquifer: Referred to as Rose City Aquifer by Hoffstetter (1984), this aquifer is composed of discontinuous lenses of sand, gravel, silt, and clay. Pump tests show that the SGA is continuous throughout the East Portland Well Field study area, but each well shows a different sequence of materials. Various mixtures of gravel and sand dominate the Upper unit (approximately 120 ft thick) while thick layers of sand with occasional silt and clay beds predominate in the Lower unit (100+ ft thick). Most of the sand in the SGA is quartzose, with a minor amount of mica. Vitric sand is not as common in the SGA as in the TGA. The gravel in the SGA consists almost entirely of basalt and quartzite clasts, and the cementation of the gravel is less tight than in the TSA. The horizontal hydraulic conductivity in the SGA is 150 ft/day (Morgan and McFarland 1996b). A spring 1988 groundwater level of approximately 10 ft msl was measured in the SGA east of the Study Area (Morgan and McFarland 1996a). Well yields for the SGA are 2,000 to 3,000 gpm.

Confining Unit 1: This unit is composed of lenticular and interbedded zones of fine-grained, lacustrine deposits of consolidated sand, silt, and clay that act as hydraulic confining layers preventing rapid water movement between the CRSA and TSA. This unit is approximately 50 ft thick at the western edge of the East Portland Well Field study area. The horizontal hydraulic conductivity in CU1 and CU2 is approximately 1 ft/day (Morgan and McFarland 1996b). The horizontal hydraulic conductivity in CU1 is approximately 1 to 10 ft/day (Morgan and McFarland 1996b).

Confining Unit 2: Referred to as Rose City Aquitard by Hoffstetter (1984), this unit is composed of lenticular and interbedded zones of fine-grained, lacustrine deposits of consolidated sand, silt, and clay that act as hydraulic confining layers preventing rapid water movement between the TSA and SGA. This unit is approximately 80 ft thick at the western edge of the East Portland Well Field study area. The horizontal hydraulic conductivity in CU2 is approximately 0.5 to 4 ft/day (Morgan and McFarland 1996b).

3.5.2 Local Hydrogeology

Local hydrogeologic conditions, such as groundwater levels, flow direction, gradient, and aquifer characteristics (e.g., hydraulic conductivity, transmissivity) were initially evaluated by Golder Associates

(1990) and later summarized by Ecology and Environment (2000). In addition, Sweet-Edwards/EMCOM (1988) evaluated groundwater levels for four borings drilled at the Facility.

Based on initial investigations and studies completed for Phase 1 and Phase 2 of the RI, the local hydrogeology has been defined as containing three distinct groundwater zones beneath the Facility including:

- A shallow saturated zone that occurs at depths ranging from 1 to 6 ft bgs, depending upon location and time of year, with seasonal fluctuations ranging from 1 to 3 ft at any particular location over the course of the year. The shallow saturated zone extends to a depth of approximately 8 to 15 ft bgs within a relatively permeable sand fill material
- An intermediate saturated zone that occurs within a sand interval between approximately 37 to 48 ft bgs
- A deep saturated zone that occurs at depths greater than approximately 90 ft bgs that is associated with the TGA gravels

As described on boring logs (Appendix D), and as depicted on the hydrogeological cross-sections prepared for the Study Area (Figures 3-2 through 3-4), the three distinct water-bearing zones are separated by saturated silt deposits with varying amounts of sand and clay.

3.5.2.1 Site Vicinity Hydrogeological Studies

Golder Associates (1990) installed pressure transducers fitted with electronic data loggers in several wells, including shallow well A-19 and deep well B-4 at the Facility. A pressure transducer and data logger were also set up in the Oregon Slough to monitor the stage in the Columbia River.

The purpose of this monitoring was to determine regional groundwater gradients, flow directions, and fluctuations. Data were collected from the middle of May 1990 through the end of July 1990. The resulting data were plotted along with Oregon Slough station elevations to determine if water level fluctuations were correlated. The resulting hydrograph did not show a clear correlation between the fluctuations in Columbia River stage and fluctuations in shallow groundwater. However, a correlation did exist between fluctuations in Columbia River stage and the fluctuation in intermediate and deep groundwater (Golder Associates 1990). Such fluctuations may be due to tidal as well as seasonal influences.

Golder Associates (1990) evaluated horizontal versus vertical hydraulic gradients in shallow, intermediate depth, and deep zones. Golder Associates speculated that the interbedded silts and fine-grained sands comprising the lacustrine and overbank deposits should act hydraulically as a semi-confining stratum or an aquitard (see Figures 3-2 through 3-4). As such, the intermediate zone should exhibit a high degree of anisotropy of horizontal versus vertical hydraulic conductivities (a 10:1 to 100:1 contrast). However, following the investigation, Golder Associates (1990) concluded that the interbedded sands and silts do not appear to isolate the shallow and deep zones but act as a continuous hydraulic system,

both in terms of vertical and horizontal gradients. On the former Stockyards site, vertical gradients were downward, allowing movement of near surface groundwater to depth. Golder Associates (1990) noted that vertical gradients between the shallow and intermediate zones ranged from 0.14 to 0.17 ft/ft, and vertical gradients generally declined with depth. Slight downward vertical gradients also were noted between intermediate and deep well clusters north of the Facility. Vertical gradients were not as pronounced at the Facility (Golder Associates 1990), in part due to the recharge of the shallow groundwater system by the former stockyard production well and leaky livestock water system in place at that time.

3.5.2.2 Site Groundwater Gradients and Flow Directions

As described in Section 2.3.1.3, synchronous water level measurements were collected from all site monitoring wells on a monthly basis from May 2008 through April 2009 (Table 2-2). From these data, specific timeframes have been selected for the preparation of groundwater elevation contour maps, which are provided in Appendix L. Specifically, groundwater elevation contour maps have been prepared for the shallow and intermediate depth groundwater zones (Figures L-1 through L-6), while groundwater elevation hydrographs for all shallow zone wells (Figure L-7), intermediate zone wells (Figure L-8), and each of the three monitoring well clusters at the site (Figures L-9 through L-11) have also been prepared.

The following sections present calculated hydraulic gradients and interpreted groundwater flow directions beneath the Study Area as identified during the RI monitoring activities.

3.5.2.2.1 Horizontal Groundwater Gradients and Flow Directions

This section discusses horizontal groundwater gradients and flow directions for the shallow, intermediate, and deep groundwater zones. In addition, seasonal fluctuations for these gradients and flow directions are discussed. Figures L-1 through L-6 showing groundwater elevations are provided in Appendix L.

Shallow Groundwater Zone: As illustrated in Figures L-1, L-3, and L-5 (Appendix L), groundwater in the shallow saturated zone, which typically ranges from between 1 and 6 ft bgs, is consistently interpreted to flow in a southwestern direction beneath the Facility toward Force Lake under relatively constant horizontal gradients. Based on the depth to water, flow direction, and profile of Force Lake, shallow groundwater discharges to Force Lake. The groundwater elevation maps included here for the three monitoring periods (June 2008, September 2008, and January 2009) are deemed representative of the flow regime identified within this water-bearing zone throughout the year. The September 2008 monitoring period represents seasonal low water levels; the January 2009 monitoring period represents seasonal high water levels. The range in calculated horizontal hydraulic gradients as calculated across the site within the shallow groundwater zone was determined to be fairly consistent, ranging from 0.011 to 0.015 ft/ft.

Intermediate Groundwater Zone: In the intermediate-depth saturated zone, monitoring indicated that flow is typically toward the west, as depicted for the seasonal low water level in September 2008 (Figure L-4, Appendix L) and for the seasonal high water level in January 2009 (Figure L-6, Appendix L). A slight shift in the groundwater flow direction to the southwest was noted within this zone during June and July 2008 (Figure L-2, Appendix L). Similar to the shallow water zone (although an order of magnitude lower) the horizontal hydraulic gradient within the intermediate water-bearing zone is relatively constant, ranging from 0.0014 to 0.0019 ft/ft.

Deep Groundwater Zone: The hydrogeological evaluations completed during Phase 1 and Phase 2 of the RI largely focused on shallow and intermediate zone groundwater. However, Golder Associates (1990) noted that deep zone groundwater flows to the northwest toward the Columbia River during periods of low river flow and southwest away from Columbia River during periods of high river flow at gradients ranging from zero (during flow reversal) to a maximum of 0.002 ft/ft.

Golder Associates (1990) also demonstrated correlation between fluctuations in Columbia River stage and the fluctuation in intermediate and deep groundwater zones, with such fluctuations likely the result of tidal as well as seasonal influences. Golder Associates' (1990) conclusion is based on the a comparison of the water level elevations in a gage station on the Oregon Slough and well B-4 at the Study Area. During periods of low river flow, the groundwater elevation in B-4 is higher than the surface water elevation in the Oregon Slough, and thus flow is northward toward the Columbia River. Conversely, during periods of high river flow, the groundwater elevation in B-4 is lower than the surface water elevation in the Oregon Slough, and thus flow is southward away from the Columbia River.

Seasonal Fluctuations: As depicted on the hydrographs for the shallow zone monitoring wells (Figure L-7, Appendix L) and the intermediate zone monitoring wells (Figure L-8, Appendix L), seasonal variations of 1 to 3 ft in the groundwater elevation occur for both of these zones, with higher levels in the winter and spring and lower levels in the summer and fall.

With regard to the shallow zone (Figure L-7, Appendix L), seasonal and localized heterogeneity exists in the relationship between monitoring well locations. Although heterogeneities exist, the overall patterns depicting seasonal effects on water levels are generally similar across the Study Area, confirming that the wells are all screened in the same overall water-bearing zone (e.g., none appear screened within perched or isolated zones).

With regard to the intermediate groundwater zone, the hydrograph (Figure L-8, Appendix L) shows that all intermediate-depth wells responded uniformly to seasonal changes, with the relationship between well locations remaining relatively constant over the course of the monitoring period.

The differing responses between the shallow and the intermediate-depth groundwater zones is consistent with findings presented by Golder

Associates (1990), with water table fluctuations in shallow wells likely related to variations in rainfall (e.g., more rapid and larger scale changes), and with water levels in intermediate and deep wells more likely correlated with Columbia River stage and tidal fluctuations.

3.5.2.2.2 Vertical Groundwater Gradients and Flow Directions

This section discusses vertical hydraulic gradients as calculated between the shallow, intermediate, and deep groundwater zones, which appear to vary throughout the year. Figures L-9 through L-11 (in Appendix L), show groundwater elevation relationships between wells within each of the three well clusters at the Study Area.

Vertical gradients observed at well clusters MW-4s/4i (upgradient portion of the site) and MW-5s/5i (middle portion of the site) were largely downward (i.e., the hydraulic head in the shallow zone was larger than the intermediate zone, and theoretical groundwater flow would occur from shallow to intermediate), with the exception of the June and July 2008 monitoring periods at the MW-5s/5i cluster, for which the gradient was upward (Figure L-10 and L-11, Appendix L).

The most notable seasonal variation in vertical gradients was observed in well cluster MW-2s/MW-2i/B-4 (Figure L-9, Appendix L). The response and trends in water levels for this cluster suggested a stronger and quicker response to seasonal fluctuations in the shallow groundwater zone, and more subdued and delayed response in the intermediate and deep groundwater zones (Figure L-9, Appendix L).

Specifically, a review of the water level data at this location suggested the following:

- From June 2008 to September 2008, the vertical gradient was generally upward. This corresponds to the dry season when groundwater elevations within the shallow zone are lowest.
- From October 2008 to January 2009, the vertical gradient shifted to downward, meaning that theoretical groundwater flow would occur from shallow to intermediate to deep zones. This shift corresponds to the rainy season when groundwater elevations in the shallow zone are found to rise sharply in this area relative to the more gradual and delayed response in both the intermediate and deep groundwater zones.
- From February 2009 to April 2009, the vertical gradients appeared to vary, with two periods of mixed gradients (i.e., upward between shallow/intermediate, upward between shallow/deep, and downward between intermediate/deep zones), separated by a period of consistent downward gradients observed in March 2009.

The vertical gradients as calculated across the Study Area between the shallow and intermediate groundwater zone ranged from a low of -0.002 ft/ft (upwards) to a high of 0.09 ft/ft (downwards). The greatest downward vertical gradients were consistently identified at the MW-4s/4i well cluster (near the northeast Facility boundary and the tank farm); the greatest and most prolonged upward gradients were identified at the MW-2s/-2i/-B-4 location (near the southwest Facility boundary).

The vertical gradients as calculated between the intermediate and deep groundwater zone (MW-4i/B-4) ranged from a low of -0.009 ft/ft (upwards) to a high of 0.009 ft/ft (downwards).

The seasonal high vertical hydraulic gradient observed at the Facility (0.09 ft/ft downward) was generally consistent with the findings presented by Golder Associates (1990) for the former Stockyards: vertical gradients between the shallow and intermediate zones ranged from 0.14 to 0.17 ft/ft (downward) at the Stockyards, with less pronounced vertical gradients at the Facility.

3.5.2.3 Aquifer Characteristics

3.5.2.3.1 Slug Tests

As discussed in Section 2.3.1.6, slug tests were performed on nine monitoring wells as part of the RI. Specifically, these tests were conducted on six shallow zone wells, two intermediate zone wells, and one deep zone well. Results of the testing are summarized in Table 3-1. Also included in Table 3-1 are the results of previous slug testing in nearby monitoring wells (Golder Associates 1990).

With regard to the shallow groundwater zone, and based on the 2008 slug test results, a range in hydraulic conductivities from 3.18×10^{-5} cm/sec (MW-2s) to 1.34×10^{-3} cm/sec (MW-3s) was calculated for the Study Area. Further analysis of the results yielded an average hydraulic conductivity of approximately 4.37×10^{-4} cm/sec (1.24 ft/day) for the shallow groundwater zone (using data from MW-2s, MW-3s, MW-4s, GA-9 and GA-34).

With regard to the intermediate groundwater zone, and based on the 2008 slug test results summarized above, hydraulic conductivities of 4.55×10^{-5} cm/sec (MW-5i) and 3.30×10^{-3} cm/sec (MW-4i) were calculated for the Study Area, yielding an average hydraulic conductivity of approximately 1.57×10^{-3} cm/sec (4.44 ft/day) for the intermediate groundwater zone. The deep zone, as measured at the B-4 location, was screened primarily in the silts above the TGA, and yielded a hydraulic conductivity of 4.87×10^{-5} cm/sec (0.138 ft/day).

Golder Associates (1990) provided slug test results for several shallow wells, including one well at the Facility (GA-30) and eight wells on regional properties (Table 3-1). The test apparatus consisted of an electronic pressure transducer, data logger, and “slug,” which initiated the water level change. The slug was introduced into the well causing an instantaneous change in water level; the recovery of the water level to pretest levels was monitored using the pressure transducer/data logger. Interpretation of the data was performed in accordance with the Hvorslev method. A hydraulic conductivity of 4×10^{-3} cm/sec was reported for shallow well GA-30 at the Facility property, which falls into the range of conductivities calculated for the shallow groundwater zone as part of the RI. With regard to offsite locations, hydraulic conductivities, as calculated by Golder Associates (1990) identified a range in values for the shallow groundwater zone, with a low of 8×10^{-4} cm/sec (2.3 ft/day) at the GA-33 location to a high of 4×10^{-1} cm/sec (1,134 ft/day) at the GA-25 location.

Table 3-1. Summary of Estimated Hydraulic Conductivities from Slug Testing

Testing Well/Zone	Analysis Method	Hydraulic Conductivity Estimate (cm/sec)
May 2008 Slug Testing		
MW-1s/shallow[a]	Bouwer & Rice	1.48×10^{-2} [a]
	Hvorslev	1.91×10^{-2} [a]
MW-2s/shallow	Bouwer & Rice	3.18×10^{-5}
	Hvorslev	3.88×10^{-5}
MW-3s/shallow	Bouwer & Rice	9.71×10^{-4}
	Hvorslev	1.34×10^{-3}
MW-4s/shallow	Bouwer & Rice	3.28×10^{-4}
	Hvorslev	4.24×10^{-4}
GA-29/shallow	Bouwer & Rice	4.69×10^{-5}
	Hvorslev	6.07×10^{-5}
GA-34/shallow	Bouwer & Rice	4.94×10^{-4}
	Hvorslev	6.35×10^{-4}
MW-4i/intermediate	Cooper-Bredehoeft-Papadopulos	3.09×10^{-3}
MW-5i/intermediate	Cooper-Bredehoeft-Papadopulos	4.55×10^{-5}
B-4/deep	Cooper-Bredehoeft-Papadopulos	4.87×10^{-5}
Previous Slug Testing[b]		
Onsite Locations		
GA-30/shallow	Hvorslev	4.00×10^{-3}
Offsite Locations		
GA-25/shallow	Hvorslev	4.00×10^{-1}
GA-26/shallow	Hvorslev	3.00×10^{-1}
GA-27/shallow	Hvorslev	1.00×10^{-1}
GA-28/shallow	Hvorslev	8.00×10^{-2}
GA-30/shallow	Hvorslev	4.00×10^{-3}
GA-33/shallow	Hvorslev	8.00×10^{-4}
GB-5a/shallow	Hvorslev	9.00×10^{-3}
GB-5b/shallow	Hvorslev	1.00×10^{-3}

[a] Average hydraulic conductivities were estimated with the omission of data generated from MW-1s because this well was not stressed sufficiently during the slug testing to yield a reliable dataset.

[b] Source: Golder Associates (1990).

3.5.2.3.2 Aquifer Pumping Test

No aquifer pumping tests were performed as part of the RI, as no suitable pumping well for evaluation of shallow, intermediate, or deep groundwater zones exists at the Facility (e.g., all wells of known construction are monitoring wells, which, as a function of their construction [2-in. in diameter], are not expected to produce a sufficient yield for the regional evaluation of hydraulic conditions). The lack of an RI aquifer pumping test is not deemed to be a data need for the RI because sufficient aquifer characteristic data are available from area studies (described below) and from site-specific well installation/slug testing activities described in preceding sections.

With regard to regional aquifer testing, Golder Associates (1990) performed an aquifer pumping test using the 210-ft-deep production well at the Stockyards. The production well was located approximately 750 ft north of the northern boundary of the Facility. Prior to the pumping test in July/August 1990, the stockyard production well reportedly was being pumped continuously at a rate of 500 gpm and supplied a piping network in the stockyard pens to supply livestock watering. The majority of the surplus water not used by the livestock was diverted through a storm drain and discharged to the Columbia River (approximately 350 gpm). The remainder of the water that was leaking from pipes reportedly infiltrated into the ground (150 gpm) causing a groundwater mound in the stock watering area. Surface runoff toward the wetlands south of the Stockyards and adjacent to the Facility was reportedly negligible. Downward vertical gradients were reported for nested wells in the stock watering area due to the groundwater mound.

The purpose of the pumping test was to determine the impact of the production well on groundwater flow and provide more reliable estimates of deep aquifer hydraulic properties than had been obtained by slug tests. During the test, pressure transducers with data loggers were installed in 13 wells, including well B-4 at the Facility (Figure 1-9). An alternate water supply was provided for the Stockyards so that the production well could be started and stopped at will. The production well was shut down for 70 hours, and then the pump was restarted and pumped at a rate of about 490 gpm. Closely timed water level measurements were collected in the production well and nearby monitoring wells.

The pump test analysis was complicated by the fact that the amplitude of variations caused by tidal influences in the Oregon Slough/Columbia River in the intermediate and deep zone wells of 0.1 to 0.4 ft is greater than the measured drawdowns in the observation wells (0.1 ft in wells located 100 ft away from the test well to 0.01 ft in wells located farther away). A discussion concerning the analysis of the interpreted effects of seasonal and tidal changes in water levels in the Oregon Slough/Columbia River is presented in Section 3.5.1.

Golder Associates (1990) developed the following conclusions from the pump test analysis:

- A drawdown of 10 ft was observed in the stockyard's production well when it operated at a rate of approximately 490 gpm.

- Transmissivities for the deep zone ranged from about 2.3×10^5 to 3.5×10^6 ft/day, with a most likely value of 2×10^6 ft/day.
- Water level drawdown at the closest observation well was less than a maximum of 0.3 ft.
- Predicted maximum drawdowns in observation wells 100 ft or more away from the pumping well could have been as high as 0.25 ft but were probably only 0.03 ft.

The observed drawdown in the production well was about 10 times greater than would be expected as a result of well loss.

3.5.2.4 Groundwater Flow Velocities

A summary of calculated horizontal gradients and calculated groundwater velocities for the shallow and intermediate groundwater zones is provided in Table 3-2.

Table 3-2. Estimated Horizontal Groundwater Gradients and Velocities of Shallow and Intermediate Groundwater Zones

Groundwater Zone	Gradient (ft/ft)	Advective Velocity (ft/day)
Shallow Groundwater Zone	0.011 to 0.015	0.038 to 0.053
Intermediate Groundwater Zone	0.0014 to 0.0019	0.018 to 0.024

The horizontal hydraulic gradient values presented in Table 3-2 are based on water level measurements made on a monthly basis from May 2008 to April 2009 (see Table 2-2), and a review of resulting groundwater elevation maps (Appendix L, Figures L-1 through L-6). The estimated horizontal advective groundwater velocity was calculated using the average hydraulic conductivity values calculated for the Study Area (Section 3.5.2.3.1) and the assumed effective porosity (0.35), which was based on the lithology screened (sand).

The advective velocities presented in Table 3-2 were calculated using the following formula:

$$v = \frac{K}{n}\left(\frac{dh}{dl}\right) \qquad \textbf{Equation 3-1}$$

Where:

V	=	horizontal pore velocity of groundwater (ft/day)
K	=	horizontal hydraulic conductivity (ft/day), estimated at 1.24 ft/day for the shallow groundwater zone and 4.44 ft/day for the intermediate zone.
n	=	effective porosity (unitless), estimated at 0.35 based on the average porosity of sand (between 0.25 and 0.50 (Freeze and Cherry 1979))
dh/dl	=	hydraulic gradient (ft/ft), calculated as the observed difference in head divided by the distance between observations

A summary of the calculated vertical gradients and calculated groundwater velocities between the shallow, intermediate, and deep groundwater zones is provided in Table 3-3.

Table 3-3. Estimated Vertical Groundwater Gradients and Velocities Between Shallow, Intermediate and Deep Groundwater Zones

Groundwater Zones	Gradient (ft/ft)[a]	Advective Velocity (ft/day)
Shallow to Intermediate Zone	-0.002 to 0.09	0.0006 (up) to 0.03 (down)
Intermediate to Deep Zone	-0.009 to 0.009	0.003 (up) to 0.003 (down)

[a] Negative indicates upward gradient; positive indicates downward gradient.

The vertical hydraulic gradient values presented in Table 3-3 are based on well cluster water level measurements made on a monthly basis from May 2008 to April 2009 (see Table 2-2), and subsequent review of the direction and magnitude of hydraulic gradients calculated for each event. The vertical gradients calculated between shallow and intermediate groundwater zones were estimated by dividing the observed head differences between screened intervals (approximately 36 ft from shallow to intermediate, and 46 ft from intermediate to deep).

In calculating the estimated vertical advective groundwater velocity, the hydraulic conductivity value calculated for well B-4 was used (Section 3.5.2.3.1), as was an assumed effective porosity (0.43), based on the lithology screened (silt). Data obtained from well B-4 were screened within the silt materials deemed typical of the silts separating the respective groundwater zones (Figures 3-2 and 3-4). As such, hydraulic conductivity data from B-4 would be most representative of vertical migration, if any, through the silt layers that separate the groundwater zones.

The vertical advective velocities presented in Table 3-3 were calculated using the same formula presented above:

$$v = \frac{K}{n}\left(\frac{dh}{dl}\right) \qquad \textbf{Equation 3-2}$$

Where:

V = vertical pore velocity of groundwater (ft/day)

K = vertical hydraulic conductivity (ft/day), estimated at 0.138 ft/day based on the slug testing results for well B-4, which is screened within the silt materials separating the respective groundwater zones. This value is considered conservative because the clay content observed within this silty material is characterized by relatively lower values of vertical hydraulic conductivity compared to horizontal hydraulic conductivity.

n = effective porosity (unitless), estimated at 0.43 based on the average porosity of silt (between 0.35 and 0.50 (Freeze and Cherry 1979)

dh/dl = hydraulic gradient (ft/ft), calculated as the observed difference in head divided by the distance between observations

3.5.2.5 Report on Deep Groundwater Sampling

Golder Associates (1991b) identified several deep production wells (i.e., large capacity drinking water, industrial process, and irrigation supply wells) in the vicinity of the Study Area that were completed in the TGA. These wells include five former Vanport City wells (Well Nos. 1 through 5), a golf course domestic well (Well No. 6), an Exposition Center

irrigation well, five James River Corporation production wells, and the Stockyards production well.

Former Vanport City wells No. 1 and 2 are at the present site of the Portland International Raceway. The exact locations and condition of these 152- and 148-ft-deep wells are not known. Wells No. 1 and 2 are both constructed with 12-in.-diameter casing, which is perforated from 132 to 145 ft bgs and 125 to 142 ft bgs, respectively. At the time of the Golder Associates (1991b) report, former Vanport City Wells Nos. 3 and 4 were sealed at the surface with a metal cap. Apparently, there were plans to rehabilitate these 136- and 137-ft-deep wells to provide additional irrigation water for the expansion of the Heron Lakes Golf Club. Wells Nos. 3 and 4 were constructed of 12- and 14-in.-diameter casings, which were perforated from 122 to 132 ft bgs and 115 to 130 ft bgs, respectively. At the time of the Golder Associates (1991b) report, the 125-ft-deep former Vanport City Well No. 5 was being used by the golf course for irrigation, and the 86-ft-deep Well No. 6 was being used as a domestic supply for the club house. Well No. 5 was constructed with a 12-in.-diameter casing, which was perforated from 106 to 120 ft bgs. Well No. 6 was constructed with a 10-in.-diameter casing, but the perforation interval is not known.

According to J. Goodling, Heron Lakes Golf Club Superintendent (personal communication November 28, 2007), Vanport City Well No. 6 has been capped and is no longer used for any purpose. There are two active wells on the Heron Lakes Golf Club (i.e., Vanport City Wells No. 4 and 5), and both are used for irrigation only. The current use status and condition of the other Vanport City wells are not known.

The 166-ft-deep Exposition Center irrigation well was used periodically to irrigate land south of the Center complex. This well has a 12-in.-diameter casing that is perforated from 147 to 162 ft bgs.

Information is available for only one of the five James River wells, a process production and water supply well that is 163 ft deep and has a casing perforated from 138 to 163 ft bgs. Golder Associates (1991b) indicated that no information was found on the specific location and construction of the other four James River wells.

Approximate well locations are shown on Figure 1-10.

3.6 Demography and Land Use

This section provides information regarding City of Portland planning and zone designations, as well as current and future land uses.

3.6.1 City of Portland Comprehensive Plan Designation

According to the February 2010 City of Portland Comprehensive Plan Designations Map (2010a), the Facility has an Industrial Sanctuary designation, as do the surrounding properties to the northwest, northeast, and southeast. The Industrial Sanctuary designation, as defined in the City of Portland Comprehensive Plan (2010a), is intended for areas

where City policy is to reserve land for existing and future industrial development. Non-industrial uses are limited to prevent land use conflicts and to preserve land for industry.

Property to the southwest of the Facility has an "Open Space" designation.

3.6.2 City of Portland Zoning Designation

The City of Portland February 20102006 Zoning Designations Map (2010e) indicates that the Facility and properties to the northwest, northeast, and southeast are zoned IG2, Industrial General 2. Property to the southwest, including the wetlands and Force Lake, is zoned OS, Open Space.

The City of Portland 1/4 Section Zoning Maps 1827 and 1927 (City of Portland 2010d, c) indicate that the Study Area is located within the PEN 1 NRMP area, and the Facility is zoned as IG2dh, as are the properties immediately to the northwest, northeast, and southeast. The "d" indicates that the Study Area is located in a Design Overlay Zone, which promotes conservation, enhancement, and continued vitality of areas of the City with special scenic, architectural, or cultural value (City of Portland 2010b). The "h" indicates that the Study Area is located in the Aircraft Landing Overlay Zone for the Portland International Airport. The property to the southwest (wetlands) has a specific zoning of OShp. The "p" is reflective of an Environmental Overlay Zone, which limits development to only "rare and unusual circumstances."

3.6.3 Future Land Uses

The zoning and comprehensive plan designations for the Study Area (Sections 3.6.1 and 3.6.2) indicate that the current and likely future land uses within the Study Area are recreation and habitat for the wetlands and Force Lake and industrial for the Harbor Oil Facility, in particular because of the Facility's Industrial Sanctuary designation.

3.6.4 City of Portland Columbia Slough Fish Consumption Study

As part of the larger investigation and improvement effort for the Columbia Slough, the City of Portland conducted a study to better understand fishing habits on the slough (2009a). A study was conducted in the fall of 2008 and the spring of 2009. As part of the study, anglers that were observed fishing in the slough were interviewed regarding their fishing frequency, preferred fishing locations, and consumption habits.

Of the 25 angler interviews conducted during the survey, 2 anglers were observed fishing at Force Lake. Key conclusions from the survey were as follows:

- Most fishing in the slough occurred at the west end of the slough (Force Lake is in the west-central portion of the slough and was not indicated as a "popular" place for anglers).

- Of the 25 anglers, 12 anglers indicated that they planned to eat any fish that they caught. Of the two Force Lake anglers, one was practicing catch and release while the other indicated that he might eat any larger fish.
- Anglers indicated a preference for fishing in the spring and summer both at Force Lake and throughout the slough.
- Of the 25 anglers interviewed, 5 anglers caught fish. Three of these five anglers planned to release their fish while the other two planned to eat their catch and share it with their families (both adults and children). No fish were caught by interviewed anglers at Force Lake.

Overall, this survey indicates that while fishing occurs at Force Lake, it is relatively infrequent compared to other locations throughout the Columbia Slough.

3.7 Ecology

This section describes the ecological setting of the Study Area, along with animal species that have been observed in the area.

3.7.1 PEN 1 NRMP

The Study Area is located within the PEN 1 NRMP area, one of a number of NRMP areas established under Title 33, Planning and Zoning, Chapter 33.430 of the City of Portland planning code. NRMPs provide a means to evaluate the cumulative effects of development and mitigation within a large ecosystem.

According to the 1997 PEN 1 NRMP (City of Portland 1997), the City of Portland was planning to develop a public-access trail along North Force Avenue and around the perimeter of the Heron Lakes Golf Club to enhance opportunities for passive recreation (e.g., bird watching). This trail was to provide access to earlier improvements made to the south side of Force Lake as part of the construction of the final nine holes Heron Lakes Great Blue Course. However, as of 2010, the improvements to enhance recreational opportunities around Force Lake have not been implemented.

According to CEC (2002) and Fishman (1989), Force Lake is only 2 to 3 ft deep on average, which was confirmed based on observations during the Phase 1 and 2 RI sampling. Information regarding the fish community present in Force Lake is provided in Section 2.7 and information regarding birds and mammals that use the Study Area is provided in Section 3.7.2.

3.7.2 City of Portland Bureau of Planning Survey

During the City of Portland Bureau of Planning survey conducted in 1997 (City of Portland 1997), observations of birds and mammals were recorded. This section summarizes those findings, which are discussed in

greater detail in Sections 2.2 and 2.3 of the ERA (Appendix J). The information collected by the City of Portland in 1997 as part of the NRMP is expected to still be representative of current conditions at the Study Area based on observations during site visits and during RI/FS sampling and the fact that land use has not changed significantly over the past 15 years.

3.7.2.1 Birds

Numerous bird species inhabit Force Lake and the surrounding area. Based on the 1997 City of Portland Bureau of Planning survey, 55 bird species have been observed in or near Force Lake, and an additional 36 bird species have been observed within PEN 1.

Birds from the following general feeding guilds have been observed:

- **Herbivorous birds:** including dabbling and diving ducks
- **Insectivorous/invertivorous birds:** including sediment-probing invertivores, birds that feed on flying insects, and terrestrial birds and aquatic ducks that feed on aquatic insect larvae and aquatic benthic invertebrates, respectively
- **Piscivorous birds:** including aquatic birds that feed predominately on fish
- **Carnivorous birds:** including terrestrial birds of prey that consume species at higher trophic levels (i.e., birds and mammals)
- **Omnivorous birds:** including birds with an opportunistic diet or a non-specific diet that includes plants and various prey species

In addition, some birds are known to nest in the vicinity of the Study Area. Great blue heron and red-tailed hawk have been observed nesting in areas near Force Lake (City of Portland 1997), and a heron rookery is located approximately one-half mile west of the Study Area in the PEN 1 area. For ruddy ducks, Force Lake represents the only breeding and nesting habitat within the Portland urban growth boundary (Fishman 1989).

Two birds that are special-status species have been observed in PEN 1 (City of Portland 1997). Tri-colored blackbirds are Oregon State sensitive species and are a federal species of concern. Bald eagles are listed in Oregon as endangered and are also protected under the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act.

3.7.2.2 Mammals

Several predominantly herbivorous mammal species, including Eastern cottontails, voles, beavers, and nutria, have been observed near Force Lake based on the 1997 City of Portland Bureau of Planning survey (City of Portland 1997). In addition, two opportunistic feeders, raccoon and opossum, have also been observed (City of Portland 1997).

Based on the available habitat, invertivorous rodents (e.g., shrew) may also be present in the wetland areas near Force Lake along with other

aquatic mammals (e.g., muskrats). However, these species have not been observed at the Study Area.

No special-status mammal species are known to be present at the Study Area or nearby habitat areas.

4.0 NATURE AND EXTENT OF CONTAMINATION

As discussed in the RI/FS Work Plan (Bridgewater et al. 2008b), the purpose of the RI is to discuss the nature and extent of contamination and potential sources of chemicals. This section discusses the nature and extent of contamination in the Study Area based on available data for Facility soil, groundwater, LNAPL, wetland soil, lake sediment, and lake surface water. Section 4.1 provides an overview of the data summarized in this section, and Section 4.2 provides a summary of known and suspected sources, both on and off the Facility. Sections 4.3 through 4.8 discuss the nature and extent of contamination, with a focus on chemicals or chemical groups determined to be important to the Study Area based on the results of the baseline HHRA and the baseline ERA (Section 6 and Appendices I and J) or based on historical activities at the Facility. Each chemical or chemical group is discussed with respect to known and suspected sources, chemical fate and transport, and medium-specific data.

4.1 Data Overview

This section presents an overview of data selection, reduction, and suitability for the RI. In addition, this section presents the chemicals or chemical groups discussed in greater detail in Sections 4.3 through 4.8, as well as a brief discussion of conservative screening levels used to provide context to the site-specific data. Note that the comparison to conservative screening levels on a point-by-point basis should not be viewed as a risk estimate; risks were fully assessed in the ERA and HHRA as presented in Appendices I and J and summarized in Section 6.0.

4.1.1 Data Selection, Reduction, and Suitability

This section presents a summary of the data available for the Study Area and discusses data selection, data reduction, and data suitability. The complete RI database is provided in Appendix B. In addition, the following appendices provide additional detail regarding the data used in this RI:

- Appendix M, Data Validation, provides the complete data validation reports prepared by EcoChem, Inc., for the Phase 1 and Phase 2 RI sampling events.
- Appendix N, Data Management, provides a summary of the computational methods used to aggregate the data for use in the RI.
- Appendix O, Laboratory Report Forms, provides the Form 1s for the Phase 1 and Phase 2 RI sampling events.

4.1.1.1 Data Selection

Two phases of sampling were conducted as part of the RI (Section 2.0). In addition, historical data were evaluated for their acceptability for use in the RI, as discussed in Section 1.3.4. A total of eight historical datasets were screened against DQOs. Of these datasets, only one dataset was determined to be acceptable: the 2000 Harbor Oil PA/site inspection (Ecology and Environment 2001).

Table 4-1 provides a summary of the data used in the RI by sampling event, and Table 4-2 provides a summary of the number of samples by media available for use in the RI. Data from all three years (2000, 2008, and 2009) are summarized in the data tables presented throughout Section 4.0.

Table 4-1. Summary of Data Used in the RI by Sampling Event

Sampling Event	Year	Media	No. of Locations[a]	Analytes
PA/ SI (Ecology and Environment 2001)	2000	facility soil	13	metals, PAHs, phthalates, other SVOCs, PCBs, pesticides, VOCs, petroleum
		groundwater	7	metals, PAHs, phthalates, other SVOCs, PCBs, pesticides, VOCs, petroleum
		LNAPL	1	PCBs, select pesticides
		wetland soil	5[b]	metals, PAHs, phthalates, other SVOCs, PCBs, pesticides, VOCs, petroleum, conventional parameters
RI Phase 1 sampling	2008	facility soil	34	metals, PAHs, phthalates, SVOCs, PCBs, pesticides, VOCs, petroleum, conventional parameters
		soil stockpile	3	metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, conventional parameters
		soil berm	9	metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, conventional parameters
		groundwater	16	metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, conventional parameters
		LNAPL	1	metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum
		wetland soil	38	metals, PAHs, phthalates, other SVOCs, PCBs, pesticides, VOCs, petroleum, conventional parameters
		lake sediment	11	metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, grain size, conventional parameters
		lake surface water	3	metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, conventional parameters
RI Phase 2 sampling	2009	facility soil	15	metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, conventional parameters
		groundwater	11	metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, conventional parameters
		wetland soil	13	metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, petroleum, conventional parameters
		lake sediment	3	metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, conventional parameters

[a] This table presents the number of locations, not samples, available for use in the RI. See Table 4-2 for the sample count by environmental media.

[b] A total of six wetland soil samples were collected during this event, but one of these samples was collected on the south side of Force Lake as a "background" sample. This sample was excluded from the RI database.

LNAPL – light non-aqueous phase liquid
PA – preliminary assessment
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RI – remedial investigation
SI – site inspection
SVOC – semivolatile organic compound
VOC – volatile organic compound

Table 4-2. Summary of Available Data for the RI by Medium

Medium	Sample Depth Category	Sample Depth or Depth Range (ft bgs)	No. of Samples
Facility soil	surface	0 – 5	57
	intermediate	2 – 8.5	35
	deep	6 – 22	35
	soil berm	0.5 – 2	9
	soil stockpile	0.5 – 6	3
Groundwater	shallow	10 – 20	28
	intermediate	48 – 50	3
	deep	97	3
LNAPL	shallow	2000: unknown 2008: 2.58 – 2.68	2
Wetland soil	surface	0 – 0.5	52
	intermediate	0.5 – 1	10
	deep	2 – 3	10
Force Lake sediment	surface	0 – 0.3	11
	intermediate	2 – 3	3
North Lake sediment	surface	0 – 0.3	3
Surface water	surface	1	3

bgs – below ground surface
LNAPL – light non-aqueous phase liquid
RI – remedial investigation

4.1.1.2 Data Reduction

Data reduction refers to computational methods used to aggregate the data for use in the RI. Procedures related to averaging, selection of the best data points when multiple data were available, selection of significant figures and rounding procedures, and calculating sums (i.e., PCBs, PAHs, DDTs, chlordane, and TPHs) are described in Appendix N.

4.1.1.3 Data Suitability

Several factors were considered in assessing the suitability of environmental data for the RI, in accordance with EPA (1988). Key factors included the degree to which the data adequately represent concentrations in the Study Area, the analytical methods, the level of review associated with the data, and the documentation of field and laboratory practices.

Because data from several investigations were available for the Study Area, these factors were evaluated for each dataset to determine whether each dataset was acceptable for use in this RI. These suitability determinations were performed in consultation with EPA as part of the Risk Assessment Scoping Memorandum (Windward and Bridgewater 2008a).

4.1.1.3.1 Representativeness of Data

The majority of data available for use in the RI were collected in 2008 and 2009 as part of the two phases of RI sampling. The sampling plan for these data was designed to collect representative data for use in the HHRA and the ERA based on the human health scenarios and ecological receptors to be assessed. In addition, the sampling plan was designed to characterize the nature and extent of chemical concentrations within the Study Area.

For example, the sample density within the Facility and the wetlands was quite high, as necessary to characterize the higher variability of expected chemical concentrations in these areas. The sample density within Force Lake was lower, as a function of the more homogeneous nature of the lake system and the chemical concentrations in Force Lake. In addition, to ensure complete characterization of the vertical extent of chemical concentrations, subsurface samples were collected at a subset of the soil and sediment locations.

Groundwater samples were collected in summer 2000, spring 2008, and spring 2009. The inclusion of data from multiple years and two seasons increased the likelihood that the temporal variability in chemical concentrations in groundwater was characterized.

Three surface sediment samples were also collected from North Lake. These samples were collected to determine whether chemicals had migrated from Force Lake to North Lake. As presented in the Preliminary Site Characterization Report (Windward et al. 2008a) and discussed in Sections 4.3 through 4.8, an analysis of these samples indicated that the migration of chemicals from Force Lake to North Lake was limited.

4.1.1.3.2 Analytical Methods

Methods selected to analyze the samples collected during the two phases of the RI sampling effort were approved by EPA in advance of sampling. These methods were detailed in the QAPP (Bridgewater et al. 2008a) and summarized in the Preliminary Site Characterization Report (Windward et al. 2008a). Methods used to collect samples for the Harbor Oil PA/site inspection (Ecology and Environment 2001) were described in sufficient detail to determine that they were acceptable.

4.1.1.3.3 Quality Assurance/Quality Control Results

One of the requirements for data use in the RI was for the data to be validated by the original authors of the individual studies or by outside third parties. Complete data validation reports for the Phase 1 and Phase 2 RI sampling events are included in Appendix M. Data validation for the Harbor Oil PA/site inspection conducted in 2000 (Ecology and Environment 2001) was included in that document. Any data qualified as unusable by the data validators were not used in the RI.

4.1.1.3.4 Documentation of Field and Laboratory Practices

For data to be used in the RI, information regarding the sampling method, sample depth, sample type, and sampling location had to be available. This information was clearly presented for the data collected as part of

the RI (Bridgewater et al. 2008a; Bridgewater et al. 2008c) and was available for the other study (Ecology and Environment 2001) that was accepted. Based on a review of these data, no issues were identified that would have adversely affected the usability of the data for risk assessment or site characterization purposes. Data collected by the Voluntary Group followed field and laboratory procedures that were approved by EPA.

4.1.2 Chemicals and Chemical Groups

To focus the discussion in this RI, a list of chemicals or chemical groups was developed based on the list of COCs from the HHRA and the list of contaminants with effects-based HQs greater than 1.0 in the ERA for which background or reference area concentrations were less than Study Area concentrations. In addition, chemicals known to be of interest at the Study Area based on past and present industrial activities were included in this discussion. Efforts were made to group chemicals based on the similarity of chemical properties and potential release sources.

The chemicals or chemical groups discussed in greater detail in Sections 4.3 to 4.7 are:

- **TPHs, PAHs, and associated VOCs:** TPHs, PAHs, and associated VOCs are of interest at the Study Area based on historical and current industrial activities, including oil treatment and processing, production of RFO, and tanker cleaning operations. For the HHRA, carcinogenic PAH (cPAH) TEQ and TPH-gasoline (aliphatic) were identified as a COC based on the potential exposure of future workers to Facility soil. In the ERA, total HPAH concentrations in three samples were greater than invertebrate soil screening values.
- **PCBs:** PCBs are of interest at the Study Area based on their known presence in used oils, fuels, or other petroleum hydrocarbons processed and refined at the Facility. In the HHRA, total PCBs were identified as a COC based on the potential exposure of future workers to Facility soil and potential indirect exposure of children and adults to Force Lake sediment through fish consumption.
- **Metals:** Metals are of interest at the Study Area because of their presence in used oils or fuels processed and refined at the Facility, their use in various industrial applications, and their potential source associated with truck cleaning at the Facility. In the HHRA, arsenic was identified as a COC based on the potential exposure of future workers to Facility soil. In the ERA, chromium, copper, mercury, and zinc were identified based on HQs for invertebrates, fish, and/or mammals.
- **DDTs:** Historical records of industrial activities at the Facility did not include any information documenting the use or handling of DDTs at the Facility. However, DDTs have been detected in samples collected from the Study Area, with distribution patterns

that suggest that DDTs in a portion of the Study Area may have been released from historical livestock trailer washing operations at the Facility. DDTs across the larger Study Area may have been released as a result of typical pest control applications in the area. In the HHRA, total DDTs were identified as a COC based on the potential exposure of future workers to Facility soil and potential indirect exposure of children and adults to Force Lake sediment through fish consumption. In the ERA, DDDs and DDEs were identified based on HQs for aquatic benthic invertebrates and total DDTs were identified based on HQs for birds and mammals.

- **Chlorinated solvents:** No chlorinated solvents were identified in the risk assessments as COCs. However, historical tanker cleaning operations at the Facility used TCE.

In addition to the chemicals or chemical groups listed above, Section 4.8 discusses all other chemicals detected in samples collected from the Study Area as part of the RI. In addition, as noted in Section 2.0, dioxins/furans were not considered to be a COI for the Study Area because there is no information to suggest that they are present as the result of activities conducted at the Facility.

4.1.3 Screening Levels

To aid in the discussion of the nature and extent of contamination, figures displaying chemical concentrations are presented in Sections 4.3 through 4.7. In these figures, human health and ecological screening levels from the HHRA and ERA, respectively, were used to provide a general risk context for the chemical concentrations. The specific screening levels used in this evaluation are described in Sections 4.1.3.1 (human health) and 4.1.3.2 (invertebrate). Note, however, that the comparisons with screening levels should not be viewed as risk estimates and the comparisons are not intended to identify areas that pose risk. See Section 6.0 for a summary of the Harbor Oil risk assessment results and Appendices I and J for the full risk assessments.

4.1.3.1 Human Health RSLs

The human health RSLs shown on the figures discussed in Sections 4.3 through 4.7 are the same as the screening levels used in the HHRA (Appendix I) to determine COPCs. RSLs are specific to both media (e.g., soil) and exposure type (i.e., industrial or residential/recreational), as discussed below.

Industrial Soil RSLs

Chemical concentrations in Facility soil were compared with the lowest of the following industrial exposure criteria:

- EPA regional screening values for industrial exposure to soil (2009c)
- DEQ human health occupational, construction, or excavation worker risk-based concentrations (RBCs) for the following exposure routes: 1) soil ingestion, dermal absorption, and

inhalation; 2) volatilization to outdoor air; 3) vapor intrusion into buildings; and 4) leaching to groundwater (2007b)

Residential or Recreational Soil RSLs

Chemical concentrations in Facility soil and wetland soil were compared with the lowest of the following residential criteria:

- EPA regional screening values for residential exposure to soil (2009c)
- DEQ RBCs for soil ingestion, dermal contact, and inhalation; residential exposure through volatilization to outdoor air; vapor intrusion into buildings; and residential exposure through leaching to groundwater (2007b)

Facility soil data were compared with residential RSLs to evaluate chemical concentrations relative to future hypothetical residential exposure, per EPA request (Bridgewater et al. 2008b; Windward and Bridgewater 2008a, b). However, as discussed in Section 3.6, the current and expected future land use of the Study Area does not include residential use or development.

No recreation-specific screening criteria were available for the Force Lake recreational user RME scenario. Therefore, as a health-protective approach, residential criteria were used in the comparison even though the wetlands are designated as open space and are not zoned for industrial or residential use. Use of the residential criteria as screening criteria is highly conservative because the exposure frequency for residential use is much higher than that for recreational use.

Lake Sediment RSLs

No sediment-specific RSLs were available for comparison with Force Lake sediment data. Thus, chemical concentrations in lake sediment were compared with the same residential criteria used to screen wetland and Facility soils. It should be noted that as with the wetlands, the lake is part of the PEN 1 NRMP area and is designated as open space, and thus the use of these soil-based residential screening criteria is highly conservative.

Surface Water RSLs

Chemical concentrations in surface water were compared with the lowest of the following screening criteria:

- EPA ambient water quality criteria (AWQC) for human water/ organism consumption and organism consumption (2009b)
- EPA regional screening values for water (2009c)
- DEQ human health occupational RBCs for the following pathways: 1) ingestion and inhalation from tap water, 2) volatilization to outdoor air, 3) vapor intrusion into buildings, and 4) leaching to groundwater during excavation (2007b)
- EPA non-zero MCLGs and MCLs (2009a)

Groundwater RSLs

Chemical concentrations in groundwater were compared with the lowest of the DEQ human health occupational RBCs for the following pathways: 1) ingestion and inhalation of tap water, 2) volatilization to outdoor air, 3) vapor intrusion into buildings, and 4) leaching to groundwater during excavation (2007b). Only DEQ RBCs were used because no other sources of worker-specific values were available. In addition, EPA non-zero MCLGs and MCLs were used for screening when the EPA levels were lower than the DEQ RBCs.

4.1.3.2 Invertebrate Screening Levels

For aquatic benthic invertebrates, sediment data were compared with the lower of the following screening levels to provide ecological context to the figures:

- Probable effects levels (PELs) reported by Smith et al. (1996)
- Probable effects concentrations (PECs) reported by MacDonald et al. (2000)

For terrestrial invertebrates, soil data were compared with the lowest of the following screening levels from the following sources to provide ecological context:

- EPA ecological soil screening levels (Eco-SSLs) (2007) protective of soil invertebrates
- Oak Ridge National Laboratory (ORNL) soil data for invertebrates (Efroymson et al. 1997)
- DEQ soil screening level values protective of terrestrial invertebrates (2001a)

The invertebrate soil and sediment levels are presented in the ERA (Appendix J).

Surface water data were compared with chronic AWQC, which are protective of aquatic species.

4.2 Overview of Known and Suspected Sources

This section provides a summary of Facility-related releases known to have occurred since the Facility was developed in the 1950s, potential Facility-related sources, and off-Facility sources located in the vicinity of the Study Area. This information is intended to provide a context for the chemical-specific nature and extent discussions in Sections 4.3 to 4.8.

4.2.1 Known Historical Facility-Related Releases

This section provides an overview of known Facility-related releases. Section 1.3.2 presents a more detailed discussion of historical operations at the Facility, as well as physical changes that took place at the facility over time. The primary purpose of this section is to describe the

mechanisms by which Facility-related releases may have distributed chemicals within the Study Area. The remainder of this section presents the information sequentially by time period. A timeline is presented in Figure 4-1 to provide an overview.

1950s – Initial Facility Development and Initiation of Cattle Truck and Tanker Truck Cleaning Operations

The earliest known Facility-related development occurred in the 1950s, with cattle truck and tanker truck cleaning operations taking place in the central portion of the Facility. It was also reported (CEC 2002) that during the same time frame, a dust-suppression business may have operated at the Facility and that the business reportedly mixed asphalt, lignite, and used oil to create the dust-suppression mix. Information regarding stormwater and process water management practices at the Facility is not available for this time frame, but unless intercepting devices (i.e., sumps, berms, or ponds) were present, it is likely that stormwater sheet flow and truck-cleaning rinsate flowed across the Facility to the wetlands area immediately southwest of the Facility. The aerial photographs presented in Appendix A were not conclusive regarding the absence or presence of these features.

1960s – Continuation of Cattle Truck and Tanker Truck Cleaning Operations

Cattle truck and tanker truck cleaning operations continued during the 1960s (CEC 2002). DEQ referenced a pond with oil-stained soil that was filled sometime before 1964 (DEQ 1995), although the location of this former pond was not identified. If this pond did exist, it suggests that some effort had been made to control the flow of the apparently oily surface water that resulted from operations at the Facility.

1970s – Drainage Ditch Construction and the Discharge of Oily Substances

Aerial photographs taken during the 1970s (Appendix A) show the development of a drainage ditch that runs along the northeast Facility boundary and extends along the northwest Facility boundary through the wetlands. Cattle truck and tanker truck cleaning operations described above continued through the 1970s, reportedly taking place on a “cement washing basin” that drained to an open ditch (likely the drainage ditch that was located along the northeast Facility boundary), which then discharged into the wetlands. In addition, it was noted that the Facility had been oiled for dust control (DEQ 1973), and thus stormwater flow may have included entrained oils from dust suppression. Reports and complaints to DEQ regarding oily discharges from the Facility to the adjacent wetlands were documented in 1973 (Ecology and Environment 2001) and 1974 (DEQ 1974a). DEQ inspections during this time identified the presence of several sumps on the Facility; the sumps contained oily water that reportedly discharged to the adjacent wetlands.

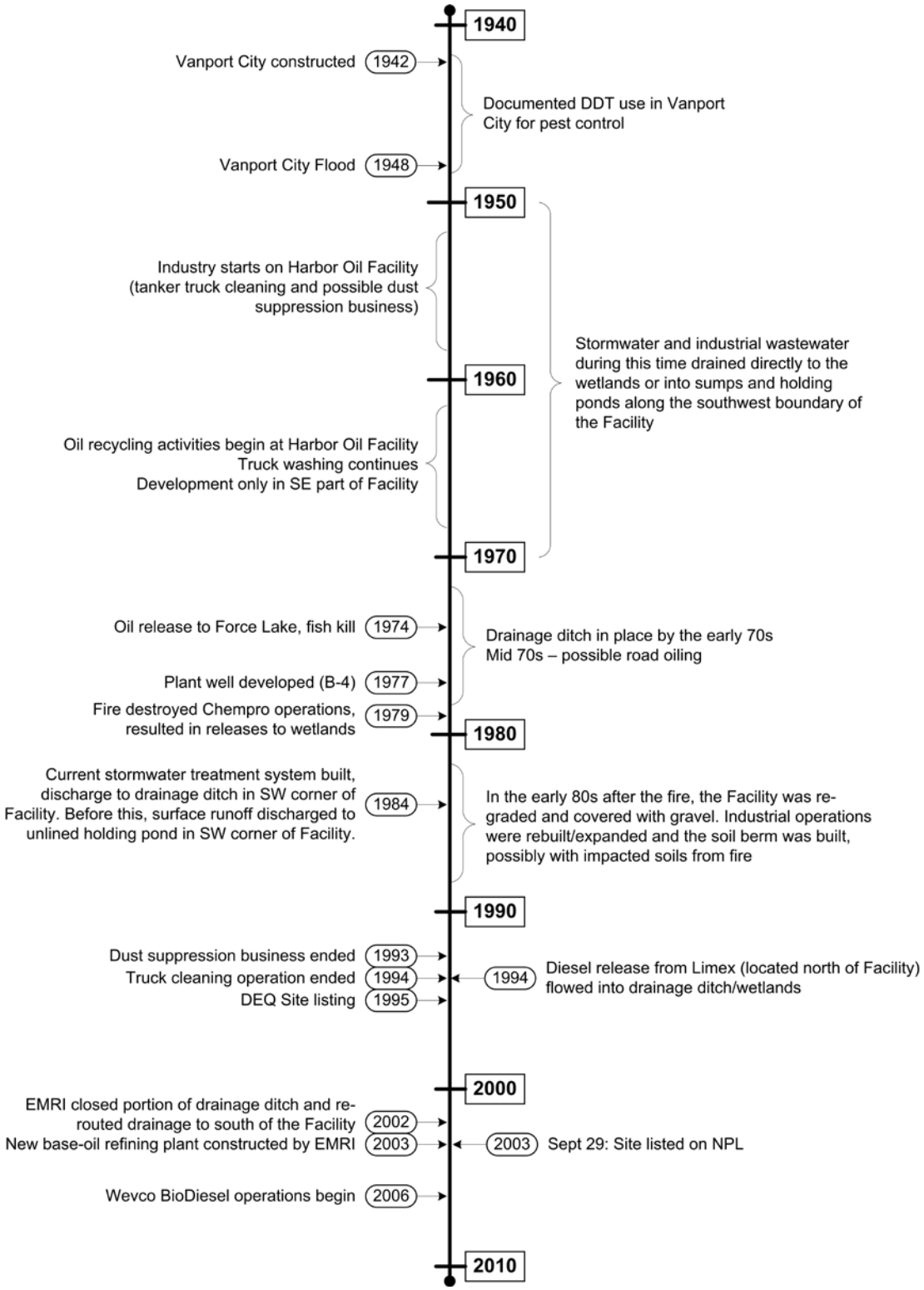


Figure 4-1. General Facility Timeline

In a 1974 letter, Empire Industries, the Facility operator at that time, stated that oil residue in the adjacent wetlands resulted from 10 to 12 years of truck cleaning operations (Empire Industries 1974). This letter also stated that during the same year, Empire Industries placed 1,146 cubic yards of rock fill in the area between the truck cleaning operation and Force Lake to provide containment of wash water. In 1975, DEQ noted that the rock containment had not been completed and there continued to be evidence of discharges into the drainage ditch along the northeast side of the Facility (DEQ 1975), which ultimately discharged to the adjacent wetlands.

In 1975, DEQ issued an NPDES Waste Discharge Permit to Chempro (the facility operator at the time) allowing Chempro to discharge to the "North Ditch of Force Lake" until 1977, after which time, discharges were to be routed to the City of Portland sewer system. In 1978, DEQ received a complaint that Chempro was discharging oily wastes into the wetlands. In 1978, DEQ discovered that the City of Portland sewer system connection had not been completed.

1979 to 1980 – Facility Fire and Post-Fire Reconstruction

In 1979, a major fire destroyed the Chempro facility and reportedly resulted in releases to the adjacent wetlands and Force Lake (DEQ 1995). As part of post-fire reconstruction effort, an earthen berm was constructed along the northwest and southwest sides of the Facility, apparently with soil that had been impacted by the fire-related releases (Ecology and Environment 2001). The soil berm has since been effective in preventing stormwater runoff from discharging into the adjacent wetlands. The Facility was also re-graded and covered with gravel. An unlined holding pond was constructed in the west corner of the Facility to receive surface water flow and act as an oil-water separator. As the pond filled, the water under the surface of floating oil was reportedly pumped off the Facility to a "swamp on the exposition center property," which was likely the wetlands to the west and south of the Facility (EPA 1980).

1983 to 1984 – Construction of Stormwater Treatment System

DEQ issued an NPDES Waste Discharge General Permit to Harbor Oil (Permit 1300-J) which required that stormwater be collected and treated by means of an oil-water separator. By 1984, Harbor Oil had installed a new oil-water separator that discharged treated water into the drainage ditch along the northwest Facility boundary near the Facility's west corner. Water in the stormwater treatment system was sampled by EPA in 1985 and found to contain TCE (Section 1.3.2.5.3).

1988 – Discharge of Truck-Cleaning Rinsate to Wetlands

During a 1988 site inspection, DEQ observed that rinsate from the tanker truck cleaning operation was discharging to the wetlands via the stormwater treatment system (DEQ 1988c). At that time, the tanker truck cleaning operation (i.e., Detrex system) consisted of a TCE-distillation unit and storage tank located on a raised concrete pad adjacent to the cleaning area. Used TCE and truck wastes were pumped into the storage tank and then into the distillation unit for reprocessing. A sample collected

in 1988 from the "bottom of the oil-water separator" (i.e., stormwater treatment system) was analyzed by DEQ. This sample contained detectable concentrations of several VOCs but no acid-base/neutral compounds, DDDs, DDEs, or DDTs were detected (DEQ 1988c). At the time these samples were collected, the stormwater treatment system discharged to the drainage ditch through a pipe located along the southwest Facility boundary near the west corner of the Facility.

Based on the 1988 site inspection, DEQ threatened to revoke Harbor Oil's stormwater discharge permit because pollutants from the tanker truck cleaning operation were entering the stormwater treatment system, which was not designed to remove these chemicals. Harbor Oil subsequently settled with DEQ and in 1989 agreed to a Stipulation and Consent Agreement that allowed Harbor Oil to continue discharging stormwater to the wetlands under the condition that process wastewater be separated and discharged to the City of Portland sanitary sewer.

1990 to 1994 – Initiation of Wastewater Discharge to Sanitary Sewer and Discussion of Detrex System

In 1990, Harbor Oil installed a new wastewater treatment system to comply with City of Portland sanitary sewer discharge requirements and with the DEQ consent order (Advanced Treatment Systems 1993). The system was designed to treat wastewater from waste oil processing and provide pre-treatment prior to discharge to the City of Portland sanitary sewer system. Prior to this, wastewater had been stored and treated in Tank 23 and then further treated through flocculation in Building 5 before being released to the stormwater treatment system.

This Advanced Treatment Systems document (1993) also discussed the Detrex system that had been used to clean the internal surfaces of trucks. The cattle and tanker truck cleaning operation included a diesel-fired heater, which was used to heat a storage tank that contained TCE and water. The TCE/steam mixture was used to clean the trucks. The spent cleaning solution was drained onto a concrete pad, where it was collected in a curtain drain and pumped back to the heated storage tank. The truck cleaning operation was reportedly a closed-loop, stand-alone process that was not physically connected to the Facility wastewater treatment system. Truck cleaning operations at the Facility ceased in 1994.

2002 to Present – Stormwater System Modifications

Use of the drainage ditch ended in approximately 2002. All stormwater from the Facility is now collected in catch basins and routed to the stormwater treatment system located in the western portion of the Facility near the southwest Facility boundary (CEC 2002). Treated stormwater is discharged to the wetlands through a pipe located on the southwest Facility boundary adjacent to the stormwater treatment system (Figure 4-2) under NPDES Industrial Stormwater Discharge Permit 1200-COLS.

Figure 4-2. Facility Features and Area Descriptions

4.2.2 Potential Facility-Related Sources

Potential sources of chemicals to soil, groundwater, surface water, or sediment at the Study Area are summarized in Section 1.3 based on the site history. Figure 4-2 shows the locations of these potential sources on the Facility property.

Briefly, these areas include:

- Former C-shaped area located in the west-central portion of the Facility (Figure 4-2). The historical purpose of this area is unknown; however, it may have collected wastewater and runoff from Facility operations, with overflow into the adjacent wetlands.
- Former unlined oil-water separator pond located in the west-central portion of the Facility (Figure 4-2). This area collected wastewater and runoff from Facility operations, with overflow into the adjacent wetlands.
- Former sumps and holding ponds along the southwest boundary of the Facility, which may have extended over the current Facility boundary into the wetlands. These areas likely collected wastewater and runoff from Facility operations during the 1950s and 1960s (Section 4.2.1), with overflow into the adjacent wetlands.
- Former tanker truck and cattle truck cleaning work area, former concrete pad, and former tanker truck cleaning operation (Detrex system)[12] in the central portion of the Facility (Figure 4-2). Wastewater from the truck cleaning operation is known to have drained directly into the wetlands, into sumps and holding ponds, and later into the wetlands via the stormwater treatment system.
- Historical discharge point for the stormwater treatment system located in the west corner of the Facility along the southwest Facility boundaries (Figure 4-2). The historical discharge point is a suspected source because of overflows and incomplete water treatment.
- Tank farm and used oil processing area located along the northeast Facility boundary (Figure 4-2). Used oil is stored in the tank farm and then heated and processed in the oil processing area to produce RFO. Spills and drips during transfers and processing may have resulted in the release of chemicals in this area.
- Tank 23 located near the north corner of the Facility (Figure 4-2). This tank was used for the storage and treatment of wastewater from waste oil processing prior to the installation of the wastewater treatment system.

[12] Note that the Detrex system consisted of a TCE distillation unit and storage tank located on a raised concrete pad adjacent to the cleaning area as discussed in Section 1.3.2.5.6.

- Soil berm located along the northwest and southwest sides of the Facility. This berm was apparently constructed from soil that was impacted by releases caused by the 1979 Facility fire.
- Soil stockpile located along the northwest Facility boundary. This stockpile was generated during the construction of the new base oil refining plant and may contain soils impacted from historical Facility surface releases in the area.
- Former drainage ditch located along the northeast and northwest boundaries of the Facility[13] that historically served as a collection conduit for the discharge of potentially impacted stormwater from the Facility into the wetlands and Force Lake.

4.2.3 Potential Off-Facility Sources

This section presents a brief overview of potential off-Facility sources. As discussed in Section 3.2.2 of the RI/FS Work Plan (Bridgewater et al. 2008b), there are a number of potential off-site sources of chemicals to the Study Area. These sources are briefly discussed below and in more detail in Section 1.3. Figure 1-4 shows the locations of these potential sources.

4.2.3.1 Heron Lakes Golf Club

The Heron Lakes Golf Club includes the Greenback Golf Course, constructed in 1969 and 1970, and the Great Blue Golf Course, constructed in 1992 (Goodling 2007). The PEN 1 NRMP (City of Portland 1997) states that the City of Portland occasionally used pesticides at the Heron Lakes Golf Club, although specific pesticides were not identified. Force Lake receives runoff and subsurface drainage from a portion of the Greenback Golf Course. Since the City of Portland began collecting twice-yearly water samples from Force Lake in 2001, only one pesticide (Clopyralid [Confront®]) has been detected (Section 1.3.3.5).

4.2.3.2 Former Vanport City Site

Vanport City, which was located immediately south of Force Lake (1943 photograph in Appendix A), was a large public housing project constructed in 1942 to house workers for shipyards located in Portland, Oregon, and Vancouver, Washington. By late 1943, it housed nearly 40,000 people. According to documentation on Vanport City (Maben 1987), residents frequently complained of pest infestations, including rodents, bedbugs, cockroaches, and other insects. Various methods were employed to address this problem without success. In 1945, an extermination company under contract with the Housing Authority of Portland began using DDT at a rate of one pint per apartment with “excellent results.”

On Memorial Day 1948, floodwaters from the Columbia River breached a railroad dike along the west side of Vanport City destroying the town. The

[13] The location of the ditch is not shown in Figure 2-1 or on any of the chemical concentration figures presented in this section because the ditch is not a well-defined drainage feature in this area.

flood may have transported soils that contained DDT into Force Lake and the wetlands based on the extent of the flooding shown in a 1948 aerial photograph (Appendix A).

4.2.3.3 Nearby Industrial Properties

Industrial properties to the north and northeast of the Facility include the Peninsula Terminal Railroad, the former Farmer's Plant Aide/former Limex Transportation/Bulk Transportation facility, the former stockyards, and the Star Oil property. These properties are not considered to be important sources of chemicals to the Study Area, but are presented here for completeness.

These properties are located on or to the south of the topographic divide that forms the northeast boundary of sub-basin A-7 (which includes the Facility), and thus stormwater runoff from these properties flows to the southwest and west towards the Facility, the wetlands, and Force Lake. In addition, shallow groundwater beneath portions of these properties flows to the southwest toward the Facility, the wetlands, and Force Lake (see Appendix K, Golder Associates' Figure 6-4).

The following provides a brief description of the industrial history of these properties. Section 1.3.3.1 provides a discussion a 1990 SIs during which samples were collected from some of these properties.

- **Peninsula Terminal Railroad:** The railroad located north of the former Farmer's Plant Aid facility was constructed sometime before 1917 (Golder Associates 1990). Railroad activities included the off-loading of chemicals, cattle, and coal.
- **Former Farmer's Plant Aide/former Limex Transportation/ Bulk Transportation facility:** This property located immediately north and uphill of the Study Area (Figure 1-4) was reported by Golder Associates (1990) to have had piles of unknown substances located near the Facility's northeast boundary in 1948. Around the 1970s, a commercial fertilizer plant (J.W. Fertilizer) began operations on the property, storing and using manure from the Stockyards. Runoff from the manure piles passed through the former drainage ditch and into the wetlands and Force Lake until the 1970s. The former Farmer's Plant Aide ceased operations at the property in 1990. The property was also occupied by Limex Transportation. In November 1994, a faulty valve on a 300-gallon AST caused the release of 50 to 150 gallons of diesel by Limex Transportation (DEQ 1995) (Section 1.3.2.6). The diesel flowed into the drainage ditch between the Limex property and the Facility, entering the wetlands. Cleanup involved product recovery and some soil removal from the most heavily impacted wetland areas. DEQ suspended soil removal activities after determining that an oily layer 16 in. below the surface represented pre-existing conditions (DEQ 1995). This property is now occupied by Bulk Transportation.
- **Former Stockyards:** The Portland Union Stockyards (Portland Stockyards) were built around 1910 and consisted of livestock

pens, with an attached complex that included covered pens, a hay barn, an auction hall, and a livestock receiving area. According to CEC (2002), the stockyards were closed in 1988.

- **Star Oil Property:** During the early 1990s, Star Oil operated a card-lock fueling facility immediately north of the Peninsula Terminal Railroad tracks on the west side of North Force Avenue.

4.3 TPH, PAHs, and Petroleum-Associated VOCs

This section presents an overview of source information, fate and transport, and media-specific data for TPHs, PAHs, and petroleum-associated VOCs. These chemicals are of interest at the Study Area based on historical and current industrial activities, including oil treatment and processing, production of RFO, and tanker cleaning operations. In the HHRA, cPAH TEQ and TPH gasoline (aliphatic) were identified as COCs based on potential future worker exposure to Facility soil. In the ERA, total HPAH concentrations in three samples were greater than invertebrate soil screening values.

Chemicals to be discussed in this section include TPH (total,[14] gasoline-range fraction, diesel-range fraction, and motor oil-range fraction), cPAH TEQ, total PAHs, and VOCs referred to as petroleum-associated VOCs (i.e., 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, benzene, ethylbenzene, isopropylbenzene, n-propylbenzene, tert-butyl methyl ether, toluene, and xylenes). These VOCs were included because of their known presence in petroleum products as identified in DEQ's *Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites* (2003).

All cPAH data in the RI are presented as cPAH benzo(a)pyrene TEQs. The cPAH TEQ is calculated using PEFs developed by the California EPA Office of Environmental Health and Hazard Assessment (California EPA 1994). As discussed in Appendix N, for each location, the cPAH TEQ was calculated by summing the products of the concentrations of individual cPAH compounds and compound-specific potency equivalency factors (PEFs). The resulting cPAH TEQ has a toxicity equivalent to that of benzo(a)pyrene.

4.3.1 Known or Suspected Sources and Release Mechanisms

Since industrial operations began at the Facility in the 1950s and 1960s (Figure 4-1), TPH, PAHs, and petroleum-associated VOCs may have been released from waste oils and fuels brought onto the Facility for processing and refinement. Sources of these petroleum-related chemicals may have included routine handling activities such as loading and unloading operations, the tank farm located along the northwest boundary of the Facility, on-Facility road oiling for dust suppression, and the former truck cleaning operation located in the central portion of the Facility

[14] As discussed in Appendix N, total petroleum hydrocarbons are defined as the sum of TPH – gasoline-range, TPH – diesel-range, and TPH – motor oil-range.

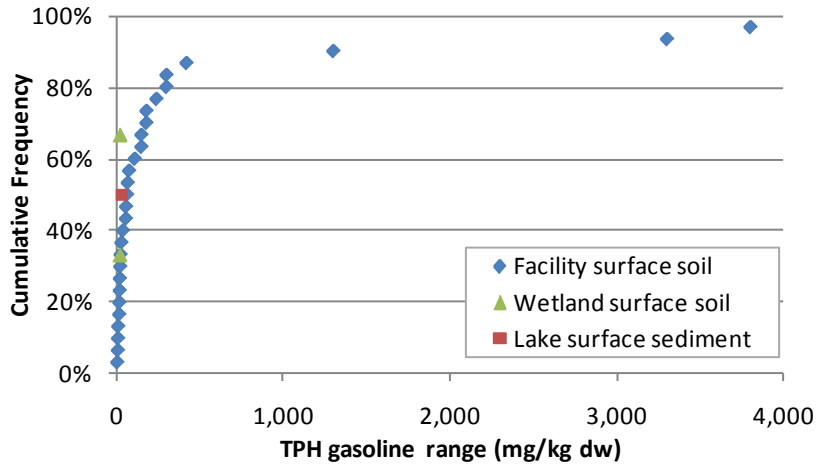
(Figure 4-2). Although TPH were detected in soils in the area where the new base oil plant is located, the plant itself is not the suspected source because of its recent construction (some soil samples were collected before the construction of the plant in 2002).

4.3.2 Concentrations by Medium

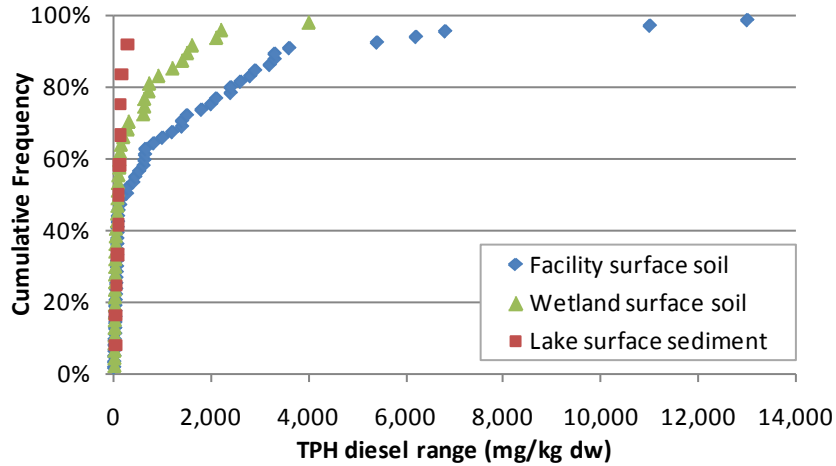
This section discusses the concentrations of TPH, PAHs, and petroleum-associated VOCs in various media within the Study Area. Summary statistics in tables are provided by location (not sample) to match the presentation in the figures. Also, duplicate samples were combined with the original sample, as described in Appendix N. The complete RI database is provided in Appendix B.

Figures were created to show the data for a subset of the chemicals discussed in this section: total TPH, TPH – gasoline range, TPH – diesel range, TPH – motor oil range, cPAH TEQ, total PAHs, and benzene. Figures were not created for other VOCs because the concentration patterns were generally the same as those for benzene, as discussed later in this section.

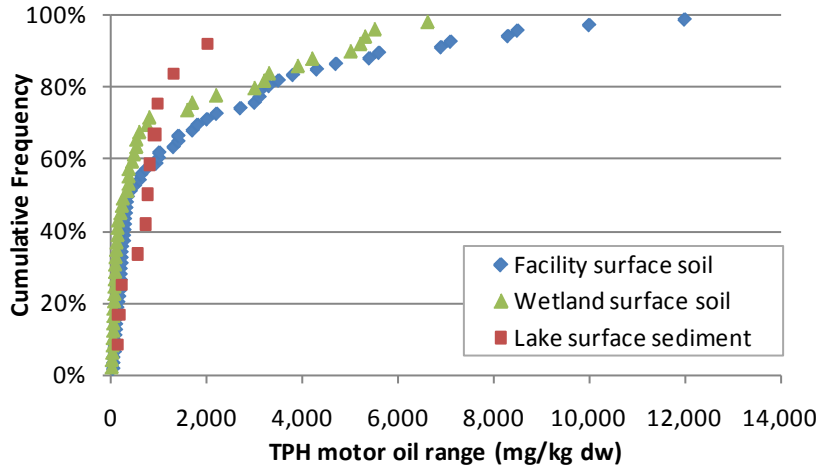
For the chemicals identified above, Figures 4-3a and 4-3b show cumulative frequency distributions of concentrations in surface soil and sediment samples collected from within the Study Area. These figures are intended to facilitate cross-media comparisons. Concentration is shown on the x-axis, and the percent rank within the dataset is shown on the y-axis. So, for example, approximately 80% of the Facility surface soil sample TPH concentrations were less than or equal to 7,500 mg/kg dw. cPAH TEQs were similar in Facility soil and wetland soil, whereas total TPH concentrations in Facility soil were usually higher than those in the wetland soil. Note that for total PAHs and benzene, a log scale was used in the cumulative frequency distribution to better display the range of concentrations.



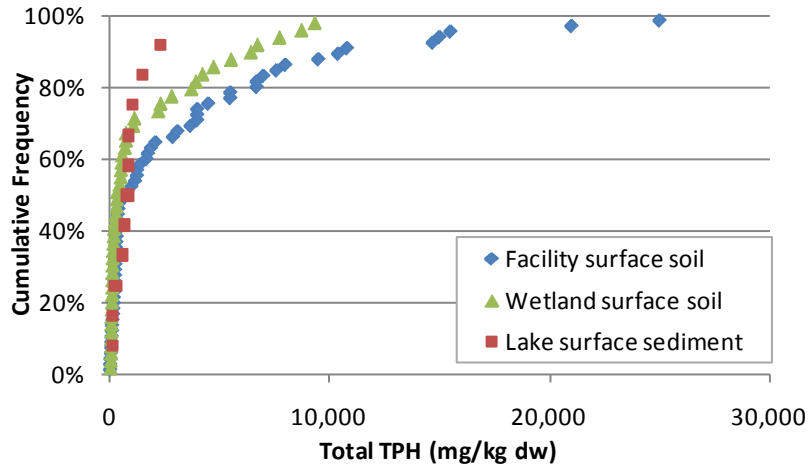
TPH – gasoline range



TPH – diesel range

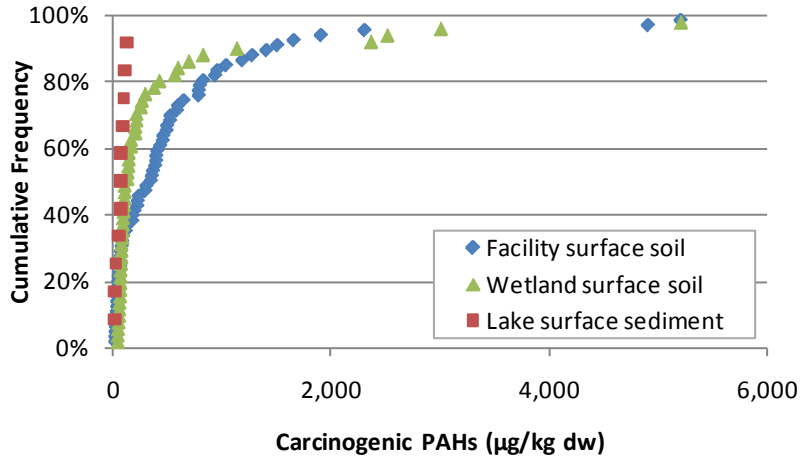


TPH – motor oil range

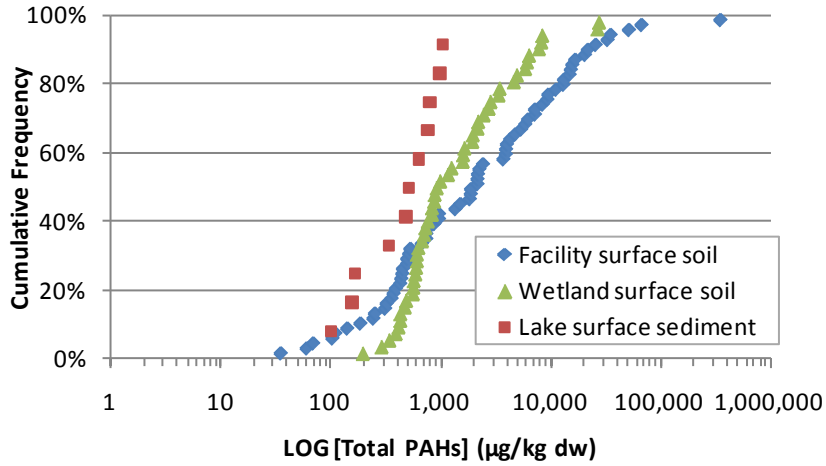


Total TPH

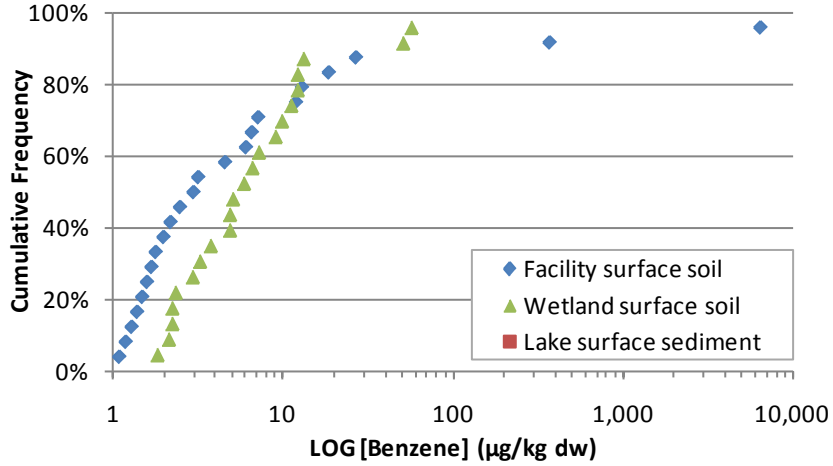
Figure 4-3a. Cumulative Frequencies for TPH Detected in Facility Surface Soil, Wetland Surface Soil, and Force Lake Surface Sediment



Carcinogenic PAHs



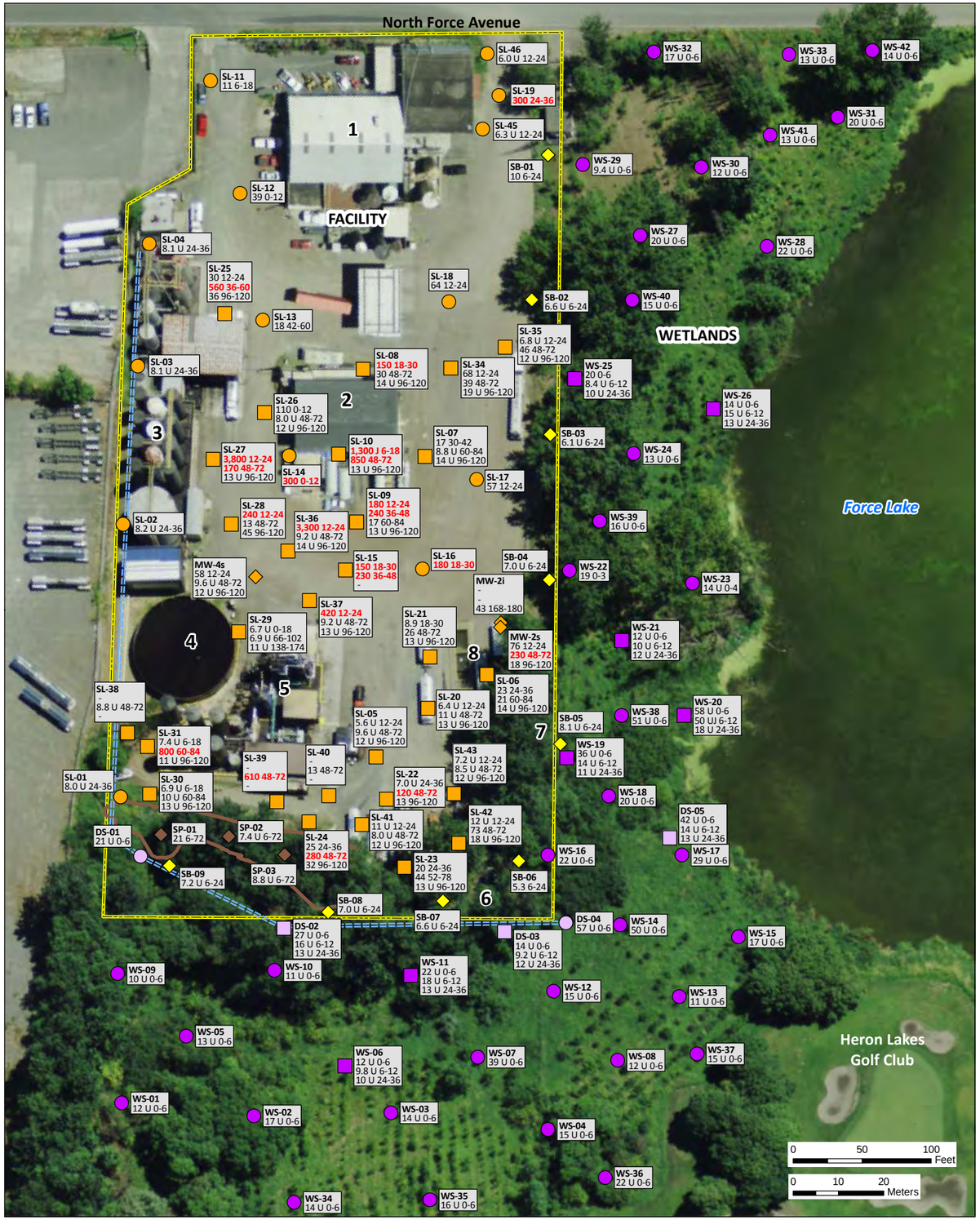
Total PAHs

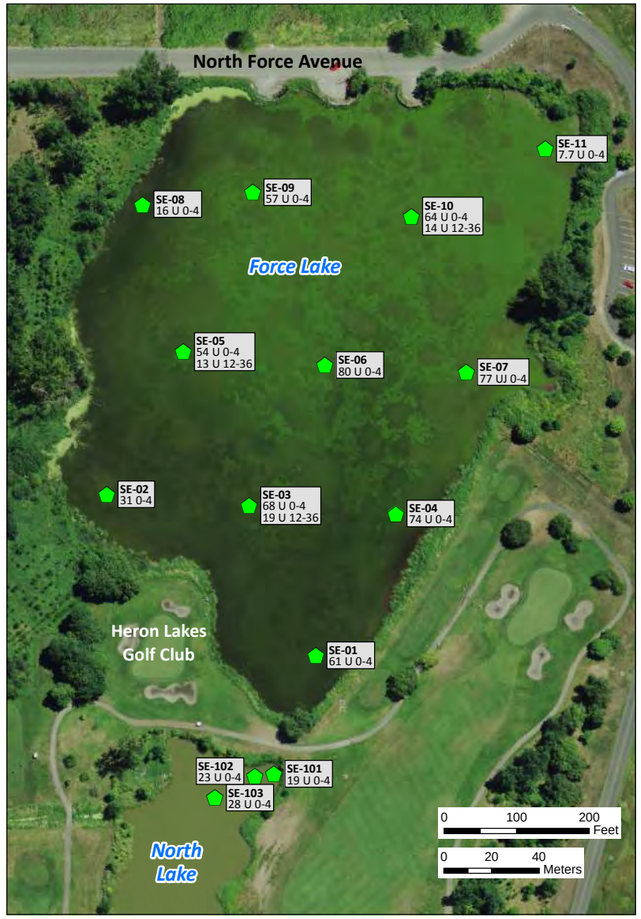


Benzene

Figure 4-3b. Cumulative Frequencies for PAHs and Benzene Detected in Facility Surface Soil, Wetland Surface Soil, and Force Lake Surface Sediment

Figures 4-4 through 4-10 present TPH (total and fractions), cPAH TEQ, total PAH, and benzene concentrations at each soil and sediment location sampled; Figures 4-11 through 4-17 present TPH (total and fractions), cPAH TEQ, total PAH, and benzene concentrations at each groundwater and surface water location sampled. These data are discussed in greater detail by media in the following subsections.





On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

THP - Gasoline-Range Screening Levels

Medium	Unit	Industrial Human Health RSL[a]	Residential Human Health RSL[a]	Invertebrate Screening Level
Facility soil	mg/kg dw	110	110	na
Wetland soil	mg/kg dw	na	110	nv
Lake sediment	mg/kg dw	na	13,000	nv

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
na - not applicable
nv - no value (i.e., no SL available for this chemical-medium combination)

Facility soil samples (mg/kg dw)[a]

- Surface soil
- Subsurface and surface soil[b]
- Soil at groundwater monitoring well[b]
- Soil berm
- Soil stockpile

Wetland and ditch soil samples (mg/kg dw)[a]

- Wetland surface soil
- Wetland surface and subsurface soil[b]
- Ditch surface soil
- Ditch surface and subsurface soil[b]

Lake sediment samples (mg/kg dw)

- Lake sediment[b]

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

[a] following locations were not analyzed for TPH - gasoline and do not appear on this map: shallow samples from DP01, DP02, DP03, SL-32, SL-33, SS01 to SS10, and WL01 to WL05; intermediate samples from DP01, DP02, and DP03; and deep samples from DP01, DP02, DP03, and SL-44.

[b] Both surface and subsurface data are shown.

Location ID — SL-00
Concentration — 2,500 12-24 / 250 JN 60-84 / 25 U 96-120
Qualifier: U=non-detect, J=estimated, N=tentatively identified
Depth in inches
Detected concentration: exceeds SL = Red; does not exceed SL = Black

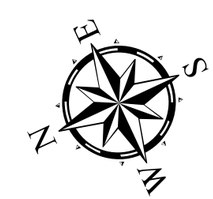


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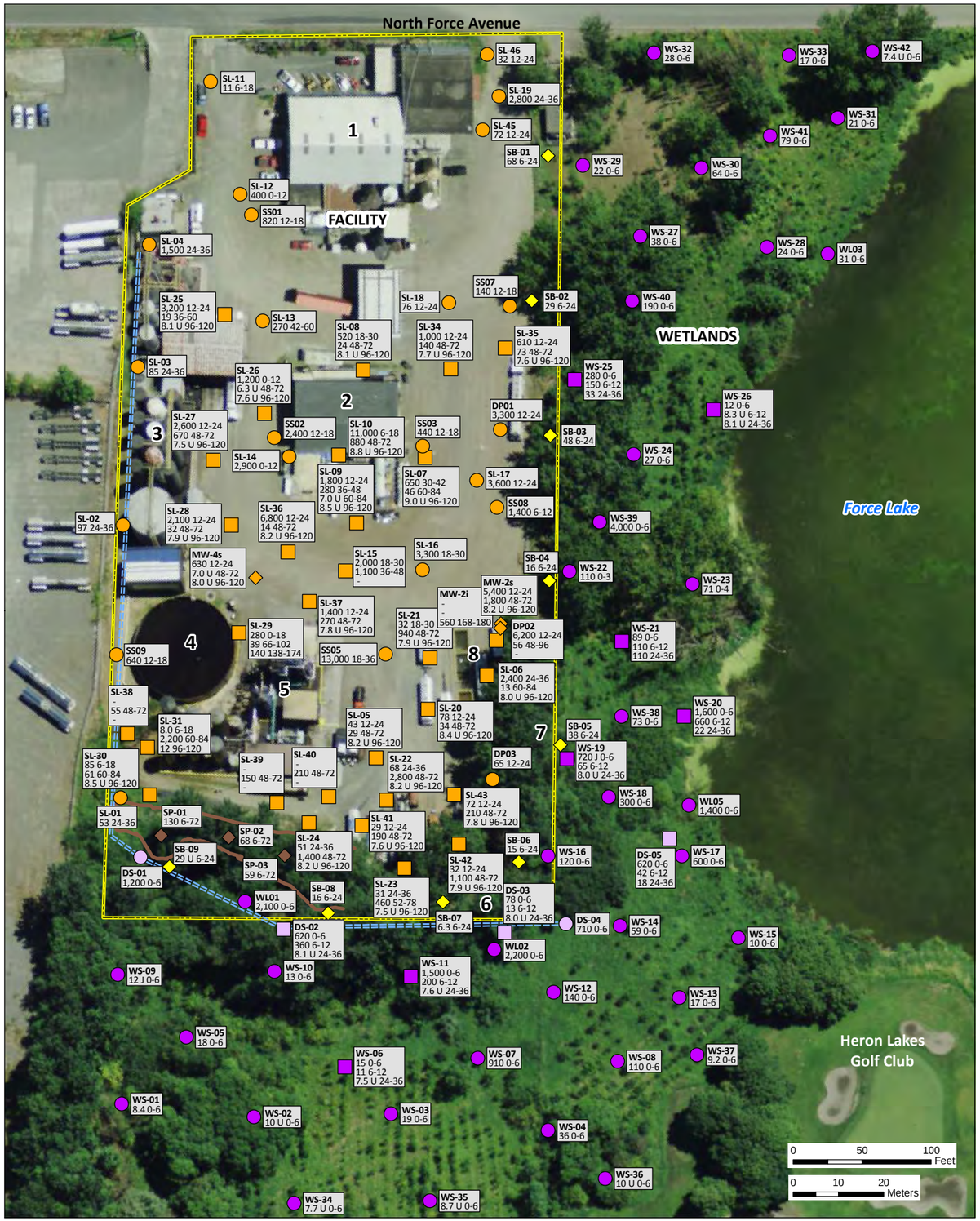
Figure 4-4. TPH – Gasoline-Range Concentrations at Facility Soil, Wetland Soil, and Lake Sediment Sampling Locations

Prepared by: CEH, 08/31/2010; MAP #4133; W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.



On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

TPH - Diesel-Range Screening Levels

Medium	Unit	Industrial Human Health RSL[a]	Residential Human Health RSL[a]	Invertebrate Screening Level
Facility soil	mg/kg dw	23,000	23,000	na
Wetland soil	mg/kg dw	na	23,000	nv
Lake sediment	mg/kg dw	na	23,000	nv

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
na - not applicable
nv - no value (i.e., no SL available for this chemical-medium combination)

Facility soil samples (mg/kg dw)[a]

- Surface soil
- Subsurface and surface soil[b]
- Soil at groundwater monitoring well[b]
- Soil berm
- Soil stockpile

Wetland and ditch soil samples (mg/kg dw)[a]

- Wetland surface soil
- Wetland surface and subsurface soil[b]
- Ditch surface soil
- Ditch surface and subsurface soil[b]

Lake sediment samples (mg/kg dw)

- Lake sediment[b]

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

[a] The following locations were not analyzed for TPH - diesel and do not appear on this map: shallow samples from SL 32, SL-33, SS04, SS06, SS10, and WL04; intermediate samples from DP01 and DP03; and deep samples from DP01, DP02, DP03, and SL-44.

[b] Both surface and subsurface data are shown.

Location ID — SL-00
Concentration — 2,500 12-24 / 250 JN 60-84 / 25 U 96-120
Detected concentration: exceeds SL = Red; does not exceed SL = Black
Qualifier: U=non-detect, J=estimated, N=tentatively identified
Depth in inches

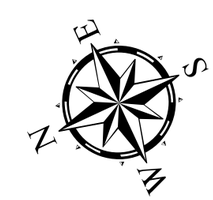


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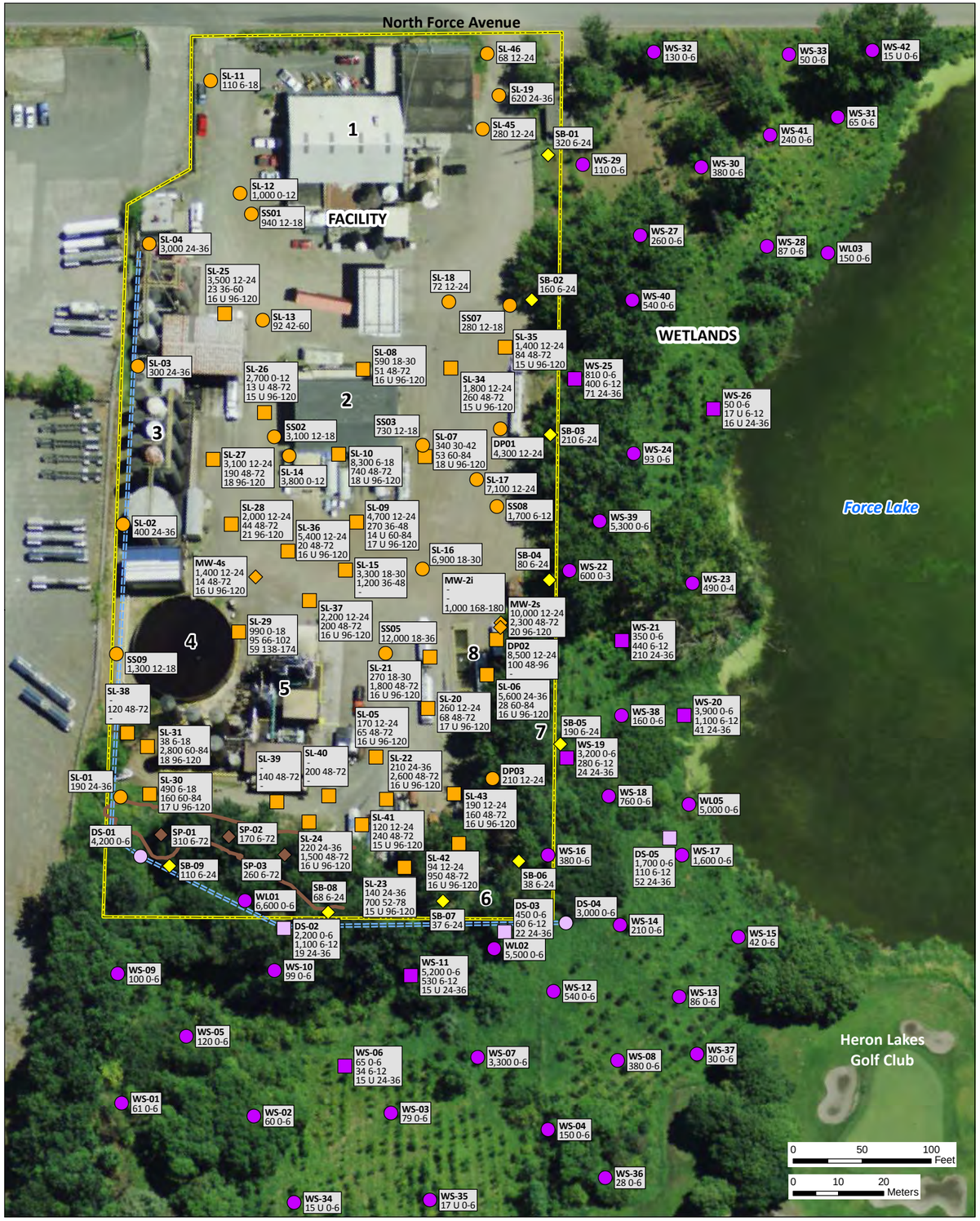
Figure 4-5. TPH – Diesel-Range Concentrations at Facility Soil, Wetland Soil, and Lake Sediment Sampling Locations

Prepared by CEH, 08/31/2010; MAP #4134; W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.



On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

TPH - Motor Oil-Range Screening Levels

Medium	Unit	Industrial Human Health RSL[a]	Residential Human Health RSL[a]	Invertebrate Screening Level
Facility soil	mg/kg dw	23,000	23,000	na
Wetland soil	mg/kg dw	na	23,000	nv
Lake sediment	mg/kg dw	na	23,000	nv

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
na - not applicable
nv - no value (i.e., no SL available for this chemical-medium combination)

Facility soil samples (mg/kg dw)[a]

- Surface soil
- Subsurface and surface soil[b]
- Soil at groundwater monitoring well[b]
- Soil berm
- Soil stockpile

Wetland and ditch soil samples (mg/kg dw)[a]

- Wetland surface soil
- Wetland surface and subsurface soil[b]
- Ditch surface soil
- Ditch surface and subsurface soil[b]

Lake sediment samples (mg/kg dw)

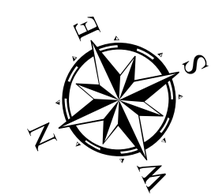
- Lake sediment[b]

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

[a] The following locations were not analyzed for TPH – motor oil and do not appear on this map: shallow samples from SL-32, SL-33, SS04, SS06, SS10, and WL04; intermediate samples from DP01 and DP03; and deep samples from DP01, DP02, DP03, and SL-44.

[b] Both surface and subsurface data are shown.

Location ID — SL-00
Concentration — 2,500 12-24 / 250 JN 60-84 / 25 U 96-120
Detected concentration: exceeds SL = Red; does not exceed SL = Black
Qualifier: U=non-detect, J=estimated, N=tentatively identified
Depth in inches



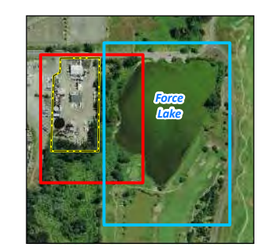


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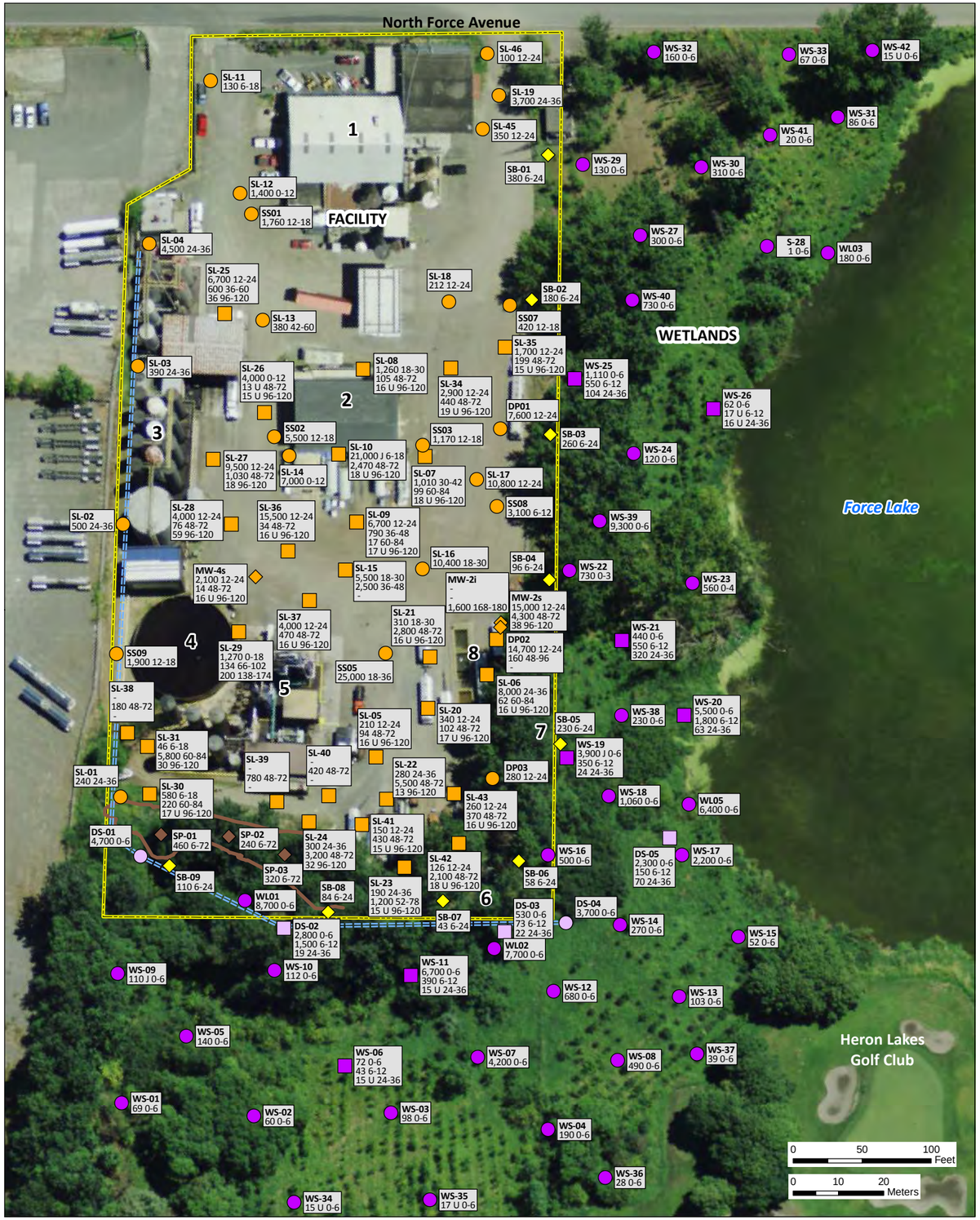
Figure 4-6. TPH – Motor Oil-Range Concentrations at Facility Soil, Wetland Soil, and Lake Sediment Sampling Locations

Prepared by CEH, 08/31/2010, MAP #4135; W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.



On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Total Petroleum Hydrocarbon Screening Levels
No human health or ecological criteria are available for TPHs. TPH is calculated as the sum of the detected concentrations of the diesel, motor oil, and gasoline fractions.

Facility soil samples (mg/kg dw)[a]

- Surface soil
- Subsurface and surface soil[b]
- Soil at groundwater monitoring well[b]
- Soil berm
- Soil stockpile

Wetland and ditch soil samples (mg/kg dw)[a]

- Wetland surface soil
- Wetland surface and subsurface soil[b]
- Ditch surface soil
- Ditch surface and subsurface soil[b]

Lake sediment samples (mg/kg dw)

- Lake sediment[b]

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

[a] The following locations were not analyzed for total petroleum hydrocarbons and do not appear on this map: shallow samples from SL-32, SL-33, SS04, SS06, SS10, and WL04; intermediate samples from DP01 and DP03; and deep samples from DP01, DP02, DP03, and SL-44.

[b] Both surface and subsurface data are shown.

Location ID — **SL-00**
Concentration — 2,500 12-24 / 250 JN 60-84 / 25 U 96-120 — Depth in inches
Qualifier
U=non-detect
J=estimated
N=tentatively identified

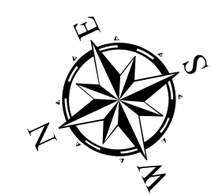


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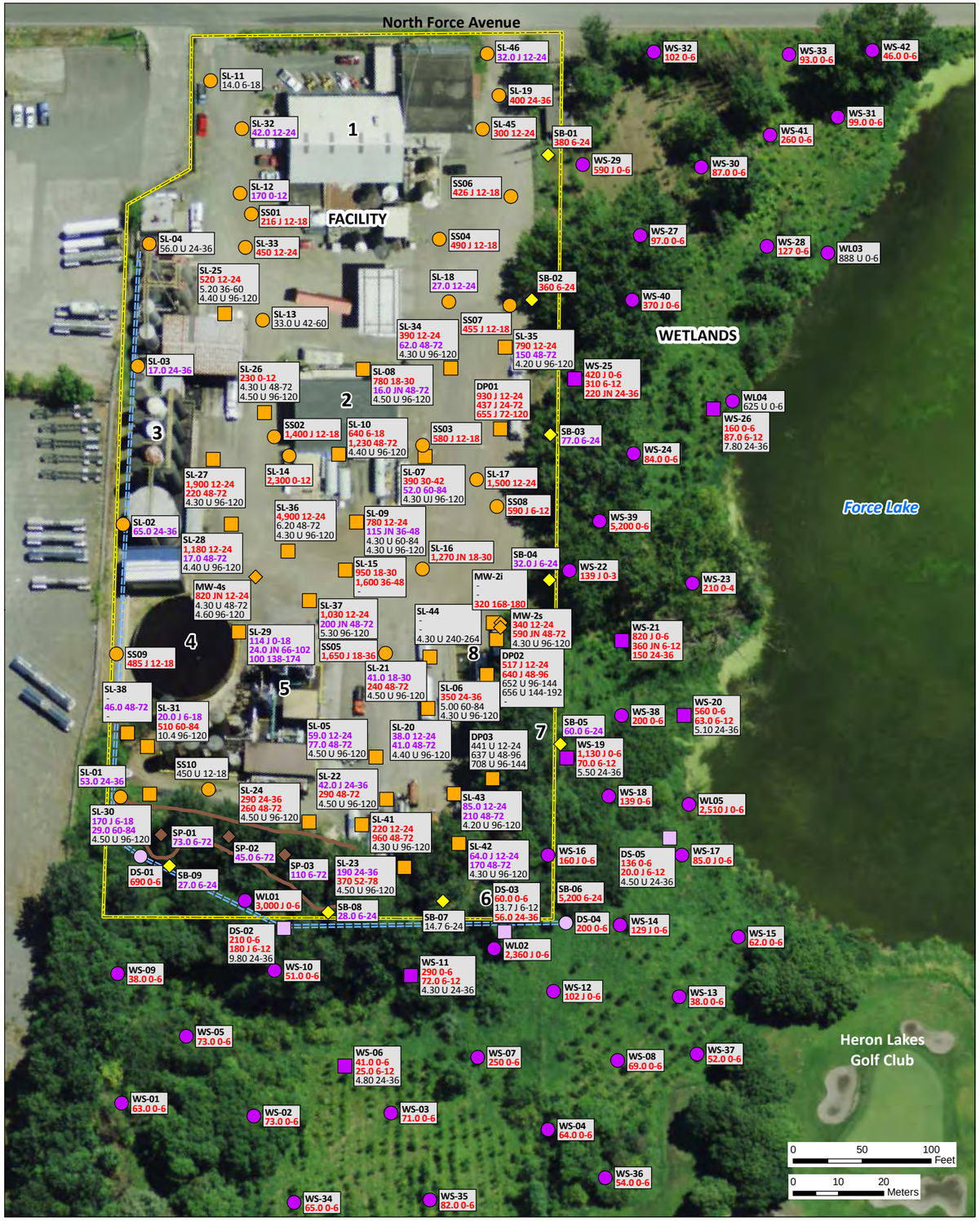
Figure 4-7. Total Petroleum Hydrocarbon Concentrations at Facility Soil, Wetland Soil, and Lake Sediment Sampling Locations

Prepared by CEH, 08/31/2010, MAP #3897; W:\Projects\Harbor_Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.



On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

cPAH TEQ Screening Levels

Medium	Unit	Industrial Human Health RSL[a]	Residential Human Health RSL[a]	Invertebrate Screening Level
Facility soil	µg/kg dw	210	15	na
Wetland soil	µg/kg dw	na	15	nv
Lake sediment	µg/kg dw	na	15	nv

Note: cPAH TEQs (i.e., benzo(a)pyrene equivalents) were calculated by summing the products of the concentrations of individual cPAH compounds and compound-specific potency equivalency factors (PEFs). Thus, RSLs are for benzo(a)pyrene, which corresponds to cPAH TEQ.
[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
na - not applicable
nv - no value (i.e., no SL available for this chemical-media combination)

Facility soil samples (µg/kg dw)[a]

- Surface soil
- Subsurface and surface soil[b]
- Soil at groundwater monitoring well[b]
- Soil berm
- Soil stockpile

Wetland and ditch soil samples (µg/kg dw)

- Wetland surface soil
- Wetland surface and subsurface soil[b]
- Ditch surface soil
- Ditch surface and subsurface soil[b]

Lake sediment samples (µg/kg dw)

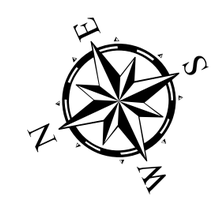
- Lake sediment[b]

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

[a] The following locations were not analyzed for cPAH TEQ and do not appear on this map: intermediate samples from SL-39 and SL-40.

[b] Both surface and subsurface data are shown.

Location ID — SL-00
Concentration — 2,500 12-24 / 250 JN 60-84 / 25 U 96-120
Qualifier: U=non-detect, J=estimated, N=tentatively identified
Depth in inches
Detected concentration: exceeds highest SL = Red; exceeds lowest SL = Purple; does not exceed SL = Black



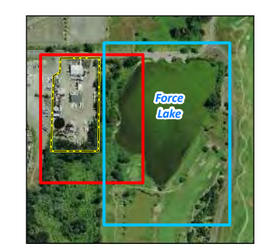


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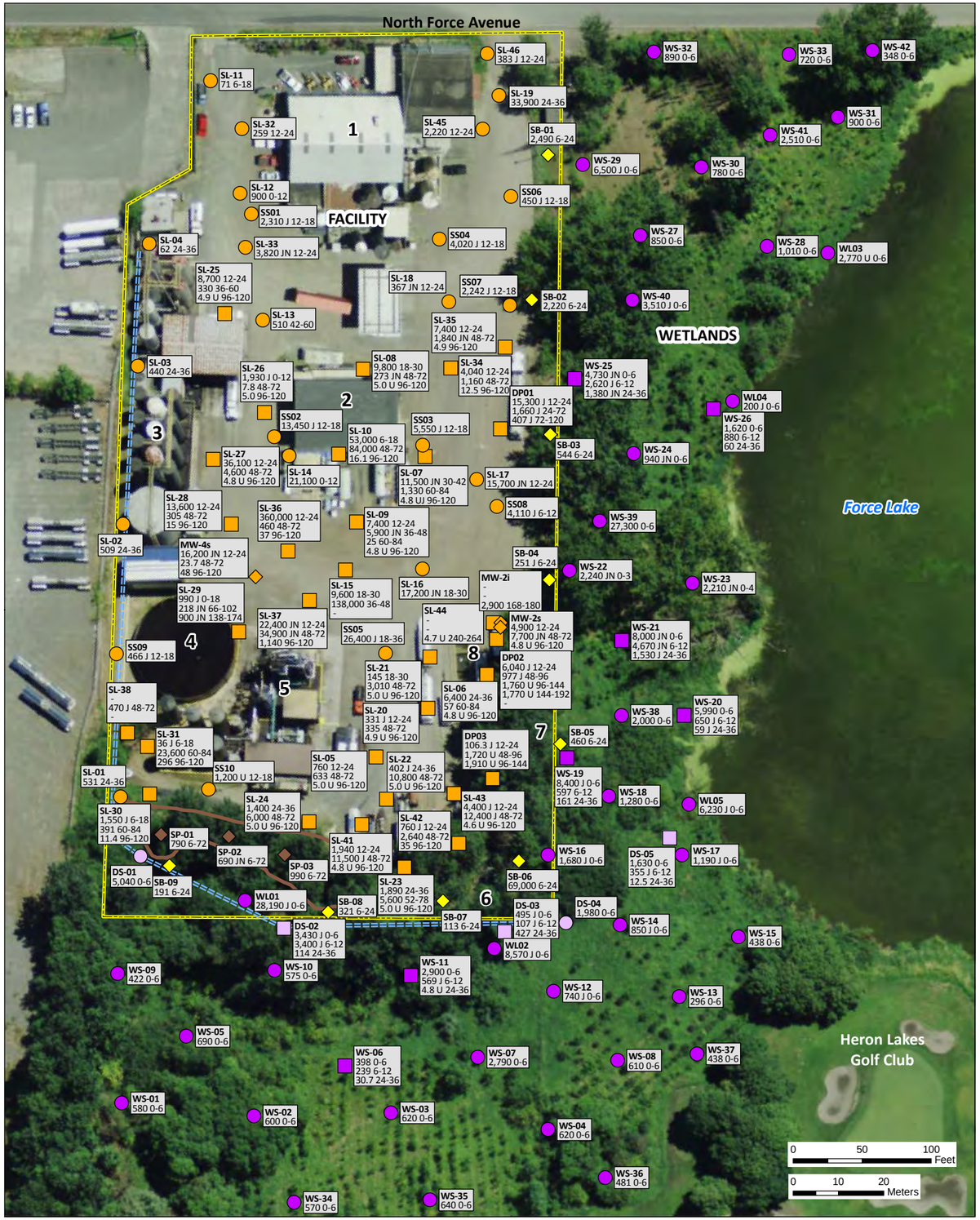
Figure 4-8. cPAH TEQs at Facility Soil, Wetland Soil, and Lake Sediment Sampling Locations

Prepared by CEH, 08/31/2010, MAP #4075, W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.



On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Total PAH Screening Levels

No human health or ecological screening levels are available for total PAH in soil or sediment. Total PAH is calculated as the sum of detected individual PAHs.

Facility soil samples (µg/kg dw)[a]

- Surface soil
- Subsurface and surface soil[b]
- Soil at groundwater monitoring well[b]
- Soil berm
- Soil stockpile

Wetland and ditch soil samples (µg/kg dw)

- Wetland surface soil
- Wetland surface and subsurface soil[b]
- Ditch surface soil
- Ditch surface and subsurface soil[b]

Lake sediment samples (µg/kg dw)

- Lake sediment[b]

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

[a] The following locations were not analyzed for total PAHs and do not appear on this map: intermediate samples from SL-39 and SL-40.

[b] Both surface and subsurface data are shown.

Location ID — SL-00
Concentration — 2,500 12-24 / 250 JN 60-84 / 25 U 96-120 — Depth in inches
Qualifier
U=non-detect
J=estimated
N=tentatively identified

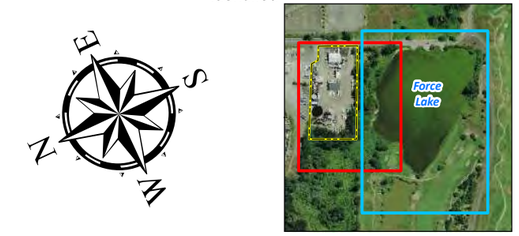


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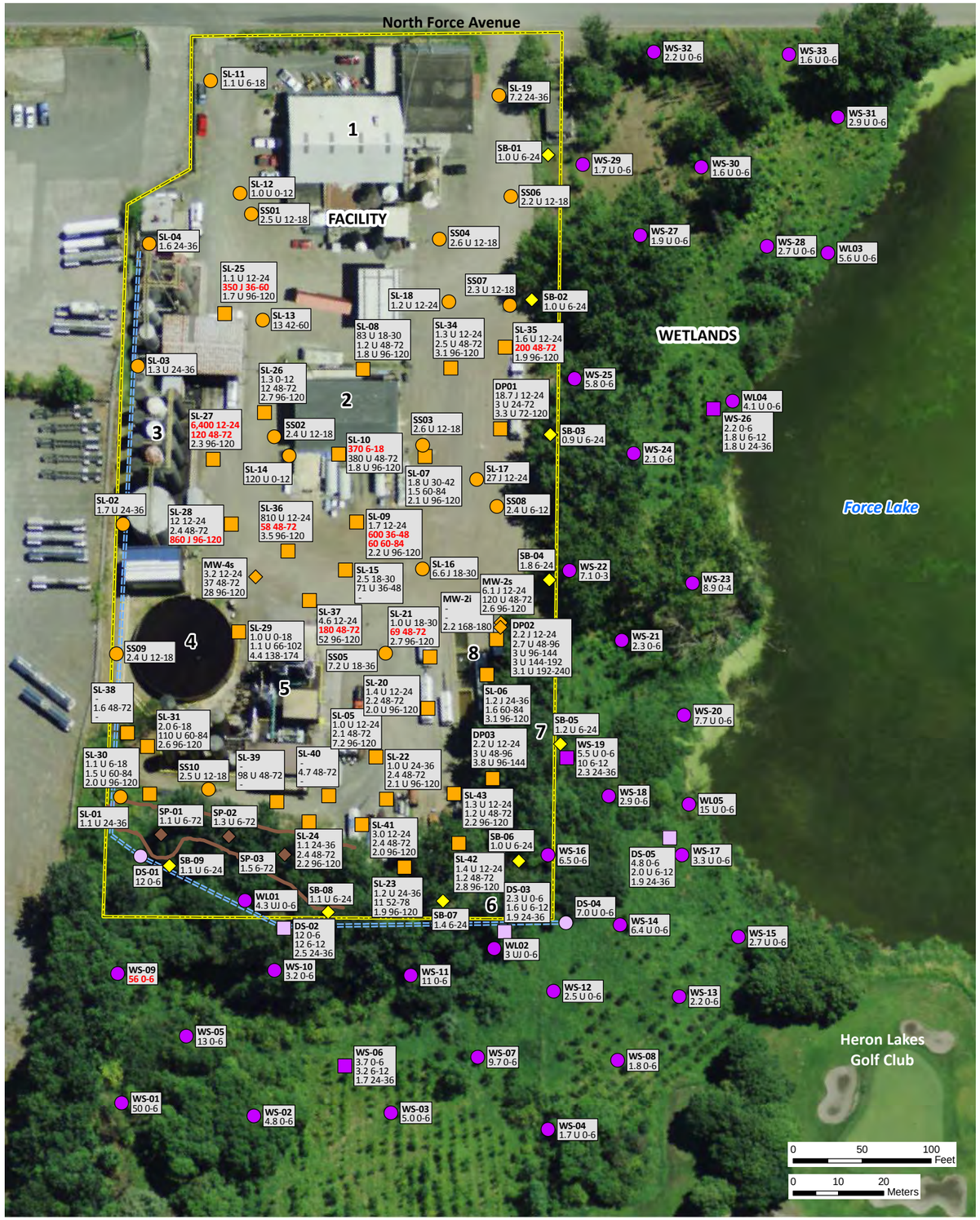
Figure 4-9. Total PAH Concentrations at Facility Soil, Wetland Soil, and Lake Sediment Sampling Locations

Prepared by CEH, 08/31/2010, MAP #4076; W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.



On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Benzene Screening Levels

Medium	Unit	Industrial Human Health RSL[a]	Residential Human Health RSL[a]	Invertebrate Screening Level
Facility soil	µg/kg dw	52	52	na
Wetland soil	µg/kg dw	na	52	nv
Lake sediment	µg/kg dw	na	660	nv

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
na - not available
nv - no value (i.e., no SL available for this chemical-medium combination)

Facility soil samples (µg/kg dw)[a]

- Surface soil
- Subsurface and surface soil[b]
- Soil at groundwater monitoring well[b]
- Soil berm
- Soil stockpile

Wetland and ditch soil samples (µg/kg dw)[a]

- Wetland surface soil
- Wetland surface and subsurface soil[b]
- Ditch surface soil
- Ditch surface and subsurface soil[b]

Lake sediment samples (µg/kg dw)

- Lake sediment[b]

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

[a] The following locations were not analyzed for benzene and do not appear on this map: shallow samples from SL-32, SL-33, SL-45, SL-46, and WS-34 to WS-42; intermediate samples from WS-11, WS-20, WS-21, and WS-25; and deep samples from SL-44, WS-11, WS-20, WS-21, and WS-25.

[b] Both surface and subsurface data are shown.

Location ID — SL-00
Concentration — 2,500 12-24 / 250 JN 60-84 / 25 U 96-120
Detected concentration: exceeds SL = Red; does not exceed SL = Black
Qualifier: U=non-detect, J=estimated, N=tentatively identified
Depth in inches

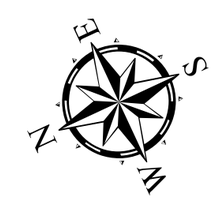


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Figure 4-10. Benzene Concentrations at Facility Soil, Wetland Soil, and Lake Sediment Sampling Locations

Prepared by CEH, 08/31/2010, MAP #3487; W:\Projects\Harbor_Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

TPH - Gasoline-Range Screening Levels

Medium	Unit	Human Health RSL[a]	Invertebrate Screening Level
Groundwater	mg/L	13	na
Surface water	mg/L	not analyzed	

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
na - not applicable

Groundwater samples (mg/L)

- Shallow groundwater
- Intermediate groundwater
- Deep groundwater

Wells where groundwater samples not collected

- Groundwater not sampled due to lack of construction details (trace to 0.02 ft of LNAPL observed)
- Groundwater not sampled due to lack of construction details
- Groundwater not sampled due to the presence of LNAPL (0.1 ft LNAPL observed here in 2008 when LNAPL sample was collected. After this time, trace to 0.02 ft of LNAPL observed).

=== Drainage ditch (approximate location)

Soil stockpile (approximate boundary)

Facility boundary

Location ID — GA-00
Sample Year — 2000: – / 2008: 1.0 U / 2009: na
Detected concentration: exceeds SL = Red; does not exceed SL = Black
Concentration: na=not analyzed; – =not collected
Qualifier: U=non-detect; J=estimated

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Figure 4-11. TPH – Gasoline-Range Concentrations in Unfiltered Samples at Facility Groundwater Sampling Locations

Prepared by CEH, 08/31/2010, MAP #4133; W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

Groundwater samples (mg/L)

- Shallow groundwater
- Intermediate groundwater
- Deep groundwater

Surface water samples (mg/L)[a]

- Lake surface water

Wells where groundwater samples not collected

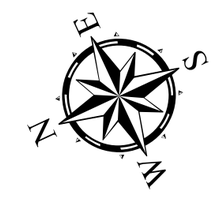
- Groundwater not sampled due to lack of construction details (trace to 0.02 ft of LNAPL observed)
- Groundwater not sampled due to lack of construction details
- Groundwater not sampled due to the presence of LNAPL (0.1 ft LNAPL observed here in 2008 when LNAPL sample was collected. After this time, trace to 0.02 ft of LNAPL observed).

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

Location ID — GA-00
Sample Year — 2000: – / 2008: 1.0 U / 2009: na
Detected concentration: exceeds SL = Red; does not exceed SL = Black
Concentration: na=not analyzed; – =not collected
Qualifier: U=non-detect; J=estimated

On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System



TPH - Diesel-Range Screening Levels

Medium	Unit	Human Health RSL[a]	Invertebrate Screening Level
Groundwater	mg/L	10	na
Surface water	mg/L	not detected; no comparison to screening levels	

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
na - not applicable

Figure 4-12. TPH – Diesel-Range Concentrations in Unfiltered Samples at Facility Groundwater and Lake Surface Water Sampling Locations

Prepared by CEH, 08/31/2010, MAP #4134; W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

Groundwater samples (mg/L)

- Shallow groundwater
- Intermediate groundwater
- Deep groundwater

Surface water samples (mg/L)[a]

- Lake surface water

Wells where groundwater samples not collected

- Groundwater not sampled due to lack of construction details (trace to 0.02 ft of LNAPL observed)
- Groundwater not sampled due to lack of construction details
- Groundwater not sampled due to the presence of LNAPL (0.1 ft LNAPL observed here in 2008 when LNAPL sample was collected. After this time, trace to 0.02 ft of LNAPL observed).

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

Location ID — GA-00
Sample Year — 2000: – / 2008: 1.0 U / 2009: na
Detected concentration: exceeds SL = Red; does not exceed SL = Black
Concentration: na=not analyzed; – =not collected
Qualifier: U=non-detect; J=estimated

On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

TPH - Motor Oil-Range Screening Levels

Medium	Unit	Human Health RSL[a]	Invertebrate Screening Level
Groundwater	mg/L	10	na
Surface water	mg/L	not detected; no comparison to screening levels	
LNAPL	mg/kg ww	na	

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
na - not applicable

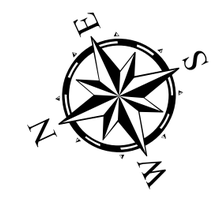


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Figure 4-13. TPH – Motor Oil-Range Concentrations in Unfiltered Samples at Facility Groundwater and Lake Surface Water Sampling Locations

Prepared by CEH, 08/31/2010, MAP #4135, W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Total Petroleum Hydrocarbon Screening Levels
No human health or ecological SLs are available for TPHs. TPH is calculated as the sum of the detected concentrations of the diesel, motor oil, and gasoline fractions.

Groundwater samples (mg/L)

- Shallow groundwater
- Intermediate groundwater
- Deep groundwater

Surface water samples (mg/L)[a]

- Lake surface water

Wells where groundwater samples not collected

- Groundwater not sampled due to lack of construction details (trace to 0.02 ft of LNAPL observed)
- Groundwater not sampled due to lack of construction details
- Groundwater not sampled due to the presence of LNAPL (0.1 ft LNAPL observed here in 2008 when LNAPL sample was collected. After this time, trace to 0.02 ft of LNAPL observed).
- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

Location ID — GA-00
Sample Year — 2000: –
2008: 1.0 U
2009: na

Concentration: na=not analyzed, – =not collected
Qualifier: U=non-detect, J=estimated

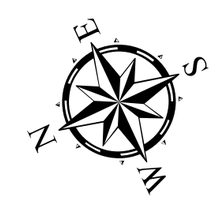

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Figure 4-14. Total Petroleum Hydrocarbon Concentrations in Unfiltered Samples at Facility Groundwater and Lake Surface Water Sampling Locations

Prepared by CEH, 09/31/2010, MAP #3897, W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

Groundwater samples (µg/L)

- Shallow groundwater
- Intermediate groundwater
- Deep groundwater

Surface water samples (µg/L)

- Lake surface water
- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

Wells where groundwater samples not collected

- Groundwater not sampled due to lack of construction details (trace to 0.02 ft of LNAPL observed)
- Groundwater not sampled due to lack of construction details
- Groundwater not sampled due to the presence of LNAPL (0.1 ft LNAPL observed here in 2008 when LNAPL sample was collected. After this time, trace to 0.02 ft of LNAPL observed).

Location ID — **GA-00**
Sample Year — 2000: – / 2008: 1.0 U / 2009: na
Detected concentration: exceeds SL = **Red**; does not exceed SL = Black
Concentration: na=not analyzed, – =not collected
Qualifier: U=non-detect, J=estimated

On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

cPAH TEQ Screening Levels

Medium	Unit	Human Health RSL[a]	Invertebrate Screening Level
Groundwater	µg/L	0.0029	na
Surface water	µg/L	not detected; no comparison to screening levels	

Note: cPAH TEQs (i.e., benzo(a)pyrene equivalents) were calculated by summing the products of the concentrations of individual cPAH compounds and compound-specific potency equivalency factors (PEFs). Thus, RSLs are for benzo(a)pyrene, which corresponds to cPAH TEQ.
[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
na - not applicable

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Figure 4-15. cPAH TEQs in Unfiltered Samples at Facility Groundwater and Lake Surface Water Sampling Locations

Prepared by CEH, 08/31/2010, MAP #4075, W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Total PAH Screening Levels
No human health or ecological screening levels are available for total PAH. Total PAH is calculated as the sum of individual PAHs.

Groundwater samples (µg/L)

- Shallow groundwater
- Intermediate groundwater
- Deep groundwater

Surface water samples (µg/L)

- Lake surface water

Wells where groundwater samples not collected

- Groundwater not sampled due to lack of construction details (trace to 0.02 ft of LNAPL observed)
- Groundwater not sampled due to lack of construction details
- Groundwater not sampled due to the presence of LNAPL (0.1 ft LNAPL observed here in 2008 when LNAPL sample was collected. After this time, trace to 0.02 ft of LNAPL observed).

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

Location ID — **GA-00**
Sample Year — 2000: –
2008: 1.0 U
2009: na

Concentration: na=not analyzed, – =not collected
Qualifier: U=non-detect, J=estimated

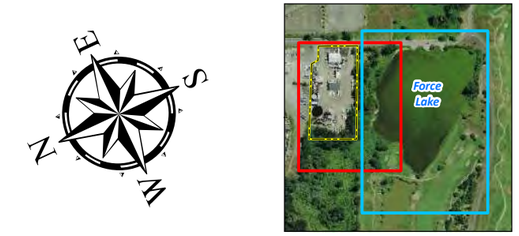

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Figure 4-16. Total PAH Concentrations in Unfiltered Samples at Facility Groundwater and Lake Surface Water Sampling Locations

Prepared by CEH, 09/31/2010, MAP #4076, W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

Groundwater samples (µg/L)

- Shallow groundwater
- Intermediate groundwater
- Deep groundwater

Surface water samples (µg/L)

- Lake surface water

Wells where groundwater samples not collected

- Groundwater not sampled due to lack of construction details (trace to 0.02 ft of LNAPL observed)
- Groundwater not sampled due to lack of construction details
- Groundwater not sampled due to the presence of LNAPL (0.1 ft LNAPL observed here in 2008 when LNAPL sample was collected. After this time, trace to 0.02 ft of LNAPL observed).

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

Location ID — GA-00
Sample Year — 2000: – / 2008: 1.0 U / 2009: na
Detected concentration: exceeds SL = Red; does not exceed SL = Black
Concentration: na=not analyzed; – =not collected
Qualifier: U=non-detect; J=estimated

On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Benzene Screening Levels

Medium	Unit	Human Health RSL[a]	Invertebrate Screening Level
Groundwater	µg/L	0.35	na
Surface water	µg/L	not detected; no comparison to screening levels	

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
na - not applicable

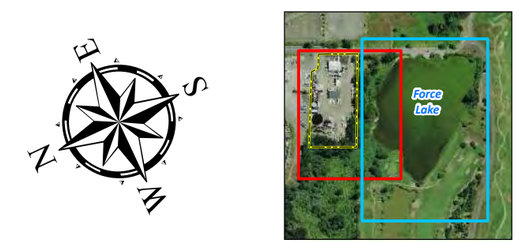

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Figure 4-17. Benzene Concentrations in Unfiltered Samples at Facility Groundwater and Lake Surface Water Sampling Locations

Prepared by CEH, 08/31/2010, MAP #3487; W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

4.3.2.1 Facility Soil

Table 4-3 summarizes concentrations of TPH, PAHs, and petroleum-associated VOCs detected in surface and subsurface soil samples collected from the Facility. The depth intervals of these samples varied depending on the sampling location, field conditions, and the sampling event (see Section 2.2). Surface soil samples at the Facility were collected just below the gravel fill layer, if present.

TPH

At least one TPH fraction was detected in all of the samples collected throughout the Facility. Concentration patterns were similar for the three TPH fractions analyzed: gasoline, diesel, and motor oil (Figure 4-4 to 4-7). The highest concentrations were detected in samples collected from the central portion of the Facility (e.g., SL-10, SL-27, SS05). The next highest diesel- and motor oil-range TPH concentrations were detected in samples collected along the southwest boundary of the Facility (e.g., SL-17 and MW-2s). Although intermediate-depth samples had higher TPH concentrations than did surface samples at some locations (e.g., SL-23 in the west corner of the Facility), concentrations in the deep samples were lower. This area with intermediate soil samples greater than surface soil samples was in an area that was filled when the Facility was expanded after the 1979 fire.

TPH concentrations were compared with conservative industrial and residential human health RSLs, which were the same for each TPH fraction. Only gasoline-range TPH concentrations were greater than the RSL, generally in the central portion of the Facility (Figure 4-4). In addition, four samples in the northwest portion of the Facility near the soil stockpile (SL-22, SL-24, SL-31, and SL-39), one sample near the southwest Facility boundary (MW-2s), and one sample near the Facility exit (SL-19) had gasoline-range TPH concentrations greater than the RSL. Note that the comparison with conservative screening levels on a point-by-point basis should not be viewed as a risk estimate; risks were fully assessed in the HHRA as presented in Appendix I and summarized in Section 6.1.

Table 4-3. Concentrations of TPH, PAHs, and Petroleum-Associated VOCs Detected in at Least One Facility Soil Sample

Chemical	Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
Petroleum (mg/kg dw)								
TPH – gasoline range	surface	26/42	62	8.9	3,800	SL-27	260	5.6 – 12
	intermediate	20/32	62	13	850	SL-10	140	6.9 – 11
	deep	6/28	21	13	45	SL-28	12	11 – 19
	soil stockpile	1/3	33	21	21	SP-01	nc	7.4 – 8.8
	soil berm	2/9	22	5.3	10	SB-01	nc	6.1 – 8.1
TPH – diesel range	surface	52/52	100	8.0	13,000	SS05	1,700	na
	intermediate	30/33	91	13	2,800	SL-22	460	6.3 – 7.0
	deep	3/28	11	12	560	MW-2i	29	7.5 – 9.0
	soil stockpile	3/3	100	59	130	SP-01	86	na
	soil berm	8/9	89	6.3	68	SB-01	28	29
TPH – motor oil range	surface	52/52	100	38	12,000	SS05	2,200	na
	intermediate	31/33	94	14	2,800	SL-31	520	13 – 14
	deep	6/28	21	18	1,000	MW-2i	47	15 – 18
	soil stockpile	3/3	100	170	310	SP-01	250	na
	soil berm	9/9	100	37	320	SB-01	130	na
Total TPH	surface	52/52	100	46	25,000	SS05	4,100	na
	intermediate	32/33	97	14	5,800	SL-31	1,100	13
	deep	9/28	32	13	1,600	MW-2i	78	15 – 19
	soil stockpile	3/3	100	240	460	SP-01	340	na
	soil berm	9/9	100	43	380	SB-01	160	na
PAHs (µg/kg dw)								
cPAH TEQ	surface	53/57	93	14.0	4,900	SL-36	565	33.0 – 450
	intermediate	29/33	88	5.00	1,600	SL-15	270	4.30 – 637
	deep	6/34	18	4.60	655 J	DP01	63.5	4.20 – 708
	soil stockpile	3/3	100	45.0	110	SP-03	76.0	na
	soil berm	9/9	100	14.7	5,200	SB-06	687	na
Total PAHs	surface	56/57	98	36 J	360,000	SL-36	13,000	1,200
	intermediate	32/33	97	7.8	138,000	SL-15	11,000	1,720
	deep	14/34	41	4.9	2,900	MW-2i	250	4.6 – 1,910
	soil stockpile	3/3	100	690 JN	990	SP-03	820	na
	soil berm	9/9	100	113	69,000	SB-06	8,400	na
Petroleum-Associated VOCs (µg/kg dw)								
1,2,4-Trimethyl benzene	surface	23/40	57	1.9 J	40,000	SL-36	3,000	1.0 – 7.1
	intermediate	23/32	72	1.3 J	9,700	SL-31	630	1.1 – 2.5
	deep	4/28	14	6.6	2,100 J	SL-28	77	1.6 – 6.9
	soil stockpile	1/3	33	2.7	2.7	SP-03	nc	1.1 – 1.3
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2

Table 4-3. Concentrations of TPH, PAHs, and Petroleum-Associated VOCs Detected in at Least One Facility Soil Sample (cont.)

Chemical	Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
1,3,5-Trimethyl benzene	surface	18/40	45	1.5	12,000	SL-27	500	1.0 – 120
	intermediate	16/32	50	1.3	3,900	SL-31	240	1.0 – 98
	deep	3/28	11	2.0	660 J	SL-28	25	1.6 – 3.5
	soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
Benzene	surface	20/53	38	1.1	6,400	SL-27	140	1.0 – 810
	intermediate	22/35	63	1.2	600	SL-09	60	1.1 – 380
	deep	20/33	61	1.9	860 J	SL-28	30	1.7 – 3.8
	soil stockpile	1/3	33	1.5	1.5	SP-03	nc	1.1 – 1.3
	soil berm	2/9	22	1.4	1.8	SB-04	nc	0.9 – 1.2
Ethylbenzene	surface	18/53	34	2.0 J	26,000	SL-27	720	1.0 – 120
	intermediate	15/35	43	1.4	1,600	SL-10	200	1.2 – 120
	deep	2/33	6	2.7	43	SL-28	nc	1.6 – 3.8
	soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
Isopropyl benzene	surface	19/51	37	1.3	2,300	SL-27	120	1.0 – 120
	intermediate	18/35	51	1.6	1,100	SL-31	100	1.1 – 120
	deep	2/33	6	14	110	SL-28	nc	1.6 – 3.8
	soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
n-Propyl benzene	surface	19/39	49	1.3	6,700	SL-27	370	1.0 – 120
	intermediate	18/32	56	1.6	2,800	SL-10/ SL-31	320	1.1 – 120
	deep	3/28	11	2.5	160	SL-28	7.1	1.6 – 3.5
	soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
tert-Butyl methyl ether	surface	3/53	6	2.2	6.9	SL-15	22	1.0 – 1,100
	intermediate	12/35	34	2.5	69	SL-08	20	1.0 – 380
	deep	19/33	58	2.0	39	MW-4s	10	1.7 – 3.8
	soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
Toluene	surface	26/53	49	1.2	49,000	SL-27	1,000	1.0 – 810
	intermediate	17/35	49	1.4	4,000	SL-09	300	1.1 – 380
	deep	3/33	9	3.9	13	SL-28	nc	1.6 – 6.7
	soil stockpile	2/3	67	2.2	4.0	SP-03	nc	1.1
	soil berm	3/9	33	1.4	1.5	SB-04	0.8	0.9 – 1.2

Table 4-3. Concentrations of TPH, PAHs, and Petroleum-Associated VOCs Detected in at Least One Facility Soil Sample (cont.)

Chemical	Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
Total xylenes	surface	28/53	53	1.8 J	150,000 J	SL-27	3,000	1.0 – 83
	intermediate	22/35	63	1.3	7,300	SL-27	600	1.2 – 380
	deep	3/33	9	4.0	4,400 J	SL-28	nc	1.6 – 13
	soil stockpile	1/3	33	1.1 J	1.1 J	SP-01	nc	1.3
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2

[a] Surface soil samples were collected immediately below the gravel layer from depths of 0 to 5 ft bgs (0.5- to 1.5-ft sampling intervals for a given sample). Intermediate soil samples were collected from depths of 2 to 8.5 ft bgs (1- to 4-ft sampling intervals for a given sample). Deep soil samples were collected from depths of 6 to 22 ft bgs (1- to 4-ft sampling intervals for a given sample). All soil berm samples were collected from 0.5 to 2 ft bgs, and all soil stockpile samples were collected from 0.5 to 6 ft bgs.

[b] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values. Means were not calculated if the detection frequency was less than 10% or if fewer than three samples had detected concentrations.

[c] RLs are for only non-detected samples.

bgs – below ground surface
cPAH – carcinogenic polycyclic aromatic hydrocarbon
dw – dry weight
J – estimated concentration
na – not applicable
nc – not calculated
nd – not detected
PAH – polycyclic aromatic hydrocarbon
RL – reporting limit
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

PAHs

cPAH TEQ and total PAHs were detected in the majority (more than 85%) of Facility surface and intermediate soil samples and in a lower percentage (18 to 41%) of Facility deep-interval soil samples. Figures 4-8 and 4-9 present Facility soil data for cPAH TEQ and total PAHs, respectively. Patterns for cPAH TEQ and total PAHs were similar, with the highest TEQs or concentrations in the central portion of the Facility near the tank farm (e.g., SL-27, SL-36, and SL-10) and in one sample collected from the soil berm in the west corner of the Facility (SB-06). While intermediate-depth samples had higher cPAH TEQ and/or total PAH concentrations than did surface soil samples at certain locations (SL-10 in the central portion of the Facility; SL-05, SL-21, SL-22, and SL-41 in the west corner of the Facility; and SL-31 in the north corner of the Facility), concentrations were generally highest in surface soil samples. With the exception of SL-10, the locations with higher intermediate-depth samples were located in areas that were later filled when the Facility was expanded (Section 4.2.1). Concentrations in deep soil samples were usually lower than in both surface and intermediate depth soil samples.

cPAH TEQs were compared with the conservative industrial and residential human health RSL for benzo(a)pyrene (210 and 15 µg/kg dw, respectively) (Figure 4-8). TEQs greater than the industrial RSL were usually located in the central portion of the Facility, along the southwest Facility boundary, and in the west corner of the Facility. The majority of detected cPAH TEQs were greater than the residential RSL. As noted above, the comparison with conservative screening levels on a point-by-point basis should not be interpreted as a risk estimate; risks were fully assessed in the HHRA as presented in Appendix I and summarized in Section 6.1. No RSL is available for total PAHs or an appropriate surrogate.

Petroleum-Associated VOCs

Concentration patterns were similar for each of the nine petroleum-associated VOCs. In general, concentrations were highest in the central portion of the Facility near the tank farm (e.g., SL-10 and SL-27), although concentrations of several VOCs (n-propylbenzene, 1,2,4-trimethylbenzene, and 1,3,5-trimethylbenzene) near the soil stockpile in the northern corner of the Facility (e.g., SL-31 and SL-39) were also higher relative to other areas on the Facility. Although the intermediate-depth samples had higher VOC concentrations than did the surface samples at some locations (e.g., SL-21 in the former C-shaped area and SL-23 in the west corner of the Facility; both areas that were later filled as the Facility was expanded after the 1979 fire), concentrations in the deep samples were generally lower.

VOC concentrations were compared with conservative industrial and residential human health RSLs, which were the same for all petroleum-associated VOCs except n-propylbenzene (although no detected concentrations were greater than either RSL for n-propylbenzene). Benzene was detected at concentrations greater than the RSL at nine

locations, which extended from the central portion of the Facility near the tank farm to the southwest Facility boundary (Figure 4-10). Xylenes were greater than the RSL at one location (SL-27 near the tank farm). Concentrations of 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene were greater than the RSL at three locations in the central portion of the Facility near the tank farm (SL-10, SL-27, SL-36) and one location in the north corner of the Facility near tank 23 (SL-31). No other VOCs were detected at concentrations greater than their residential or industrial RSLs. With one exception (benzene at SL-28), no VOC concentrations in the deep samples were greater than conservative industrial or residential human health RSLs.

Facility Soil Summary

The highest concentrations of TPH, PAHs, and petroleum-associated VOCs were generally bounded both vertically and laterally in Facility soil. The available Facility soil samples indicate that the area with concentrations greater than the conservative industrial and residential human health RSLs is generally limited to the central portion of the Facility near the tank farm and extends to the southwest boundary of the Facility.

The distribution of TPH, PAHs, and petroleum-associated VOCs suggests that these chemicals may have been introduced to the Facility as a result of operations associated with the processing and refining of used waste oils and fuels. The fact that the highest concentrations of these chemicals were generally detected in the central portion of the Facility indicates that these chemicals were released in association with the tank farm and processing activities in the north and central portions of the Facility, through road oiling for dust suppression, or through activities associated with truck cleaning operations in the central portion of the Facility. Based on the concentration pattern in Facility soil, Tank 23 does not appear to be the main source of TPH, PAHs, and petroleum-associated VOCs (i.e., the highest concentrations were not located in this area). The greatest concentrations of gasoline range TPH and benzene are adjacent to the tank farm at a location (SL-27) proximate to an underground product line. The presence of these shallow impacts in the area of the product line could be a function of a release associated with the piping in this area as well as historical surface spills in the area.

4.3.2.2 Groundwater

Table 4-4 summarizes concentrations of TPH, PAHs, and petroleum-associated VOCs detected in groundwater. These chemicals were not detected in any of the intermediate or deep groundwater samples, and thus only the shallow well sample results are presented in Table 4-4.

Table 4-4. Concentrations of TPH, PAHs, and Petroleum-Associated VOCs Detected in at Least One Shallow Groundwater Sample

Chemical	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[a]	RL or Range of RLs[b]
	Ratio	%					
Petroleum (mg/L)							
TPH – gasoline range	5/22	23	0.27	0.81	A-18	0.22	0.25
TPH – diesel range	1/22	5	0.26 J	0.26 J	A-18	nc	0.25
TPH – motor oil range	0/22	0	nd	nd	nd	nc	0.50
Total TPH	5/22	23	0.27	1.07 J	A-18	0.33	0.50
PAHs (µg/L)							
cPAH TEQ	0/28	0	nd	nd	nd	nc	0.0910 – 1.50
Total PAHs	12/28	43	0.10	6.3	A-20	1	0.10 – 4
Petroleum-Associated VOCs (µg/L)							
1,2,4-Trimethylbenzene	2/22	9	3.7	7.2	A-18	nc	0.20 – 1.0
1,3,5-Trimethylbenzene	3/22	14	1.5	3.0	A-18	0.71	0.20 – 1.0
Benzene	8/28	29	0.80	140	MW-4s	6	0.20 – 6.2
Ethylbenzene	1/28	4	1.2	1.2	A-18	nc	0.20 – 1.0
Isopropylbenzene	4/28	14	0.039 J	8.3	MW-4s	0.9	0.20 – 1.0
n-Propylbenzene	4/22	18	1.8	11	MW-4s	1.3	0.20 – 1.0
tert-Butyl methyl ether	14/28	50	1.4	160	MW-5s	10	0.50 – 1
Toluene	2/28	7	0.60	4.8	MW-4s	nc	0.20 – 1.0
Total xylenes	3/28	11	1.4	20	A-18	2	0.40 – 2.0

Note: The depth of shallow groundwater wells ranged from 10 to 20 ft bgs, the depth of intermediate wells ranged from 48 to 50 ft bgs, and the depth of the deep well was 97 ft bgs.

[a] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values. Means were not calculated if the detection frequency was less than 10% or if fewer than three samples had detected concentrations.

[b] RLs are for only non-detected samples.

bgs – below ground surface
cPAH – carcinogenic polycyclic aromatic hydrocarbon
J – estimated concentration
nc – not calculated
nd – not detected
PAH – polycyclic aromatic hydrocarbon
RL – reporting limit
TEQ – toxic equivalents
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

The highest detection frequencies for shallow well samples were for total PAHs (43%), benzene (29%), tert-butyl methyl ether (50%), gasoline-range TPH (23%), and total TPH (23%).

Chemicals with concentrations greater than the conservative human health RSLs included 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, benzene, n-propylbenzene, and tert-butyl methyl ether. Samples with chemical concentrations greater than their RSLs were collected from four shallow wells: A-18, GA-34, MW-4s, and MW-5s. These wells are located near suspected source areas (Section 3.5.2.2.1), including the tank farm, former C-shaped area, and the former truck cleaning operation in the central portion of the Facility. None of these chemicals were identified in groundwater samples from shallow monitoring wells located downgradient from these sources. Note that the comparison with conservative screening levels on a point-by-point basis should not be interpreted as a risk estimate; risks were fully assessed in the HHRA, as presented in Appendix I and summarized in Section 6.0.

In addition, it should be noted that benzene was detected at a concentration greater than the MCL of 5 µg/L in one sample (140 µg/L in the sample collected from location MW-4s in 2008). In 2009, benzene was detected at a concentration of 2.9 µg/L at the same location, which is less than the MCL. No other chemicals discussed in this section were detected at concentrations greater than the MCL or non-zero MCLG.

Based on this information, the extent of groundwater contamination for these chemicals appears to be localized in areas associated with the processing and storage of petroleum products.

4.3.2.3 LNAPL

LNAPL is not a significant component at the Facility, and its presence is localized and constrained to a small portion of the Facility. Specifically, in 2008, a thin layer (0.1 ft) of LNAPL has been observed in well GA-30 (northwest portion of the Facility near the soil stockpile) and only trace thicknesses of LNAPL (0.01 ft or less) have been observed in two of the extraction wells. After the LNAPL was sampled in 2008, only 0.01 to 0.02 ft of LNAPL (described as “viscous oil – black and thick”) has been identified at the GA-30 location. No information is available regarding the thickness of the LNAPL in the sample collected at GA-30 in 2000.

With regard to extent, no LNAPL has been observed in wells MW-1s and MW-2s located along the downgradient boundary of the Facility or in shallow monitoring wells GA-29 or A-19 located between GA-30 the downgradient property boundary (see Figure 2-2 for well locations). Furthermore, LNAPL has not been identified in any of the RI boring locations, with one exception. The presence of LNAPL was noted in the shallow-depth (6 to 18 in. bgs) sample collected at the SL-10 boring location in the former truck wash area.

One LNAPL sample was collected from GA-30 by EPA in 2000 as part of its preliminary assessment/site characterization (Ecology and Environment 2001), and another sample was collected in 2008 as part of the Phase I RI activities. The 2000 LNAPL sample was not analyzed for

any of the chemicals discussed in this subsection (LNAPL sample was analyzed only for PCBs and select pesticides; see Sections 4.4 for PCB and 4.6 for pesticide data). Chemicals detected in the 2008 sample included cPAH TEQ (45,000 µg/kg ww), total PAHs (460,000 µg/kg ww), n-propylbenzene (2,800 µg/kg ww), toluene (3,800 µg/kg ww), and total xylenes (3,800 µg/kg ww). In addition, the LNAPL sample had detectable concentrations of TPH (17,000 mg/kg ww gasoline range, 480,000 mg/kg ww diesel range, and 470,000 mg/kg ww motor oil range). Follow-up monitoring including a year of monthly measurements revealed only a thin layer of LNAPL (0.02 to 0.01 ft) had returned to the GA-30 location, an insufficient volume for additional sample collection.

4.3.2.4 Wetland and Ditch Soil

Table 4-5 presents concentrations of detected TPH, PAHs, and petroleum-associated VOCs in wetland and ditch soil. Of the chemicals discussed in this section, 1,3,5-trimethylbenzene, isopropylbenzene, and n-propylbenzene were not detected in any wetland or ditch soil samples, and thus data for these chemicals are not presented in Table 4-5.

TPH

Gasoline-range TPH were detected in only two wetland and ditch surface soil samples, located southwest of the Facility (WS-22 and WS-25) (Figure 4-4). Diesel- and motor oil-range TPH were detected in 90% or more of surface soil samples and in 40 to 90% of subsurface soil samples. The distributions of these two TPH fractions were similar (Figures 4-5 and 4-6): concentrations were highest in the former drainage ditch (e.g., WL01 and WS-11), along the north shoreline of Force Lake (e.g., WL05), and southwest of the Facility boundary (e.g., WS-39). No TPH concentrations detected in wetland or ditch soil were greater than the conservative residential human health RSLs.[15] No invertebrate screening levels were available for TPH.

The distribution of TPH concentrations indicates that TPH may have reached the wetlands via stormwater runoff, either historically via the drainage ditch or directly via sheet flow prior to the construction of the soil berm, or more recently via discharges from the current stormwater treatment system. As shown in Figure 4-3a, TPH concentrations in wetland and ditch soil were generally lower than those detected in Facility soil.

[15] Wetland soil samples were not compared to conservative industrial human health RSLs.

Table 4-5. Concentrations of TPH, PAHs, and Petroleum-Associated VOCs Detected in at Least One Wetland and Ditch Soil Sample

Chemical	Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
Petroleum (mg/kg dw)								
TPH – gasoline range	surface	2/47	4	19	20	WS-25	nc	9.4 – 58
	intermediate	0/10	0	nd	nd	nd	nc	8.4 – 50
	deep	0/10	0	nd	nd	nd	nc	10 – 18
TPH – diesel range	surface	46/51	90	8.4	4,000	WS-39	400	7.4 – 10
	intermediate	9/10	90	11	660	WS-20	160	8.3
	deep	4/10	40	18	110	WS-21	21	7.5 – 8.1
TPH – motor oil range	surface	48/51	94	28	6,600	WL01	1,200	15 – 17
	intermediate	9/10	90	34	1,100	DS-02/ WS-20	410	17
	deep	7/10	70	19	210	WS-21	46	15 – 16
Total TPH	surface	48/51	94	28	9,300	WS-39	1,500	15 – 17
	intermediate	9/10	90	43	1,800	WS-20	540	17
	deep	7/10	70	19	320	WS-21	65	15 – 16
PAHs (µg/kg dw)								
cPAH TEQ	surface	50/52	96	38.0	5,200	WS-39	438	625 – 888
	intermediate	10/10	100	13.7 J	360 JN	WS-21	120	na
	deep	8/10	80	4.80	220 JN	WS-25	46.3	4.30 – 4.50
Total PAHs	surface	51/52	98	200 J	28,190 J	WL01	3,000	2,770
	intermediate	10/10	100	107 J	4,670 JN	WS-21	1,400	na
	deep	9/10	90	12.5	1,530 J	WS-21	380	4.8
Petroleum-Associated VOCs (µg/kg dw)								
1,2,4-Trimethyl benzene	surface	3/38	8	3.6 J	9.2	WS-16	nc	1.5 – 7.7
	intermediate	1/6	17	5.8 J	5.8 J	DS-02	nc	1.6 – 2.0
	deep	0/6	0	nd	nd	nd	nc	1.5 – 1.9
Benzene	surface	22/43	51	1.8	56	WS-09	6	1.6 – 15
	intermediate	3/6	50	3.2	12	DS-02	4.7	1.6 – 2.0
	deep	5/6	83	1.7	2.5	DS-02	1.9	1.8
Ethylbenzene	surface	1/43	2	3.0	3.0	DS-01	nc	1.5 – 15
	intermediate	1/6	17	3.4	3.4	DS-02	nc	1.6 – 2.0
	deep	0/6	0	nd	nd	nd	nc	1.5 – 1.9
tert-Butyl methyl ether	surface	0/43	0	nd	nd	nd	nc	1.5 – 15
	intermediate	0/6	0	nd	nd	nd	nc	1.6 – 2.7
	deep	1/6	17	2.1	2.1	WS-19	nc	1.5 – 1.9
Toluene	surface	33/43	77	1.8	68	WS-09	10	1.6 – 15
	intermediate	3/6	50	3.2	65	DS-02	13	1.6 – 2.0
	deep	3/6	50	1.6	1.9	WS-19	1.3	1.5 – 1.9

Table 4-5. Concentrations of TPH, PAHs, and Petroleum-Associated VOCs Detected in at Least One Wetland and Ditch Soil Sample (cont.)

Chemical	Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
Total xylenes	surface	5/43	12	2.0 J	11.5	DS-01	2.4	1.5 – 29.9
	intermediate	1/6	17	15	15	DS-02	nc	1.6 – 2.0
	deep	0/6	0	nd	nd	nd	nc	1.5 – 1.9

[a] Surface soil samples were collected from 0 to 0.5 ft bgs, intermediate soil samples were collected from 0.5 to 1 ft bgs, and deep soil samples were collected from 2 to 3 ft bgs.

[b] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values. Means were not calculated if the detection frequency was less than 10% or if fewer than three samples had detected concentrations.

[c] RLs are for only non-detected samples.

bgs – below ground surface
cPAH – carcinogenic polycyclic aromatic hydrocarbon
J – estimated concentration
N – tentative identification
na – not applicable
nc – not calculated
nd – not detected
PAH – polycyclic aromatic hydrocarbon
RL – reporting limit
TEQ – toxic equivalents
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

PAHs

cPAH TEQ and total PAHs were detected in the majority (80% or more) of wetland and ditch surface and subsurface soil samples. Figures 4-8 and 4-9 present TEQs and concentrations in wetland and ditch soil for cPAH TEQ and total PAHs, respectively. The distributions of cPAHs and total PAH TEQ were similar: TEQs or PAH concentrations were highest in the former drainage ditch (e.g., WL01 and WL02), near the current stormwater discharge point (e.g., WS-19), along the north shoreline of Force Lake (e.g., WL05), and southwest of the Facility boundary (e.g., WS-39). The likely sources of chemicals in all of these areas, except near the southwest Facility boundary, were former releases to the drainage ditch, which then discharged into the wetlands. Chemical concentrations near the southwest Facility boundary were likely the result of direct releases or stormwater runoff in to this area. At all locations where subsurface soil samples were collected, PAH concentrations were highest in the surface interval with concentrations decreasing with depth.

cPAH TEQs were compared with the conservative residential human health RSL for benzo(a)pyrene (15 µg/kg dw) (Figure 4-8). Most cPAH TEQs were greater than this RSL. Note that the comparison with conservative screening levels on a point-by-point basis should not be viewed as a risk estimate; risks were fully assessed in the HHRA as presented in Appendix I and summarized in Section 6.0. No RSL was available for total PAHs or an appropriate surrogate. No invertebrate screening levels were available for PAHs.

PAH concentration patterns indicate that PAHs may have reached the wetlands via stormwater runoff, either historically via the drainage ditch, as overland flow prior to the construction of the berm, through accumulation in historical sumps and holding ponds along the southwest Facility boundary (which may have extended into what is now considered the wetlands), or more recently via discharges from the current stormwater treatment system. As shown in Figure 4-3b, concentrations of total PAHs and cPAH TEQs were similar to or somewhat lower than those in Facility soil.

Petroleum-Associated VOCs

For the most part, VOCs were detected infrequently in wetland soil, with the exception of benzene and toluene (detected in 51% and 77% of wetland and ditch surface soil samples, respectively). The distributions of all VOCs were similar, and thus benzene was selected as a representative chemical for mapping (Figure 4-10).

The highest detected concentrations of benzene were in samples collected at the Facility, not in the wetlands, as shown in Figure 4-3b. Concentrations of detected VOCs in wetland soil were compared with conservative residential human health RSLs; only benzene was detected at a concentration higher than the RSL (in one sample). This sample was collected in the northwest portion of the wetlands (WS-09) and had a concentration that was slightly higher (56 µg/kg dw) than the RSL (52 µg/kg dw). All other detected VOC concentrations were less than the RSL. No invertebrate screening levels were available for VOCs.

Wetland and Ditch Soil Summary

Based on the information discussed above for TPH, PAHs, and petroleum-associated VOCs, higher concentrations of these chemicals were generally bounded both vertically and laterally. PAH and TPH concentration patterns were similar, with the highest concentrations located in areas that suggest that these chemicals may have migrated via stormwater runoff (i.e., the highest concentrations were located in the former drainage ditch, southwest of the Facility, and near the current and past stormwater treatment system discharge points). As expected based on the chemical properties (i.e., the tendency of VOCs to volatilize and not bind with soils or sediments), VOC concentrations were low or not-detectable in wetland soil.

4.3.2.5 Lake Sediment and Surface Water

Table 4-6 summarizes concentrations of TPH, PAHs, and petroleum-associated VOCs in lake sediment samples. Of the chemicals discussed in this section, eight VOCs (1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, benzene, ethylbenzene, isopropylbenzene, n-propylbenzene, tert-butyl methyl ether, and total xylenes) were not detected in lake sediment and are not included in this table. None of the chemicals discussed in this section were detected in surface water samples, and thus no summary statistics are presented for surface water.

TPH

Gasoline-range TPH were detected in only 1 of 11 Force Lake surface sediment samples (SE-02). Diesel-range TPH and motor oil-range TPH were detected in all surface sediment samples from both Force Lake and North Lake but not in Force Lake intermediate-depth sediment samples. None of the TPH concentrations in Force Lake or North Lake samples were greater than the conservative residential human health RSL. No invertebrate screening levels were available for TPHs.

PAHs

PAHs were detected in all Force Lake surface sediment samples, with the highest concentrations in the northwest-central portion of the lake (SE-03). Concentrations were lower or not-detected in Force Lake subsurface sediment samples and in North Lake surface sediment samples.

cPAH TEQs were compared with the conservative residential human health RSL for benzo(a)pyrene (15 µg/kg dw) (Figure 4-8). Although most Force Lake surface sediment samples had cPAH TEQs greater than this RSL, it should be noted that the comparison with conservative screening levels on a point-by-point basis should not be viewed as a risk estimate. Risks were fully assessed in the ERA and HHRA as presented in Appendices I and J and summarized in Section 6.0. No RSL was available for total PAHs or an appropriate surrogate. No invertebrate screening levels were available for PAHs.

Table 4-6. Concentrations of TPH, PAHs, and Petroleum-Associated VOCs Detected in at Least One Lake Sediment Sample

Chemical	Sampling Location	Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
			Ratio	%					
Petroleum (mg/kg dw)									
TPH – gasoline range	Force Lake	surface	1/11	9	31	31	SE-02	nc	7.7 – 80
	Force Lake	intermediate	0/3	0	nd	nd	nd	nc	13 – 19
	North Lake	surface	0/3	0	nd	nd	nd	nc	19 – 28
TPH – diesel range	Force Lake	surface	11/11	100	16	270	SE-03	98	na
	Force Lake	intermediate	0/3	0	nd	nd	nd	nc	7.7 – 9.4
	North Lake	surface	3/3	100	26 J	32	SE-101	29	na
TPH – motor oil range	Force Lake	surface	11/11	100	130	2,000	SE-03	760	na
	Force Lake	intermediate	0/3	0	nd	nd	nd	nc	16 – 19
	North Lake	surface	3/3	100	200	280	SE-103	240	na
Total TPH	Force Lake	surface	11/11	100	150	2,300	SE-03	840	na
	Force Lake	intermediate	0/3	0	nd	nd	nd	nc	17 – 19
	North Lake	surface	3/3	100	230	310	SE-103	270	na
PAHs (µg/kg dw)									
cPAH TEQ	Force Lake	surface	11/11	100	11.6	118	SE-03	61.9	na
	Force Lake	intermediate	1/3	33	7.10	7.10	SE-10	nc	4.20 – 4.30
	North Lake	surface	3/3	100	46.0	55.0	SE-102	50.7	na
Total PAHs	Force Lake	surface	11/11	100	104	1,060	SE-03	560	na
	Force Lake	intermediate	2/3	67	4.6	76	SE-10	nc	4.8
	North Lake	surface	3/3	100	340	480	SE-102	430	na
Petroleum-Associated VOCs (µg/kg dw)									
Toluene	Force Lake	surface	3/11	27	1.2	17	SE-02	4.5	6.0 – 8.2
	Force Lake	intermediate	0/3	0	nd	nd	nd	nc	2.2 – 2.7
	North Lake	surface	2/3	67	3.2	10	SE-101	nc	3.8

[a] Lake surface sediment samples were collected from 0 to 4 in. below the mudline, and lake intermediate sediment samples were collected from 2 to 3 ft below the mudline.

[b] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values. Means were not calculated if the detection frequency was less than 10% or if fewer than three samples had detected concentrations.

[c] RLs are for only non-detected samples.

cPAH – carcinogenic polycyclic aromatic hydrocarbon
dw – dry weight
na – not applicable
nc – not calculated
nd – not detected
PAH – polycyclic aromatic hydrocarbon
RL – reporting limit
TEQ – toxic equivalents
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

VOCs

Of the nine VOCs discussed in this section, only toluene was detected in lake sediment. No detected toluene concentrations were greater than the conservative residential human health RSL. No invertebrate screening levels were available for VOCs.

Lake Sediment and Surface Water Summary

In lake sediment, PAHs and TPH were detected in most surface samples; VOCs were infrequently detected (of the petroleum-associated VOCs, only toluene was detected). Chemical concentrations were low or not detected in subsurface Force Lake sediment. In addition, chemical concentrations in North Lake were usually lower than those in Force Lake, indicating that migration has been limited or has not occurred. No TPH, PAHs, or petroleum-associated VOCs were detected in lake surface water.

4.3.3 Summary for TPH, PAHs, and Petroleum-Associated VOCs

In the Study Area, the concentrations of TPH, PAHs, and petroleum-associated VOCs were usually highest in surface soil samples collected from the Facility (Figure 4-3a and 4-3b). The distributions of these chemicals in Facility soil indicate that these chemicals were likely introduced during industrial activities, including oil treatment and processing, production of RFO, road oiling for dust suppression, and tanker cleaning operations. Specifically, sources of these petroleum-related chemicals may include the tank farm located along the northeast boundary of the Facility and the former truck cleaning operation located in the central portion of the Facility. The highest concentrations of TPH, PAHs, and petroleum-associated VOCs were in these areas.

Detected TPH, cPAH TEQ, and petroleum-associated VOC concentrations in groundwater were also consistent with these potential sources because the highest concentrations were detected in shallow wells near or downgradient from the tank farm, the base oil refining plant, and the former truck cleaning operation area. For total PAHs, the highest concentrations were detected in samples collected from shallow well A-20, located near the Facility exit.

The highest concentrations of TPH and PAHs in wetland and ditch soil were detected in areas that suggest that these chemicals migrated via stormwater runoff (i.e., the highest concentrations were detected in the former drainage ditch, southwest of the Facility, and near the current and former stormwater treatment system discharge points). Concentrations of VOCs were either low or not-detected in wetland and ditch soil, indicating that the migration of these chemicals was either limited or VOCs were not persistent (e.g., VOCs may have volatilized from stormwater runoff or surface soils).

TPH, PAH, and petroleum-associated VOC concentrations in lake sediment and lake surface water were either low or the chemicals were not detected, indicating has been limited migration into or low persistence of these chemicals in Force Lake.

The distribution of the chemicals and the comparison with conservative screening levels, as shown in Figures 4-4 through 4-10, indicates that higher concentrations of TPH, PAH, and petroleum-associated VOCs were generally bounded both vertically and laterally. Thus, these chemicals have been adequately delineated and the available data meet the DQOs identified in the RI/FS Work Plan (Bridgewater et al. 2008b). The TPH, PAH, and petroleum-associated VOCs concentration patterns indicate that these chemicals were introduced by industrial activities on the Facility and may have migrated, to a limited extent, into the wetlands via stormwater runoff. The data also support the conclusion that migration of these chemicals into Force Lake has been minor or that these chemicals were not persistent in the lake.

4.4 PCBs

This section presents an overview of source information, fate and transport, and media-specific data for PCBs. PCBs are of interest at the Study Area based on their known presence in petroleum products including waste oils and fuels that have been processed and refined at the Facility. In the HHRA, total PCBs were identified as a COC based on potential future worker exposure to Facility soil and based on indirect exposure to Force Lake sediment through fish consumption.

4.4.1 Known or Suspected Sources and Release Mechanisms

PCBs are highly stable synthetic chemicals that were domestically manufactured from 1929 until their manufacture was banned in 1979. Due to their physical and chemical properties (e.g., non-flammability and electrical insulating capabilities), PCBs were used in hundreds of varied commercial applications, including insulating or dielectric fluids in electrical, heat transfer, and hydraulic equipment; as plasticizers in paints, plastics, and rubber products; in pigments, dyes, and carbonless copy paper; and many other industrial applications.

No specific PCB sources and release mechanisms associated with Harbor Oil have been identified. However, some of the petroleum products, including waste oils and fuels brought onto the Facility since the 1960s for oil re-refining and fuels blending (Section 4.2.2), were known to contain PCBs up to the allowable limits authorized under the federal TSCA program (< 50 mg/kg). It is suspected that PCBs were released at the Facility in association with the processing of these petroleum products. Sources of PCBs may also have included the former truck cleaning operation located in the central portion of the Facility and oils stored within the tank farm located along the northwest boundary of the Facility. In addition, a 1986 aerial photograph (Appendix A) shows that the roadway that extends from the Facility entrance around the former tank cleaning area may have been oiled. If true, it is possible that PCBs may have been present in that oil.

Because of their stable nature and varied historical uses, PCBs have been detected within most urban environments. Given that ubiquity,

general information regarding PCBs has been compiled to provide context in evaluating the total PCB concentrations detected in soil and sediment within the Harbor Oil Study Area. This general information and available site-specific information is presented in Section 4.4.3, along with a comparison to Study Area data.

4.4.2 Concentrations by Medium

This section discusses the concentrations of total PCBs in various media within the Study Area. Summary statistics in tables are provided by location (not sample)[16] to be consistent with the figures. The complete RI database is provided in Appendix B.

Figure 4-18 presents cumulative frequency distributions of total PCB concentrations in surface soil and sediment samples collected from within the Study Area. The data are presented by concentration on the x-axis and by percent frequency within the dataset on the y-axis. For example, the total PCB concentrations in approximately 75% of Facility surface soil samples are less than 1,000 µg/kg dw. Figure 4-18 is intended to help facilitate cross-media comparisons. Total PCB concentrations were highest in Facility soil and lowest in Force Lake surface sediment.

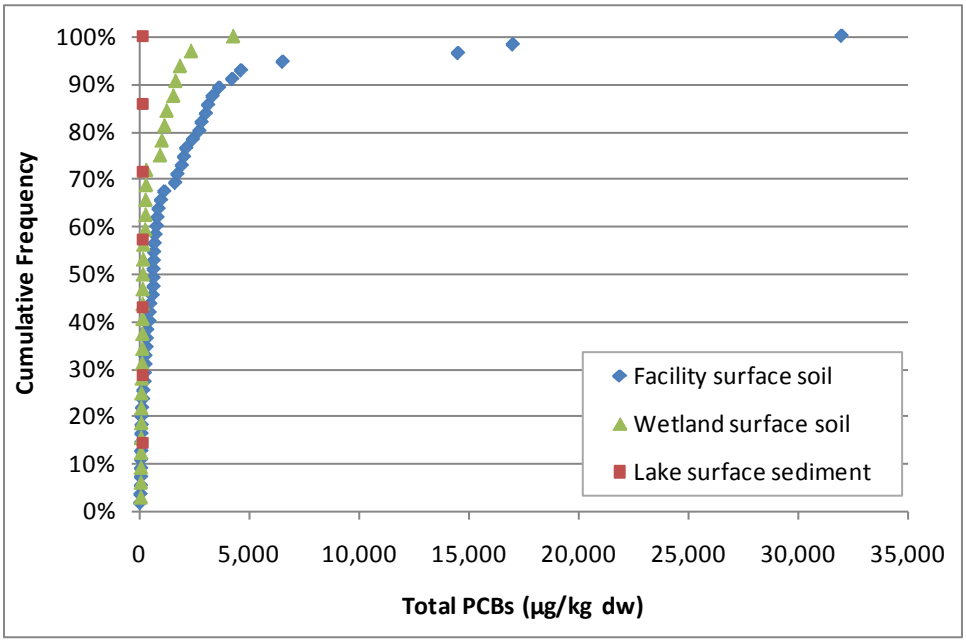
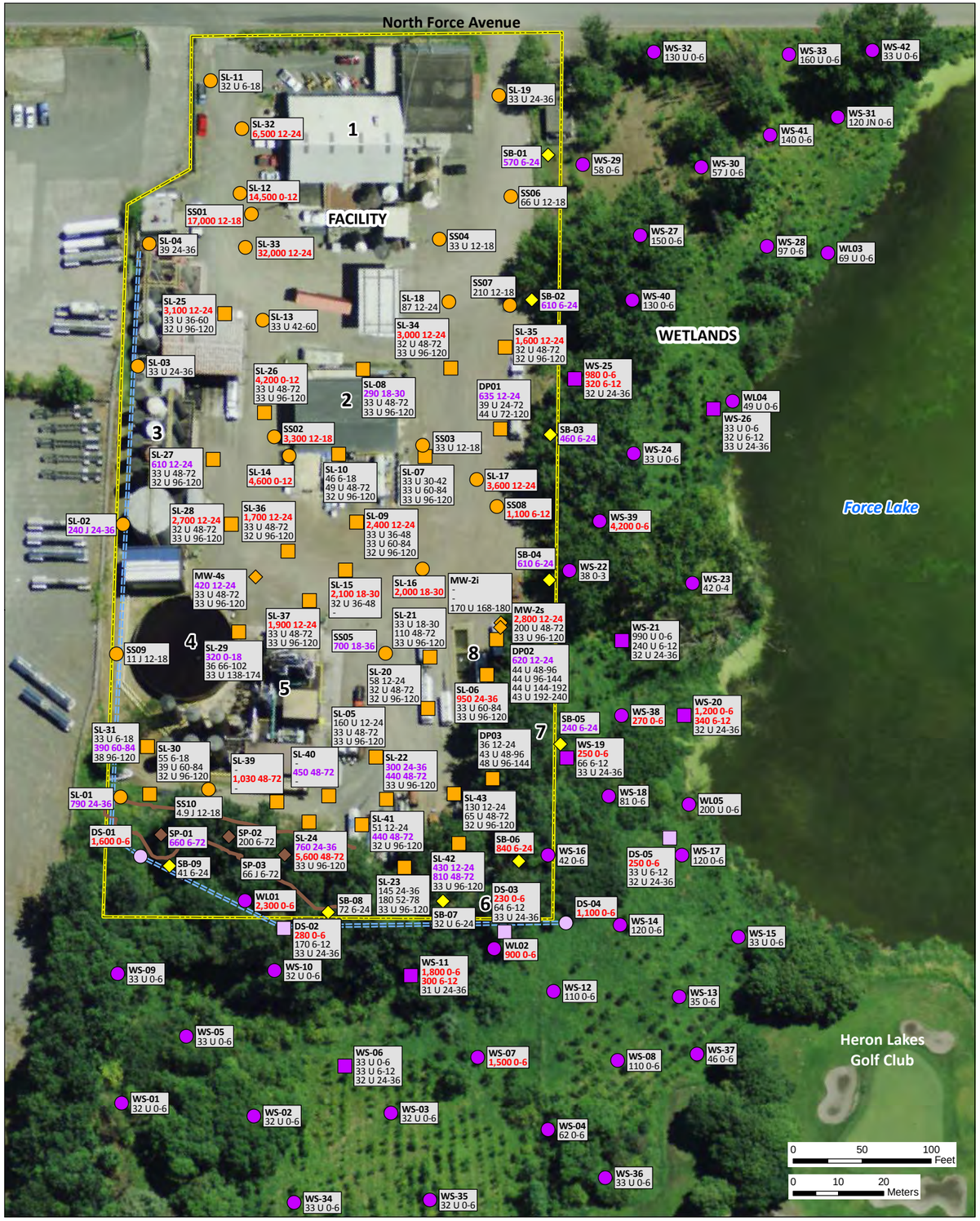


Figure 4-18. Cumulative Frequencies of Total PCBs Detected in Facility Surface Soil, Wetland Surface Soil, and Force Lake Surface Sediment

Figure 4-19 presents total PCB concentrations at each soil and sediment location sampled, whereas Figure 4-20 presents total PCB concentrations at each groundwater and surface water location sampled. These data are discussed in the following subsections.

[16] Duplicate samples were combined with the original sample, as described in Appendix N.



Facility soil samples (µg/kg dw)[a]

- Surface soil
- Subsurface and surface soil[b]
- Soil at groundwater monitoring well[b]
- Soil berm
- Soil stockpile

Wetland and ditch soil samples (µg/kg dw)

- Wetland surface soil
- Wetland surface and subsurface soil[b]
- Ditch surface soil
- Ditch surface and subsurface soil[b]

Lake sediment samples (µg/kg dw)

- Lake sediment[b]

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

[a] The following locations were not analyzed for total PCBs and do not appear on this map: shallow samples from SL 45 and SL-46; intermediate sample from SL-38; and deep sample from SL-44.

[b] Both surface and subsurface data are shown.

Location ID — SL-00
Concentration — 2,500 12-24 / 250 JN 60-84 / 25 U 96-120

Detected concentration:
exceeds highest SL = Red
exceeds lowest SL = Purple
does not exceed SL = Black

Qualifier
U=non-detect
J=estimated
N=tentatively identified

Depth in inches

On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Total PCB Screening Levels

Medium	Unit	Industrial Human Health RSL[a]	Residential Human Health RSL[a]	Invertebrate Screening Level[b]
Facility soil	µg/kg dw	830	220	na
Wetland soil	µg/kg dw	na	220	nv
Lake sediment	µg/kg dw	na	220	227

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
[b] Invertebrate (ecological) sediment screening levels are represented by the lower of the probable effects concentration (PEC) and probable effects level (PEL); invertebrate screening levels in soil are represented by the lowest of EPA, DEQ, and Oak Ridge National Laboratory soil invertebrate screening levels.
na - not applicable
nv - no value (i.e., no SL available for this chemical-media combination)

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Figure 4-19. Total PCB Concentrations at Facility Soil, Wetland Soil, and Lake Sediment Sampling Locations

Prepared by CEH, 08/31/2010, MAP #3052, W:\Projects\Harbor_Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

Groundwater samples (µg/L)

- Shallow groundwater
- Intermediate groundwater
- Deep groundwater

Surface water samples (µg/L)

- Lake surface water

Wells where groundwater samples not collected

- Groundwater not sampled due to lack of construction details (trace to 0.02 ft of LNAPL observed)
- Groundwater not sampled due to lack of construction details
- Groundwater not sampled due to the presence of LNAPL (0.1 ft LNAPL observed here in 2008 when LNAPL sample was collected. After this time, trace to 0.02 ft of LNAPL observed).

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

Location ID — **GA-00**
Sample Year — 2000: –, 2008: 1.0 U, 2009: na
Detected concentration: exceeds SL = **Red**; does not exceed SL = Black
Concentration: na=not analyzed, – =not collected
Qualifier: U=non-detect, J=estimated

On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Total PCB Screening Levels

Medium	Unit	Human Health RSL[a]	Invertebrate Screening Level
Groundwater	µg/L	0.034	na
Surface water	µg/L	not detected; no comparison to screening levels	

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
na - not applicable

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Figure 4-20. Total PCB Concentrations in Unfiltered Samples at Facility Groundwater and Lake Surface Water Sampling Locations

Prepared by CEH, 08/31/2010, MAP #3502, W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

4.4.2.1 Facility Soils

Table 4-7 summarizes total PCB concentrations in surface and subsurface soil samples collected from the Facility. The depth intervals of these samples varied depending on the sampling location, field conditions, and the sampling event (see Section 2.2). Surface soil samples at the Facility were collected just below the gravel fill layer, if present.

Table 4-7. Total PCB Concentrations in Facility Soil

Sample Type[a]	Detection Frequency		Min Detect Conc. (µg/kg dw)	Max Detect Conc. (µg/kg dw)	Location of Max Detect	Mean Conc. (µg/kg dw)[b]	RL or Range of RLs[c]
	Ratio	%					
Surface	44/55	80	4.9 J	32,000	SL-33	2,000	32 – 160
Intermediate	10/34	29	36	5,600	SL-24	290	32 – 200
Deep	1/33	3	38	38	SL-31	nc	32 – 170
Soil stockpile	3/3	100	66 J	660	SP-01	310	na
Soil berm	8/9	89	41	840	SB-06	380	32

[a] Surface soil samples were collected immediately below the gravel layer from depths of 0 to 5 ft bgs (0.5- to 1.5-ft sampling intervals for a given sample). Intermediate soil samples were collected from depths of 2 to 8.5 ft bgs (1- to 4-ft sampling intervals for a given sample). Deep soil samples were collected from depths of 6 to 22 ft bgs (1- to 4-ft sampling intervals for a given sample). Soil berm and soil stockpile samples were more consistent; all soil berm samples were collected from 0.5 to 2 ft bgs, and all soil stockpile samples were collected from 0.5 to 6 ft bgs.

[b] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values. Means were not calculated if the detection frequency was less than 10%, or if fewer than three samples had detected concentrations.

[c] RLs are for only non-detected samples.

bgs – below ground surface
dw – dry weight
J – estimated concentration
na – not applicable
nc – not calculated
PCB – polychlorinated biphenyl
RL – reporting limit

Total PCBs were detected in 80% of surface soil samples, with detected concentrations ranging from 4.9 to 32,000 µg/kg dw and a mean concentration of 2,000 µg/kg dw. Soil stockpile and soil berm total PCB concentrations were generally lower, with mean concentrations of 310 and 380 µg/kg dw, respectively. The cumulative frequencies of total PCB concentrations in Facility surface soil (including soil berm and soil stockpile samples) are shown in Figure 4-18.

Total PCBs were detected in 29% of intermediate and 3% of deep subsurface soil samples collected at the Facility. In intermediate soil samples, the mean concentration was 290 µg/kg dw. No mean concentration could be calculated for deep soil samples because PCBs were only detected in one sample (38 µg/kg dw).

Total PCB concentrations were usually highest in the surface interval and then decreased with depth. However, a few samples on the northwest portion of the Facility (near the soil stockpile) had higher concentrations in

the intermediate interval relative to the surface and deep intervals at the same location. The most notable example was the sample at SL-24, which had an intermediate interval concentration of 5,600 µg/kg dw compared with surface and deep interval concentrations of 760 and 33 U µg/kg dw, respectively. This area was an undeveloped wetland area during early industrial activities at the Facility and was later filled to create more usable land. This history may explain the presence of higher PCB concentrations in the intermediate depth intervals in this area.

Figure 4-19 presents total PCB concentrations detected in soil samples collected at the Facility. Total PCB concentrations greater than 10,000 µg/kg dw were detected in surface soil in the east corner of the Facility near the Facility entrance. Concentrations of total PCBs greater than 1,000 µg/kg dw were detected in the central portion of the Facility, and along the previously oiled U-shaped roadway that extends from the Facility entrance around the former truck cleaning area. Total PCB concentrations in these areas were generally greater than conservative industrial human health RSL (830 µg/kg dw) and residential human health RSL (220 µg/kg dw) (Figure 4-19). However, the comparison with these screening levels on a point-by-point basis should not be viewed as a risk estimate; human health risks were fully assessed in the HHRA, as presented in Appendix I and summarized in Section 6.1.

In summary, higher concentrations of total PCBs were generally bounded both vertically and laterally in Facility soil, indicating that PCBs have been adequately delineated and the available data meet the DQOs identified in the RI/FS Work Plan (Bridgewater et al. 2008b).

4.4.2.2 Groundwater

Table 4-8 summarizes total PCB concentrations in groundwater. Total PCBs were not detected in any groundwater samples collected from the Study Area. Reporting limits (RLs) for total PCBs in groundwater ranged from 0.10 to 0.96 µg/L.

Table 4-8. Total PCB Concentrations in Groundwater

Sample Type[a]	Detection Frequency		Min Detect Conc. (µg/L)	Max Detect Conc. (µg/L)	Location of Max Detect	Mean Conc. (µg/L)[b]	RL or Range of RLs[c]
	Ratio	%					
Shallow	0/28	0	nd	nd	nd	nc	0.10 – 0.96
Intermediate	0/3	0	nd	nd	nd	nc	0.10
Deep	0/3	0	nd	nd	nd	nc	0.10 – 0.92

[a] The depths of shallow groundwater wells ranged from 10 to 20 ft bgs, the depths of intermediate wells ranged from 48 to 50 ft bgs, and the depth of the deep well was 97 ft bgs.

[b] Mean concentrations were not calculated because PCBs were not detected in any groundwater samples.

[c] RLs are for only non-detected samples.

bgs – below ground surface
nc – not calculated
nd – not detected
PCB – polychlorinated biphenyl
RL – reporting limit

4.4.2.3 LNAPL

LNAPL samples were collected from shallow well GA-30 (uppermost groundwater zone) in the northwest portion of the Facility near the soil stockpile in 2000 (layer thickness unknown), and again in 2008 when a thin layer (approximately 0.1 ft) of LNAPL was observed at that location. Total PCBs in the 2000 sample were detected at a concentration of 14,900 µg/kg ww (Aroclors 1242 and 1254), while total PCBs were detected at a concentration of 26,000 µg/kg ww in the 2008 LNAPL sample. Although total PCBs were detected in the LNAPL, PCBs were not detected in groundwater at the Facility, supporting the conclusion that PCBs do not readily partition into the aqueous phase.

Follow-up monitoring in GA-30, including a year of monthly measurements, revealed thin layers of LNAPL (0.02 to 0.01 ft), although no LNAPL was observed in downgradient wells GA-29 and MW-1s (see Figure 2-2 for well locations). Thus, the lateral extent of LNAPL appears to be limited to the immediate area surrounding well GA-30.

4.4.2.4 Wetland and Ditch Soil

Table 4-9 summarizes total PCB concentrations in wetland surface and subsurface soil.

Table 4-9. Total PCB Concentrations in Wetland and Ditch Soil

Sample Type[a]	Detection Frequency		Min Detect Conc. (µg/kg dw)	Max Detect Conc. (µg/kg dw)	Location of Max Detect	Mean Conc. (µg/kg dw)[b]	RL or Range of RLs (µg/kg dw)[c]
	Ratio	%					
Surface	32/52	62	35	4,200	WS-39	400	32 – 990
Intermediate	6/10	60	64	340	WS-20	140	32 – 240
Deep	0/10	0	nd	nd	nd	nc	31 – 33

[a] Surface soil samples were collected from 0 to 0.5 ft bgs, intermediate soil samples were collected from 0.5 to 1 ft bgs, and deep soil samples were collected from 2 to 3 ft bgs.

[b] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values. Means were not calculated if the detection frequency was less than 10% or if fewer than three samples had detected concentrations.

[c] RLs are for only non-detected samples.

bgs – below ground surface
dw – dry weight
nc – not calculated
nd – not detected
PCB – polychlorinated biphenyl
RL – reporting limit

Total PCBs were detected in 62% of surface wetland soil samples, with detected concentrations ranging from 35 to 4,200 µg/kg dw and a mean concentration of 400 µg/kg dw. Total PCBs were detected in 60% of intermediate subsurface soil samples, with mean concentration of 140 µg/kg dw. PCBs were not detected in deep subsurface soil samples. As shown in Figure 4-19, total PCB concentrations were always highest in the surface interval and then decreased with depth.

Total PCB concentrations in the ditch and wetland soils were usually lower than those detected in the Facility soil (Figure 4-18). The highest

total PCB concentration in a wetland soil sample (4,200 µg/kg dw) was detected at location WS-39, which is just south of the Facility, approximately halfway between North Force Avenue and the drainage ditch. Total PCB concentrations greater than the residential RSL (220 µg/kg dw,) were also found in the ditch area along the northwest boundary of the Facility (e.g., DS-01, WL01, WS-07, and WS-11) and along the north shoreline of Force Lake (e.g., WS-20) (Figure 4-19). No invertebrate soil screening level was available for total PCBs.

Total PCBs were not detected in most of the samples collected from the periphery of the wetlands. The spatial distribution of the higher total PCB concentrations suggests that PCBs may have been associated with stormwater runoff or other releases that drained to the ditch. In addition, PCBs may have accumulated in historical sumps and holding ponds along the southwest Facility boundary, which likely accumulated water and oil from the truck cleaning operations.

4.4.2.5 Lake Sediment and Surface Water

Table 4-10 summarizes total PCB concentrations in lake surface and subsurface sediment and in lake surface water.

Table 4-10. Total PCB Concentrations in Lake Sediment and Surface Water

Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
	Ratio	%					
Force Lake Sediment (µg/kg dw)							
Surface	7/11	64	93	131	SE-06	80	32 – 49
Intermediate	0/3	0	nd	nd	nd	nc	32 – 33
North Lake Sediment (µg/kg dw)							
Surface	0/3	0	nd	nd	nd	nc	32 – 33
Force Lake Water (µg/L)							
Surface	0/3	0	nd	nd	nd	nc	0.10

[a] Force Lake surface sediment samples were collected from 0 to 4 in. below the mudline, and Force Lake intermediate sediment samples were collected from 2 to 3 ft below the mudline.

[b] The mean value is equal to the average of all detected values and one-half of the RL for non-detected values. Means were not calculated if the detection frequency was less than 10% or if fewer than three samples had detected concentrations.

[c] RLs from non-detected samples only.

dw – dry weight
nc – not calculated
nd – not detected
PCB – polychlorinated biphenyl
RL – reporting limit

Total PCBs were detected in 7 of the 11 surface sediment samples collected in Force Lake, with detected concentrations ranging from 93 to 131 µg/kg dw (Table 4-10). The mean total PCB concentration in Force Lake surface sediment (80 µg/kg dw) was significantly lower than the mean surface soil concentration in samples collected from the Facility (2,000 µg/kg dw), and was also significantly lower than the mean

concentration in the wetlands (400 µg/kg dw), although many of the surface sediment and wetland soil samples had similar (low) concentrations (Figure 4-19). None of the total PCB concentrations in lake sediment sediments were greater than residential RSLs or invertebrate screening levels. Total PCBs were not detected in the two Force Lake surface sediment samples that were collected closest to the Facility (SE-02 and SE-08).

Total PCBs were not detected in any of the three subsurface (1 to 3 ft below the mudline) sediment samples collected from Force Lake, indicating that the vertical extent of PCBs in Force Lake sediment was bounded. In addition, total PCBs were not detected in any of the three samples collected in North Lake, indicating that PCBs have not migrated into North Lake.

Total PCBs were not detected in any of the three surface water samples collected from Force Lake. The RL for total PCBs was 0.1 µg/L.

4.4.3 General PCB Information for Comparison to Study Area Data

Until their manufacture was banned in the United States in 1979, PCBs were widely used for commercial and industrial applications because of their stability and thermal insulating properties. Over their period of use, PCBs have been released to the environment through a number of mechanisms including, but not limited to, releases of liquids from electrical equipment, spills, waste disposal practices, and normal weathering of PCB-containing paints and caulking. To provide general context to Study Area concentrations, this section discusses concentrations associated with stormwater-related sampling efforts.

4.4.3.1 PCB Concentrations in Urban Area Stormwater

Even though PCB production and new uses are no longer authorized, PCBs are persistent in the environment because they are virtually insoluble in water, hydrophobic in nature, highly unreactive, and resistant to breakdown by acids, bases, and heat. PCBs are commonly detected in environmental samples not specifically associated with prior use activities because of the PCBs' persistence and redistribution in the environment over time through mass transport mechanisms, such as windblown dust and redeposition, and through sorption to organic matter that may have been eroded, transported, and redistributed by stormwater.

Stormwater catch basin sediment samples collected as part of the draft Portland Harbor RI (Integral et al. 2009) provide an indication of urban levels of PCBs in Portland associated with various land uses:

- Heavy industrial: 48.4 to 9,900 µg/kg dw (n = 24)
- Light industrial: 264 to 661 µg/kg dw (n = 2)
- Major transportation: 125 to 223 µg/kg dw (n = 3)
- Mixed land use: 74.5 to 696 µg/kg dw (n = 7)
- Open space: 4.13 µg/kg dw (n = 1)

- Residential: 66.7 to 377 µg/kg dw (n = 2)

As presented in DEQ's *Guidance for Evaluating the Stormwater Pathway at Upland Sites* (2009), PCB concentrations less than 100 µg/kg dw suggest the absence of a significant up-pipe PCB source to the stormwater conveyance system and are considered to be "typical" industrial stormwater concentrations.

4.4.3.2 Comparison of General PCB Information to Study Area Concentrations

Section 4.4.3.1 provides general information regarding the prevalence and concentration of PCBs in urban land use areas (based on stormwater catch basin samples). This general information is meant to provide a context for evaluating the concentrations detected in the Study Area. For example, total PCB concentrations in Force Lake surface sediment ranged from non-detect to 131 µg/kg dw (mean of 80 µg/kg dw) (Table 4-10). The total PCB concentrations in stormwater catch basin samples from Portland (Integral et al. 2009) for a residential land use basin ranged from 66.7 to 377 µg/kg dw. This comparison illustrates that the total PCB concentrations in Force Lake sediments are not atypical of the general level of PCBs found in urban residential areas. Further, the average concentration of PCBs in Force Lake, based on summary information provided by the City of Portland (City of Portland 2009b), is not such that a historical or ongoing up-pipe PCB source of significance would be suspected.

With respect to soil, total PCB concentrations were highly variable at the Facility and in the wetland, ranging from 4.9 to 32,000 µg/kg dw in Facility surface soil (mean of 2,000 µg/kg dw) and from 35 to 4,200 µg/kg dw in wetland surface soil (mean of 400 µg/kg dw) (Tables 4-7 and 4-9; Figure 4-19). The mean and maximum PCB concentrations in these media correspond with the PCB stormwater catch basin sample concentrations in industrial areas, which is consistent with the Facility setting and suspected source of PCBs to Facility and wetland soils as described in Section 4.4.3.

4.4.4 Summary for Total PCBs

In the Study Area, total PCB concentrations were highest in surface soils collected from the Facility. Patterns of PCBs in Facility soil indicate that releases from the tank farm, the truck cleaning operation, and road oiling may have contributed to PCB releases at the Facility. Total PCB concentrations were highest in the northeast corner of the Facility near the Facility entrance, in the central portion of the Facility near the former tanker truck cleaning operation, and along the U-shaped roadway that extends from the Facility entrance around the former truck cleaning operation area.

Total PCB concentrations were usually lower in samples collected from the wetlands than those collected from the Facility (Figure 4-18). The highest PCB concentrations in the wetlands were located just to the south of the Facility approximately halfway between North Force Avenue and the drainage ditch, in the former drainage ditch to the west of the Facility, and near the discharge point of the stormwater treatment system. Thus,

as discussed in Section 4.2.2, possible explanations for the distribution of PCBs in the wetlands include the following:

- PCBs may have accumulated in historical sumps and holding ponds along the southwest Facility boundary, which may have extended into what is now considered the wetlands. These sumps and holding ponds likely accumulated water and oil from the truck cleaning operations and are in an area that was subsequently filled to the current grade.
- PCBs may have migrated with sheet flow into the wetlands prior to the construction of the soil berm in the early 1980s.
- PCBs may have been released directly into the wetlands as a result of the 1979 Facility fire or other Facility-related releases before the soil berm was constructed.
- PCBs may have migrated from the Facility bound to contaminated particles transported in storm runoff via the drainage ditch before the construction of the current stormwater treatment system in the mid-1980s

Stormwater runoff is now collected and treated in the stormwater treatment system that discharged to the drainage ditch in the southwest corner of the Facility until 2002 and now discharges to the south of the Facility near location WS-19, which had a total PCB concentration of 250 µg/kg dw.

In Force Lake, concentrations of total PCBs were usually lower than those in Facility soil and were lower than or similar to concentrations in wetland soil (Figure 4-18). The concentrations of PCBs in Force Lake sediment were of similar magnitude to those identified by the City of Portland as being representative of stormwater catch basin sediment in an area of urban residential land use. Total PCBs were not detected in the two sediment samples collected closest to the Facility, and relatively low variability was observed in detected total PCB concentrations in Force Lake; thus, no clear gradient from the Facility was observed. In addition, total PCBs were not detected in subsurface sediment samples, which may indicate little historical sedimentation of contaminated particles in Force Lake (see Section 3.3.2).

The potential for migration of total PCBs from Force Lake into North Lake was evaluated through the collection of three surface sediment samples from North Lake. As noted previously, total PCBs were not detected in any of these three samples, indicating that PCBs have not migrated into North Lake.

PCBs were not detected in any groundwater or surface water samples, which is consistent with PCBs' high affinity for particles.

The comparison with conservative screening levels, as shown in Figures 4-19 and 4-20, indicates that PCBs were generally bounded both vertically and laterally. Thus PCBs have been adequately delineated and the available data meet the DQOs identified in the RI/FS Work Plan (Bridgewater et al. 2008b).

4.5 Metals

This section presents an overview of source information, fate and transport, and media-specific data for metals. These metals have been detected in samples collected from throughout the Study Area and may have been introduced to the Facility through historical and current industrial activities, including oil treatment and processing, production of RFO, and tanker cleaning operations. In the HHRA, arsenic was identified as a COC based on future worker exposure to Facility soil. In the ERA, chromium, copper, mercury, and zinc were identified because they had LOAEL-based HQs greater than 1.0 for at least one receptor (i.e., invertebrates, fish, or mammals) and had Study Area concentrations greater than background concentrations. This section discusses these five metals. Other metals are discussed in Section 4.8.

4.5.1 Known or Suspected Sources and Release Mechanisms

Metals are naturally occurring elements and so are commonly detected in the environment. Thus, a portion of the metals concentrations at the Study Area may not be related to sources or releases at the Facility. Regional background concentrations are available from DEQ for the five metals discussed in this section (see Section 2.8.1).

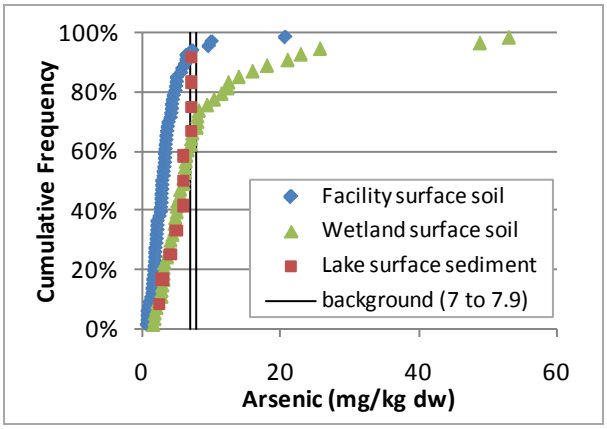
Study Area concentrations of metals higher than regional background concentrations may be associated with several different sources. Some metals, including arsenic and chromium, are known to be associated with used oils and fuels, which could have been released at the Study Area during tanker truck washing operations (in the central portion of the Facility) or during used-fuel processing and refinement. Agricultural applications that involved the use of some metals (arsenic and copper) could also account for their presence at the Facility as a result of cattle truck cleaning operations. In addition, industrial uses of all five metals (e.g., as components of paint, steel, or batteries) could have contributed to the presence of metals at the Study Area. For example, zinc is a prevalent corrosion inhibitor used on all forms of steel (e.g., building siding and roofing, piping, and tanks).

4.5.2 Concentrations by Medium

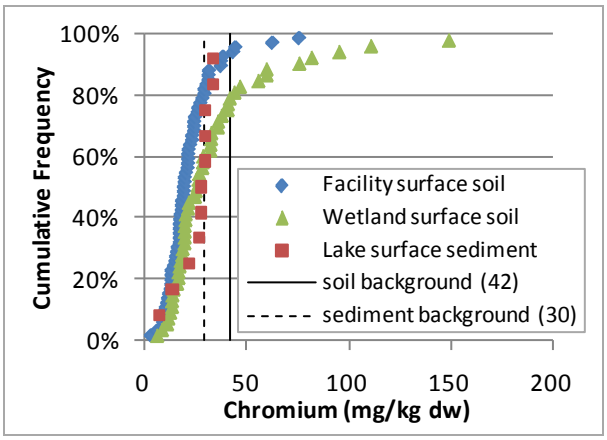
This section discusses the concentrations of arsenic, chromium, copper, mercury, and zinc in various media within the Study Area (other metals are discussed in Section 4.8). Summary statistics in tables are provided by location (not sample)[17] to be consistent with the figures. The complete RI database is provided in Appendix B.

Figure 4-21 presents cumulative frequency distributions for the five metals discussed in this section based on concentrations in surface soil and sediment samples collected from within the Study Area. Background concentrations are also shown. Concentration is presented on the x-axis, and percent rank within the dataset is presented on the y-axis. This figure

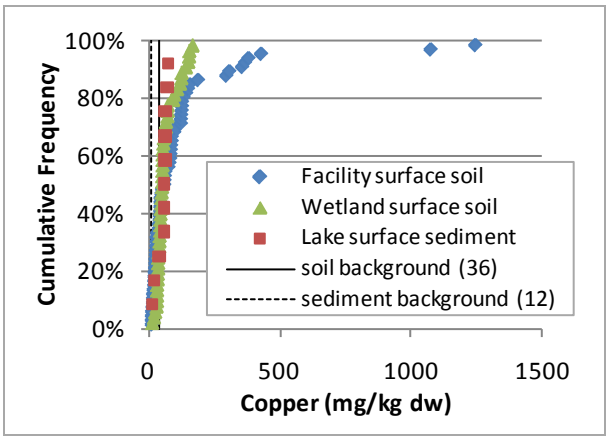
[17] Duplicate samples were combined with the original sample, as described in Appendix N.



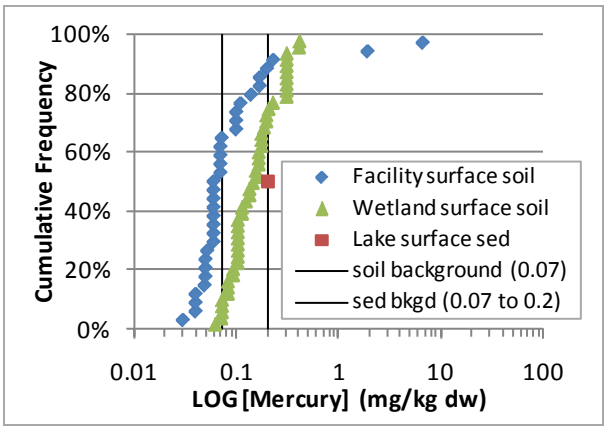
Arsenic



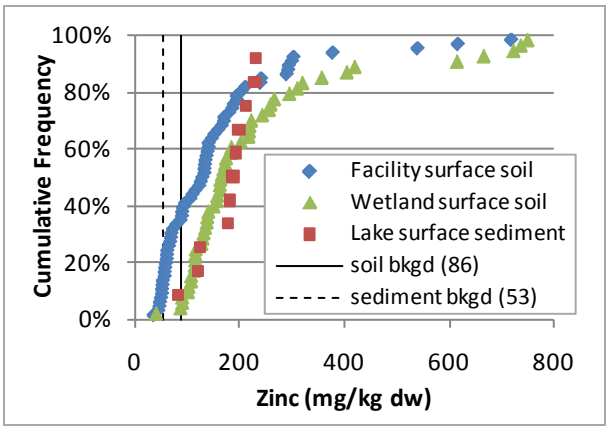
Chromium



Copper



Mercury

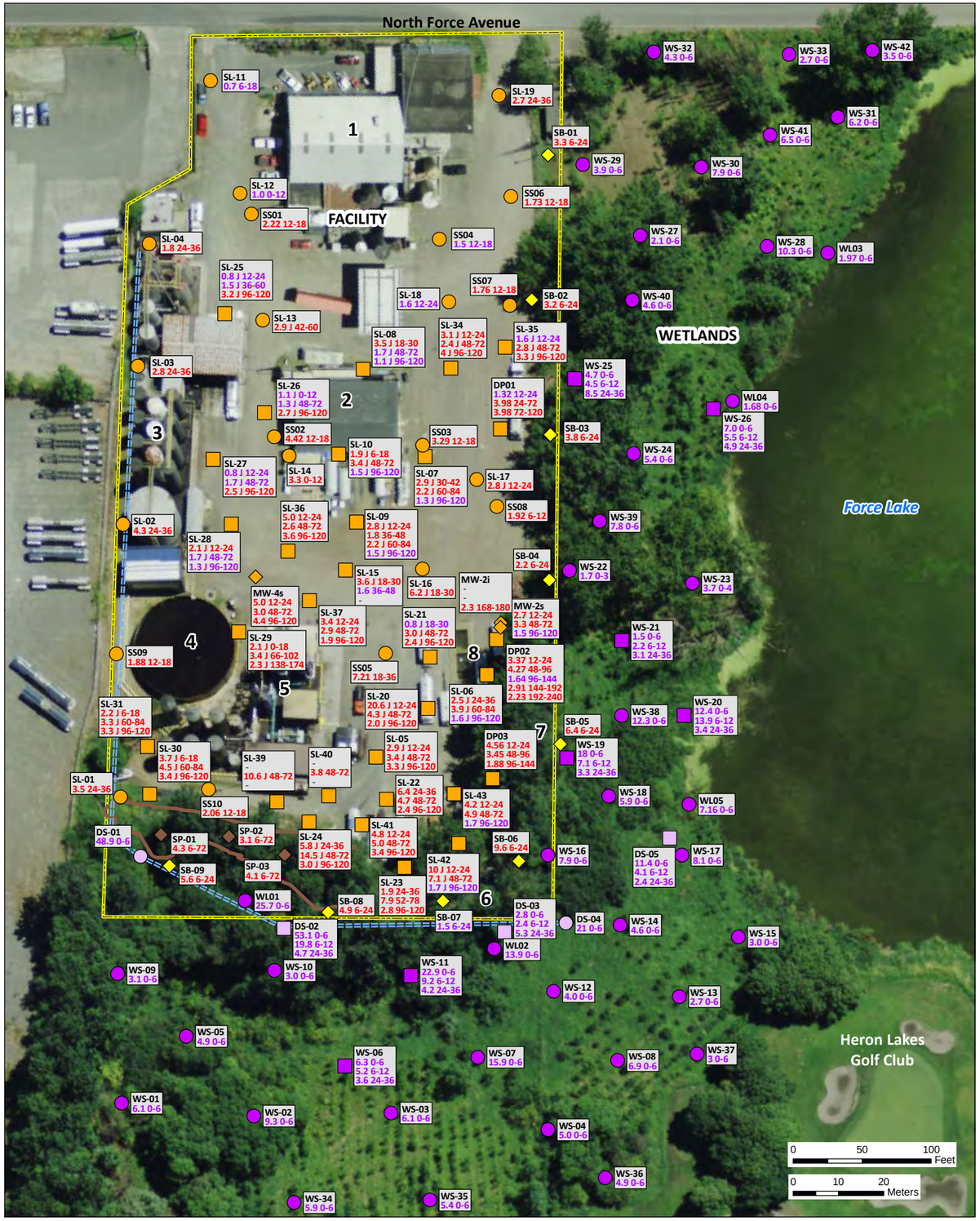


Zinc

Figure 4-21. Cumulative Frequencies for Metals Detected in Facility Surface Soil, Wetland Surface Soil, and Force Lake Surface Sediment

is intended to help facilitate cross-media comparisons and present background concentrations relative to Study Area concentrations. Maximum sediment concentrations were lower than those for Facility or wetland soil. Arsenic concentrations in approximately 90% of Facility surface soil samples were less than the background concentration. Note that for mercury, a log scale was used in the cumulative frequency distribution to better display the range of concentrations. Also note that mercury was only detected in one sediment sample.

Figures 4-22 through 4-26 present metal concentrations at each soil and sediment location sampled; Figures 4-27 through 4-31 present metal concentrations at each groundwater and surface water location sampled. These data are discussed by media in the following sections.



On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Arsenic Screening Levels

Medium	Unit	Industrial Human Health RSL[a]	Residential Human Health RSL[a]	Invertebrate Screening Level[b]
Facility soil	mg/kg dw	1.7	0.39	na
Wetland soil	mg/kg dw	na	0.39	60
Lake sediment	mg/kg dw	na	0.39	17

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
[b] Invertebrate (ecological) sediment screening levels are represented by the lower of the probable effects concentration (PEC) and probable effects level (PEL); invertebrate screening levels in soil are represented by the lowest of EPA, DEQ, and Oak Ridge National Laboratory soil invertebrate screening levels.
na - not applicable
Note: Soil background arsenic concentration: 7 mg/kg dw
Sediment background arsenic concentration: 7 to 7.9 mg/kg dw

Facility soil samples (mg/kg dw)[a]

- Surface soil
- Subsurface and surface soil[b]
- Soil at groundwater monitoring well[b]
- Soil berm
- Soil stockpile

Wetland and ditch soil samples (mg/kg dw)

- Wetland surface soil
- Wetland surface and subsurface soil[b]
- Ditch surface soil
- Ditch surface and subsurface soil[b]

Lake sediment samples (mg/kg dw)

- Lake sediment[b]

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

[a] The following locations were not analyzed for arsenic and do not appear on this map: shallow samples from SL 32, SL 33, SL 45, and SL 46; intermediate sample from SL-38; and deep sample from SL 44.

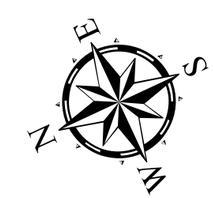
[b] Both surface and subsurface data are shown.

Location ID — SL-00
Concentration — 2,500 12-24 / 250 JN 60-84 / 25 U 96-120

Detected concentration:
exceeds highest SL = Red
exceeds lowest SL = Purple
does not exceed SL = Black

Qualifier
U=non-detect
J=estimated
N=tentatively identified

Depth in inches



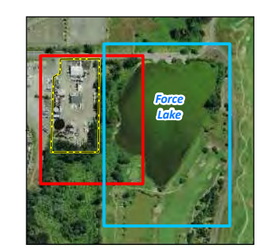


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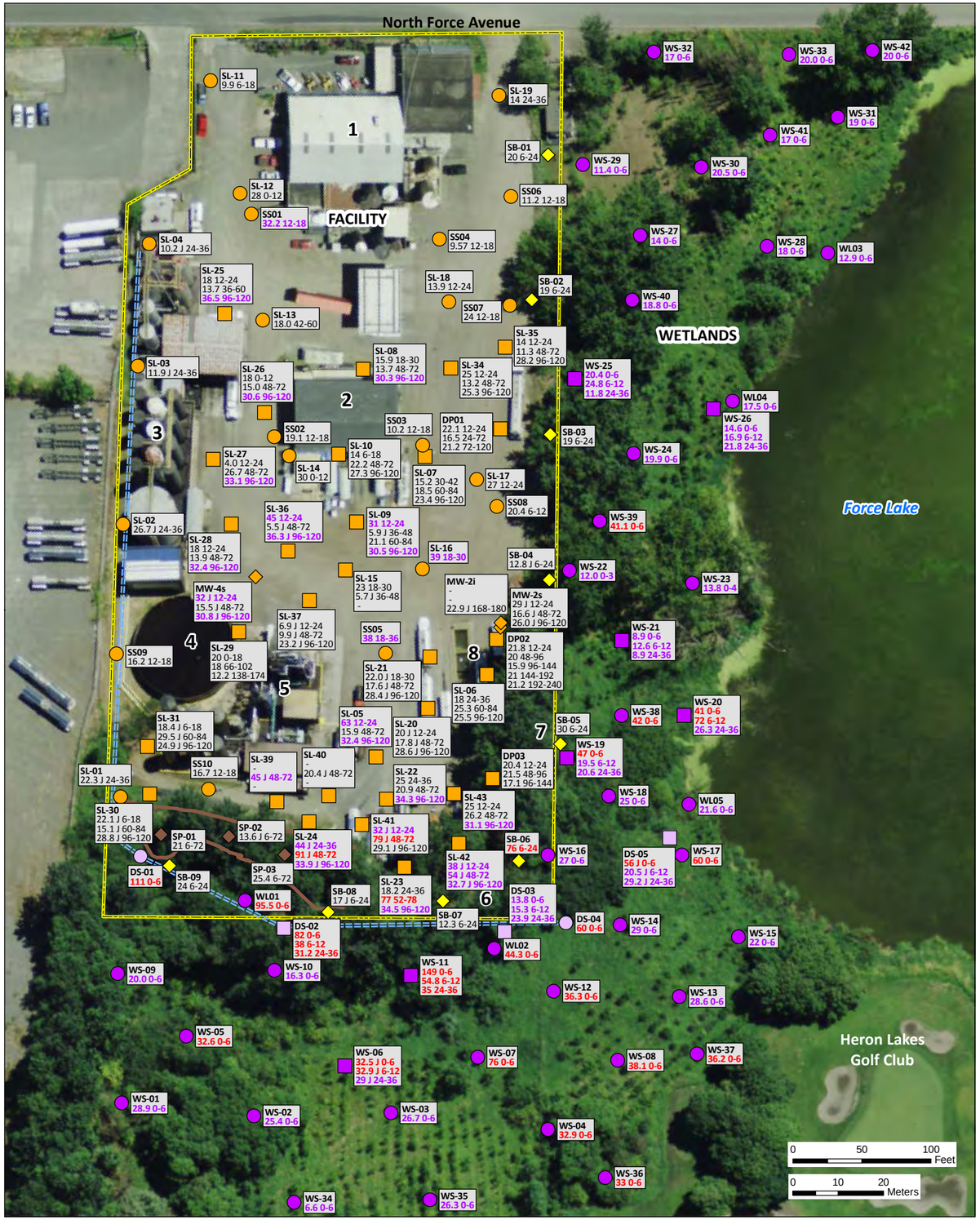
Figure 4-22. Arsenic Concentrations at Facility Soil, Wetland Soil, and Lake Sediment Sampling Locations

Prepared by CEH, 08/31/2010, MAP #4071; W:\Projects\Harbor_Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.



On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Chromium Screening Levels

Medium	Unit	Industrial Human Health RSL[a]	Residential Human Health RSL[a]	Invertebrate Screening Level[b]
Facility soil	mg/kg dw	71.2	30	na
Wetland soil	mg/kg dw	na	30	2
Lake sediment	mg/kg dw	na	30	90

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
[b] Invertebrate (ecological) sediment screening levels are represented by the lower of the probable effects concentration (PEC) and probable effects level (PEL); invertebrate screening levels in soil are represented by the lowest of EPA, DEQ, and Oak Ridge National Laboratory soil invertebrate screening levels.
na - not applicable
Note: Soil background chromium concentration: 42 mg/kg dw
Sediment background chromium concentration: 30 mg/kg dw

Facility soil samples (mg/kg dw)[a]

- Surface soil
- Subsurface and surface soil[b]
- Soil at groundwater monitoring well[b]
- Soil berm
- Soil stockpile

Wetland and ditch soil samples (mg/kg dw)

- Wetland surface soil
- Wetland surface and subsurface soil[b]
- Ditch surface soil
- Ditch surface and subsurface soil[b]

Lake sediment samples (mg/kg dw)

- Lake sediment[b]

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

[a] The following locations were not analyzed for chromium and do not appear on this map: shallow samples from SL 32, SL 33, SL 45, and SL 46; intermediate sample from SL-38; and deep sample from SL 44.

[b] Both surface and subsurface data are shown.

Location ID — SL-00
Concentration — 2,500 12-24 / 250 JN 60-84 / 25 U 96-120
Qualifier: U=non-detect, J=estimated, N=tentatively identified
Depth in inches
Detected concentration: exceeds highest SL = Red; exceeds lowest SL = Purple; does not exceed SL = Black

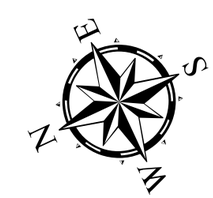


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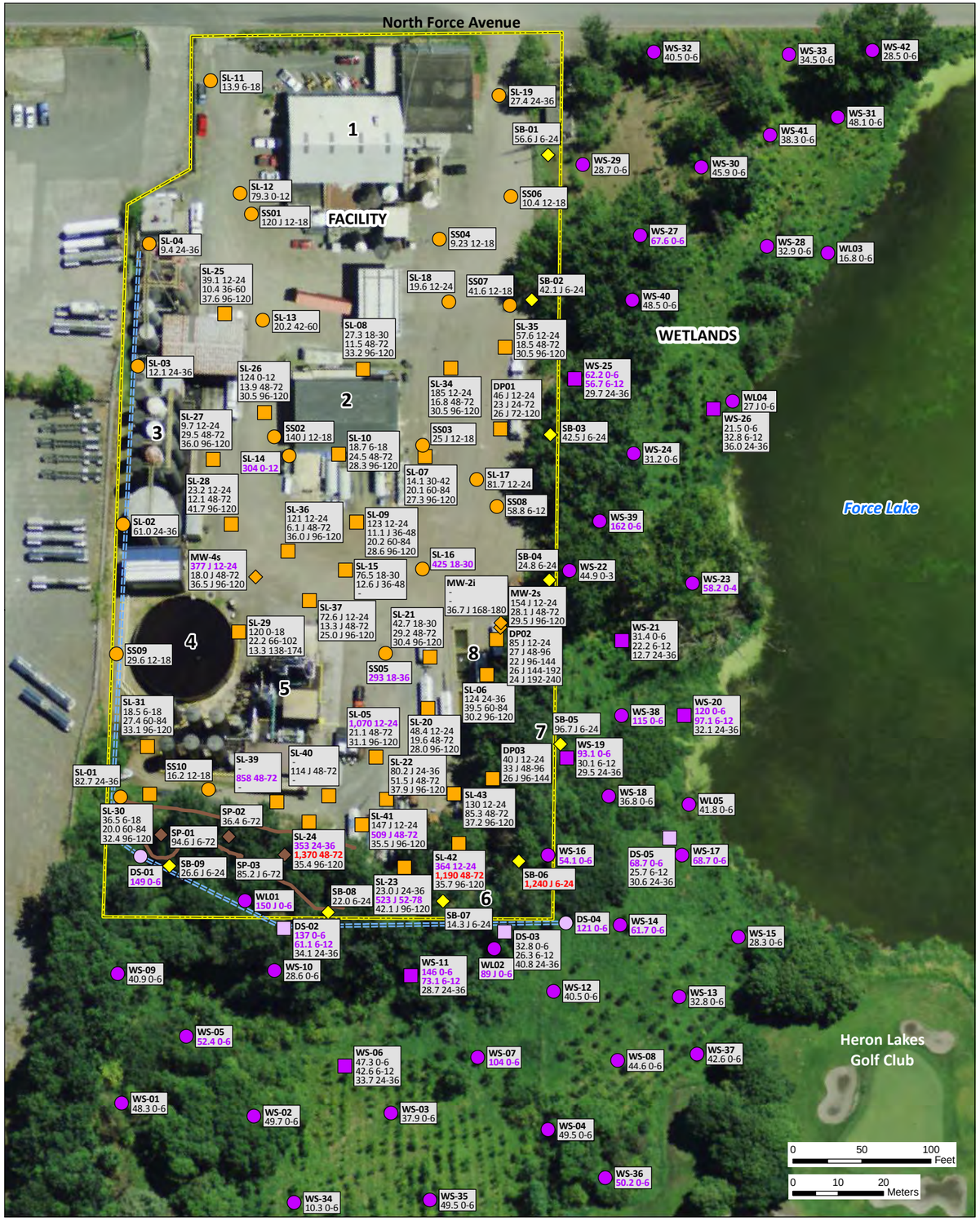
Figure 4-23. Chromium Concentrations at Facility Soil, Wetland Soil, and Lake Sediment Sampling Locations

Prepared by CEH, 12/15/2011, MAP #4073, W:\Projects\Harbor_Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.



On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Copper Screening Levels

Medium	Unit	Industrial Human Health RSL[a]	Residential Human Health RSL[a]	Invertebrate Screening Level[b]
Facility soil	mg/kg dw	1,100	291	na
Wetland soil	mg/kg dw	na	291	50
Lake sediment	mg/kg dw	na	291	149

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
[b] Invertebrate (ecological) sediment screening levels are represented by the lower of the probable effects concentration (PEC) and probable effects level (PEL); invertebrate screening levels in soil are represented by the lowest of EPA, DEQ, and Oak Ridge National Laboratory soil invertebrate screening levels.
na - not applicable
Note: Soil background copper concentration: 36 mg/kg dw
Sediment background copper concentration: 12 mg/kg dw

Facility soil samples (mg/kg dw)[a]

- Surface soil
- Subsurface and surface soil[b]
- Soil at groundwater monitoring well[b]
- Soil berm
- Soil stockpile

Wetland and ditch soil samples (mg/kg dw)

- Wetland surface soil
- Wetland surface and subsurface soil[b]
- Ditch surface soil
- Ditch surface and subsurface soil[b]

Lake sediment samples (mg/kg dw)

- Lake sediment[b]

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

[a] The following locations were not analyzed for copper and do not appear on this map: shallow samples from SL 32, SL 33, SL 45, and SL 46; intermediate sample from SL-38; and deep sample from SL 44.

[b] Both surface and subsurface data are shown.

Location ID — SL-00
Concentration — 2,500 12-24 / 250 JN 60-84 / 25 U 96-120

Qualifier: U=non-detect, J=estimated, N=tentatively identified

Depth in inches

Detected concentration: exceeds highest SL = Red; exceeds lowest SL = Purple; does not exceed SL = Black

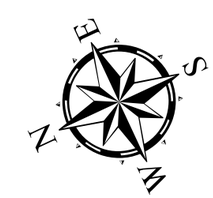


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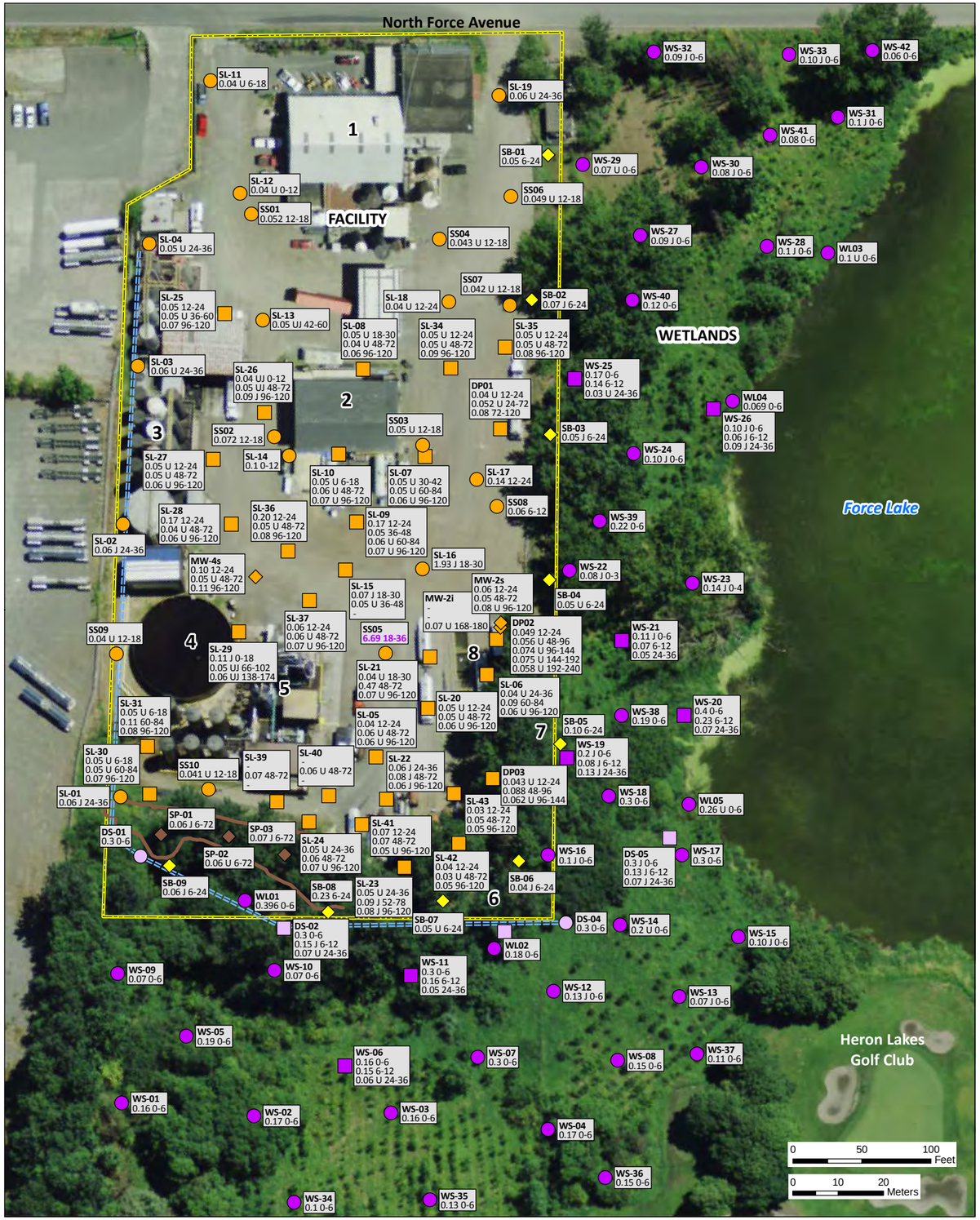
Figure 4-24. Copper Concentrations at Facility Soil, Wetland Soil, and Lake Sediment Sampling Locations

Prepared by CEH, 12/15/2011, MAP #4074, W:\Projects\Harbor_Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.



On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Mercury Screening Levels

Medium	Unit	Industrial Human Health RSL[a]	Residential Human Health RSL[a]	Invertebrate Screening Level[b]
Facility soil	mg/kg dw	9.3	2.3	na
Wetland soil	mg/kg dw	na	2.3	0.5
Lake sediment	mg/kg dw	na	2.3	0.486

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
[b] Invertebrate (ecological) sediment screening levels are represented by the lower of the probable effects concentration (PEC) and probable effects level (PEL); invertebrate screening levels in soil are represented by the lowest of EPA, DEQ, and Oak Ridge National Laboratory soil invertebrate screening levels.
na - not applicable
Note: Soil background mercury concentration: 0.07 mg/kg dw
Sediment background mercury concentration: 0.07 to 0.2 mg/kg dw

Facility soil samples (mg/kg dw)[a]

- Surface soil
- Subsurface and surface soil[b]
- Soil at groundwater monitoring well[b]
- Soil berm
- Soil stockpile

Wetland and ditch soil samples (mg/kg dw)

- Wetland surface soil
- Wetland surface and subsurface soil[b]
- Ditch surface soil
- Ditch surface and subsurface soil[b]

Lake sediment samples (mg/kg dw)

- Lake sediment[b]

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

[a] The following locations were not analyzed for mercury and do not appear on this map: shallow samples from SL 32, SL 33, SL 45, and SL 46; intermediate sample from SL-38; and deep sample from SL 44.

[b] Both surface and subsurface data are shown.

Location ID — SL-00
Concentration — 2,500 12-24 / 250 JN 60-84 / 25 U 96-120

Detected concentration:
exceeds highest SL = Red
exceeds lowest SL = Purple
does not exceed SL = Black

Qualifier
U=non-detect
J=estimated
N=tentatively identified

Depth in inches

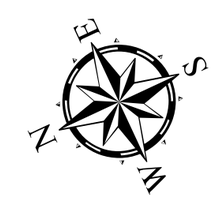


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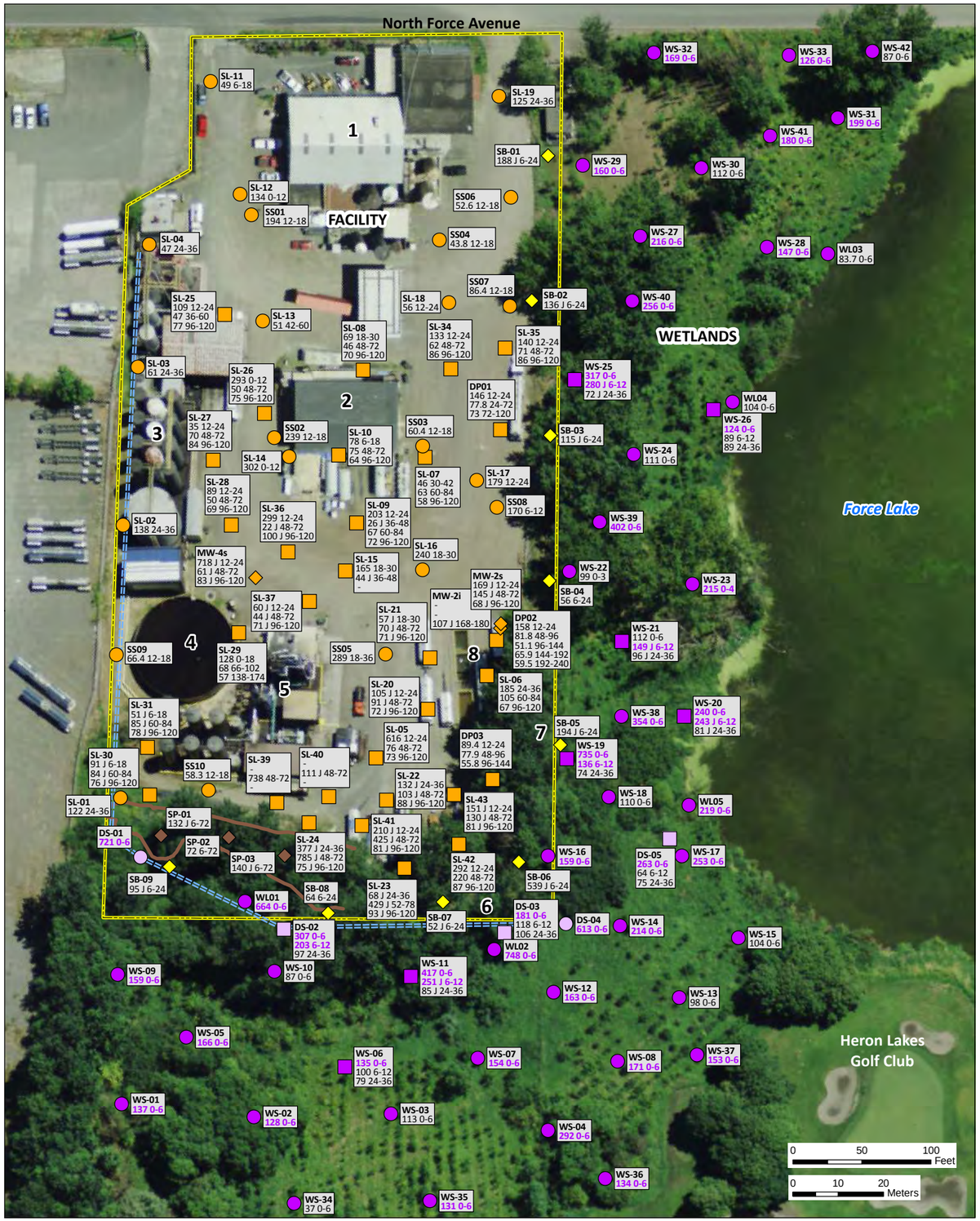
Figure 4-25. Mercury Concentrations at Facility Soil, Wetland Soil, and Lake Sediment Sampling Locations

Prepared by CEH, 12/15/2011, MAP #4077; W:\Projects\Harbor_Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.



Facility soil samples (mg/kg dw)[a]

- Surface soil
- Subsurface and surface soil[b]
- Soil at groundwater monitoring well[b]
- Soil berm
- Soil stockpile

Wetland and ditch soil samples (mg/kg dw)

- Wetland surface soil
- Wetland surface and subsurface soil[b]
- Ditch surface soil
- Ditch surface and subsurface soil[b]

Lake sediment samples (mg/kg dw)

- Lake sediment[b]

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

[a] The following locations were not analyzed for zinc and do not appear on this map: shallow samples from SL 32, SL 33, SL 45, and SL 46; intermediate sample from SL-38; and deep sample from SL 44.

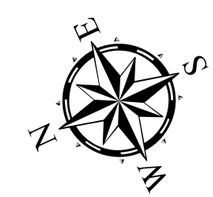
[b] Both surface and subsurface data are shown.

Location ID — SL-00
Concentration — 2,500 12-24 / 250 JN 60-84 / 25 U 96-120

Qualifier: U=non-detect, J=estimated, N=tentatively identified

Depth in inches

Detected concentration: exceeds highest SL = Red; exceeds lowest SL = Purple; does not exceed SL = Black



On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Zinc Screening Levels

Medium	Unit	Industrial Human Health RSL[a]	Residential Human Health RSL[a]	Invertebrate Screening Level[b]
Facility soil	mg/kg dw	100,000	2,350	na
Wetland soil	mg/kg dw	na	2,350	120
Lake sediment	mg/kg dw	na	2,350	315

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
[b] Invertebrate (ecological) sediment screening levels are represented by the lower of the probable effects concentration (PEC) and probable effects level (PEL); invertebrate screening levels in soil are represented by the lowest of EPA, DEQ, and Oak Ridge National Laboratory soil invertebrate screening levels.
na - not applicable
Note: Soil background zinc concentration: 86 mg/kg dw
Sediment background zinc concentration: 53 mg/kg dw

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Figure 4-26. Zinc Concentrations at Facility Soil, Wetland Soil, and Lake Sediment Sampling Locations

Prepared by: CEH, 12/15/2011; MAP #4092; W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

Groundwater samples (µg/L)

- Shallow groundwater
- Intermediate groundwater
- Deep groundwater

Surface water samples (µg/L)

- Lake surface water

Wells where groundwater samples not collected

- Groundwater not sampled due to lack of construction details (trace to 0.02 ft of LNAPL observed)
- Groundwater not sampled due to lack of construction details
- Groundwater not sampled due to the presence of LNAPL (0.1 ft LNAPL observed here in 2008 when LNAPL sample was collected. After this time, trace to 0.02 ft of LNAPL observed).

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

Location ID — GA-00
Sample Year — 2000: – / 2008: 1.0 U / 2009: na
Detected concentration: exceeds highest SL = Red; exceeds lowest SL = Purple; does not exceed SL = Black
Concentration: na=not analyzed; – =not collected
Qualifier: U=non-detect; J=estimated

On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

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Arsenic Screening Levels

Medium	Unit	Human Health RSL[a]	Invertebrate Screening Level[b]
Groundwater	µg/L	0.045	na
Surface water	µg/L	0.018	150

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
[b] Ecological water screening levels are represented by EPA chronic AWQC.
na - not applicable

Figure 4-27. Arsenic Concentrations in Filtered Samples at Facility Groundwater and Lake Surface Water Sampling Locations

Prepared by CEH, 12/15/2011, MAP #4071, W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Chromium Screening Levels

Medium	Unit	Human Health RSL[a]	Invertebrate Screening Level
Groundwater	µg/L	11	na
Surface water	µg/L	not detected; no comparison to screening levels	

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
na - not applicable

Groundwater samples (µg/L)

- Shallow groundwater
- Intermediate groundwater
- Deep groundwater

Surface water samples (µg/L)

- Lake surface water

Wells where groundwater samples not collected

- Groundwater not sampled due to lack of construction details (trace to 0.02 ft of LNAPL observed)
- Groundwater not sampled due to lack of construction details
- Groundwater not sampled due to the presence of LNAPL (0.1 ft LNAPL observed here in 2008 when LNAPL sample was collected. After this time, trace to 0.02 ft of LNAPL observed).

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

Location ID — GA-00
Sample Year — 2000: –; 2008: 1.0 U; 2009: na
Detected concentration: exceeds SL = Red; does not exceed SL = Black
Concentration: na=not analyzed; – =not collected
Qualifier: U=non-detect; J=estimated

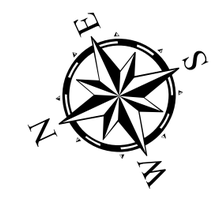

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Figure 4-28. Chromium Concentrations in Filtered Samples at Facility Groundwater and Lake Surface Water Sampling Locations

Prepared by CEH, 12/15/2011, MAP #4073, W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

Groundwater samples (µg/L)

- Shallow groundwater
- Intermediate groundwater
- Deep groundwater

Surface water samples (µg/L)

- Lake surface water

Wells where groundwater samples not collected

- Groundwater not sampled due to lack of construction details (trace to 0.02 ft of LNAPL observed)
- Groundwater not sampled due to lack of construction details
- Groundwater not sampled due to the presence of LNAPL (0.1 ft LNAPL observed here in 2008 when LNAPL sample was collected. After this time, trace to 0.02 ft of LNAPL observed).

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

Location ID — GA-00
Sample Year — 2000: –
2008: 1.0 U
2009: na

Detected concentration:
exceeds highest SL = Red
exceeds lowest SL = Purple
does not exceed SL = Black

Concentration
na=not analyzed
– =not collected

Qualifier
U=non-detect
J=estimated

On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Copper Screening Levels

Medium	Unit	Human Health RSL[a]	Invertebrate Screening Level[b]
Groundwater	µg/L	136	na
Surface water	µg/L	460	1.3

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
[b] Ecological water screening levels are represented by EPA chronic AWQC. For copper, the AWQC value was hardness-adjusted based on the average Force Lake hardness (10.7 mg/L CaCO3).

na - not applicable

Figure 4-29. Copper Concentrations in Filtered Samples at Facility Groundwater and Lake Surface Water Sampling Locations

Prepared by CEH, 12/15/2011, MAP #4074, W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

Groundwater samples (µg/L)

- Shallow groundwater
- Intermediate groundwater
- Deep groundwater

Surface water samples (µg/L)

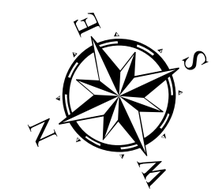
- Lake surface water

Wells where groundwater samples not collected

- Groundwater not sampled due to lack of construction details (trace to 0.02 ft of LNAPL observed)
- Groundwater not sampled due to lack of construction details
- Groundwater not sampled due to the presence of LNAPL (0.1 ft LNAPL observed here in 2008 when LNAPL sample was collected. After this time, trace to 0.02 ft of LNAPL observed).

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

Location ID — **GA-00**
Sample Year — 2000: –, 2008: 1.0 U, 2009: na
Detected concentration: exceeds SL = **Red**; does not exceed SL = Black
Concentration: na=not analyzed, – =not collected
Qualifier: U=non-detect, J=estimated



On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Mercury Screening Levels

Medium	Unit	Human Health RSL[a]	Invertebrate Screening Level
Groundwater	µg/L	1.1	na
Surface water	µg/L	not detected; no comparison to screening levels	

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
na - not applicable

Figure 4-30. Mercury Concentrations in Filtered Samples at Facility Groundwater and Lake Surface Water Sampling Locations

Prepared by CEH, 12/15/2011, MAP #4077, W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

Groundwater samples (µg/L)

- Shallow groundwater
- Intermediate groundwater
- Deep groundwater

Surface water samples (µg/L)

- Lake surface water

Wells where groundwater samples not collected

- Groundwater not sampled due to lack of construction details (trace to 0.02 ft of LNAPL observed)
- Groundwater not sampled due to lack of construction details
- Groundwater not sampled due to the presence of LNAPL (0.1 ft LNAPL observed here in 2008 when LNAPL sample was collected. After this time, trace to 0.02 ft of LNAPL observed).

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

Location ID — **GA-00**
Sample Year — 2000: –
2008: 1.0 U
2009: na

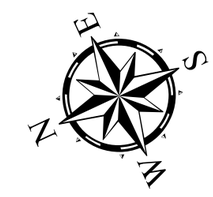
Detected concentration:
exceeds SL = **Red**
does not exceed SL = Black

Concentration
na=not analyzed
– =not collected

Qualifier
U=non-detect
J=estimated

On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System



Zinc Screening Levels

Medium	Unit	Human Health RSL[a]	Invertebrate Screening Level
Groundwater	µg/L	1,095	na
Surface water	µg/L	not detected; no comparison to screening levels	

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
na - not applicable

Figure 4-31. Zinc Concentrations in Filtered Samples at Facility Groundwater and Lake Surface Water Sampling Locations

Prepared by CEH, 12/15/2011, MAP #4092, W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

4.5.2.1 Facility Soil

Table 4-11 summarizes concentrations of metals in surface and subsurface soil samples collected at the Facility. The depth intervals of these samples varied depending on the sampling location, field conditions, and the sampling event (see Section 2.2). Surface soil samples at the Facility were collected just below the gravel fill layer, if present.

Table 4-11. Concentrations of Metals Detected in at Least One Facility Soil Sample

Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
	Ratio	%					
Arsenic (mg/kg dw)							
Surface	53/53	100	0.7	20.6 J	SL-20	3	na
Intermediate	34/34	100	1.3 J	14.5 J	SL-24	3.9	na
Deep	33/33	100	1.1 J	4.4	MW-4s	2	na
Soil stockpile	3/3	100	3.1	4.3	SP-01	3.8	na
Soil berm	9/9	100	1.5	9.6	SB-06	4.5	na
Chromium (mg/kg dw)							
Surface	53/53	100	4.0	63	SL-05	20	na
Intermediate	34/34	100	5.5 J	91 J	SL-24	20	na
Deep	33/33	100	12.2	36.5	SL-25	28	na
Soil stockpile	3/3	100	13.6 J	25.4	SP-03	20	na
Soil berm	9/9	100	12.3	76	SB-06	30	na
Copper (mg/kg dw)							
Surface	53/53	100	9.23	1,070	SL-05	100	na
Intermediate	34/34	100	6.1 J	1,370	SL-24	150	na
Deep	33/33	100	13.3	42.1 J	SL-23	31	na
Soil stockpile	3/3	100	36.4	94.6 J	SP-01	72.1	na
Soil berm	9/9	100	14.3 J	1,240 J	SB-06	174	na
Mercury (mg/kg dw)							
Surface	24/53	45	0.03	6.69	SS05	0.2	0.04 – 0.06
Intermediate	12/34	35	0.05	0.47	SL-21	0.06	0.03 – 0.06
Deep	14/33	42	0.05	0.11	MW-4s	0.05	0.05 – 0.08
Soil stockpile	2/3	67	0.06 J	0.07 J	SP-03	nc	0.06
Soil berm	7/9	78	0.04 J	0.23	SB-08	0.07	0.05
Zinc (mg/kg dw)							
Surface	53/53	100	35	718 J	MW-4s	200	na
Intermediate	34/34	100	22 J	785 J	SL-24	100	na
Deep	33/33	100	51.1	107 J	MW-2i	70	na
Soil stockpile	3/3	100	72	140 J	SP-03	110	na
Soil berm	9/9	100	52 J	539 J	SB-06	160	na

Note: Other metals (i.e., those that were not identified as COCs in the HHRA or that did not have LOAEL-based HQs greater than 1.0 for at least one receptor in the ERA) are discussed in Section 4.8.

[a] Surface soil samples were collected immediately below the gravel layer from depths of 0 to 5 ft bgs (0.5- to 1.5-ft sampling intervals for a given sample). Intermediate soil samples were collected from depths of 2 to 8.5 ft bgs (1- to 4-ft sampling intervals for a given sample). Deep soil samples were collected from depths of 6 to 22 ft bgs (1- to 4-ft sampling intervals for a given sample). All soil berm samples were collected from 0.5 to 2 ft bgs, and all soil stockpile samples were collected from 0.5 to 6 ft bgs.

Table 4-11. Concentrations of Metals Detected in at Least One Facility Soil Sample (cont.)

[b] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values. Mean concentrations were not calculated if the detection frequency was less than 10% or if fewer than three samples had detected concentrations.

[c] RLs are for only non-detected samples.

bgs – below ground surface
dw – dry weight
COC – contaminant of concern
HQ – hazard quotient
J – estimated concentration
LOAEL – lowest-observed-adverse-effect level
na – not applicable
RL – reporting limit

Arsenic, chromium, copper, and zinc were detected in 100% of Facility soil samples. Mercury was detected less frequently (in 35 to 78% of samples, depending on the sample type).

With the exception of chromium, concentrations of metals in Facility soil were usually highest in the surface soil samples (or in some cases in the intermediate sample), with lower concentrations in the deepest sample. For chromium, the depth with the highest concentrations varied by location. However, the variability of chromium concentrations was low (all chromium concentrations were within a factor of 2.2 of background [42 mg/kg dw; Section 2.8.1]).

In Facility soil, the concentrations of all metals were highest in the west corner of the Facility (e.g., SL-42 and SB-06) and in the area of the former unlined holding pond/C-shaped area (e.g., SS05 and SL-20) (Figures 4-22 to 4-26). Relative to other Facility soil samples, metals concentrations were higher in the central portion of the Facility (e.g., SL-14 for copper and zinc) and in one sample in the northwestern portion of the soil berm (SB-08 for mercury). The next highest concentrations were detected in samples collected from the soil berm and in several intermediate-depth soil samples. In general, concentrations of metals in soil stockpile and soil berm samples were lower than those in Facility surface soil samples (Table 4-11).

Concentrations of metals in Facility soil samples were compared with conservative industrial and residential human health RSLs (Figures 4-22 to 4-26). Many of the samples (105 of the 132 surface and subsurface samples) had arsenic concentrations greater than the industrial RSL (1.7 mg/kg dw), and all samples had concentrations greater than the residential RSL (0.39 mg/kg dw). However, both RSLs were lower than the regional soil background concentration of 7 mg/kg dw. Eight surface and subsurface samples in the west corner of the Facility had arsenic concentrations greater than the background concentration; all other arsenic concentrations in Facility soil samples were less than the background concentration (Figure 4-22). There were also four samples (chromium) and three samples (copper) with detected concentrations greater than the conservative industrial human health RSLs, all in the west corner of the Facility in areas where arsenic concentrations were also highest (Figures 4-23 and 4-24, respectively). In addition, 30 samples had concentrations of chromium, 13 samples had concentrations of copper, and 1 sample had a concentration of mercury greater than their respective conservative residential human health RSLs. Most of these samples were from the central portion and west corner of the Facility. Note that the comparison with conservative screening levels on a point-by-point basis should not be viewed as a risk estimate; risks were fully assessed in the HHRA as presented in Appendix I and summarized in Section 6.1.

4.5.2.2 Groundwater

Table 4-12 summarizes concentration data for metals detected in at least one filtered or unfiltered groundwater sample. Chromium, copper, and mercury were detected only in shallow well samples. Therefore, summary

statistics for intermediate and deep samples are not shown for these metals.

Table 4-12. Concentrations of Metals Detected in at Least One Groundwater Sample

Sample Type[a]	Fraction	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
Arsenic (µg/L)								
Shallow	D	22/22	100	0.8	32.2	MW-4s	10	na
	T	28/28	100	1	31.6	MW-4s	10	na
Intermediate	D	3/3	100	2.4	4.7	MW-4i	3.5	na
	T	3/3	100	2.3	4.6	MW-4i	3.4	na
Deep	D	1/2	50	6.3	6.3	B-4	nc	0.2
	T	3/3	100	0.3	6.4	B-4	3	na
Chromium (µg/L)								
Shallow	D	0/22	0	nd	nd	na	nc	5
	T	4/28	14	6 J	8.1	A-18	4	5
Copper (µg/L)								
Shallow	D	2/22	9	3	5	MW-2s	nc	2
	T	8/28	29	2	25.1	A-18	3	2 – 4
Mercury (µg/L)								
Shallow	D	0/22	0	nd	nd	na	nc	0.1
	T	1/28	4	0.14	0.14	A-20	nc	0.1
Zinc (µg/L)								
Shallow	D	2/22	9	40	80	MW-4s	nc	10
	T	10/28	36	8.7	1,180	A-18	60	4 – 10
Intermediate	D	0/3	0	nd	nd	na	nc	10
	T	0/3	0	nd	nd	na	nc	10
Deep	D	1/2	50	9,870	9,870	PW-01	nc	10
	T	2/3	67	57.3	10,100	PW-01	nc	10

Note: Other metals (i.e., those that were not identified as COCs in the HHRA or that did not have LOAEL-based HQs greater than 1.0 for at least one receptor in the ERA) are discussed in Section 4.8.

[a] The depth of shallow groundwater wells ranged from 10 to 20 ft bgs, the depth of intermediate wells ranged from 48 to 50 ft bgs, and the depth of the deep well was 97 ft bgs.

[b] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values. Mean concentrations were not calculated if the detection frequency was less than 10% or if fewer than three samples had detected concentrations.

[c] RLs are for only non-detected samples.

bgs – below ground surface
D – dissolved concentrations (i.e., filtered)
COC – contaminant of concern
HQ – hazard quotient
na – not applicable
LOAEL – lowest-observed-adverse-effect level
nc – not calculated
nd – not detected
RL – reporting limit
T – total concentrations (i.e., unfiltered)

With the exception of arsenic, which was detected in almost all groundwater samples, metals were detected infrequently in groundwater. The variability of metals concentrations in groundwater was relatively low and was likely the result of the natural variability of these metals in the environment, with the possible exceptions of arsenic and zinc (Table 4-12 and Figures 4-27 through 4-31).

Of the metals discussed in this section, only arsenic and zinc were detected in groundwater samples at concentrations greater than the conservative human health RSLs. All detected concentrations of arsenic were greater than the conservative human health RSL of 0.045 µg/L. The highest arsenic concentrations (concentrations greater than 26 µg/L) were detected in samples from MW-4s (a shallow well located in the north-central part of the Facility) that were collected in 2008 and 2009. In addition, arsenic was detected at concentrations greater than the MCL of 10 µg/L in 12 of 27 dissolved water samples and in 16 of 34 total (unfiltered) water samples. Concentrations were greater than the MCL or non-zero MCLG by factors ranging from 1.1 to 3.2. Similar concentrations of arsenic were detected in groundwater across the Facility, including shallow groundwater at the upgradient property boundary near the northeastern corner of the Facility (arsenic concentrations in samples from well GA-34 were approximately 19 µg/L). Arsenic concentrations in groundwater are discussed further in Section 4.5.3.

No other metals discussed in this section were detected at concentrations greater than the MCL or non-zero MCLG.

Detected zinc concentrations were greater than the conservative human health RSL (1,095 µg/L) in the filtered and unfiltered water samples collected from PW-01 (a deep well located near the Facility entrance) in 2008 and in the unfiltered water sample collected from A-18 (a shallow well located near the new base oil refining plant) in 2000. Zinc was not detected in well A-18 in 2008 or 2009 in either filtered or unfiltered water samples. PW-01 was not sampled in 2009.

4.5.2.3 LNAPL

As discussed in Section 4.3.3.3, LNAPL is not a significant component at the Facility, and its presence is localized and constrained to a small portion of the Facility.

One LNAPL sample (layer thickness unknown) was collected in 2000 from GA-30 (in the uppermost groundwater zone) in the northwest portion of the Facility near the soil stockpile and again in 2008 when a thin layer (approximately 0.1 ft) of LNAPL was observed at that location. Metals were analyzed only in the 2008 sample. Of the five metals discussed in this section, only chromium (11 µg/L), copper (9 µg/L), and zinc (120 µg/L) were detected in this sample (other metals are discussed in Section 4.8). Because of its limited extent, LNAPL is not considered to be a source of metals in groundwater.

Follow-up monitoring, which included a year of monthly measurements, revealed thin layers of LNAPL (0.02 to 0.01 ft) in GA-30, although no LNAPL was observed in downgradient wells GA-29 and MW-1s (see

Figure 2-2 for well locations). Thus, the lateral extent of LNAPL appears to be limited to the immediate area surrounding well GA-30.

4.5.2.4 Wetland and Ditch Soil

Concentrations of metals detected in wetland and ditch surface and subsurface soil samples are summarized in Table 4-13 and presented in Figures 4-22 to 4-26. Metals were detected in the 90% or more of wetland and ditch surface soil samples and were also detected frequently in subsurface soil samples.

The highest concentrations of arsenic, mercury, and zinc were generally detected in surface soil samples, with concentrations decreasing with depth. The depth interval with the highest concentrations of chromium and copper varied, but all deep samples had concentrations that were less than or similar to regional background soil concentrations.

Concentrations of all five metals discussed in this section were highest in the former drainage ditch area to the west of the Facility and in the west corner of the Facility near the current and former stormwater treatment system discharge points (Figures 4-22 to 4-26). Concentrations of many of the metals were also relatively higher to the south of the Facility midway between North Force Avenue and the drainage ditch. In these areas, concentrations of metals were greater than their respective background concentrations (as presented in Section 2.8.1), and were greater than either the conservative human health residential RSLs (arsenic) or invertebrate screening levels (chromium, copper, mercury, and zinc). Note that the comparison with conservative screening levels on a point-by-point basis should not be viewed as a risk estimate; risks were fully assessed in the ERA and HHRA as presented in Appendices I and J and summarized in Section 6.0.

Table 4-13. Concentrations of Metals Detected in at Least One Wetland and Ditch Soil Sample

Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
	Ratio	%					
Arsenic (mg/kg dw)							
Surface	52/52	100	1.5	53.1	DS-02	9	na
Intermediate	10/10	100	2.2	19.8	DS-02	7.4	na
Deep	10/10	100	2.4	8.5	WS-25	4.3	na
Chromium (mg/kg dw)							
Surface	52/52	100	6.6	149	WS-11	30	na
Intermediate	10/10	100	12.6	72	WS-20	31	na
Deep	10/10	100	8.9	35	WS-11	24	na
Copper (mg/kg dw)							
Surface	52/52	100	10.3	162	WS-39	60	na
Intermediate	10/10	100	22.2	97.1	WS-20	46.8	na
Deep	10/10	100	12.7	40.8	DS-03	30.8	na
Mercury (mg/kg dw)							
Surface	47/52	90	0.06	0.4	WS-20	0.2	0.07 – 0.26
Intermediate	10/10	100	0.06 J	0.23	WS-20	0.1	na
Deep	7/10	70	0.05	0.13 J	WS-19	0.06	0.03 – 0.07
Zinc (mg/kg dw)							
Surface	52/52	100	37	748	WL02	230	na
Intermediate	10/10	100	64	280 J	WS-25	200	na
Deep	10/10	100	72 J	106	DS-03	85	na

Note: Other metals (i.e., those that were not identified as COCs in the HHRA or that did not have LOAEL-based HQs greater than 1.0 for at least one receptor in the ERA) are discussed in Section 4.8.

[a] Surface soil samples were collected from 0 to 0.5 ft bgs, intermediate soil samples were collected from 0.5 to 1 ft bgs, and deep soil samples were collected from 2 to 3 ft bgs.

[b] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values.

[c] RLs are for only non-detected samples.

bgs – below ground surface
dw – dry weight
COC – contaminant of concern
HQ – hazard quotient
J – estimated concentration
LOAEL – lowest-observed-adverse-effect level
na – not applicable
RL – reporting limit

4.5.2.5 Lake Sediment and Surface Water

Tables 4-14 and 4-15 summarize metals data for lake sediment and surface water, respectively.

Table 4-14. Concentrations of Metals Detected in at Least One Lake Sediment Sample

Sampling Location	Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
Arsenic (mg/kg dw)								
Force Lake	surface	11/11	100	2.6	7	SE-03, 06, 07, 10	6	na
Force Lake	intermediate	3/3	100	1.5	2.7	SE-10	2.0	na
North Lake	surface	3/3	100	3.2	5.0	SE-103	4.0	na
Chromium (mg/kg dw)								
Force Lake	surface	11/11	100	7.7	34	SE-06, 10	30	na
Force Lake	intermediate	3/3	100	23.8	25.6	SE-03	24.7	na
North Lake	surface	3/3	100	17	30	SE-103	20	na
Copper (mg/kg dw)								
Force Lake	surface	11/11	100	16.2	72	SE-06	53	na
Force Lake	intermediate	3/3	100	30.6	32.0	SE-05	31.3	na
North Lake	surface	3/3	100	49.0	71.4	SE-101	60.2	na
Mercury (mg/kg dw)								
Force Lake	surface	1/11	9	0.2 J	0.2 J	SE-02	0.2	0.06 – 0.3
Force Lake	intermediate	1/3	33	0.05	0.05	SE-10	nc	0.03
North Lake	surface	0/3	0	nd	nd	nd	nc	0.1 – 0.2
Zinc (mg/kg dw)								
Force Lake	surface	11/11	100	80	229	SE-06	200	na
Force Lake	intermediate	3/3	100	73	74	SE-10	73	na
North Lake	surface	3/3	100	99	119	SE-102	110	na

Note: Other metals (i.e., those that were not identified as COCs in the HHRA or that did not have LOAEL-based HQs greater than 1.0 for at least one receptor in the ERA) are discussed in Section 4.8.

[a] Surface lake sediment samples were collected from 0 to 4 inches below the mudline and intermediate lake sediment samples were collected from 2 to 3 ft below the mudline.

[b] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values. Mean concentrations were not calculated if the detection frequency was less than 10% or if fewer than three samples had detected concentrations.

[c] RLs are for only non-detected samples.

dw – dry weight
COC – contaminant of concern
HQ – hazard quotient
J – estimated concentration
na– not applicable
nc – not calculated
nd – not detected
LOAEL – lowest-observed-adverse-effect level
RL – reporting limit

Table 4-15. Concentrations of Metals Detected in at Least One Lake Surface Water Sample

Fraction	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[a]	RL or Range of RLs[b]
	Ratio	%					
Arsenic (µg/L)							
Filtered	3/3	100	0.9	1.0	SW-02, -03	1	na
Unfiltered	3/3	100	1.1	1.2	SW-01, -03	1.2	na
Copper (µg/L)							
Filtered	1/3	33	4	4	SW-01	nc	2
Unfiltered	1/3	33	6	6	SW-01	nc	2

Note: Lake surface water samples were collected from 1 ft below the water surface. Other metals (i.e., those that were not identified as COCs in the HHRA or that did not have LOAEL-based HQs greater than 1.0 for at least one receptor in the ERA) are discussed in Section 4.8.

[a] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values. Mean concentrations were not calculated if the detection frequency was less than 10% or if fewer than three samples had detected concentrations.

[b] RLs are for only non-detected samples.

COC – contaminant of concern
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effect level
na – not applicable
nc – not calculated
RL – reporting limit

Metals were detected in most of the lake sediment samples (Figures 4-22 to 4-26). Concentrations were lower or not detected in Force Lake subsurface sediment samples, indicating that the vertical extent of metals has been adequately delineated.

With the exception of copper, concentrations of metals in North Lake sediment were either lower than those in Force Lake or were similar to background sediment concentrations, indicating that there had been limited migration of metals into North Lake. Concentrations of copper were similar in North Lake and Force Lake.

When compared to conservative residential human health RSLs, only arsenic was greater than the RSL (in all lake sediment samples). However, all arsenic samples were less than or equal to the sediment background concentration (7 to 7.9 mg/kg dw). No metals were detected at concentrations greater than the invertebrate screening level. Note that the comparison with conservative screening levels on a point-by-point basis should not be viewed as a risk estimate; risks were fully assessed in the ERA and HHRA as presented in Appendices I and J and summarized in Section 6.0.

Only two of the metals discussed in this section were detected in lake surface water. Arsenic was detected in all three of the surface water samples at concentrations greater than the human health RSL, and copper was detected in one of the three samples at a concentration greater than the ecological screening level.

4.5.3 Additional Information Regarding Arsenic Concentrations in Groundwater

As discussed in Section 4.5.2.2, arsenic was detected in groundwater samples at concentrations greater than the MCL (10 µg/L) in approximately half of the shallow groundwater samples at the Facility. Dissolved arsenic concentrations in shallow groundwater samples ranged from 0.8 µg/L to a maximum detected concentration of 32.2 µg/L (Figure 4-27). Arsenic concentrations were less than the MCL in intermediate and deep groundwater samples.

The following subsections present additional information to provide perspective on the arsenic concentrations in groundwater at the Study Area. Section 4.5.3.1 discusses regional arsenic groundwater concentrations, Section 4.5.3.2 discusses the potential for arsenic concentrations in groundwater to be the result of site-related contamination, and Section 4.5.3.3 presents a summary of this information and conclusions regarding arsenic concentrations in shallow groundwater.

4.5.3.1 Regional Arsenic Concentrations in Groundwater

A literature review was conducted to further evaluate regional arsenic concentrations in groundwater. A US Geological Survey (USGS) study entitled *Arsenic in Groundwater of the Willamette Basin* provided the following information regarding arsenic concentrations in groundwater in this region (Hinkle and Polette 1999):

- Elevated arsenic concentrations, defined as concentrations greater than 50 µg/L in this report, were commonly associated with alluvial sediments and silicic volcanic rocks in the Willamette Basin. In alluvial sediments, naturally occurring arsenic is commonly sorbed by or coprecipitated with iron oxides or sorbed to clay mineral surfaces.
- "Naturally occurring" concentrations of arsenic in the groundwater of the Willamette Basin ranged from less than 1 µg/L to 2,000 µg/L at 728 spatially distinct locations.
- Arsenic concentrations in groundwater (greater than 10 µg/L but less than 50 µg/L) are widespread and found in many parts of the Willamette Basin and in a variety of geologic materials. Arsenic concentrations in groundwater greater than the MCL of 10 µg/L were detected in 21.7% of the 728 spatially distinct samples.

Additional studies conducted by DEQ were reported in the *Molalla-Pudding Sub basin Total Maximum Daily Load (TMDL) and Water Quality Management Plan (WQMP)* (DEQ 2008b), which described arsenic concentrations in groundwater of the eastern Willamette Basin. As part of these studies, arsenic was analyzed in groundwater samples collected from 18 shallow wells in the Woodburn and Canby areas (south of Portland). The median dissolved arsenic concentration reported for these samples was 6.5 µg/L; the dissolved concentrations ranged from less than 5 to 21 µg/L. Thus, the DEQ report supports the USGS study conclusion that arsenic concentrations in groundwater greater than the 10 µg/L MCL are not unusual.

For reference, Table 4-16 presents arsenic concentrations in groundwater samples collected from the Study Area compared with arsenic concentrations from the USGS and DEQ reports. Median concentrations were similar in the DEQ and Harbor Oil datasets and maximum concentrations were well within the range reported in the USGS study.

Table 4-16. Summary of Regional Arsenic Concentrations in Groundwater

Study	Fraction	Count of Samples	Arsenic Concentration (µg/L)			Percent of Samples > MCL of 10 µg/L
			Median	Minimum	Maximum	
USGS	dissolved and total[a]	728	nr	< 1	2,000	21.7%
DEQ	dissolved	18	6.5	< 5	21	nr
	total	35	5	< 5	22	nr
Harbor Oil RI	dissolved	27	10	< 0.2	32.2	44%
	total	34	9.7	< 0.3	31.6	47%

[a] Samples analyzed for dissolved and total arsenic were reported together in this report based on an analysis that indicated these concentrations were similar.

DEQ – Oregon Department of Environmental Quality

MCL – maximum contaminant level

nr – not reported

USGS – US Geological Survey

4.5.3.2 Potential for Arsenic Concentrations in Groundwater to be the Result of Site-Related Contamination

Facility groundwater data were examined to specifically assess whether arsenic concentrations could be related to Facility operations, with a focus on the following questions.

1. Could Facility-related waste oils be the source of arsenic at the Study Area?
2. Are higher arsenic concentrations in groundwater found in areas with higher arsenic concentrations in soil?
3. Are arsenic concentrations in groundwater at neighboring properties similar to those at the Study Area?
4. Can arsenic concentrations at the Study Area be explained based on geochemical and physical conditions?

In response to the first question, arsenic can be a component of waste oils. If waste oils were the source of arsenic in the Study Area, then higher arsenic concentrations would be expected to be co-located with other components of waste oils, such as TPHs and PAHs. Thus, correlation analyses were conducted for arsenic and TPHs and for arsenic and PAHs in Facility soil samples. No relationships were found between samples with high TPH or PAH concentrations and arsenic concentrations greater than the regional soil background concentration of 7 mg/kg dw (R^2 values were less than 0.006). Thus, higher arsenic concentrations in soil do not appear to be related to waste oils.

In response to the second question, the distribution of arsenic concentrations in co-located soil and shallow groundwater samples was evaluated to determine if there was a correlation. Arsenic concentrations in soil at or near all well locations were relatively homogeneous, ranging from approximately 1.8 mg/kg dw near well GA-34 to 10.6 mg/kg dw near well A-18. No relationship between soil and groundwater arsenic concentrations was apparent, indicating that concentrations of arsenic in the soil do not appear to explain the distribution of arsenic concentrations in shallow groundwater at the Facility.

In response to the third question, groundwater data from the 1990 Golder Associates investigation were examined. In this investigation, Golder Associates, Inc., completed a subsurface investigation of the nearby Stockyards property, which included the collection of arsenic data for shallow groundwater at several locations on the Stockyards property, the Peninsula Terminal property, and the Harbor Oil property. Although the data from the Golder investigation was not be used for the Harbor Oil RI based on the data quality screen (because of a lack of QA/QC documentation), the data are useful in evaluating whether the arsenic concentrations in groundwater are consistent with concentrations at nearby sites. Arsenic concentrations in shallow groundwater in the Golder Associates investigation were as follows:

- **Stockyards property**: Arsenic concentrations ranged from 2.4 to 6 µg/L (maximum concentration was detected in well A-10).

- **Peninsula Terminal property**: Arsenic concentrations ranged from 2.4 to 3.4 µg/L (maximum concentration was detected in well GA-26).
- **Harbor Oil property**: Arsenic concentrations ranged from 2.1 to 3.6 µg/L (maximum concentration was detected in well A-18, located in the northwestern portion of the Facility).

The Stockyards and the Peninsula Terminal properties are located to the north of Harbor Oil in hydraulically up-gradient locations and had concentrations that are similar to those reported at the Harbor Oil property in this RI, supporting the contention that arsenic concentrations in groundwater did not appear to have a source at the Facility prior to 1990. Available information suggests that since that time, practices at the Facility have been well regulated. Additionally, arsenic concentrations in groundwater systems can vary based on seasonal or methodological differences (Hinkle and Polette 1999), and thus the differences between current arsenic concentrations at the Study Area and those from 1990 may not be significant.

In response to the fourth question, geochemical conditions at the Study Area were considered. As a naturally occurring metal in soil, arsenic is ubiquitous in groundwater. The potential for arsenic to partition from soil to groundwater varies for different soil types and horizons depending on localized geochemical conditions (e.g., dissolved oxygen [DO] levels, redox potential, and pH). At the Facility, arsenic concentrations were higher in shallow groundwater than in deeper groundwater. This difference may be attributable to differing soil types in these horizons rather than specific Facility-related sources. The shallow wells were screened predominantly within fine sands, silts and clays, while the deeper wells were screened across zones that consisted predominantly of sands with little to no silt and clay.

With regard to geochemical conditions, the DEQ report describes the co-occurrence of higher concentrations of arsenic, iron, and manganese in groundwater where dissolved oxygen levels were low, with the highest concentrations of metals detected at locations with lower DO levels (less than 3 mg/L) (DEQ 2008b). The sample with the highest detected arsenic concentration had a DO level of less than 0.5 mg/L. The low DO levels in groundwater at the Study Area (all were less than 0.5 mg/L, regardless of depth) favor the mobilization of metals from soil matrices. Combined with a differing soil matrix in the shallow horizon, higher concentrations of arsenic in shallow groundwater relative to deeper horizons are not inconsistent with naturally occurring conditions.

To further evaluate this theory, concentrations of iron and manganese (two other redox-sensitive metals) were compared with arsenic concentrations. Concentrations of manganese and iron were also several times higher in shallow groundwater than in intermediate and deep groundwater samples. A correlation analysis found a relationship both between concentrations of arsenic and iron and between arsenic and manganese in groundwater (R^2 values were equal to 0.6 and 0.3, respectively), supporting the idea that all three metals are mobilized in

response to the low redox conditions. Thus, the distribution of arsenic at the Study Area may well be related to soil type and low redox conditions rather than a Facility-specific source.

4.5.3.3 Summary

Dissolved arsenic concentrations detected in shallow groundwater samples at the Harbor Oil Facility ranged from 0.8 µg/L to a maximum detected concentration of 32.2 µg/L. Available information regarding regional concentrations of naturally occurring arsenic in groundwater suggests that concentrations greater than 10 µg/L but less than 50 µg/L are widespread and found in many parts of the Willamette Basin (Hinkle and Polette 1999). Furthermore, geochemical and geologic conditions in shallow groundwater at the Study Area are conducive to arsenic mobilization from the soil matrix under naturally occurring conditions. Thus, based on the various lines of evidence presented in the previous subsections, it is reasonable to conclude that the arsenic concentrations detected in shallow groundwater during the RI sampling events are likely a function of naturally-occurring arsenic in shallow soils in the area, and are not attributable to Facility-related releases.

4.5.4 Summary for Metals

In the Study Area, the areas with the highest concentrations of metals included the west corner of the Facility, the area of the former unlined holding pond/C-shaped area, the former drainage ditch to the west of the Facility, and the area near the current and former stormwater treatment system discharge points near the southwest corner of the Facility (Figures 4-22 to 4-26). The portions of the Facility with the highest concentrations of metals were areas that likely collected stormwater and wastewater until they were later filled to expand the Facility.

In general, the locations of the highest metals concentrations suggest that the distribution of metals in the Study Area was influenced by stormwater or industrial waste water drainage from the Facility (Section 4.2.2). However, the highest concentrations of metals (except copper and mercury) were detected in the wetlands, indicating that either the Facility was not the primary source of these metals or the metals accumulated at greater concentrations in the wetlands than at the Facility (Figure 4-21). Detected metals concentrations in Force and North Lake sediment were lower than those for Facility or wetland soil (Figure 4-21).

Concentrations of metals were compared to the conservative screening levels and/or background concentrations. Arsenic concentrations were greater than conservative industrial and/or residential human health RSLs in the majority of samples, but only eight samples collected from the west corner of the Facility had concentrations that were greater than the background concentration. Chromium, copper, and mercury were also detected at concentrations greater than conservative industrial and/or residential human health RSLs at the Facility (also in the west corner of the Facility). In groundwater, arsenic and zinc were detected at concentrations greater than the conservative human health RSL. In wetland soil, concentrations of metals detected at concentrations greater

than conservative residential human health RSLs or invertebrate screening levels (or background concentrations for arsenic) were generally located in the former drainage ditch area to the west of the Facility and in the south corner of the Facility near the current and former stormwater treatment system discharge points. No lake sediment samples were greater than these values, but concentrations of arsenic and copper were greater than conservative invertebrate screening levels in at least one Force Lake water sample. Risks for metals were fully assessed in the ERA and HHRA as presented in Appendices I and J and summarized in Section 6.0.

The comparison of metals concentrations to conservative screening levels and background concentrations, as shown in Figures 4-22 to 4-31, indicates that higher concentrations of metals were generally bounded both vertically and laterally. Thus, metals have been adequately delineated and the available data meet the DQOs identified in the RI/FS Work Plan (Bridgewater et al. 2008b).

4.6 DDTs

This section presents an overview of source information, fate and transport, and media-specific data for DDTs. Historical records of industrial activities at the Facility did not include any information documenting the use or handling of DDTs at the Facility. However, DDTs have been detected in samples collected from the Study Area, with distribution patterns that suggest that DDTs in a portion of the Study Area may have been released from historical livestock trailer washing operations at the Facility, while DDTs across the larger Study Area may have been released as a result of typical pest control applications in the area.

In the HHRA, total DDTs were identified as a COC based on potential future worker exposure to Facility soil and based on indirect exposure to Force Lake sediment through fish consumption. In the ERA, DDD and DDE concentrations (but not total DDT concentrations) in Force Lake sediments had effects-based HQs greater than 1.0 for invertebrates, and total DDTs in wetland soil had LOAEL-based HQs greater than 1.0 for red-tailed hawk and shrew.

This section discusses total DDTs, which are calculated as the sum of 2,4′-DDD, 4,4′-DDD, 2,4′-DDE, 4,4′-DDE, 2,4′-DDD, and 4,4′-DDD (Appendix N). This section also discusses DDT metabolites, or breakdown products, which include DDD and DDE isomers.

4.6.1 Known or Suspected Sources and Release Mechanisms

No specific DDT sources associated with the Harbor Oil Facility have been identified. Although several possible explanations regarding potential sources of DDTs have been hypothesized based on the observed distribution or possible uses of DDTs, there is no definitive information available to confirm any specific source or sources.

Because no definitive source information exists, general information regarding DDTs has been compiled, per EPA request, to provide context for the total DDT concentrations detected within the Harbor Oil Study Area. This general information and available site-specific information is presented in Section 4.6.4, along with a comparison to Study Area data.

4.6.2 Concentrations by Medium

This section presents the concentrations of total DDTs and metabolites in various media within the Study Area. Summary statistics in the tables are provided by location (not sample)[18] to be consistent with the data presented on the figures. The complete RI database is provided in Appendix B.

Figure 4-32 presents cumulative frequency distributions of total DDT concentrations in surface soil and sediment samples collected from within the Study Area. The data are presented by concentration on the x-axis and by percent frequency within the dataset on the y-axis. For example, approximately 90% of Facility surface soil samples are less than 20,000 µg/kg dw. This figure is intended to help facilitate cross-media comparisons. Total DDT concentrations were highest in Facility soil and lowest in Force Lake surface sediment. Total DDT concentrations in wetland soils were intermediate.

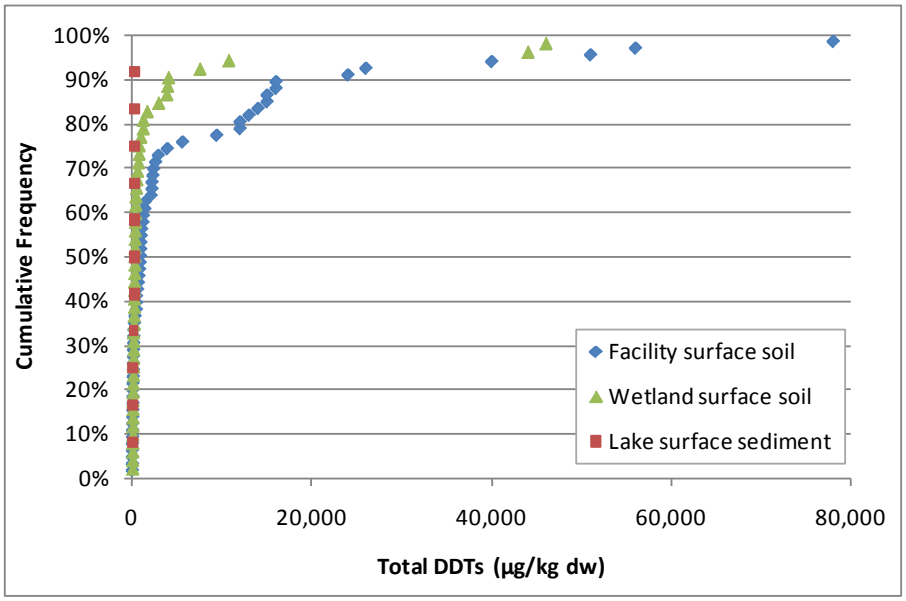
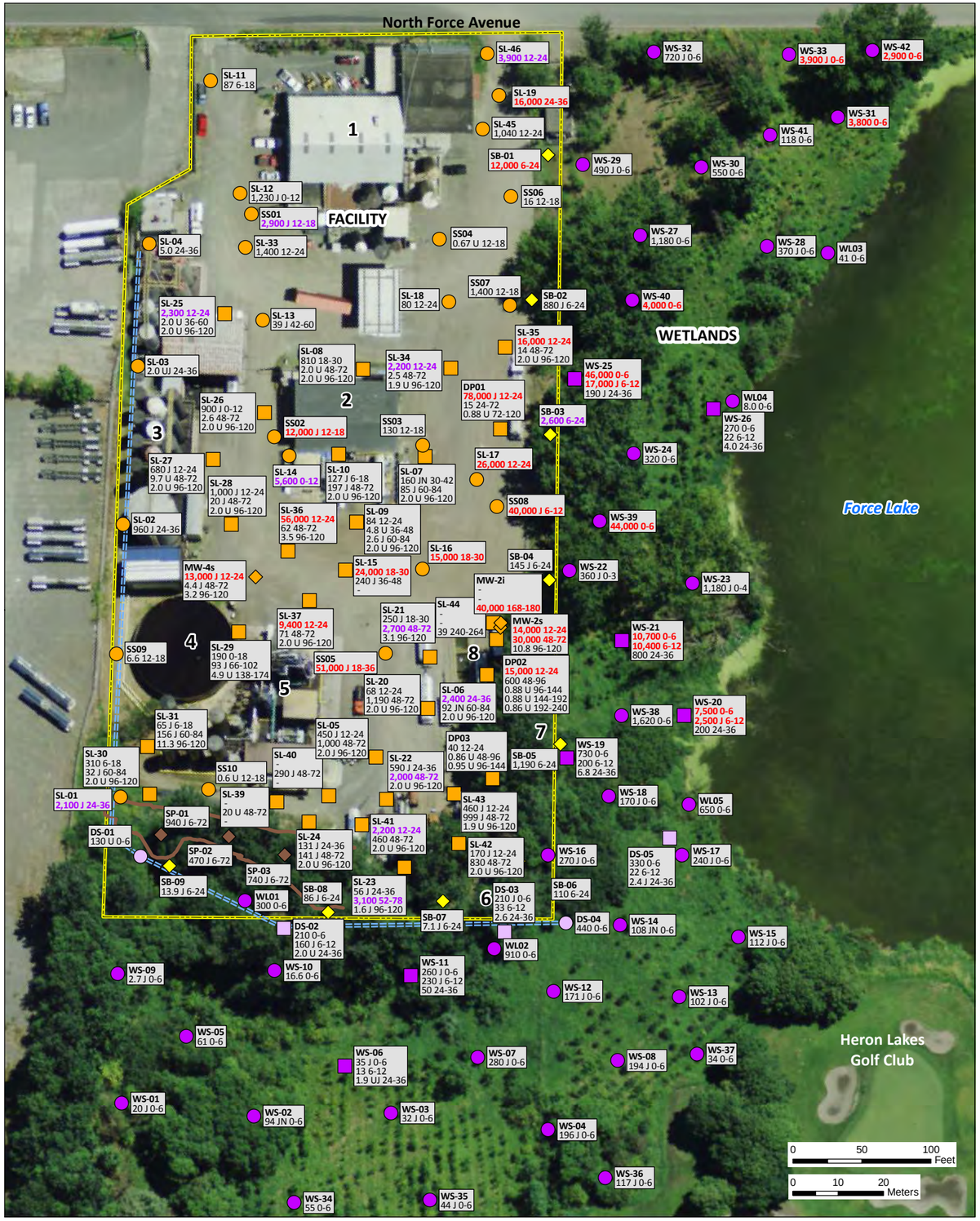


Figure 4-32. Cumulative Frequencies of Total DDTs Detected in Facility Surface Soil, Wetland Surface Soil, and Force Lake Surface Sediment

[18] Duplicate samples were combined with the original sample, as described in Appendix N.

Figure 4-33 presents total DDT concentrations at each soil and sediment location sampled; whereas Figure 4-34 presents total DDT concentrations at each groundwater and surface water location sampled. These data are discussed in the following subsections.



On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Total DDT Screening Levels

Medium	Unit	Industrial Human Health RSL[a]	Residential Human Health RSL[a]	Invertebrate Screening Level[b]
Facility soil	µg/kg dw	7,700	1,700	na
Wetland soil	µg/kg dw	na	1,700	nv
Lake sediment	µg/kg dw	na	1,700	572

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ. RSLs are based on 4,4'-DDT.
[b] Invertebrate (ecological) sediment screening levels are represented by the lower of the probable effects concentration (PEC) and probable effects level (PEL).
na - not applicable
nv - no value (i.e., no SL available for this chemical-media combination)

Facility soil samples (µg/kg dw)[a]

- Surface soil
- Subsurface and surface soil[b]
- Soil at groundwater monitoring well[b]
- Soil berm
- Soil stockpile

Wetland and ditch soil samples (µg/kg dw)

- Wetland surface soil
- Wetland surface and subsurface soil[b]
- Ditch surface soil
- Ditch surface and subsurface soil[b]

Lake sediment samples (µg/kg dw)

- Lake sediment[b]

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

[a] The following locations were not analyzed for total DDTs and do not appear on this map: shallow sample from SL 32; and intermediate sample from SL-38.

[b] Both surface and subsurface data are shown.

Location ID — SL-00
Concentration — 2,500 12-24 / 250 JN 60-84 / 25 U 96-120

Detected concentration:
exceeds highest SL = Red
exceeds lowest SL = Purple
does not exceed SL = Black

Qualifier
U=non-detect
J=estimated
N=tentatively identified

Depth in inches

Wind Ward environmental LLC

Figure 4-33. Total DDT Concentrations at Facility Soil, Wetland Soil, and Lake Sediment Sampling Locations

Prepared by CEH, 12/15/2011; MAP #3533; W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

Groundwater samples (µg/L)

- Shallow groundwater
- Intermediate groundwater
- Deep groundwater

Surface water samples (µg/L)

- Lake surface water

Wells where groundwater samples not collected

- Groundwater not sampled due to lack of construction details (trace to 0.02 ft of LNAPL observed)
- Groundwater not sampled due to lack of construction details
- Groundwater not sampled due to the presence of LNAPL (0.1 ft LNAPL observed here in 2008 when LNAPL sample was collected. After this time, trace to 0.02 ft of LNAPL observed).

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

Location ID — GA-00
Sample Year — 2000: – / 2008: 1.0 U / 2009: na
Detected concentration: exceeds SL = Red; does not exceed SL = Black
Concentration: na=not analyzed, – =not collected
Qualifier: U=non-detect, J=estimated

On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Total DDT Screening Levels

Medium	Unit	Human Health RSL	Invertebrate Screening Level
Groundwater	µg/L	0.20	na
Surface water	µg/L	not detected; no comparison to screening levels	

Note: Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ. RSLs are based on 4,4'-DDT.

na - not applicable

Wind Ward environmental LLC

Figure 4-34. Total DDT Concentrations in Unfiltered Samples at Facility Groundwater and Lake Surface Water Sampling Locations

Prepared by CEH, 12/15/2011; MAP #3533; W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

4.6.2.1 Facility Soil

Table 4-17 summarizes concentrations of DDTs in surface and subsurface soil samples collected at the Facility. The depth intervals of these samples varied depending on the sampling location, field conditions, and the sampling event (see Section 2.2). Surface soil samples at the Facility were collected just below the gravel fill layer, if present.

Total DDTs were detected in 95% of Facility surface soil samples, with detected concentrations ranging from 5.0 to 78,000 µg/kg dw and a mean concentration of 8,000 µg/kg dw. Soil stockpile and soil berm total DDT concentrations were generally lower, with mean concentrations of 720 and 1,900 µg/kg dw, respectively. In Facility subsurface soil samples, total DDTs were detected in 82% of intermediate and 29% of deep samples, with mean concentrations of 1,300 and 1,100 µg/kg dw, respectively. Total DDTs were usually highest in the surface interval, with concentrations decreasing with depth.

A few samples in the northwest portion of the Facility had higher concentrations in the intermediate interval relative to the surface and deep intervals of those samples (e.g., SL-21 and SL-23). At MW-2i, only a deep soil sample was collected; it had a detected concentration of 40,000 µg/kg dw total DDTs. This sample (MW-2i) was collected from an area that was undeveloped during the early history of the Facility, a low area that reportedly included unlined sumps and a possible bermed area and holding pond used for the management of surface water discharges from upland portions of the Facility. This area was filled in the late 1970s or early 1980s as the Facility was expanded to the west and southwest, which may explain the presence of higher DDT concentrations at depth in this area. In addition, this sample was collected from an area (MW-2i) where DDTs were detected in all shallow, intermediate, and deep groundwater samples, as discussed in Section 4.5.3.3.

Table 4-17. Concentrations of DDTs Detected in at Least One Facility Soil Sample

Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
	Ratio	%					
2,4′-DDD (µg/kg dw)							
Surface	34/43	79	7.4	12,000	SL-36	1,000	2.0 – 540
Intermediate	18/31	58	2.8	5,800	MW-2s	280	1.9 – 20
Deep	4/30	13	2.2	3,400	MW-2i	110	1.9 – 4.9
Soil stockpile	3/3	100	96	250	SP-01	170	na
Soil berm	6/9	67	17	950	SB-01	170	4.9 – 5.0
4,4′-DDD (µg/kg dw)							
Surface	53/56	95	5.0	64,000	DP01	6,000	0.6 – 2.0
Intermediate	28/34	82	2.5	21,000	MW-2s	940	0.86 – 9.7
Deep	10/35	29	1.6 J	14,000	MW-2i	400	0.86 – 4.9
Soil stockpile	3/3	100	310	580	SP-01	440	na
Soil berm	7/9	78	5.0 J	1,900	SB-01	350	4.9 – 27
2,4′-DDE (µg/kg dw)							
Surface	1/43	2	7.0	7.0	SL-09	nc	2.0 – 9,600
Intermediate	0/31	0	nd	nd	nd	nc	1.9 – 990
Deep	0/30	0	nd	nd	nd	nc	1.9 – 2,400
Soil stockpile	0/3	0	nd	nd	nd	nc	5.9 – 24
Soil berm	0/9	0	nd	nd	nd	nc	4.9 – 240
4,4′-DDE (µg/kg dw)							
Surface	22/56	39	1.6	5,200 J	DP01	400	0.6 – 9,600
Intermediate	12/34	35	2.2	160	SL-23	40	0.86 – 990
Deep	1/35	3	5.1	5.1	SL-31	nc	0.86 – 2,400
Soil stockpile	3/3	100	18 J	28 J	SP-01	22	na
Soil berm	4/9	44	66	580	SB-01	97	4.9 – 6.0
2,4′-DDT (µg/kg dw)							
Surface	1/43	2	3.0 J	3.0 J	SL-31	nc	2.0 – 9,600
Intermediate	0/31	0	nd	nd	nd	nc	1.9 – 990
Deep	0/30	0	nd	nd	nd	nc	1.9 – 2,400
Soil stockpile	0/3	0	nd	nd	nd	nc	5.9 – 24
Soil berm	4/9	44	94 J	920	SB-01	160	4.9 – 6.0
4,4′-DDT (µg/kg dw)							
Surface	22/56	39	5.6	8,400	DP01	600	0.6 – 9,600
Intermediate	9/34	26	0.95	2,700	MW-2s	96	0.86 – 97
Deep	1/35	3	23,000	23,000	MW-2i	nc	0.86 – 4.9
Soil stockpile	3/3	100	42 J	130	SP-03	84	na
Soil berm	9/9	100	7.1 J	7,600	SB-01	1,100	na
Total DDTs (µg/kg dw)							
Surface	53/56	95	5.0	78,000 J	DP01	8,000	0.6 – 2.0

Table 4-17. Concentrations of DDTs Detected in at Least One Facility Soil Sample (cont.)

Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
	Ratio	%					
Intermediate	28/34	82	2.5	30,000	MW-2s	1,300	0.86 – 20
Deep	10/35	29	1.6 J	40,000	MW-2i	1,100	0.86 – 4.9
Soil stockpile	3/3	100	470 J	940 J	SP-01	720	na
Soil berm	9/9	100	7.1 J	12,000	SB-01	1,900	na

[a] Surface soil samples were collected immediately below the gravel layer from depths of 0 to 5 ft bgs (0.5- to 1.5-ft sampling intervals for a given sample). Intermediate soil samples were collected from depths of 2 to 8.5 ft bgs (1- to 4-ft sampling intervals for a given sample). Deep soil samples were collected from depths of 6 to 22 ft bgs (1- to 4-ft sampling intervals for a given sample). All soil berm samples were collected from 0.5 to 2 ft bgs, and all soil stockpile samples were collected from 0.5 to 6 ft bgs.

[b] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values. Mean concentrations were not calculated if the detection frequency was less than 10% or if fewer than three samples had detected concentrations.

[c] RLs are for only non-detected samples.

bgs – below ground surface
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
J – estimated concentration
na – not applicable
nc – not calculated
nd – not detected
RL – reporting limit

Figure 4-33 presents total DDT concentrations in soil at the Facility. Total DDT concentrations were highest (i.e., greater than 10,000 µg/kg dw) in the central portion of the Facility near the former truck cleaning operation, in the C-shaped area to the west of the former truck cleaning operation, and along the southwest boundary of the Facility. Concentrations of DDTs greater than 2,000 µg/kg dw were detected in the north corner of the Facility and in the northwest portion of the Facility near the soil stockpile. The fact that these areas had the highest DDT concentrations suggests that the former truck cleaning operation could have been a source of DDTs at the Facility. In addition, total DDTs were detected at a concentration of 40,000 µg/kg dw in the deep soil sample collected from MW-2i. This sampling location was in an area where historical documents and aerial photographs (Appendix A) suggest the presence of unlined sumps and holding ponds. As described in Section 4.6.4.5, these features, in conjunction with the predominance of livestock trailer washing activities upslope from this area, may help explain the higher DDT concentrations at depth in this area.

The available Facility soil data indicate that concentrations greater than the conservative industrial human health RSL (7,700 µg/kg dw) were limited in extent to the central portion of the Facility (e.g., SL-15 and SS05) and to the southwest boundary of the Facility (e.g., DP02 and SS08). Concentrations of DDTs were also greater than the conservative residential human health RSL (1,700 µg/kg dw) in samples near the Facility exit (SL-25 and SS01) and in samples in the west corner of the Facility (e.g., SL-22 and SL-41). Note that the comparison with conservative screening levels on a point-by-point basis should not be viewed as a risk estimate; risks were fully assessed in the HHRA as presented in Appendix I and summarized in Section 6.1. Higher concentrations of total DDTs were generally bounded both vertically and laterally in Facility soil, indicating that DDTs have been adequately delineated and the available data meet the DQOs identified in the RI/FS Work Plan (Bridgewater et al. 2008b).

4.6.2.2 Groundwater

Table 4-18 summarizes concentrations of detected DDTs in groundwater. Of the six component total DDTs, only two were detected in groundwater, including 2,4′-DDD and 4,4′-DDD.

DDTs were analyzed in unfiltered (i.e., total) water samples from all locations sampled. In addition, a subset of samples collected as part of the Phase 2 RI sampling event were analyzed for DDTs in filtered (i.e., dissolved) samples to evaluate the effect of particulates on DDT concentrations in groundwater. Samples with detectable concentrations of DDTs in unfiltered water often also had detectable DDT concentrations in the filtered water. Concentrations of DDTs in filtered water ranged from 30 to 100% of the unfiltered water concentration. The fact that DDTs were detected in filtered water samples indicates that concentrations in groundwater samples were not attributable solely to the presence of particulates.

Table 4-18. Concentrations of DDTs Detected in at Least One Groundwater Sample

Sample Type[a]	Fraction	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
2,4′-DDD (µg/L)								
Shallow	D	1/4	25	0.014	0.014	MW-2s	nc	0.010
	T	6/22	27	0.0063 J	0.032	MW-2s	0.0082	0.010
Intermediate	D	0/1	0	nd	nd	nd	nc	0.010
	T	1/4	25	0.012	0.012	MW-2i	nc	0.010
Deep	D	0/1	0	nd	nd	nd	nc	0.010
	T	1/3	33	0.0073 J	0.0073 J	B-4	nc	0.010
4,4′-DDD (µg/L)								
Shallow	D	2/4	50	0.011	0.059 J	MW-2s	nc	0.010
	T	12/28	43	0.0071 J	0.24 J	A-20	0.027	0.010 – 0.019
Intermediate	D	1/1	100	0.017	0.017	MW-2i	nc	na
	T	2/4	50	0.015	0.036	MW-2i	nc	0.010
Deep	D	1/1	100	0.011	0.011	B-4	nc	na
	T	2/4	50	0.012	0.014	B-4	nc	0.010 – 0.018
Total DDTs (µg/L)								
Shallow	D	2/4	50	0.011	0.073 J	MW-2s	nc	0.010
	T	12/28	43	0.0071 J	0.24 J	A-20	0.030	0.010 – 0.019
Intermediate	D	1/1	100	0.017	0.017	MW-2i	nc	na
	T	2/4	50	0.015	0.048	MW-2i	nc	0.010
Deep	D	1/1	100	0.011	0.011	B-4	nc	na
	T	2/4	50	0.012	0.021 J	B-4	nc	0.010 – 0.018

[a] The depth of shallow groundwater wells ranged from 10 to 20 ft bgs, the depth of intermediate wells ranged from 48 to 50 ft bgs, and the depth of the deep well was 97 ft bgs.

[b] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values. Mean concentrations were not calculated if the detection frequency was less than 10% or if fewer than three samples had detected concentrations.

[c] RLs are for only non-detected samples.

bgs – below ground surface
D – dissolved water concentration (i.e., filtered)
DDD – dichlorodiphenyldichloroethane
DDT – dichlorodiphenyltrichloroethane
J – estimated concentration
na – not applicable
nc – not calculated
nd – not detected
RL – reporting limit
T – total water concentration (i.e., unfiltered)

DDTs were detected in shallow groundwater samples in some of the areas where DDT concentrations in soil samples were highest (i.e., greater than 10,000 µg/kg dw) (Section 4.5.3.1), including the central portion of the Facility, the exit driveway, and along the southwest boundary of the Facility (Figure 4-34).

Concentrations of DDTs were detected in deeper groundwater samples from the MW-2s/MW-2i/B-4 well cluster in the south-central portion of the Facility but were not detected in any other groundwater samples collected from intermediate monitoring wells or the plant well (PW-01). DDTs were detected in the sample from the intermediate-depth well MW-2i in 2008 and 2009 and in the sample from the deep well B-4 in 2008 and 2009. The soil sample collected at monitoring well MW-2i had a detected total DDT concentration of 40,000 µg/kg dw at a depth of 14 to 15 ft. bgs. Given the low mobility of DDTs, one possible explanation for the presence of DDTs in intermediate and deep wells is that B-4 is an older well established prior to 1990 and may have served as a conduit for the deeper migration of DDTs from surrounding soils. However, the mobility of DDTs in soil is usually low.

No MCL or non-zero MCLG was available for DDTs.

4.6.2.3 LNAPL

In 2000, EPA collected an LNAPL sample (layer thickness unknown) from shallow well GA-30 (in the uppermost groundwater zone) in the northwest portion of the Facility near the soil stockpile. In 2008, another sample was collected from this shallow well as part of the Phase I RI activities when a thin layer (approximately 0.1 ft) of LNAPL was observed at this location. DDTs were analyzed only in the 2008 sample and DDTs were not detected.

Follow-up monitoring, including a year of monthly measurements, revealed thin layers of LNAPL (0.01 to 0.02 ft) in GA-30, although no LNAPL was observed in downgradient wells GA-29 and MW-1s (see Figure 2-2 for well locations). Thus, the lateral extent of LNAPL appears to be limited to the area immediately surrounding well GA-30.

4.6.2.4 Wetland and Ditch Soil

Table 4-19 summarizes concentrations of DDTs in wetland and ditch surface and subsurface soil samples.

Table 4-19. Concentrations of DDTs Detected in at Least One Wetland and Ditch Soil Sample

Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
	Ratio	%					
2,4′-DDD (µg/kg dw)							
Surface	32/47	68	4.2	7,700	WS-39	360	1.9 – 78
Intermediate	8/10	80	6.4	890 J	WS-25	240	2.0
Deep	5/10	50	2.2	53	WS-21	14	1.9 – 2.0
4,4′-DDD (µg/kg dw)							
Surface	49/52	94	2.4 J	27,000	WS-39	900	2.5 – 130
Intermediate	10/10	100	2.6	1,900	WS-25	560	na
Deep	7/10	70	2.4 J	140	WS-20	30	1.9 – 2.0
2,4′-DDE (µg/kg dw)							
Surface	4/47	9	4.5 J	370	WS-25	39	1.9 – 980
Intermediate	0/10	0	nd	nd	nd	nc	2.0 – 960
Deep	0/10	0	nd	nd	nd	nc	1.9 – 39
4,4′-DDE (µg/kg dw)							
Surface	40/52	77	3.8	2,700	WS-25	220	2.4 – 980
Intermediate	8/10	80	3.9	2,400	WS-21	370	2.0 – 20
Deep	5/10	50	4.0	170	WS-21	21	1.9 – 2.0
2,4′-DDT (µg/kg dw)							
Surface	20/47	43	6.6	11,000	WS-25	330	1.9 – 160
Intermediate	2/10	20	740	3,300	WS-25	nc	2.0 – 200
Deep	2/10	20	33	57	WS-21	nc	1.9 – 9.7
4,4′-DDT (µg/kg dw)							
Surface	36/52	69	2.6	27,000	WS-25	890	0.97 – 160
Intermediate	4/10	40	3.0	10,000	WS-25	1,500	2.0 – 200
Deep	2/10	20	110 J	420	WS-21	nc	1.9 – 9.7
Total DDTs (µg/kg dw)							
Surface	51/52	98	2.7 J	46,000	WS-25	3,000	130
Intermediate	10/10	100	13	17,000 J	WS-25	3,100	na
Deep	8/10	80	2.4 J	800	WS-21	130	1.9 – 2.0

[a] Surface soil samples were collected from 0 to 0.5 ft bgs, intermediate soil samples were collected from 0.5 to 1 ft bgs, and deep soil samples were collected from 2 to 3 ft bgs.

[b] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values. Mean concentrations were not calculated if the detection frequency was less than 10% or if fewer than three samples had detected concentrations.

[c] RLs are for only non-detected samples.

bgs – below ground surface
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
J – estimated concentration
na – not applicable
nc – not calculated
nd – not detected
RL – reporting limit

Total DDTs were detected in 98% of surface wetland and ditch soil samples, with detected concentrations ranging from 2.7 to 46,000 µg/kg dw and a mean concentration of 3,000 µg/kg dw. In subsurface soil samples, total DDTs were detected in 100% of intermediate and 80% of deep soil samples, with mean concentrations of 3,100 and 130 µg/kg dw, respectively. As shown in Figure 4-33, DDT concentrations were always highest in the surface interval on a location-by-location basis, with concentrations decreasing with depth.

Figure 4-33 presents total DDT concentrations for wetland and ditch soil. Total DDT concentrations in the wetland and ditch soil were generally similar to or lower than those detected in Facility soil; the highest total DDT concentrations were detected at the Facility (Figure 4-32). The highest total DDT concentrations in the wetlands were detected at WS-25 and WS-39 (46,000 and 44,000 µg/kg dw, respectively), which are located just southwest of the Facility approximately halfway between North Force Avenue and the drainage ditch. Total DDT concentrations were greater than 1,700 µg/kg dw, the conservative residential human health RSL, at other locations in this area (WS-20, WS-21, and WS-40). Concentrations of DDTs were generally usually low in samples collected from the periphery of the wetlands, except for several sampling locations adjacent to North Force Avenue (WS-31, WS-33, and WS-42).

As discussed above, higher concentrations of total DDTs were generally bounded both vertically and laterally in wetland and ditch soil, indicating that DDTs have been adequately delineated and the available data meet the DQOs identified in the RI/FS Work Plan (Bridgewater et al. 2008b).

4.6.2.5 Lake Sediment and Surface Water

Table 4-20 summarizes concentrations of detected DDTs in lake sediment samples. Of the six components of total DDTs, three were detected in lake sediment (2,4′-DDD, 4,4′-DDD, and 4,4′-DDE).

No DDTs were detected in lake surface water samples (RLs for all samples were equal to 0.01 µg/L).

Total DDTs were detected in 100% of surface sediment samples collected from Force Lake, with concentrations ranging from 22 to 250 µg/kg dw and a mean of 160 µg/kg dw. The mean total DDT concentration in Force Lake surface sediment (160 µg/kg dw) was significantly less than the mean concentration in Facility surface soil (8,000 µg/kg dw) and was well below the mean detected concentration in wetland surface soil (3,000 µg/kg dw) (Figure 4-32).

Total DDTs were detected in one of the three subsurface (intermediate and deep) sediment samples collected from Force Lake, at a concentration of 4.5 µg/kg dw. These data indicate that the vertical extent of DDTs is limited. In addition, total DDTs were detected in one of the three surface sediment samples collected from North Lake, at a concentration of 51 µg/kg dw.

Table 4-20. Concentrations of DDTs Detected in at Least One Lake Sediment Sample

Sampling Location	Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
2,4′-DDD (µg/kg dw)								
Force Lake	surface	8/11	73	8.6 JN	61 JN	SE-05	32	4.8 – 25
	intermediate	0/3	0	nd	nd	nd	nc	1.9 – 2.0
North Lake	surface	0/3	0	nd	nd	nd	nc	23 – 25
4,4′-DDD (µg/kg dw)								
Force Lake	surface	11/11	100	11 J	47	SE-05	37	na
	intermediate	0/3	0	nd	nd	nd	nc	1.9 – 2.0
North Lake	surface	1/3	33	25 J	25 J	SE-101	nc	23 – 25
4,4′-DDE (µg/kg dw)								
Force Lake	surface	11/11	100	9.1	150	SE-06	92	na
	intermediate	1/3	33	4.5	4.5	SE-10	nc	2.0
North Lake	surface	1/3	33	26	26	SE-101	nc	23 – 25
Total DDTs (µg/kg dw)								
Force Lake	surface	11/11	100	22 J	250	SE-06	160	na
	intermediate	1/3	33	4.5	4.5	SE-10	nc	2.0
North Lake	surface	1/3	33	51 J	51 J	SE-101	nc	23 – 25

[a] Surface lake sediment samples were collected from 0 to 4 in. below the mudline, and intermediate lake sediment samples were collected from 2 to 3 ft below the mudline.

[b] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values. Mean concentrations were not calculated if the detection frequency was less than 10% or if fewer than three samples had detected concentrations.

[c] RLs are for only non-detected samples.

DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
J – estimated concentration
N – tentative identification
na – not applicable
nc – not calculated
nd – not detected
RL – reporting limit

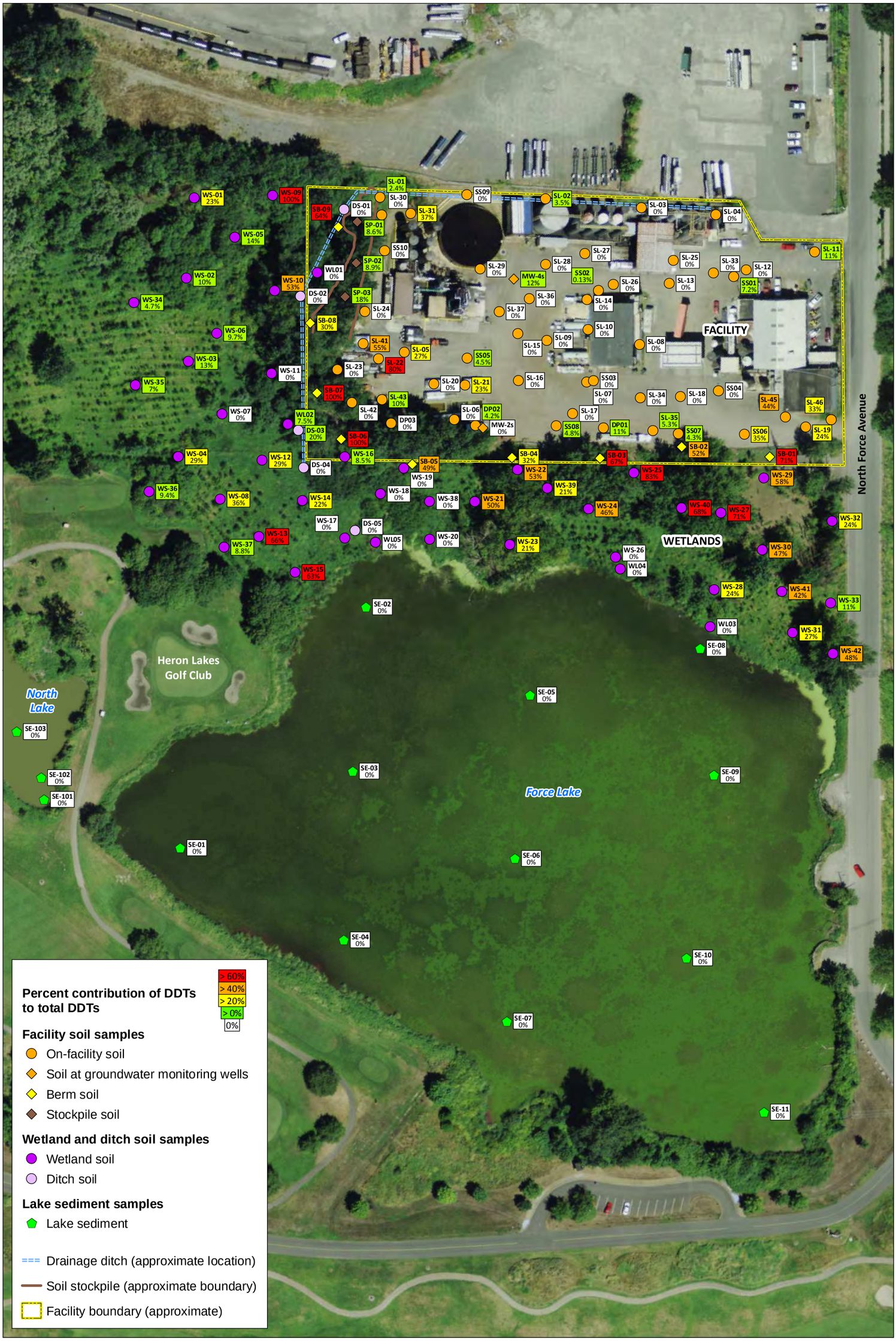
Concentrations in surface sediment were all less than the invertebrate screening level for total DDTs. However, as discussed in Section 6.2 and Appendix J (ERA), the concentrations of DDE and DDD were greater than screening levels at some of the sediment sampling locations (see Section 5.1.1 in Appendix J for a full discussion).

4.6.3 Percent Contribution of DDD, DDE, and DDT

In addition to the distribution of total DDT concentrations, the percent contribution of DDD (2,4′-DDD or 4,4′-DDD), DDE (2,4′-DDE or 4,4′-DDE), and DDT (2,4′-DDT or 4,4′-DDT) was also examined. Because of the tendency of DDT to break down into DDD and DDE (Section 4.6.2), a low percent DDT may indicate an old source or higher rates of DDT degradation.

As shown in Figure 4-35, throughout most of the Facility, in the west portion of the wetlands, and in Force Lake sediment, the percent DDT was very low (less than 20% DDT). Locations with the highest percent DDT (greater than 60%) include the soil berm and some nearby samples, one location in the northwest portion of the Facility near the stockpile (SL-22), two locations southwest of the Facility in the wetlands (WS-27 and WS-40), and two locations just west of the ditch in the wetlands (WS-13 and WS-15). With the exception of WS-25, all samples with higher percent DDT were surface soil samples. At location WS-25, the surface, intermediate, and deep wetland soil samples all contained greater than 60% DDT. These areas of high percent DDT do not correspond with areas with higher total DDT concentrations, indicating that percent DDT is not a function of total DDT concentrations.

As previously noted, areas with low percent DDTs may indicate areas impacted by an older release, although DDT degradation rates may vary greatly based on environmental conditions. The soil berm, an area with higher percent DDTs, was constructed around the northwest and southwest sides of the Facility after the 1979 Facility fire, apparently from soil impacted by releases caused by this fire.



Wind Ward LLC environmental

0 100 200 Feet

0 25 50 Meters

Figure 4-35. Percent Contribution of DDT to Total DDTs (DDD, DDE, and DDT) in Facility Surface Soil, Wetland Surface Soil, and Lake Surface Sediment Samples

Prepared by CEH, 12/15/2011, MAP #4118, W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

4.6.4 General DDT Information

Until they were banned in the United States in 1972, DDTs were widely used to control both agricultural and disease-causing pests. Thus, DDTs were released to the environment through their direct application and in association with DDT production and waste disposal. This section discusses DDT concentrations related to these pathways to provide general context for Study Area concentrations.

4.6.4.1 Soil Concentrations Associated with DDT Production or Disposal

DDTs were produced at many sites within the United States prior to their ban in 1972. Some of these sites are now Superfund sites that have data regarding residual concentrations of DDTs. Two Superfund sites were identified as having DDT concentration information, and two other sites were identified because of their regional relevance. Details regarding these sites are summarized below.

- **Baird and McGuire Superfund site (Holbrook, Massachusetts):** At this site, DDT contamination was the result of over 60 years of DDT production. In a 1985 study, average concentrations of DDD, DDE, and DDT were 70,000, 10,000, and 61,000 µg/kg dw, respectively. Summing these averages results in a total DDT concentration of 141,000 µg/kg dw (ATSDR 2002).
- **Palos Verde Shelf (Los Angeles, California):** DDT contamination at this site was the result of discharge from a DDT manufacturer. A 1996 study reported surface sediment concentrations of DDD, DDE, and DDT ranging from 10,000 to 38,000, 16,000 to 372,000, and non-detect to 8,000 µg/kg dw, respectively. Based on these numbers, approximate total DDT concentrations could have ranged from 26,000 to 418,000 µg/kg dw (ATSDR 2002).
- **Farmcraft Facility (Tigard, Oregon):** Farmcraft operated as a pesticide formulation facility between 1953 and 1983. It received raw ingredients (e.g., DDT, talc, and diesel) and then formulated, packaged, and distributed pesticides. DDT concentrations in the site soil in 1993 were as high as 4,700,000 µg/kg dw, or about 0.5% (DEQ 2008a).
- **Rhodia Facility (Portland, Oregon):** On-site disposal of pesticide wastes occurred within two ponds on this property from the 1940s through 1990. DEQ reported concentrations of 4,4′-DDT in soil at this property of up to 3,100,000 µg/kg dw. Note that no total DDT concentrations were reported.
- **Arkema Facility (Portland, Oregon):** Pennwalt, Inc., manufactured DDT at this property during the late 1940s and early 1950s. Concentrations of 4,4′-DDT in surface soils were reportedly greater than 1,200,000 µg/kg dw, with a maximum 4,4′-DDT concentration of 150,000,000 µg/kg dw reported in the DEQ database for a sample collected in 1994. Note that no total DDT concentrations were reported.

4.6.4.2 Soil Concentrations Associated with Agricultural Applications

A few studies identified through a literature search provided information related to DDT concentrations in soils following agricultural applications. A 1966 study of DDT residues in orchard soil found that three New Jersey orchards contained an average of 113 lbs of DDT per acre, most of which was in the top 4 in. of the soil (Terriere et al. 1966). Assuming loosely packed soil (75 lbs per cubic ft), this would correspond to a DDT concentration of approximately 70,000 to 100,000 µg/kg dw (DDT in the top 4 to 6 in. of soil) at the time of the study. These concentrations would likely be significantly lower now, following almost 40 years of degradation (DDT was banned in 1972).

A more recent (1998) study of DDT concentrations in soil after agricultural applications in British Columbia, Canada, reported DDT concentrations ranging from 194 to 763 µg/kg dw in silt loam soils and from 2,984 to 7,162 µg/kg dw in muck soils (Aigner et al. 1998; as cited in ATSDR 2002), indicating that the degradation rate is dependent on the soil type or environmental conditions (DDT tends to be more persistent in muck soils than in drier soils).

4.6.4.3 Soil Concentrations Associated with Pest Control

DDT was also commonly used in pest control applications throughout the United States. DDT was used in nearby Vanport City by the Housing Authority of Portland as a method of pest control in the 1940s (Maben 1987). A DDT spray (likely 5 to 10% DDT based on typical applications (Bureau of Medicine and Surgery 1944) was used at apartments to combat insect and rodent infestations. Furthermore, a July 9, 2010, discussion with Mr. Chris Wirth, program manager for Multnomah County Vector and Nuisance Control, indicated that Multnomah County would have used a DDT spray mixture in the county for mosquito control prior to the banning of DDT in 1972 (Wirth 2010). Mr. Wirth noted that the county does not have records of the volumes of pesticides that were used or the locations that were sprayed with DDT, but that the vector program would have used such a formulation because it was the standard of the day.

Although insufficient information is available to estimate soil DDT concentrations associated with the activities described above, a 1944 manual on DDT insecticide use discusses recommended DDT application rates for controlling various pests (e.g., mosquitoes and bedbugs) (Bureau of Medicine and Surgery 1944).

For mosquito control, it was recommended that 0.5 to 1 lb of DDT be applied per acre (5 to 10% DDT in kerosene or oil). Under the same assumptions as those for the New Jersey orchards described above (loosely packed soil and DDTs in the top 4 to 6 in.), concentrations of DDTs in soil would range from approximately 300 to 900 µg/kg dw at the time of application.

Similarly, for bedbug control, it was recommended that 250 cubic cm of a 5% DDT kerosene spray be used to treat each bed, which is equivalent to 0.025 lbs of DDT per bed. Assuming a high density of apartments (100 beds per acre), as was the case at Vanport City near the Study Area

(Maben 1987), this could translate into approximately 2.5 lbs of DDT per acre and a total DDT concentration in soil of approximately 2,000 µg/kg dw. With regard to the duration of application, Vanport was constructed in 1943 and was destroyed in 1948 by flooding, at which time spraying for bedbugs would have ceased. Although Vanport no longer existed after 1948, it can reasonably be assumed that the area continued to be sprayed for mosquito control, which pre-dated Vanport's existence.

The above calculations for both mosquito and bedbug control are for a single application; periodic applications were likely necessary to maintain the effectiveness of the insecticide. The *Manual on DDT Insecticide* noted that DDT was effective in preventing bedbugs for 6 months or more (Bureau of Medicine and Surgery 1944). Assuming a twice-annual application rate over 30 years (DDT was commonly used starting in 1939 until its ban in 1972), DDT concentrations in shallow soils as a result of pest control efforts could have ranged from 9,000 to 60,000 µg/kg dw.

Note that all estimated concentrations in this section are highly uncertain and are based on a number of assumptions. The duration of use or frequency of application would affect the resulting DDT concentrations in soil, as would the degradation rates and amount of time since application, among other factors.

Also of note, the Portland Union Stockyard, located to the north of the Facility, operated from 1910 to 1988 (Section 4.2.3.3). Although it is possible that DDT was used on or transferred onto this property for pest control related to livestock (e.g., the control of cattle lice or ticks), a review of available historical records and investigations at the stockyard property (Section 1.3.3.1) identified no information concerning the use of DDTs and no analysis of environmental samples for DDTs. Thus, no information is available to confirm whether DDTs were used at the stockyard. The use of DDT for pest control related to livestock was widely practiced prior to its ban in 1972. Literature suggests that DDT would typically be applied at a concentration of 0.5 to 5% in a liquid solution or 10% as a dust. For liquid application on cattle, between 0.5 and 6 gal. of the DDT mixture might be required per animal per application to sufficiently wet the animal. Although there are too many variables to estimate the resulting concentration of DDT in soil that might be tracked into a livestock transport trailer, the preceding information does describe a plausible mechanism for the identified DDT concentrations in soil proximate to the former truck cleaning operation at the Facility.

4.6.4.4 Land Use-Related DDT Concentrations in Stormwater

The above sections discussed DDT concentrations in soil associated with the production, disposal, and use of DDT prior to its ban in 1972. Even though DDT production and use are no longer authorized, DDT is persistent in the environment and is still commonly detected in environmental samples. Stormwater catch basin samples collected as part of the draft Portland Harbor RI (Integral et al. 2009) provide an indication of the typical concentrations of DDTs associated with various land uses in the vicinity of the Portland Harbor Superfund Site study area:

- Heavy industrial: 4.8 to 160,000 µg/kg dw (n = 18)

- Light industrial: 34 µg/kg dw (n = 1)
- Major transportation: 3.4 to 17 µg/kg dw (n = 2)
- Mixed land use: 6.3 to 180 µg/kg dw (n = 6)
- Open space: 3.9 µg/kg dw (n = 1)
- Residential**:** 36 to 260 µg/kg dw (n = 3)

4.6.4.5 Comparison of General DDT Information with Study Area Concentrations

General information regarding the prevalence and concentrations of DDTs in areas where they were historically produced or disposed of or where they were historically applied for agricultural or pest-control purposes, as well as in present-day urban areas (based on stormwater catch basin samples) was compiled in the previous subsections. Although this information, which is by no means exhaustive, provides a general context for the concentrations detected at the Study Area, it does not identify specific sources for those DDT concentrations. Furthermore, it should be noted that this comparison is not meant to imply that stormwater catch basin sediment is equivalent to bedded lake sediment. Instead, this comparison is meant to serve solely as a means to provide context for DDT concentrations at the Study Area.

For example, total DDT concentrations ranged from 22 to 250 µg/kg dw in Force Lake surface sediment (mean of 160 µg/kg dw) (Table 4-20). The total DDT concentrations in the vicinity of the Portland Harbor Superfund Site study area stormwater catch basin samples (Integral et al. 2009) ranged from 3.4 to 260 µg/kg dw, illustrating that total DDT concentrations in Force Lake sediments are not atypical of the concentrations of DDT present in areas that have a variety of land uses (e.g., open space, residential, transportation corridors, industrial, mixed).

With respect to soil, total DDT concentrations were highly variable at the Facility and in the wetland, ranging from 0.6 to 78,000 µg/kg dw in Facility surface soil (mean of 8,000 µg/kg dw) and from 2.7 to 46,000 µg/kg dw in wetland surface soil (mean of 3,100 µg/kg dw) (Tables 4-17 and 4-19; Figure 4-33). Even the highest of these concentrations were at the low end of the ranges reported for sites where DDTs were produced or where production-related waste was disposed (26,000 to 4,700,000 µg/kg dw).

The 1998 British Columbia study of DDT concentrations in soil resulting from historical DDT applications also reported lower concentrations (194 to 7,162 µg/kg dw, depending on the soil type); these concentrations are similar to those for the majority of samples within the Study Area. Because the adjacent Vanport City area was known to have been treated with DDT to control bedbugs, and the Study Area may have been sprayed for mosquito control, it is possible that the DDT concentrations throughout much of the Study Area are associated with these known or suspected treatments.

Explanations for the higher DDT concentrations in the central Facility area are also speculative. However, based on the Facility history, the most likely source of DDTs in this area is the former cattle truck cleaning operation. It is known that pesticides, including DDTs, were commonly

used at livestock yards for vector and insect control, typically by dusting, spraying, or dipping the animals. Trucks that were cleaned at the Facility may have been contaminated with DDTs associated with livestock applications, which could have resulted in the presence of DDTs in wash water from cleaning operations. Wash water would have migrated via sheet flow to other parts of the Facility (Section 4.2.1) and may have accumulated in sumps, holding ponds, and low-lying areas that were historically located near the southwest Facility boundary, but which have subsequently been filled. These areas likely extended into what is now considered the wetlands. This theory may best explain the distribution of DDTs in that portion of the Study Area.

4.6.5 Summary for DDTs

In the Study Area, total DDT concentrations were highest in surface soils collected at the Facility. In Facility soil, DDTs were highest in the central portion of the Facility near the former truck cleaning operation, in the C-shaped area to the west of the former truck cleaning operation, and along the southwest boundary of the Facility.

In the wetlands, total DDT concentrations were often similar to or lower than those at the Facility (Figure 4-32): the mean total DDT concentration in Facility surface soil samples was 8,000 µg/kg dw, compared with the mean concentration of 3,000 µg/kg dw in surface soil samples collected in the wetlands. The highest DDT concentrations in the wetlands were located just southwest of the Facility boundary, in close proximity to the highest DDT concentrations detected at the Facility. These higher concentrations of DDTs may be the result of the migration of wash water from the truck washing operation off of the Facility via sheet flow. This water may have accumulated in historical sumps and holding ponds along the southwest Facility boundary, which extended into what is now considered the wetlands.

Moderate DDT concentrations detected in samples near the former stormwater system discharge point and in the drainage ditch indicate that DDTs from truck washing operations also may have entered the wetlands via stormwater runoff.

Lower concentrations of DDTs (in the range 2.7 to 280 µg/kg dw) were detected in lake sediment and in the wetlands to the west of the drainage ditch. The lower DDT concentrations in this area may not be associated with the Facility, although no specific information is available to confirm this. Possible explanations for these lower concentrations of DDTs in this part of the Study Area may include the following:

- DDTs may have migrated from the former truck cleaning operation to other parts of the Study Area. Concentrations may be lower in the west wetlands because of the drainage ditch (constructed as a hydraulic control to prevent Facility stormwater from discharging into the northwestern portion of the wetlands) and may be lower in Force Lake because the wetlands acted as a buffer, preventing migration.

- The documented use of DDTs for pest control in the adjacent Vanport City and the possible use of DDT for mosquito control within the Study Area and surrounding region could explain the lower DDT concentrations (Section 4.6.1.1) at the Study Area.
- The application of DDT for agricultural or pest control purposes was common in the region from the early 1940s to 1972. As discussed in Section 4.6.4.4, DDT concentrations in Portland area stormwater catch basin samples were similar to the lower concentrations at the Study Area, potentially indicating general urban influences throughout much of the Study Area.

Thus, although there is no information to definitively identify the source of DDTs in the Study Area, based on a weight-of-evidence approach, the highest concentrations may be the result of truck cleaning operations that began in the 1950s, when DDT use was common. The history of the Facility and the concentration patterns in the Study Area indicate that the source or sources are historical and that no continuing source of DDTs exists.

4.7 Chlorinated Solvents

This section presents an overview of source information, fate and transport, and media-specific data for chlorinated solvents. None of these chemicals were identified as COCs in the HHRA or as having LOAEL-based HQs greater than 1.0 in the ERA. However, because TCE was used as part of historical tanker truck cleaning operation at the Facility, chlorinated solvents are discussed in this RI. In addition to TCE, other chlorinated solvents detected at the Study Area include 1,1,1-trichloroethane, 1,1,2-trichloroethane, 1,1-dichloroethane, chloroethane, cis-1,2-dichloroethene, PCE, and vinyl chloride.

4.7.1 Known or Suspected Sources and Release Mechanisms

The Detrex system (discussed in Sections 1.3 and 4.2) used a mixture of TCE and water to clean the internal surfaces of tanker trucks until truck cleaning operations ceased in 1994 (CEC 2002). Although tanker truck and cattle truck cleaning operations started in the 1950s, the earliest documented use of TCE as part of the Detrex system was in the late 1980s. There is no historical information suggesting that TCE or other chlorinated solvents were used in earlier truck cleaning operations.

A 1993 document (Advanced Treatment Systems 1993) indicated that the used cleaning solution was collected and then re-used in a closed-loop system (i.e., no waste products were drained to the stormwater system). However, a 1988 DEQ SI and follow-up confirmed that wash water from the truck cleaning operation drained to the wetlands via the stormwater treatment system (DEQ 1988b, c). Although the Detrex system is the only known use of TCE at the Facility, waste oils processed at the Facility may also have contained other chlorinated solvents.

Concentrations of chlorinated solvents (i.e., PCE and TCE) have been detected at relatively low and uniform concentrations in deep groundwater throughout the area. The source or sources of these chemicals have not been identified, although data do not suggest the Harbor Oil Facility to be a source, as described below. TCE was also detected in soil samples collected at the Peninsula Terminal Railroad property to the north of the Facility (Section 4.2.3).

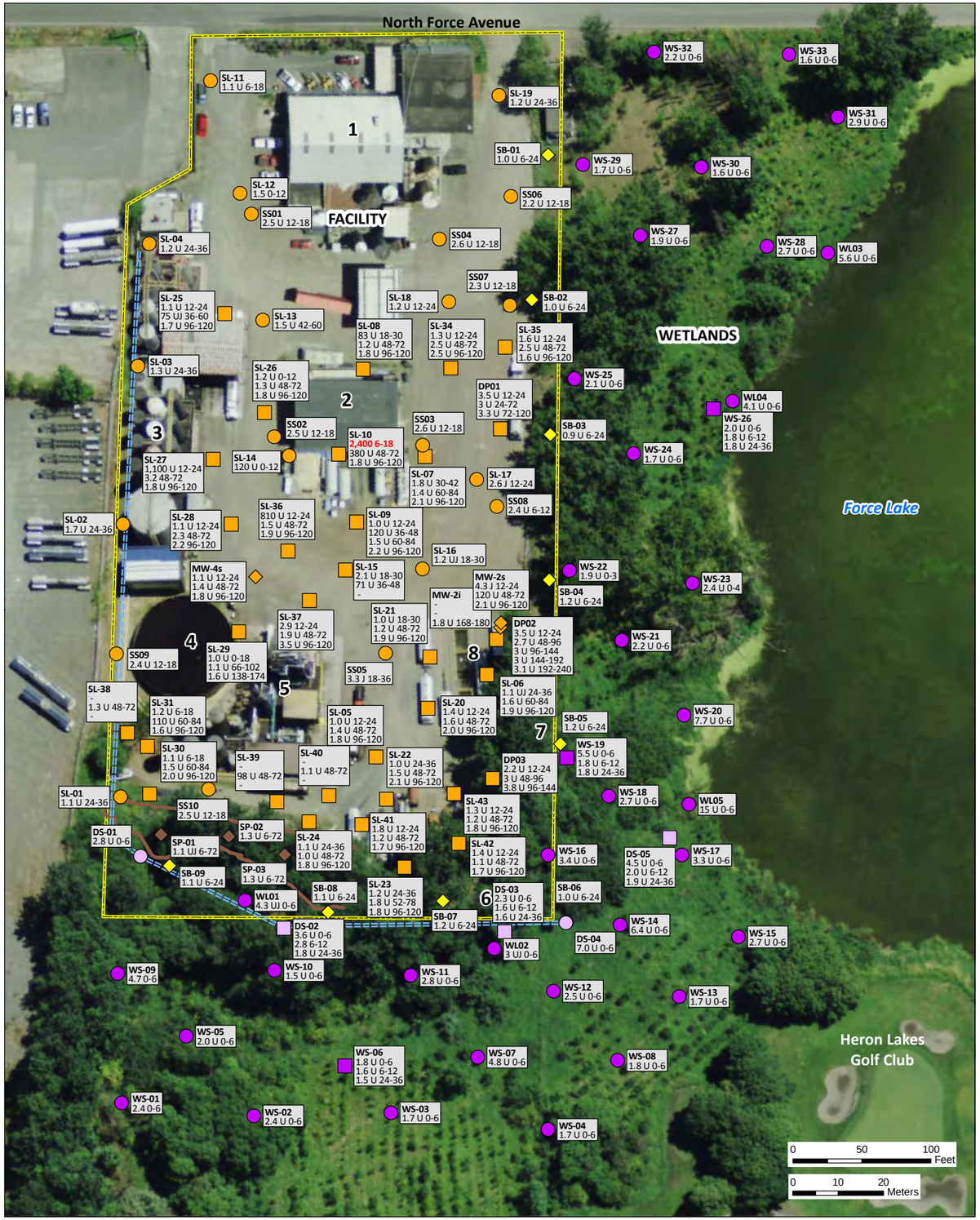
4.7.2 Concentrations by Medium

This section discusses the concentrations of chlorinated solvents in various media within the Study Area. Summary statistics in tables are provided by location (not sample)[19] to be consistent with the figures. The complete RI database is provided in Appendix B.

Cumulative frequency figures were not created for chlorinated solvents because of the low detection frequency of these chemicals. Concentrations were highest in Facility soil samples (generally in the central portion of the Facility), with detected concentrations up to 130,000 µg/kg dw (for cis-1,2-dichloroethene at SL-10). Chlorinated solvents were also detected in wetland soil and groundwater samples. No chlorinated solvents were detected in lake sediment or surface water.

Because of the low detection frequencies and the similar concentration patterns for these chemicals, concentrations were mapped for only two chlorinated solvents. TCE concentrations were mapped because of the known historical use of TCE at the Facility, and cis-1,2-dichloroethene samples were mapped at EPA's request (EPA 2010b) because of their relatively higher detection frequency at intermediate depths in soil as compared with those of other chlorinated solvents. Figures 4-36 and 4-37 present concentrations for each soil and sediment location sampled for TCE and cis-1,2-dichloroethene, respectively; Figures 4-38 and 4-39 present concentrations for each groundwater and surface water location sampled for TCE and cis-1,2-dichloroethene, respectively. In addition, Figures 4-40 and 4-41 show the sampling locations where chlorinated solvents were detected and where concentrations were greater than the applicable screening levels in soil/sediment samples and in groundwater/surface water samples, respectively. These data are discussed in the following subsections.

[19] Duplicate samples were combined with the original sample, as described in Appendix N.



On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Trichloroethene Screening Levels

Medium	Unit	Industrial Human Health RSL[a]	Residential Human Health RSL[a]	Invertebrate Screening Level
Facility soil	µg/kg dw	9.9	9.9	na
Wetland soil	µg/kg dw	na	9.9	nv
Lake sediment	µg/kg dw	na	43	nv

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
na - not applicable
nv - no value (i.e., no SL available for this chemical-medium combination)

Facility soil samples (µg/kg dw)[a]

- Surface soil
- Subsurface and surface soil[b]
- Soil at groundwater monitoring well[b]
- Soil berm
- Soil stockpile

Wetland and ditch soil samples (µg/kg dw)[a]

- Wetland surface soil
- Wetland surface and subsurface soil[b]
- Ditch surface soil
- Ditch surface and subsurface soil[b]

Lake sediment samples (µg/kg dw)

- Lake sediment[b]

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

[a] The following locations were not analyzed for TCE and do not appear on this map: shallow samples from SL-32, SL-33, SL-45, SL-46, and WS-34 to WS-42; intermediate samples from WS-11, WS-20, WS-21, and WS-25; and deep samples from SL-44, WS-11, WS-20, WS-21, and WS-25.

[b] Both surface and subsurface data are shown.

Location ID — SL-00
Concentration — 2,500 12-24 / 250 JN 60-84 / 25 U 96-120
Qualifier: U=non-detect, J=estimated, N=tentatively identified
Depth in inches
Detected concentration: exceeds SL = Red; does not exceed SL = Black

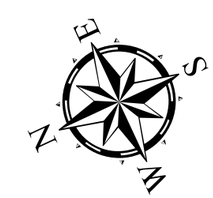


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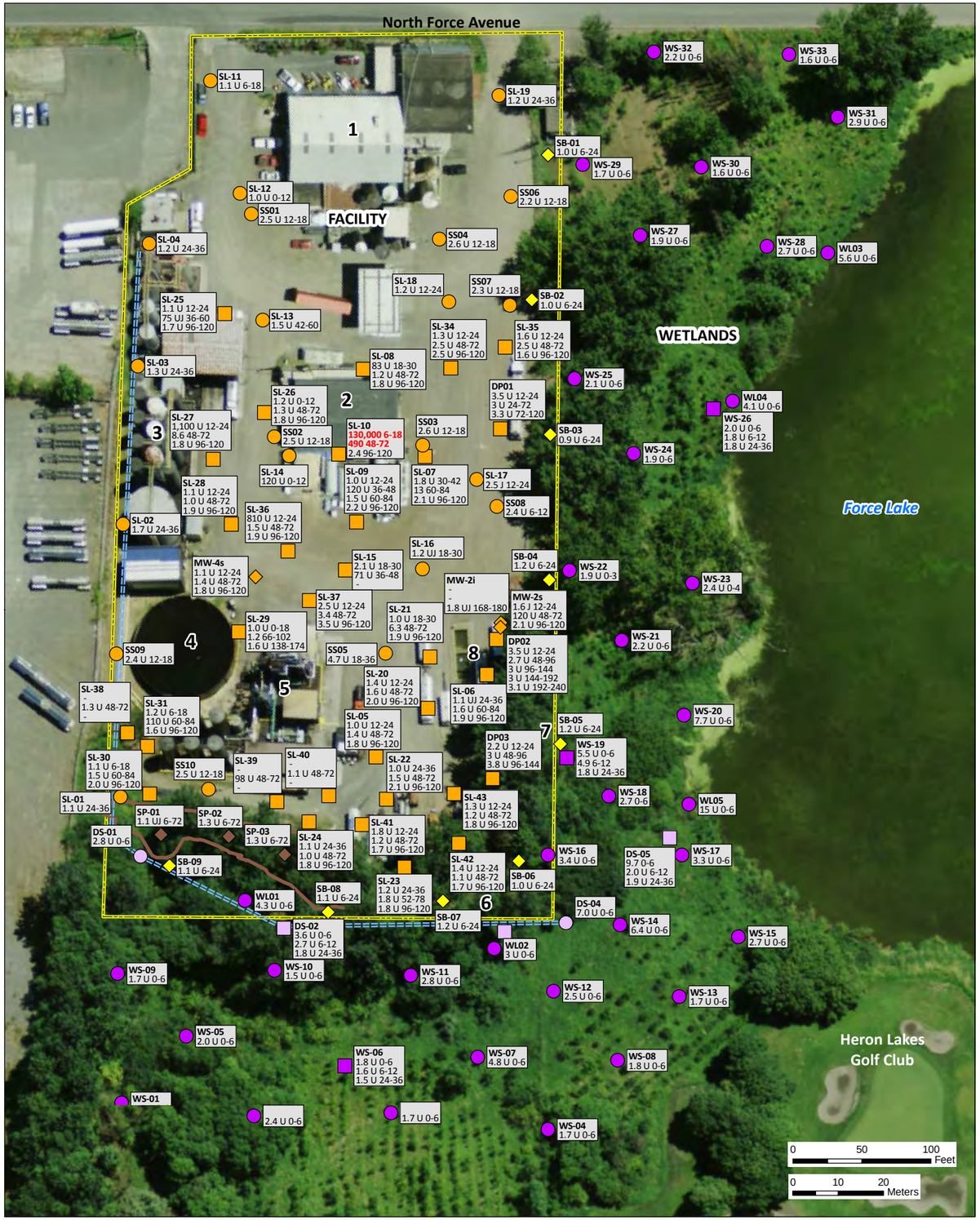
Figure 4-36. TCE Concentrations at Facility Soil, Wetland Soil, and Lake Sediment Sampling Locations

Prepared by CEH, 12/15/2011, MAP #3483, W:\Projects\Harbor_Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.



On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

				brate ning el
Wetland soil	µg/kg dw	na	400	nv
Lake sediment	µg/kg dw	na	400	nv

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
na - not applicable
nv - no value (i.e., no SL available for this chemical-medium combination)

Facility soil samples (mg/kg dw)[a]

- Surface soil
- Subsurface and surface soil[b]
- Soil at groundwater monitoring well[b]
- Soil berm
- Soil stockpile

Wetland and ditch soil samples (mg/kg dw)[a]

- Wetland surface soil
- Wetland surface and subsurface soil[b]
- Ditch surface soil
- Ditch surface and subsurface soil[b]

Lake sediment samples (mg/kg dw)

- Lake sediment[b]

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

[a] The following locations were not analyzed for cis-1,2-Dichloroethene and do not appear on this map: .

[b] Both surface and subsurface data are shown.

Location ID — SL-00
Concentration — 2,500 12-24 / 250 JN 60-84 / 25 U 96-120
Qualifier: U=non-detect, J=estimated, N=tentatively identified
Depth in inches
Detected concentration: exceeds SL = Red; does not exceed SL = Black

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Figure 4-37. cis-1,2-Dichloroethene Concentrations at Facility Soil, Wetland Soil, and Lake Sediment Sampling Locations

Prepared by craigh, 12/15/2011; W:\Projects\Harbor Oil\Data\GIS\RI\Fig 4-37 4433 cis-1,2-dichloroethene in on- and off-facility locations soil.mxd

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

Trichloroethene Screening Levels

Medium	Unit	Human Health RSL[a]	Invertebrate Screening Level
Groundwater	µg/L	0.028	na
Surface water	µg/L	not detected; no comparison to screening levels	

[a] Human health regional screening levels (RSLs) are represented by the lowest of the available screening levels from EPA and DEQ.
na - not applicable

Groundwater samples (µg/L)

- Shallow groundwater
- Intermediate groundwater
- Deep groundwater

Surface water samples (µg/L)

- Lake surface water

Wells where groundwater samples not collected

- Groundwater not sampled due to lack of construction details (trace to 0.02 ft of LNAPL observed)
- Groundwater not sampled due to lack of construction details
- Groundwater not sampled due to the presence of LNAPL (0.1 ft LNAPL observed here in 2008 when LNAPL sample was collected. After this time, trace to 0.02 ft of LNAPL observed).

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

Location ID — GA-00
Sample Year — 2000: – / 2008: 1.0 U / 2009: na
Detected concentration: exceeds SL = Red; does not exceed SL = Black
Concentration: na=not analyzed; – =not collected
Qualifier: U=non-detect; J=estimated

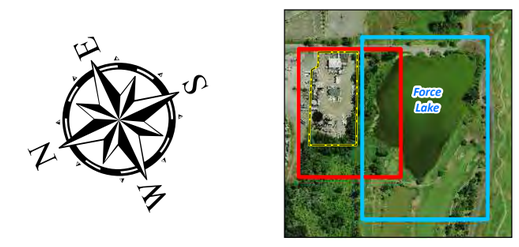

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Figure 4-38. TCE Concentrations in Unfiltered Samples at Facility Groundwater and Lake Surface Water Sampling Locations

Prepared by CEH, 12/15/2011, MAP #3483, W:\Projects\Harbor Oil\Data\GIS\RI

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

On-Facility Features

1. Office/Shop/Warehouse Building
2. Former Tanker Truck Cleaning Operation
3. Tank Farm and Used-Oil Processing Area
4. Tank 23
5. New Base Oil Refining Plant
6. Former Stormwater Discharge Point
7. Current Stormwater Discharge Point
8. Stormwater Treatment System

cis-1,2-Dichloroethene Screening Levels

Medium	Unit	Human Health RSL[a]	Invertebrate Screening Level
Groundwater	µg/L	6.1	na
Surface water	µg/L	not detected; no comparison	

[a] Human health regional screening levels (RSLs) are represented by

na - not applicable

Groundwater samples (mg/L)

- Shallow groundwater
- Intermediate groundwater
- Deep groundwater

Surface water samples (mg/L)

- Lake surface water

Wells where groundwater samples not collected

- Groundwater not sampled due to lack of construction details (trace to 0.02 ft of LNAPL observed)
- Groundwater not sampled due to lack of construction details
- Groundwater not sampled due to the presence of LNAPL (0.1 ft LNAPL observed here in 2008 when LNAPL sample was collected. After this time, trace to 0.02 ft of LNAPL observed).

- Drainage ditch (approximate location)
- Soil stockpile (approximate boundary)
- Facility boundary

Location ID — **GA-00**
Sample Year — 2000: – / 2008: 1.0 U / 2009: na
Detected concentration: exceeds SL = **Red**; does not exceed SL = Black
Concentration: na=not analyzed, – =not collected
Qualifier: U=non-detect, J=estimated

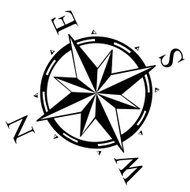

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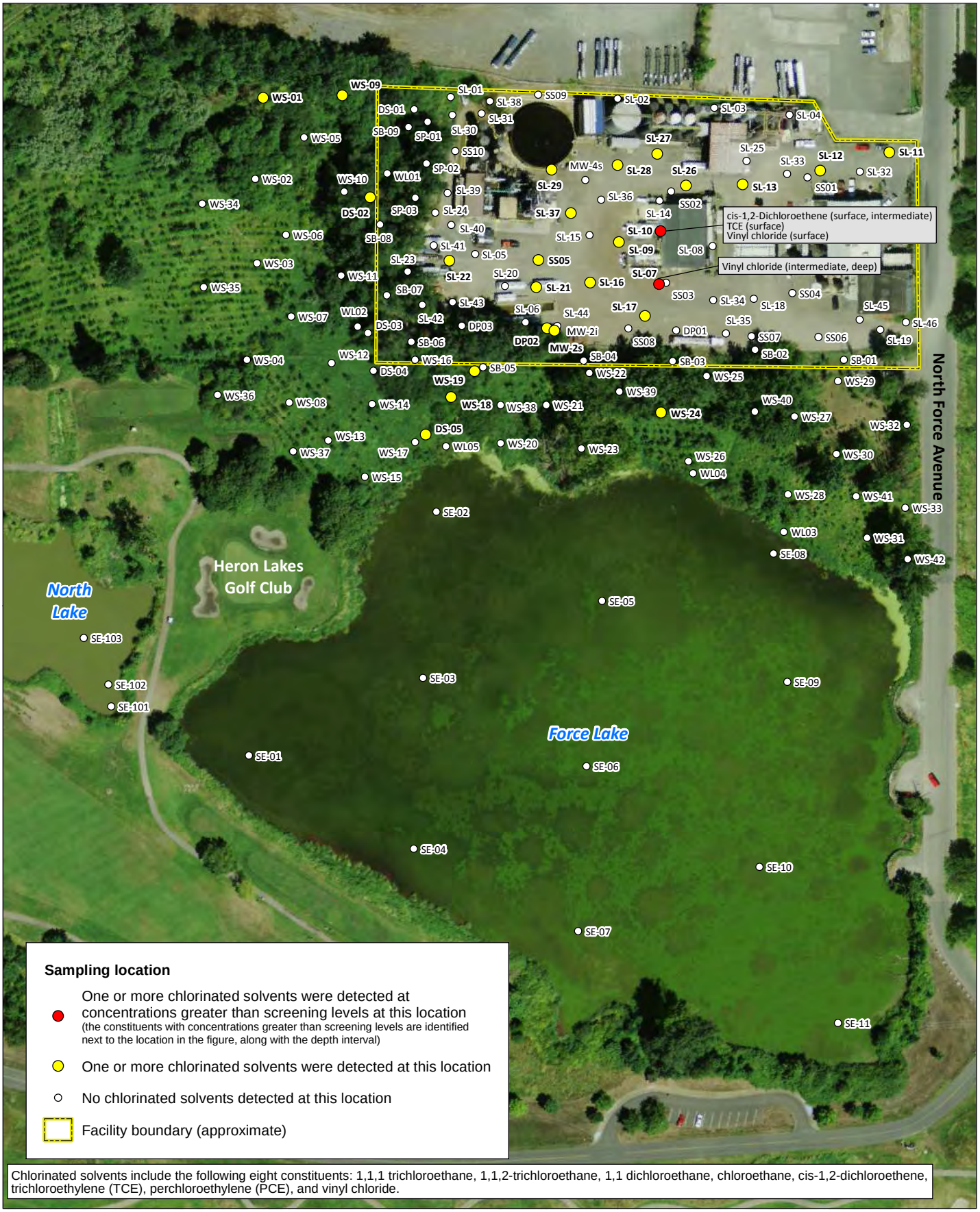
Figure 4-39. cis-1,2-dichloroethene Concentrations in Unfiltered Samples at Facility Groundwater and Lake Surface Water Sampling Locations

Prepared by craigh, 12/15/2011; W:\Projects\Harbor Oil\Data\GIS\RI\Fig 4-39 4433 cis-1,2-dichloroethene in on- and off-facility locations water.mxd

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.



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N E S W

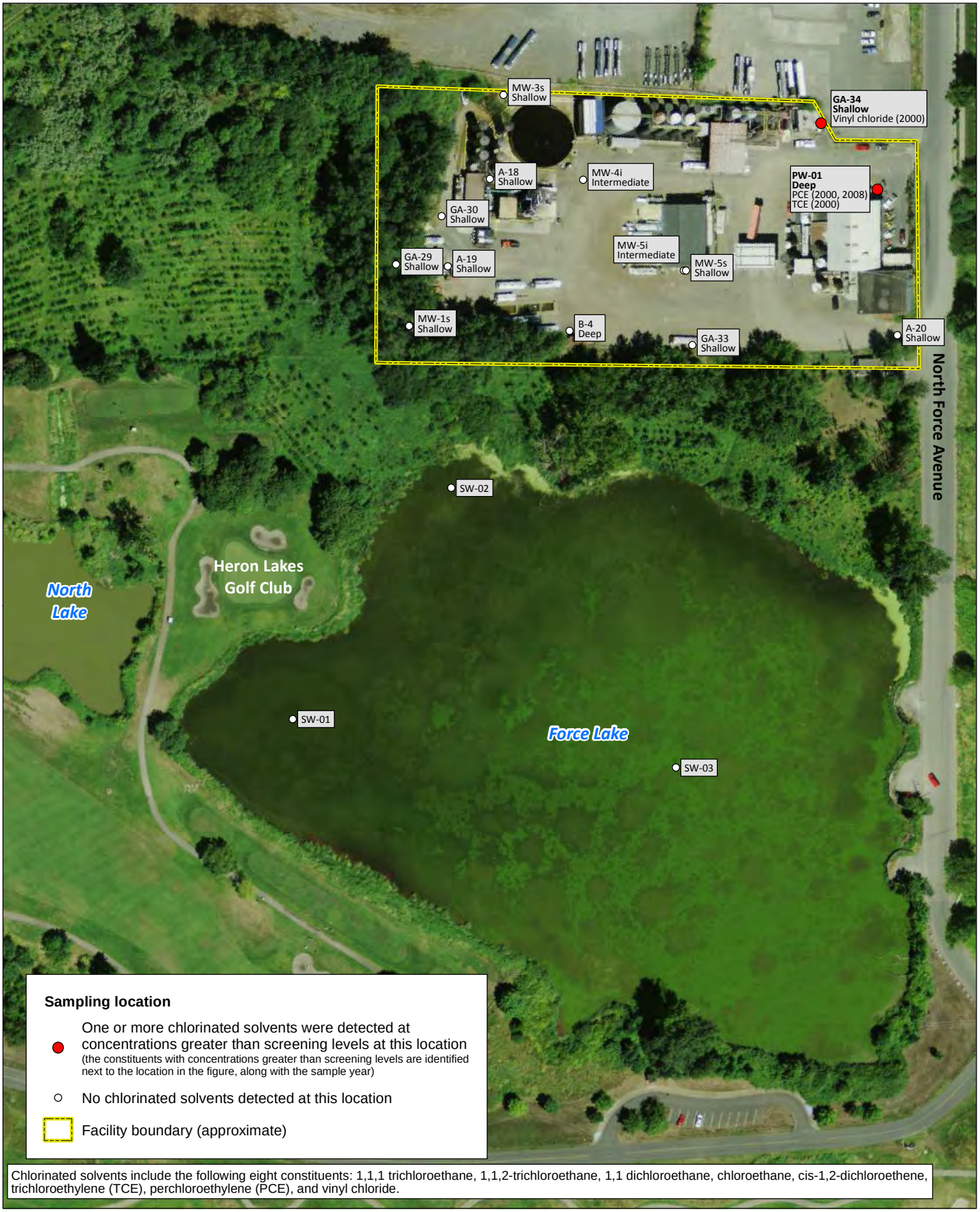
0 100 200 Feet

0 25 50 Meters

Figure 4-40. Facility Soil, Wetland Soil, and Lake Sediment Sampling Locations with Detected Concentrations of Chlorinated Solvents and Concentrations Greater than Screening Levels

Prepared by CEH, 12/15/2011; MAP #4348; W:\Projects\Harbor Oil\Data\GIS\R1

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.



Wind Ward environmental LLC

N E S W

0 100 200 Feet

0 25 50 Meters

Figure 4-41. Facility Groundwater and Lake Surface Water Sampling Locations with Detected Concentrations of Chlorinated Solvents and Concentrations Greater than Screening Levels

Prepared by CEH, 12/15/2011; MAP #4348; W:\Projects\Harbor Oil\Data\GIS\R1

Photo source: Metro Data Resource Center, 1 ft resolution natural color ortho-rectified digital imagery, Portland, OR, July/Aug 2007.

4.7.2.1 Facility Soil

Table 4-21 summarizes concentrations of chlorinated solvents in surface and subsurface soil samples collected at the Facility. The depth intervals of these samples varied depending on the sampling location, field conditions, and the sampling event (see Section 2.2). Surface soil samples at the Facility were collected just below the gravel fill layer, if present.

Table 4-21. Concentrations of Chlorinated Solvents Detected in at Least One Facility Soil Sample

Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
	Ratio	%					
1,1,1-Trichloroethane (µg/kg dw)							
Surface	1/53	2	170	170	SL-10	nc	1.0 – 1,100
Intermediate	0/35	0	nd	nd	nd	nc	1.0 – 380
Deep	0/33	0	nd	nd	nd	nc	1.6 – 3.8
Soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
Soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
1,1,2-Trichloroethane (µg/kg dw)							
Surface	2/53	4	1.5 J	41	SL-13	nc	1.0 – 1,100
Intermediate	0/35	0	nd	nd	nd	nc	1.0 – 380
Deep	0/33	0	nd	nd	nd	nc	1.6 – 3.8
Soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
Soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
1,1-Dichloroethane (µg/kg dw)							
Surface	3/53	6	1.1	680	SL-10	nc	1.0 – 1,100
Intermediate	1/35	3	1.9	1.9	SL-21	nc	1.0 – 380
Deep	0/33	0	nd	nd	nd	nc	1.6 – 3.8
Soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
Soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
Chloroethane (µg/kg dw)							
Surface	1/53	2	2.9	2.9	SL-26	nc	1.0 – 1,100
Intermediate	0/35	0	nd	nd	nd	nc	1.0 – 380
Deep	0/33	0	nd	nd	nd	nc	1.6 – 3.8
Soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
Soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
cis-1,2-Dichloroethene (µg/kg dw)							
Surface	3/53	6	1.6 J	130,000	SL-10	nc	1.0 – 1,100
Intermediate	6/35	17	1.2	490	SL-10	20	1.0 – 120
Deep	1/33	3	2.4	2.4	SL-10	nc	1.6 – 3.8
Soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
Soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
PCE (µg/kg dw)							
Surface	5/53	9	1.9	10.8 J	SS05	nc	1.0 – 1,100
Intermediate	1/35	3	3.0 J	3.0 J	SL-22	nc	1.0 – 380
Deep	0/33	0	nd	nd	nd	nc	1.6 – 3.8
Soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
Soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2

Table 4-21. Concentrations of Chlorinated Solvents Detected in at Least One Facility Soil Sample (cont.)

Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
	Ratio	%					
TCE (µg/kg dw)							
Surface	6/53	11	1.5	2,400	SL-10	66	1.0 – 1,100
Intermediate	2/35	6	2.3	3.2	SL-27	nc	1.0 – 380
Deep	1/33	3	2.2	2.2	SL-28	nc	1.6 – 3.8
Soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
Soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
Vinyl Chloride (µg/kg dw)							
Surface	1/53	2	1,200	1,200	SL-10	nc	1.0 – 1,100
Intermediate	1/35	3	13	13	SL-07	nc	1.0 – 380
Deep	1/33	3	13	13	SL-07	nc	1.6 – 3.8
Soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
Soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2

[a] Surface soil samples were collected immediately below the gravel layer from depths of 0 to 5 ft bgs (0.5- to 1.5-ft sampling intervals for a given sample). Intermediate soil samples were collected from depths of 2 to 8.5 ft bgs (1- to 4-ft sampling intervals for a given sample). Deep soil samples were collected from depths of 6 to 22 ft bgs (1- to 4-ft sampling intervals for a given sample). All soil berm samples were collected from 0.5 to 2 ft bgs, and all soil stockpile samples were collected from 0.5 to 6 ft bgs.

[b] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values. Means were not calculated if the detection frequency was less than 10% or if fewer than three samples had detected concentrations.

[c] RLs are for only non-detected samples.

bgs – below ground surface
dw – dry weight
J – estimated concentration
nc – not calculated
nd – not detected
PCE – perchloroethylene
RL – reporting limit
TCE – trichloroethene

All eight chlorinated solvents were detected in at least one Facility soil sample, although all were detected infrequently. The highest concentrations were detected near the former truck cleaning operations located in the center of the Facility, particularly in the surface soil sample from location SL-10 (Figures 4-36, 4-37, and 4-40).

Concentrations of three chlorinated solvents were greater than the conservative industrial and residential human health RSLs (industrial and residential RSLs were the same for each chlorinated solvent): 2 of 10 samples with detected concentrations of cis-1,2-dichloroethene were greater than the RSL, 1 of 9 samples with detected concentrations of TCE was greater than the RSL, and all 3 samples with detected concentrations of vinyl chloride were greater than the RSL (Figure 4-40).[20] Concentrations of all three of these chlorinated solvents were greater than the RSL in the surface soil sample collected from SL-10, and the cis-1,2-dichloroethene concentration was greater than the RSL in the intermediate-depth sample at this location. In addition, concentrations of vinyl chloride in the intermediate and deep samples from SL-07 (13 µg/kg dw in both samples) were just above the RSL (10 µg/kg dw). SL-10 and SL-07 are both located in the central portion of the Facility near the former truck cleaning operation (Figure 4-40). Note that the comparison with conservative screening levels on a point-by-point basis should not be viewed as a risk estimate; risks were fully assessed in the HHRA as presented in Appendix I and summarized in Section 6.1.

Concentrations of chlorinated solvents were generally bounded both vertically and laterally in Facility soil, indicating that chlorinated solvents have been adequately delineated and the available data meet the DQOs identified in the RI/FS Work Plan (Bridgewater et al. 2008b).

4.7.2.2 Groundwater

Table 4-22 summarizes concentrations of chlorinated solvents detected in at least one groundwater sample (1,1,1-trichloroethane, cis-1,2-dichloroethene, PCE, TCE, and vinyl chloride).

[20] Both of the samples with cis-1,2-dichloroethene concentrations greater than the screening level were from the same location (SL-10), and two of the three samples with concentrations of vinyl chloride greater than the screening level were from the same location (SL-07) (see Figure 4-40).

Table 4-22. Concentrations of Chlorinated Solvents Detected in at Least One Groundwater Sample

Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
	Ratio	%					
1,1,1-Trichloroethane (µg/L)							
Shallow	0/28	0	nd	nd	nd	nc	0.20 – 1.0
Intermediate	0/3	0	nd	nd	nd	nc	1.0
Deep	1/3	33	0.52 J	0.52 J	PW-01	nc	1.0
cis-1,2-Dichloroethene (µg/L)							
Shallow	1/28	4	0.23 J	0.23 J	GA-34	nc	0.20 – 1.0
Intermediate	0/3	0	nd	nd	nd	nc	1.0
Deep	1/3	33	0.79 J	0.79 J	PW-01	nc	1.0
PCE (µg/L)							
Shallow	0/28	0	nd	nd	nd	nc	0.20 – 1.0
Intermediate	0/3	0	nd	nd	nd	nc	1.0
Deep	2/3	67	1.4	4.2	PW-01	nc	1.0
TCE (µg/L)							
Shallow	0/28	0	nd	nd	nd	nc	0.20 – 1.0
Intermediate	0/3	0	nd	nd	nd	nc	1.0
Deep	1/3	33	6.1	6.1	PW-01	nc	1.0
Vinyl Chloride (µg/L)							
Shallow	1/28	4	0.22 J	0.22 J	GA-34	nc	0.20 – 1.0
Intermediate	0/3	0	nd	nd	nd	nc	1.0
Deep	0/3	0	nd	nd	nd	nc	1.0

[a] The depths of shallow groundwater wells ranged from 10 to 20 ft bgs, the depths of intermediate wells ranged from 48 to 50 ft bgs, and the depth of the deep well was 97 ft bgs.

[a] Mean concentrations were not calculated because fewer than three samples for a given solvent and depth interval had detected concentrations.

[b] RLs are for only non-detected samples.

bgs – below ground surface
J – estimated concentration
nc – not calculated
nd – not detected
PCE – perchloroethylene
RL – reporting limit
TCE – trichloroethene

Cis-1,2-dichloroethene (Figure 4-39) and vinyl chloride were each detected in one groundwater sample collected in 2000 from shallow well GA-34 (located in the east corner of the Facility). Samples collected from this well in 2008 and 2009 did not contain detectable concentrations of these chemicals.

1,1,1-Trichloroethane, cis-1,2-dichloroethene (Figure 4-39), PCE, and TCE were all detected in the groundwater sample collected in 2000 from deep well PW-01 (also located in the east corner of the Facility). In the RI sample collected from this well in 2008 only TCE was detected, but at a

lower concentration (1.4 µg/L) than in the 2000 sample (4.2 µg/L) (Figure 4-38). No sample was collected from PW-01 in 2009.

Of the five chlorinated solvents that were detected in groundwater samples, detected concentrations were greater than the conservative human health RSLs in all samples with detectable concentrations of PCE (two samples from deep well PW-01), TCE (one sample from deep well PW-01), and vinyl chloride (one sample from shallow well GA-34). Note that the comparison with conservative screening levels on a point-by-point basis should not be viewed as a risk estimate; risks were fully assessed in the HHRA as presented in Appendix I and summarized in Section 6.1.

In addition, it should be noted that TCE was detected at a concentration just greater than the MCL of 5 µg/L in one sample (6.1 µg/L in the sample from location PW-01 in 2000). TCE was not detected in the sample collected at PW-01 in 2008, and the well was not sampled in 2009 (Figure 4-38). No other chemicals discussed in this section were detected at concentrations greater than the MCL or non-zero MCLG.

As noted above, chlorinated solvents were detected only in samples collected from deep well PW-01 or shallow well GA-34, both of which are located in the east corner of the Facility near the Facility entrance and office buildings (Figure 4-41).

Well GA-34 is located at the upgradient margin of the Facility based on the shallow groundwater flow direction. Vinyl chloride and cis-1,2-dichloroethylene were detected at low concentrations and in a limited number of samples (year 2000 only) at this location. In conjunction with the upgradient position of this well on the property, these data do not suggest an on-site or continuing off-site source for these VOCs.

The PCE and TCE detections in deep well samples do not appear to be site-related because neither of these chemicals were detected in samples from shallow or intermediate groundwater wells. In addition, as described in Section 1.3.3.2, chlorinated solvents have been detected in other deep groundwater monitoring wells in the general vicinity of the Study Area, indicating a regional presence.

4.7.2.3 LNAPL

One LNAPL sample (layer thickness unknown) was collected in 2000 from shallow well GA-30 (in the uppermost groundwater zone) in the northwest portion of the Facility near the soil stockpile, and again in 2008, when a thin layer (approximately 0.1 ft) of LNAPL was observed at that location. VOCs (including chlorinated solvents) were analyzed only in the 2008 sample. In this 2008 sample, none of the eight chlorinated solvents discussed in this section were detected, and only two VOCs were detected (n-butylbenzene and sec-butylbenzene; Section 4.8.2.3).

Follow-up monitoring, including a year of monthly measurements, revealed thin layers of LNAPL (0.02 to 0.01 ft) at GA-30, although no LNAPL was observed in downgradient wells GA-29 and MW-1s (see Figure 2-2 for well locations). Thus, the lateral extent of LNAPL appears to be limited to the immediate area surrounding well GA-30.

4.7.2.4 Wetland and Ditch Soil

Table 4-23 summarizes concentrations of detected chlorinated solvents in wetland and ditch surface and subsurface soil samples. Of the eight chlorinated solvents discussed in this section, only cis-1,2-dichloroethene, PCE, and TCE were detected in wetland and ditch soil.

Table 4-23. Concentrations of Chlorinated Solvents Detected in at Least One Wetland and Ditch Soil Sample

Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
	Ratio	%					
cis-1,2-Dichloroethene (µg/kg dw)							
Surface	3/43	7	1.9	9.7	DS-05	nc	1.5 – 15
Intermediate	1/6	17	4.9	4.9	WS-19	nc	1.6 – 2.7
Deep	0/6	0	nd	nd	nd	nc	1.5 – 1.9
PCE (µg/kg dw)							
Surface	2/43	5	5.1	30	WS-19	nc	1.5 – 15
Intermediate	0/6	0	nd	nd	nd	nc	1.6 – 2.7
Deep	0/6	0	nd	nd	nd	nc	1.5 – 1.9
TCE (µg/kg dw)							
Surface	2/43	5	2.4	4.7	WS-09	nc	1.5 – 15
Intermediate	1/6	17	2.8	2.8	DS-02	nc	1.6 – 2.0
Deep	0/6	0	nd	nd	nd	nc	1.5 – 1.9

[a] Surface soil samples were collected from 0 to 0.5 ft bgs, intermediate soil samples were collected from 0.5 to 1 ft bgs, and deep soil samples were collected from 2 to 3 ft bgs.

[a] Mean concentrations were not calculated because detection frequencies were either less than 10% or fewer than three samples for a given solvent and depth interval had detected concentrations.

[b] RLs are for only non-detected samples.

bgs – below ground surface
dw – dry weight
nc – not calculated
nd – not detected
PCE – perchloroethylene
RL – reporting limit
TCE – trichloroethene

Detection frequencies of the three chlorinated solvents detected in wetland and ditch soil were low. Samples with detected concentrations of chlorinated solvents were located near the current stormwater treatment discharge point (WS-18, WS-19, and DS-05), in the former drainage ditch (DS-02), in the north portion of the wetlands (WS-01 and WS-09), and southwest of the Facility approximately halfway between North Force Avenue and the drainage ditch (WS-24) (Figure 4-40). With the exception of the samples in the northwest portion of the wetlands, these samples were collected in areas that may have received runoff from the former tanker truck cleaning operations (Section 4.2).

Concentrations of chlorinated solvents in wetland and ditch soils, where detected, were significantly lower than those detected in Facility soils. As

shown in Figure 4-40, none of the detected concentrations were greater than the conservative residential human health RSLs. Chlorinated solvents were generally bounded both vertically and laterally in wetland and ditch soil, indicating that chlorinated solvents have been adequately delineated and the available data meet the DQOs identified in the RI/FS Work Plan (Bridgewater et al. 2008b).

4.7.2.5 Lake Sediment and Surface Water

No chlorinated solvents were detected in lake sediment or lake surface water (Figures 4-40 and 4-41), indicating that either the migration of these chemicals to the lake was limited or that the solvents were not persistent in the lake.

4.7.3 Summary for Chlorinated Solvents

In summary, chlorinated solvents were infrequently detected in Facility soil, groundwater, and wetland and ditch soil and were not detected in lake sediment or lake surface water (Figures 4-40 and 4-41).

Concentrations of chlorinated solvents greater than conservative industrial human health RSLs were detected only at SL-07 and SL-10 in the central portion of the Facility, near the former truck cleaning operations (Figure 4-40). This concentration pattern is consistent with the known use of TCE, and possibly other chlorinated solvents, in the former truck cleaning operation. With the exception of two samples in the central portion of the Facility, all concentrations were below the conservative industrial and residential human health screening levels.

In the wetlands, chlorinated solvent concentrations were lower than those in Facility soil samples; samples with detected concentrations of chlorinated solvents were usually located south of the Facility (Figure 4-40). All detected concentrations of chlorinated solvents in the wetlands were less than conservative residential human health RSLs (no invertebrate screening levels were available for chlorinated solvents). This pattern may indicate that some level of migration occurred into the wetlands in the past. However, no chlorinated solvents were detected in either lake sediment or surface water, indicating that either the migration of these chemicals to the lake was limited or that the solvents were not persistent in the lake.

Chlorinated solvents were detected in groundwater in only two wells: deep well PW-01 and shallow well GA-34, both of which are located in the east corner of the Facility near the Facility entrance and office buildings (Figure 4-41). The flow of shallow groundwater is to the southwest, suggesting that if groundwater was contaminated as a result of the former tanker truck cleaning operations, chlorinated solvents would have been detected in wells in the southwest portion of the Facility (e.g., MW-2s), rather than in a well in the east corner of the Facility. This suggests that these VOCs are potentially migrating onto the Facility from upgradient sources. Except for the detection of vinyl chloride in a groundwater sample collected from GA-34 in 2000, no chlorinated solvents were detected in any shallow wells.

The comparison of chlorinated solvents with conservative screening levels and the infrequent detection of these chemicals, as shown in Figures 4-36 through 4-41, indicate that higher concentrations of chlorinated solvents were generally bounded both vertically and laterally. Thus, chlorinated solvents have been adequately delineated and the available data meet the DQOs identified in the RI/FS Work Plan (Bridgewater et al. 2008b).

4.8 Other Chemicals

Sections 4.3 though 4.7 discussed a subset of chemicals identified as COCs in the HHRA or contaminants with LOAEL-based HQs greater than 1.0 in the ERA. This section discusses other chemicals that were detected in at least one media type in the Study Area, including 15 metals, 2 PAHs, 4 phthalates, 17 other SVOCs, 3 pesticides, and 16 VOCs. None of the chemicals discussed in this section were identified as COCs in the HHRA or had LOAEL-based HQs greater than 1.0 in the ERA for which background or reference area concentrations were less than Study Area concentrations. However, it should be noted that some chemicals did not have screening levels in the HHRA (see Section 3.2 and Attachment 3 of the HHRA [Appendix I]) or the ERA (see Section 2.6 of the ERA [Appendix J]), and thus risks from these chemicals could not be assessed.

The chemicals discussed in this section include the following:

- **Metals**: aluminum, antimony, barium, beryllium, cadmium, cobalt, iron, lead, magnesium, manganese, nickel, selenium, silver, thallium, and vanadium
- **PAHs**: 2-methylnaphthalene and dibenzofuran[21]
- **Phthalates**: bis(2-ethylhexyl) phthalate (BEHP), butyl benzyl phthalate, diethyl phthalate, di-n-butyl phthalate
- **Other SVOCs**: 1,2,4-trichlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 2,4-dimethylphenol, 2-chlorophenol, 2-methylphenol, 4-methylphenol, acetophenone, benzaldehyde, benzoic acid, benzyl alcohol, biphenyl, carbazole, hexachlorobenzene, pentachlorophenol, and phenol
- **Pesticides**: delta-benzene hexachloride (BHC), endrin, and methoxychlor
- **VOCs**: 1,2-dichloropropane, 2-chlorotoluene, acetone, carbon disulfide, chlorobenzene, cyclohexane, p-cymene, dichloromethane, methyl ethyl ketone, methyl isobutyl ketone, methylcyclohexane, n-butylbenzene, sec-butylbenzene, styrene, tert-butylbenzene, and trans-1,2-dichloroethene

These chemicals are discussed in the following subsections. However, because these chemicals are of lesser significance in the Study Area—

[21] These PAHs were not included in the total PAH or cPAH sums discussed in Section 4.3.

from both a risk and a historical use perspective—than those chemicals discussed in Sections 4.3 through 4.7, the discussion of these chemicals is less detailed, and the data for these chemicals were not mapped.

4.8.1 Known or Suspected Sources and Release Mechanisms

As discussed in Section 4.2, industrial operations began at the Facility in the 1950s. Although no specific sources have been identified for the chemicals discussed in this section, their presence at detectable concentrations indicates that they may be the result of industrial activities at the Facility and/or from off-Facility sources.

In addition, metals (including the 15 metals evaluated in this section) are naturally occurring elements and are thus expected to be present in the environment.

4.8.2 Concentrations by Medium

This section discusses the concentrations of "other chemicals" in the Study Area and is organized by media. Note that summary statistics in the tables in this section are provided by location (not sample)[22] to be consistent with the data shown on figures. The complete RI database is provided in Appendix B.

4.8.2.1 Facility Soils

Table 4-24 summarizes the concentrations of other chemicals detected in surface and subsurface soil samples collected from the Facility. Surface soil samples at the Facility were collected just below the gravel fill layer, if present. The depth intervals of Facility soil samples varied depending on the sampling location, field conditions, and the sampling event (see Section 2.2). Concentrations of these other chemicals in Facility soil were low from a human health risk perspective. Antimony, thallium, delta-BHC, methoxychlor, and 1,2-dichloropropane were not detected in any Facility soil samples and thus data for these chemicals are not presented in Table 4-24.

[22] Duplicate samples were combined with the original sample, as described in Appendix N.

Table 4-24. Concentrations of Other Chemicals Detected in at Least One Facility Soil Sample

Chemical	Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
Metals (mg/kg dw)[d]								
Aluminum	surface	13/13	100	5,280	11,200	DP03	8,400	na
	intermediate	3/3	100	10,100	12,100	DP02	10,900	na
	deep	5/5	100	8,400	11,900	DP02	11,000	na
Barium	surface	53/53	100	36.5	1,170 J	SL-37	200	na
	intermediate	34/34	100	103	385	SL-24	190	na
	deep	33/33	100	122	253	SL-25	190	na
	soil stockpile	3/3	100	118 J	172 J	SP-03	141	na
	soil berm	9/9	100	76.4 J	341 J	SB-06	150	na
Beryllium	surface	13/13	100	0.29	0.601	SS08	0.4	na
	intermediate	3/3	100	0.526	0.7	DP03	0.6	na
	deep	5/5	100	0.616	0.783	DP02	0.676	na
Cadmium	surface	33/53	62	0.2 J	3.76	SS05	0.4	0.2 – 0.3
	intermediate	16/34	47	0.3 J	0.9	SL-43	0.3	0.2 – 0.3
	deep	14/33	42	0.2	0.6 J	SL-06	0.3	0.3
	soil stockpile	2/3	67	0.3	0.4	SP-01	nc	0.2
	soil berm	6/9	67	0.2	0.6	SB-01	0.3	0.2 – 0.3
Cobalt	surface	53/53	100	4.1 J	30	SL-05	10	na
	intermediate	34/34	100	2.7 J	35 J	SL-24	10	na
	deep	33/33	100	6.3	12.4	SL-25/ SL-35	9.5	na
	soil stockpile	3/3	100	7.8 J	13.8	SP-01	11	na
	soil berm	9/9	100	6.6	32	SB-06	14	na
Iron	surface	13/13	100	1,400	46,200	SS08	28,000	na
	intermediate	3/3	100	18,900	23,000	DP02	21,000	na
	deep	5/5	100	12,100	24,500	DP01	20,000	na
Lead	surface	53/53	100	3	337	SS05	50	na
	intermediate	34/34	100	4	199 J	SL-34	20	na
	deep	33/33	100	6 J	20	MW-2i	10	na
	soil stockpile	3/3	100	13	31 J	SP-01	24	na
	soil berm	9/9	100	6 J	65 J	SB-02	30	na
Magnesium	surface	13/13	100	2,880	5,370	SS07	3,800	na
	intermediate	3/3	100	4,370	4,870	DP02	4,660	na
	deep	5/5	100	3,550	5,560	DP02	4,590	na
Manganese	surface	13/13	100	158	977	SS02	470	na
	intermediate	3/3	100	306	405	DP02	340	na
	deep	5/5	100	220	382	DP01	300	na

Table 4-24. Concentrations of Other Chemicals Detected in at least one Facility Soil Sample (cont.)

Chemical	Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
Nickel	surface	53/53	100	4	50 J	SL-21	20	na
	intermediate	34/34	100	5 J	50 J	SL-41	20	na
	deep	33/33	100	12	25	SL-35	20	na
	soil stockpile	3/3	100	13 J	20	SP-01	20	na
	soil berm	9/9	100	11	30	SB-06	20	na
Selenium	surface	4/53	8	0.1	0.7 J	SL-07	0.3	0.1 – 0.7
	intermediate	2/34	6	0.14	0.8	SL-09	nc	0.5 – 0.7
	deep	2/33	6	0.22	0.23	DP03	nc	0.5 – 0.8
	soil stockpile	0/3	0	nd	nd	nd	nc	0.6
	soil berm	0/9	0	nd	nd	nd	nc	0.5 – 0.6
Silver	surface	12/13	92	0.42	3.16	SS05	1	0.4
	intermediate	3/3	100	0.76	0.89	DP02	0.84	na
	deep	5/5	100	0.5	0.95	DP01	0.8	na
Vanadium	surface	53/53	100	29.4 J	165	SL-06	83	na
	intermediate	34/34	100	15.5 J	105 J	SL-42	53	na
	deep	33/33	100	32.2	88.4	SL-25	64	na
	soil stockpile	3/3	100	47.1 J	85.8	SP-01	63.9	na
	soil berm	9/9	100	49.7	116	SB-01	87.3	na
PAHs (µg/kg dw)								
2-Methyl-naphthalene	surface	46/57	81	14	29,000	SL-10	2,000	9.7 – 131
	intermediate	29/33	88	5.4	11,000	SL-15	1,300	4.8 – 172
	deep	7/34	21	4.9	320	MW-2i	25	4.6 – 191
	soil stockpile	3/3	100	140	260	SP-02	200	na
	soil berm	7/9	78	13	54	SB-01	22	5.0
Dibenzo-furan	surface	38/57	67	7.2	18,000	SL-36	540	9.7 – 131
	intermediate	23/33	70	6.4	12,000	SL-15	750	4.5 – 190
	deep	3/34	9	6.4	49 JN	MW-2i	15	4.6 – 191
	soil stockpile	3/3	100	35	54	SP-02	41	na
	soil berm	4/9	44	5.1	150	SB-06	25	5.0 – 14
Phthalates (µg/kg dw)								
BEHP	surface	24/30	80	11 J	5,730	SS05	1,000	56 – 133
	intermediate	1/3	33	184	184	DP01	nc	172 – 175
	deep	0/4	0	nd	nd	nd	nc	176 – 191
Butyl benzyl phthalate	surface	6/30	20	190	1,700	SL-10	300	20 – 1,440
	intermediate	0/3	0	nd	nd	nd	nc	784 – 874
	deep	0/4	0	nd	nd	nd	nc	881 – 954

Table 4-24. Concentrations of Other Chemicals Detected in at least one Facility Soil Sample (cont.)

Chemical	Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
Diethyl phthalate	surface	1/30	3	184 J	184 J	SS02	nc	20 – 440
	intermediate	0/3	0	nd	nd	nd	nc	157 – 175
	deep	0/4	0	nd	nd	nd	nc	176 – 191
Di-n-butyl phthalate	surface	1/30	3	194	194	DP02	nc	20 – 440
	intermediate	0/3	0	nd	nd	nd	nc	157 – 175
	deep	0/4	0	nd	nd	nd	nc	176 – 191
Other SVOCs (µg/kg dw)								
1,2,4-Trichloro-benzene	surface	2/53	4	7.2 J	24 J	SL-37	nc	2.2 – 4,000
	intermediate	0/35	0	nd	nd	nd	nc	2.7 – 1,900
	deep	0/33	0	nd	nd	nd	nc	3 – 18
	soil stockpile	0/3	0	nd	nd	nd	nc	5.5 – 6.7
	soil berm	0/9	0	nd	nd	nd	nc	4.4 – 6.2
1,2-Dichloro-benzene	surface	11/52	21	1.3 JN	980	SL-36	30	1.0 – 440
	intermediate	8/35	23	1.3	290	SL-31	20	1.0 – 380
	deep	3/33	9	2.7	4.3	SL-28	1	1.6 – 3.8
	soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
1,3-Dichloro-benzene	surface	4/51	8	1.4 J	2.7 J	SS02	16	1.0 – 810
	intermediate	3/35	9	1.3	120 J	SL-25	20	1.0 – 380
	deep	1/33	3	27	27	SL-29	nc	1.6 – 3.8
	soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
1,4-Dichloro-benzene	surface	13/52	25	2.2	99	SL-08	19	1.0 – 810
	intermediate	7/35	20	1.6	490 J	SL-25	30	1.0 – 380
	deep	2/33	6	3.9	61	SL-29	nc	1.6 – 3.8
	soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
2,4-Dimethyl-phenol	surface	3/30	10	70	480	SS03	93	20 – 440
	intermediate	1/3	33	69.4 J	69.4 J	DP01	nc	172 – 175
	deep	0/4	0	nd	nd	nd	nc	176 – 191
2-Chloro-phenol	surface	0/30	0	nd	nd	nd	nc	20 – 440
	intermediate	0/3	0	nd	nd	nd	nc	157 – 175
	deep	0/4	0	nd	nd	nd	nc	176 – 191

Table 4-24. Concentrations of Other Chemicals Detected in at least one Facility Soil Sample (cont.)

Chemical	Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
2-Methyl-phenol	surface	2/30	7	163	518	SS03	nc	20 – 440
	intermediate	1/3	33	78 J	78 J	DP01	nc	172 – 175
	deep	0/4	0	nd	nd	nd	nc	176 – 191
4-Methyl-phenol	surface	4/30	13	58	1,240	SS03	140	20 – 440
	intermediate	1/3	33	990	990	DP01	nc	172 – 175
	deep	1/4	25	194	194	DP01	nc	176 – 191
Aceto-phenone	surface	2/13	15	68.2 J	307	SS04	nc	119 – 1,730
	intermediate	0/3	0	nd	nd	nd	nc	168 – 175
	deep	0/4	0	nd	nd	nd	nc	176 – 191
Benzald-ehyde	surface	1/12	8	37.2 J	37.2 J	DP02	nc	119 – 288
	intermediate	0/3	0	nd	nd	nd	nc	157 – 175
	deep	1/4	25	49.3 J	49.3 J	DP02	nc	176 – 191
Benzoic acid	surface	0/17	0	nd	nd	nd	nc	200 – 4,400
Benzyl alcohol	surface	0/17	0	nd	nd	nd	nc	20 – 440
Biphenyl	surface	5/13	38	44.7 J	1,000	SS05	200	119 – 254
	intermediate	1/3	33	74.2 J	74.2 J	DP01	nc	172 – 175
	deep	0/4	0	nd	nd	nd	nc	176 – 191
Carbazole	surface	6/30	20	40	940	SL-10	110	20 – 440
	intermediate	0/3	0	nd	nd	nd	nc	157 – 175
	deep	0/4	0	nd	nd	nd	nc	176 – 191
Hexachloro-benzene	surface	1/56	2	230	230	SL-33	nc	0.97 – 4,800
	intermediate	1/34	3	3.2	3.2	SL-39	nc	0.97 – 500
	deep	0/34	0	nd	nd	nd	nc	0.96 – 1,200
	soil stockpile	1/3	33	18	18	SP-01	nc	2.9 – 12
	soil berm	1/9	11	42	42	SB-03	nc	2.4 – 120
Pentachloro-phenol	surface	0/30	0	nd	nd	nd	nc	98 – 2,200
	intermediate	0/3	0	nd	nd	nd	nc	784 – 874
	deep	0/4	0	nd	nd	nd	nc	881 – 954
Phenol	surface	2/30	7	156	825	SS03	nc	20 – 440
	intermediate	1/3	33	91.5 J	91.5 J	DP01	nc	172 – 175
	deep	0/4	0	nd	nd	nd	nc	176 – 191
Pesticides (µg/kg dw)[e]								
Endrin	surface	1/56	2	2.6	2.6	SS03	nc	0.6 – 9,600
	intermediate	0/34	0	nd	nd	nd	nc	0.78 – 990
	deep	0/35	0	nd	nd	nd	nc	0.86 – 2,400
	soil stockpile	0/3	0	nd	nd	nd	nc	5.9 – 24

Table 4-24. Concentrations of Other Chemicals Detected in at least one Facility Soil Sample (cont.)

Chemical	Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
	soil berm	0/9	0	nd	nd	nd	nc	4.9 – 240
VOCs (µg/kg dw)[f]								
2-Chloro-toluene	surface	0/38	0	nd	nd	nd	nc	1.0 – 1,100
	intermediate	0/32	0	nd	nd	nd	nc	1.0 – 380
	deep	1/28	4	2.4	2.4	SL-29	1.0	1.6 – 3.5
	soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
Acetone	surface	35/53	66	11	800	SL-10	200	5.6 – 5,600
	intermediate	25/35	71	19	720	SL-09	100	39 – 1,900
	deep	28/33	85	28	240	SL-37	70	60 – 75
	soil stockpile	3/3	100	86	220	SP-03	140	na
	soil berm	9/9	100	12	220	SB-05	120	na
Carbon disulfide	surface	21/53	40	1.4	460	SL-10	30	1.0 – 1,100
	intermediate	14/35	40	1.3	11 J	SL-06	16	1.1 – 380
	deep	4/33	12	2.0 J	4.3 J	SL-06	2.2	1.6 – 15.1
	soil stockpile	1/3	33	5.1	5.1	SP-02	nc	1.1 – 1.6
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.6
Chloro-benzene	surface	7/53	13	1.2 JN	320	SL-10	36	1.0 – 1,100
	intermediate	16/35	46	1.5	2,900 J	SL-25	100	1.0 – 120
	deep	3/33	9	9.3	66	SL-29	4	1.6 – 3.8
	soil stockpile	1/3	33	3.6	3.6	SP-03	nc	1.1 – 1.3
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
Cyclohexane	surface	3/13	23	1.3 J	31.6 J	DP01	4.9	2.2 – 3.5
	intermediate	0/3	0	nd	nd	nd	nc	2.7 – 3
	deep	0/5	0	nd	nd	nd	nc	3 – 3.8
p-Cymene	surface	17/40	42	1.3	11,000 J	SL-10	430	1.0 – 83
	intermediate	10/32	31	1.4 J	620	SL-10	70	1.0 – 98
	deep	2/28	7	3.0	11	SL-28	nc	1.6 – 3.5
	soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
Dichloro-methane	surface	14/53	26	2.0	370	SL-10	59	1.9 – 2,200
	intermediate	8/35	23	2.6	29	SL-29	46	2.1 – 770
	deep	10/33	30	4.5	17	SL-37	35	3.1 – 673
	soil stockpile	0/3	0	nd	nd	nd	nc	2.2 – 2.7
	soil berm	3/9	33	2.1	2.9	SB-07	1.6	1.9 – 2.5

Table 4-24. Concentrations of Other Chemicals Detected in at least one Facility Soil Sample (cont.)

Chemical	Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
Methyl ethyl ketone	surface	24/53	45	8.4	110 J	MW-2s	100	5.0 – 5,600
	intermediate	10/35	29	7.0	100	SL-23	83	4.8 – 1,900
	deep	24/33	73	8.7	117	DP02	21	8.7 – 12
	soil stockpile	3/3	100	13	22	SP-03	18	na
	soil berm	7/9	78	7.6	26	SB-01	12	4.9 – 5.9
Methyl isobutyl ketone	surface	2/53	4	5.2 J	18	SL-28	nc	4.8 – 5,600
	intermediate	2/35	6	30	100	MW-4s	nc	4.8 – 1,900
	deep	0/33	0	nd	nd	nd	nc	7.8 – 18
	soil stockpile	0/3	0	nd	nd	nd	nc	5.5 – 6.7
	soil berm	0/9	0	nd	nd	nd	nc	4.4 – 6.2
Methylcyclo-hexane	shallow	5/13	38	3.7	185 J	DP01	20	2.2 – 3.5
	intermediate	1/3	33	3.8	3.8	DP01	nc	2.7 – 3
	deep	0/5	0	nd	nd	nd	nc	3 – 3.8
n-Butyl-benzene	surface	19/40	48	1.4 J	12,000	SL-10	480	1.0 – 83
	intermediate	14/32	44	1.3	2,600	SL-10	260	1.1 – 2.5
	deep	1/28	4	1.9	1.9	MW-2i	nc	1.6 – 3.5
	soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
sec-Butyl-benzene	surface	11/38	29	1.2	2,000	SL-10	120	1.0 – 1,100
	intermediate	11/32	34	1.3	740	SL-10	75	1.1 – 120
	deep	0/28	0	nd	nd	nd	nc	1.6 – 3.5
	soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
Styrene	surface	1/53	2	1.9	1.9	SL-12	nc	1.0 – 1,100
	intermediate	0/35	0	nd	nd	nd	nc	1.0 – 380
	deep	0/33	0	nd	nd	nd	nc	1.6 – 3.8
	soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2
tert-Butyl-benzene	surface	0/38	0	nd	nd	nd	nc	1.0 – 1,100
	intermediate	1/32	3	2.0	2.0	SL-23	nc	1.0 – 380
	deep	0/28	0	nd	nd	nd	nc	1.6 – 3.5
	soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2

Table 4-24. Concentrations of Other Chemicals Detected in at least one Facility Soil Sample (cont.)

Chemical	Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
trans-1,2-Dichloro-ethene	surface	1/40	2	5,500	5,500	SL-10	nc	1.0 – 1,100
	intermediate	0/32	0	nd	nd	nd	nc	1.0 – 380
	deep	0/28	0	nd	nd	nd	nc	1.6 – 3.5
	soil stockpile	0/3	0	nd	nd	nd	nc	1.1 – 1.3
	soil berm	0/9	0	nd	nd	nd	nc	0.9 – 1.2

[a] Surface soil samples were collected immediately below the gravel layer from depths of 0 to 5 ft bgs (0.5- to 1.5-ft sampling intervals for a given sample). Intermediate soil samples were collected from depths of 2 to 8.5 ft bgs (1- to 4-ft sampling intervals for a given sample). Deep soil samples were collected from depths of 6 to 22 ft bgs (1- to 4-ft sampling intervals for a given sample). All soil berm samples were collected from 0.5 to 2 ft bgs, and all soil stockpile samples were collected from 0.5 to 6 ft bgs.

[b] The mean concentration is equal to the average of all detected values and one-half of the RL for non-detected values. Means were not calculated if the detection frequency if fewer than 10% or if fewer than three samples had detected concentrations.

[c] RLs are for only non-detected samples.

[d] Concentrations of antimony and thallium are not presented because these chemicals were not detected in any Facility soil samples.

[e] Concentrations of delta-BHC and methoxychlor are not presented because these chemicals were not detected in any Facility soil samples.

[f] Concentrations of 1,2-dichloropropane are not presented because this chemical was not detected in any Facility soil samples.

BEHP – bis(2-ethylhexyl) phthalate
bgs – below ground surface
BHC – benzene hexachloride
dw – dry weight
J – estimated concentration
N – tentative identification
na – not applicable
nc – not calculated
nd – not detected
PAH – polycyclic aromatic hydrocarbon
RL – reporting limit
SVOC – semivolatile organic compound
VOC – volatile organic compound

Metals

All 15 metals had high detection frequencies in Facility soil samples, except for antimony and thallium, which were not detected in any Facility soil sample, and selenium, which was infrequently detected. Cadmium was detected in approximately half of the samples analyzed. Mean concentrations of metals were similar across all soil depth intervals. Of these metals, only lead was detected at concentrations greater than the conservative industrial human health RSL. Nearly all of the samples had lead concentrations that were greater than the RSL, with the highest concentrations (greater than 150 mg/kg dw) in samples collected from near the former C-shaped area (SL-15 and SS05) and near the southwest Facility boundary (SL-34). In addition, concentrations of some metals were greater than conservative residential human health screening levels: aluminum (16 samples), iron (20 samples), lead (131 samples), manganese (12 samples), and vanadium (113 samples). The comparison with conservative screening levels on a point-by-point basis should not be interpreted as a risk estimate; risks were fully assessed in the ERA and HHRA as presented in Appendices I and J and summarized in Section 6.0.

PAHs, Phthalates, and Other SVOCs

SVOCs were infrequently detected in Facility soil samples, with the exception of the two PAHs and BEHP. Dibenzofuran and 2-methylnaphthalene were detected in more than 65% of soil stockpile and surface and intermediate Facility soil samples and in a lower percentage of deep interval and soil berm samples. BEHP was the most commonly detected phthalate (detected in 80% of surface soil samples). No phthalates were detected in intermediate or deep soil samples, except for BEHP, which was detected in one sample. PAH and phthalate concentrations usually decreased with depth.

The other 17 SVOCs were detected in less than 33% of Facility surface or intermediate soil samples and in less than 25% of deep soil samples. Hexachlorobenzene was the only SVOC detected in stockpile and soil berm samples (in only one sample of each type).

None of these chemicals were detected at concentrations greater than the conservative industrial or residential human health RSLs. The highest concentrations of PAHs, phthalates, and other SVOCs were generally from samples collected in the central portion of the Facility (e.g., SL-10 and SL-15), near the tank farm (e.g., SL-27), and near the former C-shaped area (e.g., SS05).

Pesticides

With the exception of endrin, no pesticides were detected in any Facility surface soil samples. Endrin was detected in one sample (SS03) located in the central portion of the Facility at a concentration less than the conservative industrial and residential RSLs.

VOCs

All 16 VOCs were detected in at least one Facility soil sample, except for 1,2-dichloropropane. Similar to the PAH and TPH concentration patterns discussed in Section 4.3.3.1, the highest concentrations of individual VOCs were usually located in the central portion of the Facility, extending to the southwest boundary of the Facility. Concentrations of all VOCs were less than the conservative industrial and residential human health RSLs, with two exceptions: one sample had a detected concentration of chlorobenzene greater than the industrial and residential RSL (at SL-25, located to the southwest of the tank farm), and one sample had a detected concentration of trans-1,2-dichloroethene greater than the industrial and residential RSL (at SL-10, located in the central portion of the Facility).

4.8.2.2 Groundwater

Table 4-25 summarizes the concentrations of the other chemicals detected in groundwater. Concentrations of these chemicals in groundwater were low from a risk perspective. Seven SVOCs and nine VOCs were not detected in any groundwater samples and thus data for these chemicals are not presented in Table 4-25.

Metals

All metals were detected in at least one groundwater sample. Aluminum, barium, iron, magnesium, and manganese were frequently detected in groundwater samples at all three depth intervals (shallow, intermediate, and deep). The highest concentrations of these five metals were detected in shallow or intermediate groundwater samples. Eight metals (antimony, beryllium, cadmium, cobalt, nickel, selenium, silver, and thallium) were detected in shallow groundwater but not in intermediate or deep groundwater samples. Lead and vanadium were detected in shallow and deep groundwater samples but not in intermediate samples. The highest concentrations for each metal were often detected in shallow wells A-18, A-19, A-20, and MW-1s (Figure 2-2).

With regard to iron, and as summarized on Table 4-25, concentrations of this naturally occurring metal have been identified in shallow groundwater beneath the Facility at concentrations typically ranging from 20,000 µg/L to 65,700 µg/L, several times higher than concentrations detected in deeper groundwater zones. The extent to which iron dissolves in groundwater is primarily a function of the amount of oxygen in the water, as well as the general iron content of the materials that comprise the matrix of the water-bearing zone. When levels of DO are low (e.g., less than 1 mg/L), iron has a tendency to occur as Fe^{2+}, which dissolves in water much more readily than the form of iron that is typically present in zones of higher oxygen content (Fe^{3+}).

Table 4-25. Concentrations of Other Chemicals Detected in at Least One Groundwater Sample

Chemical[a]	Sample Type[b]	Frac-tion	Detection Frequency		Min Detect Conc. (µg/L)	Max Detect Conc. (µg/L)	Location of Max Detect	Mean Conc. (µg/L)[c]	RL or Range of RLs[d]
			Ratio	%					
Metals									
Aluminum	shallow	T	6/6	100	193	5,890	A-20	1,330	na
	deep	T	1/1	100	20	20	PW-01	nc	na
Antimony	shallow	D	5/22	23	0.2	0.6	MW-1s	0.1	0.2
		T	2/28	7	0.2	0.5	MW-1s	nc	0.2 – 1.6
	intermediate	D	0/3	0	nd	nd	nd	nc	0.2
		T	0/3	0	nd	nd	nd	nc	0.2
	deep	D	0/2	0	nd	nd	nd	nc	0.2
		T	0/3	0	nd	nd	nd	nc	0.2 – 1.6
Barium	shallow	D	22/22	100	65	389	A-19	190	na
		T	28/28	100	65	497	A-19	230	na
	intermediate	D	3/3	100	121	139	MW-5i	129	na
		T	3/3	100	123	136	MW-5i	128	na
	deep	D	2/2	100	9	202	B-4	nc	na
		T	3/3	100	9	204	B-4	70	na
Beryllium	shallow	T	1/6	17	1.5	1.5	A-20	nc	1
	deep	T	0/1	0	nd	nd	nd	nc	1
Cadmium	shallow	D	0/22	0	nd	nd	na	nc	0.2
		T	4/28	14	0.3	1.31	A-18	0.2	0.2
	Intermediate	D	0/3	0	nd	nd	na	nc	0.2
		T	0/3	0	nd	nd	na	nc	0.2
	deep	D	0/2	0	nd	nd	na	nc	0.2
		T	0/3	0	nd	nd	na	nc	0.2
Cobalt	shallow	D	9/22	41	3	25	MW-1s	5	3
		T	9/28	32	3	23	MW-1s	4	3 – 5
	intermediate	D	0/3	0	nd	nd	nd	nc	3
		T	0/3	0	nd	nd	nd	nc	3
	deep	D	0/2	0	nd	nd	nd	nc	3
		T	0/3	0	nd	nd	nd	nc	3 – 5
Iron	shallow	D	22/22	100	1,720	64,400	MW-2s	29,000	na
		T	28/28	100	3,130	65,700	MW-2s	31,000	na
	intermediate	D	3/3	100	7,920	11,600	MW-5i	9,430	na
		T	3/3	100	7,690	11,400	MW-5i	9,290	na
	deep	D	1/2	50	13,700	13,700	B-4	nc	50
		T	3/3	100	34.7	14,000	B-4	5,000	na

Table 4-25. Concentrations of Other Chemicals Detected in at least one Groundwater Sample (cont.)

Chemical[a]	Sample Type[b]	Frac-tion	Detection Frequency		Min Detect Conc. (µg/L)	Max Detect Conc. (µg/L)	Location of Max Detect	Mean Conc. (µg/L)[c]	RL or Range of RLs[d]
			Ratio	%					
Lead	shallow	D	0/22	0	nd	nd	nd	nc	1
		T	8/28	29	0.36	19.6	A-18	2	1
	intermediate	D	0/3	0	nd	nd	nd	nc	1
		T	0/3	0	nd	nd	nd	nc	1
	deep	D	1/2	50	3	3	PW-01	nc	1
		T	2/3	67	0.21	8	PW-01	nc	1
Magnesium	shallow	T	6/6	100	24,900	95,800	A-19	45,700	na
	deep	T	1/1	100	12,900	12,900	PW-01	nc	na
Manganese	shallow	D	22/22	100	724	6,510	A-19	3,100	na
		T	28/28	100	667	7,860	A-19	3,400	na
	intermediate	D	3/3	100	563	867	MW-5i	696	na
		T	3/3	100	570	849	MW-5i	690	na
	deep	D	2/2	100	122	1,590	B-4	nc	na
		T	3/3	100	3.6	1,600	B-4	580	na
Nickel	shallow	D	5/22	23	10 J	20	MW-1s/ MW-2s	7	10
		T	8/28	29	10	25	A-18	8	10
	intermediate	D	0/3	0	nd	nd	nd	nc	10
		T	0/3	0	nd	nd	nd	nc	10
	deep	D	0/2	0	nd	nd	nd	nc	10
		T	0/3	0	nd	nd	nd	nc	10
Selenium	shallow	D	8/22	36	0.5	1.2	MW-4s	0.7	0.5 – 2
		T	10/28	36	0.5	4.7	A-19	1	0.5 – 2
	intermediate	D	0/3	0	nd	nd	nd	nc	0.5
		T	0/3	0	nd	nd	nd	nc	0.5
	deep	D	0/2	0	nd	nd	nd	nc	0.5
		T	0/3	0	nd	nd	nd	nc	0.5 – 2
Silver	shallow	T	1/6	17	1	1	GA-33	nc	1
	deep	T	0/1	0	nd	nd	nd	nc	1
Thallium	shallow	T	6/6	100	0.00894	0.0527	A-18	0.0242	na
	deep	T	0/1	0	nd	nd	nd	nc	1
Vanadium	shallow	D	5/22	23	3	9	MW-1s	3	3
		T	14/28	50	3	54.4	A-20	7	3
	intermediate	D	0/3	0	nd	nd	nd	nc	3
		T	0/3	0	nd	nd	nd	nc	3
	deep	D	0/2	0	nd	nd	nd	nc	3
		T	1/3	33	11.9	11.9	PW-01	nc	3

Table 4-25. Concentrations of Other Chemicals Detected in at least one Groundwater Sample (cont.)

Chemical[a]	Sample Type[b]	Frac-tion	Detection Frequency		Min Detect Conc. (µg/L)	Max Detect Conc. (µg/L)	Location of Max Detect	Mean Conc. (µg/L)[c]	RL or Range of RLs[d]
			Ratio	%					
PAHs									
2-Methyl-naphthalene	shallow	na	7/28	25	0.1 J	1.8	A-18	nc	0.10 – 0.38
	intermediate	na	0/3	0	nd	nd	nd	nc	0.10 – 0.11
	deep	na	0/3	0	nd	nd	nd	nc	0.10 – 0.38
Dibenzo-furan	shallow	na	2/28	7	0.16	0.18	A-18	nc	0.10 – 0.4
	intermediate	na	0/3	0	nd	nd	nd	nc	0.10 – 0.11
	deep	na	0/3	0	nd	nd	nd	nc	0.10 – 0.38
Phthalates									
BEHP	shallow	na	5/6	83	0.59	1.8	A-18	1.0	0.38
	deep	na	0/1	0	nd	nd	nd	nc	0.38
Butyl benzyl phthalate	shallow	na	0/6	0	nd	nd	nd	nc	1.8 – 2
	deep	na	0/1	0	nd	nd	nd	nc	1.9
Diethyl phthalate	shallow	na	1/6	17	0.25 J	0.25 J	A-20	nc	0.37 – 0.4
	deep	na	0/1	0	nd	nd	nd	nc	0.38
Di-n-butyl phthalate	shallow	na	2/6	33	0.1 J	0.15 J	A-20	nc	0.37 – 0.4
	deep	na	0/1	0	nd	nd	nd	nc	0.38
Other SVOCs[e]									
1,2-Dichloro-benzene	shallow	na	2/28	7	0.22 J	0.50	A-18	nc	0.20 – 1.0
	intermediate	na	0/3	0	nd	nd	nd	nc	1.0
	deep	na	0/3	0	nd	nd	nd	nc	1.0
1,3-Dichloro-benzene	shallow	na	2/28	7	0.2 J	0.35 J	GA-34	nc	0.20 – 1.0
	intermediate	na	0/3	0	nd	nd	nd	nc	1.0
	deep	na	0/3	0	nd	nd	nd	nc	1.0
1,4-Dichloro-benzene	shallow	na	4/28	14	0.18 J	1.4	A-20	0.5	0.20 – 1.0
	intermediate	na	0/3	0	nd	nd	nd	nc	1.0
	deep	na	0/3	0	nd	nd	nd	nc	1.0
2-Chloro-phenol	shallow	na	1/6	17	0.97	0.97	GA-34	nc	0.37 – 0.38
	deep	na	0/1	0	nd	nd	nd	nc	0.38
Aceto-phenone	shallow	na	1/6	17	0.16 J	0.16 J	GA-34	nc	0.37 – 0.38
	deep	na	0/1	0	nd	nd	nd	nc	0.38
Benzald-ehyde	shallow	na	2/6	33	0.12 J	0.13 J	A-19	nc	0.37 – 0.4
	deep	na	0/1	0	nd	nd	nd	nc	0.38

Table 4-25. Concentrations of Other Chemicals Detected in at least one Groundwater Sample (cont.)

Chemical[a]	Sample Type[b]	Frac-tion	Detection Frequency		Min Detect Conc. (µg/L)	Max Detect Conc. (µg/L)	Location of Max Detect	Mean Conc. (µg/L)[c]	RL or Range of RLs[d]
			Ratio	%					
Hexachloro-benzene	shallow	D	0/4	0	nd	nd	nd	nc	0.0050
		T	0/28	0	nd	nd	nd	nc	0.0050 – 0.4
	intermediate	D	0/1	0	nd	nd	nd	nc	0.0050
		T	0/4	0	nd	nd	nd	nc	0.0050
	deep	D	1/1	100	0.0095	0.0095	B-4	nc	na
		T	0/4	0	nd	nd	nd	nc	0.0050 – 0.38
Phenol	shallow	na	5/6	83	0.095 J	0.37 J	GA-34	0.19	0.38
	deep	na	0/1	0	nd	nd	nd	nc	0.38
VOCs[f]									
1,2-Dichloro-propane	shallow	na	0/28	0	nd	nd	nd	nc	0.20 – 1.0
	intermediate	na	0/3	0	nd	nd	nd	nc	1.0
	deep	na	1/3	33	0.18 J	0.18 J	PW-01	nc	1.0
Acetone	shallow	na	11/28	39	4.4	18	MW-2s	6	2 – 15.6
	intermediate	na	1/3	33	9.4	9.4	MW-4i	nc	5.0
	deep	na	1/3	33	10	10	B-4	nc	2 – 5.0
Chloro-benzene	shallow	na	15/28	54	0.20	130	GA-34	10	0.20 – 1.0
	intermediate	na	0/3	0	nd	nd	nd	nc	1.0
	deep	na	0/3	0	nd	nd	nd	nc	1.0
p-Cymene	shallow	na	1/22	5	0.30	0.30	A-18	nc	0.20 – 1.0
	intermediate	na	0/3	0	nd	nd	nd	nc	1.0
	deep	na	0/2	0	nd	nd	nd	nc	1.0
n-Butyl-benzene	shallow	na	1/22	5	0.50	0.50	A-18	nc	0.20 – 1.0
	intermediate	na	0/3	0	nd	nd	nd	nc	1.0
	deep	na	0/2	0	nd	nd	nd	nc	1.0
sec-Butyl-benzene	shallow	na	1/22	5	0.40	0.40	A-18	nc	0.20 – 1.0
	intermediate	na	0/3	0	nd	nd	nd	nc	1.0
	deep	na	0/2	0	nd	nd	nd	nc	1.0
Styrene	shallow	na	1/28	4	0.24 J	0.24 J	GA-34	nc	0.20 – 1.0
	intermediate	na	0/3	0	nd	nd	nd	nc	1.0
	deep	na	0/3	0	nd	nd	nd	nc	1.0

[a] Concentrations of pesticides (i.e., delta-BHC, endrin, and methoxychlor) were not presented in this table because these chemicals were not detected in any groundwater sample.

[b] The depths of shallow groundwater wells ranged from 10 to 20 ft bgs, the depths of intermediate wells ranged from 48 to 50 ft bgs, and the depths of the deep well was 97 ft bgs.

[c] Mean concentrations were not calculated because fewer than three samples for a given solvent and depth interval had detected concentrations.

[d] RLs are for only non-detected samples.

Table 4-25. Concentrations of Other Chemicals Detected in at least one Groundwater Sample (cont.)

[e] Concentrations of 1,2,4-trichlorobenzene, 2,4-dimethylphenol, 2-methylphenol, 4-methylphenol, biphenyl, carbazole, and pentachlorophenol are not presented because these chemicals were not detected in any groundwater samples.

[f] Concentrations of 2-chlorotoluene, carbon disulfide, cyclohexane, dichloromethane, methyl ethyl ketone, methyl isobutyl ketone, methylcyclohexane, tert-butylbenzene, and trans-1,2-dichloroethene are not presented because these chemicals were not detected in any groundwater sample.

BEHP – bis(2-ethylhexyl) phthalate
bgs – below ground surface
BHC – benzene hexachloride
D – dissolved concentrations (i.e., filtered)
J – estimated concentration
na – not applicable
nc – not calculated
nd – not detected
PAH – polycyclic aromatic hydrocarbon
RL – reporting limit
SVOC – semivolatile organic compound
T – total water concentrations (i.e., unfiltered)
VOC – volatile organic compound

DO levels in the shallow, intermediate, and deep groundwater zones, as recorded on groundwater sampling records, were typically detected at concentrations less than 0.5 mg/L. Low DO levels are not unusual in groundwater because of the lack of atmospheric mixing. DO levels can drop even lower as a result of oxygen consumption related to the degradation of organic matter, which could occur in the presence of woody debris, petroleum, coal, sawdust, plant matter, etc., which has been documented in the shallow groundwater zone. The detected DO levels in groundwater at the Facility are typical for the region and do not suggest a unique condition at the Facility.

As reported in Table 4-24, total iron concentrations of soil samples collected from within the uppermost groundwater zone were found to have concentrations that ranged from 200,000 µg/kg to 280,000 µg/kg, which given the low DO levels, would appear to support and explain the dissolved iron levels (20,000 µg/L to 65,700 µg/L) detected in this zone.

In addition, it should be noted that lead was detected at a concentration greater than the MCL 15 µg/L in one sample (19.6 µg/L in the sample collected from location A-18 in 2000). Lead was not detected in samples collected from this well in 2008 or 2009. No other chemicals discussed in this section were detected at concentrations greater than the MCL or non-zero MCLG.

PAHs, Phthalates, and Other SVOCs

In general, SVOCs were infrequently detected in shallow groundwater, and none of the PAHs, phthalates, or 17 other SVOCs were detected in intermediate or deep groundwater, except for hexachlorobenzene, which was detected in one deep groundwater sample from well B-4 (located near the southwest Facility boundary). BEHP and phenol were the most frequently detected SVOCs in groundwater; both were detected at five out of six shallow sampling locations. The highest concentrations were detected in shallow wells A-18 near the base oil refining plant, A-20 in the south corner of the Facility, and GA-34 in the east corner of the Facility. Because shallow wells A-20 and GA-34 are upgradient monitoring wells located in the south and east corners of the Facility, respectively, detections at these locations may indicate migration onto the Facility from upgradient sources.

No chemicals discussed in this section were detected at concentrations greater than the MCL or non-zero MCLG.

Pesticides

Delta-BHC, endrin, and methoxychlor were not detected in any groundwater sample.

VOCs

Seven of sixteen VOCs were detected in at least one groundwater sample, and most of the detected concentrations occurred in shallow groundwater samples. Acetone was detected at all groundwater sample depths. However, acetone is a common laboratory contaminant. Chlorobenzene was detected in approximately half of all shallow

groundwater samples but not in any intermediate or deep samples. 1,2-Dichloropropane, p-cymene, n-butylbenzene, sec-butylbenzene, and styrene were each detected in one groundwater sample. 1,2-Dichloro-propane was detected only in plant well PW-01, located in the east corner of the Facility. p-Cymene, n-butyl-benzene, and sec-butyl-benzene were detected only in shallow well A-18, located in the north corner of the Facility near the new base oil refining plant. Concentrations were greater than conservative human health RSLs for two VOCs: the 1,2-dichloropropane concentration was greater than the RSL (0.16 µg/L) at PW-01 (0.18 µg/L), and the chlorobenzene concentration was greater than the RSL (9.1 µg/L) in samples from GA-34 and A-20 (Figure 2-2). As previously noted, these shallow wells are upgradient monitoring wells, which may indicate migration onto the Facility from upgradient sources.

In addition, it should be noted that chlorobenzene was detected at a concentration just greater than the MCL of 100 µg/L in one sample (130 µg/L in the sample collected from location GA-34 in 2009). No other detected concentrations of chlorobenzene were greater than the MCL. No other chemicals discussed in this section were detected at concentrations greater than the MCL or non-zero MCLG.

4.8.2.3 LNAPL

One LNAPL sample (layer thickness unknown) was collected in 2000 from shallow well GA-30 (in the uppermost groundwater zone) in the northwest portion of the Facility near the soil stockpile by EPA, and again in 2008 as part of the Phase I RI activities, when a thin layer (approximately 0.1 ft) of LNAPL was observed at that location. This was the only well in which LNAPL was observed.

In the 2000 sample, select pesticides and PCBs were analyzed. PCB results are described in Section 4.4 and pesticide testing results are shown in Table 4-26. Of the chemicals discussed in this subsection, only four of the metals (barium, cobalt, lead, and vanadium) and two of the VOCs (n-butylbenzene and sec-butylbenzene) were detected in the LNAPL sample collected in 2008 (Table 4-25). Pesticides were analyzed but not detected in the 2008 sample, as indicated in the table.

Follow-up monitoring, including a year of monthly measurements, revealed only a thin layer of LNAPL (0.02 to 0.01 ft) in GA-30, although no LNAPL was observed in downgradient wells GA-29 and MW-1s (see Figure 2-2 for well locations). Thus, the lateral extent of LNAPL appears to be limited to the immediate area surrounding well GA-30.

Table 4-26. Concentrations of Other Chemicals Detected in LNAPL

Chemical	LNAPL Concentration	
	2000 Sample	2008 Sample
Metals (µg/L)		
Barium	na	130
Cobalt	na	40
Lead	na	40
Vanadium	na	20
Pesticides (µg/kg ww)		
alpha-BHC	110 J	620 U
alpha-chlordane	61 J	620 U
beta-BHC	130 J	620 U
Dieldrin	150	1,200 U
Endosulfan sulfate	210	1,200 U
Endrin aldehyde	160	1,200 U
Gamma-chlordane	87 J	620 U
Heptachlor epoxide	61 J	620 U
VOCs (µg/kg ww)		
n-Butylbenzene	na	4,400
sec-Butylbenzene	na	2,700

BHC – benzene hexachloride
J – estimated concentration
LNAPL – light non-aqueous phase liquid
na – not analyzed
U – non-detect (reporting limit shown)
VOC – volatile organic compound
ww – wet weight

4.8.2.4 Wetland and Ditch Soil

Table 4-27 presents concentrations of other chemicals detected in wetland and ditch surface and subsurface soil. Concentrations of these chemicals in wetland and ditch soil were low from a risk perspective (Appendices I and J). Thallium, diethyl phthalate, 7 other SVOCs, and 10 VOCs were not detected in wetland and ditch soil samples, and thus data for these chemicals are not presented in Table 4-27.

Table 4-27. Concentrations of Other Chemicals Detected in at Least One Wetland and Ditch Soil Sample

Chemicals	Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
Metals (mg/kg dw)[d]								
Aluminum	surface	5/5	100	5,990	12,100	WL01	9,500	na
Antimony	surface	7/52	13	0.7 J	8.4 J	WL01	0.6	0.3 – 4.5
	intermediate	0/10	0	nd	nd	nd	nc	0.3 – 0.8
	deep	0/10	0	nd	nd	nd	nc	0.3
Barium	surface	52/52	100	64.5	481	DS-01	190	na
	intermediate	10/10	100	111	299	WS-20	210	na
	deep	10/10	100	145	395	WS-25	210	na
Beryllium	surface	5/5	100	0.36	0.544	WL04	0.5	na
Cadmium	surface	48/52	92	0.3	4	DS-04	1	0.3 – 0.4
	intermediate	9/10	90	0.3	1.7	WS-20	0.8	0.3
	deep	4/10	40	0.4	0.6	DS-03	0.3	0.3
Cobalt	surface	52/52	100	3.5	34.3	WS-11	10	na
	intermediate	10/10	100	3.7	15.4	WS-11	10	na
	deep	10/10	100	3.6	15.1	DS-02	9.5	na
Iron	surface	5/5	100	17,400	56,500	WL02	29,500	na
Lead	surface	52/52	100	11.9 J	320	WS-11	70	na
	intermediate	10/10	100	13	151	WS-20	60	na
	deep	10/10	100	9	24	DS-03	10	na
Magnesium	surface	5/5	100	2,800	4,700	WL04	3,800	na
Manganese	surface	5/5	100	417	1,090	WL01	724	na
Nickel	surface	52/52	100	10	48	DS-01	20	na
	intermediate	10/10	100	10	34	WS-20	20	na
	deep	10/10	100	8	24	DS-02/ WS-11	20	na
Selenium	surface	2/52	4	0.55	1.1	WL01	nc	0.1 – 3
	intermediate	1/10	10	0.7	0.7	WS-21	nc	0.6 – 2
	deep	2/10	20	0.9	1.3	WS-25	nc	0.7 – 0.8
Silver	surface	5/5	100	0.55	1.5	WL02	0.90	na
Vanadium	surface	52/52	100	16.1	148	DS-01	70	na
	intermediate	10/10	100	24.9	91	WS-20	61	na
	deep	10/10	100	24.4	98 J	WS-06	62	na
PAHs (µg/kg dw)								
2-Methyl-naphthalene	surface	48/52	92	5.0	2,880	WL01	220	72 – 277
	intermediate	9/10	90	6.1	1,400	WS-21	210	5.0
	deep	4/10	40	6.3	510	WS-21	72	4.7 – 5.0
Dibenzofuran	surface	31/52	60	4.8	781 J	WL01	70	4.8 – 782

Table 4-27. Concentrations of Other Chemicals Detected in at least one Wetland and Ditch Soil Sample (cont.)

Chemicals	Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
	intermediate	5/10	50	9.0	350	WS-21	56	4.7 – 24
	deep	3/10	30	9.2	120	WS-21	18	4.7 – 5.0
Phthalates (µg/kg dw)[e]								
BEHP	surface	13/15	87	22	9,100	WS-19	1,000	195 – 277
	intermediate	4/4	100	14 J	180	WS-19	88	na
	deep	1/4	25	22	22	WS-19	nc	20
Butyl benzyl phthalate	surface	1/15	7	3,140 J	3,140 J	WL01	nc	20 – 3,910
	intermediate	1/4	25	86	86	DS-02	nc	20
	deep	0/4	0	nd	nd	nd	nc	20
Di-n-butyl phthalate	surface	3/15	20	59	2,400	WS-19	270	20 – 883
	intermediate	2/4	50	22	56	DS-03	nc	20
	deep	1/4	25	31	31	WS-19	nc	20
Other SVOCs (µg/kg dw)[f]								
1,4-Dichloro-benzene	surface	2/43	5	2.3 J	19 J	WS-16	nc	1.5 – 15
	intermediate	0/6	0	nd	nd	nd	nc	1.6 – 2.7
	deep	0/6	0	nd	nd	nd	nc	1.5 – 1.9
4-Methyl-phenol	surface	4/15	27	25	190	DS-04/ DS-05	170	20 – 1,000
	intermediate	2/4	50	17 J	49	DS-05	nc	20
	deep	1/4	25	31	31	DS-05	15	20
Acetophenone	surface	1/5	20	630 J	630 J	WL01	nc	195 – 782
Benzaldehyde	surface	5/5	100	59.6 J	1,080 J	WL01	470	na
Benzoic acid	surface	8/10	80	250	28,000	WS-19	3,200	590 – 880
	intermediate	4/4	100	120 J	1,400	WS-19	480	na
	deep	2/4	50	120 J	280	WS-19	nc	200
Benzyl alcohol	surface	5/10	50	15 J	2,100	WS-19	250	20 – 99
	intermediate	2/4	50	39	180	WS-19	nc	20
	deep	0/4	0	nd	nd	nd	nc	20
Biphenyl	surface	1/5	20	836 J	836 J	WL01	nc	195 – 782
Carbazole	surface	4/15	27	12 J	66 J	WS-29	150	20 – 1,000
	intermediate	1/4	25	13 J	13 J	DS-02	nc	20
	deep	0/4	0	nd	nd	nd	nc	20
Pentachloro-phenol	surface	1/15	7	80 J	80 J	WS-22	nc	98 – 5,200
	intermediate	0/4	0	nd	nd	nd	nc	98 – 100
	deep	0/4	0	nd	nd	nd	nc	98 – 100
Phenol	surface	5/15	33	53	498 J	WL01	150	20 – 1,000
	intermediate	0/4	0	nd	nd	nd	nc	20 – 25

Table 4-27. Concentrations of Other Chemicals Detected in at least one Wetland and Ditch Soil Sample (cont.)

Chemicals	Sample Type[a]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[b]	RL or Range of RLs[c]
		Ratio	%					
	deep	0/4	0	nd	nd	nd	nc	20
Pesticides (µg/kg dw)[g]								
delta-BHC	surface	2/52	4	3.0	3.0	WS-35/ WS-36	nc	0.92 – 490
	intermediate	0/10	0	nd	nd	nd	nc	0.98 – 480
	deep	0/10	0	nd	nd	nd	nc	0.96 – 19
Methoxychlor	surface	1/52	2	4.6 J	4.6 J	WL04	nc	0.92 – 4,900
	intermediate	0/10	0	nd	nd	nd	nc	9.8 – 4,800
	deep	0/10	0	nd	nd	nd	nc	9.6 – 190
VOCs (µg/kg dw)[h]								
Acetone	surface	38/43	88	120 JN	2,300	WS-11	530	61.1 – 299
	intermediate	6/6	100	76	410	DS-02	180	na
	deep	6/6	100	21	210	WS-06	91	na
Carbon disulfide	surface	3/43	7	3.9	7.5	DS-01	3.1	1.5 – 59.8
	intermediate	0/6	0	nd	nd	nd	nc	1.6 – 2.7
	deep	0/6	0	nd	nd	nd	nc	1.5 – 1.9
p-Cymene	surface	3/38	8	3.4 J	72 J	WS-09	3.6	1.5 – 7.7
	intermediate	0/6	0	nd	nd	nd	nc	1.6 – 2.7
	deep	0/6	0	nd	nd	nd	nc	1.5 – 1.9
Dichloro-methane	surface	2/43	5	4.1	5.3	DS-03	nc	3.0 – 58.7
	intermediate	2/6	33	4.4	4.6	WS-06	nc	3.1 – 5.4
	deep	1/6	17	4.1	4.1	WS-06	nc	3.2 – 3.8
Methyl ethyl ketone	surface	38/43	88	12	260	WS-11	60	30.6 – 150
	intermediate	4/6	67	9.7	60	DS-02	21	9.0 – 9.2
	deep	3/6	50	13	30	DS-05	13	7.9 – 8.9
Methyl isobutyl ketone	surface	1/43	2	15	15	DS-01	nc	7.5 – 59.8
	intermediate	1/6	17	16	16	DS-02	nc	7.8 – 10
	deep	0/6	0	nd	nd	nd	nc	7.5 – 9.4

[a] Surface soil samples were collected from 0 to 0.5 ft bgs, intermediate soil samples were collected from 0.5 to 1 ft bgs, and deep soil samples were collected from 2 to 3 ft bgs.

[b] Mean concentrations were not calculated because detection frequencies were either less than 10%, or fewer than three samples for a given solvent and depth interval had detected concentrations.

[c] RLs are for only non-detected samples.

[d] Concentrations of thallium were not presented because these chemicals were not detected in any wetland and ditch soil samples.

[e] Concentrations of diethyl phthalate were not presented because these chemicals were not detected in any wetland and ditch soil samples.

[f] Concentrations of 1,2,4-trichlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 2,4-dimethylphenol, 2-chlorophenol, 2-methylphenol, and hexachlorobenzene were not presented because these chemicals were not detected in any wetland and ditch soil samples.

Table 4-27. Concentrations of Other Chemicals Detected in at least one Wetland and Ditch Soil Sample (cont.)

[g] Concentrations of endrin were not presented because these chemicals were not detected in any wetland and ditch soil samples.

[h] Concentrations of 1,2-dichloropropane, 2-chlorotoluene, chlorobenzene, cyclohexane, methylcyclohexane, n-butylbenzene, sec-butylbenzene, styrene, tert-butylbenzene, and trans-1,2-dichloroethene were not presented because these chemicals were not detected in any wetland and ditch soil samples.

BEHP – bis(2-ethylhexyl) phthalate
bgs – below ground surface
BHC – benzene hexachloride
dw – dry weight
J – estimated concentration
N – tentative identification
na – not applicable
nc – not calculated
nd – not detected
PAH – polycyclic aromatic hydrocarbon
RL – reporting limit
SVOC – semivolatile organic compound
VOC – volatile organic compound

Metals

All 15 metals were frequently detected in wetland and ditch surface and subsurface soil samples, except for thallium, which was not detected in any wetland and ditch soil sample, and selenium, which was infrequently detected. Mean concentrations of metals were similar across soil depth intervals. Of these metals, concentrations were greater than the conservative residential human health RSLs for aluminum (4 samples), antimony (1 sample), cadmium (1 sample), iron (5 samples), lead (72 samples), manganese (5 samples), and vanadium (66 samples). Concentrations were greater than the invertebrate screening levels for aluminum (5 samples), barium (2 samples), and manganese (5 samples). The comparison with conservative screening levels on a point-by-point basis should not be interpreted as a risk estimate; risks were fully assessed in the ERA and HHRA as presented in Appendices I and J and summarized in Section 6.0.

PAHs, Phthalates, and Other SVOCs

SVOCs were infrequently detected in wetland and ditch soil samples, with the exception of the two PAHs, BEHP, benzylaldehyde, benzoic acid, and benzyl alcohol. Dibenzofuran and 2-methylnaphthalene were detected in at least half (50 to 92%) of wetland and ditch surface- and intermediate-interval soil samples and in a lower percentage of deep-interval samples. BEHP was the most commonly detected phthalate. Concentrations of phthalates and other SVOCs (e.g., benzylaldehyde, benzoic acid, and benzyl alcohol) were highest in soil samples collected in or near the former drainage ditch. PAH, phthalate, and other SVOC concentrations decreased with depth, indicating that the nature and extent of these chemicals was bounded. Diethyl phthalate and seven of the other SVOCs were not detected in any wetland and ditch soil samples. No concentrations were greater than the available conservative residential human health RSLs or invertebrate screening levels.

Pesticides

The three pesticides were infrequently detected in wetland soil. Endrin was never detected, and delta-BHC and methoxychlor were detected in less than 5% of wetland surface soil samples. No concentrations were greater than the available conservative residential human health RSLs or invertebrate screening levels.

VOCs

Six of the sixteen VOCs were detected in at least one wetland soil sample. Acetone, dichloromethane, and methyl ethyl ketone were detected at all wetland soil sample depths. Carbon disulfide and p-cymene were detected only in wetland surface soil samples (in less than 10% of surface soil samples). Methyl isobutyl ketone had a low detection frequency in both surface- and intermediate-interval samples. VOC concentrations were highest in soil samples collected in the area of the former drainage ditch. No concentrations were greater than the available conservative residential human health RSLs or invertebrate screening levels.

4.8.2.5 Lake Sediment and Surface Water

Table 4-28 summarizes the concentrations of other chemicals detected in lake surface and subsurface sediment. Of the chemicals discussed in this section, seven metals (aluminum, beryllium, iron, magnesium, manganese, silver, and thallium), all four phthalates, and two VOCs (cyclohexane, and methylcyclohexane) were not analyzed in lake sediment samples, as discussed in the RI/FS Work Plan (Bridgewater et al. 2008b). In addition, 2 metals and 10 VOCs were not detected in lake sediment; no pesticides or other SVOCs were detected in lake sediment. Concentrations of these detected chemicals in lake sediment and surface water were low from a risk perspective (Appendices I and J). Table 4-29 summarizes the concentrations of the two chemicals (barium and acetone) that were detected in Force Lake surface water samples.

Table 4-28. Concentrations of Other Chemicals Detected in at Least One Lake Sediment Sample

Chemical[a]	Location	Sample Type[b]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[c]	RL or Range of RLs[d]
			Ratio	%					
Metals (mg/kg dw)[e]									
Barium	Force Lake	surface	11/11	100	128	220	SE-06	190	na
	Force Lake	intermediate	3/3	100	161	172	SE-05	167	na
	North Lake	surface	3/3	100	124	208	SE-103	175	na
Cadmium	Force Lake	surface	8/11	73	2	2	SE-01, 03, 04, 05, 06, 07, 09, 10	2	0.3 – 0.7
	Force Lake	intermediate	0/3	0	nd	nd	nd	nc	0.3 – 0.4
	North Lake	surface	0/3	0	nd	nd	nd	nc	0.5 – 0.7
Cobalt	Force Lake	surface	11/11	100	7.3	15	SE-06/ SE-10	13	na
	Force Lake	intermediate	3/3	100	8.6	10.2	SE-05	9.3	na
	North Lake	surface	3/3	100	10.3	12	SE-103	11	na
Lead	Force Lake	surface	11/11	100	9	56	SE-06	40	na
	Force Lake	intermediate	3/3	100	6	10	SE-10	8	na
	North Lake	surface	3/3	100	13	18	SE-103	15	na
Nickel	Force Lake	surface	11/11	100	11	31	SE-06/ SE-10	24	na
	Force Lake	intermediate	3/3	100	18	20	SE-03/ SE-05	20	na
	North Lake	surface	3/3	100	17	25	SE-103	21	na
Vanadium	Force Lake	surface	11/11	100	32.7	74	SE-06	60	na
	Force Lake	intermediate	3/3	100	57.8	61.7	SE-05	60.1	na
	North Lake	surface	3/3	100	61.8	76	SE-103	69	na
PAHs (µg/kg dw)									
2-Methyl-naphthalene	Force Lake	surface	7/11	64	7.9	31	SE-02	14	5.0 – 30
	Force Lake	intermediate	0/3	0	nd	nd	nd	nc	4.6 – 5.0
	North Lake	surface	0/3	0	nd	nd	nd	nc	19 – 20
Dibenzo-furan	Force Lake	surface	3/11	27	5.0	7.4	SE-06	6.1	5.0 – 30
	Force Lake	intermediate	0/3	0	nd	nd	nd	nc	4.6 – 5.0
	North Lake	surface	0/3	0	nd	nd	nd	nc	19 – 20
VOCs (µg/kg dw)[f]									
Acetone	Force Lake	surface	10/11	91	78 JN	1,100	SE-06	650	35
	Force Lake	intermediate	3/3	100	120 J	180	SE-10	140	na
	North Lake	surface	3/3	100	200	320	SE-101	270	na
Carbon disulfide	Force Lake	surface	11/11	100	4.9	140	SE-05	40	na
	Force Lake	intermediate	1/3	33	5.8	5.8	SE-10	nc	2.6 – 2.7
	North Lake	surface	3/3	100	5.9	9.7	SE-103	8.2	na

Table 4-28. Concentrations of Other Chemicals Detected in at Least One Lake Sediment Sample (cont.)

Chemical[a]	Location	Sample Type[b]	Detection Frequency		Min Detect Conc.	Max Detect Conc.	Location of Max Detect	Mean Conc.[c]	RL or Range of RLs[d]
			Ratio	%					
Dichloro-methane	Force Lake	surface	0/11	0	nd	nd	nd	nc	2.1 – 16
	Force Lake	intermediate	3/3	100	6.3	8.3	SE-03	nc	na
	North Lake	surface	0/3	0	nd	nd	nd	nc	5.5 – 7.6
Methyl ethyl ketone	Force Lake	surface	10/11	91	9.4	140	SE-06	78	5.3
	Force Lake	intermediate	3/3	100	14	25	SE-10	18	na
	North Lake	surface	3/3	100	29	45	SE-101	38	na

[a] Concentrations of other SVOCs and pesticides were not presented because these chemicals were not detected in any lake sediment samples. Phthalates were not analyzed in lake sediment samples.

[b] Surface lake sediment samples were collected from 0 to 4 in. below the mudline, and intermediate lake sediment samples were collected from 2 to 3 ft below the mudline.

[c] Mean concentrations were not calculated because detection frequencies were either less than 10%, or fewer than three samples for a given solvent and depth interval had detected concentrations.

[d] RLs are for only non-detected samples.

[e] Concentrations of antimony and selenium were not presented because these chemicals were not detected in any lake sediment samples. Aluminum, beryllium, iron, magnesium, manganese, silver, and thallium were not analyzed in lake sediment samples.

[f] Concentrations of 1,2-dichloropropane, 2-chlorotoluene, chlorobenzene, p-cymene, methyl isobutyl ketone, n-butylbenzene, sec-butylbenzene, styrene, tert-butylbenzene, and trans-1,2-dichloroethene were not presented because these chemicals were not detected in any lake sediment samples. Cyclohexane and methylcyclohexane were not analyzed in lake sediment samples.

BEHP – bis(2-ethylhexyl) phthalate
bgs – below ground surface
BHC – benzene hexachloride
dw – dry weight
na – not applicable
nc – not calculated
nd – not detected
J – estimated concentration
N – tentative identification
PAH – polycyclic aromatic hydrocarbon
RL – reporting limit
SVOC – semivolatile organic compound
VOC – volatile organic compound

Table 4-29. Concentrations of Other Chemicals in Force Lake Surface Water

Chemical	Fraction	Detection Frequency		Min Detect Conc. (µg/L)	Max Detect Conc. (µg/L)	Location of Max Detect	Mean Conc. (µg/L)[a]	RL or Range of RLs[b]
		Ratio	%					
Metals								
Barium	D	3/3	100	26	28	SW-02	nc	na
	T	3/3	100	30	31	SW-02	nc	na
VOCs								
Acetone	na	3/3	100	5.4	6.5	SW-03	nc	na

Note: Surface water samples were collected from 0 to 1 ft below the water surface.

[a] Mean concentrations were not calculated because detection frequencies were either less than 10%, or fewer than three samples for a given solvent and depth interval had detected concentrations.

[b] RLs are for only non-detected samples.

D – dissolved
na – not applicable
nc – not calculated
RL – reporting limit
T – total
VOC – volatile organic compound

Metals

Barium was the only metal detected in Force lake surface water and was detected in all three samples. The detected concentrations of barium in these samples were greater than the ecological screening level.

Six metals (barium, cadmium, cobalt, lead, nickel, and vanadium) were detected in all Force Lake and North Lake sediment samples, and two metals (antimony and selenium) were not detected in any lake sediment samples. Mean concentrations of metals were higher in Force Lake surface samples than in Force Lake subsurface samples or North Lake surface samples. The highest metals concentrations were detected in Force Lake surface sediments from SE-06, which was located in the center of the lake. Of these metals, concentrations of vanadium in sediment were greater than the conservative residential human health RSL (16 of 17 samples). No concentrations were greater than the available invertebrate screening levels.

PAHs, Phthalates, and Other SVOCs

Dibenzofuran and 2-methylnaphthalene were the only SVOCs detected in lake sediment; these two chemicals were detected in surface sediment samples from Force Lake, but not detected in subsurface samples from Force Lake or surface samples from North Lake. No PAHs, phthalates, or other SVOCs were detected in any lake sediment samples or in Force Lake surface water. No concentrations were greater than the available conservative residential human health RSLs or invertebrate screening levels.

Pesticides

Delta-BHC, endrin, and methoxychlor were not detected in any lake sediment or surface water samples. No concentrations were greater than the available conservative residential human health RSLs or invertebrate screening levels.

VOCs

Acetone was the only VOC detected in lake surface water and was detected in all three samples. Only 4 of the 14 VOCs analyzed in lake sediment were detected in at least one lake sediment sample. Concentrations of acetone, carbon disulfide, and methyl ethyl ketone were highest in Force Lake surface sediment, although these chemicals were also detected in subsurface sediment samples from Force Lake and surface samples from North Lake. Dichloromethane was detected only in subsurface sediment from Force Lake. No concentrations were greater than the available conservative residential human health RSLs or invertebrate screening levels.

4.8.3 Summary for Other Chemicals

The concentrations of the chemicals discussed in this section were low from human health and ecological risk perspectives. A summary of the concentrations across media for each of the chemical groups discussed in this section follows.

Metals

Most of the 15 metals discussed in this section were frequently detected in Facility soil, wetland soil, groundwater, and sediment. All of these metals are naturally occurring in the environment. In general, concentrations were not highly variable with soil depth, although metals concentrations were higher in surface sediment than in subsurface sediment. Metals concentrations in Facility soil and wetland soil were similar, except for lead, manganese, and selenium, which were slightly higher in wetland soil. Concentrations in sediment were similar to or less than both Facility and wetland soil concentrations. Groundwater metals concentrations were highest in the surface or intermediate depth samples.

PAHs, Phthalates, and Other SVOCs

Most of the PAHs, phthalates, and other SVOCs discussed in this section were infrequently detected, except for BEHP and the two PAHs (2-methylnaphthalene and dibenzofuran). These two PAHs and BEHP were most frequently detected in surface and intermediate soil samples at the Facility and in the wetlands. PAH concentrations were higher in Facility soil samples than in wetland soil samples, whereas BEHP concentrations in soil were similar between the Facility and the wetlands. In the Facility and wetland soil, PAH, phthalate, and other SVOC concentrations generally decreased with depth. In wetland soil, phthalate and other SVOC concentrations (e.g., benzylaldehyde, benzoic acid, and benzyl alcohol) were highest in samples collected in or near the wetland

ditch. SVOCs were infrequently detected in groundwater and lake sediment. No SVOCs were detected in lake surface water.

Pesticides

The three pesticides discussed in this section were infrequently detected in Facility and wetland soil and were never detected in groundwater, lake sediment, or lake surface water.

VOCs

VOCs were most frequently detected in Facility soil, where concentrations were higher than those in wetland soil and in sediment. In most cases, the highest concentrations of individual VOCs in Facility soil were detected in the central portion of the Facility, extending to the southwest boundary of the Facility. VOCs were infrequently detected in wetland soil, groundwater, lake sediment, and lake surface water; detected concentrations were low.

5.0 CONCEPTUAL SITE MODEL

This section discusses the CSM for the Study Area as it relates to fate and transport processes that affect the distribution of chemicals and the pathways through which human and ecological receptors may be exposed to impacted environmental media. Thus, this section provides a link between Section 4.0, which discussed the nature and extent of contamination, and Section 6.0, which presents a summary of the risk assessment results.

Four elements are required to establish a complete exposure pathway between a source and a receptor:

- A chemical source and mechanism of chemical release to the environment
- An environmental transport medium for a released chemical
- A point of potential contact with the impacted medium
- An exposure route (e.g., dermal contact) at the exposure point

Elements of the CSM, with an emphasis on the potential routes of chemical migration from the source area to the potential receptor, are provided in the subsections that follow. Known or suspected chemical sources and release mechanisms are briefly summarized in Section 5.1. Chemical properties related to solubility, volatility, degradation, bioaccumulation potential, and bioavailability are discussed in Section 5.2 for the chemical groups discussed in Section 4.0 (TPH, PAHs, petroleum-associated VOCs, PCBs, metals, DDTs, and chlorinated solvents). Lastly, Section 5.3 discusses the fate and transport of these chemicals through various migration pathways. Those pathways deemed potentially complete are summarized in Section 5.3.6, with distinctions made between chemical transport pathways that are likely to be more important at the Study Area versus those pathways likely to be of lesser significance.

5.1 Sources and Release Mechanisms

As described in Sections 1.3 and 4.2, known or suspected sources of chemicals to the Facility and the adjacent wetland appear to be related to the historical processing of used oils and other petroleum products, the drainage of wash water from former truck cleaning operation, spills, and the periodic oiling of the Facility road surfaces. Specifically, truck cleaning operations began in the central portion of the Facility in the 1950s and oil recycling activities began at the southeast portion of the Facility in 1961. Oil recycling operations expanded to the north portion of the property in the 1970s with the development of a tank farm and loading and unloading/processing area (Figures 1-6 and 4-2).

Known or suspected mechanisms for the release of chemicals to Facility soils included the spillage of oily rinsate from truck cleaning operations to the ground surface, as well as spillage of petroleum products stored or handled at the Facility for processing. In addition, oils may have been used on the Facility roadway for dust suppression purposes. A fire at the Facility in 1979 also likely resulted in the release of oils. Runoff from these historical spills and releases (as described in Section 1.3.2) appears to have discharged into the adjacent wetland and Force Lake to varying degrees.

In addition to areas where direct releases to the ground surface may have occurred, there were several areas where oily discharges or surface water were historically managed at the Facility. Specifically, a C-shaped bermed area, possibly used to impound surface water flow from the truck cleaning operation, was historically located along the western portion of the Facility in the 1950s and into the 1960s (Figure 4-2). In the 1980s, an unlined holding pond located near the west corner of the Facility was used to collect surface water runoff from portions of the Facility; this pond acted as an oil-water separator before the collected water was discharged to the adjacent wetland. In addition, surface soils at the Facility were used to construct a soil berm along the southwest and northwest Facility boundaries after the 1979 fire, and surface soils generated from grading for the construction of the base oil refining plant in 1983 were stockpiled near the north corner of the Facility (Figure 4-2).

With regard to release mechanisms to the wetland and Force Lake (see Section 4.2 for history), oily wash water and suspended soil particles were transported in stormwater runoff directly to the wetlands south and west of the Facility prior to the construction of a ditch in the 1970s. The ditch, located along the northeast property boundary, extended around the property to the west and discharged to the wetland near the southwest corner of the Facility. Subsequent to the ditch construction, Facility runoff was directed both to the ditch and to the adjacent wetlands to the west and south via overland flow. Based on a review of the aerial photographs, the Facility was filled to current grade in several stages in a general east to west direction corresponding to the direction of site development. A soil berm constructed along the southwest and northwest sides of the Facility in 1979 prevented overland flow from directly entering the wetland (Figure 1-6). An unlined holding pond was constructed in the southwest portion of the Facility in 1980; stormwater and tanker truck rinsate was discharged from this pond (after oil-water separation) to the adjacent wetland near the west corner of the Facility. Tanker truck rinsate was completely separated from the stormwater runoff in 1990, with the rinsate subsequently undergoing pretreatment and discharge to the sanitary sewer. Discharges of stormwater from the northern portion of the Facility to the drainage ditch continued until 2002, when the drainage ditch was closed off.

The current stormwater treatment system was constructed in 1983; since 2002, this system has collected stormwater runoff generated from the entire Facility. The system provides oil-water separation followed by

discharge of the treated stormwater to the wetland immediately south of the Facility (Figure 1-3) under a DEQ-issued NPDES permit.

A summary of the primary chemical groups described in Section 4, including known or suspected sources for these chemicals in the Study Area, is provided below:

- **TPHs, PAHs, associated VOCs:** In the Study Area, the concentrations of TPH, PAHs, and petroleum-associated VOCs were often highest in surface soil samples collected from the Facility. The distributions of these chemicals in Facility soil indicate that these chemicals were likely introduced during industrial activities, including oil treatment and processing, production of RFO, road oiling for dust suppression, and tanker cleaning operations. Specifically, sources of these petroleum-related chemicals may include the tank farm located along the northeast boundary of the Facility and the former truck cleaning operation located in the central portion of the Facility. The highest concentrations of TPH, PAHs, and petroleum-associated VOCs were in these areas.
- **PCBs:** No specific PCB sources and release mechanisms associated with Harbor Oil have been identified. However, some of the petroleum products, including waste oils and fuels brought onto the Facility for oil re-refining and fuels blending since the 1960s, were known to contain PCBs up to the allowable limits authorized under the federal TSCA program (< 50 mg/kg). It is suspected that PCBs were released at the Facility in association with the processing of these petroleum products. In the Study Area, total PCB concentrations were highest in surface soils collected from the Facility. Patterns of PCBs in Facility soil suggest that releases from the tank farm, the truck cleaning operation, and the road oiling may have contributed to PCB releases at the Facility. Total PCB concentrations were highest in the northeast corner of the Facility near the Facility entrance, in the central portion of the Facility near the former tanker truck cleaning operation, and along the U-shaped roadway that extends from the Facility entrance around the former truck cleaning operation area.
- **Metals:** Metals are naturally occurring elements and are thus commonly detected in the environment. Thus, a portion of the metals concentrations at the Study Area may not be related to chemical sources or releases at the Facility. Study Area concentrations of metals higher than background concentrations may be associated with several different sources. Some metals, including arsenic and chromium, are known to be associated with used oils and fuels, which could have been released at the Study Area during tanker truck washing operations or during used fuel processing and refinement. In the Study Area, the areas with the highest concentrations of metals included the west corner of the Facility, the area of the former unlined holding pond/C-shaped area, the former drainage ditch to the west of the Facility, and the

area near the current and former stormwater treatment system discharge points near the southwest corner of the Facility. In general, the locations of the highest metals concentrations suggest that the distribution of metals in the Study Area was influenced by stormwater or industrial waste water drainage from the Facility.

- **DDTs:** No specific DDT sources and release mechanisms associated with Harbor Oil have been identified. In the Study Area, total DDT concentrations were highest in surface soils collected at the Facility. In Facility soil, DDTs were highest in the central portion of the Facility near the former truck cleaning operation, in the C-shaped area to the west of the former truck cleaning operation, and along the southwest boundary of the Facility. The highest DDT concentrations in the wetlands were located just southwest of the Facility boundary, in close proximity to the highest DDT concentrations detected at the Facility. There is no historical information suggesting that DDTs were used or handled at the Facility; however, one potential source of DDTs in the Study Area, based on observed distribution, is the former livestock truck cleaning operation in the central portion of the Facility. Trucks that were cleaned at the Facility may have been contaminated with DDTs associated with livestock applications. Although no documentation concerning the use of DDT for livestock applications was identified at the adjacent stockyards (source for a majority of the livestock trucks), dipping, spraying, and dusting cattle with DDT were common historical practices. If DDT was present on residues within the cattle trucks at the time of cleaning, it could explain the observed distribution in Study Area soils. Lower concentrations of DDTs within soils in other areas of the Study Area are typical of concentrations found in an urban environment where DDT was used historically for pest control (e.g., spraying in the area by the Portland Housing Authority or the City of Portland Insect Control Bureau).

- **Chlorinated solvents:** In the Study Area, chlorinated solvents were infrequently detected in Facility soil, groundwater, and wetland and ditch soil and were not detected in lake sediment or lake surface water. Concentrations of chlorinated solvents greater than industrial human health RSLs were detected only in soils (not groundwater) in the central portion of the Facility, near the former truck cleaning operations. This concentration pattern is consistent with the known use of TCE in the former truck cleaning operation. The location and distribution of chlorinated VOCs detected in groundwater indicate that these chemicals are a regional concern with regard to the deep groundwater zone and are not sourced in the Study Area (because these chemicals were detected at similar concentrations in samples collected from locations upgradient of Facility operations in relation to groundwater flow direction).

5.2 Chemical Properties

This section provides a discussion of the key chemical properties and processes that control the fate and transport of the primary chemical groups. Site-specific factors that affect fate and transport (e.g., solubility, degradation rates) and bioavailability (e.g., TOC content) are also described in this section.

Chemical-specific properties that affect the ability of a chemical to sorb to soil or sediment, volatilize to air, biodegrade, or bioaccumulate are listed below:

- Water solubility
- Organic carbon-normalized partitioning coefficient (K_{OC})
- Octanol-water partitioning coefficient (log K_{OW})
- Vapor pressure
- Henry's Law constant vapor-water partitioning coefficient
- Biodegradation rate

The solubility of a chemical in water affects the extent to which partitioning between soil and groundwater may occur. Because water is a polar solvent, polar chemicals have a greater tendency to be in solution than non-polar chemicals. The solubility of a non-polar compounds is further controlled by an affinity to bind with organic carbon in soils and sediments. Both K_{OC} and K_{OW} partitioning coefficients are used to predict the degree of sorption to organic matter in soil or sediments. The higher the K_{OW}, the greater the affinity for partitioning or adhering to organic carbon. Vapor pressure and Henry's Law constant provide an indication of how readily a chemical will volatilize from water into air. The biodegradation rate, when known, provides the rate at which a chemical may be expected to break down.

The preceding properties provide important information regarding the fate of a chemical in the environment and can be used to predict mechanisms by which each chemical group may move through or be retained by the environmental media. Typical values for some of these factors are included on Table 5-1 to facilitate comparison among the different chemical groups, and solubility, vapor pressure, and biodegradation rate are discussed further below.

Table 5-1. Properties of Chemical Groups

Chemical	Water Solubility (mg/L, unless otherwise indicated)	Vapor Pressure (mm mercury)	Log K_{OW}	Log K_{OC}
PAHs				
Acenaphthylene	3.93	0.029 at 20 °C	4.07	1.40
Acenaphthene	1.93	0.0047	3.98	3.66
Anthracene	0.076	1.7×10^{-5} at 25 °C	4.45	4.15
Benzo(a)anthracene	0.010	2.2×10^{-8} at 20 °C	5.61	5.30
Benzo(a)pyrene	0.0023	5.6×10^{-9}	6.06	6.74
Benzo(b)fluoranthene	0.0012	5.0×10^{-7} at 20 to 25 °C	6.04	5.74
Benzo(g,h,i)perylene	0.00026 at 25 °C	1.03×10^{-10} at 25 °C	6.50	6.20
Benzo(k)fluoranthene	0.00076 at 25 °C	9.59×10^{-11}	6.06	5.74
Chrysene	0.0028	6.3×10^{-7} at 25 °C	5.16	5.30
Dibenzo (a,h)anthracene	0.0005	1×10^{-10} at 20 °C	6.84	6.52
Fluoranthene	0.20 to 0.26	5.0×10^{-6} at 25 °C	4.90	4.58
Fluorene	1.68 to 1.98	3.2×10^{-4} at 20 °C	4.18	3.68
Indeno(1,2,3-cd)pyrene	0.062	10^{-6} to 10^{-11} at 20 °C	6.58	6.20
Naphthalene	31.7	0.087	3.29	2.97
Phenanthrene	1.20	6.8×10^{-4} at 25 °C	4.45	4.15
Pyrene	0.077	2.5×10^{-6} at 25 °C	4.88	4.58
VOCs				
Benzene	0.19% w/w	75	2.13	1.8 to 1.9
TCE	1,370 at 25 °C	74 at 25 °C	2.42	2.03 to 2.66
PCBs[a]				
Aroclor 1242	0.10 at 24°C to 0.34 at 25 °C	4.06×10^{-4} at 25 °C	5.6	no data
Aroclor 1248	no data	no data	no data	no data
Aroclor 1254	0.012 to 0.057 at 24 °C	7.71×10^{-5} at 25 °C	6.5	no data
Aroclor 1260	0.0027 to 0.08 at 24 °C	4.05×10^{-5} at 25 °C	6.8	no data
Metals[b]				
Arsenic	insoluble	0.0075 at 280 °C	no data	no data
Chromium	insoluble	1 at 1,616 °C	no data	no data
Copper	insoluble	1 at 1,628 °C	no data	no data
Mercury	0.28 µmoles/L at 25 °C	0.002 at 25 °C	5.95	no data
Zinc	insoluble	1 at 487 °C	no data	no data
Pesticides				
4,4′-DDD	0.090	1.4×10^{-6}	5.5[c]	5.48[c]
4,4′-DDE	0.12	6.0×10^{-6}	6.51	4.70
4,4′-DDT	0.025	1.6×10^{-7}	6.2[c]	6.19[c]

Source: ATSDR toxicological profiles (ATSDR 2010), except as noted.

[a] Only the Aroclors detected at the Study Area are shown in this table.

Table 5-1. Properties of Chemical Groups (cont.)

[b] Chemical properties for multiple forms of metals are provided in the ATSDR toxicological profiles. This table presents the chemical properties for the elemental forms.

[c] The source of these values is IPEN (2005).

ATSDR – Agency for Toxic Substances and Disease Registry
C – Celsius
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
K_{OC} – organic carbon-normalized partitioning coefficient
K_{OW} – octanol-water partitioning coefficient
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
TCE – trichloroethylene
VOC – volatile organic compound

5.2.1 Solubility

The distribution of chemicals between solid particles and water is known as partitioning. The octanol-water partition coefficient (K_{OW}) is the ratio of the concentration of a chemical in octanol and in water at equilibrium. Chemicals with high K_{OW} values are much more strongly associated with solid phases, such as sediment or soils, relative to their affinity for aqueous solutions. Chemicals with high K_{OW} values, therefore, are less soluble (and less mobile) in water.

Non-polar organic compounds, such as DDTs and most PAHs, typically have a strong affinity for organic matter associated with soil and sediment particles and are therefore less soluble in water. PCBs also are highly insoluble in water (ATSDR 2000b). These non-polar chemicals also have less tendency to leach into groundwater or deeper layers of soil or sediment (ATSDR 2000b, 2002).

Many PAHs tend to have relatively high K_{OW} values (and low water solubilities), which increase with increasing molecular weight. Low-molecular-weight PAHs (LPAHs), such as naphthalene, are somewhat more mobile than high molecular-weight PAHs (HPAHS). In aquatic environments, roughly a third of PAHs are present in dissolved form (the remainder are associated with particles) (ATSDR 1995).

Metal ions form metal-ligand complexes (i.e., complexes with natural organic compounds, such as humic and fulvic acids), which can increase the solubility and mobility of metals in environments with high dissolved organic carbon concentrations. Metal ions also sorb onto clay and oxide minerals because of the negative charges on the surfaces of these particles. Ion exchange may also occur at the particle surface, where metal ions of one element replace those of another element because of different properties of the elements or environmental conditions. The oxidation state of the metal ion influences the speciation of the metal. Reduced iron and manganese species are soluble, whereas, under oxic conditions, these metals form insoluble oxides that sorb other metals to their surfaces. The solubility of metal is also dependent on metal speciation. For example, the most common organic form of mercury, methylmercury, is soluble and mobile, whereas inorganic forms of mercury can be insoluble. The solubility of methylmercury will decrease with increased dissolved organic matter content in water (ATSDR 1999a).

For several divalent metals (i.e., cadmium, copper, lead, nickel, and zinc), a key factor controlling cationic metal activity in sediment appears to be acid-volatile sulfide (AVS) (Carlson et al. 1991; DiToro et al. 1991; DiToro et al. 1992; Allen et al. 1993). As previously discussed, the presence of sulfide (especially in reducing environments such as subsurface sediments) makes these metals less bioavailable.

5.2.2 Volatility

Volatility is the tendency of a chemical to partition to air and migrate as a vapor; volatility is a function of vapor pressure. VOCs, such as benzene and TCE, are characterized by high vapor pressure and moderate to high

aqueous solubility. Therefore, they are highly volatile and have low affinities for soils and sediments. VOCs tend to be less persistent in the environment than are most PAHs, as they readily evaporate when exposed to air.

The volatility of PAHs varies. In general, LPAHs have higher vapor pressure and are present in air predominately in the vapor phase. In contrast, HPAHs have lower vapor pressure and are predominantly present in the particulate phase (ATSDR 1995).

TPH are quantified based on the molecular-weight range of the dominant hydrocarbons. TPH in the diesel and motor oil range typically consist of heavy oils and are not highly volatile. TPH in the gasoline range are more volatile inasmuch as they mostly consist of VOCs.

PCBs and DDTs can volatilize from surface soil and surface water into the atmosphere. Volatilization of DDT, DDE, and DDD can account for losses of these chemicals from soil surfaces and water (ATSDR 2002). PCBs in the atmosphere are more mobile in the vapor phase than those that are particle bound (ATSDR 2000b).

Most forms of metals in aqueous and soil environments are not highly volatile.

5.2.3 Degradation Processes

Degradation processes can play an important role in the fate of chemicals in the environment. Degradation processes for organic compounds, including PCBs and DDTs, include photodegradation, hydrolysis, and biodegradation. In aqueous systems, degradation rates are dependent upon the concentrations of nutrients, presence of PM, temperature, oxygen concentration, redox potential, microbial populations, and the concentration of the chemical (Sinkkonen and Paasivirta 2000).

Degradation processes for the various chemical groups discussed in Section 4 are summarized below:

- **DDTs and metabolites**: Bacteria and fungi can biodegrade pesticides, including DDTs. Under aerobic conditions, DDT biodegrades primarily to DDE; under anaerobic conditions (e.g., groundwater in the Study Area), DDT biodegrades to DDD. Degradation rates of DDT are also dependent on conditions in the soil. In flooded soils, the degradation rate of DDT to DDD depends on the organic content of the soil (ATSDR 2002). In soils with low concentrations of metals, DDT has been found to more slowly degrade to DDE than in soils with high metals concentrations (ATSDR 2002). DDT and its metabolites are persistent; field and laboratory studies have demonstrated that very little breakdown of DDT occurs in estuarine sediments over the course of 46 days (EXTOXNET 1996). DDTs have been found to be more persistent in muck soils than dry forest soils (ATSDR 2002). In a study of sprayed forest soils in Maine, the half-life of DDT residues was noted to be 20 to 30 years (Dimond and Owen 1996).

- **PCBs**: PCBs are stable under typical environmental conditions and thus are highly persistent. As with DDTs, biodegradation by bacteria and fungi may significantly transform PCBs, but the transformation process is slow (Alder et al. 1993). Half-lives of various PCB congeners in sediment have been estimated to range from 3 to 38 years. Half-lives in temperate regions have been reported to range from 2.3 to 16.7 years.
- **PAHs**: Degradation processes for PAHs in aqueous systems include photodegradation, hydrolysis, and biodegradation. HPAHs, which have four or more aromatic rings, tend to persist in sediment. Half-lives for HPAHs range from months to years. LPAHs tend to be less persistent. LPAHs, such as phenanthrene and anthracene, are subject to photodegradation in the water column (Nagata and Kondo 1972).
- **VOCs**: VOCs, such as benzene and TCE, are also subject to photodegradation and biodegradation. Under aerobic conditions, benzene rapidly degrades in water and soil (ATSDR 2007). The half-life for TCE is relatively short; the degradation rate of TCE in soil increases with organic matter in soil (ATSDR 1997).
- **TPHs**: Petroleum products can migrate through soil either as a bulk oil flow or as individual compounds that have separated from the bulk mixture and dissolved in air or water (ATSDR 1999b). Lower weight aliphatic and aromatic fractions of TPHs are more likely to biodegrade than heavier TPH fractions. The rate of TPH biodegradation is dependent on several factors, including oxygen content, pH, moisture content, temperature, nutrient concentrations, and the microbiota present (ATSDR 1999b).
- **Metals:** The fate and transport of metals is primarily driven by the speciation of the metal, which is a function of a number of variables, including Eh (oxidation and reduction potential), pH, temperature, and the type and concentrations of available organic and inorganic ligands (i.e., chemicals, such as sulfate, iron oxides, or natural organic matter, that bond with metal ions). Equilibrium constants and kinetics also determine whether a metal will be associated primarily with the particulate or dissolved fraction and the nature of the solid or dissolved complex. The dissolved speciation and sorption of metals to solids affect their bioavailability and subsequent toxicity. Stable elements, such as zinc, do not degrade in the environment, but instead can change forms through chemical reactions that occur under a wide range of common environmental conditions (ATSDR 2005b).

5.2.4 Bioaccumulation Potential

Bioaccumulation refers to the uptake of chemicals by organisms. DDTs, PCBs, and mercury are highly bioaccumulative chemicals. In a study of a freshwater lake, DDT was found to accumulate at higher concentrations in fattier, higher trophic level fish than in leaner, lower trophic level fish (Kidd et al. 2001). PCBs, also a lipophillic chemical, accumulate at

greater concentrations in organisms with higher lipid content (ATSDR 2000b). DDTs, PCBs, and mercury accumulate in greater concentrations at higher trophic levels (e.g., piscivorous fish). Methylmercury is accumulated in tissue to a greater extent than inorganic forms of mercury (ATSDR 1999a).

Most metals other than mercury have low or moderate bioaccumulation potential and do not biomagnify through the food chain. The bioconcentration of these metals (e.g., arsenic, copper, zinc) is higher in low trophic level organisms, such as aquatic invertebrates, than in higher trophic level organisms such as fish (ATSDR 2004b, 2005a, b).

VOCs, PAHs, and TPHs do not usually bioaccumulate. Benzene has not been found to accumulate in marine organisms and bioconcentration factors measured in studies have indicated a low tendency of TCE to bioaccumulate (ATSDR 1997, 2007). Some TPH fractions (particularly PAHs) may accumulate in aquatic organisms; however, lower weight aliphatics and aromatics do not accumulate (ATSDR 1999b). PAHs may bioaccumulate in lower trophic level aquatic organisms, such as mollusks, and to some extent in terrestrial mammals through ingestion of prey and soil; however, fish and crustaceans metabolize PAH, and therefore, PAHs (such as benzo[a]pyrene) are typically found at low levels in fish and crustaceans (ATSDR 1995).

5.2.5 Bioavailability

The bioavailability of a chemical is a measure of the availability of a chemical for uptake by an organism. The bioavailability of a chemical in sediment or soil is dependent on many factors, including the moisture content or pH of the sediment or soil; the redox potential and organic content of the sediment or soil, as well as physical properties of the chemical; and the route of exposure (ATSDR 1997, 2000a, 2005a, 1999b). The partitioning of chemical to organic matter in sediment and soil can reduce the bioavailability of certain chemical. The association of non-polar organic compounds with particles is correlated with organic carbon content (Chiou et al. 1979). Thus, soils and sediments with high TOC tend to have higher non-polar chemical concentrations, such as PAHs, DDTs, and PCBs, than do soils and sediments with lower TOC. It is common for sediment concentrations of these compounds to be compared on an organic-carbon normalized basis, thereby providing a better indication of their potential bioavailability.

Samples of Study Area soils and of sediments from Force Lake were analyzed for TOC (Table 5-2). The TOC content was relatively high in Force Lake surface sediment (average of 7.1%) and wetland surface and intermediate soil (averages of 10 and 7.9%, respectively), limiting bioavailability of non-polar chemical concentrations, such as PAHs, DDTs, and PCBs. The TOC contents were somewhat lower in Facility soil (averaging 0.98 to 4.6%), in deep subsurface wetland soils (4.6%), and in subsurface sediments (1.3%).

Table 5-2. Summary of TOC in Study Area Soil and Sediment

Media	Count	TOC (%)		
		Minimum	Maximum	Average
Facility Soil				
Surface (0 to 5 ft)	44	0.01	14.6	2.6
Intermediate (3 to 8 ft)	32	0.153	41.3	4.6
Deep (8 to 22 ft)	30	0.532	2.78	0.98
Soil stockpile (0.5 to 6 ft)	3	1.66	2.31	2.1
Soil berm (0.5 to 2 ft)	9	0.435	2.54	1.3
Wetland Soil				
Surface (0 to 0.5 ft)	51	2.09	30.2	10
Intermediate (0.5 to 1 ft)	10	1.19	29.9	7.9
Deep (2 to 3 ft)	10	0.371	18.2	4.3
Force Lake Sediment				
Surface (0 to 0.33 ft)	11	1.34	13.1	7.1
Subsurface (1 to 3 ft)	3	0.629	2.32	1.3

TOC – total organic carbon

For certain metals (e.g., cadmium, copper, lead, nickel, and zinc), the presence of sulfide (especially in reducing environments such as subsurface sediments) can reduce the bioavailability of these chemicals. Copper has also been found to bind strongly to soils with high TOC (ranging from 14 to 34% dry weight [dw]) (ATSDR 2004b).

5.3 Fate and Transport

Following the release of chemicals to surface or shallow subsurface soils at the Facility, the migration of chemicals may have historically occurred, or may occur, via the following potential pathways. The relative importance of these pathways varies for the chemicals and chemical groups discussed in Section 4.0 (TPH, PAHs, petroleum-associated VOCs, PCBs, metals, DDTs, and chlorinated solvents). The potential pathways include:

Groundwater Migration

- Vertical migration of dissolved-phase chemicals through the unsaturated zone to the shallow saturated zone as a result of rainfall infiltration and percolation
- Horizontal migration in the shallow saturated zone via advection and dispersion
- Vertical migration via advection and dispersion from the shallow saturated zone to the intermediate and, potentially, deep saturated zones

Non-Aqueous Phase Liquid Migration

- Horizontal migration of LNAPL on the water table surface
- Dissolution of LNAPL into the dissolved phase with groundwater migration via advective flow

Stormwater Migration and Erosion

- Direct runoff, soil erosion, and release to the drainage ditch and wetland
- Discharge from the former holding pond and current stormwater treatment system to the drainage ditch and wetland
- Sediment deposition into Force Lake

Surface Water and Sediment Migration from Force Lake

- Surface water and sediment migration out of Force Lake into North Lake, especially during the wet season

Vapor Phase Migration

- Vertical and horizontal migration in the unsaturated zone as a result of the volatilization of VOCs in the unsaturated zone and from the shallow saturated zone

Each of the known historical or potential pathways of chemical migration at the Study Area is described in the following subsections.

5.3.1 Groundwater Migration

Based on investigations and studies completed as part of the RI, and as described in Section 3.5.2, the hydrogeology beneath the Facility has been defined as containing three distinct groundwater zones. Each of the distinct groundwater zones is separated by saturated silt deposits with varying amounts of sand and clay. The three distinct water-bearing zones are described as follows:

- **Shallow Zone:** The shallow saturated zone has a surface that occurs at a depth ranging from 1 to 6 ft bgs, depending on the location and time of year. The bottom of the shallow saturated zone occurs at a depth of 8 to 15 ft bgs, depending on the location. Saturated soils within the shallow zone include relatively permeable sand fill material. Groundwater in this zone flows in a southwestern direction beneath the Facility toward, and with likely discharge to, Force Lake at an estimated advective pore velocity of between 0.038 and 0.053 ft per day.
- **Intermediate Zone:** An intermediate saturated zone that occurs within a sand interval from approximately 37 to 48 ft bgs. Groundwater in this zone flows in a western to southwestern direction beneath the Facility at an estimated advective pore velocity of between 0.018 and 0.024 ft per day.

- **Deep Zone:** A deep saturated zone that occurs at depths greater than approximately 90 ft bgs that is associated with the TGA gravels. Groundwater within the deep zone flows to the northwest toward the Columbia River during periods of low river flow, and southwest away from Columbia River during periods of high river flow (Golder Associates 1990).

As described in Sections 4.3 through 4.8, and as summarized below, chemicals attributable to historical Facility operations are restricted to the shallow groundwater zone. As such, the primary potential route of migration for chemicals in groundwater is a function of shallow groundwater flow toward, with ultimate discharge to, Force Lake.

5.3.1.1 Vertical Migration to the Intermediate Groundwater Zone

Vertical groundwater migration from the shallow zone to the intermediate zone is a potential pathway based on downward vertical gradients between these zones. However, based on the lack of detected chemicals in the intermediate zone, combined with the presence of an intervening lower-permeability silt deposit, migration to the intermediate zone does not appear to be a significant pathway.

Specifically, and as discussed in Sections 4.3 though 4.8, concentrations of metals in the intermediate zone were similar to or lower than those detected in the shallow zone. With the exception of acetone (a common laboratory contaminant) and DDD, no organic compounds were detected in any intermediate zone wells.

As described in Section 4.6, DDD was detected in shallow groundwater samples in some of the areas where total DDT concentrations in soil samples were highest (the central portion of the Facility, the exit driveway, and along the southwest boundary of the Facility). DDD was detected in deeper groundwater samples from the MW-2s/MW-2i/B-4 well cluster in the south-central portion of the Facility but was not detected in any other groundwater samples collected from intermediate monitoring wells or the plant well (PW-01). DDD was detected in the sample from the intermediate depth well MW-2i in 2008 and 2009 and in the sample from the deep well B-4 in 2008 and 2009.

The specific mechanism for the transport of DDD vertically from the shallow groundwater zone to the intermediate and deep groundwater zones at this single location is not known, but through a weight-of-evidence analysis, as described below, the presence would appear most likely attributable to a breach in the seal for well B-4.

In summary, total DDT (2,4-DDD + 4,4-DDD) was detected at the MW-2s/MW-2i/B-4 location in shallow groundwater at a concentration of 0.126 µg/L (total) and 0.073 µg/L (dissolved), in intermediate groundwater at a concentration of 0.015 µg/L (total) and 0.017 µg/L (dissolved), and in deep groundwater at a concentration of 0.012 µg/L (total) and 0.011 µg/L (dissolved). All detected concentrations were below the lowest human health screening level (0.20 µg/L). Gasoline-, diesel-, and oil-range petroleum hydrocarbons (hydrocarbon range of typical DDT carrier solvents) have not been detected in groundwater at the MW-2i or the B-4

well locations, and therefore it does not appear that DDD migrated to these depths within a carrier solution.

It is estimated (Section 5.3.1.2) that DDD transport in the shallow groundwater zone will experience a 14,000 times retardation factor. Using the same retardation factor for potential vertical transport, and using estimated vertical advective velocities between shallow and intermediate and intermediate and deep zones as summarized in Section 3.5.2.4, it is estimated that the time of migration for DDD to migrate through the natural system between MW-2s (shallow) and B-4 (deep) would be approximately 450,000 years. As such, the presence of DDD in the deep groundwater zone at B-4 is likely not the result of migration through the natural system.

Based on the preceding analysis, it appears that one of two scenarios, both related to well construction, may account for the groundwater results. The first scenario is that the borehole seals for wells B-4 and MW-2i were both physically breached due to a construction fault, allowing DDD in groundwater from the shallow zone to circumvent the native soils and migrate vertically through the well bore or other potential drilling-related voids into the intermediate (MW-2i; 38 to 48 ft bgs) and deep groundwater (B-4; 85 to 95 ft bgs) zones. The other possible scenario is that silty soils containing elevated DDD as documented at the MW-2 cluster location adhered to the drill casing and were advanced down the borehole during drilling and incorporated into the sandpack region of the well bore, thereby contaminating the groundwater at these well locations.

Based on data as presented and evaluated in the RI, it does not appear that chemicals have migrated from the shallow to the intermediate and deep groundwater zones via natural processes; therefore, this pathway does not appear to be complete or significant.

5.3.1.2 Lateral Migration within the Shallow Groundwater Zone

Data from four shallow monitoring wells (MW-1S, MW-2S, GA-33, and A-20) located along the south (downgradient) boundary of the Facility and data from two shallow wells (GA-29 and A-19) located at the southwest (downgradient) portion of the Facility were reviewed to assess the potential for the lateral migration of chemicals to off-Facility areas (e.g., to the wetland and Force Lake) via shallow groundwater flow. These wells are suitable sentinel wells for the evaluation of potential migration of chemicals detected in soil samples and in shallow monitoring wells located in the central and north portion of the Facility (see Figure 2-2 for well locations).

To examine this pathway, an evaluation of select chemicals with differing solubility and transport characteristics was conducted. Specifically, this evaluation was conducted for TPH – diesel range; TPH – oil range; TPH – gasoline range; benzene; and DDT, DDD, and DDE (representing total DDTs). PCBs, which also have a low solubility in groundwater and a high tendency to adsorb to soil organic matter, were not detected in groundwater beneath the Facility.

TPH – diesel range and TPH – oil range were only detected in one shallow well (A-18) during the 2008 sampling event; no TPH – diesel range or TPH – oil range were detected in any groundwater monitoring wells in 2009. TPH – gasoline range was detected in only two shallow monitoring wells in 2008 (A-18 and MW-4s) and in three shallow wells in 2009 (A-18, GA-34, and MW-4s). With regard to benzene, based on 2008 data, the highest concentration (140 µg/L) was detected in groundwater at shallow well MW-4s, and it was detected at three other locations (GA-34, MW-5s and A-18) at concentrations ranging from 2.0 to 4.2 µg/L. Similar benzene concentrations were detected at GA-34, MW-5s, and A-18 in 2009, but the benzene concentration was much lower (2.9 µg/L) at the MW-4s location in 2009 (compared with 140 µg/L in 2008).

No TPH – diesel range, TPH – oil range, or TPH – gasoline range or benzene concentrations, with the exception of certain low-level PAHs (below conservative screening levels as described in Section 4.3), have been detected in shallow monitoring wells located along the downgradient Facility boundary or in the southwest corner of the Facility, demonstrating that the migration of TPH-related chemicals off the Facility is limited or not occurring.

With regard to DDTs, DDD was detected in two shallow monitoring wells (MW-4s and MW-5s) within the Facility and in all four of the shallow monitoring wells located along the south downgradient boundary of the Facility. Because of the strong affinity of DDD to sorb to soil organic matter, groundwater migration of DDD would be very slow. The evaluation presented below demonstrates that DDD migration to Force Lake in shallow groundwater does not appear to be a significant pathway.

Based on the estimated advective velocity for shallow groundwater of 0.05 ft per day (see Table 3-2) and the 180-ft distance between the south boundary of the Facility and Force Lake, groundwater flow from the Facility to Force Lake would take approximately 10 years. DDD and DDT migration would be expected to take much longer because of their tendency to sorb to organic material in the soil matrix. One measure of the potential for an organic compound to sorb to soil is the K_{ow}. According to information provided in the *IPEN Body Burden Community Monitoring Handbook* (IPEN 2005), DDD has a log K_{ow} of 5.5 and DDT has a log K_{ow} of 6.2. Lyman et al. (1982) provides a formula for converting a log K_{ow} to a log organic carbon partition coefficient (K_{oc}) for a variety of insecticides, herbicides, and fungicides:

$$\log K_{oc} = 1.029 \log K_{ow} - 0.18 \qquad \textbf{Equation 5-1}$$

Where:

K_{oc} = organic carbon partition coefficient

K_{ow} = octanol-water partition coefficient

The calculated log K_{oc} is 5.48 (DDD) and 6.19 (DDT), and the K_{oc} would be approximately 3.0×10^5 mL/g (DDD) and 1.5×10^6 mL/g (DDT).

Using the average fraction of organic carbon (f_{oc}) of 0.0099 g organic carbon per g of soil (0.99%) measured for the lower subsurface soil

samples collected at the Facility, the soil-water partition coefficient (K_d) for DDD would be 2,970 mL/g, and for DDT would be 14,850 mL/g based on the following equation:

$$K_d = K_{oc} \times f_{oc}$$ **Equation 5-2**

Where:

K_d = soil-water partition coefficient (mL/g)

K_{oc} = organic carbon partition coefficient (mL/g)

F_{oc} = fraction of organic carbon (g organic carbon/g soil)

Note that the lower subsurface soil samples were typically collected from the silt unit underlying the sand unit, which is where most of the shallow groundwater flow occurs. The average organic carbon content for the upper (i.e., intermediate) subsurface samples collected from the sand unit had an average f_{oc} of 0.046 (4.6%).

The site-specific retardation factor (R), which expresses how much slower a contaminant moves relative to groundwater, would be approximately 14,000 for DDD and approximately 70,000 for DDT based on an average soil porosity of 35% (Table 3-2) and an assumed bulk density (r_b) of 1.66 mg/cm^3 per EPA's on-line site assessment calculation (EPA 2010c).

$$R = 1 + \frac{r_b \times k_d}{q}$$ **Equation 5-3**

Where:

R = retardation factor (unitless)

r_b = bulk density (mg/cm^3)

q = porosity

K_d = soil-water partition coefficient (mL/g)

Based on Equation 5-3, DDD is predicted to migrate through the shallow groundwater zone over 14,000 times slower than the estimated advective groundwater flow, resulting an estimated travel time of approximately 140,000 years for DDD and approximately 700,000 years for DDT, making DDT and the DDD metabolites essentially immobile in groundwater. Studies have shown that depending on environmental conditions, DDT metabolite half-lives can range from less than 1 month to up to 30 years (Section 4.6.2). Even at the higher end estimated half-life, by the time DDD could reach Force Lake, these DDT metabolites would have degraded.

Based on the preceding evaluation, and the discussions of the nature and extent of the shallow zone groundwater provided in Sections 4.3 through 4.8, it does not appear that the transport of chemicals to off-Facility locations (e.g., wetland and Force Lake) is a significant migration pathway. However, because shallow groundwater beneath the Facility does migrate toward, and discharges to, Force Lake, this pathway was

assessed in the uncertainty analysis of the ERA as summarized in Section 6.0 and detailed in Appendix J.

5.3.2 Non-Aqueous Phase Liquid Migration

LNAPL was first described and sampled at the site during a 2000 EPA site inspection (well GA-30). RI activities have concluded that LNAPL is not significant at the Facility, and its presence is highly localized and confined to a small portion of the Facility. Specifically, a thin layer (0.1 ft) of LNAPL was measured in well GA-30 in 2008, and trace thicknesses of LNAPL (0.01 ft or less) were observed in two of the precautionary extraction wells (EW-1 and EW-3) (Table 2-2). No LNAPL has been observed in wells MW-1s and MW-2s, which are located along the downgradient boundary of the Facility, or in shallow monitoring wells GA-29 or A-19, which are located between GA-30 the downgradient property boundary. Furthermore, field screening conducted during the RI soil sampling did not identify the presence of LNAPL at any boring locations.

After the LNAPL was removed from GA-30 during sampling in May 2008, only trace (i.e., non-measurable) to minor amounts (up to 0.02 ft) of LNAPL were measured at this location over the following year of monthly monitoring. The fact that LNAPL was not observed at GA-30 in any significant amount a year after its removal suggests that the LNAPL presence was minimal. Other than removal for sampling purposes as described above, no LNAPL extraction has occurred at the Facility. The noted extraction wells (EW-1 through EW-3), as described in Section 1.3.2.7.5, were installed for contingency/convenience purposes only and have never been used, because LNAPL has not been observed in sufficient quantity to sample.

Further, LNAPL does not appear to be a significant source of dissolved chemicals to shallow groundwater at the Facility. TPH – diesel range and TPH – oil range (a primary LNAPL component) were detected in only one shallow well (A-18) during the 2008 sampling event; no TPH – diesel range and TPH – oil range were detected in any monitoring wells in 2009. TPH – gasoline range was detected in only two shallow monitoring wells in 2008 (A-18 and MW-4s) and in three shallow wells in 2009 (A-18, GA-34, and MW-4s). Benzene was detected in only shallow groundwater at four wells in 2008 and 2009; one of these wells (A-18) was adjacent to the upgradient Facility boundary. No TPH – diesel range, TPH – oil range, TPH – gasoline range, or benzene concentrations were detected in shallow monitoring wells located along the downgradient Facility boundary or in the southwest corner of the Facility.

Based on the preceding evaluation, LNAPL (either through the migration on the water table or through the release of chemicals into groundwater) is not a significant migration pathway.

5.3.3 Stormwater Migration and Erosion

Historical stormwater migration was likely the primary mechanism for the transport of chemicals from the Facility to the adjacent wetland and Force Lake. The significance of this pathway is supported by the Facility history

and the distribution of chemicals, both at the Facility and within the wetland, as summarized in Section 4.0.

Chemicals likely migrated from the Facility bound to soil particles transported in stormwater runoff via the drainage ditch prior to the construction of the current stormwater treatment system in the mid-1980s. In addition, chemicals likely migrated from the Facility into the wetland prior to the construction of the soil berm after the 1979 fire at the Facility.

As described in Section 1.3.2, prior to construction of the drainage ditch around the northwestern margin of the Facility in the early 1970s, historical site topography would have directed surface water runoff from the operating portions of the Facility to adjacent low-lying areas to the south and west of the Facility. After ditch construction, and prior to the final period of fill placement on the western portion of the Facility between 1977 and 1984 (likely as part of reconstruction after the 1979 fire), runoff would have been directed to the south and southwestern low-lying areas, both by the ditch and by direct overland flow.

Over the course of operations, these low-lying areas included portions of the existing wetlands and Force Lake, as well as areas of the existing Facility footprint, that were lower in elevation at the time but were subsequently filled to match the existing grade. Specifically, the areas within the Facility included the former pond, reported sumps, and C-shaped area in the southwestern portion of the Facility. This drainage pattern would have resulted in particles containing bound chemicals settling at these locations, resulting in higher chemical concentrations in deeper samples than in surface samples in these areas. As discussed in Section 4, chemical concentrations detected in samples collected from the Study Area are consistent with this drainage pattern. Concentrations were generally highest in surface soil samples (both at the Facility and in the wetlands), except in now-buried low-lying areas where historical holding ponds or sumps were known to have been located. In these areas (e.g., the former pond, reported sumps, and C-shaped area in the southwestern portion of the Facility), concentrations were highest in surface or intermediate soil samples. Stormwater runoff is now collected and treated in the stormwater treatment system, which discharged to the drainage ditch in the southwest corner of the Facility until 2002 and now discharges from a pipe along the southwest boundary near the west corner of the Facility in accordance with an NPDES permit (Figure 4-2).

As described in Section 1.0, most of the Facility was covered with an approximate 12-in. layer of hard-packed gravel that was placed as part of Facility reconstruction following the 1979 fire. The gravel layer has been regularly maintained through the placement of fresh gravel on the surface, as needed. During the fall of 2011, the majority of the Facility (all areas except for the western-most portion) was paved with asphalt. The gravel and asphalt pavement layers, in conjunction with current stormwater management practices, prevents the erosion or transport of chemicals in underlying soils to the adjacent wetland and limits fugitive dust emissions.

Although several areas of the Facility are not protected from erosion by gravel or pavement, vegetation within these areas acts to prevent erosion. Therefore, these areas likely do not represent a significant migration pathway for the transport of soil particles from the Facility.

Specific areas of the Facility that do not have a gravel or pavement surface include:

- The former north ditch area, which also includes a vegetated area in the vicinity of MW-3s, SL-31 and SL-38
- The northwest portion of the Facility, which includes the soil stockpile area, the west portion of the perimeter soil berm, and non-gravel areas near SL-42, MW-1s, and GA-29
- The southwest Facility boundary and associated perimeter soil berm
- A portion of the southeast Facility boundary adjacent to North Force Avenue

Of the above, as a result of proximity and slope, the area that has the greatest potential for chemicals in Facility soils to migrate off of the Facility (via erosion) and pose a risk to ecological receptors is the soil berm located along the northwest and southwest Facility boundaries. This berm is currently intact, vegetated, and has no known areas of erosion. Thus, runoff from the berm is unlikely to present a significant migration pathway.

With regard to the wetland areas west and south of the Facility, there is a low potential for chemical migration to Force Lake from the wetland via soil erosion based on the relatively flat topography and extensive vegetative cover. An analysis presented in the ERA supports this conclusion (Appendix J).

5.3.4 Surface Water and Sediment Migration from Force Lake

As described in Section 3.3, Force Lake is 590 to 890 ft in diameter and has a surface area of about 12 ac with an average depth of approximately 2.5 ft. The estimated storage volume of the lake is about 30 ac-ft.

There are only two known inflow points into Force Lake. A catch basin drains a small area along the east side of North Force Avenue, just north of its intersection with North Victory Street (Figure 1-11) (Goodling 2007). Stormwater captured in this catch basin is conveyed beneath North Force Avenue and discharged into Force Lake. In addition, an underdrain for one of the greens on the Greenback Golf Club drains into Force Lake.

The current stormwater treatment system located at the Facility does not discharge directly into Force Lake but rather into the wetland just south of the Facility (Figure 4-2). Historical impacts on the wetland south of the Facility and on Force Lake resulting from oily wash water and stormwater discharges from the Facility (prior to the construction of the existing treatment system) have been documented, as described in Section 4.2.

During the construction at the Heron Lakes Golf Club in 1969 and 1970, the narrow west end of Force Lake was bisected (with fill material) to create North Lake. As described in the PEN 1 NRMP (City of Portland 1997), Force Lake outflows to North Lake, with outflow controlled by two culverts located on the west side of Force Lake. These culverts were installed approximately 0.8 ft higher than the previous water level, thus raising the water level that is required for water in Force Lake to flow into North Lake. As a result, outflow volumes from Force Lake are much less than inflow volumes and are often minimal for storm events (those less than a 2-year recurrence interval event).

According to the NRMP (City of Portland 1997), because of the hydraulic control on outflows from Force Lake, chemicals conveyed to Force Lake via runoff from its tributary sub-basin will remain in Force Lake and not be transported downstream. Surface water samples collected from North Lake and surface sediment samples collected from North Lake and Force Lake as part of the RI support the City of Portland's finding.

As presented in Section 4.0, TPH, PCBs, DDTs, and PAHs were not detected in surface water samples collected from Force Lake. Only four chemicals (arsenic, barium, copper, and acetone) were detected in at least one surface water sample. These metals occur naturally in the environment, and none of the identified concentrations appear to be attributed to releases from the Facility (see Section 4.5).

With regard to sediment samples, as described in Section 4.0, concentrations of PCBs, metals, and pesticides were relatively consistent throughout Force Lake. Metals concentrations (e.g., arsenic, lead, and mercury) had little spatial variability. The highest total PCB and total DDT concentrations were detected in the central portion of Force Lake; there was no gradient that indicated the presence of a source to the north of the lake. The spatial variations of PAH and TPH concentrations were slightly different. Total PAH concentrations were highest in samples from SE-02 and SE-03 in the northern portion of Force Lake, and total TPH concentrations were highest in samples from SE-03, SE-04, and SE-06 in the central western portion of Force Lake.

Detected concentrations of total PAHs, TPH, arsenic, and lead in the three sediment samples (SE-101 [11 ft from the culvert], SE-102 [38 ft from the culvert], and SE-103 [98 ft from the culvert]) collected from North Lake did not indicate the presence of a concentration gradient between the lakes. Total PCBs and mercury were not detected in any sediment samples from North Lake. Total DDTs were detected in one of the three samples collected from North Lake; the detected DDD and DDE concentrations were lower than detected concentrations in Force Lake.

In summary, because inflows and outflows from Force Lake are limited, the lake is a quiescent water body that acts as a settling basin. The water velocity or current is low, and suspended solids that enter the lake tend to settle to the bottom rather than being transported downstream. As such, chemicals that have entered the lake have usually stayed in the lake because of the hydraulics, the tendency for solids to settle, and the fact that most of the chemicals that have been detected above screening

levels (as described in Section 4.0) have a tendency to adsorb to organic matter and settleable solids. These chemicals have not been detected in filtered surface water (representative of dissolved phase transport), and thus it is unlikely that any significant migration of these chemicals from Force Lake has occurred, as was supported by the sampling conducted in North Lake as part of the RI.

Thus, in summary, chemical migration from Force Lake via the flow of water or sediment resuspension and transport does not appear to be a significant pathway based on Force Lake hydraulics, North Lake surface water sampling results, and North Lake sediment sampling results.

5.3.5 Vapor Phase Migration

VOCs from vadose zone soil and shallow groundwater can volatilize to outdoor air or into overlying or nearby structures via vapor intrusion. Certain chemicals (metals, PAHs, PCBs, and pesticides) are unlikely to volatilize and are not of concern with regard to this migration pathway. The limited extent and low concentrations of VOCs in vadose zone soil and shallow groundwater in the Study Area suggest that these pathways are not of significance. Nevertheless, these pathways were evaluated in the HHRA to be conservative (Appendix I).

5.3.6 Migration Pathway Summary

As described in Section 5.2.1, the key migration pathway for the distribution of COPCs is stormwater runoff. Specifically, chemicals may have migrated as a function of the historical direct discharge of oily rinsate and the entrainment and mass transport of chemicals contained on or sorbed to soil particles from the Facility. This migration pathway has resulted in the presence of chemicals in shallow groundwater, Facility soil, wetland soil, and Force Lake sediment. Oily rinsate and stormwater runoff from operational areas on the Facility would have flowed to low areas in the south and southwest and accumulated in historical sumps and holding ponds along the southwest Facility boundary, which may have extended into what is now considered the wetlands. These former low-lying areas were subsequently filled to current grade, and therefore these areas indicate deeper chemical presence than other areas on the Facility.

Facility modifications with regard to operations (e.g., the termination of truck cleaning operations), and stormwater management (e.g., the capture and treatment of all stormwater) have likely mitigated this pathway so that it is less likely to result in the continued transport of chemicals from the Facility.

Other pathways identified as potentially complete, but likely of lesser significance, include the following:

- Potential future erosion of soils from the soil berm located at the northwest and southwest property boundaries to the wetland
- Potential erosion of wetland soil into Force Lake

- Potential migration of chemicals in shallow groundwater to Force Lake sediment
- Potential volatilization of VOCs from Facility vadose zone soil or shallow groundwater to indoor or outdoor air

6.0 BASELINE RISK ASSESSMENTS

This section presents a summary of the baseline HHRA and ERA, which are included in this document as Appendices I and J, respectively.

6.1 Human Health Risk Assessment

The baseline HHRA presented risk estimates for humans for various scenarios involving exposure to COPCs found in soil, lake sediment, lake water, groundwater, and fish caught in Force Lake. The scenarios assessed in this HHRA were developed to be protective of the reasonable maximum level of exposure at the Study Area, and thus risk estimates, although uncertain, are intended to be health protective.

The baseline HHRA was conducted in accordance with the following guidance:

- EPA's Risk *Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual, Part A* (1989)
- EPA's *Risk Assessment Guidance for Superfund, Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors* (1991a)
- *EPA Region 10 Supplemental Risk Assessment Guidance for Superfund* (1996)
- EPA's *Risk Assessment Guidance for Superfund. Volume 1. Human Health Evaluation Manual. Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments* (1998b)
- EPA's *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (2004)
- DEQ's *Guidance for Conduct of Deterministic Human Health Risk Assessments (1998c)*
- DEQ's *Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites (2003)*

The baseline HHRA (Appendix I) presented a data evaluation, CSM and exposure assessment, toxicity assessment, risk characterization, and uncertainty analysis, each of which is briefly summarized in the following subsections.

6.1.1 Data Evaluation

Data used in the assessment included the data collected from the Study Area during the two phases of RI data collection (April 2008 and April 2009). In addition, one of the eight historical datasets available for the Study Area was also found to be acceptable for use in this HHRA. The

historical data used in the HHRA were collected by EPA in 2000 (Ecology and Environment 2001). In total, the HHRA dataset included Facility soil samples, groundwater samples, wetland soil samples, lake sediment samples, and lake surface water samples. The available data were found to be representative of Study Area concentrations and appropriate for use in estimating potential human exposures.

6.1.2 Conceptual Site Model and Exposure Assessment

Based on the current and likely future land uses within the Study Area, the human health CSM described generalized scenarios in which people could be exposed to chemicals within the Study Area (Figure 6-1) through various pathways. Although not differentiated in Figure 6-1, exposures might occur on the Facility (workers) or in the nearby wetlands or Force Lake (recreational users or fish consumers). In addition, a screening assessment for hypothetical future residents was assessed as described in Section 6.1.5, even through residential land use is unlikely (the Facility has an Industrial Sanctuary designation, as do the surrounding properties to the northwest, northeast, and southeast).

On the Facility, exposure pathways included direct contact with Facility soil and groundwater, as well as the inhalation of soil or water vapors and soil particles during work activities. For non-Facility portions of the Study Area, exposure pathways included direct contact with wetland soil, lake sediment, or lake surface water during recreation, as well as indirect exposure through the consumption of fish from Force Lake. The human health CSM identified pathways as complete or incomplete. All complete pathways, except those with low exposure potential, were evaluated quantitatively in the HHRA.

In accordance with EPA guidance (1989), the four scenarios selected for analysis in this HHRA were parameterized as RME scenarios. RME is the highest exposure that is reasonably expected to occur at a site and is generally used by EPA to determine whether to conduct a feasibility study for potential remedial actions (EPA 1989). RME scenarios, by definition, likely overestimate exposure for many individuals but are used here to ensure that this baseline HHRA is health-protective. Risks associated with a fifth scenario, the industrial/commercial worker vapor intrusion scenario, were calculated based on a comparison of Study Area concentrations with published screening levels for the vapor intrusion pathway (EPA 2002d), and thus it was not necessary to define exposure parameters for this scenario.

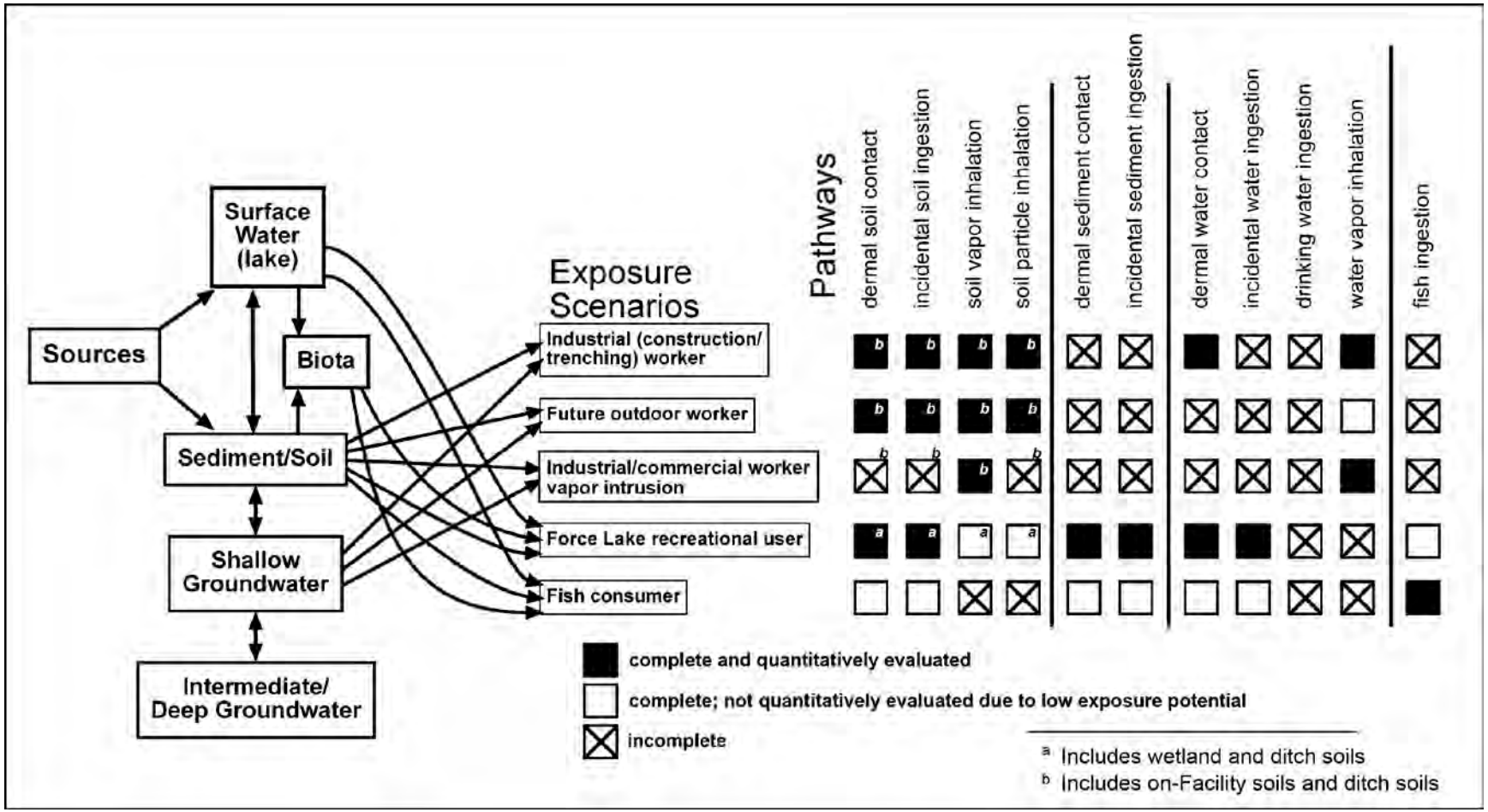


Figure 6-1. Human Health CSM

The following scenarios were evaluated for the HHRA to assess the exposure of workers to COPCs at the Facility:

- **Industrial (construction/trenching) worker RME scenario:** Current and future onsite workers may be exposed to chemicals in Facility soil via incidental ingestion, dermal absorption, inhalation of airborne soil particulates, and inhalation of volatilized chemicals. Exposure to chemicals in groundwater may occur via dermal absorption and the inhalation of volatilized chemicals.
- **Future outdoor worker RME scenario:** Future outdoor workers may be exposed to chemicals in Facility soil via incidental ingestion, dermal absorption, inhalation of airborne soil particulates, and inhalation of volatilized chemicals.
- **Industrial/commercial worker vapor intrusion scenario:** Current and future onsite workers may be exposed to chemicals in Facility soil or groundwater via the inhalation of chemicals volatilized to indoor air.

The following scenarios were evaluated in the HHRA to assess the exposure of individuals to COPCs in the non-Facility portions of the Study Area:

- **Force Lake recreational user RME scenario:** Individuals who use Force Lake as a recreational area both currently and in the future may be exposed to chemicals in wetland soil or lake sediment via incidental ingestion and dermal absorption (lake and wetland exposure were evaluated separately) and to chemicals in lake surface water through incidental ingestion and dermal absorption.
- **Force Lake fish consumer RME scenario:** Many of the chemicals found at the Study Area are persistent in the environment and can bioaccumulate in the food chain. Thus, individuals who fish recreationally at Force Lake both currently and in the future may be exposed to chemicals in fish tissue via the consumption of fish caught in Force Lake.

In the first step of the exposure assessment, a conservative risk-based screen was performed in accordance with EPA guidance (as presented in Section 6.1) to identify the media-specific COPCs to be evaluated for each scenario. A total of 34 chemicals or chemical groups were identified as COPCs for one or more scenarios, including 15 metals, 2 PAHs, 1 other SVOC, PCBs, DDTs, 14 VOCs, and 2 TPH ranges. Details of this screen are presented in Section 3.2 of the HHRA (Appendix I). The next step involved the estimation of the potential exposure of people to COPCs for each scenario. Exposures were calculated using concentration data for each COPC and health-protective assumptions.

Exposure point concentrations (EPCs) were calculated to represent estimates of COPC concentrations in soil, groundwater, lake sediment, lake surface water, and fish tissue. These EPCs were then used in the exposure equations to calculate COPC intake or exposure. The EPC was

either the maximum concentration or the UCL concentration[23] of a COPC and was intended to represent a long-term exposure concentration. In some cases, the EPC was set equal to one-half the maximum RL if this value was higher than the maximum detected concentration or if there were no detected concentrations of the COPC. EPCs for the direct exposure scenarios (i.e., worker and recreation scenarios) were calculated for the area over which the exposure could potentially occur. Literature biota-sediment accumulation factors (BSAFs) were used along with Force Lake sediment concentrations to estimate the fish tissue EPCs.

6.1.3 Toxicity Assessment

EPA toxicity values were identified for all COPCs. Toxicity values included slope factors (SFs) and inhalation unit risk factors to estimate carcinogenic risks, as well as reference doses (RfDs) and reference concentrations (RfCs) to estimate the potential for effects other than cancer. Carcinogenic toxicity values (i.e., SFs and inhalation unit risk factors) provide a health-protective means to assess risks because they represent upper-bound estimates of carcinogenic potency. Similarly, non-cancer toxicity values (i.e., RfDs and RfCs) are health-protective because they are typically based on the most sensitive endpoint and population for which adequate data are available and include uncertainty factors or extrapolations to account for sensitive sub-populations or other limitations of the toxicity study data on which they were based.

6.1.4 Risk Characterization and Uncertainty Analysis

Carcinogenic risks and non-carcinogenic health effects were evaluated separately in the HHRA because of fundamental differences in the mechanisms of these toxic effects. Carcinogenic risk estimates were calculated by multiplying the estimated chemical intake by the SF or inhalation unit risk factor. Cancer risk estimates were compared with EPA's target risk range of 10^{-6} to 10^{-4} established in the National Contingency Plan for Superfund sites (40 CFR 300). For reference, the lifetime risk of developing cancer in the US population is one in two (i.e., 5×10^{-1}) for men and one in three (i.e., 3×10^{-1}) for women (American Cancer Society 2006). A 1×10^{-6} excess cancer risk represents an additional one-in-one-million probability that an individual may develop cancer over a 70-year lifetime through exposure to COPCs at the Study Area.

Chemicals with non-carcinogenic health effects are generally not toxic below a certain threshold; a critical dose must be exceeded before adverse health effects are observed. The potential for non-carcinogenic health effects is represented by the ratio of the estimated chemical intake to the critical dose (known as an RfD) and is expressed as an HQ. Exposures resulting in an HQ less than or equal to 1 are unlikely to result in non-cancer adverse health effects. When the sum of all HQs, regardless of endpoint, exceeded 1, endpoint-specific hazard indices

[23] Data management rules for calculating EPCs are presented in Attachment 2 of the HHRA (Appendix I).

(HIs) were calculated by summing the HQs for chemicals with common toxicological endpoints (e.g., all HQs calculated for the developmental endpoint).

For worker scenarios based on exposure to COPCs at the Facility, the total excess cancer risk estimates for the future outdoor worker RME scenario and the industrial (construction/trenching) worker RME scenario were equal to 2×10^{-5} and 3×10^{-6}, respectively (Table 6-1). For scenarios evaluating risks associated with COPCs in the non-Facility portions of the Study Area (Force Lake and the wetlands), the total excess cancer risk was equal to 2×10^{-5} for the Force Lake fish consumer RME scenario and was equal to 1×10^{-5} for the Force Lake recreational user RME scenario across all media (i.e., wetland soil, lake sediment, and lake surface water).

Table 6-1. Summary of Total Excess Cancer Risks and Non-Cancer HQs

Scenario and Associated Media	Total Excess Cancer Risk	Overall HI[a]
Industrial (construction/trenching) worker RME scenario (cumulative risk across media)	3×10^{-6}	1
Future outdoor worker RME scenario	2×10^{-5}	0.6
Industrial/commercial worker vapor intrusion scenario	9×10^{-7}	ne[b]
Force Lake recreational user RME scenario (cumulative risk across media)	1×10^{-5}	0.4[c]
Force Lake fish consumer RME scenario	2×10^{-5}	3 (endpoint-specific HIs were less than or equal to 1)[c, d]

[a] The overall HI is equal to the sum of HQs across multiple exposure pathways, endpoints, and/or target organs.

[b] Risks for this scenario were calculated based on a comparison of Study Area groundwater concentrations with vapor intrusion screening levels, which are based on the more stringent of the cancer or non-cancer risks (i.e., whichever one results in lower screening levels). For this scenario, screening levels for all COPCs were based on cancer risks, and thus it was not possible to calculate non-cancer risks.

[c] The overall HI is based on children 0 to 6 years of age. This HI is higher than HIs for the integrated 0-to-30 year age group and for older age groups (i.e., 7 to 16 years and 17 to 30 years), and thus is typically used for risk management decisions.

[d] The overall HI for this scenario was equal to 3. Because this value was greater than 1, endpoint-specific HIs were calculated per EPA guidance (1989). No endpoint-specific HIs were greater than 1 (see Section 5.3.5 of the HHRA [Appendix I] for details).

COPC – contaminant of potential concern
HI – hazard index
HQ – hazard quotient
ne – not evaluated
RME – reasonable maximum exposure

The overall HI (i.e., sum of non-cancer HQs for all COPCs across all endpoints) was less than or equal to 1 for all scenarios except the Force Lake fish consumer RME scenario (Table 6-1). However, when endpoint-specific HIs were calculated for the fish consumer RME scenario, no endpoint-specific HIs were greater than 1.

Based on the risk estimates, arsenic, cPAH TEQ, total PCBs, total DDTs, and TPH-gasoline (aliphatic) were identified as COCs (i.e., COPCs with excess cancer risks greater than 10^{-6}). Figure 6-2 presents a comparison of risk estimates by COPC for each of the scenarios with a total excess cancer risk greater than or equal to 1×10^{-6}. All excess cancer risk estimates were within EPA's target risk range of 10^{-6} to 10^{-4}. This information is also presented in Table 6-2, along with risk estimates based on background or reference area concentrations.

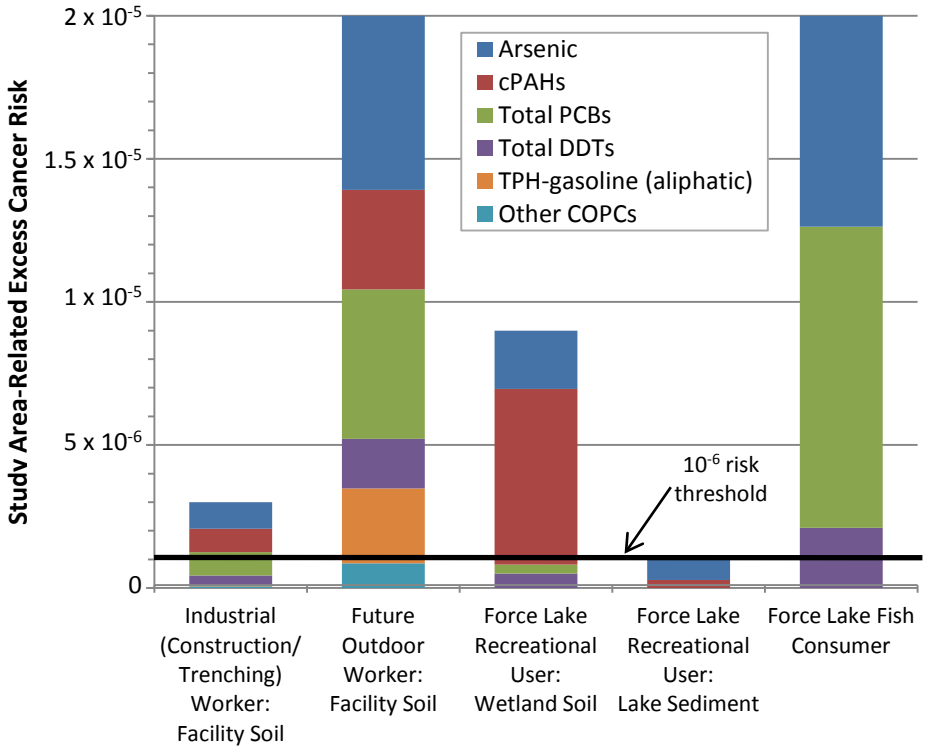


Figure 6-2. Proportion of Total Excess Cancer Risk for Each COC and for other COPCs

Table 6-2. Summary of Excess Cancer Risks for Scenarios with Total Excess Cancer Risks Greater than or Equal to 1×10^{-6}

COCs and other COPCs	Excess Cancer Risks (Percent of Total)				
	Industrial (Construction/ Trenching) Worker: Facility Soil	Future Outdoor Worker: Facility Soil	Force Lake Recreational User: Wetland Soil	Force Lake Recreational User: Lake Sediment	Force Lake Fish Consumer
Total Risk Estimates for Individual COPCs					
Arsenic	8×10^{-7} (31%)	7×10^{-6} (30%)	2×10^{-6} (23%)	1×10^{-6} (71%)	7×10^{-6} (37%)
cPAH TEQ	7×10^{-7} (27%)	4×10^{-6} (17%)	6×10^{-6} (68%)	4×10^{-7} (29%)	na
Total PCBs	7×10^{-7} (27%)	6×10^{-6} (26%)	3×10^{-7} (3%)	na	1×10^{-5} (53%)
Total DDTs	3×10^{-7} (12%)	2×10^{-6} (9%)	5×10^{-7} (6%)	na	2×10^{-6} (11%)
TPH-gasoline (aliphatic)	3×10^{-8} (1%)	3×10^{-6} (13%)	na	na	na
Other COPCs	5×10^{-8} (2%)	1×10^{-6} (5%)	2×10^{-10} (0%)	na	na
Total risk	**3×10^{-6}**	**2×10^{-5}**	**9×10^{-6}**	**1×10^{-6}**	**2×10^{-5}**
Background or Reference Area Risk Estimates[a]					
Arsenic	6×10^{-7}	4×10^{-6}	2×10^{-6}	2×10^{-6}	8×10^{-6} to 9×10^{-6}
cPAH TEQ	6×10^{-9} to 4×10^{-8}	3×10^{-8} to 2×10^{-7}	4×10^{-8} to 3×10^{-7}	7×10^{-7} to 8×10^{-7}	na
Total PCBs	5×10^{-9}	2×10^{-8}	nc	na	3×10^{-6} to 4×10^{-6}
Total DDTs	nc	2×10^{-9} to 5×10^{-8}	nc	na	2×10^{-7}

[a] Background or reference area concentrations and sources are discussed in Attachment 7 of Appendix I. Concentrations for metals are representative of background concentrations and concentrations for organic compounds are representative of reference area concentrations. No background or reference area concentrations were available for TPH gasoline (aliphatic).

cPAH – carcinogenic polycyclic aromatic hydrocarbon
COC – contaminant of concern
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
na – not applicable (not a COPC)
nc – not calculated
PCB – polychlorinated biphenyl
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons

For these COCs, background or reference area data from local and regional sources were used to estimate risks for comparison with Study Area risk estimates. Risk estimates based on background concentrations were similar to those based on Study Area concentrations for arsenic for most of the scenarios (Table 6-2). With one exception, risk estimates based on reference area concentrations were less than Study Area risk estimates for cPAH TEQ, total PCBs, or total DDTs for all scenarios (Table 6-2). The exception was for the Force Lake recreational user based on exposure to wetland soil: cPAH TEQs from reference areas were slightly higher than or similar to those at the Study Area. No background or reference area data were available for TPH-gasoline (aliphatic).

Uncertainties associated with the risk estimates for each exposure scenario were discussed in the HHRA. Because the scenarios evaluated were either RME scenarios or comparisons to conservative screening levels, the selected exposure assumptions should be protective of the workers at the Facility and the general public. The RME risk estimates likely overestimate risks for most individuals, although it is possible that risks could also be underestimated.

Risk estimates were highest for the Force Lake fish consumer RME scenario and the future outdoor worker RME scenario (equal to 2×10^{-5} for both scenarios). For the Force Lake fish consumer RME scenario, the main uncertainties included the use of BSAFs (rather than actual fish tissue data) to estimate fish tissue concentrations and the use of an estimated fish consumption rate to calculate risks (for further discussion fo these uncertainties, see Sections 6.1.4 and 6.1.5 of the HHRA [Appendix I], respectively). To ensure that the scenario was health-protective, the values selected for both of these parameters were intended to be conservative. For example, the assumed adult fish consumption rate would require the annual consumption of 5 to 10 times the number of fish observed during the 2009 Force Lake survey (Windward 2009b). If each adult was also assumed to be feeding one child, even more fish would be needed (the annual consumption of 6 to 11 times the number of fish observed during the 2009 Force Lake survey). For the future outdoor worker RME scenario, the main uncertainty was the assumption that the gravel and pavement layers that currently cover the Facility would be removed, which would increase the exposure beyond existing conditions.

Additional analyses presented in Appendix I address uncertainties associated with the chemistry data, exposure assumptions, and toxicities of the COPCs. The final risk estimates reflect uncertainties associated with using data and assumptions from multiple sources; the combined effect of those uncertainties on risk estimates cannot be quantified. However, the assessment tended to overestimate risks, consistent with the health-protective nature of risk assessment. Therefore, the baseline characterization of RME risks for the Study Area is considered to be health-protective and sufficient to support risk management decisions.

6.1.5 Screening-Level Assessment for Future Resident Scenario

In addition to the risk evaluations described in Section 6.1.4, a screening assessment was conducted to estimate risks based on the exposure of hypothetical future residents to chemicals at the Study Area (see Appendix I, Attachment 1). This scenario was based on the dermal absorption and incidental ingestion of Facility soils, wetland soils, and groundwater and on the ingestion of groundwater as drinking water. Per EPA request (Bridgewater et al. 2008b; Windward and Bridgewater 2008a, b), this screening-level assessment was included in the HHRA despite the current and expected future land use of the Study Area, which does not include residential use or development.

The screening assessment for hypothetical future residents indicated that total excess cancer risks would likely be greater than the upper end of EPA's target risk range (10^{-4}) and that HQs for some chemicals would likely be greater than 1 based on the risks calculated using residential RSLs (EPA 2009c). However, the wetlands are currently zoned as open space, and the Facility and other surrounding areas are currently zoned for industrial use. City of Portland planning documents indicate that these designations are not likely to change in the future, especially given the Industrial Sanctuary designation for the property on which the Facility is located and the fact that the non-Facility portions of the Study Area are in an NRMP area established under the City of Portland planning code. Based on this information, and as stated in the RI/FS Work Plan (Bridgewater et al. 2008b), residential development in this area is unlikely.

6.2 Ecological Risk Assessment

The baseline ERA for the Harbor Oil Superfund Site Study Area is included as Appendix J. This section presents a summary of the baseline ERA, which was conducted in accordance with the following guidance:

- EPA's *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (1997a)
- *EPA Region 10 Supplemental Ecological Risk Assessment Guidance for Superfund* (1997b)
- EPA's *Guidelines for Ecological Risk Assessment* (1998a)

The baseline ERA presents risk estimates for benthic invertebrates, terrestrial invertebrates, fish, and wildlife species that may be exposed to COPCs in wetland soil, Force Lake surface sediment, Force Lake surface water, and aquatic or terrestrial biota. The risk assessment was designed to be protective of the range of species that have been observed at or could use the Study Area. Conservative assumptions, such as the use of the lowest toxicity values and the use of UCL concentrations for estimating exposure, were used in an attempt to ensure that risk estimates, although uncertain, were protective of ecological receptors.

The baseline ERA presented a problem formulation, exposure assessment, effects assessment, risk characterization, and uncertainty analysis. Each of these elements is briefly summarized in the following subsections.

6.2.1 Problem Formulation

The ERA problem formulation established the overall scope of the assessment, which included the identification of the receptors of concern (ROCs) and COPCs that were further evaluated in the exposure and effects assessment, risk characterization, and uncertainty analysis.

A systematic process, consistent with EPA guidance (1997a, 1998a), was followed to select representative species as ROCs. This process, which was presented in the risk assessment scoping memorandum (Windward and Bridgewater 2008a) and approved by EPA, resulted in the selection of species for which the risk conclusions would be protective of other species that were not explicitly evaluated. The following ROCs representing various feeding guilds were selected for this ERA:

- **Invertebrates:** aquatic benthic invertebrate community and wetland invertebrate community
- **Fish:** brown bullhead (omnivorous fish) and pumpkinseed (invertivorous fish)
- **Birds:** ruddy duck (invertivorous bird), great blue heron (piscivorous bird), and red-tailed hawk (higher-trophic-level carnivorous bird)
- **Mammals:** shrew (invertivorous mammal) and Eastern cottontail (herbivorous mammal)

These selected ROCs are known to use the Study Area for habitat or could potentially use the Study Area based on its habitat characteristics.

The problem formulation also included a description of the data available for conducting the ERA, the suitability of the data for risk assessment purposes, and the methods for and results of using a risk-based screening process to identify COPCs. The dataset used in the baseline ERA consisted of historical data and data collected from the Study Area during two phases of RI data collection (April 2008 and April 2009). Only one of the eight historical datasets available for the Study Area was acceptable for use in the ERA. The historical data used in the ERA were collected by EPA in 2000 (Ecology and Environment 2001).

Data used in the ERA consisted of wetland surface (0 to 6 in.), intermediate (6 to 12 in.), and berm[24] (6 to 24 in.) soil chemistry data, Force Lake surface (0 to 4 in.) sediment chemistry data, Force Lake surface water chemistry data, and shallow groundwater chemistry data.[25]

[24] The soil berm is approximately 2 to 3 feet high and 5 to 6 feet wide at its base and extends along the border of the Facility to the west and south; the berm is intended to prevent stormwater runoff from flowing into the adjacent wetlands.

[25] Shallow groundwater data were evaluated only as part of an exposure assessment presented in the uncertainty analysis, wherein shallow groundwater data were compared with AWQC.

Chemical concentrations in various tissue types were estimated from abiotic concentrations. The available data were found to be representative of Study Area concentrations and appropriate for use in estimating potential ecological exposures.

For each receptor of concern (ROC) selected, COPCs were identified through a conservative risk-based screening process using no-adverse-effect levels or other protective toxicity thresholds for the following analyte groups: metals, PAHs, phthalates, other SVOCs, VOCs, pesticides, and PCBs. During the screening process, COIs, which were defined as all detected chemicals, were screened against conservative screening thresholds. COIs with maximum detected concentrations greater than conservative screening values were identified as COPCs. In accordance with EPA guidance (1997a, 2001), an additional screening step was then conducted to further refine the list of COPCs. In the refined screening step, Study Area concentrations were compared with background/reference area[26] concentrations to eliminate COPCs from the Study Area that had concentrations less than or equal to those in background/reference areas. This refinement step streamlined the baseline ERA, providing greater clarity and transparency to the assessment. Refined COPCs were evaluated further in the baseline ERA. COIs with no available screening thresholds could not be screened and were discussed in the uncertainty assessment.

The following summarizes the results of the refined COPC screening process for each receptor group:

- **Aquatic benthic invertebrates:** COIs for aquatic benthic invertebrates were defined as any chemical detected in surface sediment or surface water. Forty-eight COIs were identified for aquatic benthic invertebrates. Sediment thresholds were not available for 13 COIs (3 metals, 2-methylnaphthalene, dibenzofuran, 4 VOCs, and 4 petroleum hydrocarbon mixtures), and thus risks to aquatic benthic invertebrates from exposure to these COIs could not be evaluated. Water thresholds were available for all four surface water COIs. Twelve refined COPCs (cadmium, copper, lead, nickel, zinc, fluoranthene, phenanthrene, total PCBs, 2,4′-DDD, 4,4′-DDD, 4,4′-DDE, and total DDTs) were identified in sediment.
- **Terrestrial invertebrates:** COIs for terrestrial invertebrates were defined as any chemical detected in surface soil. Eighty-eight chemical (or chemical groups) were identified as COIs for terrestrial invertebrates. Soil thresholds were not available for 48 COIs (vanadium, PCBs, DDTs, delta-BCH, methoxychlor, 2 PAHs, 10 SVOCs, 16 VOCs, and 6 petroleum hydrocarbon mixtures), and thus risks to terrestrial invertebrates from exposure to these COIs could not be evaluated. Five refined COPCs (chromium,

[26] The term reference area is used instead of background for organic compounds because no specific background concentrations that are representative of anthropogenic background have been selected or approved by EPA. Instead, concentrations from reference areas (urban areas in the vicinity of the Study Area) area presented for comparison with Study Area concentrations.

copper, mercury, zinc, and total HPAHs) were identified in wetland soil.

- **Fish:** COIs for fish were defined as any chemical detected in surface sediment or surface water. Forty-eight chemicals (or chemical groups) were identified as COIs for fish and evaluated as dietary COIs, tissue COIs, or surface water COIs. Effects data for fish were not available for five of the dietary COIs (three metals, 2-methylnaphthalene, and dibenzofuran), and no tissue TRVs were available for eight COIs (acetone, carbon disulfide, methyl ethyl ketone, toluene, and 4 petroleum hydrocarbon mixtures), and thus risks to fish from exposure to these COIs could not be evaluated. Water thresholds were available for all four surface water COIs. Two refined COPCs (cadmium and copper) were identified for fish diet, and one refined COPC (total PCBs) was identified for fish tissue.
- **Aquatic birds:** COIs for aquatic birds were defined as any chemical detected in surface sediment. Forty-eight chemical (or chemical groups) were identified as COIs for aquatic ROCs, including ruddy duck. Effects data for birds were not available for 10 COIs (barium, 3 VOCs, 2 PAHs, and 4petroleum hydrocarbon mixtures), and thus risks to aquatic birds from exposure to these COIs could not be evaluated. Two refined COPCs (mercury and total DDTs) were identified for ruddy duck, and one refined COPC (total DDTs) was identified for great blue heron.
- **Terrestrial birds:** COIs for terrestrial birds were defined as any chemical detected in surface soil. Eighty-eight chemical (or chemical groups) were identified as COIs for terrestrial ROCs. Effects data for birds were not available for 37 COIs (5 metals, 2 PAHs, 9 SVOCs, 15 VOCs, and 6 petroleum hydrocarbon mixtures), and thus risks to terrestrial birds from exposure to these COIs could not be evaluated. One refined COPC (total DDTs) was identified for red-tailed hawk.
- **Terrestrial mammals:** COIs for terrestrial birds were defined as any chemical detected in surface soil. Eighty-eight chemicals (or chemical groups) were identified as COIs for terrestrial ROCs. Effects data for mammals were not available for 31 COIs (4 metals, 7 SVOCs, 14 VOCs, and 6 petroleum hydrocarbon mixtures), and thus risks to terrestrial mammals from exposure to these COIs could not be evaluated. Five refined COPCs (cobalt, copper, mercury, vanadium, and total PAHs) were identified for Eastern cottontail, and ten refined COPCs (arsenic, cadmium, cobalt, copper, lead, mercury, zinc, total PAHs, total PCBs, and total DDTs) were identified for shrew.

Additional details regarding the COPC screening process are provided in Section 2.6 of the ERA (Appendix J).

The problem formulation also presented the CSMs for the aquatic and terrestrial ROCs. The CSM was used to define assessment endpoints and measures of exposure and effect. The CSMs for the terrestrial and

aquatic ecological ROCs are presented as Figures 6-3 and 6-4, respectively. The significant pathways evaluated in the ERA included direct exposure to surface sediment, direct exposure to surface water, direct exposure to wetland soil, and indirect exposure through the dietary ingestion of biota. The protection and maintenance (i.e., survival, growth, and reproduction) of ROCs were the key endpoints evaluated in this assessment. Risk questions and measurement endpoints were developed for all ROCs based on the complete and significant exposure pathways identified in the CSMs. Table 6-3 presents an overview of the proposed assessment endpoints, hypotheses (phrased as questions), representative ROCs, measurement endpoints, and data that were used in the ERA.

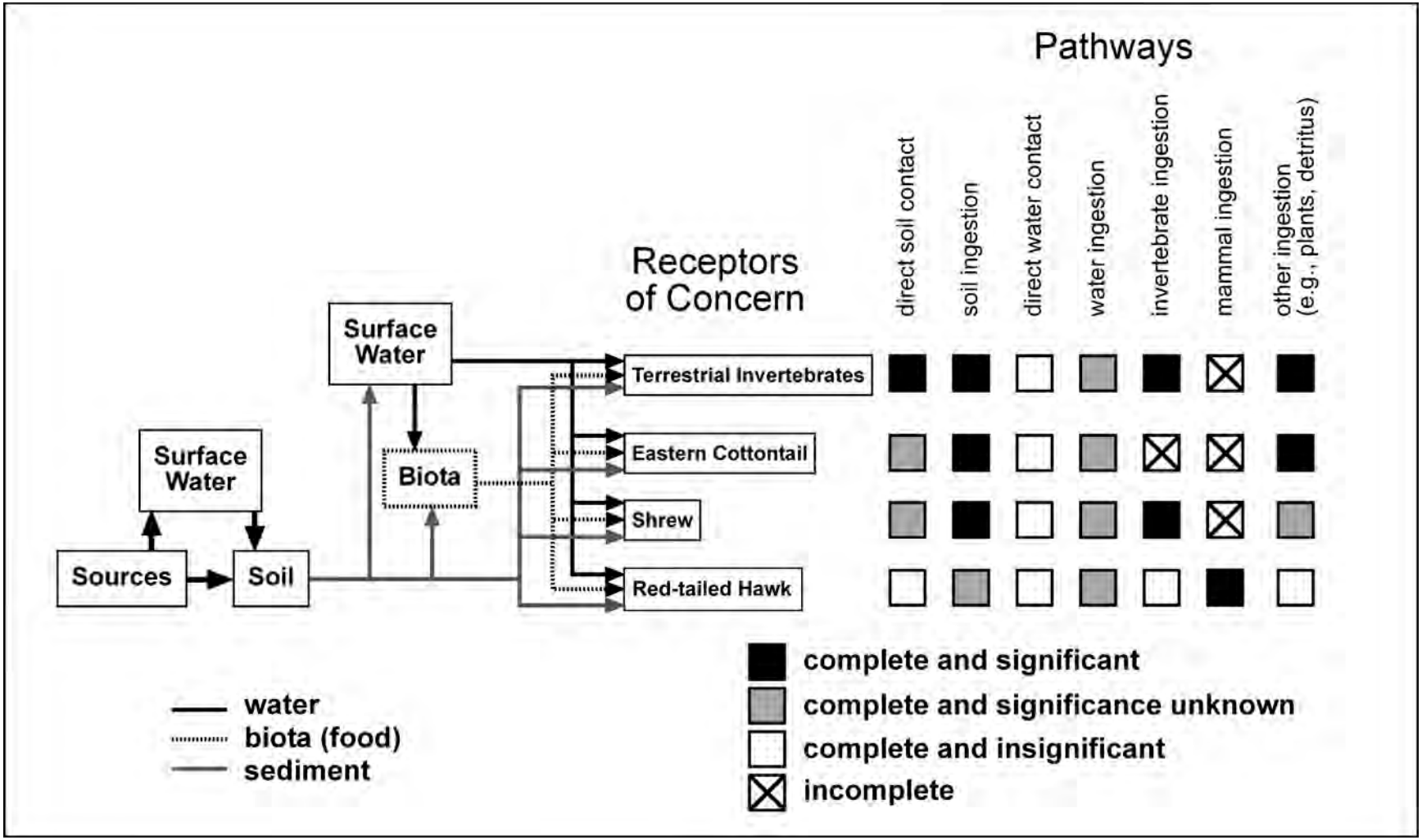


Figure 6-3. Ecological CSM – Terrestrial Receptors of Concern

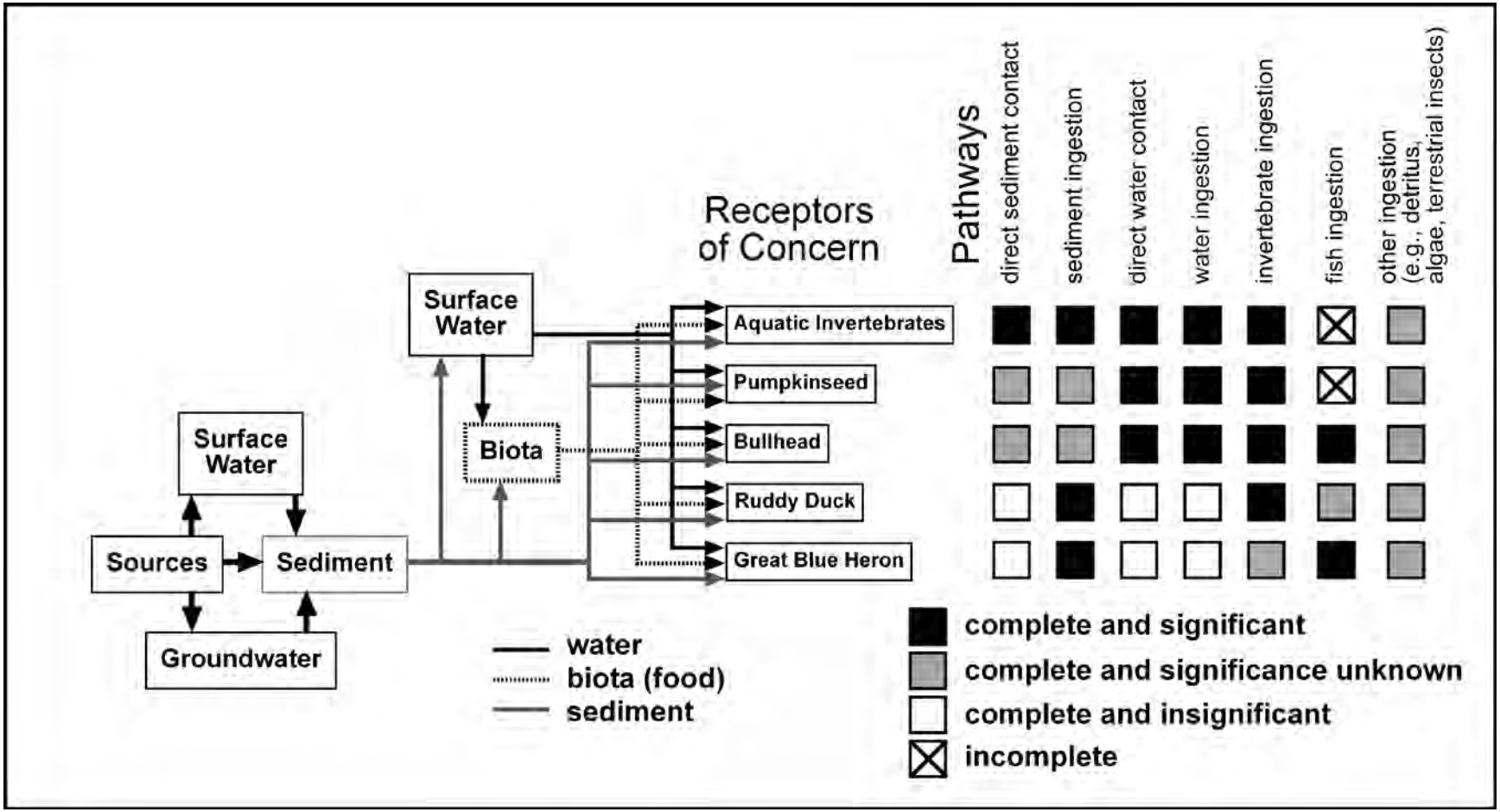


Figure 6-4. Ecological CSM – Aquatic Receptors of Concern

Table 6-3. Assessment Endpoints for ROCs and Measures of Effect and Exposure

Assessment Endpoint by ROC	Testable Risk Question	Description of Measurement Endpoint	Data to be Evaluated from the Study Area
Invertebrates			
Protection and maintenance (i.e., survival, growth, and reproduction) of the aquatic benthic invertebrate community	Are COPC concentrations in Force Lake surface sediment at levels that might cause an adverse effect on survival, growth, and/or reproduction of the Force Lake benthic invertebrate community?	concentrations in sediment compared with sediment thresholds from the literature that are protective of aquatic benthic invertebrates	concentrations in Force Lake surface sediment samples
	Are COPC concentrations in surface water from Force Lake at levels that might cause an adverse effect on survival, growth, and/or reproduction of the Force Lake aquatic benthic invertebrate community?	concentrations in surface water compared with water thresholds from the literature that are protective of aquatic benthic invertebrates	concentrations in Force Lake surface water samples
	Are COPC concentrations in shallow groundwater samples nearest to Force Lake at levels that might cause an adverse effect on survival, growth, and/or reproduction of the Force Lake benthic invertebrate community?	concentrations in groundwater compared with water thresholds from the literature that are protective of aquatic benthic invertebrates	concentrations in shallow groundwater well samples closest to Force Lake[a]
Protection and maintenance (i.e., survival, growth, and reproduction) of the terrestrial invertebrate community	Are COPC concentrations in wetland soils at levels that might cause an adverse effect on survival, growth, and/or reproduction of the terrestrial invertebrate community present at the Study Area wetlands?	concentrations in wetland soil compared with soil thresholds from the literature that are protective of terrestrial invertebrates	concentrations in wetland, ditch, and berm soil samples
Fish			
Protection and maintenance (i.e., survival, growth, and reproduction) of fish (i.e., pumpkinseed and brown bullhead)	Are estimated COPC concentrations in fish tissue at levels that might cause an adverse effect on survival, growth, and/or reproduction of populations of fish that use Force Lake?	ROC-specific estimated concentrations in fish tissue compared with literature-based tissue-residue TRVs	estimated concentrations in brown bullhead and pumpkinseed
	Are modeled dietary exposures to COPCs from Force Lake prey at levels that might cause an adverse effect on survival, growth, and/or reproduction of fish populations that use Force Lake?	ROC-specific modeled daily doses (estimated from surface sediment and invertebrate and/or fish tissue chemistry) compared with literature-based dietary-dose TRVs	estimated concentrations in aquatic benthic invertebrates and/or fish and concentrations in surface sediment
	Are COPC concentrations in surface water from Force Lake at levels that might cause an adverse effect on survival, growth, and/or reproduction of fish populations that use Force Lake?	concentrations in surface water compared with water thresholds from the literature that are protective of fish	concentrations in Force Lake surface water samples
	Are COPC concentrations in shallow groundwater samples nearest to Force Lake at levels that might cause an adverse effect on survival, growth, and/or reproduction of fish populations that use Force Lake?	concentrations in groundwater compared with water thresholds from the literature that are protective of fish	concentrations in shallow groundwater well samples closest to Force Lake[a]

Table 6-3. Assessment Endpoints for ROCs and Measures of Effect and Exposure (cont.)

Assessment Endpoint by ROC	Testable Risk Question	Description of Measurement Endpoint	Data to be Evaluated from the Study Area
Birds			
Protection and maintenance (i.e., survival, growth, and reproduction) of terrestrial (i.e., red-tailed hawk) and aquatic birds (i.e., great blue heron and ruddy duck) populations	Are modeled dietary doses of COPCs based on Force Lake sediment and biota prey at levels that might cause an adverse effect on survival, growth, and/or reproduction of ruddy duck populations that use Force Lake?	ROC-specific modeled daily doses (estimated from surface sediment and invertebrate tissue chemistry) compared with literature-based dietary-dose TRVs	estimated concentrations in aquatic benthic invertebrates and concentrations in Force Lake surface sediment
	Are modeled dietary doses of COPCs based on Force Lake sediment and biota prey at levels that might cause an adverse effect on survival, growth, and/or reproduction of great blue heron populations that use Force Lake?	ROC-specific modeled daily doses (estimated from surface sediment and invertebrate and fish tissue chemistry) compared with literature-based dietary-dose TRVs	estimated concentrations in aquatic benthic invertebrates and fish and concentrations in Force Lake surface sediment
	Are modeled dietary doses of COPCs based on wetland soils and biota prey at levels that might cause an adverse effect on survival, growth, and/or reproduction of red-tailed hawk populations that use Study Area wetlands?	ROC-specific modeled daily doses (estimated from wetland soil and mammal tissue chemistry) compared with literature-based dietary-dose TRVs	estimated concentrations in terrestrial small mammals and concentrations in wetland, ditch, and berm soil samples
Mammals			
Protection and maintenance (i.e., survival, growth, and reproduction) of terrestrial mammal (i.e., shrew and Eastern cottontail) populations	Are modeled dietary doses of COPCs based on Force Lake sediment, wetland soil, and biota prey at levels that might cause an adverse effect on survival, growth, and/or reproduction of shrew populations that use Study Area wetlands and Force Lake?	ROC-specific modeled daily doses (estimated from wetland soil, sediment, and aquatic benthic invertebrate and terrestrial invertebrate tissue chemistry) compared with literature-based dietary-dose TRVs	estimated concentrations in aquatic and terrestrial invertebrates and concentrations in Force Lake sediment and wetland, ditch, and berm soil samples
	Are modeled dietary doses of COPCs based on wetland soils and biota prey at levels that might cause an adverse effect on survival, growth, and/or reproduction of Eastern cottontail populations that use Study Area wetlands?	ROC-specific modeled daily doses (estimated from wetland soil and plant tissue chemistry) compared with literature-based dietary-dose TRVs	estimated concentrations in terrestrial plants and concentrations in wetland, ditch, and berm soil samples

[a] Based on the hydrogeology of the Study Area, only shallow groundwater is likely to recharge Force Lake. Thus, the shallow groundwater well samples closest to Force Lake (i.e., MW-1s, MW-2s, GA-33, and A-20 [see Figure 2-2]) were evaluated as part of the uncertainty analysis (Section 5.1.1 in Appendix J).

COPC – contaminant of potential concern
ROC – receptor of concern
TRV – toxicity reference value

6.2.2 Exposure Assessment

The exposure assessment estimated the potential exposure of each ROC/refined COPC pair identified in the problem formulation:

- The exposure of the aquatic benthic invertebrate community to refined COPCs was estimated based on concentrations in individual surface sediment and surface water samples.
- The exposure of the terrestrial invertebrate community to refined COPCs was estimated based on concentrations in individual wetland and berm soil samples.
- The exposure of fish to refined COPCs was characterized based on estimated concentrations in fish tissue, concentrations in surface water, and estimated dietary doses using ROC-specific exposure parameters.
- The exposure of birds and mammals to refined COPCs was characterized based on estimated dietary doses using ROC-specific exposure parameters.

In the dietary-dose evaluation for fish and wildlife ROCs, the exposure assessment presented equations and identified parameters to quantify the ingested dose. Dietary doses for fish and wildlife were estimated using available information on ROC biology and life histories, including body weight, feeding behavior, site usage, and diet. Aquatic and terrestrial tissue concentrations were estimated from sediment and wetland soil concentrations using BSAFs and bioaccumulation factors (BAFs), respectively.

6.2.3 Effects Assessment

Toxicity data for potential adverse effects (i.e., reduced survival, reduced growth, or impaired reproduction), screening thresholds, and criteria were identified as outlined in the risk assessment scoping memorandum (Windward and Bridgewater 2008a) and summarized in the effects assessment. Published effects thresholds were identified for the evaluation of the benthic invertebrate community exposure to sediment and terrestrial invertebrate community exposure to soil.

For fish, tissue-residue and dietary-dose TRVs were summarized for the identified refined COPCs based on a detailed evaluation of toxicological studies in the scientific literature that documented the effects of COPCs on the ROCs or similar species. This literature review identified concentrations in fish tissue and doses associated with no effects (i.e., safe concentrations or doses) in addition to the lowest concentrations or doses that were associated with adverse effects. Both sets (i.e., no-observed-adverse-effect level [NOAEL] and LOAEL) of TRVs were summarized, and the rationale for TRV selection was provided.

For wildlife, dietary-dose TRVs were summarized for the identified ROC-refined COPC pairs based on a detailed evaluation of toxicological

studies in the scientific literature. Both NOAEL and LOAEL TRVs were identified; the rationale for the selection of specific values was presented.

6.2.4 Risk Characterization and Uncertainty Analysis

The exposure and effects data in the risk characterization were compared to calculate HQs, which were used, along with the uncertainty analysis, to assess the potential for adverse effects from specific refined COPCs. In ERAs, HQs greater than 1.0 indicate that the exposures of some receptors are estimated to be greater than toxicological benchmarks. Such a finding is generally regarded as an indication of a potential for adverse effects, particularly if the benchmark is an effects concentration (or dose) at which adverse effects were observed (i.e., a LOAEL). HQs may also be calculated based on a NOAEL. The potential for adverse effects associated with a NOAEL HQ greater than 1.0 is uncertain unless the LOAEL is also assessed, because the true threshold for effects occurs at a concentration (or dose) somewhere between the NOAEL and LOAEL. An exposure between the NOAEL and LOAEL may or may not result in an adverse effect. Therefore, both types of HQs were calculated and presented to better describe the potential for adverse effects.

The results for each of the ROCs are summarized in Table 6-4 and discussed below. Table 6-4 provides a summary of HQs for all ecological ROCs for which the LOAEL-based, PEL- or PEC-based HQs were greater than 1.0. Table 6-4 presents HQs based on Study Area data as well as effects-based HQs derived using background concentrations (for metals) or reference area concentrations (for organic compounds). Note that although background concentrations have been recommended by DEQ for soils, sediment, and surface water for metals, similar recommendations are unavailable for organic compounds, such as DDTs and PAHs. For organic compounds, concentrations from reference areas (i.e., urban areas within the vicinity of the Study Area) were used for comparison with Study Area concentrations because specific background concentrations have not been established.

Table 6-4. COPCs and ROCs with LOAEL-Based HQs Greater than 1.0

COPC	Matrix	NOAEL-Based HQ	LOAEL-Based HQ	Background or Reference Area[a] LOAEL-Based HQ
Aquatic Benthic Invertebrate Community				
DDD	surface sediment	**2.4 – 17**[b]	1.0 **– 7.2**[c]	0.072 – 0.79[c]
DDE	surface sediment	**6.4 – 110**[b]	**1.3 – 22**[c]	1.0 – 1.5[c]
Terrestrial Invertebrate Community				
Chromium	wetland soil	**3.3 – 75**[d]		**21**[d]
Copper	wetland soil	0.21 – **25**[d]		0.72[d]
Zinc	wetland soil	0.31 – **6.2**[d]		0.72[d]
Total HPAHs	wetland soil	0.0056 **– 3.2**[d]		0.003 – 0.022[d]
Fish – Pumpkinseed				
Copper	diet	**3.5**	**1.8**	0.30
Fish – Brown Bullhead				
Copper	diet	**2.1**	**1.1**	0.18
Birds – Red-Tailed Hawk				
Total DDTs	diet	**5.8**	**1.2**	0.020 – 0.47
Mammals – Eastern Cottontail				
Mercury	diet	**5.9**	**1.2**	0.54
Mammals – Shrew				
Mercury	diet	**65**	**13**	**5.7 – 15**
Total DDTs	diet	**9.2**	**8.5**	0.053 – 0.41

[a] Background and reference area concentrations and sources are discussed in Attachment 4 of the ERA (Appendix J). Concentrations for metals are representative of background concentrations and concentrations for organic compounds are representative of reference area concentrations.

[b] HQs were developed based on a comparison to a TEL or a TEC.

[c] HQs were developed based on a comparison to a PEL or a PEC; total DDT concentrations were less than the total DDT PEL/PEC.

[d] HQs were developed based on a comparison to soil screening levels.

COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effect level
NOAEL – no-observed-adverse-effect level
PEC – probable effects concentration
PEL – probable effects level
ROC – receptor of concern
SL – screening level
TEC – threshold effects concentration
TEL – threshold effects level
TRV – toxicity reference value

Bold identifies HQs greater than 1.0.

Aquatic Benthic Invertebrate Community: Concentrations of refined COPCs (including metals, PAHs, PCBs, and total DDTs) were greater than threshold effects concentrations (TECs) or threshold effects levels (TELs) but less than PECs or PELs. Exceedances of TECs and TELs do not necessarily predict toxicity; therefore, risks to benthic invertebrates are expected to be relatively low because these COPCs had concentrations greater than TECs/TELs but less than PECs/PELs. DDD and DDE were the only COPCs with concentrations in sediment that were also greater than PECs or PELs (thresholds associated with adverse effects); however, total DDT concentrations were less than these thresholds, and the bioavailability of DDD and DDE would be limited because TOC concentrations in the sediment were high, reducing the likelihood of effects on biota. No refined COPCs were identified for surface water; therefore, no risks to the aquatic benthic invertebrate community from exposure to surface water are expected.

As part of the uncertainty analysis, the potential exposure of aquatic benthic invertebrates to chemicals detected in nearby wetland soils and in shallow groundwater wells closest to Force Lake was evaluated. It was determined that shallow groundwater along the downgradient (i.e., south) side of the Facility is not expected to be a significant pathway of exposure for aquatic benthic invertebrates. Also, the potential for unacceptable risk to aquatic benthic invertebrates from the potential erosion of wetland soil into the lake is minimal because: 1) metals and PCB concentrations in wetland soil near Force Lake were low compared with PELs and PECs, and 2) total DDT concentrations in lake sediment were much lower than those in wetland soil likely indicating that there is limited transport of wetland soil to Force Lake.

Terrestrial Invertebrate Community: Five refined COPCs (chromium, copper, mercury, zinc, and total HPAHs) were evaluated for the terrestrial invertebrate community. HQs were less than 6.5, except for copper (with HQs from 0.21 to 25 and a background HQ of 0.72) and chromium (with HQs from 3.3 to 75 and a background HQ of 21). This assessment likely overestimated risk because the soil screening levels are conservative thresholds intended only for screening (i.e., they are not intended to serve as cleanup values), and they do not take into account site-specific bioavailability. The conservative screening level used for chromium is 21 times greater than the background soil concentration. In addition, although soil concentrations were greater than soil TRVs, earthworms were frequently observed during field sampling in areas with higher concentrations of metals. The samples with concentrations greater than background concentrations and conservative screening values were relatively limited, with the highest concentrations found in wetland soil collected from or near the ditch area.

Fish: Three measures of assessment were evaluated for the two fish ROCs (pumpkinseed and brown bullhead): tissue residue, surface water, and dietary dose. Three refined COPCs were evaluated (total PCBs in tissue and cadmium and copper in diet). Of these three COPCs, only copper had an exposure concentration greater than the LOAEL TRV, indicating the potential for adverse effects. However, the LOAEL-based

HQs were low (1.8 for pumpkinseed and 1.1 for brown bullhead). Consistent with the uncertainty evaluation conducted for the aquatic benthic invertebrate community, the potential for the exposure of fish to COPCs in shallow groundwater discharging into Force Lake is not expected to be a significant pathway of exposure.

Uncertainties that may affect the fish ROC risk estimates include the use of literature-based BSAFs (effect on risk estimates is unknown) and the dietary composition selected for pumpkinseed (risks may be overestimated based on the assumption of aquatic benthic invertebrate prey).

Birds: For birds (ruddy duck, great blue heron, and red-tailed hawk), two COPCs (mercury and total DDTs) were evaluated based on the results of the refined COPC screen. Estimated dietary doses for were less than those associated with adverse effects. The LOAEL-based HQ for total DDTs for the red-tailed hawk was 1.2, indicating the potential for adverse effects.

Uncertainties that may affect the risk estimates include the use of literature-based BSAFs and BAFs (effect on risk estimates is unknown).

Mammals: For mammals (Eastern cottontail and shrew), 11 COPCs were evaluated based on the results of the COPC screen. The LOAEL-based HQ for Eastern cottontail for mercury (1.2), was greater than 1.0, indicating the potential for adverse effects. However, the background LOAEL-based HQ for mercury (0.54) was half the Study Area HQ, indicating that background contributions to the risk were significant.

For shrew, LOAEL-based HQs for mercury (13), and total DDTs (8.5) were greater than 1.0, indicating the potential for adverse effects. The background LOAEL-based HQs for mercury ranged from 5.7 to 15 (compared with a Study Area HQ of 13), indicating that background concentrations are an important consideration for mercury. Reference area LOAEL-based HQs for total PCBs and total DDTs were less than 1.0.

Uncertainties that may affect the mammal risk estimates include the use of the site by shrew and the use of literature-based BAFs and BSAFs.

To further evaluate risks to shrew from total DDTs, a map was created (Figure 6-5) to evaluate the spatial extent of areas with concentrations that resulted in LOAEL-based HQs greater than 1.0. Shrew were assumed to consume both aquatic and terrestrial invertebrates; however, the majority of their exposure to total DDTs (> 99%) can be attributed to total DDT concentrations in wetland soil (i.e., through the terrestrial food chain). Wetland areas with total DDT concentrations that resulted in area-wide HQs greater than 1.0 were limited to a few highly localized areas, generally within the central portion of the wetlands between the Facility and Force Lake.

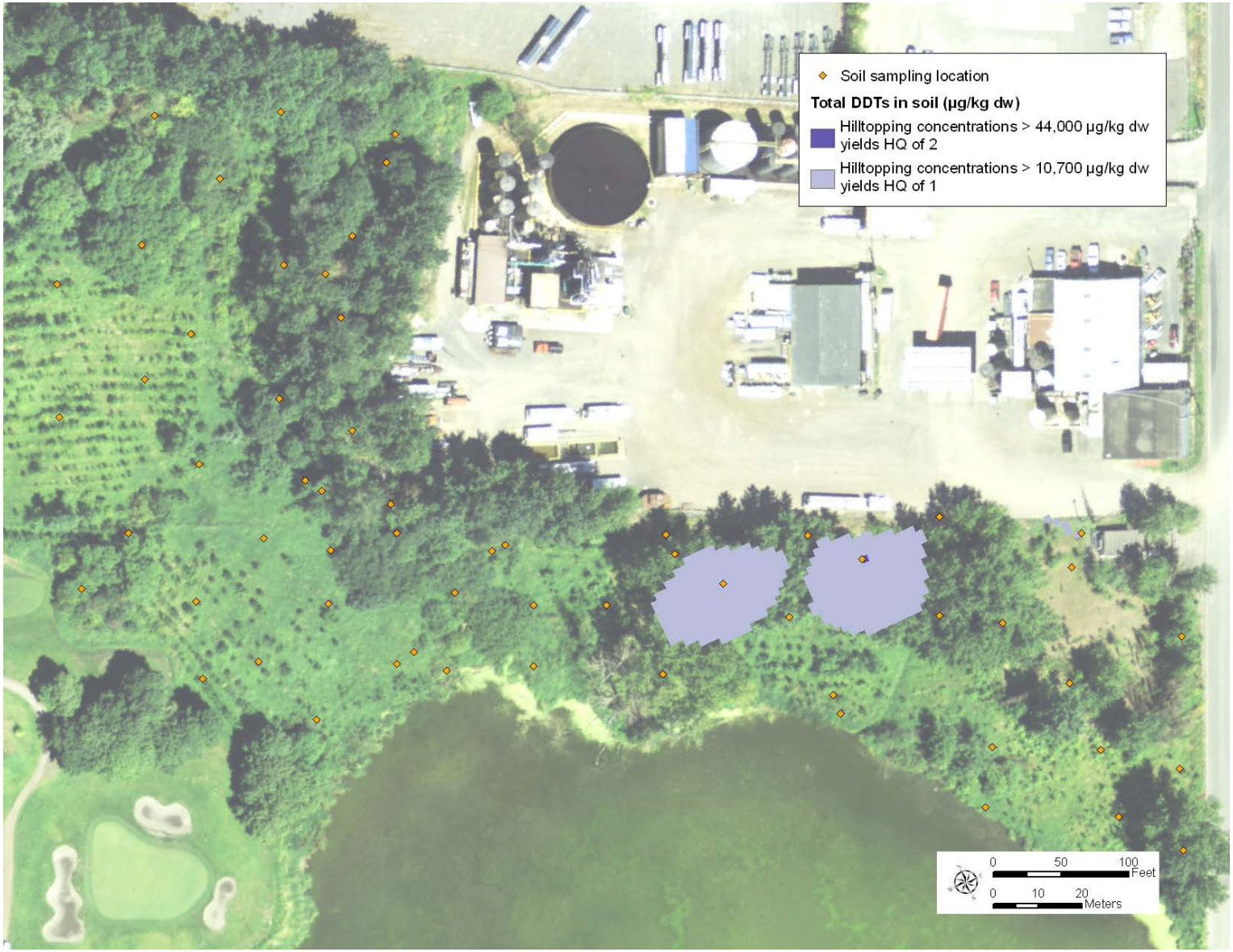


Figure 6-5. Interpolation of Total DDTs in Soil Relative to Risks to Shrew

7.0 SUMMARY AND CONCLUSIONS

This section presents a summary of the RI findings (Section 7.1), as well as a synthesis of the pathway, nature and extent, and risk conclusions for the Facility, the wetlands, and Force Lake (Section 7.2). RAOs are discussed in Section 7.3.

7.1 Summary of the RI

This section provides a brief summary of each section of the RI report.

7.1.1 Site Description and History

Section 1.0 presented an introduction to the Site, including a site description and history. In accordance with the May 2007 AOC, the Site encompasses the Facility, the adjacent wetland to the south and west of the Facility, and Force Lake. The following provide a brief overview of the Study Area (see Figure 7-1), which includes the Site and a portion of North Lake.

- The Facility is an approximately 4.1-ac parcel of land located in an industrial area of north Portland. The Study Area is approximately 19 acres. Until recently, most of the Facility was unpaved and covered with gravel. However, during the fall of 2011, the majority of the Facility (all areas except for the western-most portion) was paved with asphalt.
- EMRI (which took over the operation of the Facility in 1999 after Harbor Oil, Inc., ceased doing business on the property) currently operates a treatment and processing facility for used oil, fuels, and oily water at the Facility.
- Facility features related to the used oil processing include the tank farm and used oil processing area (located along the northeast side of the Facility), Tank 23 (located to the northwest of the tank farm), and the used-oil processing plant constructed in 2003 (located to the west of the tank farm and used oil processing area).
- Stormwater from the Facility is collected and sent to the stormwater treatment system located near the southwest Facility boundary. Treated stormwater is discharged to the wetlands, southwest of the Facility, under an NPDES Industrial Stormwater Discharge Permit. A soil berm, which extends along the southwest and northwest Facility boundaries, is intended to prevent Facility stormwater runoff from flowing into the adjacent wetlands.

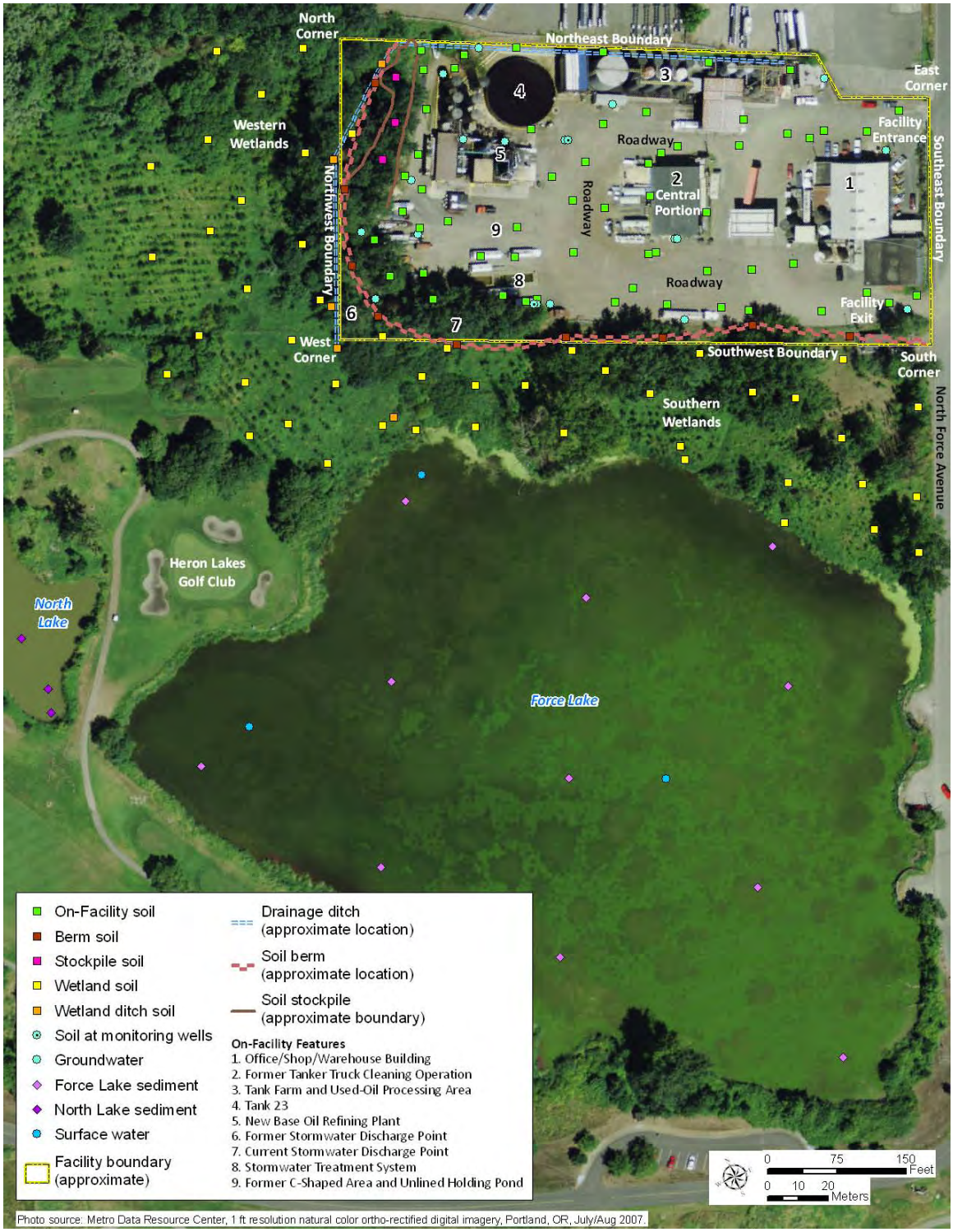


Figure 7-1. Facility Features, Area Descriptions, and RI Sampling Locations

Key points regarding the Facility history (Section 1.3) that are likely most relevant to the distribution of chemicals at the Study Area are listed below:

- **Cattle truck and tanker truck cleaning operations:** Truck cleaning operations began in the 1950s and continued until 1994. The Detrex system, which used TCE, was put in service during the mid- to late 1980s and was used until operations ceased in 1994.
- **Dust suppression business and road oiling:** Dust suppression operations started sometime in the 1950s and continued until 1993. Historical aerial photographs (Appendix A) and DEQ documentation (DEQ 1973) suggest that the Facility road was oiled in the early 1970s and mid-1980s.
- **Oil treatment and processing activities:** Empire Industries began oil recycling activities at the Facility in 1961, which continue to this day. EMRI currently treats and processes used oil, oily water, and other water at the Facility.
- **1979 Facility fire:** A fire destroyed the Facility in 1979 and reportedly resulted in releases to the adjacent wetlands and Force Lake. After the fire, the soil berm was constructed (apparently with soil that had been impacted by the fire-related releases) to prevent direct stormwater flow or other releases into the wetlands, and the Facility was expanded and reconstructed.
- **Stormwater drainage patterns:** During early operations at the Facility, stormwater and industrial wastewater likely drained to sumps and holding ponds located along the southwest Facility boundary and in the western portion of the Facility (which may have extended into what is now considered the wetlands). These features were identified in a 1974 DEQ report (DEQ 1974a), but there is no evidence of them in the aerial photographs. In the 1970s, a drainage ditch was constructed along the northeast Facility boundary that discharged Facility stormwater to the wetlands. The ditch remained open until 2002 when it was filled. The current stormwater treatment system (constructed in 1983 and 1984) discharges to the southwest of the Facility, is regulated under an NPDES permit, and incorporates an oil-water separator.

Section 1.0 of the RI also summarized multiple field investigations conducted at the Facility, adjacent wetland areas, and Force Lake since 1988. The data from one sampling event (Ecology and Environment 2001) were considered acceptable for use in the RI. Data from seven other historical sampling events did not meet DQOs and were unsuitable for use.

7.1.2 Study Area Investigation

Field sampling activities at the Study Area conducted as part of the RI were presented in Section 2.0. The RI was conducted in accordance with the EPA DQO process to clarify RI objectives and develop an appropriate

data collection design to support necessary decision making. All activities were completed in accordance with an EPA-approved RI/FS Work Plan (Bridgewater et al. 2008b). Field sampling activities supported the primary objectives developed for the RI, including characterization of the nature and extent of contamination, determination of potential migration pathways, verification of the preliminary CSMs, and evaluation of risks to human health and ecological receptors.

The RI site characterization was conducted in two phases. Phase 1 sampling was conducted in April-May 2008, and Phase 2 was completed in March-April 2009. These sampling events included the following activities:

- Collection of surface or subsurface soil samples at 61 locations at the Facility (including 9 soil berm or 3 soil stockpile locations)
- Collection of wetland and ditch soil samples at 52 surface and 10 subsurface locations
- Collection of surface sediment samples at 11 locations in Force Lake, subsurface sediment samples at 3 locations in Force Lake, and surface sediment samples at 3 locations in North Lake
- Collection of surface water samples at 3 locations in Force Lake
- Installation of 8 new monitoring wells followed by the collection of groundwater samples from the 8 new wells, 7 existing monitoring wells, and the plant well
- Aquifer slug testing at 9 monitoring well locations
- Collection of monthly groundwater and lake elevations between May 2008 and April 2009
- Completion of a fish population survey in Force Lake in April 2009 to obtain information on the types of fish present in the lake and estimate the abundance and sizes of these fish

7.1.3 Physical Characteristics of the Study Area

The physical characteristics of the Study Area, including surface features, meteorology, surface water hydrology, geology, hydrogeology, demography and land use, and ecology were presented in Section 3.0. Key points regarding the physical characteristics of the Study Area are summarized below:

- **Surface features:** The land surface of the Facility is relatively flat with a slight slope from northeast to southwest toward the wetlands and Force Lake. A soil berm extends along the northwest and southwest sides of the Harbor Oil Facility, preventing untreated runoff from entering the adjacent wetlands.
- **Meteorology:** The Study Area is in a temperate marine climate characterized by wet winters and dry summers. The average annual amount of precipitation (primarily as rain) is 37 in.; the average annual temperature is 54°F.

- **Surface water hydrology:** The Study Area is located within the Columbia River floodplain, an area with numerous wetlands and small lakes. Force Lake, the main water body in the Study Area, is approximately 12 ac in size with an average depth of 2.5 ft. Inflows and outflows from the Force Lake are limited, and thus, Force Lake acts as a settling basin. Suspended solids that enter the lake tend to settle to the bottom, rather than being transported downstream.
- **Geology:** One non-native (i.e., fill) lithologic layer and several native lithologic layers are present beneath the Facility, as observed in Facility borings. The native lithologic layers are usually consistent with a fluvial depositional environment of predominantly low energy (e.g., sediments deposited from swamps or marshes), with occasional changes to a fluvial depositional environment of moderate energy (e.g., sediments deposited from river or stream flooding).
- **Hydrogeology:** Beneath the Facility, local hydrogeology has been defined as three distinct groundwater zones (each separated by saturated silt deposits), Depth to uppermost groundwater beneath the Facility (shallow saturated zone) ranges from less than 1 ft to approximately 6 ft bgs, depending on location and the time of year. An intermediate depth saturated zone (37 to 48 ft bgs), and a deep saturated zone (greater than 90 ft bgs) are also present beneath the Facility. Based on water level measurements collected during the RI sampling events, groundwater flow is to the southwest in the shallow zone, with flow towards and discharge to, Force Lake. Groundwater flow within the intermediate zone is to the west or southwest, and alternates between the northwest and southwest in the deep zone. Vertical gradients in the upgradient and central portions of the Facility are largely downward; vertical gradients in the southern portion of the Facility tend upward during the dry season and alternate between upward and downward during the wet season.
- **Demography and land use:** The zoning and comprehensive plan designations for the Study Area indicate that the current and likely future land use designation at the Facility is industrial, particularly given its designation as an Industrial Sanctuary. The current and likely future land use of the wetlands and Force Lake is as open space, indicating that these areas will continue to be used for recreation and as habitat for ecological receptors. Current human uses at the Study Area include the daily activities of workers at the Facility, as well as recreational activities in the wetlands and Force Lake (e.g., golf ball retrieval, fishing). As part of the larger investigation and improvement effort for the Columbia Slough, the City of Portland found that although fishing occurs at Force Lake, it is relatively infrequent compared with other locations throughout the slough.
- **Ecology:** The Study Area is located within the PEN 1 NRMP area, which is one of the NRMP areas developed by the City of Portland

to evaluate the cumulative effects of development and mitigation within a large ecosystem. The Study Area provides habitat for numerous birds and several species of mammals.

7.1.4 Nature and Extent of Contamination

The nature and extent of contamination in the Study Area was presented in Section 4.0. Data that met DQOs for all chemicals analyzed in samples collected from the Study Area were summarized and discussed. To focus the discussion, chemicals or chemical groups were discussed in greater detail if they were COCs identified in the HHRA, contaminants with effects-based HQs greater than 1.0 in the ERA for which Study Area concentrations were greater than background or reference area concentrations, or chemicals known to be of interest in the Study Area based on past or present industrial activities. These chemicals or chemical groups included TPHs, PAHs, petroleum-associated VOCs, PCBs, metals, DDTs, and chlorinated solvents. Data for these chemicals were presented on a medium-specific basis and compared with conservative human health RSLs and ecological screening levels (all key chemicals) and with regional background concentrations (metals only).

Key findings of the nature and extent evaluation are summarized below. Additional details are summarized by medium and chemical or chemical group in the summary tables provided in Section 7.2.

- Chemical concentrations were generally highest at the Facility, with the exception of some metals for which the highest concentrations were in the wetlands near the west corner of the Facility. At the Facility, the highest concentrations for most chemicals were in the central portion of the Facility, near the tank farm along the northeast Facility boundary, along the southwest Facility boundary, near the Facility entrance in the east corner of the Facility, along the Facility roadway, in the area of the former unlined holding pond/C-shaped area, or in the west corner of the Facility. The locations with the highest chemical concentrations (which were usually greater than screening levels) varied by chemical:
    - The highest cPAH TEQs were detected in the central portion of the Facility (near the tank farm and former truck cleaning operation) and in one sample from the soil berm in the west corner of the Facility.
    - TPH concentrations were highest near the former truck cleaning operation and along the southwest boundary of the Facility.
    - The highest total PCB concentrations were detected near the Facility entrance, in the central portion of the Facility, and along the Facility roadway.
    - The highest total DDT concentrations were detected in the central portion of the Facility, in the former C-shaped area where the unlined holding pond was located, and along the

southwest boundary of the Facility and wetlands where historical ponds and sumps that received drainage from the truck wash were located.

  - The highest concentrations of arsenic (and other metals) were detected in the west corner of the Facility, near the C-shaped area where the unlined holding pond was located and in the former drainage ditch.

- In most cases, concentrations were highest in surface soil samples (both at the Facility and in the wetlands), except in areas where historical holding ponds or sumps were known to have been located. In these areas, concentrations were sometimes highest in intermediate soil samples but lower in deep soil samples, indicating that the extent of the highest concentrations was limited.
- Patterns of chemical concentrations in the wetlands are consistent with former drainage patterns at the Facility as well as the location of historical sumps and holding ponds along the southwest Facility boundary (which may have extended into what is now considered the wetlands).
- In general, detected concentrations of chemicals were limited to shallow groundwater, with detected concentrations low relative to screening levels and of limited lateral extent. Detections of metals, DDD, six VOCs, and one SVOC in intermediate or deep well samples were likely attributable to non-Facility-related sources because detections were located upgradient of Facility operations or, with regard to DDD, to a possible well seal breach or drilling-induced drag-down of impacted soil into the screen interval at the MW-2i/B-4 well cluster location.
- A thin layer (0.1 ft) of LNAPL was collected from well GA-30 in 2008; only trace thicknesses (0.01 to 0.02 ft) have been observed in this well during follow-up monitoring. Trace thicknesses of LNAPL (0.01 ft or less) have been observed in two of the precautionary (i.e., never used) extraction wells. Thus, the presence of LNAPL is localized and constrained to a small portion of the Facility. No LNAPL has been observed in wells located along the downgradient boundary of the Facility.
- Chemical concentrations in Force Lake sediment and surface water were usually low relative to concentrations in Facility or wetland soils and were mostly lower than screening levels or, for metals, background concentrations. No lateral concentration gradients were apparent in lake sediments. Concentrations in Force Lake surface sediment were higher than those in Force Lake subsurface sediment.
- With the exception of metals, chemical concentrations in North Lake sediment were usually lower than those in Force Lake sediment. Concentrations of metals in North Lake sediment were generally similar to those in Force Lake and to background

concentrations. These results indicate that there is minimal transport of chemicals from Force Lake.

The comparison of chemical concentrations with conservative screening levels (and background concentrations for metals) indicated that higher chemical concentrations were generally bounded both vertically and laterally. Thus, chemicals have been adequately delineated, and the available data met the DQOs identified in the RI/FS Work Plan (Bridgewater et al. 2008b).

7.1.5 Conceptual Site Model

The CSM for the Study Area was presented in Section 5.0 and focused on the potential environmental routes of chemical migration from the source area to potential receptors. A summary of the key components of the CSM is provided below:

- Known or suspected sources of chemicals at the Facility and in the adjacent wetland appear to be associated with the historical processing of used oils and other petroleum products, the drainage of wash water from the former truck cleaning operation, spills, and the possible periodic oiling of the Facility road surfaces.
- Known or suspected mechanisms for the release of chemicals to Facility soils include the discharge of oily rinsate from the former truck cleaning operations to the ground surface, the spillage of petroleum products stored or handled at the Facility for processing, the placement of used oils on the Facility roadway for dust suppression purposes, the release of oils and other materials present at the Facility during the 1979 fire, and the overflow or discharge of oily rinsate/stormwater from sumps or an unlined pond formerly located in the southwest portion of the Facility.

Based on the site history and nature and extent of chemicals at the Study Area, the primary migration pathway for chemicals associated with industrial activities at Facility appears to be related to historical direct discharge and transport via stormwater runoff. This historical migration pathway has resulted in the presence of chemicals in shallow groundwater beneath portions of the Facility, in wetland soil, and in Force Lake sediment.

Facility physical and operational modifications such as the termination of truck cleaning operations, installation of a stormwater collection and treatment system, and the placement of a hard-packed gravel cover and/or pavement throughout the Facility have mitigated the primary migration pathway (direct discharge and stormwater runoff). Chemicals were likely bound to soil particles that were transported in surface water runoff from the areas of spillage or discharge to low-lying areas historically located to the south and west. Over the course of operations, these low-lying areas included existing wetlands and Force Lake to the south of the Facility, as well as areas of the existing Facility footprint that were lower in elevation at the time but were subsequently filled to match the existing grade. This fill history resulted in chemical impacts deeper in soils in certain areas relative to other portions of the Facility.

This historical migration pathway has resulted in the presence of chemicals in Facility soils, shallow groundwater beneath portions of the Facility, in wetland soil, and in Force Lake sediment.

Based on the distribution of chemicals in media at the Study Area and other site-specific information, the following potential migration pathways were also assessed, though they were not found to be pathways of likely significance for chemicals migration:

- Potential future erosion of soils from the soil berm located at the northwest and southwest property boundary to the wetland
- Potential erosion of wetland soil into Force Lake
- Potential migration of chemicals in shallow groundwater to Force Lake sediment
- Potential volatilization of VOCs from Facility vadose zone soil or shallow groundwater to indoor or outdoor air

7.1.6 Baseline Risk Assessments

The baseline HHRA and ERA were summarized in Section 6.0 and are presented in Appendices I and J, respectively.

7.1.6.1 Human Health Risk Assessment

The baseline HHRA presented human health risk estimates associated with potential exposures to chemicals in soil, lake sediment, lake water, groundwater, and fish caught in Force Lake. The exposure scenarios and assumptions assessed in the HHRA are consistent with a reasonable maximum level of exposure, and thus, although uncertain, risk estimates are intended to be health protective (EPA 1989).

The following scenarios were evaluated in the HHRA to assess risks for workers at the Facility:

- **Industrial (construction/trenching) worker RME scenario:** evaluated risks to current and future workers involved in construction or excavation work conducted outdoors at the Facility
- **Future outdoor worker RME scenario:** evaluated risks to future outdoor workers in the event that different operations or activities are conducted at the Facility and/or that the surficial gravel fill material and pavement that currently covers most of the Facility are removed
- **Industrial/commercial worker vapor intrusion scenario:** evaluated risks to current and future workers performing routine activities inside buildings at the Facility

The following scenarios were evaluated in the HHRA to assess risks for recreational users and fish consumers in the non-Facility portions of the Study Area:

- **Force Lake recreational user RME scenario:** evaluated risks to current and future recreational users during recreation-associated activities at Force Lake and in the surrounding wetlands, including bird watching, remote-control boating, or golf ball retrieval
- **Force Lake fish consumer RME scenario:** evaluated risks to current and future fish consumers based on the consumption of fish caught in Force Lake

Table 7-1 summarizes the total excess cancer risk and overall HI for each of the scenarios evaluated in the HHRA. When applicable, these risk estimates are the combined risks across the relevant exposure media. All excess cancer risk estimates were within or less than EPA's target risk range of 10^{-6} to 10^{-4}. The overall HI (i.e., sum of non-cancer HQs for all COPCs across all endpoints) was less than or equal to 1 for all scenarios except the Force Lake fish consumer RME scenario (Table 7-1). However, when endpoint-specific HIs (e.g., developmental or nervous system endpoints) were calculated for this scenario, no endpoint-specific HIs were greater than 1.

Table 7-1. Summary of Total Excess Cancer Risks and Non-Cancer HIs

Scenario Name	Total Excess Cancer Risk	Overall HI[a]
Industrial (construction/trenching) worker RME scenario (cumulative risk across media)	3×10^{-6}	1
Future outdoor worker RME scenario	2×10^{-5}	0.6
Industrial/commercial worker vapor intrusion	9×10^{-7}	ne[b]
Force Lake recreational user RME scenario (cumulative risk across media)	1×10^{-5}	0.4[c]
Force Lake fish consumer RME scenario	2×10^{-5}	3 (endpoint-specific HIs were less than or equal to 1)[c, d]

[a] The overall HI is equal to the sum of HQs across multiple exposure pathways, endpoints, and/or target organs.

[b] Risks for this scenario were calculated based on a comparison of Study Area concentrations with vapor intrusion screening levels, which are based on the more stringent of the cancer or non-cancer risks (i.e., whichever one results in lower screening levels). For this scenario, screening levels for all COPCs were based on cancer risks, and thus it was not possible to calculate non-cancer risks.

[c] The overall HI is based on children 0 to 6 years of age. This HI is higher than HIs for the integrated 0-to-30 year age group and for older age groups (i.e., 7 to 16 years and 17 to 30 years), and thus are typically used for risk management decisions.

[d] The overall HI for this scenario was equal to 3. Because this value was greater than 1, endpoint-specific HIs were calculated per EPA guidance (1989). No endpoint-specific HIs were greater than 1 (see Section 5.3.5 of the HHRA [Appendix I] for details).

COPC – contaminant of potential concern
HI – hazard index
HQ – hazard quotient
ne – not evaluated
RME – reasonable maximum exposure

In addition to the scenarios shown in Table 7-1, a screening assessment was conducted to estimate risks based on the exposure of hypothetical future residents to chemicals at the Study Area (see Appendix I, Attachment 1). This assessment indicated that excess cancer risks would likely be greater than the upper end of EPA's target risk range (10^{-4}) and that some chemicals would have HQs greater than 1. The City of Portland has designated the Facility property as an Industrial Sanctuary, indicating that its industrial land-use designation is unlikely to change in the future. The non-Facility portions of the Study Area are zoned as open space and are in an NMRP area established by the City of Portland. Future residential development in the Study Area is unlikely.

Based on the results of the HHRA, arsenic, cPAH TEQ, total PCBs, total DDTs, and TPH-gasoline (aliphatic) were identified through the HHRA as COCs (i.e., COPCs with risks greater than 10^{-6}). No COPCs had HQs greater than 1. Table 7-2 presents a summary of excess cancer risks by COPC for each of the scenarios with risk estimates greater than or equal to 1×10^{-6}.

In addition, Table 7-2 presents risk estimates based on background or reference area concentrations. Note that although background concentrations have been recommended by DEQ for metals, similar recommendations are unavailable for organic compounds (DDTs, cPAH TEQ, and PCBs). For these organic compounds, concentrations from reference areas (i.e., urban areas within the vicinity of the Study Area) were used for comparison with Study Area concentrations because specific background concentrations have not been established. No background or reference area concentrations were available for TPHs for the sources used in this assessment.

Background risk estimates for arsenic were similar to those based on Study Area concentrations for most exposure scenarios (Table 7-2). With one exception, risk estimates based on reference area concentrations were less than Study Area risk estimates for cPAH TEQ, total PCBs, or total DDTs for all scenarios (Table 7-2). The exception was for the Force Lake recreational user based on exposure to wetland soil: cPAH TEQs from reference areas were slightly higher than or similar to those at the Study Area.

Table 7-2. Summary of Excess Cancer Risks for Scenarios with Total Excess Cancer Risks Greater than or Equal to 1×10^{-6}

COCs and other COPCs	Excess Cancer Risks (Percent of Total)				
	Industrial (Construction/ Trenching) Worker: Facility Soil	**Future Outdoor Worker: Facility Soil**	**Force Lake Recreational User: Wetland Soil**	**Force Lake Recreational User: Lake Sediment**	**Force Lake Fish Consumer**
Total Risk Estimates for Individual COPCs					
Arsenic	8×10^{-7} (31%)	7×10^{-6} (30%)	2×10^{-6} (23%)	1×10^{-6} (71%)	7×10^{-6} (37%)
cPAH TEQ	7×10^{-7} (27%)	4×10^{-6} (17%)	6×10^{-6} (68%)	4×10^{-7} (29%)	na
Total PCBs	7×10^{-7} (27%)	6×10^{-6} (26%)	3×10^{-7} (3%)	na	1×10^{-5} (53%)
Total DDTs	3×10^{-7} (12%)	2×10^{-6} (9%)	5×10^{-7} (6%)	na	2×10^{-6} (11%)
TPH-gasoline (aliphatic)	3×10^{-8} (1%)	3×10^{-6} (13%)	na	na	na
Other COPCs	5×10^{-8} (2%)	1×10^{-6} (5%)	2×10^{-10} (0%)	na	na
Total risk	**3×10^{-6}**	**2×10^{-5}**	**9×10^{-6}**	**1×10^{-6}**	**2×10^{-5}**
Background or Reference Area Risk Estimates[a]					
Arsenic	6×10^{-7}	4×10^{-6}	2×10^{-6}	2×10^{-6}	8×10^{-6} to 9×10^{-6}
cPAH TEQ	7×10^{-9} to 4×10^{-8}	3×10^{-8} to 2×10^{-7}	4×10^{-8} to 3×10^{-7}	7×10^{-7} to 8×10^{-7}	na
Total PCBs	5×10^{-9}	2×10^{-8}	nc	na	3×10^{-6} to 4×10^{-6}
Total DDTs	nc	2×10^{-9} to 5×10^{-8}	nc	na	2×10^{-7}

[a] Background or reference area concentrations and sources are discussed in Attachment 7 of Appendix I and in Section 2.8. Concentrations for metals are representative of background concentrations, and concentrations for organic compounds are representative of regional reference area concentrations (i.e., concentrations in urban areas within the vicinity of the Study Area). No background or reference area concentrations were available for TPH-gasoline (aliphatic).

COC – contaminant of concern
COPC – contaminant of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
HHRA – human health risk assessment
na – not applicable (not a COPC for this scenario)
nc – not calculated
PCB – polychlorinated biphenyl
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons

7.1.6.2 Ecological Risk Assessment

The baseline ERA presented risk estimates for benthic invertebrates, terrestrial invertebrates, fish, and wildlife species that may be exposed to chemicals in wetland soil, Force Lake surface sediment, Force Lake surface water, and aquatic or terrestrial biota (i.e., as prey through dietary consumption). The risk assessment was designed to be protective of the range of species that have been observed at or could use the Study Area. Conservative assumptions, such as the use of the lowest toxicity values and the use of UCL concentrations for estimating exposure, were used in an attempt to ensure that risk estimates, although uncertain, were protective of ecological receptors.

The following ROCs, representing various feeding guilds, were selected:

- **Invertebrates:** aquatic benthic invertebrate community and wetland invertebrate community
- **Fish:** brown bullhead (omnivorous fish) and pumpkinseed (invertivorous fish)
- **Birds:** ruddy duck (invertivorous bird), great blue heron (piscivorous bird), and red-tailed hawk (higher-trophic-level carnivorous bird)
- **Mammals:** shrew (invertivorous mammal) and Eastern cottontail (herbivorous mammal)

Table 7-3 provides a summary of HQs for all ROC-COPC pairs with effects-based HQs that were greater than 1.0. Table 7-3 also presents HQs based on background (for metals) or reference area (for organic compounds) concentrations[27] for comparison with those based on Study Area concentrations. Note that although background concentrations have been recommended by DEQ for soils, sediment, and surface water for metals; similar recommendations are unavailable for organic compounds, such as DDTs and PAHs. For organic compounds, concentrations from reference areas (urban areas within the vicinity of the Study Area) were used for comparison with Study Area concentrations because specific background concentrations have not been established.

[27] See notes on background concentrations in Section 6.2.1. The term reference area is used instead of background for organic compounds because no specific background concentrations that are representative of anthropogenic background have been selected or approved by EPA.

Table 7-3. COPCs and ROCs with LOAEL-Based HQs Greater than 1.0

COPC	Matrix	NOAEL-Based HQ	LOAEL-Based HQ	Background or Reference Area[a] LOAEL-Based HQ
Aquatic Benthic Invertebrate Community				
DDD	surface sediment	**2.4 – 17**[b]	1.0 **– 7.2**[c]	0.072 – 0.079[c]
DDE	surface sediment	**6.4 – 110**[b]	**1.3 – 22**[c]	1.0 – **1.5**[c]
Terrestrial Invertebrate Community				
Chromium	wetland soil	**3.3 - 75**[d]		**21**[d]
Copper	wetland soil	0.21 – **25**[d]		0.72[d]
Zinc	wetland soil	0.31 – **6.2**[d]		0.72[d]
Total HPAHs	wetland soil	0.0056 **– 3.2**[d]		0.003 – 0.022[d]
Fish – Pumpkinseed				
Copper	diet	**3.5**	**1.8**	0.30
Fish – Brown Bullhead				
Copper	diet	**2.1**	**1.1**	0.18
Birds – Red-Tailed Hawk				
Total DDTs	diet	**5.8**	**1.2**	0.020 – 0.47
Mammals – Eastern Cottontail				
Mercury	diet	**5.9**	**1.2**	0.54
Mammals – Shrew				
Mercury	diet	**65**	**13**	**5.7 – 15**
Total DDTs	diet	**9.2**	**8.5**	0.0053 – 0.41

[a] Background and reference area concentrations and sources are discussed in Section 2.8 and in Attachment 4 of the ERA (Appendix J). Concentrations for metals are representative of background concentrations and concentrations for organic compounds are representative of reference area concentrations.

[b] HQs were developed based on a comparison to a TEL or a TEC; total DDT concentrations were less than the total DDT PEL/PEC.

[c] HQs were developed based on a comparison to a PEL or a PEC.

[d] HQs were developed based on a comparison to soil screening levels.

COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effect level
NOAEL – no-observed-adverse-effect level
PEC – probable effects concentration
PEL – probable effects level
ROC – receptor of concern
SL – screening level
TEC – threshold effects concentration
TEL – threshold effects level
TRV – toxicity reference value

Bold identifies HQs greater than 1.0.

LOAEL-based HQs were greater than 1.0 for metals, DDTs, and HPAHs for at least one receptor (Table 7-3). LOAEL-based HQs were greater than 5 for DDE (aquatic invertebrates), DDD (aquatic invertebrates), chromium (terrestrial invertebrates), copper (terrestrial invertebrates), total DDTs (shrew), and zinc (terrestrial invertebrates). LOAEL-based HQs were also greater than 5 for mercury, but mercury concentrations were within the range of DEQ background concentrations.

Key uncertainties in these risk estimates include the terrestrial invertebrate screening levels; the observation of earthworms in areas with higher concentrations of metals (which may indicate that invertebrate screening levels are overly protective for the Study Area); and the bioavailability of DDTs in lake sediments (the TOC was high in sediment, likely limiting the potential for toxicological effects).

7.2 Conclusions

This section presents a synthesis of pathway, nature and extent, and risk information for the Facility, groundwater, wetlands, and Force Lake. Conclusions are presented in the subsections below and also summarized in Tables 7-4 through 7-8. This information is intended to help inform EPA's risk management decisions in each part of the Study Area.

Table 7-4. Facility Soil Summary

Summary of Nature and Extent (see Section 4.0)	Summary of Risk Assessments (see Section 6.0; Appendices I and J)	Potential Migration Pathway(s)/Transport (see Sections 4.0 and 5.0)	Current Status of Potential Pathway (see Section 1.0)
TPHs, PAHs, and petroleum-associated VOCs: Concentrations were highest near the tank farm, located along the northeast boundary of the Facility, and the former truck cleaning operation, located in the central portion of the Facility.	**HHRA:** cPAH TEQ excess cancer risks of 4×10^{-6} (future outdoor worker) and 7×10^{-7} (industrial construction/trenching worker). TPH-gasoline (aliphatic) excess cancer risks of 3×10^{-6} (future outdoor worker) and 3×10^{-8} (industrial construction/trenching worker) **ERA:** No exposure pathway	Potential migration into the ditch and wetlands via stormwater runoff, direct releases from Facility-related operations, and discharge from the stormwater treatment system Potential migration from existing stormwater treatment system into the wetlands Potential erosion of soils from the soil berm located at the northwest and southwest property boundary to the wetland	Facility controls are in place to prevent these types of releases (e.g., the soil berm constructed after the 1979 fire to prevent direct discharge into the wetlands and the closure of the drainage ditch). All Facility stormwater is collected and treated by the stormwater treatment system. The treatment system has an NPDES permit with effluent limitations and ongoing monitoring of oil and grease, copper, lead, zinc, bacteria, and several conventional parameters. PCBs and pesticides are not monitored in the effluent from the treatment system. The soil berm is intact, vegetated, has no identified areas of erosion and thus is unlikely to be a significant migration pathway.
PCBs: Concentrations were highest in the northeast corner of the Facility, near the Facility entrance; in the central portion of the Facility, near the former tanker truck cleaning operation; and along the U-shaped roadway that extends from the Facility entrance around the former truck cleaning operation area.	**HHRA:** PCB excess cancer risks of 6×10^{-6} (future outdoor worker) and 7×10^{-7} (industrial construction/trenching worker) **ERA:** No exposure pathway		
Metals (arsenic, cadmium, chromium, copper, mercury, and zinc): Concentrations were highest in the west corner of the Facility and in the area of the former unlined holding pond/C-shaped area.	**HHRA:** Arsenic excess cancer risks of 7×10^{-6} (future outdoor worker) and 8×10^{-7} (industrial construction/trenching worker). Background arsenic risk estimates were 4×10^{-6} and 6×10^{-7}, respectively, for the above scenarios. **ERA:** No exposure pathway		
DDTs: Concentrations were highest in the central portion of the Facility near the former truck cleaning operation, in the unlined holding pond/C-shaped area to the west of the former truck cleaning operation, and along the southwest boundary of the Facility where sumps/ponds were apparently located.	**HHRA:** DDT excess cancer risks of 2×10^{-6} (future outdoor worker) and 3×10^{-7} (industrial construction/trenching worker) **ERA:** No exposure pathway		
Chlorinated solvents: Concentrations of TCE were highest in the central portion of the Facility in the location of the former truck cleaning operation.	**HHRA:** No COCs (excess cancer risks $<10^{-6}$ and HQs <1) **ERA:** No exposure pathway		
Other chemicals: Concentrations of these chemicals were not discussed in detail because they were low relative to human health or ecological risk thresholds.	**HHRA:** No COCs (excess cancer risks $<10^{-6}$ and HQs <1) **ERA:** No exposure pathway		

COC – contaminant of concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
ERA – ecological risk assessment
HHRA – human health risk assessment
HQ – hazard quotient
NPDES – National Pollutant Discharge Elimination System
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
TCE – trichloroethene
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

Table 7-5. Groundwater Summary

Summary of Nature and Extent (see Section 4.0)	Summary of Risk Assessments (see Section 6.0; Appendices I and J)	Potential Migration Pathway(s)/Transport (see Sections 4.0 and 5.0)	Current Status of Potential Pathway (see Section 1.0)
TPHs, PAHs, and petroleum-associated VOCs: Concentrations were detected in groundwater, primarily in the central/western portion of the Facility near or west of the former truck cleaning/C-shaped area. The distribution of TPH, PAH, and petroleum-associated VOCs (including LNAPL, which has minimal presence at the Facility) has been delineated at the Facility; with the exception of certain PAHs, these chemicals do not extend to the downgradient (southern boundary) portion of the Facility.	**HHRA:** No COCs (excess cancer risks $<10^{-6}$ and HQs <1) **ERA:** Concentrations in groundwater at the downgradient portion of the Facility (at the southwest boundary) were less than AWQC. These chemicals are not expected to contribute to toxicity in Force Lake.	Migration of chemicals in groundwater to Force Lake Dissolution of LNAPL chemicals into groundwater	Chemicals were generally not detected in groundwater samples from wells located on the downgradient portions of the Facility. If detected, chemicals were present at concentrations below levels of concern for ecological or human health. Concentrations of metals in groundwater were likely attributable to the fact that metals occur naturally in the environment. Because DDD was detected in downgradient Facility wells, an evaluation was performed to estimate the time required for DDD in groundwater to migrate to Force Lake. Because of DDD's strong affinity to soil matrix organic matter, DDD tends to sorb to these particles and thus is essentially immobile in groundwater (moving 14,000 times slower than groundwater). Therefore, the degradation processes would likely break down DDD in groundwater before it could reach Force Lake. The presence of LNAPL is localized and confined to a small portion of the Facility. In addition, after LNAPL was collected in 2008, follow-up monitoring revealed only trace (i.e., non-measurable) to minor amounts (up to 0.02 ft) of LNAPL.
PCBs: Not detected in groundwater samples collected at the Facility.	**HHRA:** No COCs (excess cancer risk $<10^{-6}$ and HQ <1) **ERA:** PCBs were not detected in groundwater.		
Metals (arsenic, cadmium, chromium, copper, mercury, and zinc): Except for arsenic, metals were detected infrequently in groundwater. The variability of metals concentrations in groundwater was relatively low, except for arsenic and zinc concentrations, which were likely more variable as a result of natural variability in the environment.	**HHRA:** No COCs (excess cancer risks $<10^{-6}$ and HQs <1) **ERA:** Concentrations of metals in groundwater at the downgradient portion of the Facility (at the southwest boundary), Force Lake surface water, and Force Lake sediment were assessed in the uncertainty analysis; these chemicals are not expected to contribute to toxicity in Force Lake from groundwater recharge.		
DDTs: DDD, a DDT metabolite, was detected in shallow groundwater samples in the central portion of the Facility and in shallow, intermediate, and deep groundwater samples from the southern downgradient portions of the Facility.	**HHRA:** No COCs (excess cancer risk $<10^{-6}$ and HQ <1) **ERA:** Concentrations of DDD in groundwater at the downgradient portion of the Facility (at the southwest boundary), Force Lake surface water, and Force Lake sediment were assessed in the uncertainty analysis; DDD is not expected to contribute to toxicity in Force Lake from groundwater recharge.		
Chlorinated solvents: Chlorinated solvents were detected only in samples collected from deep well PW-01 or shallow well GA-34, both of which are located in the east corner of the Facility near the Facility entrance and office buildings. Solvents detected in deep well PW-01 were not identified in shallow groundwater at the Facility and are therefore not deemed to be related to activities at the Facility. Solvents detected at shallow well GA-34 were identified in 2000 and not in 2008 or 2009.	**HHRA:** No COCs (excess cancer risks $<10^{-6}$ and HQs <1) **ERA:** Concentrations of chlorinated solvents were not identified in groundwater at the downgradient portion of the Facility (at the southwest boundary) (in 2000), and in 2008 and 2009, were not identified at any location in shallow groundwater beneath the Facility. Therefore, these contaminants are not expected to contribute to toxicity in Force Lake.		
Other chemicals: Other chemicals have been detected in groundwater but not at concentrations of concern.	**HHRA:** No COCs (excess cancer risks $<10^{-6}$ and HQs <1) **ERA:** Concentrations of other chemicals in groundwater at the downgradient portion of the Facility (at the southwest boundary) were either not detected or were less than AWQC and therefore these chemicals are not expected to contribute to toxicity in Force Lake.		

AWQC – ambient water quality criteria
COC – contaminant of concern
DDD – dichlorodiphenyldichloroethane
DDT – dichlorodiphenyltrichloroethane
ERA – ecological risk assessment
HHRA – human health risk assessment
HQ – hazard quotient
LNAPL – light non-aqueous phase liquid
NPDES – National Pollutant Discharge Elimination System
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
TCE – trichloroethene
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

Table 7-6. Wetland Soil Summary

Summary of Nature and Extent (see Section 4.0)	Summary of Risk Assessments (see Section 6.0; Appendices I and J)	Potential Migration Pathway(s)/Transport (see Sections 4.0 and 5.0)	Current Status of Potential Pathway (see Section 1.0)
TPHs, PAHs, and petroleum-associated VOCs: Highest concentrations were detected in the former drainage ditch, southwest of the Facility, and near the current and former stormwater treatment system discharge points (i.e., in areas that indicate that these chemicals have migrated via stormwater runoff).	**HHRA:** Recreational user excess cancer risk of 6×10^{-6} for cPAH TEQ **ERA:** HPAHs – HQs of 0.0056 to 3.2 as compared with invertebrate screening levels (3% of samples had HQs >1.0)	Migration of chemicals in runoff from the Facility through the drainage ditch to Force Lake Migration of chemicals via sheet flow from wetland soil to Force Lake and erosion of wetland soil into Force Lake	The drainage ditch was closed in 2002 and is no longer an active pathway. No gradient of chemicals exists in Force Lake sediment, suggesting that Facility-related releases to Force Lake are not ongoing. There is a low potential for chemical migration to Force Lake from the wetland via soil erosion based on the relatively flat topography of the wetlands and extensive vegetative cover. An analysis presented in the ERA supports this conclusion (Appendix J).
PCBs: Highest concentrations were detected just to the south of the Facility, approximately halfway between North Force Avenue and the drainage ditch, in the former drainage ditch to the west of the Facility, and near the discharge point of the stormwater treatment system.	**HHRA:** Recreational user excess cancer risk of 3×10^{-7} for PCBs **ERA:** No LOAEL-based HQs >1.0		
Metals (arsenic, cadmium, chromium, copper, mercury, and zinc): Highest concentrations were detected in the former drainage ditch to the west of the Facility and in the area near the current and former stormwater treatment system discharge points, near the west corner of the Facility.	**HHRA:** Recreational user excess cancer risks of 2×10^{-6} for arsenic. The background arsenic risk estimates was also equal to 2×10^{-6}. **ERA**: HQs for invertebrates vs. screening levels – chromium (3.3 to 75), copper (0.21 to 25), zinc (0.31 to 6.2) Eastern cottontail – LOAEL-based HQ of 1.2 for mercury (0.54 background HQ) Shrew – LOAEL-based HQ of 13 for mercury (5.7 to 15 background HQ)		
DDTs: Highest concentrations were detected just southwest of the Facility boundary (in close proximity to the highest DDT concentrations detected at the Facility).	**HHRA:** Recreational user excess cancer risk of 5×10^{-7} for DDTs. **ERA:** Red-tailed hawk – LOAEL-based HQ of 1.2 Shrew – LOAEL-based HQ of 8.5		
Chlorinated solvents: Chlorinated solvents were infrequently detected in wetland soil; detected concentrations in wetland soil were significantly lower than those in Facility soils, and samples with detected concentrations were often collected from areas that may have received runoff from the former tanker truck cleaning operations (e.g., stormwater treatment system discharge point and the former drainage ditch).	**HHRA:** No COCs (excess cancer risks $<10^{-6}$ and HQs <1) **ERA:** No LOAEL-based HQs >1.0		
Other chemicals: Concentrations of these chemicals were not discussed in detail because they were low relative to human health or ecological risk thresholds.	**HHRA:** No COCs (excess cancer risks $<10^{-6}$ and HQs <1) **ERA:** No LOAEL-based HQs >1.0		

COC – contaminant of concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
ERA – ecological risk assessment
HHRA – human health risk assessment
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effects level
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

Table 7-7. Force Lake Sediment Summary

Summary of Nature and Extent (see Section 4.0)	Summary of Risk Assessments (see Section 6.0; Appendices I and J)	Potential Migration Pathway(s)/Transport (see Sections 4.0 and 5.0)	Current Status of Potential Pathway (see Section 1.0)
TPHs, PAHs, and petroleum-associated VOCs: The highest concentrations in lake sediment were detected in the central portion of Force Lake, although the variability in sediment concentrations was low.	**HHRA:** No COCs (excess cancer risks <10^{-6} and HQs <1) **ERA:** No LOAEL-based HQs >1.0	Migration of sediment into North Lake	Force Lake acts as a settling basin because the water velocity or current is low; thus suspended solids that enter the lake tend to settle to the bottom rather than being transported downstream. As such, chemicals that have entered the lake have, for the most part, remained because of the natural hydraulic regime of the lake.
PCBs: The highest concentrations in lake sediment were detected in the central portion of Force Lake, although the variability in sediment concentrations was low.	**HHRA:** Force Lake fish consumer excess cancer risk of 1×10^{-5} for PCBs **ERA:** No LOAEL-based HQs >1.0		
Metals (arsenic, cadmium, chromium, copper, mercury, and zinc): Concentrations in Force Lake sediment were relatively uniform.	**HHRA:** Force Lake fish consumer excess cancer risk of 7×10^{-6} for arsenic. The background risk was slightly greater than Study Area risk for arsenic (8×10^{-6} to 9×10^{-6}). **ERA:** Pumpkinseed –LOAEL-based HQ of 1.8 for copper (0.3 background HQ) Brown bullhead –LOAEL-based HQ of 1.1 for copper (0.18 background HQ)		
DDTs: The highest concentrations in lake sediment were detected in the central portion of Force Lake, although the variability in sediment concentrations was low.	**HHRA:** Force Lake fish consumer excess cancer risk of 2×10^{-6} for DDTs **ERA:** Benthic invertebrates – HQs relative to effects screening levels of 1.0 to 7.2 (DDD) and 1.3 to 22 (DDE) (HQ <1.0 for total DDTs)		
Chlorinated solvents: Chlorinated solvents were not detected in lake sediment.	**HHRA:** No COCs (excess cancer risks <10^{-6} and HQs <1) **ERA:** No LOAEL-based HQs >1.0		
Other chemicals: Other chemicals, such as phthalates, other SVOCs, and VOCs, that were not otherwise included in the defined chemical groups described above, have been detected in lake sediment with generally low variability in concentrations.	**HHRA:** No COCs (excess cancer risks <10^{-6} and HQs <1) **ERA:** No LOAEL-based HQs >1.0		

COC – contaminant of concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
ERA – ecological risk assessment
HHRA – human health risk assessment
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effects level
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

Table 7-8. Force Lake Surface Water Summary

Summary of Nature and Extent (see Section 4.0)	Summary of Risk Assessments (see Section 6.0; Appendices I and J)	Potential Migration Pathway(s)/Transport (see Sections 4.0 and 5.0)	Current Status of Potential Pathway (see Section 1.0)
TPHs, PAHs, and petroleum-associated VOCs: Not detected in surface water.	**HHRA:** No COCs (excess cancer risks <10^{-6} and HQs <1) **ERA:** No refined COPCs	Outflow of water and suspended sediments to North Lake	Concentrations in North Lake were generally lower than those in Force Lake, indicating that migration is limited or has not occurred. For several naturally occurring chemicals (e.g., copper), concentrations in North Lake sediment were similar to those in Force Lake sediment, likely indicating the presence of regional levels of a given chemical or other potential area-wide sources.
PCBs: Not detected in surface water.	**HHRA:** No COCs (excess cancer risks <10^{-6} and HQs <1) **ERA:** No refined COPCs		
Metals (arsenic, cadmium, chromium, copper, mercury, and zinc): Arsenic and copper were detected in lake surface water samples.	**HHRA:** No COCs (excess cancer risks <10^{-6} and HQs <1) **ERA:** No refined COPCs		
DDTs: Not detected in surface water.	**HHRA:** No COCs (excess cancer risks <10^{-6} and HQs <1) **ERA:** No refined COPCs		
Chlorinated solvents: Not detected in surface water.	**HHRA:** No COCs (excess cancer risks <10^{-6} and HQs <1) **ERA:** No refined COPCs		
Other chemicals: With the exception of acetone and barium, other chemicals were not detected in surface water.	**HHRA:** No COCs (excess cancer risks <10^{-6} and HQs <1) **ERA:** No refined COPCs		

AWQC – ambient water quality criteria
COC – contaminant of concern
DDT – dichlorodiphenyltrichloroethane
DEQ – Oregon Department of Environmental Quality
ERA – ecological risk assessment
HHRA – human health risk assessment
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effects level
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

7.2.1 Facility Soil

Key findings for Facility soil are listed below and summarized in Table 7-4.

- In the HHRA scenarios associated with current activities at the Facility, risks were within EPA's target risk range of 10^{-4} to 10^{-6} (3×10^{-6} for the industrial [construction/trenching] worker). HQs were less than or equal to 1.
- In the HHRA scenario associated with potential future activities at the Facility, risks were also within EPA's target risk range of 10^{-4} to 10^{-6} (2×10^{-5} for the future outdoor worker) but would be higher than risks for workers currently working outdoor at the Facility. HQs were less than 1. This future risk scenario assumes exposure to soils without the gravel layer and pavement that currently cover the Facility.
- Although the Facility is currently zoned for industrial use, risks to hypothetical future residents were assessed. Based on the results of this analysis (i.e., calculation of risks using the published screening levels), the total excess cancer risks would likely be greater than the upper end of EPA's target risk range (10^{-4}) and HQs for some chemicals would likely be greater than 1. However, City of Portland planning documents indicate that zoning designations for the Facility are not likely to change in the future. Thus, future residential development of the Facility is unlikely.
- The areas with the highest chemical concentrations in Facility soil varied by individual chemical or chemical group and are summarized below.
    - The highest cPAH TEQs were detected in the central portion of the Facility (near the tank farm and former truck cleaning operation) and in one sample from the soil berm in the west corner of the Facility.
    - TPH concentrations were highest near the former truck cleaning operation and along the southwest boundary of the Facility.
    - The highest total PCB concentrations were detected near the Facility entrance, in the central portion of the Facility, and along the Facility roadway.
    - The highest total DDT concentrations were detected in the central portion of the Facility, in the former C-shaped area where the unlined holding pond was located, and along the southwest boundary of the Facility where historical ponds and sumps that received drainage from the truck wash were located.
    - The highest concentrations of arsenic (and other metals) were detected in the west corner of the Facility and near

the C-shaped area where the unlined holding pond was located.

- Chemical concentration patterns are consistent with what is known regarding historical uses and releases at the Facility; ongoing activities appear to be controlled (surface water runoff is now controlled, treated, and monitored under an NPDES permit). Concentrations were usually highest in surface soil samples, except in areas where historical holding ponds or sumps were known to have been located. In these areas, concentrations were sometimes highest in intermediate soil samples, but lower in deep soil samples, indicating that the extent of the highest concentrations was limited.

7.2.2 Groundwater

Key findings for Facility groundwater are listed below and summarized in Table 7-5.

- In the HHRA scenarios associated with potential current exposure to groundwater, risks were less than EPA's target risk range of 10^{-4} to 10^{-6} (8×10^{-8} for the industrial [construction/trenching] worker and 9×10^{-7} for the industrial/commercial worker vapor intrusion scenario). HQs were less than 1.
- Although the Facility is currently zoned for industrial use, risks to hypothetical future residents were assessed as part of the HHRA. Based on the results of this analysis (i.e., calculation of risks using the published screening levels), the total excess cancer risks would likely be greater than the upper end of EPA's target risk range (10^{-4}) and HQs for some chemicals would likely be greater than 1. However, City of Portland planning documents indicate that zoning designations for the Facility are not likely to change in the future. Thus, future residential development in this area is unlikely.
- The majority of chemicals detected in groundwater were detected only in samples collected from shallow wells. Metals, DDD, six VOCs, and one SVOC were detected in intermediate or deep well samples.
- Chlorinated solvents (including 1,1,1-trichloroethane, cis-1,2-dichloroethene, PCE, TCE, and vinyl chloride) were detected in groundwater in only two wells, deep well PW-01 and shallow well GA-34, both of which are located in the east corner of the Facility near the Facility entrance and office buildings. These data suggest that these VOCs are attributable to upgradient or documented regional impacts potentially migrating onto the Facility. Despite the known use of TCE in former truck cleaning operations, TCE was not detected in any downgradient wells.
- DDD was detected in shallow groundwater samples in some of the areas where DDD concentrations in soil samples were highest. The mobility of DDD is low, and DDD is not expected to migrate

off of the Facility in groundwater to Force Lake. Furthermore, DDD was detected in deeper groundwater samples at a single well cluster location in the south-central portion of the Facility. With regard to the deeper DDD detections, and given the low mobility of DDD as demonstrated by calculations using the estimated retardation factor, it is suspected that the deeper presence is likely attributable to drilling artifacts or to a breach in the seals of the wells in this cluster and is not the result of vertical migration through natural processes.

- LNAPL is not a significant component at the Facility, and its presence is localized and constrained to a small portion of the Facility. Specifically, a thin layer (0.1 ft) of LNAPL was observed in well GA-30, which was sampled, and trace thicknesses of LNAPL (0.01 ft or less) have been observed in two of the precautionary (e.g., never used) extraction wells. No LNAPL has been observed in wells located along the downgradient boundary of the Facility. In 2009 (a year after sample collection), insufficient volume of LNAPL was available for additional sample collection at well GA-30.
- Groundwater impacts from the Facility do not appear to be widespread, and groundwater does not appear to be migrating off the Facility.

In addition, it should be noted that five chemicals were detected in groundwater samples at concentrations greater than the MCL. These MCL exceedances are summarized below by chemical:

- **Benzene (1 of 28 samples > MCL):** Detected at a concentration greater than the MCL of 5 µg/L in one sample (140 µg/L in the sample collected from location MW-4s in 2008). In 2009, benzene was detected at a concentration of 2.9 µg/L (which is less than the MCL) at the same location.
- **Arsenic (12 of 27 [filtered] and 16 of 34 [unfiltered] samples > MCL):** Detected at concentrations greater than the MCL of 10 µg/L in 12 of 27 filtered water samples and in 16 of 34 total (unfiltered) water samples (maximum detected concentrations were equal to 32.2 and 31.6 µg/L for filtered and unfiltered water samples, respectively). Concentrations were greater than the MCL or non-zero MCLG by factors ranging from 1.1 to 3.2. Similar concentrations of arsenic were detected in groundwater across the Facility, including shallow groundwater at the upgradient property boundary near the northeastern corner of the Facility (arsenic concentrations in samples from well GA-34 were approximately 19 µg/L (for both filtered and unfiltered water samples). These results suggest that the arsenic concentrations may be typical of those in shallow groundwater in the vicinity of the Study Area, including areas upgradient of the Facility
- **TCE (1 of 28 samples > MCL):** Detected at a concentration above the MCL of 5 µg/L in one sample (6.1 µg/L in the sample from location PW-01 in 2000). TCE was not detected in the

sample collected at PW-01 in 2008, and the well was not sampled in 2009.

- **Chlorobenzene (1 of 28 samples > MCL):** Detected at a concentration above the MCL of 100 µg/L in one sample (130 µg/L in the sample collected from location GA-34 in 2009)
- **Lead (1 of 28 samples > MCL):** Detected at a concentration greater than the MCL of 15 µg/L in one sample (19.6 µg/L in the sample collected from location A-18 in 2000). Lead was not detected in samples collected from this well in 2008 or 2009.

7.2.3 Wetland Soil

Key findings for wetland soil are listed below and summarized in Table Table 7-6.

- In the HHRA scenarios associated with current activities at the wetlands, risks were within EPA's target risk range of 10^{-4} to 10^{-6} for current recreational users (9×10^{-6}). HQs were less than 1.
- Although the wetlands are currently zoned as open space, risks to hypothetical future residents were assessed. Based on the results of this analysis (i.e., calculation of risks using the published screening levels), the total excess cancer risks would likely be greater than the upper end of EPA's target risk range (10^{-4}) and HQs for some contaminants would likely be greater than 1. However, City of Portland planning documents indicate that zoning designations for the wetlands are not likely to change in the future. Thus, future residential development of the wetlands is unlikely.
- In the ERA, dietary effects-based HQs were between 1 and 10 for red-tailed hawk (1.2 for total DDTs), Eastern cottontail (1.2 for mercury), and shrew (8.5 for total DDTs). All other HQs were less than 1 or within background or reference area ranges.
- Wetland soil concentrations were greater than invertebrate SLs (e.g., for earthworms) for chromium (up to 75 times the SL or up to 3.5 times background), copper (up to 25 times the SL), zinc (up to 6.2 times the SL), and HPAHs (up to 3.2 times the SL).
- Wetland areas with the highest concentrations included the former drainage ditch to the northwest of the Facility (TPH, PAHs, PCBs, metals, and DDTs), the area near the former discharge point of the stormwater treatment system (TPH, PAHs, PCBs, and metals), and the area south of the Facility between North Force Avenue and the drainage ditch (TPH, PAHs, and PCBs). Chemical concentrations generally decreased with depth in wetland soils.

- Patterns of chemical concentrations are consistent with drainage patterns from the Facility as well as the location of historical sumps and holding ponds along the southwest Facility boundary (which may have extended into what is now considered the wetlands). The migration of chemicals from the Facility into the wetlands now appears to be controlled: surface water runoff is collected, treated, and monitored under an NPDES permit.

7.2.4 Force Lake Sediment and Surface Water

Key findings for Force Lake sediment and surface water are listed below and summarized in Tables 7-7 and 7-8.

- In the HHRA scenarios associated with current activities at Force Lake, excess cancer risks were less than or equal to the low end of EPA's target risk range of 10^{-4} to 10^{-6} for recreational users (between 1×10^{-7} and 1×10^{-6} for sediment and surface water exposure by Force Lake recreational users). HQs were less than 1.
- Risks were within EPA's target risk range of 10^{-4} to 10^{-6} for current exposure via fish consumption (2×10^{-5}). HQs were less than or equal to 1. A portion of this total risk estimate is attributable to background arsenic concentrations. The risk estimate for arsenic based on the regional background concentration was greater than the Study Area risk estimate. For both PCBs and DDTs, the Study Area risk estimate was higher than the reference area risk estimate, indicating that reference area concentrations are not an important factor when considering risk for these contaminants.
- In the ERA, effects-based HQs were between 1 and 2 for pumpkinseed (1.8 for copper) and brown bullhead (1.1 for copper). Sediment concentrations were greater than dry-weight effects-based SLs for benthic invertebrates for DDD (up to 7.2 times the SL) and DDE (up to 22 times the SL); total DDT concentrations were less than the effects-based SL. TOC in the sediment was relatively high (mean of 7.1% in Force Lake), which would limit site-specific bioavailability and toxicity.
- No lateral concentration gradients were apparent in lake sediment; mean concentrations were less than those on the Facility or in wetland soil and decreased with sediment depth. In addition, sampling results indicate that there is minimal transport of chemicals from Force Lake to North Lake.
- With the exception of metals, concentrations in North Lake sediment were usually lower than those in Force Lake sediment. Concentrations of metals were generally similar to those in Force Lake and to background concentrations. These results indicate that there is minimal transport of metals from Force Lake.
- Surface water concentrations of copper and barium were greater than ecological thresholds (HQ for copper was 3.1 and for barium HQ was 7.5 to 7.8). Background copper water concentrations

were 6.9 times as high as the water threshold. Background surface water concentrations were not available for barium; however, Study Area sediment and soil concentrations of barium were less than or similar to background concentrations.

7.3 Evaluation of Preliminary RAOs

The Harbor Oil SOW identified preliminary RAOs for the Harbor Oil Study Area. These preliminary RAOs were provided in Appendix D, Remedial Action Objectives Technical Memorandum, of the RI/FS Work Plan (Bridgewater et al. 2008b).

EPA guidance states that RAOs are media-specific goals for protecting human health and the environment (EPA 1988). The SOW included the following general preliminary RAOs for the Study Area:

- Control or eliminate ongoing sources of contamination, or other Study Area COCs, to groundwater, surface water, and sediment.
- Reduce or eliminate human and ecological exposure to any Study Area-related contaminated media that may lead to potential current or future unacceptable risk.

Table 7-9 summarizes the findings and risk estimates from the RI, HHRA, and ERA, along with the preliminary media-specific RAOs that were provided in the RAOs Technical Memorandum (Bridgewater et al. 2008b). Based on work completed in the HHRA, one additional preliminary RAO was added under wetland soil in Table 7-9: control exposure to chemicals in wetland soil that may result in unacceptable risk to human health. Based on the site-specific environmental information gathered during the RI and the findings of the HHRA and ERA, the preliminary RAOs appear to be inclusive and relevant for the assessment and management of current and future risks posed by the Harbor Oil Study Area.

Based on the results of the RI and baseline risk assessments, EPA will make risk management decisions for the Study Area and will determine whether risks are unacceptable. As discussed in EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988), if the baseline risk assessments determine that risks are acceptable for humans and ecological receptors, the conclusions of the risk assessments and RI may serve as the primary means of documenting this decision. EPA guidance (1991b) states that action is generally not warranted when carcinogenic risks are less than 10^{-4}, non-carcinogenic risks are less than a HQ of 1, and MCLs and non-zero MCLGs are not exceeded. This guidance also indicates that risk assessments should characterize uncertainties when determining whether risks to human health or the environment are unacceptable (EPA 1991b).

Table 7-9. Preliminary Remedial Action Objectives and Associated Remedial Investigation Findings

Preliminary RAO[a]	RI, HHRA, and ERA Findings	Summary
Facility Soil		
Reduce worker exposure to chemicals in soil that may result in unacceptable risk.	In the HHRA, risks were within EPA's target risk range of 10^{-4} to 10^{-6} for current worker exposure (3×10^{-6} for the industrial [construction/trenching] worker). Risks were less than 10^{-6} for the industrial/commercial worker vapor intrusion scenario. Risks for future outdoor worker exposure were also within EPA's target risk range of 10^{-4} to 10^{-6} (2×10^{-5}) but would be somewhat higher than the current outdoor worker scenario. The future risk estimate assumes that workers would be directly exposed to soils (i.e., without the existing gravel layer and pavement covering the Facility). All worker scenarios had HQs that were less than or equal to 1.	Risks for current and future workers were less than the upper end of EPA's target risk range (10^{-4}), and HQs were less than or equal to 1.
Control migration from the soil berm of chemicals that may result in unacceptable risks to ecological receptors or humans.	The soil berm is intact, vegetated, and has no identified areas of soil erosion. Concentrations were not necessarily higher or lower in the soil berm as compared with the surrounding wetland or Facility soil, indicating that the soil berm is not a source. In addition, no clear concentration gradient was observed (i.e., concentrations in wetland soil did not consistently decrease with distance from the soil berm).	The findings of the RI do not indicate that the soil berm is a source of contamination to wetland soil or Facility soil.
Groundwater		
Reduce worker exposure to chemicals from the Study Area in shallow saturated zone groundwater that may result in unacceptable risk.	In the HHRA, excess cancer risks were less than 10^{-6}, and HQs were less than 1 for current worker exposure to groundwater (8×10^{-8} for the industrial [construction/trenching] worker). Risks were also below these thresholds for the industrial/commercial worker vapor intrusion scenario. Detected concentrations in groundwater were greater than the chemical-specific MCL or non-zero MCLG in shallow groundwater for arsenic, lead, benzene, and chlorobenzene, and in deep groundwater for TCE. Arsenic was detected at concentrations up to 3 times greater than the MCL in about 45% of samples (both dissolved and total water samples). The other four chemicals were detected at concentrations greater than their MCLs in only 1 of the 28 samples collected at the Study Area. However, it should be noted that MCLs and non-zero MCLGs are intended to be protective of the consumption of groundwater as drinking water. Groundwater at the Study Area is not currently used for drinking water, and this is not expected to change in the future based on land use designations.	Risks based on exposure to groundwater were less than 10^{-6}, and HQs were less than 1. Although detected concentrations of five chemicals were greater than their specific MCL or non-zero MCLG, exceedances were infrequent for four of the chemicals (in only 1 of 28 samples for lead, benzene, chlorobenzene, and TCE). Arsenic concentrations were greater than the MCL more frequently, but concentrations were similar in an upgradient well, suggesting regional influences. Groundwater at the Study Area is not currently used for drinking water, and this is not expected to change in the future based on land use designations.

Table 7-9. Preliminary Remedial Action Objectives and Associated Remedial Investigation Findings (cont.)

Preliminary RAO[a]	RI, HHRA, and ERA Findings	Summary
Control migration of chemicals in shallow saturated zone groundwater that may result in unacceptable risks to ecological receptors or humans.	In the HHRA, risks from all chemicals detected in groundwater were less than 10^{-6} and had HQs less than 1. In the ERA, an analysis was done to examine risks to ecological receptors if shallow groundwater were to migrate to Force Lake. This evaluation concluded that groundwater discharging into the lake likely does not represent a significant pathway of exposure. The presence of LNAPL is localized and constrained to a small portion of the Facility in the vicinity of well GA-30. A 0.1-ft thick layer of LNAPL has been observed in well GA-30, and trace thicknesses (0.01 ft or less) have been observed in two of the extraction wells. No LNAPL has been observed in wells located along the downgradient boundary of the Facility. In 2009 (a year after sample collection), insufficient volume of LNAPL was available for collection at well GA-30.	Risks to humans from shallow groundwater were less than 10^{-6}, and HQs were less than 1. For ecological receptors, HQs are not expected to be greater than 1 based on the uncertainty analysis performed in the ERA. The migration of chemicals from shallow groundwater does not appear to be a concern based on the concentrations and extent of chemicals in both shallow groundwater and LNAPL. In addition, the observed “thick and viscous” nature of the LNAPL as seen at well GA-30, the inability to gain entry into surrounding wells or re-entry into well GA-30, and the absence of LNAPL in surrounding borings would suggest that LNAPL is of limited extent and mobility potential.
Control migration of chemicals from shallow saturated zone groundwater to the deep saturated zone that may result in unacceptable risk to humans using deep groundwater as a potential future drinking water supply.	With the exception of DDD at one location, chemicals potentially attributable to historical releases within the Study Area that were detected in the deep groundwater zone at the Facility were not detected in the shallow or intermediate groundwater zones. Detected DDD concentrations in deep groundwater were below risk-based screening levels established for drinking water and, as described below, appear to be attributable to a well construction issue. Therefore, the shallow groundwater zone is not a suspected source to the deep groundwater zone. DDD, a hydrophobic, nearly insoluble, and immobile chemical, was detected in the shallow, intermediate, and deep groundwater zones at the MW-2s/MW-2i/B-4 well cluster but at concentrations below the human health RSL. Given the low mobility of DDD, the presence of DDD is likely attributable to well construction methods or the integrity of deep well B-4 and is not a function of vertical migration. Well B-4 was developed pre-1990 and may have served as a conduit for the deeper migration of DDD from surrounding soils. The mobility of DDD is low, and thus DDD is not expected to migrate in groundwater from the Facility to Force Lake. Based on the paucity of chemicals detected in the intermediate groundwater zone, combined with the presence of intervening lower-permeability silt deposits that separate the three groundwater zones, chemicals present beneath portions of the Facility in shallow groundwater do not appear to have significant migration potential to the deep groundwater zone.	Based on the findings of the RI, the vertical migration of chemicals within groundwater from the shallow saturated zone to the deep saturated zone does not appear to be a concern. It is suggested that well B-4 be decommissioned by the property owner because of the well’s lack of structural integrity.

Table 7-9. Preliminary Remedial Action Objectives and Associated Remedial Investigation Findings (cont.)

Preliminary RAO[a]	RI, HHRA, and ERA Findings	Summary
Wetland Soil		
Reduce ecological receptor exposure to chemicals in wetland soil that may result in unacceptable risk.	**Wildlife:** In the ERA, effects-based HQs were less than 1.0 for many chemicals and receptors but were estimated to be greater than 1.0 for red-tailed hawk (1.2 for total DDTs), Eastern cottontail (1.2 for mercury), and shrew (13 for mercury and 8.5 for total DDTs). HQs were equal to 1.2 for hawk and cottontail and thus were essentially equal to 1. HQs for shrew were higher but are uncertain, particularly from a population-level perspective. In addition, the background LOAEL-based HQ for mercury ranged from 5.7 to 15 (compared with a Study Area HQ of 13), indicating that background is an important consideration.	Risk estimates for most of the COPC/receptor pairs were less than or equal to 1.0 or were less than background risk estimates. Uncertainty exists regarding the likelihood that these COPCs would result in unacceptable population-level risks.
	Invertebrates: Wetland soil concentrations were greater than invertebrate SLs (e.g., for earthworms) for chromium (up to 75 times the SL or up to 3.5 times background), copper (up to 25 times the SL), zinc (up to 6.2 times the SL), and HPAHs (up to 3.2 times the SL). The highest chromium and copper concentrations were detected in the drainage ditch located to the west of the Facility. Although soil concentrations were greater than thresholds for these contaminants, earthworms were frequently observed during field sampling, including in those areas with higher concentrations of metals.	Although HQs calculated using general screening levels developed for the protection of earthworms were greater than 1.0 for five contaminants, earthworm population-level effects were not observed at the Study Area.
Control exposure to chemicals in wetland soil that may result in unacceptable risk to human health.	In the HHRA, risks were within EPA's target risk range of 10^{-4} to 10^{-6} for current Force Lake recreational users exposed to wetland soil (9×10^{-6}), and HQs were less than 1.	Risks for recreational users based on exposure to wetland soil were less than the upper end of EPA's target risk range (10^{-4}), and HQs were less than 1.
Control migration of chemicals in wetland soil that may result in unacceptable risk to ecological receptors or humans.	No lateral concentration gradients were apparent in Force Lake sediment (i.e., concentrations were not higher in the northern part of the lake or in the sediment area located near the discharge point of the ditch). Because concentrations of some chemicals were significantly higher in some wetland areas than in lake sediment, limited or no contaminated soil migration appears to have occurred from the highly vegetated wetlands to the lake.	The findings of the RI do not indicate that significant migration of chemicals is occurring.

Table 7-9. Preliminary Remedial Action Objectives and Associated Remedial Investigation Findings (cont.)

Preliminary RAO[a]	RI, HHRA, and ERA Findings	Summary
Lake Sediment		
Reduce recreational user exposure to chemicals in lake sediment that may result in unacceptable risk.	In the HHRA, risks were equal to the lower end of EPA's target risk range of 10^{-6} to 10^{-4} for current recreational users exposed to Force Lake sediment (1×10^{-6}). HQs were less than 1. Risks were within EPA's target risk range of 10^{-4} to 10^{-6} for exposure via fish consumption (2×10^{-5}), and HQs for all COPCs were less than or equal to 1. A portion of this total risk estimate is attributable to background or reference area concentrations. The risk estimate for arsenic based on the regional background concentration was greater than the Study Area risk estimate. For both PCBs and DDTs, the Study Area risk estimate was higher than the reference area risk estimate, indicating that reference area concentrations are not an important consideration.	Risks for recreational users and fish consumers based on direct or indirect exposure to lake sediment were less than the upper end of EPA's target risk range (10^{-4}). HQs for individual COPCs and endpoint-specific HIs were less than or equal to 1.
Reduce ecological receptor exposure to chemicals in lake sediment that may result in unacceptable risk.	In the ERA, effects-based HQs were estimated to be greater than 1.0 for pumpkinseed (1.8 for copper) and brown bullhead (1.1 for copper). HQs were also greater than 1.0 for aquatic invertebrates for DDD and DDE but not for total DDTs. High TOC in the lake likely limits the bioavailability of these contaminants and thus limits the potential for effects.	HQs for fish and aquatic invertebrates were greater than 1.0 for some contaminants. Uncertainty exists regarding the likelihood that these COPCs would result in unacceptable population-level risks.
If contaminated, control migration of chemicals in lake sediment to connected water bodies and exposures that may result in unacceptable risk to ecological receptors or humans.	With the exception of metals, concentrations in North Lake sediment were generally lower than those in Force Lake sediment. Concentrations of metals were generally similar to those in Force Lake and to background concentrations. These results indicate that the migration of chemicals from Force Lake has been minimal and has not resulted in the presence of higher concentrations in North Lake. In addition, Force Lake acts as a settling basin because the water velocity or current is low; thus suspended solids that enter the lake tend to settle to the bottom rather than being transported downstream. As a result, chemicals that have entered the lake have, for the most part, remained because of the natural hydraulic regime of the lake.	The findings of the RI do not indicate that significant migration of chemicals is occurring from Force Lake to North Lake.
Lake Surface Water		
Reduce recreational user exposure to chemicals in lake surface water that may result in unacceptable risk.	In the HHRA, risks were less than 10^{-6} for current recreational users exposed to Force Lake surface water (1×10^{-7}). HQs were less than 1.	Risks for recreational users based on exposure to lake surface water were less than EPA's target risk range (10^{-6} to 10^{-4}), and HQs were less than 1.
Reduce ecological receptor exposure to chemicals in lake surface water that may result in unacceptable risk.	In the ERA, no refined COPCs were identified for surface water; therefore, no risks to ecological receptors from exposure to surface water are expected.	No refined COPCs were identified for ecological receptors.

[a] Bridgewater et al. (2008b [Appendix D])

Table 7-9. Preliminary Remedial Action Objectives and Associated Remedial Investigation Findings (cont.)

AWQC – ambient water quality criteria
COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDT – dichlorodiphenyltrichloroethane
DEQ – Oregon Department of Environmental Quality
EPA – US Environmental Protection Agency
ERA – ecological risk assessment
HHRA – human health risk assessment
HPAHs –high-molecular-weight polycyclic aromatic hydrocarbon
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effect level
LNAPL –light non-aqueous phase liquid
MCL – maximum contaminant level
MCLG – maximum contaminant level goal
PCB – polychlorinated biphenyl
RAO – remedial action objective
RI – remedial investigation
RSL – regional screening level
SL – screening level
TOC – total organic carbon
TRV – toxicity reference value

Below is a summary of the results of the RI and baseline risk assessments relative to EPA guidance:

- Carcinogenic risks for current and future RME scenarios in the HHRA were less than 10^{-4}, the upper level of EPA's target risk range, which is typically used by EPA for risk management decisions (EPA 1991b).
- Non-cancer HQs for individual COPCs and endpoint-specific HIs were less than or equal to 1 for all RME scenarios.
- For ecological receptors HQs were less than 1.0 or were less than or similar to background or reference area concentrations, with the exception of two COPCs for wildlife (mercury and total DDTs), one COPCs for fish (copper), and four COPCs for terrestrial invertebrates (chromium, copper, zinc, and total HPAHs). Uncertainty exists regarding the likelihood that these COPCs would result in unacceptable population-level risks.
- Detected concentrations in groundwater were greater than the MCL or non-zero MCLG for 12 of 27 dissolved water arsenic samples and 16 of 34 total water arsenic samples (approximately 45% of samples), as well as for 1 of 28 samples each for lead, benzene, chlorobenzene, and trichloroethene (Section 7.2.2). However, the groundwater at the Study Area is not currently used as drinking water, and this is not expected to change in the future.

A screening assessment for hypothetical future residents conducted as part of the HHRA indicated that total excess cancer risks would be greater than the upper end of EPA's target risk range (10^{-4}) and non-cancer HQs for some chemicals would be greater than 1. The results of this assessment indicate that if the land use designation were to change, additional analyses would be needed. It should be noted that future residential land use is unlikely at the Study Area based on current and expected future land use designations (industrial at the Facility and open space in the wetlands). In addition, as noted in EPA guidance (EPA 1991b), the NCP states that "the assumption of future residential land use may not be justifiable if the probability that the site will support residential use in the future is small."

EPA will carefully evaluate the information presented in this RI relative to the RAOs for the Study Area to determine what next steps, if any, are necessary.

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