Baseline Human Health Risk Assessment for the Harbor Oil Study Area

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

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IN ASSOCIATION WITH
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List of Acronyms

ABS	dermal absorption fraction
ALM	Adult Lead Model
AOC	Administrative Settlement Agreement and Order on Consent for the Remedial Investigation/Feasibility Study
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	ambient water quality criteria
BaP	benzo[a]pyrene
BCA	bias-corrected accelerated
BHC	benzene hexachloride
BSAF	biota-sediment accumulation factor
Cal EPA	California Environmental Protection Agency
CDC	Centers for Disease Control
CDI	chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminant of concern
COI	contaminant of interest
COPC	contaminant of potential concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CSM	conceptual site model
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DEQ	Oregon Department of Environmental Quality
DQO	data quality objective
dw	dry weight
EC	exposure concentration
EDB	ethylene dibromide
EF	exceedance factor
EMRI	Energy & Material Recovery, Inc.
EPC	exposure point concentration
EPA	US Environmental Protection Agency

Facility	Harbor Oil facility
GI	gastrointestinal
GSD	geometric standard deviation
H-UCL	UCL based on Land's H-statistic
HCID	hydrocarbon identification
HEAST	Health Effects Assessment Summary Tables
HHRA	human health risk assessment
HI	hazard index
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
HQ	hazard quotient
IARC	International Agency for Research on Cancer
IEUBK	Integrated Exposure Uptake Biokinetic Model for Lead in Children
IRIS	Integrated Risk Information System
J-qualifier	estimated concentration
KM	Kaplan Meier method for calculating a UCL
LNAPL	light non-aqueous phase liquid
LPAH	low-molecular-weight polycyclic aromatic hydrocarbon
MEL	Manchester Environmental Laboratory
NRMP	natural resource management plan
OSWER	Office of Solid Waste and Emergency Response
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEF	particulate emission factor
PPRTV	Provisional Peer-Reviewed Toxicity Value
QA/QC	quality assurance/quality control
ODHS	Oregon Department of Human Services
RAGS	Risk Assessment Guidance for Superfund
RAIS	Risk Assessment Information System
RBC	risk-based concentration
RfC	reference concentration
RfD	reference dose
RFO	refined fuel oil
RI/FS	remedial investigation/feasibility study

RL	reporting limit
RME	reasonable maximum exposure
RSL	regional screening level
RZA	Rittenhouse-Zeman and Associates
SD	standard deviation
SF	slope factor
Study Area	Harbor Oil Superfund Study Area
SVOC	semivolatile organic compound
TEQ	toxic equivalent
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
UCL	upper confidence limit on the mean
U-qualifier	not detected at given concentration
UF	uncertainty factor
VOC	volatile organic compound
Windward	Windward Environmental LLC
ww	wet weight

EXECUTIVE SUMMARY

This document presents the baseline human health risk assessment (HHRA) for the Harbor Oil Superfund Site Study Area[1] in Portland, Oregon. This baseline HHRA presents risk estimates for humans associated with potential exposures to contaminants found in soil, lake sediment, lake water, groundwater, and fish caught in Force Lake. The exposure scenarios and assumptions assessed in this HHRA are consistent with a reasonable maximum level of exposure, and thus, although uncertain, risk estimates are intended to be health protective for individuals.

Overall, risks at the Study Area were low for workers at the Facility and for individuals using the off-Facility portions of the Study Area for recreation. Total risks for all scenarios were less than the upper end of the US Environmental Protection Agency's (EPA's) target risk range (1×10^{-4}), although risks for some scenarios were greater than the lower end of EPA's target risk range (1×10^{-6}). Risks were highest for the fish consumption and future outdoor worker scenarios (2×10^{-5} for both scenarios). Risks based on the industrial (construction/trenching) worker (3×10^{-6}) and recreational user scenarios (which ranged from 1×10^{-7} to 9×10^{-6} for the various exposure media) were also greater than the lower end of EPA's target risk range. No contaminant of potential concern (COPC)-specific hazard quotients (HQs) or endpoint-specific hazard indices (HIs) were greater than 1 for any scenario. Based on their risk levels and contribution to the total risk, arsenic, carcinogenic polycyclic aromatic hydrocarbon (cPAH) toxic equivalent (TEQ), total polychlorinated biphenyls (PCBs), total dichlorodiphenyltrichloroethanes (DDTs), and total petroleum hydrocarbons (TPH)-gasoline (aliphatic) were identified as contaminants of concern (COCs) in this HHRA.

The baseline HHRA includes sections on data evaluation, conceptual site model (CSM) and exposure assessment, toxicity assessment, risk characterization, and uncertainty analysis, each of which is briefly summarized below.

ES.1 Data Evaluation

Data used in the assessment included data collected from within the Study Area during the two phases of remedial investigation (RI) data collection (April 2008 and April 2009). In addition, one of the eight historical datasets available for the Study Area was found to be acceptable for use in this HHRA. The historical data used in the HHRA

[1] The Harbor Oil Superfund Site encompasses the Harbor Oil facility (Facility), an approximately 4.1-acre parcel of property located at 11535 N Force Avenue, the adjacent wetlands to the south and west of Force Lake, and Force Lake.

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.

ES.2 Conceptual Site Model and Exposure Assessment

The CSM describes scenarios in which people could be exposed to chemicals within the Study Area through various exposure pathways. Although not differentiated in the graphical CSM, exposures might occur on the Facility, or outside the Facility in the nearby wetlands or Force Lake. On the Facility, exposure pathways included direct contact with Facility soil and groundwater (i.e., dermal absorption and incidental ingestion), as well as inhalation of chemicals volatilized from soil or groundwater and inhalation of airborne soil particulates 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 (i.e., dermal absorption and incidental ingestion) 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 values used to assess exposure in this HHRA were selected to represent a reasonable maximum exposure (RME). 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 were 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 2002c).

The following scenarios were evaluated for the HHRA to assess the exposure of workers to chemicals 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 chemicals 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 addition, a screening assessment was conducted to evaluate risks based on the exposure of hypothetical future residents to chemicals. In this screening assessment, exposure to chemicals in Facility and wetland soil was assumed to occur via dermal absorption, incidental ingestion, and inhalation of airborne soil particulates. Exposure to chemicals in groundwater was assumed to occur as a result of household use of groundwater. The evaluation was included at the request of EPA (Bridgewater et al. 2008b; Windward and Bridgewater 2008a, b), despite the current and expected future land use of the Study Area, which does not include residential use or development. As stated in the Remedial Investigation/Feasibility Study (RI/FS) work plan (Bridgewater et al. 2008b), the zoning and comprehensive plan designations for the Study Area indicate that the current and likely future use of the Facility is industrial, particularly given its Industrial Sanctuary designation, and the current and likely future use of the wetland area is open space.

In the first step of the exposure assessment, a conservative risk-based screen was performed in accordance with EPA guidance to identify the media-specific COPCs to be evaluated for each scenario. 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) are the concentrations of COPCs in soil, groundwater, lake sediment, lake surface water, or 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 upper confidence limit on the mean concentration[2] of a COPC and is intended to represent a long-term exposure concentration. In some cases, the EPC was set equal to one-half the maximum reporting limit 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.

ES.3 Toxicity Assessment

EPA toxicity values were identified for all COPCs. Toxicity values included slope factors (SFs) or inhalation unit risk factors used to evaluate carcinogenic risks, or reference doses [RfDs] or 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 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.

ES.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 COPC 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

[2] Data management rules for calculating EPCs, as presented in Section B.3.4.3, considered the detection frequency and the number of samples.

may develop cancer through exposure to COPCs at the Study Area when averaged over a 70-year lifetime.

Non-carcinogenic health effects generally do not occur below a certain concentration or critical dose (although it should be noted that carcinogenic effects may occur below this dose for COPCs that have both carcinogenic and non-carcinogenic effects). The potential for non-carcinogenic health effects is represented by the ratio of the estimated intake to the critical dose (known as a reference dose) and is expressed as an HQ. Exposures resulting in HQs less than or equal to 1 are unlikely to result in non-cancer adverse health effects.

HQs were summed across all exposure pathways and endpoints to derive an overall HI. When the overall HI, regardless of endpoint, was greater than 1, endpoint specific HIs were calculated by summing the HQs for COPCs 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 greater than 1×10^{-6} (2×10^{-5} and 3×10^{-6}, respectively) (Table ES-1). The total excess cancer risk for the industrial/commercial worker vapor intrusion scenario (9×10^{-7}) was less than 1×10^{-6}.

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 greater than 1×10^{-6} for the Force Lake fish consumer RME scenario (2×10^{-5}) and for the Force Lake recreational user RME scenario (1×10^{-5} across all media) (Table ES-1). The COPC-specific HQs and endpoint-specific non-cancer HIs were less than or equal to 1 for all scenarios.

Table ES-1. Summary of Total Excess Cancer Risks and Non-Cancer HQs

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 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 for all COPCs across multiple exposure pathways, endpoints, and/or target organs.

[b] Risks for this scenario were calculated using the vapor intrusion screening levels, which are based on the more stringent of the cancer or non-cancer risks (i.e., whichever 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 (i.e., combined) 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 is equal to 3. Because this value is greater than 1, endpoint-specific HIs were calculated per EPA guidance (EPA 1989). No endpoint-specific HIs were greater than 1 (see Section 5.3.5 for details).

COPC – contaminant of potential concern

HI – hazard index

HQ – hazard quotient

ne – not evaluated

RME – reasonable maximum exposure

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 some chemicals would have an HQ greater than 1 based on the comparison of Study Area concentrations with regional screening levels (EPA 2009i). 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 a natural resource management planning 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.

Based on the risk estimates, arsenic, cPAH TEQ, total PCBs, total DDTs, and TPH-gasoline (aliphatic) were identified as COCs (i.e., COPCs with risks greater than 10^{-6}). Figure ES-1 presents a comparison of risk estimates broken down by COPC for each of the scenarios with risk estimates greater than 1×10^{-6}. All excess cancer risk estimates were within EPA's target risk range of 10^{-6} to 10^{-4}.

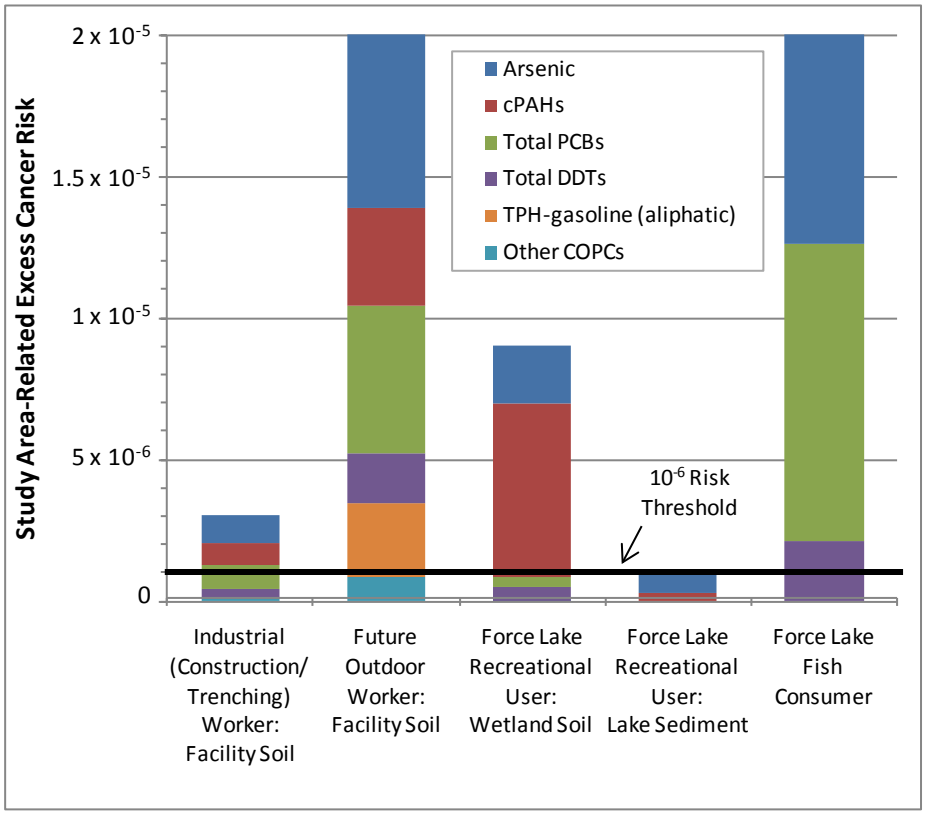


Figure ES-1. Proportion of Total Excess Cancer Risks for Each COC and for other COPCs

For these COCs, background concentrations (for metals) or reference area concentrations[3] from local and regional sources (for organic compounds) were used to estimate risks. These risk estimates were compared to Study Area risk estimates. Risk estimates based on background concentrations were similar to those based on Study Area concentrations for arsenic for most scenarios. Risk estimates based on reference area concentrations were generally less than Study Area risk estimates for cPAH TEQ, total PCBs, and total DDTs for all scenarios. No background or reference area concentrations were available for TPH-gasoline.

Uncertainties associated with the risk estimates for each exposure scenario are discussed in this 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, although uncertain, likely overestimate risks for most individuals.

Risk estimates were highest for the Force Lake fish consumer RME scenario and for the future outdoor worker RME scenario. For the Force

[3] 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 (i.e., urban areas in the vicinity of the Study Area) are presented for comparison with Study Area concentrations.

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 an estimated fish consumption rate. 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 significantly increase the exposure beyond existing conditions.

Additional analyses presented in this document discuss 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.

1.0 INTRODUCTION

1.1 Document Purpose and Scope

On May 31, 2007, the Portland General Electric Company, Bonneville Power Administration, Avista Corporation, NorthWestern Corporation, Union Oil Company of California, and Waste Management Disposal Services of Oregon, Inc. (Voluntary Group for the Harbor Oil Study Area Remedial Investigation/Feasibility Study [RI/FS] [Voluntary Group]) entered into an Administrative Settlement Agreement and Order on Consent for the RI/FS (AOC), Docket No. CERCLA-10-2007-0106, with the US Environmental Protection Agency (EPA) for the Harbor Oil Superfund site (Site) in Portland, Oregon. In accordance with the AOC, the Study Area encompasses the Harbor Oil facility (Facility), an approximately 4.1-acre parcel of land located at 11535 N Force Avenue, the adjacent wetland to the south and west of the main facility, and Force Lake. The AOC statement of work requires that the Voluntary Group prepare an RI that includes a baseline human health risk assessment (HHRA).

This document is the baseline HHRA for the Study Area and presents the characterization of risks for humans at the Study Area, as identified below:

- Section 2.0, Data Evaluation
- Section 3.0, Exposure Assessment
- Section 4.0, Toxicity Assessment
- Section 5.0, Risk Characterization
- Section 6.0, Uncertainty Analysis
- Section 7.0, Conclusions
- Section 8.0, References

The parameters used to assess risks in this HHRA are considered to be conservative regarding exposure and toxicity, as is appropriate for a baseline HHRA, to ensure the adequate protection of humans. This baseline HHRA was prepared by Windward Environmental LLC (Windward) for the Voluntary Group.

1.2 Study Area Location and Facility Description

This section briefly describes the Study Area, as discussed in the RI/FS Work Plan (Bridgewater et al. 2008b), to provide a foundation for the exposure scenarios and pathways discussed in Sections 2.2 and 3.2. The

Study Area is located in north Portland, Multnomah County, Oregon, and includes the Facility, adjacent wetlands to the south and west of the Facility, and Force Lake (Figure 1-1).

According to Coles Environmental Consulting, Inc. (2002), Energy & Material Recovery, Inc. (EMRI), currently operates a waste treatment and processing facility for used oil, oily water, and other wastewater 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 (Figure 1-2). A portion of this building is also used by Wevco Biodiesel Products LLC for the manufacture of biodiesel. Another portion of the building is occupied by Phoenix Asphalt, an asphalt coating business. Immediately to the west of the building is a card-lock fueling station operated by another tenant of EMRI. 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.

Historically, the production of refined fuel oil (RFO) was carried out at a tank farm and used-oil processing area located along the northeast side of the Facility. 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 discharged to Tank 23 for treatment. Tank 23 is no longer used. Currently, the RFO is further processed in a base oil refining plant that was constructed in 2003 (west of the tank farm). Soils excavated during the construction of the base oil refining plant were stockpiled to the northwest of the plant, hereafter referred to as the soil stockpile (Figure 1-2).

A structure in the central area of the Facility was previously used as a tanker truck cleaning operation. The western portion of this structure is currently leased to the asphalt coating business, and the eastern portion is used by EMRI for vehicle and equipment storage.

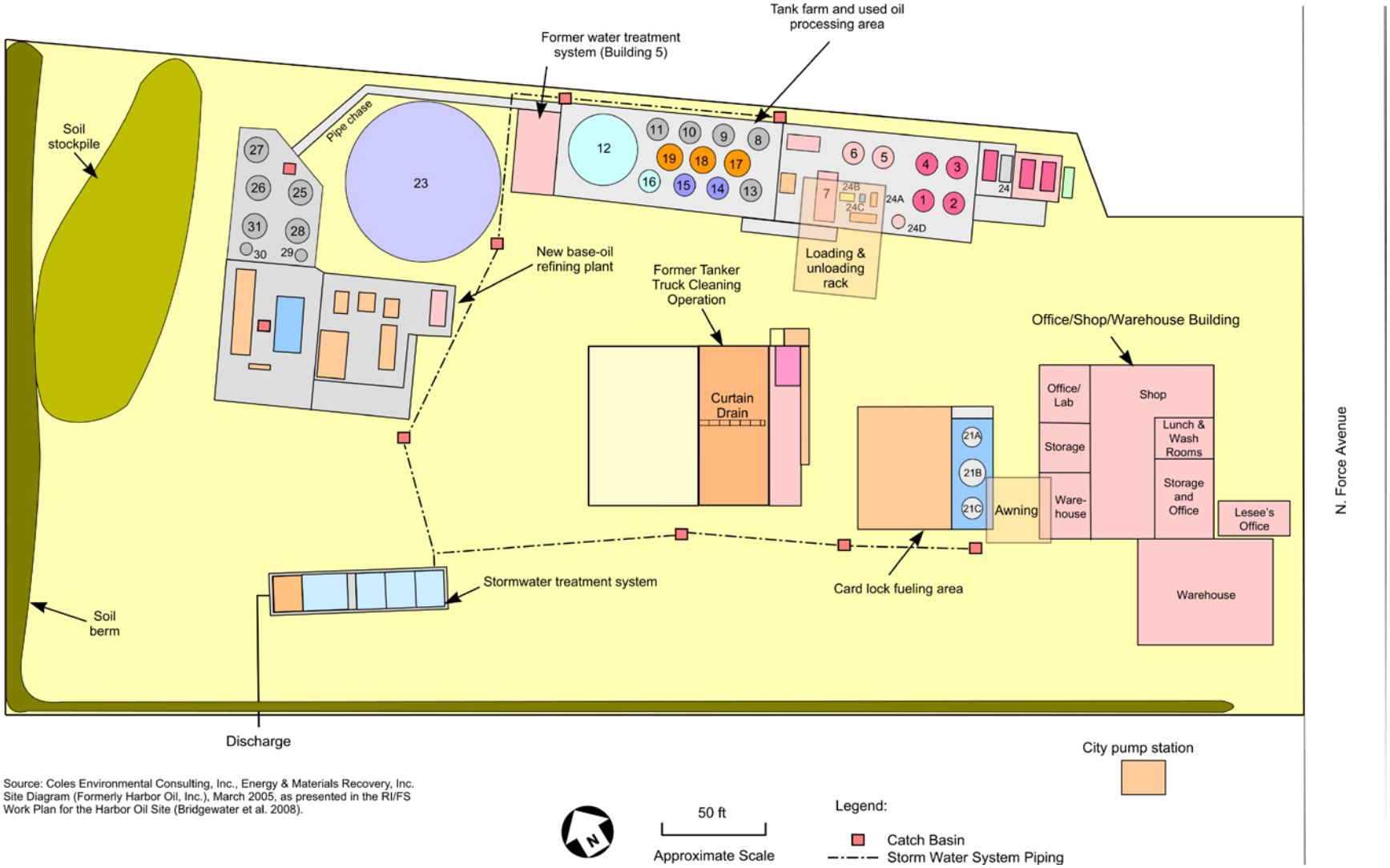
A soil berm that is approximately 2 to 3 feet high and 5 to 6 feet wide at its base extends along the border of the Facility to the west and south; the berm is intended to prevent stormwater runoff from flowing into the adjacent wetlands (Figure 1-2). As stated in the RI/FS Work Plan (Bridgewater et al. 2008b), the soil berm was constructed shortly after a fire that occurred at the Facility in 1979.

A narrow stretch of natural forested wetlands borders the Facility to the south and west, providing habitat for wetland and terrestrial species (Figure 1-1) and separating the Facility from Force Lake. The lake is 590 to 890 feet in diameter and has a surface area of approximately 12 acres (City of Portland 1997). The depth of the lake ranges from approximately 2 to 6 feet, with an average depth of 2 to 3 feet (Fishman 1989).

The lake is bordered on the east by N Force Avenue and on the south and west by the Heron Lakes Golf Course. There are two known direct discharge points into Force Lake: a catch basin that drains a small area along the east side of N Force Avenue and an underdrain for one of the greens on the golf course (Goodling 2007). The Facility's existing stormwater treatment system does not discharge directly to the lake but

rather drains into the wetlands just south of the Facility. Force Lake drains through two culverts to North Lake, which is northwest of Force Lake and is connected to a series of ditches and other water bodies located on the golf course.

Figure 1-1. Harbor Oil Study Area



Source: Coles Environmental Consulting, Inc., Energy & Materials Recovery, Inc. Site Diagram (Formerly Harbor Oil, Inc.), March 2005, as presented in the RI/FS Work Plan for the Harbor Oil Site (Bridgewater et al. 2008).

Figure 1-2. Current Facility Features

2.0 DATA EVALUATION

Exposure to chemicals at the Study Area may occur through direct or indirect contact with lake sediment, wetland soil, Facility soil, groundwater, lake surface water, or fish tissue. This section presents a summary of the data available for the Study Area and discusses their use in the baseline HHRA. The following subsections describe data availability (Section 2.1), data reduction (Section 2.2), and the suitability of data for risk assessment purposes (Section 2.3).

2.1 Data Availability and Selection

This section discusses the various data sources that are available for the Study Area and identifies which of these datasets are appropriate for use in this HHRA.

2.1.1 Historical Datasets

This section summarizes the methods and results of a data quality screen that was conducted as part of the data quality objective (DQO) process to determine whether historical data are acceptable for use in the RI, as presented in the risk assessment scoping memorandum (Windward and Bridgewater 2008a). This data quality screen ensured that data used in this HHRA were of adequate quality.

Multiple field investigations at the Facility, adjacent wetland areas, and Force Lake have been conducted since 1988 (Table 2-1). 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 2.1.1.1.

Table 2-1. Datasets Reviewed for Data Quality and Documentation for the Harbor Oil RI

Year	Sampling Event	Data Summary
2001 to 2006	Heron Lakes Golf Course 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 preliminary assessment/site inspection (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	Peninsula Drainage District 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 site investigation 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 for the HHRA based on the sampling locations and descriptions. Additionally, 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 HHRA.

EMRI – Energy & Material Recovery, Inc.
LNAPL – light non-aqueous phase liquid
NRMP – natural resource management plan
PCB – polychlorinated biphenyl
RI – remedial investigation
RZA – Rittenhouse-Zeman and Associates
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

2.1.1.1 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. All new data collected through the RI process outlined in the RI/FS Work Plan met these criteria through compliance with the methods detailed in the quality assurance project plan (Bridgewater et al. 2008b).

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.

Although EPA has not established definitive guidelines specifying the level of data validation required for the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), EPA Order 5360.1 and Office of Solid Waste and Emergency Response (OSWER) Directive 9355.9-01 (EPA 1993) require environmental measurements to be of known quality, verifiable, and defensible. 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 to be used for decision-making.

2.1.1.2 Historical Data Screen Results

The results of the data screen are presented in Table 2-2. The data from one sampling event (Ecology and Environment 2001) are considered acceptable for use in the HHRA. Data from seven sampling events did not meet minimum DQOs and were determined to be unsuitable for use in this HHRA. These seven sampling events are listed in Table 2-2 with the rationale for their exclusion.

2.1.2 Data Acceptable for Use in the Baseline HHRA

As described in Section 2.1.1, only one of the eight historical datasets available for the Study Area was acceptable for use in this HHRA. In addition to this historical sampling event, two phases of RI data collection were conducted at the Study Area (the first in April 2008 and the second in April 2009). Table 2-3 presents a summary of the chemistry data available from these three sampling events. In addition, Figure 2-1 shows the locations of these samples.

Details on all of the specific samples used in the HHRA (across all three sampling events listed above) are summarized in Table 2-4.

Table 2-2. 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 Course 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 preliminary assessment/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, Inc., 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	Peninsula Drainage District 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 site investigation 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 resource management plan
QA/QC – quality assurance/quality control
RI – remedial investigation
RZA – Rittenhouse-Zeman and Associates
SVOC – semivolatile organic compound
VOC – volatile organic compound

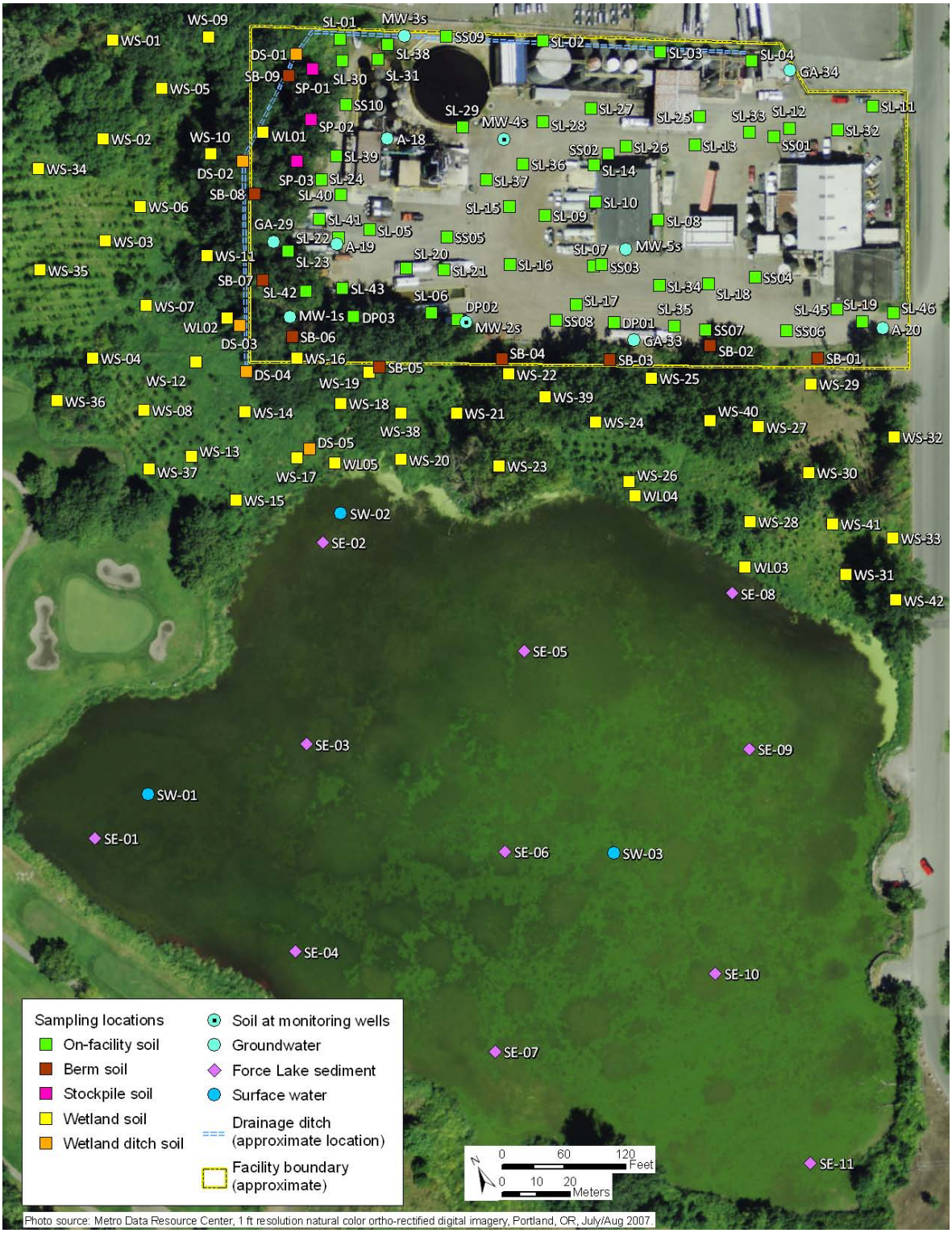


Figure 2-1. Sampling Locations for Data Used in the Baseline HHRA

Table 2-3. Summary of Data Used in the Baseline HHRA by Sampling Event

Sampling Event	Year	Media	Number of Locations[a]	Source	Analytes
Preliminary assessment/ site inspection	2000	facility soil	13	Ecology and Environment (2001)	metals, PAHs, phthalates, other SVOCs, PCBs, pesticides, VOCs, petroleum
		groundwater	7		metals, PAHs, phthalates, other SVOCs, PCBs, pesticides, VOCs, petroleum
		wetland soil	5[b]		metals, PAHs, phthalates, other SVOCs, PCBs, pesticides, VOCs, petroleum, conventionals
RI Phase 1 sampling	2008	facility soil	34	Windward et al. (2008)	metals, PAHs, phthalates, SVOCs, PCBs, pesticides, VOCs, petroleum, conventionals
		soil stockpile	3		metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, conventionals
		soil berm	9		metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, conventionals
		groundwater	16		metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, conventionals
		wetland soil	33		metals, PAHs, phthalates, other SVOCs, PCBs, pesticides, VOCs, petroleum, conventionals
		lake sediment	11		metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, grain size, conventionals
		lake surface water	3		metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum
RI Phase 2 sampling	2009	facility soil	15	Harbor Oil RI database	metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, conventionals
		groundwater	11		metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, conventionals
		wetland soil	13		metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, petroleum, conventionals
		lake sediment	3		metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, conventionals

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

[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 HHRA database.

HHR A – human health risk assessment
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RI – remedial investigation
SVOC – semi-volatile organic compound
VOC – volatile organic compound

Table 2-4. Summary of Data Used in the Baseline HHRA

Media	Sample Description	Sample Depth Category	Range of Sample Depth	No. of Samples
Industrial (construction/ trenching) worker RME scenario	Facility soil	surface	0 to 60 inches	57
		intermediate and deep	24 to 102 inches	34
	wetland ditch soil	surface	0 to 6 inches	7
		intermediate and deep	6 to 36 inches	6
	soil berm	na	6 to 24 inches	9
	soil stockpile	na	6 to 72 inches	3
	groundwater	shallow	0 to 20 feet	18
Future outdoor worker RME scenario	Facility soil	surface	0 to 60 inches	57
	wetland ditch soil	surface	0 to 6 inches	7
	soil berm	na	6 to 24 inches	9
Industrial/commercial vapor intrusion worker scenario (current)	groundwater	shallow	0 to 20 feet	4
Industrial/commercial vapor intrusion worker scenario (hypothetical)	groundwater	shallow	0 to 20 feet	22
Force Lake recreational user RME scenario	wetland soil	surface	0 to 6 inches	52
	soil berm	na	6 to 24 inches	9
	Force Lake sediment	shallow	0 to 4 inches	11
	Force Lake surface water	surface	12 inches	3
Force Lake fish consumer RME scenario	Force Lake sediment	shallow	0 to 4 inches	11

HHRA – human health risk assessment
na – not applicable
RME – reasonable maximum exposure

In addition, as a part of the RI Phase 2 sampling, a survey of the fish population in Force Lake was conducted to obtain information on the types of fish present in the lake and estimate the abundance and sizes of these fish. This survey was necessary to provide additional information for use in the fish consumer scenario developed as part of this baseline HHRA (Section 3.3.3).

2.2 Data Reduction

Data reduction refers to computational methods used to aggregate the data for use in the HHRA. The most significant use of aggregated data was for the calculation of exposure point concentrations (EPCs). The methods used to calculate EPCs are described in detail in the exposure assessment (Section 3.3.4).

Additional procedures related to averaging, selection of the best data points when multiple data were available, selection of significant figures and rounding procedures, and calculating totals for chemical groupings (i.e., polychlorinated biphenyls [PCBs], polycyclic aromatic hydrocarbons [PAHs], dichlorodiphenyltrichloroethane [DDT], chlordane, and total petroleum hydrocarbons [TPH]) are described below.

2.2.1 Duplicate or Replicate Samples

Chemical concentrations obtained from the analysis of laboratory duplicate and triplicate samples (two or more analyses of the same sample) were compared to the results of the original sample. A single value that represented the original sample and laboratory duplicate and triplicate samples were selected. This final result could be verified through the use of the original laboratory reports (i.e., Form Is). Final result selection rules were dependent on whether the individual results were detected. If all concentrations were detected for a single chemical, the maximum detected concentration was selected as the final result. If all results for a given parameter were not detected, the minimum RL was selected for the final result. If the concentrations were a mixture of detected concentrations and RLs, the maximum detected concentration was selected as the final result, regardless of whether the RLs were higher or lower than the detected concentration.

Exceptions to these rules were made for some specific conventional parameters (i.e., grain size, total organic carbon, total solids). For these parameters, the result from the original sample was selected as the final reported result.

2.2.2 Selection of Best Results

In some instances, the laboratory generated more than one result for a chemical for a given sample. Multiple results could have occurred for several reasons, including: 1) the original result does not meet the laboratory's internal QC guidelines and a reanalysis is performed, 2) the original result does not meet other project DQOs, such as a sufficiently low RL, and a reanalysis is performed, or 3) a chemical is analyzed by more than one method for a given sample. In each case, a single best result was selected for use, as described below:

- Detected and not qualified, then the result from the lowest dilution was selected, unless multiple results from the same dilution were available, in which case, the result with the highest concentration was selected.

- A combination of estimated and unqualified detected results, then the unqualified result was selected. This situation most commonly occurred when the original result was outside of the calibration range, thus requiring a dilution.
- All estimated, then the "best result" was selected using best professional judgment in consideration of the rationale for qualification. For example, a result qualified based on laboratory duplicate results outside of QC objectives for precision was preferred to a qualified result that was outside the calibration range.
- A combination of detected and undetected results, then the detected result was selected. If there was more than one detected result, the applicable rules for multiple results (as discussed above) were followed.
- All undetected results, then the lowest RL was selected.

2.2.3 Significant Figures and Rounding

Analytical laboratories reported results with various numbers of significant figures depending on the laboratory's standard operating procedures, the instrument, chemical, and the reported concentration relative to the RL. The reported (or assessed) precision of each result was explicitly stored in the project database by recording the number of significant figures. Tracking of significant figures is important when calculating averages and performing other data summaries. When a calculation involves addition, such as totaling PCBs, the calculation could only be as precise as the least precise number that went into the calculation. For example:

> 210 + 19 = 229 would be reported as 230 because although 19 is reported to 2 significant digits, and the trailing zero in the number 210 is not significant.

When a calculation involved multiplication or division, the final result was rounded at the end of the calculation to reflect the value used in the calculation with the fewest significant figures. For example:

> 59.9 × 1.2 = 71.88 would be reported as 72 because there are two significant figures in the number 1.2.

When rounding, if the number following the last significant figure was less than 5, the digit was left unchanged. If the number following the last significant figure was equal to or greater than 5, the digit was increased by 1. All calculated means and medians were reported to two significant figures.

2.2.4 Calculating Totals

Total PCBs, total DDTs, total PAHs, and total chlordane were calculated by summing the detected values for the individual components available for each sample. For individual samples in which none of the individual components was detected, the total value was given a value equal to the

highest RL[4] of an individual component and assigned the same qualifier (U or UJ), indicating an undetected result. For individual samples that had both detected and undetected results for individual components, only the detected concentrations were summed, and the RLs for the undetected components were ignored. Concentrations for the analyte sums were calculated as follows:

- **Total PCBs** were calculated using only detected values for seven Aroclor mixtures.[5] For individual samples in which none of the seven Aroclor mixtures was detected, total PCBs were reported as equal to the highest RL of the seven Aroclors and assigned a U-qualifier.
- **Total DDTs** were calculated using only detected values for the DDT isomers: 2,4′-dichlorodiphenyldichloroethane (DDD); 4,4′-DDD; 2,4′-dichlorodiphenyldichloroethylene (DDE); 4,4′-DDE; 2,4′-DDT and 4,4′-DDT. For individual samples in which none of the isomers was detected, total DDTs were given a value equal to the highest RL of the isomers and assigned a U-qualifier, indicating the lack of detected concentrations.
- **Total chlordane** was calculated using only detected values for the following compounds: alpha-chlordane, gamma-chlordane, oxychlordane, cis-nonachlor, and trans-nonachlor. For individual samples in which none of these compounds was detected, total chlordane was given a value equal to the highest RL of the compounds listed above and assigned a U-qualifier, indicating the lack of detected concentrations.
- **Carcinogenic polycyclic aromatic hydrocarbons (cPAHs)** were summed based on potency equivalency factors (Table 2-5). This sum is considered a toxic equivalent (TEQ) because the concentrations of the individual cPAHs are scaled based on their potency relative to that of benzo(a)pyrene (the most toxic cPAH). The cPAH TEQ for each sample was calculated by summing the product of the concentration of each individual compound and its specific potency equivalency factor. Compounds that were not detected for a given sample were assigned a value equal to one-half the sample-specific RL for use in the TEQ equation.

[4] It should be noted that the treatment of RLs in calculating totals is different than the treatment of RLs for duplicate or replicate samples (Section 2.2.1) or in the selection of best results (Section 2.2.2). The highest RL is used in calculated totals to be conservative; whereas the lowest RL is used in data reduction in order to select the most precise analytical RL reported.

[5] Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260.

Table 2-5. Potency Equivalency Factors for cPAHs

Compound	Potency Equivalency Factors[a]
Benzo(a)pyrene	1
Benzo(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.1
Chrysene	0.01
Dibenzo(a,h)anthracene	0.4
Indeno(1,2,3-cd)pyrene	0.1

[a] Potency equivalency factors for cPAHs were developed by Cal EPA, Office of Environmental Health Hazard Assessment, and were presented in Appendix B (Table 8) of Cal EPA's air toxics hot spots risk assessment guidance (California EPA 2009). Potency equivalency factors for other PAHs are also available; those presented here are for PAHs analyzed in Harbor Oil samples.

Cal EPA – California Environmental Protection Agency

cPAH – carcinogenic polycyclic aromatic hydrocarbon

2.2.5 Aliphatic TPH

For risk assessment purposes, EPA's recent TPH guidance (2009f) recommends assessing TPH as six fractions: the aliphatic and aromatic fractions of low-, medium-, and high-carbon content. For the Study Area, TPH were analyzed as three fractions – gasoline, diesel, and motor oil ranges – which roughly correspond to the low-, medium-, and high-carbon ranges, respectively. Therefore, in consultation with EPA (Windward 2010), the following methodology was used to ensure that both aliphatic and aromatic TPH fractions were addressed in this HHRA:

- **Aliphatic TPH fractions**: The aliphatic TPH fraction concentrations were estimated by assuming a percentage of each fraction (i.e., gasoline, diesel, and motor oil) was aliphatic. Based on information presented in ATSDR (1999), 85% of each fraction was assumed to be aliphatic (the midpoint of the range of 80 to 90% presented in ATSDR for various petroleum products). The estimated aliphatic TPH fractions were treated the same as all other chemicals in this HHRA (i.e., the aliphatic TPH fractions were compared with screening levels; and if concentrations were greater than screening levels, they were selected as COPCs for further evaluation in this HHRA).
- **Aromatic TPH fractions**: Aromatic TPH fractions are predominantly composed of various VOCs and PAHs (e.g., benzene, naphthalene, and toluene), which were evaluated as individual components in this HHRA. Risks for the aromatic fraction were not directly calculated to avoid double-counting risks from these chemicals.

2.3 Suitability of Data for Risk Assessment

There are several factors to consider in assessing the suitability of environmental data for risk assessments (EPA 1989, 1992b). Of primary importance is the degree to which the data adequately represent expected human exposures in the Study Area. Also important to consider are the data quality criteria goals and the source, documentation, analytical methods, RLs, and level of review associated with the data. Because data from several investigations were available for the Study Area, these factors were evaluated for each dataset to determine whether it was reasonable to combine all data for use in this baseline HHRA. These suitability determinations were performed in consultation with EPA.

2.3.1 Representativeness to Study Area Concentrations

The majority of data available for use in this HHRA were collected during the two phases of RI sampling. Because the sampling plan for the RI was designed to accommodate the risk assessments and to characterize the nature and extent of chemical concentrations at the site, the distribution of samples across the site adequately reflects the site-related concentrations. For example, the density of Facility soil and wetland sampling locations was high in order to more accurately characterize the higher variability in chemical concentrations in these areas. The density of lake sediment and surface water samples is lower, reflecting the more homogeneous nature of the chemical concentrations in Force Lake. In addition, to ensure complete characterization of the chemical concentrations at the Study Area, surface and subsurface samples were collected at various locations.

Groundwater samples were collected in summer 2000, spring 2008, and spring 2009. The inclusion of data from multiple years and seasons makes it more likely that temporal variability in chemical concentrations in groundwater has been captured, as compared with reliance on data from only a single monitoring event.

It should also be noted that surface sediment samples were collected from North Lake but are not included in this HHRA. These samples were collected to determine the extent of chemical migration from Force Lake to North Lake. As presented in the preliminary site characterization report (Windward et al. 2008; Section 6.5.2), an analysis of these samples indicated that the migration of chemicals from Force Lake to North Lake is limited. Thus, the samples collected from North Lake are not representative of concentrations related to the Facility and are not included in the HHRA. The inclusion of these samples in the lake exposure dataset would have reduced exposure concentrations because chemical concentrations are lower in North Lake than in Force Lake.

2.3.2 Representativeness to Expected Human Exposure

People may come in contact with chemicals at the Study Area through various activities, including working at the Facility and participating in recreational activities in and around Force Lake. A more detailed description of these activities is provided in Section 3.1. The overall distribution of samples reflects the expected human exposure from activities at the Study Area.

In addition, the collection of both surface and subsurface soil samples allows for a more complete characterization of risks for individuals who might contact deeper material.

2.3.3 Quality Assurance/Quality Control Results

As discussed in Section 2.1.1.1, the dataset used in the HHRA had to meet specific criteria. One of these requirements was that all datasets had to be validated by the original authors of the individual studies or by outside third parties. No additional data validation is planned for this HHRA, but the data used in the HHRA have been sufficiently validated. Any data qualified as unusable by the data validators were not used in this HHRA.

2.3.4 Other Factors

This section discusses several additional factors that were important in the determination of data suitability for this HHRA.

2.3.4.1 Documentation of Field and Laboratory Practices

Documenting field and laboratory procedures allows for the assessment of the impact of any deviation from these procedures on data usability. For data to be considered for use in this HHRA, information regarding the sampling method, sample depth, sample type, and sampling location had to be available, as discussed in Section 2.1.1.1. The determination that a dataset was usable for this HHRA indicated that a thorough review of the documentation provided (e.g., method descriptions, QC results) for the various studies did not reveal any issues that would adversely affect the usability of the data for risk assessment purposes. Data collected by the Voluntary Group followed field and laboratory procedures that were approved by EPA and met the criteria outlined above.

2.3.4.2 Analytical Data Review

The level of analytical data review can also affect data usability. All data used in this HHRA were subjected to a thorough data reduction and validation process. All datasets considered suitable for use in this HHRA had sufficient documentation to complete this review.

2.3.4.3 Analytical Methods

Analytical methods selected for use in analyzing the samples collected during the two phases of the RI sampling effort were approved by EPA in advance of sampling. For the samples collected as part of the RI sampling effort, the analytical methods are described in the quality assurance project plan (Bridgewater et al. 2008a) and were summarized in the preliminary site characterization report (Windward et al. 2008). For samples collected as part of the Harbor Oil preliminary assessment/site inspection (Ecology and Environment 2001), the methods were adequately described in the sampling documentation to determine that they were acceptable.

3.0 EXPOSURE ASSESSMENT

This section describes the scenarios in which people may be exposed to chemicals present at the Study Area and provides the methods that will be used to assess the risks associated with these scenarios. Section 3.1 presents the conceptual site model (CSM) for the Study Area, Section 3.2 presents the screening of the data for the selection of contaminants of potential concern (COPCs), Section 3.3 describes the exposure parameters for each scenario and the calculation of the chronic daily intake (CDI), Section 3.4 presents the CDI rates for each COPC.

3.1 Conceptual Site Model

The CSM is a representation of chemical sources, transport mechanisms, exposure pathways, exposure routes, and potentially exposed populations. It provides the basis for developing exposure scenarios to be evaluated in the exposure assessment component of the HHRA.

In accordance with EPA guidance (1989), the values used to assess exposure in this HHRA were selected to represent a reasonable maximum exposure (RME), which is the highest exposure that is reasonably expected to occur at a site. RME by definition likely overestimates exposure for most individuals but was used here to ensure that this baseline HHRA is sufficiently health-protective. Risks associated with a fifth scenario, the industrial/commercial worker vapor intrusion scenario, were calculated using the default exposure parameters used to develop the published vapor intrusion screening levels (EPA 2002c), and thus site-specific exposure parameters were not needed.

These five exposure scenarios were developed to represent potentially exposed populations. Each exposure scenario involved at least one potential pathway of exposure to contaminated media and a potential exposure route through which chemicals can enter the body of an exposed individual. However it should be noted that the importance of some pathway/route combinations is minor or incomplete for some scenarios.

The five scenarios presented are not mutually exclusive; an individual could be exposed through the activities included in more than one scenario. Therefore, several of the scenarios are evaluated cumulatively in the risk characterization summary. For example, individuals exposed to lake sediment, wetland soil, and lake surface water through recreational activities could also consume fish caught in Force Lake.

The five scenarios presented in the CSM for this baseline HHRA are briefly described below:

- **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 contaminants. 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.
- **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 Harbor Oil 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 addition, at the request of EPA, a screening assessment was conducted to evaluate risks associated with hypothetical future residential exposure (see Attachment 1). In this screening assessment, exposure to chemicals in Facility and wetland soil was assumed to occur via dermal absorption, incidental ingestion, and the inhalation of airborne soil particulates. Exposure to chemicals in groundwater was assumed to occur as a result of household use of groundwater as tap water. Consistent with past agreements with EPA (Bridgewater et al. 2008b; Windward and Bridgewater 2008a, b), this screening level assessment was included in this HHRA even though the current and expected future land uses are industrial for the Facility and open space for the wetlands and Force Lake.

Figure 3-1 presents the CSM for risk to human health from the Study Area. The preliminary CSM was presented in the RI/FS Work Plan (Bridgewater et al. 2008b). The five scenarios listed above were developed to characterize risk from exposure to chemicals at the Study Area. The following subsections summarize the scenarios, provide

information on the exposure pathways/routes considered for each scenario, and discuss which data were used to estimate exposures.

Each scenario shown in Figure 3-1 and Table 3-1 is discussed qualitatively in the subsections that follow. The exposure parameters for each scenario are presented in Section 3.3.2.

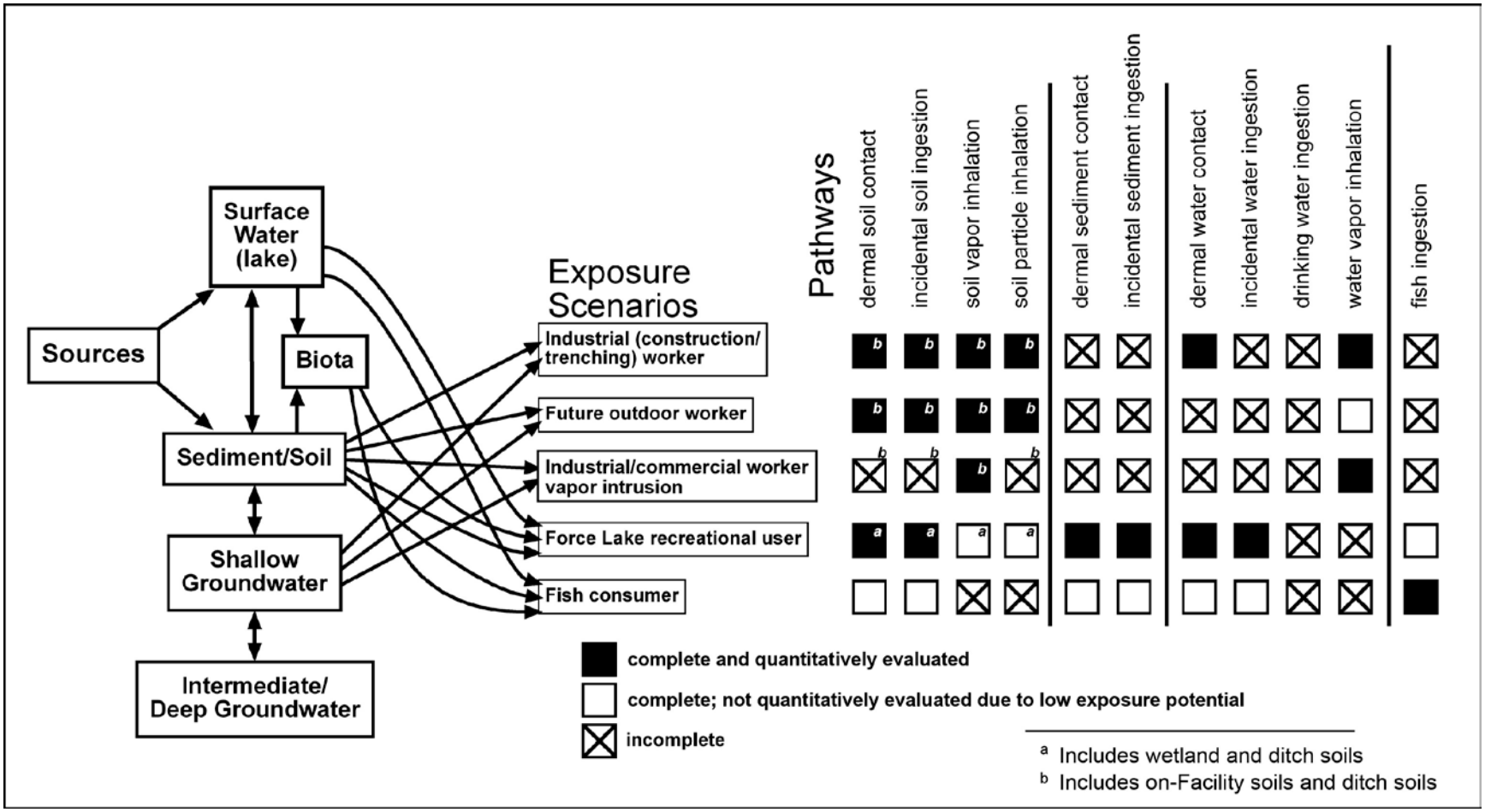


Figure 3-1. Human Health CSM

Table 3-1. Rationale for the Selection or Exclusion of Exposure Pathways

Exposure Scenario	Exposure Point	Exposure Timeframe	Exposure Medium	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Industrial (construction/ trenching) worker RME scenario	Harbor Oil Facility	current and future	Facility soil	worker	adult	dermal	quantitative	Represents the most likely direct contact pathway for soil exposure.
						ingestion[a]	quantitative	
						inhalation	quantitative	Inhalation of airborne soil particulates and chemicals volatilized from soil are possible.
			ground-water	worker	adult	dermal	quantitative	Dermal contact with groundwater is possible.
						ingestion[a]	qualitative	Exposure typically not quantified because of low exposure potential and high level of uncertainty (DEQ 2003).
						inhalation	quantitative	Inhalation of chemicals volatilized from water is possible.
Future outdoor worker RME scenario	Harbor Oil Facility	future	Facility soil	worker	adult	dermal	quantitative	Represents the most likely direct contact pathway for soil exposure.
						ingestion[a]	quantitative	
						inhalation	qualitative	Inhalation of airborne soil particulates and inhalation of chemicals volatilized from soil are possible.
			ground-water	worker	adult	inhalation	qualitative	Inhalation of chemicals volatilized from water is insignificant compared with direct contact with soil.
Industrial/ commercial worker scenario	Harbor Oil Facility	current and future	Facility soil	worker	adult	inhalation	quantitative	Exposure through the inhalation of soil particulates or inhalation of chemicals volatilized from water that have intruded into buildings is possible.
			ground-water	worker	adult	inhalation	quantitative	

Table 3-1. Rationale for the Selection or Exclusion of Exposure Pathways

Exposure Scenario	Exposure Point	Exposure Timeframe	Exposure Medium	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Force Lake recreational user RME scenario	Harbor Oil Study Area (excluding the Facility)	current and future	wetland soil	visitor	adult/ child	dermal	quantitative	Represents the most likely direct contact pathway for soil exposure.
						ingestion[a]	quantitative	
						inhalation	qualitative	Inhalation of soil particulates or inhalation of chemicals volatilized from soil is insignificant compared with direct contact with soil.
			Force Lake sediment			dermal	quantitative	Represents the most likely direct contact pathway for sediment exposure.
						ingestion[a]	quantitative	
			Force Lake surface water			dermal	quantitative	Represents the most likely direct contact pathway for water exposure.
						ingestion[a]	quantitative	
Force Lake fish consumer RME scenario	Force Lake	current and future	fish tissue	visitor	adult/ child	ingestion	quantitative	Although available data suggest fish consumption rates from Force Lake are low, it is possible for individuals to catch fish in Force Lake.

[a] Incidental ingestion associated with dermal contact.

DEQ – Oregon Department of Environmental Quality

RME – reasonable maximum exposure

3.1.1 Industrial (Construction/Trenching) Worker RME Scenario

The construction/trenching industrial worker RME scenario was evaluated to estimate risks to workers involved in construction or other intrusive work conducted outdoors at the Facility, such as digging shallow trenches (assumed to be no more than waist deep) or excavating dirt to prepare for new buildings at the Facility. This type of work is not likely to occur at the Facility for an extended duration. Thus, the exposure assumptions were developed to represent exposure to soil and groundwater during work conducted over a limited time period (1 year). To ensure that this scenario is sufficiently conservative, health-protective parameters were selected from DEQ's *Guidance for Conduct of Deterministic Human Health Risk Assessments* (1998), DEQ's *Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites* (2003), and EPA's *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (2002d).

These workers could be exposed through the following exposure routes:

- **Facility surface and subsurface soils:** dermal absorption, incidental ingestion, inhalation of soil particulates, and inhalation of chemicals volatilized from soil
- **Groundwater:** dermal absorption and inhalation of chemicals volatilized from water

Exposure to Facility soil was assessed using all surface soil samples and subsurface soil samples (to a depth of 4 to 6 feet below ground surface) collected at the Facility, including soil stockpile, soil berm, and ditch soil samples as discussed in the RI/FS Work Plan (Bridgewater et al. 2008b) and risk assessment scoping memorandum (Windward and Bridgewater 2008a). Exposure to groundwater was assessed using all shallow groundwater samples. The saturated zone for shallow groundwater at the Facility is close to the surface (1 to 6 ft bgs), and thus it is likely that there would be a small amount of standing water at the bottom of the trench in some locations. In addition, risks from inhalation exposures were assessed for chemicals in groundwater and soil. Concentrations associated with volatilized chemicals were modeled as described in Section 3.3.1 and in Attachment 4.

Exposure pathways that were considered incomplete or complete and insignificant for the industrial (construction/trenching) worker RME scenario are discussed below, along with rationale regarding the exclusion of these pathways:

- **Dermal sediment contact or incidental sediment ingestion:** Workers at the Facility were not expected to come into contact with lake sediment.
- **Incidental water ingestion:** While workers may come into contact with groundwater, the incidental ingestion of groundwater was considered incomplete because of the low exposure potential and

a high level of uncertainty regarding risk calculations for this pathway (see Table 3-1).

- **Drinking water ingestion:** Groundwater at the Facility is not a source of drinking water.
- **Fish ingestion:** Workers at the Facility were not expected to consume fish from Force Lake.

3.1.2 Future Outdoor Worker RME Scenario

The future outdoor worker RME scenario was evaluated to assess risks to outdoor workers in the event that the surficial gravel fill material and pavement that currently covers most of the Facility is removed. These workers are assumed to be performing routine activities at the Facility (e.g., walking between operations); these activities would not involve digging or construction work. Exposure to chemicals could occur through dermal absorption, incidental ingestion, inhalation of airborne soil particulates, and inhalation of volatilized chemicals in Facility soil. The exposure parameters for this scenario were based on the occupational worker described in DEQ's *Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites* (2003) and the outdoor worker described in EPA's *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (2002d).

A current outdoor worker scenario was not assessed because the exposure of current Facility workers is expected to be lower than the exposure for the future outdoor worker RME scenario because gravel fill material and/or pavement that currently covers most of the Facility. In addition, current Facility workers spend most of their time working indoors in the base-oil plant or sitting in tanker trucks, although they also spend some time outdoors walking between operations.

Future outdoor worker exposure to Facility soil was assessed using all surface soil samples collected at the Facility, including soil stockpile, soil berm, and ditch soil samples as discussed in the RI/FS Work Plan (Bridgewater et al. 2008b) and risk assessment scoping memorandum (Windward and Bridgewater 2008a).

Exposure pathways that were considered incomplete or complete and insignificant for the future outdoor worker RME scenario are listed below, along with rationale regarding the exclusion of these pathways:

- **Dermal sediment contact or incidental sediment ingestion:** Workers at the Facility were not expected to come into contact with lake sediment.
- **Dermal water contact or incidental water ingestion:** Exposure to groundwater was not expected based on the daily activities of workers at the Facility.
- **Drinking water ingestion:** Groundwater at the Facility is not a source of drinking water.

- **Inhalation of chemicals volatilized from water:** Risks associated with inhalation were not assessed because of the low exposure potential and because risks from inhalation were expected to be insignificant compared to risks from dermal contact and incidental ingestion of soil.
- **Fish ingestion:** Workers at the Facility were not expected to consume fish from Force Lake.

3.1.3 Industrial/Commercial Worker Vapor Intrusion Scenario

The industrial/commercial worker vapor intrusion scenario was evaluated to estimate risks to workers associated with the intrusion of vapors into buildings at the Facility. These workers were assumed to be performing routine activities inside buildings at the Facility, such as administrative tasks or other office work. Workers involved in everyday activities are not likely to be in contact with potentially contaminated soils because of the layer of packed gravel (approximately 12 inches thick in most locations) and pavement that cover the Facility. Thus, potential exposure for typical workers is largely via indoor exposure, and exposure to contaminants in soil via direct contact is expected to be low relative to the inhalation of volatiles.

Two separate vapor intrusion evaluations were conducted. The first addressed the risks to workers associated with current buildings at the Facility (not including the covered open-air fueling station located in the middle of the Facility). As recommended in EPA guidance (2002c), only those samples collected within 100 feet of existing buildings were used to estimate indoor vapor concentrations. Thus, groundwater samples collected from shallow wells A-20 and GA-34 were used to evaluate risks. Data from samples farther than 100 feet from current buildings were not used to estimate exposure because chemical migration at this distance without a natural or man-made conduit is considered unlikely.

The second evaluation assessed risks to workers based on hypothetical future buildings at the Facility. This scenario included all other groundwater samples to determine hypothetical vapor intrusion risks if additional buildings were to be constructed in the future. Figure 3-2 shows the samples groups used for these two scenarios.

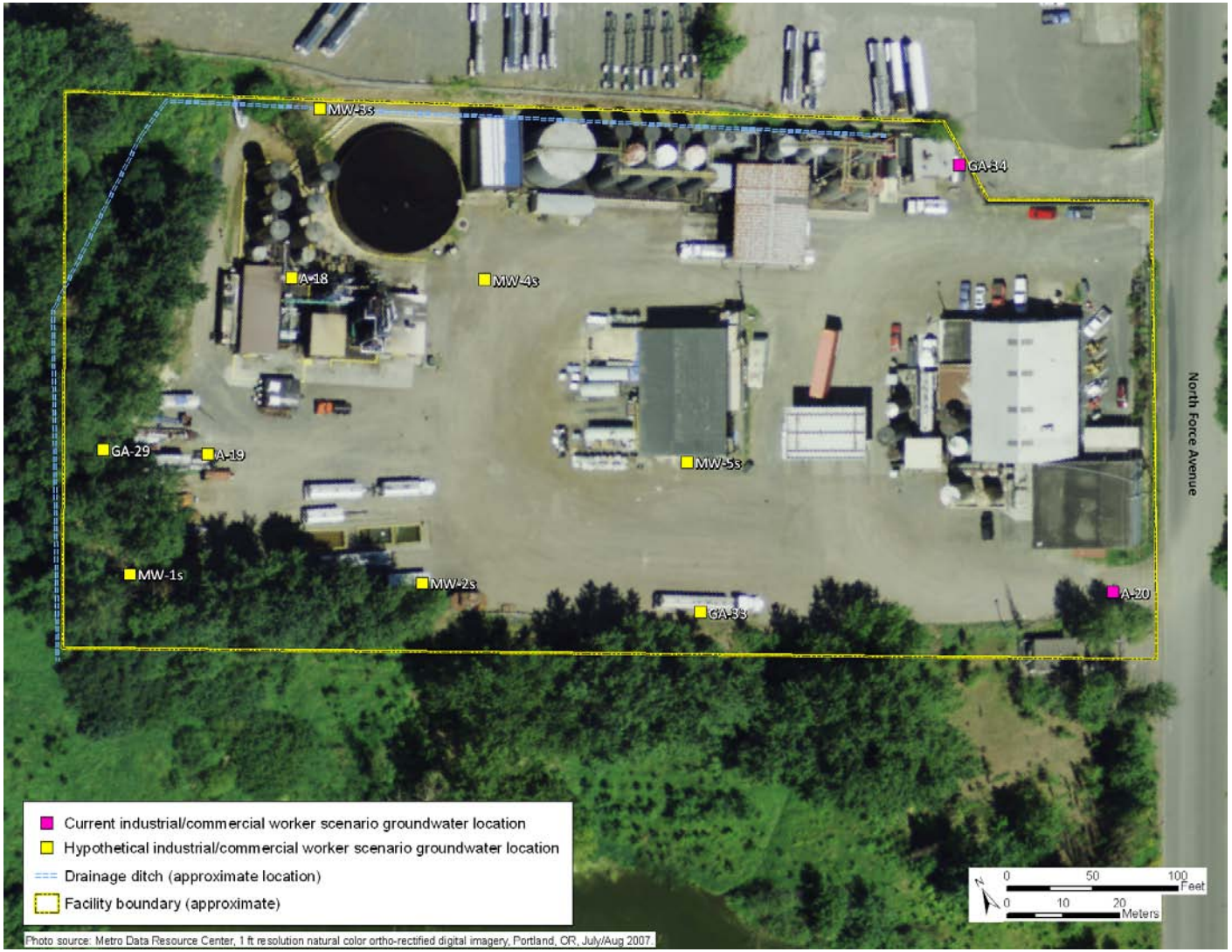


Figure 3-2. Sampling Locations for the Industrial/Commercial Worker Vapor Intrusion Scenarios

Exposure pathways that were considered incomplete or complete and insignificant for the industrial/commercial worker vapor intrusion scenario are listed below, along with rationale regarding the exclusion of these pathways:

- **Dermal soil contact or incidental soil ingestion:** Exposure to soil was considered to be low relative to the inhalation of volatiles.
- **Inhalation of airborne soil particulates:** Exposure via the inhalation of airborne soil particulates was considered to be low.
- **Dermal sediment contact or incidental sediment ingestion:** Workers at the Facility were not expected to come into contact with lake sediment.
- **Dermal water contact or incidental water ingestion:** Exposure to water was not expected based on the daily activities of workers at the Facility.
- **Drinking water ingestion:** Groundwater at the Facility is not a source of drinking water.
- **Fish ingestion:** Workers at the Facility were not expected to consume fish from Force Lake.

3.1.4 Force Lake Recreational User RME Scenario

Exposure to chemicals at the Study Area could occur through recreation-associated activities at Force Lake and in the surrounding wetlands, including bird watching, remote-control boating, or golf ball retrieval. In addition, some individuals may be exposed to lake sediment or water while fishing at Force Lake. The recreational user RME scenario was designed to estimate risks from the following exposure routes:

- **Lake water:** dermal contact and incidental ingestion
- **Lake sediment:** dermal contact and incidental ingestion
- **Wetland soils:** dermal contact and incidental ingestion

Risks from exposure to each of these media were calculated separately, and were then summed to calculate the risk to recreational users across exposure media.

In order to ensure that this scenario is protective, the total exposure duration of 30 years (EPA 1989) was assumed to start at age 0 to combine the most sensitive exposure period with adult exposure. To allow for the use of age-specific exposure parameters, exposure parameters for three separate age groups were used). The first age group was younger children (up to 6 years of age), the second age group was older children (7 to 16 years of age), and the third age group was adults (17 to 30 years of age). Integrated risks are presented across these age groups.

As discussed in the RI/FS Work Plan (Bridgewater et al. 2008b) and risk assessment scoping memorandum (Windward and Bridgewater 2008a), exposure to wetland soil was assessed using all surface wetland and

ditch soil samples; subsurface soil samples were not included because contact with these deeper soils is unlikely during recreational activities. Exposure to lake sediment was assessed using all surface sediment samples collected from Force Lake. As noted above for the wetland soil samples, contact with deeper lake sediment during recreational activities is unlikely. Additionally, the analysis of subsurface sediment samples during Phase 2 of the RI sampling found that chemical concentrations were low in subsurface sediment. Sediment samples collected from North Lake were not included in this HHRA (see Sections 2.3.1).

Exposure to surface water was assessed using all water samples collected from Force Lake; no water samples were collected from North Lake. This evaluation of risks associated with Force Lake surface water also provided an indication of the level of risks associated with stormwater from the Facility (i.e., low risks associated with exposure to Force Lake surface water would indicate that the concentrations in stormwater did not increase concentrations in lake water to levels that would result in risks greater than EPA's target risk range).

Exposure pathways that were considered incomplete or complete and insignificant for the Force Lake recreational user RME scenario are listed below, along with rationale regarding the exclusion of these pathways:

- **Inhalation of airborne soil particulates or inhalation of chemicals volatilized from soil:** Risks associated with inhalation were not assessed because of the low exposure potential and because risks from inhalation were expected to be insignificant compared to risks from dermal and incidental ingestion of soil.
- **Drinking water ingestion:** Groundwater and surface water at the Study Area are not sources of drinking water.
- **Inhalation of chemicals volatilized from water:** Risks associated with inhalation were not assessed because of the low exposure potential and because risks from inhalation were expected to be insignificant compared to risks from dermal and incidental ingestion.

Cumulative risks for the recreational user and Force Lake fish consumer scenarios are presented in Section 5.5.

3.1.5 Force Lake Fish Consumer RME Scenario

The Force Lake fish consumer scenario was evaluated in response to EPA comments on the risk assessment scoping memorandum (EPA 2008c; Windward and Bridgewater 2008b) to assess risks to humans if they were to consume fish from Force Lake. As with the Force Lake recreational user scenario, the total exposure duration of 30 years was assumed to start at age 0 to combine the most sensitive exposure period (0 to 6 years of age) with adult exposure. To allow for the use of age-specific exposure parameters, exposure parameters for three separate age groups were used as described in Section 3.1.4.

Based on the available information regarding the fish population present in Force Lake, the observed fishing frequency, and the availability of public access (see Section 3.3.3), the group most likely to be fishing at Force Lake would be recreational anglers. It is possible that ethnic populations or transient individuals may fish at Force Lake to supplement their diets. However, given the results of the 2009 fish survey, it is unlikely that individuals could rely solely on fish from Force Lake for their diet. Using conservative assumptions to assess risks for the Force Lake fish consumer RME scenario, anglers were assumed to visit the lake several times a year during the warmer months to fish. Based on the available information on the fish population present in the lake and the use of the lake by anglers (see Section 3.3.3), anglers were assumed to eat a total of 6 meals per year of fish collected from Force Lake.

Risks associated with fish consumption are assessed in Section 5.3.5 based on estimated fish tissue concentrations using biota-sediment accumulation factors (BSAFs) and all surface sediment data from Force Lake (see Attachment 2). In addition, because of the possibility that individuals could be exposed through multiple exposure scenarios, cumulative risks from the Force Lake fish consumer RME scenario and the Force Lake recreational user RME scenario are presented in Section 5.5.

Exposure pathways that were considered incomplete or complete and insignificant for the Force Lake recreational user RME scenario are listed below, along with rationale regarding the exclusion of these pathways:

- **Dermal contact with and incidental ingestion of soil:** The potential for exposure to soil during fishing was considered to be low (note that risks based on water exposure were assessed separately as discussed in Section 3.1.4; the cumulative risks are presented in Section 5.5).
- **Inhalation of airborne soil particulates or inhalation of chemicals volatilized from soil:** Risks associated with inhalation were not assessed because of the low exposure potential and because risks from inhalation were expected to be insignificant during fishing.
- **Dermal contact with and incidental ingestion of sediment:** The potential for exposure to sediment during fishing was considered to be low (note that risks based on sediment exposure were assessed separately as discussed in Section 3.1.4, the cumulative risks are presented in Section 5.5).
- **Dermal contact with and incidental ingestion of water:** The potential for exposure to water during fishing was considered to be low (note that risks based on water exposure were assessed separately as discussed in Section 3.1.4, the cumulative risks are presented in Section 5.5).
- **Drinking water ingestion:** Groundwater and surface water at the Study Area is not a source of drinking water.

- **Inhalation of chemicals volatilized from water:** Risks associated with inhalation were not assessed because of the low potential for exposure to volatile chemicals while fishing.

3.1.6 Selection of Exposure Scenarios for Quantification

EPA guidance (1989) states that "actions at Superfund sites should be based on an estimate of the RME expected to occur under both current and future land-use conditions."

Specific exposure assumptions were developed to quantify exposure pathways for the scenarios shown in Figure 3-1. A complete exposure pathway includes an exposure medium and exposure point; a potentially exposed population, including receptor age (i.e., adult vs. child); and an exposure route. Table 3-1 presents the exposure routes illustrated in the CSM and provides the rationale for the selection or exclusion of those pathways identified as either complete and significant or complete and insignificant. The exposure parameters for these scenarios are discussed in Section 3.3.

3.2 COPC Screening and Evaluation

Based on EPA guidance (1996a), a risk-based screening approach was used to develop a list of COPCs from the list of contaminants of interest (COIs) for detailed analysis in the baseline HHRA. A scenario-specific COPC list was developed based on the most appropriate screening levels for each scenario.

All chemicals analyzed in soil, sediment, or water were considered as COIs. Figure 3-3 presents the screening process used to identify the COPCs from the COI list. Screening was conducted separately for each media type relevant to each scenario using the regional screening levels (RSLs) discussed in Section 3.2.1.[6] The full results of the COPC screen are presented in Attachment 3.

[6] RSLs are concentrations associated with specific risk levels, behaviors, and exposure pathways that are used for screening purposes. More detail is provided in Section 3.2.1.

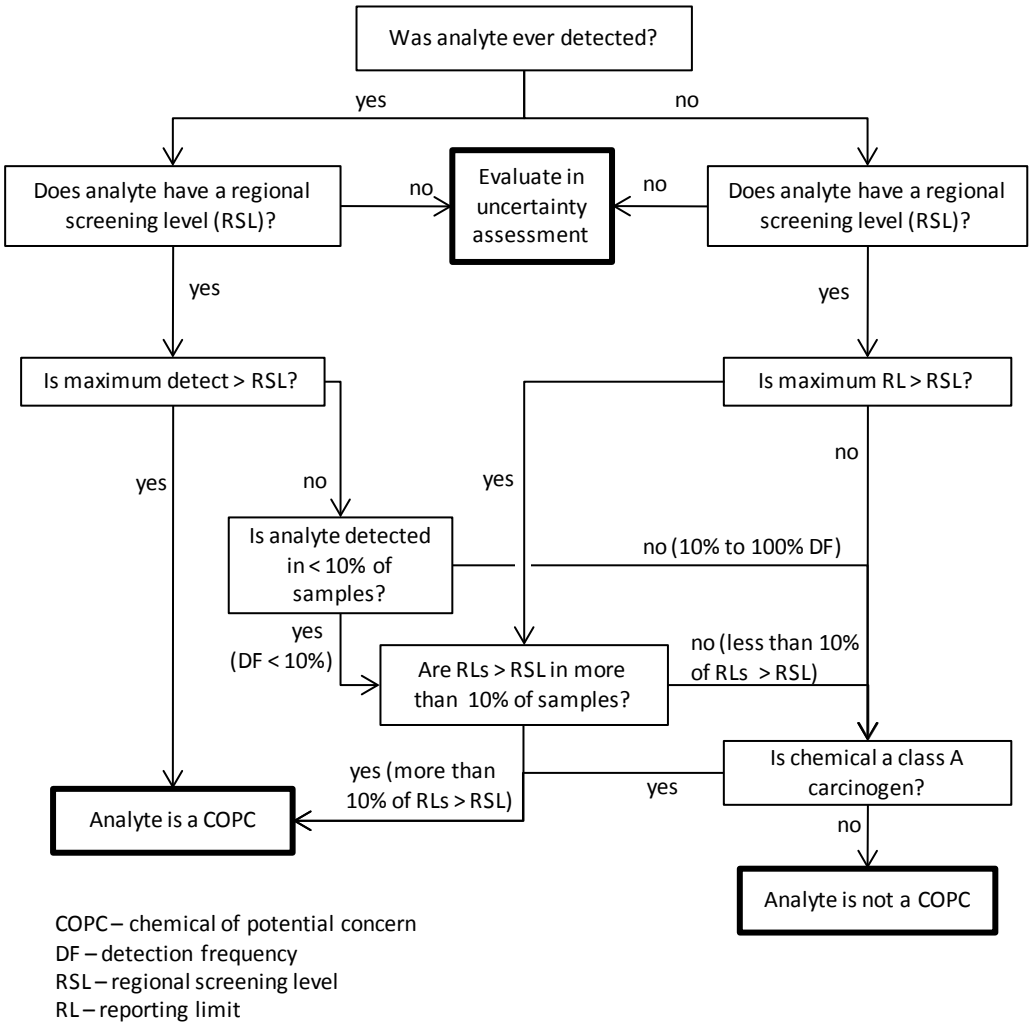


Figure 3-3. Human health COPC screening process

3.2.1 RSLs for COPC Screen or Screening-Level Assessment

RSLs were compiled on a media- and scenario-specific basis for the identification of COPCs as described above. For all media, criteria for non-carcinogenic endpoints were adjusted per EPA Region 10 risk assessment guidance (1996a) to be based on a hazard quotient (HQ) of 0.1 to account for cumulative risks from non-carcinogenic COIs.[7] RSLs for carcinogenic COIs were based on an excess cancer risk of 1×10^{-6} and were not modified as was necessary for the RSLs based on non-carcinogenic endpoints.

In addition, as discussed in Section 2.2.5, it should be noted that TPH were assessed as aliphatic fractions and as various PAH and VOC components in the COPC screen. Aliphatic TPH, assumed to be 85%

[7] EPA RSLs and DEQ thresholds for human health are based on a hazard quotient of 1 for all media.

of each TPH fraction based on ATSDR (1999), was compared with DEQ screening levels.

3.2.1.1 Exposure to Groundwater and Lake Surface Water

To determine COPCs based on exposure to groundwater and surface water, the following screening criteria are available, as shown in Attachment 3:

- EPA ambient water quality criteria (AWQC) for human water/ organism consumption and organism consumption (2009c)
- EPA RSLs for tap water (2009i)
- DEQ human health occupational risk-based concentrations (RBCs) for the following pathways: ingestion and inhalation from tap water, volatilization to outdoor air, and exposure to groundwater during excavation (2007b)
- EPA non-zero maximum contaminant level goals and maximum contaminant levels (2009b)
- DEQ groundwater RBCs for TPH fractions (2003)

The lowest value for each COI was selected from these four sources for use in COPC selection for the Force Lake recreational user RME scenario and the screening assessment for hypothetical future residents. For the industrial (construction/trenching) worker and future outdoor worker scenarios, the lowest value from the DEQ source was used because worker-specific values were available only from this source.

For the industrial/commercial worker vapor intrusion scenario, groundwater concentrations were compared with screening levels from EPA's OSWER Draft *Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils* (EPA 2002c).

3.2.1.2 Exposure to Soil (Industrial)

To identify COPCs based on exposure to Facility soils through industrial activities, surface and intermediate subsurface soil concentrations were compared to industrial soil screening levels for the two industrial worker scenarios, as stated in the RI/FS Work Plan (Bridgewater et al. 2008b). Samples were screened against the lowest value from the following criteria, as shown in Attachment 3:

- EPA RSLs for industrial exposure to soil (2009i)
- DEQ human health occupational, construction worker, or excavation worker RBCs for the following exposure routes: soil ingestion, dermal absorption, and inhalation; volatilization to outdoor air; and leaching to groundwater (2007b)
- DEQ soil RBCs for TPH fractions (2003)

3.2.1.3 Exposure to Soil (Residential or Recreational)

To determine COPCs based on residential or recreational exposure to soils, concentrations were compared to residential soil screening levels, as stated in the RI/FS Work Plan (Bridgewater et al. 2008b). It should be noted that for the Force Lake recreational user RME scenario, no recreation-specific screening criteria are available. As a health-protective approach, residential criteria were selected, even though the wetlands are designated as open space and are not zoned for industrial or residential use. Use of the residential criteria as a default results is highly conservative screening values because the exposure frequency for residential use is much higher than that for recreational use.

Samples were screened against the lowest value from the following criteria, as shown in Attachment 3:

- EPA RSLs for residential exposure to soil (2009i)
- DEQ RBCs for soil ingestion, dermal contact, and inhalation; residential exposure through volatilization to outdoor air; and residential exposure through leaching to groundwater (2007b)
- DEQ soil RBCs for TPH fractions (2003)

3.2.1.4 Exposure to Lake Sediment (Residential or Recreational)

To determine COPCs based on exposure to lake sediment, sediment data were screened against the same residential criteria used to screen soils. No sediment-specific criteria are available for assessing risks to human health. Like the wetlands, the lake is designated as open space and is part of the Pen 1 natural resource management planning area, and thus the use of these soil-based residential screening criteria as a default is highly conservative. As with wetland soil, the lowest value from the available criteria was used.

3.2.1.5 Fish Tissue Consumption

To determine COPCs based on fish tissue consumption, calculated fish tissue concentrations were screened against EPA Region 3 fish tissue screening levels (2009h), which are shown in Table 9 of Attachment 3. Methods for calculating chemical concentrations in fish tissue are described in Attachment 2.

3.2.2 Scenario-Specific COPCs

Using the process outlined in Figure 3-3 and the RSLs described in Section 3.2.1, scenario- and media-specific COPC lists were developed. Additional details regarding this selection process are provided in Attachment 3.

As noted in Figure 3-3, all known human carcinogens were retained as COPCs, even when concentrations were less than the applicable RSLs, as directed by EPA (2009a, 2010a). Known human carcinogens include arsenic, benzene, and vinyl chloride (EPA 2006c; accessed January

2010).[8] Tables 3-2 through 3-6 present the COPCs based on both detected and non-detected concentrations in the applicable media for each scenario. Those COPCs that screen in based only on their status as known human carcinogens are noted in the tables.

Table 3-2. COPCs for the Industrial (Construction/Trenching) Worker RME Scenario

Detected COPCs	Non-Detected COPCs
Facility Soil	
Metals	**Other SVOCs**
Arsenic	2,6-Dinitrotoluene
Cobalt	3,3'-Dichlorobenzidine
Copper	N-Nitroso-di-n-propylamine
Lead	**Pesticides**
PAHs	Dieldrin
Naphthalene	alpha-BHC
cPAH TEQ	Toxaphene
PCBs	**VOCs**
Total PCBs	1,2-Dibromo-3-chloropropane
Pesticides	1,2-Dibromoethane (EDB)
Total DDTs	1,2-Dichloroethane
VOCs	Bromodichloromethane
1,1-Dichloroethane	Bromomethane
1,2,4-Trimethylbenzene	Carbon tetrachloride
1,3,5-Trimethylbenzene	Chloroform
Benzene	
Chlorobenzene	
cis-1,2-Dichloroethene	
Dichloromethane	
Ethylbenzene	
trans-1,2-Dichloroethene	
Trichloroethene	
Vinyl chloride	
Total xylene	
TPH	
TPH-gasoline (aliphatic)	
Groundwater	
Metals	**PAHs**
Arsenic (total)[a]	cPAH TEQ
Lead (total)	**Other SVOCs**
Manganese (total)[a]	2,6-Dinitrotoluene
PAHs	3,3'-Dichlorobenzidine
Naphthalene	Hexachlorobenzene
Other SVOCs	Pentachlorophenol
1,4-Dichlorobenzene	**PCBs**
Pesticides	Total PCBs

[8] It should be noted that some forms of nickel (i.e., nickel refinery dust and nickel subsulfide) are considered Class A carcinogens, but these forms of nickel are related to nickel refineries and are not expected to be present at the Study Area. Nickel (soluble salts) was considered the most appropriate form of nickel for this HHRA.

Table 3-2. COPCs for the Industrial (Construction/Trenching) Worker RME Scenario

Detected COPCs	Non-Detected COPCs
Total DDTs	**Pesticides**
VOCs	Aldrin[b]
1,2,4-Trimethylbenzene	Dieldrin[b]
1,3,5-Trimethylbenzene	alpha-BHC
Benzene	Heptachlor
Chlorobenzene	Heptachlor epoxide
n-Propylbenzene	Toxaphene (filtered and unfiltered)
tert-Butyl methyl ether	**VOCs**
Vinyl chloride	1,2-Dibromoethane (EDB)
	1,2-Dichloroethane
	Bromodichloromethane
	Bromomethane
	Carbon tetrachloride
	Chloroform
	Trichloroethene

[a] Both the total and dissolved fraction were greater than the screening level. To be conservative, the total fraction was assessed in this HHRA because it is slightly higher than the dissolved fraction.

[b] Concentrations in both the filtered and unfiltered groundwater samples were greater than the RSL.

BHC – benzene hexachloride
COPC – contaminant of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
EDB – ethylene dibromide
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure
RSL – regional screening level
SVOC – semivolatile organic compound
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

Table 3-3. COPCs for the Future Outdoor Worker RME Scenario

Detected COPCs	Non-Detected COPCs
Facility Soil	
Metals	**Other SVOCs**
Arsenic	2,6-Dinitrotoluene
Cobalt	3,3'-Dichlorobenzidine
Copper	N-Nitroso-di-n-propylamine
Lead	**Pesticides**
PAHs	Aldrin
Naphthalene	Dieldrin
cPAH TEQ	alpha-BHC
PCBs	gamma-BHC
Total PCBs	Heptachlor epoxide
Pesticides	Toxaphene
Total DDTs	**VOCs**
VOCs	1,2-Dibromoethane (EDB)
1,1-Dichloroethane	
1,2,4-Trimethylbenzene	
1,3,5-Trimethylbenzene	
Benzene	
cis-1,2-Dichloroethene	
Dichloromethane	
Ethylbenzene	
trans-1,2-Dichloroethene	
Trichloroethene	
Vinyl chloride	
Total xylenes	
TPH	
TPH-gasoline (aliphatic)	

BHC – benzene hexachloride
COPC – contaminant of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
EDB – ethylene dibromide
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure
RSL – regional screening level
SVOC – semivolatile organic compound
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

Table 3-4. COPCs for the Industrial/Commercial Worker Vapor Intrusion Scenario

Detected COPCs[a]	Non-Detected COPCs[a]
VOCs	**Other SVOCs**
Benzene[b]	Hexachlorobutadiene
Vinyl chloride[b]	**VOCs**
	1,1-Dichloropropene
	1,2-Dibromoethane (EDB)
	Bromoform
	cis-1,3-Dichloropropene
	trans-1,3-Dichloropropene

[a] Per EPA (2002c) guidance, chemicals that have either molecular weights greater than 200 g/mole or have a Henry's Law constant less than 1×10^{-5} are not volatile by definition and thus are not evaluated for vapor intrusion risks.

[b] Maximum concentration is less than the RSL, but chemical is a COPC because it is a known human carcinogen.

COPC – contaminant of potential concern
EDB – ethylene dibromide
EPA – US Environmental Protection Agency
SVOC – semivolatile organic compound
VOC – volatile organic compound

Table 3-5. COPCs for the Force Lake Recreational User RME Scenario

Detected COPCs	Non-Detected COPCs	
Wetland Soil		
Metals Aluminum Antimony Arsenic Chromium Cobalt Copper Iron Lead Manganese Vanadium **PAHs** Naphthalene c PAH TEQ **PCBs** Total PCBs **Pesticides** Total DDTs **VOCs** Benzene Trichloroethene **TPH** TPH-gasoline (aliphatic) TPH-diesel (aliphatic)	**Metals** Thallium **Other SVOCs** 2,4-Dinitrophenol 2,4-Dinitrotoluene 2,6-Dinitrotoluene 3,3'-Dichlorobenzidine 4,6-Dinitro-o-cresol Atrazine bis(2-chloroethyl)ether N-Nitroso-di-n-propylamine Pentachlorophenol	**Pesticides** Aldrin Dieldrin alpha-BHC gamma-BHC Toxaphene **VOCs** 1,2-Dibromo-3-chloropropane 1,2-Dibromoethane (EDB) 1,2-Dichloroethane Bromodichloro methane Chloroform Vinyl chloride
Force Lake Sediment		
Metals Arsenic Chromium Cobalt Lead Vanadium **PAHs** cPAH TEQ **TPH** TPH-gasoline (aliphatic)	**Pesticides** alpha-BHC Dieldrin Toxaphene	**VOCs** 1,2-Dibromo-3-chloropropane 1,2-Dibromoethane (EDB) 1,2-Dichloroethane Benzene[a] Bromodichloro methane Chloroform Trichloroethene Vinyl chloride

Table 3-5. COPCs for the Force Lake Recreational User RME Scenario

Detected COPCs	Non-Detected COPCs	
Force Lake Surface Water		
Metals	**Metals**	**VOCs**
Arsenic (total)[b]	Cobalt (dissolved and total)	1,1,1,2-Tetrachloroethane
	PAHs	1,1,2,2-Tetrachloroethane
	cPAH TEQ	1,1,2-Trichloroethane
	Other SVOCs	1,2,3-Trichloropropane
	1,2,4-Trichlorobenzene	1,2-Dibromo-3-chloropropane
	1,4-Dichlorobenzene	1,2-Dibromoethane (EDB)
	Hexachlorobenzene	1,2-Dichloroethane
	PCBs	1,2-Dichloropropane
	Total PCBs	Benzene
	Pesticides	Bromodichloromethane
	Aldrin	Bromomethane
	Dieldrin	Carbon tetrachloride
	alpha-BHC	Chloroform
	beta-BHC	cis-1,3-Dichloropropene
	gamma-Chlordane	Dibromochloromethane
	Total chlordane	Tetrachloroethene
	Heptachlor	trans-1,3-Dichloropropene
	Heptachlor epoxide	Trichloroethene
	Toxaphene	Vinyl chloride

[a] Maximum concentration is less than the RSL, but chemical is a COPC because it is a known human carcinogen.

[b] Both the total and dissolved fraction were greater than the screening level. To be conservative, the total fraction was assessed in this HHRA because it is slightly higher than the dissolved fraction.

BHC – benzene hexachloride
COPC – contaminant of potential concern
cPAH – carcinogenic PAH
EDB – ethylene dibromide
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure
RSL – regional screening level
SVOC – semivolatile organic compound
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

Table 3-6. COPCs for the Force Lake Fish Consumer RME Scenario

Detected COPCs	Non-Detected COPCs
Metals	**Metals**
Arsenic	Antimony
Barium	Selenium
Cadmium	**Pesticides**
Cobalt	Aldrin
Copper	Dieldrin
Lead	alpha-BHC
Mercury	beta-BHC
Nickel	gamma-BHC
Vanadium	alpha-Chlordane
Zinc	Total chlordane
PCBs	Heptachlor
Total PCBs	Heptachlor epoxide
Pesticides	Toxaphene
Total DDTs	**VOCs**
	1,2,3-Trichloropropane
	1,2-Dibromo-3-chloropropane
	Benzene[a]
	Vinyl chloride

Note: COPCs for the Force Lake fish consumer scenario were determined based on calculated fish tissue concentrations using Force Lake sediment data and literature BSAFs (see Attachment 2).

[a] Maximum concentration is less than the RSL, but chemical is a COPC because it is a known human carcinogen.

BHC – benzene hexachloride
BSAF – biota-sediment accumulation factor
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
PCB – polychlorinated biphenyl
RSL – regional screening level
RME – reasonable maximum exposure
VOC – volatile organic compound

Based on this COPC screen, the risks for detected COPCs are presented in Section 5.0. The non-detected COPCs are discussed in the uncertainty analysis (Section 6.3.1). In addition, it should be noted that for scenarios that consider exposure to multiple exposure media (e.g., facility soil and groundwater for the future outdoor worker), the COPC lists for these scenarios were not necessarily the same. For example, in Table 3-2, copper is a COPC for the industrial (construction/trenching) worker scenario based on exposure to Facility soil, but it is not a COPC for groundwater. Thus, when risks from Facility soil and groundwater were summed for this scenario, only the risk from copper based on Facility soil was included because the copper risk from groundwater was assumed to be insignificant since it was not identified as a COPC for this pathway. Table 3-7 summarizes the numbers of COPCs that were identified for each scenario.

Table 3-7. Summary of COPCs by Scenario

Scenario	Table	Detected COPCs	Non-Detected COPCs
Industrial (Construction/Trenching) Worker RME Scenario			
Facility soil	Table 3-2	21	13
Groundwater		14	19
Future Outdoor Worker RME Scenario			
Facility soil	Table 3-3	20	10
Industrial/Commercial Worker Vapor Intrusion Scenario			
Groundwater	Table 3-4	2[a]	7
Force Lake Recreational User RME Scenario			
Wetland soil	Table 3-5	16	21
Lake sediment		6	11
Lake surface water		1	34
Force Lake Fish Consumer RME Scenario			
Fish tissue	Table 3-6	12	15

[a] Benzene and vinyl chloride, the only detected COPCs, were identified as COPCs based only on their classification as a known human carcinogens not because concentrations were greater than screening levels.

COPC – contaminant of potential concern

RME – reasonable maximum exposure

3.3 Selection of Exposure Parameters and Calculation of Chronic Daily Intake

This section presents the equations used to calculate the CDI rates (Section 3.3.1), the scenario-specific parameters needed to calculate the CDIs (Section 3.3.2), the method used to calculate COPC in fish tissue (Section 3.3.3), the exposure point concentrations (Section 3.3.4), and the methods used to calculate exposure to lead (Section 3.3.5).

3.3.1 Chronic Daily Intake Rate Calculations

COPC exposure is expressed as the CDI rate. The CDI is calculated based on an EPC and site-specific exposure parameters.

This section presents the equations that were used to calculate the CDI for the following exposure routes:

- Incidental ingestion of soil or sediment (Equation 3-1)
- Incidental ingestion of water (e.g., during swimming or wading) (Equation 3-2)
- Dermal absorption from soil or sediment (Equation 3-3)
- Dermal absorption from water (Equation 3-4), including calculations of the absorbed dose per event (Equations 3-5 to 3-7)

- Inhalation of COPCs associated with airborne soil particulates (Equation 3-8), including the calculation of respirable soil particulates in the air (Equation 3-9)
- Inhalation of COPCs associated with vapors

Incidental ingestion of soil or sediment:

$$CDI_{oral} = \frac{(EPC \times IR \times FI \times EF \times ED \times CF1)}{(BW \times AT)}$$ **Equation 3-1**

Where:

CDI	mg/kg-day	COPC-specific chronic daily intake rate
EPC	mg/kg	COPC-specific exposure point concentration
IR	g/day	ingestion rate
FI	unitless	fractional intake from site media
EF	days/yr	exposure frequency
ED	years	exposure duration
CF1	kg/g	conversion factor
BW	kg	body weight
AT	days	averaging time (cancer or non-cancer)

Incidental ingestion of water:

$$CDI_{oral} = \frac{(EPC \times CR \times FI \times ET \times EF \times ED)}{(BW \times AT)}$$ **Equation 3-2**

Where:

CDI	mg/kg-day	COPC-specific chronic daily intake rate
EPC	mg/L	COPC-specific exposure point concentration
CR	L/hour	contact rate
FI	unitless	fractional intake from site media
ET	hours/day	event time
EF	days/yr	exposure frequency
ED	years	exposure duration
BW	kg	body weight
AT	days	averaging time (cancer or non-cancer)

Dermal absorption from soil or sediment:

$$CDI_{dermal-soil} = \frac{(EPC \times ABS \times SA \times AF \times FI \times EF \times ED \times CF2)}{(BW \times AT)}$$ **Equation 3-3**

Where:

CDI	mg/kg-day	COPC-specific chronic daily intake rate
EPC	mg/kg	COPC-specific exposure point concentration
ABS	unitless	dermal absorption fraction (EPA 2004)
SA	cm^2	exposed skin surface area
AF	mg/cm^2	sediment or soil to skin adherence factor by event (EPA 1997)
FI	unitless	fractional intake from site media
EF	days/yr	exposure frequency
ED	years	exposure duration
CF2	kg/mg	conversion factor

BW	kg	body weight
AT	days	averaging time (cancer or non-cancer)

Dermal absorption from water:

$$CDI_{dermal-water} = \frac{(DA_{event} \times SA \times FI \times EV \times EF \times ED)}{(BW \times AT)}$$ **Equation 3-4**

Where:

CDI	mg/kg-day	COPC-specific chronic daily intake rate
DA_{event}	mg/cm^2-event	COPC-specific absorbed dose per event
SA	cm^2	exposed skin surface area
FI	unitless	fractional intake from site media
EV	events/day	event frequency
EF	days/yr	exposure frequency
ED	years	exposure duration
BW	kg	body weight
AT	days	averaging time (cancer or non-cancer)

Calculation of the absorbed dose per event (EPA 2004):

For organic COPCs when ET $\leq$ t*:

$$DA_{event} = 2 \times FI \times K_p \times EPC \times \sqrt{\frac{6 \times T \times ET}{\pi}}$$ **Equation 3-5**

For organic COPCs when ET > t*:

$$DA_{event} = FI \times K_p \times EPC \times \left[\frac{ET}{1+B} + 2 \times T \times \left(\frac{1+3B+3B^2}{(1+B)^2} \right) \right]$$ **Equation 3-6**

For inorganic COPCs:

$$DA_{event} = K_p \times EPC \times ET$$ **Equation 3-7**

Where:

DA_{event}	mg/cm^2-event	COPC-specific absorbed dose per event
FI	unitless	fractional intake from site media
Kp	cm/hr	COPC-specific dermal permeability coefficient of compound in water
EPC	mg/cm^3	COPC-specific exposure point concentration
T	hrs/event	COPC-specific lag time per event
ET	hrs	event time
t*	hrs	COPC-specific time to reach steady state
B	unitless	COPC-specific dimensionless ratio of the permeability coefficient across the viable epidermis (ve)

The COPC-specific values for these parameters along with the CDI calculations are presented in Attachment 5.

Inhalation of airborne soil particulates and inhalation of COPCs volatilized from soil or water:

As discussed in EPA's supplemental guidance for inhalation risk assessment (EPA 2009j), risks associated with the inhalation of COPCs should be assessed using Equation 3-8, not the generic equation presented in Part A of Risk Assessment Guidance for Superfund (RAGS). Per EPA (2009j), the calculated exposure concentration is time-weighted over the duration of exposure for the scenario and incorporates information regarding activity patterns at the site.

$$EC = \frac{(CA \times FI \times ET \times EF \times ED)}{(AT \times CF3)}$$ **Equation 3-8**

Where:

EC	µg/m^3	time-weighted COPC-specific exposure concentration
$CA_{particulates}$	µg/m^3	COPC-specific concentration of respirable particulates in the air
FI	unitless	fractional intake from site media
ET	hrs/day	event time
EF	days/yr	exposure frequency
ED	years	exposure duration
AT	days	averaging time (cancer or non-cancer)
CF3	hrs/day	conversion factor

Calculation of COPC concentrations associated with soil particulates:

The COPC-specific concentration of respirable soil particulates in the air is calculated from the COPC concentration in soil based on DEQ guidance (1998) as follows:

$$CA_{particle} = \frac{C_{soil}}{PEF} \times F_s \times CF4$$ **Equation 3-9**

Where:

$CA_{particulates}$	µg/m^3	COPC-specific concentration of respirable particulates in the air
C_{soil}	mg/kg dw	COPC concentration in soil
PEF	m^3/kg	particulate emission factor
F_s	unitless	fraction of soil contaminated
CF4	µg/mg	conversion factor

A default particulate emission factor (PEF) of 1.32×10^9 m^3/kg was used, as recommended by EPA (1996b). This PEF was derived using default values for a rapid assessment procedure applicable to a typical hazardous waste site, where the surface contamination provides the potential for a relatively constant emission over an extended period of time (e.g., years). This PEF represents an annual average emission rate based on wind erosion and should be used with chronic health criteria.

Calculation of COPC concentrations associated with airborne vapors:

COPC concentrations in outdoor air were modeled from soil and groundwater concentrations using a series of equations based on equilibrium partitioning. The use of an equilibrium partitioning model to calculate vapor concentrations represents a significant source of uncertainty. Because of the relatively large number of equations and variables that were used to calculate these concentrations, a detailed discussion of the methods is presented in Attachment 4.

3.3.2 Exposure Parameters

The exposure parameters needed to calculate the CDI rates are presented in this section. The tables that present the parameters for each scenario are listed below:

- **Industrial (construction/trenching) worker RME scenario:** Tables 3-8 to 3-11
- **Future outdoor worker RME scenario:** Tables 3-12 to 3-14
- **Industrial/commercial worker vapor intrusion scenario:** No scenario-specific parameters were needed for this scenario because risks for these COPCs were calculated using the default exposure parameters that were used by EPA (2002c) to calculate the vapor intrusion screening levels, as discussed in Section 5.3.3.
- **Force Lake recreational user RME scenario:** Tables 3-15 to 3-18
- **Force Lake fish consumer RME scenario:** Table 3-19

Scenario-specific parameters were not developed for the screening assessment for hypothetical future residents because default exposure parameters were used to evaluate risks associated with this scenario (Attachment 1).

Table 3-8. Daily Intake Calculations – Incidental Ingestion of Soil During Industrial (Construction/Trenching) Work

Scenario timeframe: Current/future

Exposure media: Facility soil

Exposure route: Ingestion (incidental)

Intake equation: CDI (mg/kg dw) = EPC × IRs × FI × EF × ED × CF × 1/BW × 1/AT

Parameter Code	Parameter Description	Value	Rationale and Reference
EPC	exposure point concentration (mg/kg dw)	na	COPC specific
IR-s	incidental soil ingestion rate (g/day)	0.33	based on a construction worker (EPA 2002d)
FI	fractional intake from site	1	assumes 100% exposure to site
EF	exposure frequency (d/yr)	250	based on a construction worker (DEQ 2003)
ED	exposure duration (yrs)	1	
CF	conversion factor	0.001	conversion from kg to g
BW	body weight (kg)	70	default value (EPA 1989)
AT_c	cancer averaging time (days)	25,550	default value (EPA 1989)
AT_nc	non-cancer averaging time (days)	365	EPA (1989)

CDI – chronic daily intake
DEQ – Oregon Department of Environmental Quality
dw – dry weight
EPA – US Environmental Protection Agency
na – not applicable

Table 3-9. Daily Intake Calculations – Dermal Contact with Soil During Industrial (Construction/Trenching) Work

Scenario timeframe: Current/future

Exposure media: Facility soil

Exposure route: Ingestion (incidental)

Intake equation: CDI (mg/kg dw) = EPC × ABS × AF × SA × FI × EF × ED × CF × 1/BW × 1/AT

Parameter Code	Parameter Description	Value	Rationale and Reference
EPC	exposure point concentration (mg/kg dw)	na	COPC specific
ABS	dermal absorption fraction	na	COPC specific
AF	adherence factor by event (mg/cm^2)	1	EPA (2004)
SA	exposed skin surface area (cm^2)	3,300	based on an excavation/construction worker (DEQ 2003; EPA 2002d)
FI	fractional intake from site	1	assumes 100% exposure to site
EF	exposure frequency (d/yr)	250	based on a construction worker (DEQ 2003)
ED	exposure duration (yrs)	1	
CF	conversion factor	0.000001	conversion from mg to kg
BW	body weight (kg)	70	default value (EPA 1989)
AT_c	cancer averaging time (days)	25,550	default value (EPA 1989)
AT_nc	non-cancer averaging time (days)	365	EPA (1989); equal to ED × 365 days

CDI – chronic daily intake
DEQ – Oregon Department of Environmental Quality
dw – dry weight
EPA – US Environmental Protection Agency
na – not applicable

Table 3-10. Daily Intake Calculations – Dermal Contact with Groundwater During Industrial (Construction/Trenching) Work

Scenario time frame: Current/future

Exposure media: Groundwater

Exposure route: Dermal

Intake equation: CDI (mg/kg dw) = DA_{event} × SA × EF × EV × ED × 1/BW × 1/AT

Parameter Code	Parameter Description	Value	Rationale and Reference
DA_{event}	absorbed dose per event	na	COPC specific (see Equations 3-5 to 3-7)
SA	exposed skin surface area (cm^2)	3,300	based on an excavation/construction worker (DEQ 2003; EPA 2002d)
EF	exposure frequency (d/yr)	250	based on a construction worker (DEQ 2003)
EV	event frequency (events/day)	1	
ED	exposure duration (yrs)	1	
BW	body weight (kg)	70	default value (EPA 1989)
AT_c	cancer averaging time (days)	25,550	EPA (1989)
AT_nc	non-cancer averaging time (days)	365	EPA (1989); equal to ED × 365 days
FI[a]	fractional intake from site	1	assumes 100% exposure to site
ET[a]	exposure time (hrs/day)	2	based on a construction worker (DEQ 2003)

[a] These parameters are not listed in the CDI equation shown in this table, but are scenario-specific parameters needed to calculate the absorbed dose per event (DA_{event}).

CDI – chronic daily intake

DEQ – Oregon Department of Environmental Quality

dw – dry weight

EPA – US Environmental Protection Agency

na – not applicable

Table 3-11. Daily Intake Calculations – Inhalation of COPCs from Soil/Water During Industrial (Construction/Trenching) Work

Scenario timeframe: Current/future

Exposure media: Facility soil and groundwater

Exposure route: Inhalation of volatiles (from soil and groundwater) and particulates (from soil)

Volatilization intake equation: EC_{vapor} (µg/m^3) = (CA_{vapor} × ET × EF × ED)/AT

Particulate intake equation: $EC_{particulate}$ (µg/m^3) = $CA_{particulates}$ × FI × ET × EF × ED × (1/AT) × (1/CF)

Parameter Code	Parameter Description	Value	Rationale and Reference
General			
EF	exposure frequency (d/yr)	250	based on a construction worker (DEQ 2003)
ED	exposure duration (yrs)	1	
ET	exposure time (hrs/day)	2	based on a construction worker (DEQ 2003)
BW	body weight (kg)	70	default value (EPA 1989)
FI	fractional intake from site	1	assumes 100% exposure to site
AT_c	cancer averaging time (days)	25,550	default value (EPA 1989)
AT_nc	non-cancer averaging time (days)	365	EPA (1989)
CF	conversion factor	24	conversion from days to hours
Volatile Inhalation (from soil and groundwater)			
CA_{vapor}	vapor exposure concentration in the air (µg/m^3)	na	COPC-specific exposure concentration (see Attachment 4 for calculation details)
Particulate Inhalation (from soil)			
$CA_{particulates}$	particulate exposure concentration in the air (µg/m^3)	na	COPC-specific exposure concentration calculated using Equation 3-9
C_{soil}	concentration in soil (mg/kg dw)	na	COPC-specific soil concentration
PEF[a]	particulate emission factor (m^3/kg)	1.32×10^9	default value (EPA 1996b)
F_s[a]	fraction of soil contaminated	1	default value

[a] These parameters are not listed in the CDI equation shown in this table but are scenario-specific parameters needed to calculate the COPC concentration of respirable particulates in the air (Equation 3-9).

CDI – chronic daily intake
COPC – contaminant of potential concern
DEQ – Oregon Department of Environmental Quality
dw – dry weight
EC – exposure concentration
EPA – US Environmental Protection Agency
na – not applicable

Table 3-12. Daily Intake Calculations – Incidental Ingestion of Soil During Future Outdoor Work

Scenario timeframe: Current/future

Exposure media: Facility soil

Exposure route: Ingestion (incidental)

Intake equation: CDI (mg/kg dw) = EPC × IR-s × FI × EF × ED × CF × 1/BW × 1/AT

Parameter Code	Parameter Description	Value	Rationale and Reference
EPC	exposure point concentration (mg/kg dw)	na	COPC specific
IR-s	incidental soil ingestion rate (g/day)	0.1	based on an occupational worker (DEQ 2003) or outdoor worker (EPA 2002d)
FI	fractional intake from site	1	assumes 100% exposure to site
EF	exposure frequency (d/yr)	250	based on an occupational worker (DEQ 2003) or outdoor worker (EPA 2002d)
ED	exposure duration (yrs)	25	
CF	conversion factor	0.001	conversion from kg to g
BW	body weight (kg)	70	default value (EPA 1989)
AT_c	cancer averaging time (days)	25,550	default value (EPA 1989)
AT_nc	non-cancer averaging time (days)	9,125	EPA (1989)

CDI – chronic daily intake
DEQ – Oregon Department of Environmental Quality
dw – dry weight
EPA – US Environmental Protection Agency
na – not applicable

Table 3-13 Daily Intake Calculations – Dermal Contact with Soil During Future Outdoor Work

Scenario timeframe: Current/future

Exposure media: Facility soil

Exposure route: Ingestion (incidental)

Intake equation: CDI (mg/kg dw) = EPC × ABS × AF × SA × FI × EF × ED × CF × 1/BW × 1/AT

Parameter Code	Parameter Description	Value	Rationale and Reference
EPC	exposure point concentration (mg/kg dw)	na	COPC specific
ABS	dermal absorption fraction	na	COPC specific
AF	adherence factor by event (mg/cm^2)	0.1	based on an occupational worker (DEQ 2003) or outdoor worker (EPA 2002d)
SA	exposed skin surface area (cm^2)	3,300	
FI	fractional intake from site	1	assumes 100% exposure to site
EF	exposure frequency (d/yr)	250	based on an occupational worker (DEQ 2003) or outdoor worker (EPA 2002d)
ED	exposure duration (yrs)	25	
CF	conversion factor	0.000001	conversion from mg to kg
BW	body weight (kg)	70	default value (EPA 1989)
AT_c	cancer averaging time (days)	25,550	default value (EPA 1989)
AT_nc	non-cancer averaging time (days)	9,125	EPA (1989)

CDI – chronic daily intake
DEQ – Oregon Department of Environmental Quality
dw – dry weight
EPA – US Environmental Protection Agency
na – not applicable

Table 3-14. Daily Intake Calculations – Inhalation of COPCs from Soil During Future Outdoor Work

Scenario timeframe: Current/future

Exposure media: Facility soil

Exposure route: Inhalation of volatiles (from soil) and particulates (from soil)

Volatilization intake equation: EC_{vapor} (µg/m^3) = (CA_{vapor} × ET × EF × ED)/AT

Particulate intake equation: $EC_{particulate}$ (µg/m^3) = $CA_{particulate}$ × FI × ET × EF × ED × (1/AT) × (1/CF)

Parameter Code	Parameter Description	Value	Rationale and Reference
General			
EF	exposure frequency (d/yr)	250	based on an occupational worker (DEQ 2003) or outdoor worker (EPA 2002d)
ED	exposure duration (yrs)	25	
ET	exposure time (hrs/day)	8	assumes an 8 hour work day
BW	body weight (kg)	70	default value (EPA 1989)
FI	fractional intake from site	1	assumes 100% exposure to site
AT_c	cancer averaging time (days)	25,550	default value (EPA 1989)
AT_nc	non-cancer averaging time (days)	365	EPA (1989)
CF	conversion factor	24	conversion from days to hours
Volatile Inhalation			
CA_{vapor}	vapor exposure concentration in the air (µg/m^3)	na	COPC-specific exposure concentration (see Attachment 4 for calculation details)
Particulate Inhalation			
$CA_{particulate}$	particulate exposure concentration in the air (µg/m^3)	na	COPC-specific exposure concentration calculated using Equation 3-9
C_{soil}	concentration in soil (mg/kg dw)	na	COPC-specific soil concentration
PEF[a]	particulate emission factor (m^3/kg)	1.32×10^9	default value (EPA 1996b)
F_s[a]	fraction of soil contaminated	1	default value

[a] These parameters are not listed in the CDI equation shown in this table but are scenario-specific parameters needed to calculate the COPC concentration of respirable particulates in the air (Equation 3-9).

CDI – chronic daily intake

COPC – contaminant of potential concern

DEQ – Oregon Department of Environmental Quality

dw – dry weight

EC – exposure concentration

EPA – US Environmental Protection Agency

na – not applicable

Table 3-15. Daily Intake Calculations – Incidental Ingestion of Soil or Sediment During Force Lake Recreation

Scenario timeframe: Current/future

Exposure media: Lake sediment or wetland soil

Exposure route: Ingestion (incidental)

Intake equation: CDI (mg/kg dw) = EPC × IRs × FI × EF × ED × CF × 1/BW × 1/AT

Parameter Code	Parameter Description	Value	Rationale and Reference
General			
EPC	exposure point concentration	na	COPC specific
FI	fractional intake from site	1	assumes 100% exposure to site
EF	exposure frequency (d/yr)	22	based on the assumption that individuals visit the Study Area once per week during the summer (13 weeks) and once per month during the rest of the year (9 months) (Note that EPA (2008b) guidance recommends using site-specific values, which are not available for the Study Area.)
ED	total exposure duration (yrs)	30	EPA (1989)
CF	conversion factor	0.001	conversion from kg to g
AT_c	cancer averaging time (days)	25,550	EPA (1989)
AT_nc	non-cancer averaging time (days)	ED × 365	EPA (1989); equal to ED × 365 days
Adult (aged 17 to 30)			
IR-s_a	incidental ingestion rate (g/day)	0.1	based on an occupational worker (DEQ 2003) or outdoor worker (EPA 2002d)
ED_a	exposure duration (yrs)	14	EPA (1989); 30 yrs minus child exposure durations
BW_a	body weight (kg)	70	default value (EPA 1989)
Older Child (aged 7 to 16)			
IR-s_co	incidental ingestion rate (g/day)	0.2	EPA (1997)
ED_co	exposure duration (yrs)	10	EPA (1991)
BW_co	body weight (kg)	44.3	(EPA 2008b, Table ES-1)
Young Child (aged 0 to 6)			
IR-s_c	incidental ingestion rate (g/day)	0.2	EPA (1997)
ED_c	exposure duration (yrs)	6[a]	EPA (1991)
BW_c	body weight (kg)	variable by age[b]	EPA (2008b)

[a] The total exposure duration is 6 years, but exposure is calculated in 1-year increments by age class (< 1, 1 to 2, 2 to 3, 3 to 4, 4 to 5, and 5 to 6 years). For incidental ingestion, Equation 3-1 was modified as follows to better capture the different exposure by age group:

$$CDI = \frac{EPC \times IR \times FI \times EF \times CF}{AT} \times \left(\frac{ED_1}{BW_1} + \frac{ED_2}{BW_2} + \frac{ED_3}{BW_3} + \frac{ED_4}{BW_4} + \frac{ED_5}{BW_5} + \frac{ED_6}{BW_6} \right)$$

[b] Different body weights were used for each 1-year age class to reflect the increasing body weight during this age range. Average weights for boys and girls are as follows (EPA 2008b):

Age Class	BW (kg)	Age Class	BW (kg)
< 1	9.1	3 – 4	15.3
1 – 2	11.3	4 – 5	17.4
2 – 3	13.3	5 – 6	19.7

CDI – chronic daily intake
dw – dry weight
EPA – US Environmental Protection Agency
na – not applicable

Table 3-16. Daily Intake Calculations – Dermal Contact with Soil or Sediment During Force Lake Recreation

Scenario timeframe: Current/future

Exposure media: Lake sediment or wetland soil

Exposure route: Dermal

Intake equation: CDI (mg/kg dw) = EPC × ABS × AF × SA × FI × EF × ED × CF × 1/BW × 1/AT

Parameter Code	Parameter Description	Value	Rationale and Reference
General			
EPC	exposure point concentration	na	COPC specific
ABS	dermal absorption fraction	na	COPC specific
AF	adherence factor by event (mg/cm^2)	0.2	EPA (2004)
FI	fractional intake from site	1	assumes 100% exposure to site
EF	exposure frequency (d/yr)	22	based on the assumption that individuals visit the Study Area once per week during the summer (13 weeks) and once per month during the rest of the year (9 months) (Note that EPA guidance (2008b) recommends using site-specific values, which are not available for the Study Area.)
ED	total exposure duration (yrs)	30	EPA (1989)
CF	conversion factor	0.000001	conversion from mg to kg
AT_c	cancer averaging time (days)	25,550	EPA (1989)
AT_nc	non-cancer averaging time (days)	ED × 365	EPA (1989); equal to ED × 365 days
Adult (aged 17 to 30)			
SA_a	exposed skin surface area (cm^2)	5,800	95th percentile for outdoor activity (EPA 1997; Table 6-16)
ED_a	exposure duration (yrs)	14	EPA (1989); 30 yrs minus child exposure durations
BW_a	body weight (kg)	70	default value (EPA 1989)
Older Child (aged 7 to 16)			
SA_co	exposed skin surface area (cm^2)	4,700	(EPA 2008b, Table 7-1), assuming 35% of the total surface area (EPA 1992a)
ED_co	exposure duration (yrs)	10	EPA (1991)
BW_co	body weight (kg)	44.3	(EPA 2008b, Table ES-1)
Young Child (aged 0 to 6)			
SA_c	exposed skin surface area (cm^2)	variable by age[c]	EPA (1997)
ED_c	exposure duration (yrs)	6[a]	EPA (1991)
BW_c	body weight (kg)	variable by age[b]	EPA (2008b)

[a] The total exposure duration was 6 years, but exposure was calculated in 1-year increments by age class (< 1, 1 to 2, 2 to 3, 3 to 4, 4 to 5, and 5 to 6 years). For dermal absorption, Equation 3-3 was modified as follows to better capture the different exposure by age group:

$$CDI = \frac{EPC \times ABS \times FI \times EF \times CF}{AT} \times \left(\frac{ED_1 \times SA_1}{BW_1} + \frac{SA_2 \times ED_2}{BW_2} + \frac{SA_3 \times ED_3}{BW_3} + \frac{SA_3 \times ED_4}{BW_4} + \frac{SA_5 \times ED_5}{BW_5} + \frac{SA_6 \times ED_6}{BW_6} \right)$$

[b] Different body weights and surface areas were used for each 1-year age class to reflect the increasing body weight during this age range. Average weights for boys and girls are as follows (EPA 2008b):

Age Class	BW (kg)	Age Class	BW (kg)
< 1	9.1	3 – 4	15.3
1 – 2	11.3	4 – 5	17.4
2 – 3	13.3	5 – 6	19.7

[c] Skin surface area for children varies by age class. For the purpose of this scenario, children were assumed to be wearing a short-sleeve shirt, short pants, and no shoes (corresponding to approximately 35% of the total surface area) (EPA 1992a). Values shown are this fraction of the 50th percentile of surface areas for boys and girls in the following age classes (EPA 2008b):

Age Class	SA (cm^2)	Age Class	SA (cm^2)
< 1	1,330	3 – 4	2,298
1 – 2	1,750	4 – 5	2,515
2 – 3	2,069	5 – 6	2,751

CDI – chronic daily intake

dw – dry weight

EPA – US Environmental Protection Agency

na – not applicable

Table 3-17. Daily Intake Calculations – Incidental Ingestion of Surface Water During Force Lake Recreation

Scenario timeframe: Current/future

Exposure media: Lake surface water

Exposure route: Ingestion (incidental)

Intake equation: CDI (mg/kg dw) = EPC × CR × ET × FI × EF × ED × CF × 1/BW × 1/AT

Parameter Code	Parameter Description	Value	Rationale and Reference
General			
EPC	exposure point concentration	na	COPC specific
CR	contact rate (L/hr)	0.05	default value (EPA 1989)
FI	fractional intake from site	1	assumes 100% exposure to site
EF	exposure frequency (d/yr)	22	based on the assumption that individuals visit the Study Area once per week during the summer (13 weeks) and once per month during the rest of the year (9 months) (Note that EPA guidance (2008b) recommends using site-specific values, which are not available for the Study Area.)
ED	total exposure duration (yrs)	30	EPA (1989)
AT_c	cancer averaging time (days)	25,550	EPA (1989)
AT_nc	non-cancer averaging time (days)	ED × 365	EPA (1989); equal to ED × 365 days
Adult (aged 17 to 30)			
ET_a	exposure time (hrs/day)	3.3	average time people spend outdoors at a park (EPA 1997; Table 5-109)
ED_a	exposure duration (yrs)	14	EPA (1989); 30 yrs minus child exposure durations
BW_a	body weight (kg)	70	default value (EPA 1989)
Older Child (aged 7 to 16)			
ET_co	exposure time (hrs/day)	2.35	average time children spend outdoors at a park (EPA 2008b, Table 16-37)
ED_co	exposure duration (yrs)	10	EPA (1991)
BW_co	body weight (kg)	44.3	(EPA 2008b, Table ES-1)
Young Child (aged 0 to 6)			
ET_c	exposure time (hrs/day)	1.7	average time children spend outdoors at a park (EPA 2008b, Table 16-37)
ED_c	exposure duration (yrs)	6[a]	EPA (1991)
BW_c	body weight (kg)	variable by age[b]	EPA (2008b)

[a] The total exposure duration was 6 years, but exposure was calculated in 1-year increments by age class (< 1, 1 to 2, 2 to 3, 3 to 4, 4 to 5, and 5 to 6 years). For incidental ingestion, Equation 3-1 was modified as follows to better capture the different exposure by age group:

$$CDI = \frac{EPC \times IR \times FI \times EF \times CF}{AT} \times \left(\frac{ED_1}{BW_1} + \frac{ED_2}{BW_2} + \frac{ED_3}{BW_3} + \frac{ED_4}{BW_4} + \frac{ED_5}{BW_5} + \frac{ED_6}{BW_6} \right)$$

[b] Different body weights were used for each 1-year age class to reflect the increasing body weight during this age range. Average weights for boys and girls were as follows (EPA 2008b):

Age Class	BW (kg)	Age Class	BW (kg)
< 1	9.1	3 – 4	15.3
1 – 2	11.3	4 – 5	17.4
2 – 3	13.3	5 – 6	19.7

CDI – chronic daily intake

dw – dry weight

EPA – US Environmental Protection Agency

na – not applicable

Table 3-18. Daily Intake Calculations – Dermal Contact with Surface Water During Force Lake Recreation

Scenario time frame: Current/future

Exposure media: Lake surface water

Exposure route: Dermal

Intake equation: CDI (mg/kg dw) = DA_{event} × SA × EF × EV × ED × 1/BW × 1/AT

Parameter Code	Parameter Description	Value	Rationale and Reference
General			
DA_{event}	absorbed dose per event	na	COPC specific (see Equations 3-5 to 3-7)
EF	exposure frequency (d/yr)	22	based on the assumption that individuals visit the Study Area once per week during the summer (13 weeks) and once per month during the rest of the year (9 months) – one event per day (Note that EPA guidance (2008b) recommends using site-specific values, which are not available for the Study Area.)
EV	event frequency (events/day)	1	
ED	total exposure duration (yrs)	30	EPA (1989)
AT_c	cancer averaging time (days)	25,550	EPA (1989)
AT_nc	non-cancer averaging time (days)	ED × 365	EPA (1989); equal to ED × 365 days
FI[a]	fractional intake from site	1	assumes 100% exposure to site
Adult (aged 17 to 30)			
SA_a	exposed skin surface area (cm^2)	5,800	95th percentile for outdoor activity (EPA 1997; Table 6-16)
ED_a	exposure duration (yrs)	14	EPA (1989); 30 yrs minus child exposure durations
BW_a	body weight (kg)	70	default value (EPA 1989)
ET_a[a]	exposure time (hrs/day)	3.3	average time people spend outdoors at a park (EPA 1997; Table 5-109)
Older Child (aged 7 to 16)			
SA_co	exposed skin surface area (cm^2)	4,700	(EPA 2008b, Table 7-1), assuming 35% of the total surface area (EPA 1992a)
ED_co	exposure duration (yrs)	10	EPA (1991)
BW_co	body weight (kg)	44.3	(EPA 2008b, Table ES-1)
ET_co[a]	exposure time (hrs/day)	2.35	average time children spend outdoors at a park (EPA 2006a, Table 9-67)
Young Child (aged 0 to 6)			
SA_c	exposed skin surface area (cm^2)	variable by age[d]	EPA (1997)
ED_c	exposure duration (yrs)	6[b]	EPA (1991)
BW_c	body weight (kg)	variable by age[c]	EPA (2008b)
ET_c[a]	exposure time (hrs/day)	1.7	average time children spend outdoors at a park (EPA 2006a, Table 9-67)

[a] These parameters were not listed in the CDI equation shown in this table, but were scenario-specific parameters needed to calculate the absorbed dose per event (DA_{event}).

[b] The total exposure duration was 6 years, but exposure was calculated in 1-year increments by age class (< 1, 1 to 2, 2 to 3, 3 to 4, 4 to 5, and 5 to 6 years). For incidental ingestion, Equation 3-4 was modified as follows to better capture the different exposure by age group:

$$CDI = \frac{EPC \times IR \times FI \times EF \times CF}{AT} \times \left(\frac{ED_1}{BW_1} + \frac{ED_2}{BW_2} + \frac{ED_3}{BW_3} + \frac{ED_4}{BW_4} + \frac{ED_5}{BW_5} + \frac{ED_6}{BW_6} \right)$$

[c] Different body weights were used for each 1-year age class to reflect the increasing body weight during this age range. Average weights for boys and girls were as follows (EPA 2008b):

Age Class	BW (kg)	Age Class	BW (kg)
< 1	9.1	3 – 4	15.3
1 – 2	11.3	4 – 5	17.4
2 – 3	13.3	5 – 6	19.7

[d] Skin surface area for children varies by age class. For the purpose of this scenario, children were assumed to be wearing a short-sleeve shirt, short pants, and no shoes (corresponding to approximately 35% of the total surface area) (EPA 1992a). Values shown are this fraction of the 50th percentile of surface areas for boys and girls in the following age classes (EPA 2008b):

Age Class	SA (cm^2)	Age Class	SA (cm^2)
< 1	1,330	3 – 4	2,298
1 – 2	1,750	4 – 5	2,515
2 – 3	2,069	5 – 6	2,751

CDI – chronic daily intake

dw – dry weight

EPA – US Environmental Protection Agency

na – not applicable

Table 3-19. Daily Intake Calculations – Consumption of Fish Tissue from Force Lake

Scenario timeframe: Current/future

Exposure media: Calculated Force Lake fish tissue

Exposure route: Ingestion

Intake equation: CDI (mg/kg dw) = EPC × IR-f × FI × EF × ED × CF × 1/BW × 1/AT

Parameter Code	Parameter Description	Value	Rationale and Reference
General			
EPC	exposure point concentration (mg/kg ww)	na	COPC specific
FI	fractional intake from site	1	assumes 100% exposure to site
EF	exposure frequency (d/yr)	365	ingestion rate calculated based on 365 days per year
ED	total exposure duration (yrs)	30	EPA (1989)
CF	conversion factor	0.001	conversion from kg to g
AT_c	cancer averaging time (days)	25,550	EPA (1989)
AT_nc	non-cancer averaging time (days)	ED × 365	EPA (1989); equal to ED × 365 days
Adult (aged 17 to 30)			
IR-f_a	fish ingestion rate (g/day)	3.75	assumes the consumption of six meals per year from Force Lake[a] (see Section 3.3.3)
ED_a	exposure duration (yrs)	14	EPA (1989); 30 yrs minus child exposure durations
BW_a	body weight (kg)	70	default value (EPA 1989)
Older Child (aged 7 to 16)			
IR-f_co	fish ingestion rate (g/day)	1.63	assumes the consumption of six meals per year from Force Lake with a meal size equal to 99 g[b] (see Section 3.3.3)
ED_co	exposure duration (yrs)	10	EPA (1991)
BW_co	body weight (kg)	44.3	(EPA 2008b, Table ES-1)
Young Child (aged 0 to 6)			
IR-f_c	fish ingestion rate (g/day)	1.05	assumes the consumption of six meals per year from Force Lake with a meal size equal to 64 g[b] (see Section 3.3.3)
ED_c	exposure duration (yrs)	6[c]	EPA (1991)
BW_c	body weight (kg)	variable by age[d]	EPA (2008b)

[a] Adult meal size was assumed to be 8 oz or 228 g.

[b] The older child meal size of 99 g was based on the average finfish meal size for children 6 to 19 years of age and the young child meal size of 64 g was based on the average finfish meal size for children 2 to 5 years of age, as reported in Table 10-28 of EPA's *Child-Specific Exposure Factors Handbook* (2008b).

[c] The total exposure duration was 6 years, but exposure was calculated in 1-year increments by age class (< 1, 1 to 2, 2 to 3, 3 to 4, 4 to 5, and 5 to 6 years). For incidental ingestion, Equation 3-4 was modified as follows to better capture the different exposure by age group:

$$CDI = \frac{EPC \times IR \times FI \times EF \times CF}{AT} \times \left(\frac{ED_1}{BW_1} + \frac{ED_2}{BW_2} + \frac{ED_3}{BW_3} + \frac{ED_4}{BW_4} + \frac{ED_5}{BW_5} + \frac{ED_6}{BW_6} \right)$$

[d] Different body weights were used for each 1-year age class to reflect the increasing body weight during this age range. Average weights for boys and girls were as follows (EPA 2008b):

Age Class	BW (kg)	Age Class	BW (kg)
< 1	9.1	3 – 4	15.3
1 – 2	11.3	4 – 5	17.4
2 – 3	13.3	5 – 6	19.7

CDI – chronic daily intake
dw – dry weight
EPA – US Environmental Protection Agency
ww – wet weight
na – not applicable

3.3.3 Fish Consumption Rate

At the direction of EPA in comments on the risk assessment scoping memorandum (EPA 2008c), a fish consumer scenario was developed as part of this baseline HHRA. To assess the level of fishing that may be occurring at Force Lake, site-specific information was gathered regarding the fish population present in the lake and the use of the lake by anglers. The following subsections provide a rationale for selection of a fish consumption rate of six meals per year (one meal per month during the warmer months) as a conservative fish ingestion rate for purposes of the risk assessment.

3.3.3.1 April 2009 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 that are present in the lake and estimate the abundance and sizes of these fish (Windward 2009b). The survey was conducted in accordance with the fish survey sampling design memorandum approved by EPA (Windward 2009a) and used several collection methods under good conditions[9] to provide a representative picture of the fish population present in Force Lake.

A total of 88 fish were collected, approximately 86% of which were 14 cm (5.5 inches) 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 (5.9 to 7.9 inches), and 2 of which were in the 20 to 25 cm range (7.9 to 9.8 inches). Additionally, one or two larger carp were observed during the survey but were not captured (i.e., they were not fully stunned and were able to escape), as discussed by Windward (2009b).

The electrofishing results and the types of fish caught in Force Lake were 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 generally stunted as a result of the available habitat, meaning that most of the fish would be small in size because of the intense competition for food. The competition is magnified by the lack of large predator fish, which would otherwise tend to reduce the population numbers of forage fish. Only carp (all less than 22 cm), pumpkinseed (all less than 12 cm), and one small brown bullhead (6.7 cm) 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 were consistent with the results of an earlier survey conducted in the late 1980s (Fishman 1989), during which a similarly low number of larger fish were caught (only four large carp [30 cm or greater in length] and at least two large bullhead [25 cm or greater in length]). Thus, the results of the 2009 survey support the conclusion that there is a small population of carp in Force Lake and a stunted pumpkinseed fishery, largely because of the limited habitat in Force Lake.

[9] Lake conditions conducive to an optimal catch per unit effort during the fish survey included a moderate water temperature, good water clarity, shallow water depth, and lack of habitat to provide cover for the fish.

Additionally, information regarding past fish kills in Force Lake may help explain the fish population observed during the 2009 survey. Jesse Goodling, the 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 have depressed oxygen levels in Force Lake (Goodling 2009). This type of event is another indicator supporting the 2009 Survey results, which suggest the presence of a relatively small fish population with few fish species.

3.3.3.2 Study Area-Specific Information Regarding Fishing at Force Lake

Information regarding the extent of fishing that occurs at Force Lake is available in the Harbor Oil Public Health Assessment conducted by the Oregon Department of Human Services (ODHS) (2004). This report assessed the potential for unacceptable risks to people based on consumption of fish from Force Lake. As part of this effort, a small survey of residents from the surrounding neighborhoods was conducted (n = 12). Only 3 respondents had seen or heard of people fishing at Force Lake, indicating that limited fishing is occurring. ODHS recommended in the report that signs be posted around the lake to warn people about potentially unacceptable risks associated with fish consumption, but that recommendation was not based on an assessment of fish tissue data from Force Lake.

3.3.3.3 Selected Fish Consumption Rate

Based on the information presented here, a fish consumption rate of 1 meal per month during the spring and summer months (April to September) is assumed for the Force Lake fish consumer RME scenario. This fishing scenario assesses risks to individuals who eat the equivalent of six meals per year of fish caught in Force Lake. This scenario is intended to assess risks to either recreational anglers, ethnic populations using fish collected from Force Lake to supplement their diet, or transient individuals collecting several meals from Force Lake as they move around the area. Note that individuals who collect fish from Force Lake may also collect fish from other nearby water bodies (e.g., those throughout the Columbia Slough).

This consumption rate is based on best professional judgment using the information presented above regarding the fish population in Force Lake and information regarding fishing frequency.

Table 3-20 presents the numbers of fish that would be required to support six anglers[10] who each ate six meals per year, compared to the number of fish caught during the 2009 survey.

Table 3-20. Hypothetical Fish Catch Rates for Six Anglers Consuming Six Meals per Year from Force Lake

Fish Size Category	No. of Fish Collected During the 2009 Survey	Annual No. of Fish Needed for Six Anglers (six meals per year)	
		Adults Only[a]	Adults and Children[b]
Small fish (less than 15 cm in length)	77	360 to 540	461 to 691
Medium-sized fish (15 to 25 cm in length)	12	72 to 108	92 to 138
Large fish (over 50 cm in length)	1 to 2[c]	36	46

[a] One meal (8 oz or 228 g) was assumed to be equal to either 1 large fish (over 50 cm in length), 2 to 3 medium-sized fish (15 to 25 cm in length), or 10 to 15 small fish (less than 15 cm in length). For example, for one angler to eat six meals per year of medium-sized fish from Force Lake it would require that 12 to 18 fish be caught each year (i.e., 2 to 3 times 6). Thus, for six anglers to eat at this rate, a total of 72 to 108 medium-sized fish would need to be caught each year (i.e., 12 to 18 times 6).

[b] This scenario assumes each adult catching fish from Force Lake is also feeding one young child. The meal size for children was assumed to be equal to 64 g/meal, based on the average meal size of finfish consumed by children aged 2 to 5 from EPA's *Child-Specific Exposure Factors Handbook* (EPA 2008b; Table 10-28).

[c] The large fish (carp) were observed during the fish survey but were not captured.

The Force Lake fish survey was not designed to estimate the total number of fish in the lake. However, given the methods that were used, the conditions under which the survey was conducted, and the extensive electrofishing effort, the survey effort was sufficient to conclude reliably that the lake contains a relatively small population of fish, especially compared to the numbers of fish that would be needed to support fishing at the rate proposed (Table 3-20). In order for six anglers to catch enough fish to eat six meals per year of fish from Force Lake, 5 to 10 times the number of fish observed during the Force Lake survey would need to be caught by these anglers every year to feed six adults. If each of these adults was assumed to also be feeding a child fish from Force Lake, 6 to 11 times the number of fish observed during the Force Lake survey would need to be caught by these anglers every year. Thus, the survey results indicate that the proposed consumption rate of six meals per year is conservative (Table 3-20).

[10] This evaluation was done assuming six anglers because Jesse Goodling, Heron Lakes Golf Course Superintendent, reported seeing five to six people fishing at Force Lake during the summer months (Goodling 2008).

3.3.4 Dermal Absorption Fractions

Sediment and soil exposure scenarios were developed in Section 3.3 for workers and recreational users. For those scenarios that include dermal exposure to soil or sediment, most of the exposure parameters relative to this exposure routes are provided in Tables 3-8 to 3-19. This section discusses the COPC-specific dermal absorption fraction (ABS) and the oral adjustment factor. The ABS is multiplied by the exposure dose for the dermal pathway (as shown in Tables 3-8 to 3-19) and refers to the fraction of the COPC in sediment applied to the skin surface that is absorbed into the bloodstream. The oral adjustment factor is used to convert the administered/external dose to an absorbed/internal dose (as shown in Table 3-21) to account for the increased potency of the absorbed dose as compared with the ingested dose because of incomplete absorption across the gastrointestinal tract (EPA 2004).

Many studies have focused on the topic of chemical-specific dermal absorption, but there is considerable uncertainty regarding chemical-specific values (EPA 1992a). EPA (2004) has developed supplemental guidance for dermal risk assessment that provides ABS values for most of the organic COPCs but provides ABS values for only two metal COPCs (arsenic and cadmium) and no volatile organic compounds (VOCs) (Table 3-21). With regard to metals, the guidance document (EPA 2004) states that the speciation of inorganic substances is crucial to estimating dermal absorption, and data are insufficient to derive default values for other inorganic substances. Older EPA guidance (2001) on dermal absorption provided a general value of 0.01 for all metals, reflecting a generally low dermal absorption of metals. With regard to VOCs, the guidance document stated that VOCs would likely volatilize from the soil adhering to skin, and should instead be accounted for via inhalation routes.

Risks based on dermal exposure were not quantified for COPCs for which specific ABS were not provided (EPA 2004, Exhibit 3-4). As suggested in the guidance documents (EPA 2004), the potential health risks from dermal exposure to these COPCs is evaluated further in the uncertainty analysis (Section 6.0).

In this assessment, cadmium was the only COPC with both a recommended dermal absorption factor and reduced oral absorption. However, cadmium was a COPC only for the fish consumption pathway and thus was not evaluated based on dermal exposure.

For other COPCs lacking an ABS, no dermal absorption was assumed for the risk characterization; and therefore, the reference dose (RfD) adjustment was not relevant. Alternative dermal absorption assumptions for exposure through direct sediment contact for COPCs without an ABS are explored in the uncertainty analysis.

Table 3-21. Dermal Absorption Fractions

COPC	ABS (unitless)[a]	Oral Absorption Adjustment[b]
Metals		
Aluminum	none	none
Antimony	none	RfD multiplied by 0.15
Arsenic	0.03	none
Barium	none	RfD multiplied by 0.07
Cadmium	0.001	RfD multiplied by 0.025
Chromium	none	RfD multiplied by 0.025
Cobalt	none	none
Copper	none	none
Iron	none	none
Lead	none	none
Manganese	none	RfD multiplied by 0.04
Mercury	none	RfD multiplied by 0.07
Nickel	none	RfD multiplied by 0.04
Vanadium	none	RfD multiplied by 0.026
Zinc	none	none
PAHs		
Naphthalene	0.13	none
cPAH TEQ	0.13	none
Other SVOCs		
1,4-Dichlorobenzene	0.1	none
PCBs		
Total PCBs	0.14	none
Pesticides		
Total DDTs	0.03	none
VOCs		
1,1-Dichloroethane	none	none
1,2,4-Trimethylbenzene	none	none
1,3,5-Trimethylbenzene	none	none
Benzene	none	none
Chlorobenzene	none	none
cis-1,2-Dichloroethene	none	none
Dichloromethane	none	none
Ethylbenzene	none	none
n-Propylbenzene	none	none
tert-Butyl methyl ether	none	none
trans-1,2-Dichloroethene	none	none
Trichloroethene	none	none

Table 3-21. Dermal Absorption Fractions

COPC	ABS (unitless)[a]	Oral Absorption Adjustment[b]
Vinyl chloride	none	none
Total xylenes	none	none

Source: RAGS Part E (EPA 2004)

[a] The ABS values are presented in Exhibit 3-4 of EPA (2004).

[b] The oral adjustment values are presented in Exhibit 4-1 of EPA (2004).

ABS – dermal absorption fraction
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
EPA – US Environmental Protection Agency
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RAGS – Risk Assessment Guidance for Superfund
RfD – reference dose
SVOC – semivolatile organic compound
TEQ – toxic equivalent
VOC – volatile organic compound

3.3.5 Calculation of Exposure Concentrations

EPCs were calculated to represent exposure concentrations for the risk estimates. In accordance with EPA guidance (1989), the EPC is defined as the average concentration contacted at the exposure point(s) over the duration of the exposure period. EPA recommends using the average concentration to represent "a reasonable estimate of the concentration likely to be contacted over time" (EPA 1989). Use of the average concentration is also consistent with EPA toxicity criteria, which are based on lifetime average exposures. Because it is generally not possible to know the true average, the 95% upper confidence limit on the mean (UCL) is typically used in CERCLA risk assessments to represent the average concentration. The UCL is defined as a value that, when calculated repeatedly for randomly drawn subsets of data, equals or exceeds the mean of the true population 95% of the time. Using a UCL can also help account for uncertainties associated with a limited number of samples and an uneven spatial distribution of contaminant concentrations. If sufficient data (i.e., six or more detected concentrations) were available, UCLs were calculated using ProUCL 4.00.04, which includes provisions for handling non-detected values (EPA 2009e). The UCL recommended by ProUCL was used as the EPC for the risk assessment.

If insufficient data were available to calculate a UCL using ProUCL, the EPC was set equal to the higher of either the maximum detected value or one-half of the maximum RL. When fewer than six detected values are available, the UCL may not provide a reliable estimate of the true mean concentration, particularly if the dataset is positively skewed, as is often the case with environmental sampling. When the number of samples used to characterize an exposure area is very small (e.g., $n < 6$), there is substantial uncertainty associated with any estimate of the mean concentration. Thus, per EPA guidance (2009e), a maximum value is selected in an attempt to avoid underestimating the true mean for the dataset.

Summary statistics and EPCs for the all COPCs identified in Section 3.2 are presented in Table 3-22. In addition, Table 3-23 provides a summary of these EPCs to aid in comparison across scenarios. In addition, data tables, ProUCL input files, and ProUCL output data tables are presented as an electronic supplement to Attachment 5.

Table 3-22. Exposure Point Concentrations and Summary Statistics for the Baseline HHRA

COPC	Unit	Detection Frequency (ratio)	Maximum Detection	Maximum RL	Mean Detect	Mean Value[a]	KM Mean[b]	EPC	Selected Statistic
Industrial (Construction/Trenching) Worker: Facility Soil									
Arsenic	mg/kg dw	112/112	53.1	na	5	5	na	8.3	95% Chebyshev (mean, SD) UCL
Cobalt	mg/kg dw	112/112	35 J	na	10	10	na	13	95% approximate gamma UCL
Copper	mg/kg dw	112/112	1,370	na	100	100	na	270	97.5% Chebyshev (mean, SD) UCL
Lead[c]	mg/kg dw	112/112	337	na	40	40	na	77	97.5% Chebyshev (mean, SD) UCL
Naphthalene	µg/kg dw	85/115	19,000	242 U	920	680	680	2,000	97.5% KM (Chebyshev) UCL
cPAH TEQ	µg/kg dw	106/115	5,200	637 U	506	473	470	950	97.5% KM (Chebyshev) UCL
Total PCBs	µg/kg dw	74/114	32,000	200 U	2,000	1,000	1,200	3,400	97.5% KM (Chebyshev) UCL
Total DDTs	µg/kg dw	104/115	78,000 J	130 U	5,000	4,000	4,200	11,000	97.5% KM (Chebyshev) UCL
1,1-Dichloroethane	µg/kg dw	4/113	680	1,100 U	170	20	na	680	maximum detect
1,2,4-Trimethylbenzene	µg/kg dw	49/95	40,000	7.1 UJ	3,000	1,000	1,300	5,300	97.5% KM (Chebyshev) UCL
1,3,5-Trimethylbenzene	µg/kg dw	34/95	12,000	120 U	800	300	300	1,300	97.5% KM (Chebyshev) UCL
Benzene	µg/kg dw	52/113	6,400	810 U	170	90	78	330	95% KM (Chebyshev) UCL
Chlorobenzene	µg/kg dw	24/113	2,900 J	1,100 U	200	60	46	220	97.5% KM (Chebyshev) UCL
cis-1,2-Dichloroethene	µg/kg dw	10/113	130,000	1,100 U	13,000	1,000	1,200	8,700	97.5% KM (Chebyshev) UCL
Dichloromethane	µg/kg dw	27/113	370	2,200 U	31	43	9.6	20	95% KM (BCA) UCL
Ethylbenzene	µg/kg dw	35/113	26,000	120 U	1,200	400	390	1,900	97.5% KM (Chebyshev) UCL
trans-1,2-Dichloroethene	µg/kg dw	1/95	5,500	1,100 U	5,500	70	na	5,500	maximum detect
Trichloroethene	µg/kg dw	9/113	2,400	1,100 U	270	40	23	160	97.5% KM (Chebyshev) UCL
Vinyl chloride	µg/kg dw	2/113	1,200	1,100 U	610	30	na	1,200	maximum detect
Total xylenes	µg/kg dw	53/113	150,000 J	380 U	4,000	2,000	1,800	10,000	97.5% KM (Chebyshev) UCL
TPH-gasoline (aliphatic)[d]	mg/kg dw	49 / 97	3,230	48 U	270	140	140	430	97.5% KM (Chebyshev) UCL
Industrial (Construction/Trenching) Worker: Groundwater									
Arsenic (total)[e]	µg/L	28/28	31.6	na	10	10	na	15	95% Student's-t UCL
Lead (total)[c]	µg/L	8/28	19.6	1 U	5	2	1.7	3	95% KM (t) UCL

Table 3-22. Exposure Point Concentrations and Summary Statistics for the Baseline HHRA

COPC	Unit	Detection Frequency (ratio)	Maximum Detection	Maximum RL	Mean Detect	Mean Value[a]	KM Mean[b]	EPC	Selected Statistic
Manganese (total)[e]	µg/L	28/28	7,860	na	3,400	3,400	na	4,000	95% Student's-t UCL
Naphthalene	µg/L	7/28	1.5	0.4 U	0.47	0.2	0.19	0.33	95% KM (BCA) UCL
1,4-Dichlorobenzene	µg/L	4/28	1.4	1 U	0.8	0.5	na	1.4	maximum detect
Total DDTs	µg/L	12/28	0.24 J	0.019 U	0.063	0.030	0.031	0.049	95% KM (t) UCL
1,2,4-Trimethylbenzene	µg/L	2/22	7.2	1.0 U	5.5	0.91	na	7.2	maximum detect
1,3,5-Trimethylbenzene	µg/L	3/22	3.0	1.0 U	2.3	0.71	na	3	maximum detect
Benzene	µg/L	8/28	140	6.2 U	20	6	6.3	39	97.5% KM (Chebyshev) UCL
Chlorobenzene	µg/L	15/28	130	1 U	30	10	14	80	99% KM (Chebyshev) UCL
n-Propylbenzene	µg/L	4/22	11	1.0 U	5.3	1.3	na	11	maximum detect
tert-Butyl methyl ether	µg/L	14/28	160	1 U	30	10	14	28	95% KM (BCA) UCL
Vinyl chloride	µg/L	1/28	0.22 J	1 U	0.22	0.4	na	0.5	half maximum RL
Future Outdoor Worker: Facility Soil									
Arsenic	mg/kg dw	69/69	53.1	na	6	6	na	11	95% Chebyshev (mean, SD) UCL
Cobalt	mg/kg dw	69/69	32	na	10	10	na	14	95% Student's-t UCL
Copper	mg/kg dw	69/69	1,240 J	na	100	100	na	150	95% H-UCL
Lead[c]	mg/kg dw	69/69	337	na	60	60	na	71	95% approximate gamma UCL
Naphthalene	µg/kg dw	52/73	19,000	242 U	1,000	750	740	2,600	97.5% KM (Chebyshev) UCL
cPAH TEQ	µg/kg dw	69/73	5,200	450 U	645	617	610	1,100	95% KM (Chebyshev) UCL
Total PCBs	µg/kg dw	59/71	32,000	160 U	2,000	2,000	1,800	5,200	97.5% KM (Chebyshev) UCL
Total DDTs	µg/kg dw	68/72	78,000 J	130 U	6,000	6,000	6,100	16,000	97.5% KM (Chebyshev) UCL
1,1-Dichloroethane	µg/kg dw	3/69	680	1,100 U	230	30	na	680	maximum detect
1,2,4-Trimethylbenzene	µg/kg dw	24/54	40,000	7.1 UJ	4,000	2,000	1,900	13,000	99% KM (Chebyshev) UCL
1,3,5-Trimethylbenzene	µg/kg dw	18/54	12,000	120 U	1,000	400	380	3,000	99% KM (Chebyshev) UCL
Benzene	µg/kg dw	25/69	6,400	810 U	280	100	100	510	95% KM (Chebyshev) UCL
cis-1,2-Dichloroethene	µg/kg dw	4/69	130,000	1,100 U	33,000	2,000	na	130,000	maximum detect

Table 3-22. Exposure Point Concentrations and Summary Statistics for the Baseline HHRA

COPC	Unit	Detection Frequency (ratio)	Maximum Detection	Maximum RL	Mean Detect	Mean Value[a]	KM Mean[b]	EPC	Selected Statistic
Dichloromethane	µg/kg dw	18/69	370	2,200 U	44	47	13	47	95% KM (Chebyshev) UCL
Ethylbenzene	µg/kg dw	19/69	26,000	120 U	2,000	600	550	3,100	97.5% KM (Chebyshev) UCL
trans-1,2-Dichloroethene	µg/kg dw	1/54	5,500	1,100 U	5,500	100	na	5,500	maximum detect
Trichloroethene	µg/kg dw	6/69	2,400	1,100 U	400	50	36	270	97.5% KM (Chebyshev) UCL
Vinyl chloride	µg/kg dw	1/69	1,200	1,100 U	1,200	30	na	1,200	maximum detect
Total xylenes	µg/kg dw	29/69	150,000 J	83 U	6,000	3,000	2,600	16,000	97.5% KM (Chebyshev) UCL
TPH-gasoline (aliphatic)[d]	mg/kg dw	28/56	3,230	48 U	330	170	170	660	97.5% KM (Chebyshev) UCL
Industrial/Commercial Worker Vapor Intrusion Scenario: Groundwater									
Benzene	µg/L	2/6	2.9	6.2 U	2.6	2	na	3.1	half maximum RL
Vinyl chloride	µg/L	1/6	0.22 J	1 U	0.22	0.5	na	0.5	half maximum RL
Force Lake Recreational User: Wetland Soil									
Aluminum	mg/kg dw	5/5	12,100	na	9,500	9,500	na	12,000	maximum detect
Antimony	mg/kg dw	7/61	8.4 J	4.5 U	2	0.5	0.84	1.1	95% KM (% Bootstrap) UCL
Arsenic	mg/kg dw	61/61	53.1	na	8	8	na	9.6	95% H-UCL
Chromium	mg/kg dw	61/61	149	na	30	30	na	37	95% H-UCL
Cobalt	mg/kg dw	61/61	34.3	na	10	10	na	12	95% Modified-t UCL
Copper	mg/kg dw	61/61	1,240 J	na	77	77	na	160	95% Chebyshev (mean, SD) UCL
Iron	mg/kg dw	5/5	56,500	na	29,500	29,500	na	57,000	maximum detect
Lead[c]	mg/kg dw	61/61	320	na	60	60	na	80	95% H-UCL
Manganese	mg/kg dw	5/5	1,090	na	724	724	na	1,100	maximum detect
Vanadium	mg/kg dw	61/61	148	na	70	70	na	76	95% approximate gamma UCL
Naphthalene	µg/kg dw	55/61	4,210	277 U	210	200	190	640	97.5% KM (Chebyshev) UCL
cPAH TEQ	µg/kg dw	59/61	5,200	888 U	478	475	470	1,100	95% KM (Chebyshev) UCL
Total PCBs	µg/kg dw	40/61	4,200	990 U	500	400	770	770	95% KM (Chebyshev) UCL
Total DDTs	µg/kg dw	60/61	46,000	130 U	3,000	3,000	2,500	9,100	97.5% KM (Chebyshev) UCL

Table 3-22. Exposure Point Concentrations and Summary Statistics for the Baseline HHRA

COPC	Unit	Detection Frequency (ratio)	Maximum Detection	Maximum RL	Mean Detect	Mean Value[a]	KM Mean[b]	EPC	Selected Statistic
Benzene	µg/kg dw	24/52	56	15 U	9.6	5	5.3	7.7	95% KM (t) UCL
Trichloroethene	µg/kg dw	2/52	4.7	15 U	3.6	2	na	7.5	half maximum RL
TPH-gasoline (aliphatic)[d]	mg/kg dw	4/56	17	49 U	12	8.4	na	25	half maximum RL
TPH-diesel (aliphatic)[d]	mg/kg dw	54/60	3,400	25 U	320	290	290	780	97.5% KM (Chebyshev) UCL
Force Lake Recreational User: Lake Sediment									
Arsenic	mg/kg dw	11/11	7	na	6	6	na	6.4	95% Student's-t UCL
Chromium	mg/kg dw	11/11	34	na	30	30	na	30	95% Student's-t UCL
Cobalt	mg/kg dw	11/11	15	na	13	13	na	14	95% Student's-t UCL
Lead[c]	mg/kg dw	11/11	56	na	40	40	na	62	95% Chebyshev (mean, SD) UCL
Vanadium	mg/kg dw	11/11	74	na	60	60	na	67	95% Student's-t UCL
cPAH TEQ	µg/kg dw	11/11	118	na	61.9	61.9	na	81	95% Student's-t UCL
TPH-gasoline (aliphatic)[d]	mg/kg dw	1/11	26	68 U	26	24	na	34	half maximum RL
Force Lake Recreational User: Lake Surface Water									
Arsenic (total)[e]	µg/L	3/3	1.2	na	1.2	1.2	na	1.2	maximum detect
Force Lake Fish Consumer: Fish Tissue[f]									
Arsenic	mg/kg ww	11/11	0.24	na	0.19	0.19	na	0.22	95% Student's-t UCL
Barium	mg/kg ww	11/11	62	na	53	53	na	57	95% Student's-t UCL
Cadmium	mg/kg ww	8/11	0.44	0.09 U	0.44	0.34	na	0.44	maximum detect[g]
Cobalt	mg/kg ww	11/11	4.2	na	3.5	3.5	na	3.9	95% Student's-t UCL
Copper	mg/kg ww	11/11	20	na	15	15	na	22	Use 95% Chebyshev (mean, SD) UCL
Lead[c]	mg/kg ww	11/11	2.8	na	2.0	2.0	na	3.1	95% Chebyshev (mean, SD) UCL
Mercury	mg/kg ww	1/11	0.021	0.021 U	0.021	0.017	na	0.021	maximum detect
Nickel	mg/kg ww	11/11	8.7	na	6.7	6.7	na	7.7	95% Student's-t UCL
Vanadium	mg/kg ww	11/11	21	na	17	17	na	19	95% Student's-t UCL
Zinc	mg/kg ww	11/11	120	na	89	89	na	100	95% Student's-t UCL

Table 3-22. Exposure Point Concentrations and Summary Statistics for the Baseline HHRA

COPC	Unit	Detection Frequency (ratio)	Maximum Detection	Maximum RL	Mean Detect	Mean Value[a]	KM Mean[b]	EPC	Selected Statistic
Total PCBs	mg/kg ww	7/11	0.44	0.29 U	0.32	0.26	0.29	0.33	95% KM (percentile bootstrap) UCL
Total DDTs	mg/kg ww	11/11	0.41	na	0.25	0.25	na	0.30	95% Student's-t UCL

[a] The mean value is equal to the average of all detected values and one-half of the RL for all non-detect values.

[b] The KM mean is calculated in ProUCL for datasets with a mix of detected and non-detected data. As with UCL calculations discussed at the beginning of this section, KM means can only be calculated for datasets with 6 or more detected values.

[c] Lead is included in this table because it was designated as a COPC. However, risks associated with lead were evaluated separately, as discussed in Section B.3.3.6, using the IEUBK and the ALM for characterizing risks associated with adult lead exposure. As discussed in Section 3.3.6, mean concentrations, rather than UCL values, were used for lead modeling.

[d] As discussed in Section 2.2.5, aliphatic TPH fractions were assumed to be equal to 85% of each TPH fraction based on ATSDR (1999).

[e] Both the total and dissolved fraction of this COPC were greater than the screening level. As a conservative assumption, the total fraction was assessed in this HHRA because it is slightly higher than the dissolved fraction.

[f] Fish tissue concentrations were calculated from lake sediment concentrations using BSAFs (see Attachment 2).

[g] All detected values were equal, and thus there were too few unique values for the calculation of a UCL in ProUCL. The detected concentration was used as the EPC.

ALM – Adult Lead Model
BCA – bias-corrected accelerated
BSAF – biota-sediment accumulation factor
COPC – contaminant of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPA – US Environmental Protection Agency
EPC – exposure point concentration
HHRA – human health risk assessment
H-UCL – UCL based on Land's H-statistic
IEUBK – Integrated Exposure Uptake Biokinetic Model for Lead in Children
J – estimated concentration
KM – Kaplan-Meier
na – not applicable
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RL – reporting limit
SD – standard deviation
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons
U – not detected at given concentration
UCL – upper confidence limit on the mean
ww – wet weight

Table 3-23. Summary of EPCs Used in Baseline HHRA

COPC	Fish Tissue (mg/kg ww)	Facility Soil (mg/kg dw)[a]		Wetland Soil (mg/kg dw)	Lake Sediment (mg/kg dw)	Groundwater (µg/L)[b]		Lake Water (µg/L)
	Force Lake Fish Consumer	Industrial (Construction/ Trenching) Worker	Future Outdoor Worker	Force Lake Recreational User	Force Lake Recreational User	Industrial (Construction/ Trenching) Worker	Industrial/ Commercial Worker	Force Lake Recreational User
Metals								
Aluminum	na	na	na	12,000	na	na	na	na
Antimony	na	na	na	1.1	na	na	na	na
Arsenic	0.22	8.3	11	9.6	6.4	15	na	1.2
Barium	57	na	na	na	na	na	na	na
Cadmium	0.44	na	na	na	na	na	na	na
Chromium	na	na	na	37	30	na	na	na
Cobalt	3.9	13	14	12	14	na	na	na
Copper	22	270	150	160	na	na	na	na
Iron	na	na	na	57,000	na	na	na	na
Lead[b]	3.1	77	71	80	62	3	na	na
Manganese	na	na	na	1100	na	4,000	na	na
Mercury	0.021	na	na	na	na	na	na	na
Nickel	7.7	na	na	na	na	na	na	na
Vanadium	19	na	na	76	67	na	na	na
Zinc	100	na	na	na	na	na	na	na
PAHs								
Naphthalene	na	2.0	2.6	0.64	na	0.33	na	na
cPAH TEQ	na	0.95	1.1	1.1	0.081	na	na	na
Other SVOCs								
1,4-Dichlorobenzene	na	na	na	na	na	1.4	na	na
PCBs								
Total PCBs	0.33	3.4	5.2	0.77	na	na	na	na

Table 3-23. Summary of EPCs Used in Baseline HHRA

COPC	Fish Tissue (mg/kg ww)	Facility Soil (mg/kg dw)[a]		Wetland Soil (mg/kg dw)	Lake Sediment (mg/kg dw)	Groundwater (µg/L)[b]		Lake Water (µg/L)
	Force Lake Fish Consumer	Industrial (Construction/ Trenching) Worker	Future Outdoor Worker	Force Lake Recreational User	Force Lake Recreational User	Industrial (Construction/ Trenching) Worker	Industrial/ Commercial Worker	Force Lake Recreational User
Pesticides								
Total DDTs	0.30	11	16	9.1	na	0.049	na	na
VOCs								
1,1-Dichloroethane	na	0.68	0.68	na	na	na	na	na
1,2,4-Trimethylbenzene	na	5.3	13	na	na	7.2	na	na
1,3,5-Trimethylbenzene	na	1.3	3.0	na	na	3	na	na
Benzene	na	0.33	0.51	0.0077	na	39	3.1	na
Chlorobenzene	na	0.22	na	na	na	80	na	na
cis-1,2-Dichloroethene	na	8.7	130	na	na	na	na	na
Dichloromethane	na	0.020	0.047	na	na	na	na	na
Ethylbenzene	na	1.9	3.1	na	na	na	na	na
n-Propylbenzene	na	na	na	na	na	11	na	na
tert-Butyl methyl ether	na	na	na	na	na	28	na	na
trans-1,2-Dichloroethene	na	5.5	5.5	na	na	na	na	na
Trichloroethene	na	0.16	0.27	0.0075	na	na	na	na
Vinyl chloride	na	1.2	1.2	na	na	0.5	0.5	na
Total xylenes	na	10	16	na	na	na	na	na
TPH								
TPH-gasoline (aliphatic)[c]	na	430	660	25	34	na	na	na
TPH-diesel (aliphatic)[c]	na	na	na	780	na	na	na	na

[a] Facility soil EPCs are different for the worker scenarios because different exposure areas were assumed for these datasets (see Section 3.1).

[b] Lead is included in this table because it was designated as a COPC. However, risks associated with lead were evaluated separately, as discussed in Section B.3.3.6, using the IEUBK and the ALM for characterizing risks associated with adult lead exposure. As discussed in Section 3.3.6, mean concentrations, rather than UCL values, were used for lead modeling.

[c] As discussed in Section 2.2.5, aliphatic TPH fractions were assumed to be equal to 85% of each TPH fraction based on ATSDR (1999).

ALM – Adult Lead Model
COPC – contaminant of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPA – US Environmental Protection Agency
EPC – exposure point concentration
IEUBK – Integrated Exposure Uptake Biokinetic Model for Lead in Children
na – not applicable (not a COPC for that scenario-media combination)
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons
VOC – volatile organic compound
ww – wet weight

3.3.6 Evaluation of Exposures to Lead

Risk estimates from lead exposure were not made using the equations presented in Section 3.3.1 because of the unique toxicology of lead. As discussed in EPA guidance on lead risk assessment (EPA 2011), lead is evaluated based on a blood lead level for the following reasons:

- **Lack of an RfD:** RfDs, as discussed in Section 4.0, are developed based on concentrations below which no adverse health effects have been observed. For lead, no RfD is available because exposure to even very low concentrations of lead has been observed to result in adverse health effects.
- **Toxicokinetics:** The toxicokinetics of lead (i.e., the rate at which lead enters the body and its fate once it is in the body) are well understood, which makes it possible to correlate blood lead levels with exposure. EPA and the Centers for Disease Control and Prevention (CDC) have determined that adverse health effects are associated with a blood lead level of 10 µg/dL or higher in children.

Two models were used in this HHRA: the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) (EPA 1994) and the Adult Lead Model (ALM) (EPA 2003b), for which the sensitive endpoint is a fetus. The details of each model are discussed in the following subsections.

3.3.6.1 Children (IEUBK)

The IEUBK model (Version 1.1 build 9 for Microsoft Windows®) predicts blood-lead concentrations for children exposed to lead in their environment. The model requires relevant absorption parameters and intake and exposure rates and then estimates the concentration of lead in blood of children aged 0 to 6 years.

Default input parameters in the model for lead intake via air, drinking water, and diet were available for the evaluation of child exposure to lead at the Study Area. The IEUBK model also allows for alternate dietary data to be used if site-specific data are available. If site-specific data are available, they are used as input on both the concentration of lead in the alternate dietary sources as well as the proportion of total dietary intake these categories represent. The alternate dietary data are then added to the other source data to derive a combined intake from all sources.

For this HHRA, all default parameters recommended for use in the model by EPA were maintained except for alternate dietary source (fish) and soil lead concentrations (data for other food-borne sources of lead were not available). The default values for diet varied from 1.95 to 2.26 µg/day. Table 3-24 presents the alternate food source lead concentration (in fish) as well as the proportion of dietary intake represented by fish.

Table 3-24. Input parameters for IEUBK lead model

Parameter	Value	Unit
Mean lead concentration	60 (wetland soil) 40 (Force Lake sediment)	mg/kg dw
Time-weighted average lead concentrations based on sediment and soil exposures[a]	192 (wetland soil) 190 (Force Lake sediment)	mg/kg dw
Ingestion rate	1.05 (children aged 0 to 6)	g/day
Alternate food source concentration	2.0	µg lead/g
Alternate food source fraction[b]	1.07 (children aged 0 to 6)	%

[a] Derived from lead values: $[(Pb_s \times EF_s) + (Pb_{defalt} \times EF_{defalt})/(EF_s + EF_{defalt})]$

Where:

Pb_s = mean sediment or soil lead concentration (mg/kg dw)

EF_s = Force Lake recreational user exposure frequency (22 days/year)

Pb_{defalt} = average default soil lead concentration (200 mg/kg dw)

EF_{defalt} = soil exposure frequency; calculated by subtracting the Study Area exposure frequency from the total number of days in the year, $EF_s + EF_{defalt} = 365$ (value is 343 days/yr)

[b] 1.05 g/day (child aged 0 to 6 fish ingestion rate)/98.05 g/day (total meat consumed per day) (EPA 2006b).

dw – dry weight

EPC – exposure point concentration

Alternate dietary data from the child portion of the Force Lake fish consumer RME scenario were included in the model as described in Table 3-24. The IEUBK model applies average or CT estimates for all terms (EPA 1994). The fish consumption rate of 1.05 g/day for children aged 0 to 6 was used for this evaluation. The percentage of this alternate food source (fish) of its food group (all meat) was set at 1.07% (Table 3-24). Table 3-24 presents the input parameter used in the lead fish consumption model.

Exposure to lead in soil or sediment was calculated as a time-weighted average in accordance with direct sediment exposure scenarios for children. On days when a child visited the Study Area, all of their lead exposure was assumed to come from the Study Area; on days when the Study Area was not visited, the default value of 200 µg/g was used. Using a weighted average allowed for a better estimate of true soil exposure. However, it should be noted that the pre-set value of 200 µg/g was higher than all lead concentrations detected in Force Lake sediment and higher than all but four of the lead concentrations detected in wetland soil. This default value represents the concentration of lead immediately outside the home (as compared to the Study Area).

For calculating the time-weighted average EPC, an exposure frequency of 22 days per year was assumed for exposure to both soil and sediment at the Study Area (calculated separately). On days when exposure to sediment or soil at the Study Area did not occur (i.e., 343 days per year), children were assumed to be exposed to soils at the default lead concentration of 200 mg/kg dw. The time-weighted average EPC was

calculated for each exposure area by multiplying the sediment or soil concentration by the number of days exposed to either the default lead concentration or to the Study Area lead concentration. These values were summed, and the results were divided by an averaging time of 365 days per year. The results of these calculations are presented in Table 3-24.

The values calculated using default values recommended by EPA in the IEUBK model manual along with these site-specific data may not fully reflect the extent of lead exposure to children living in areas surrounding the Study Area because of the lack of site-specific data for lead in household dust, water, and residential soils in the neighborhoods surrounding the Study Area. These values included an assumed 200 mg/kg dw default soil lead concentration, which was intended to reflect an anthropogenic geometric mean concentration in urban areas. A regional soil background value of 17 mg/kg dw for lead is available from DEQ (2002), but because of the uncertainty associated with lead concentrations in urban areas, the more conservative (i.e., health-protective) default value from the IEUBK model was used.

It should be noted that even the highest time-weighted average lead EPCs presented in Table 3-23 based on Study Area sediment or soil exposure is less than the IEUBK model default value of 200 mg/kg dw. The results of the IEUBK model runs are presented in Section 5.4.1.

3.3.6.2 Adult (ALM)

The ALM is based on protecting the developing fetus of a pregnant woman. The model incorporates exposure to soil that is more representative of older children and adults than young children. Accordingly, EPA has used this model to estimate soil lead cleanup levels for sites at which the likely exposed population would be older children or adults. Although the model was developed to assess soil exposures, it has been applied to the Study Area to evaluate exposure to lead in wetland soil, lake sediment, and fish tissue consumption. Adjustments were made to the model to account for fish intake (EPA 2007a). This approach provides a way to evaluate cumulative exposure to lead at the Study Area from both sediment contact and fish consumption.

The ALM applied for the Study Area estimates an average blood lead level in adults based on additional exposure (above a baseline level) from lead in soil, sediment, fish, and air. An estimated fetal blood lead level is then calculated from the estimated adult blood lead levels (Equation 3-10). The contribution of lead from air at the Study Area was considered negligible because blood lead levels are much less sensitive to passive re-entrainment of lead from soil in air. The equation is thus:

$$PbB_{adult,central} = \frac{PbB_0 + BKSF \times FI \times ((PB_s \times IR_s \times AF_s \times EF_s) + (PB_f \times IR_f \times AF_f \times EF_f))}{AT}$$

Equation 3-10

where $PbB_{adult,central}$ is the geometric mean blood lead level (µg/dL) in exposed adults. The definition and parameterization of the other variables in the equation above are provided in Table 3-25. A summary of the

dataset to determine mean EPC values is presented in Table 3-26. This information replicates what is presented in EPC Tables 3-22 and 3-23, but is presented again here for the convenience of the reader. The same dataset was used to determine these mean EPCs as was used for the calculation of EPCs for other COPCs.

Table 3-25. Input Parameters for ALM

Parameter	Description	Value	Unit
General			
PbB_0	adult baseline (geometric mean) blood lead level	1.5	µg/dL
BKSF	biokinetic slope factor	0.4 (EPA default)	µg/dL per µg/day
FI	fractional intake	1	unitless
AF_s	GI absorbance fraction for lead in sediment	0.12 (EPA default for soil)[a]	unitless
AF_f	GI absorbance fraction for lead in tissue	0.12[b]	unitless
AT	averaging time	365	days
Industrial (Construction/Trenching) Worker			
IR_s	soil incidental ingestion rate	0.33	g/day
EF	exposure frequency	250	days/year
Pb_s	lead concentration in soil	40	mg/kg dw
Pb_w	lead concentration in groundwater	2	µg/L
Future Outdoor Worker			
IR_s	soil incidental ingestion rate	0.1	g/day
EF	exposure frequency	250	days/year
Pb_s	lead concentration in soil	60	mg/kg dw
Force Lake Recreational User			
IR_s	soil or sediment incidental ingestion rate	0.1	g/day
EF	exposure frequency	22	days/year
Pb_s	lead concentration in wetland soil	60	mg/kg dw
Pb_w	lead concentration in Force Lake sediment	40	mg/kg dw
Force Lake Fish Consumer			
IR_f	fish consumption rate	3.75	g/day
EF	exposure frequency	365	days/year
Pb_f	lead concentration in fish tissue (calculated)	1.4	mg/kg ww

[a] Gastrointestinal absorption fraction for lead in sediment (EPA 2003b).
[b] Gastrointestinal absorption fraction for lead in tissue (EPA 2007a).

ALM – Adult Lead Model
GI – gastrointestinal
dw – dry weight
ww – wet weight
EPA – US Environmental Protection Agency

Table 3-26. Summary of Lead Data and Mean EPC Values

Exposure Scenario	Media	Detection Frequency	Concentration (mg/kg dw)			
			Mean EPC	Max Detect	Max RL	UCL EPC
Industrial (construction/ trenching worker)	Facility soil	112/112	40	337	na	71
	groundwater	8/28	2	19.6	1 U	3.0
Future outdoor worker	Facility soil	69/69	60	337	na	77
Force Lake recreational user	wetland soil	61/61	60	320	na	80
	Force Lake sediment	11/11	40	56	na	62
Force Lake fish consumer	calculated fish tissue[a]	11/11	2.0	2.8	na	3.1

[a] Fish tissue concentrations were calculated using BSAFs (see Attachment 2).

BSAF – biota-sediment accumulation factor
dw – dry weight
EPC – exposure point concentration
na – not applicable
RL – reporting limit
UCL – upper confidence limit on the mean
U – not detected at given concentration

Lead EPC values were calculated for all exposure media based on the UCL as was done for all other COPCs evaluated in the HHRA. However, because the ALM guidelines (EPA 2003b) recommend using mean sediment and tissue values for calculating risks from lead exposure, mean values were calculated and applied in the ALM. Table 3-26 presents the mean concentrations as well as the EPC values based on the 95th UCL for all scenario-media combinations in which lead was identified as a COPC. The model output includes both central tendency (geometric mean) and 95th percentile fetal blood lead levels. The 95th percentile fetal blood lead level was calculated using Equation 3-11:

$$PbB_{fetal95} = PbB_{adult,central} \times GSD_{i,adult}^{1.645} \times R_{fetal/maternal}$$ **Equation 3-11**

Where:

$PbB_{fetal95}$	=	95th percentile fetal blood lead level (µg/dL)
$PbB_{adult,central}$	=	central estimate of maternal adult blood lead concentration
$GSD_{i,adult}$	=	geometric standard deviation of the blood lead distribution
1.645	=	95th percentile value for the Student's t distribution
$R_{fetal/maternal}$	=	proportionality constant between fetal and maternal blood lead concentration

The geometric standard deviation (GSD) is an estimation of variation in blood lead levels around the geometric mean. It is used to estimate upper percentile blood lead levels for an individual and provides a health-protective estimate of the probability of an individual exceeding a given blood lead level (target risk goal). In accordance with EPA (2002a), a

GSD of 2.11 was applied to this model. Fetal blood lead levels were predicted based on the EPA assumption that fetal blood lead levels at birth are 90% of the maternal blood lead level. A 10 µg/dL blood lead level for a fetus is associated with a 11.1 µg/dL blood lead level for the mother according to EPA (2003b). The probability of exceeding the 10-µg/dL blood lead threshold for an individual was calculated using the following mathematical function in Microsoft Excel® using Equation 3-12:

$$P_{exceedance} = 1 - \text{Normdist}(\text{Ln}(Pb_{target}/Pb_{central} \times R_{fetal/maternal}) / \text{Ln}(GSD))$$

Equation 3-12

Where:

Pb_{target}	=	child threshold blood lead level (in this application, 10 µg/dL)
$Pb_{central}$	=	child central tendency blood lead estimate
$R_{fetal/maternal}$	=	proportionality constant between fetal and maternal blood lead concentration
GSD	=	geometric standard deviation of the blood lead distribution

3.4 Chronic Daily Intake

The CDI is defined in RAGS as “exposure expressed as mass of a substance contacted per unit body weight per time unit averaged over a long period of time” and is thus presented in units of milligrams per kilogram of body weight per day (mg/kg-day) (EPA 1989). The CDI is calculated differently for carcinogenic effects than for non-carcinogenic effects. Each is described below:

- **Carcinogens:** The CDI is based on the estimated exposure duration, extrapolated over an estimated 70-year lifetime. This is consistent with the cancer slope factors (SFs), which are based on lifetime exposures, and on the assumptions that the risk of carcinogenic effects is cumulative and continues even after exposure has ceased.
- **Non-carcinogens:** The CDI is averaged over the estimated exposure period to be consistent with the assumption that adverse effects are not expected to occur after exposure has ceased. Thus, the CDI is used to represent the potential for adverse health effects over the period of exposure.

Tables 1 through 6 in Attachment 5 present the results of CDI calculations performed using Equations 3-1 through 3-9 and the exposure parameters provided in Tables 3-8 through 3-19. The CDI results are used in the risk characterization (Section 5.0).

4.0 TOXICITY ASSESSMENT

A toxicity assessment includes two steps:

- Hazard identification, which determines whether exposure to a chemical may result in a deleterious health effect in humans. It consists of a characterization of the nature of the effect and the strength of the evidence that the chemical will cause the observed effect.
- Dose-response assessment, which includes a characterization of the relationship between the dose and the incidence and/or severity of the adverse health effect in the exposed population.

For risk assessment purposes, chemicals are generally categorized based on whether they exhibit carcinogenic or non-carcinogenic health effects. Because chemicals that are suspected carcinogens may also have non-carcinogenic effects, they must be evaluated separately for both effects. The toxicity assessment is an evaluation of each COPC's potential to cause health effects based on available toxicological information.

Quantitative estimates of toxicity have been developed by EPA and other agencies; this section presents a summary of the toxicity values for each COPC. Additional information regarding the toxicity, pharmacokinetics, acute toxicity, chronic toxicity, and potential carcinogenicity of each COPC is presented in Attachment 6. According to a hierarchy provided by EPA (2003a, 2009j), the following sources were used to estimate risks to humans in the baseline HHRA:

- **Tier 1:** EPA's Integrated Risk Information System (IRIS) database
- **Tier 2:** EPA's Provisional Peer-Reviewed Toxicity Values (PPRTVs) (developed as requested by EPA's Superfund program by the Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center)
- **Tier 3:** Other toxicity values, including additional EPA and non-EPA sources. Sources included California EPA (Cal EPA), the Agency for Toxic Substances and Disease Registry (ATSDR), and EPA's 1997 Health Effects Assessment Summary Tables (HEAST) document. Toxicity values were selected from current sources that were publicly available, were peer-reviewed, and were transparent in the presentation of methods used.

For each COPC, both cancer and non-cancer risks were quantitatively evaluated when toxicity information was available. Cancer risks were estimated using an oral cancer SF or an inhalation unit risk factor; non-cancer risks were estimated using an oral RfD or an inhalation reference concentration (RfC). For each COPC, a search was conducted to identify

both cancer and non-cancer toxicity values. If no toxicity information was available, a similar chemical was used as a surrogate when an appropriate surrogate existed (e.g., ethylbenzene was used as a surrogate for n-propylbenzene).

The RfD and RfC are estimates of the daily exposure of the human population, including sensitive sub-populations, that is not predicted to result in deleterious effects during a lifetime. These toxicity values are presented in Tables 4-1 and 4-2. In developing toxicity values for non-carcinogenic effects, EPA reviews available data to identify the most sensitive endpoint and population (i.e., the effects that occur at the lowest concentration). These available data include effects on children and other sensitive sub-populations. COPCs may have additional adverse effects that occur at higher exposure levels. The uncertainty in the RfD and RfC estimates is perhaps an order of magnitude or greater (EPA 2010b), as shown by the uncertainty factors in Tables 4-1 and 4-2, which were used by EPA when deriving RfDs and RfCs to ensure that these values would be sufficiently conservative (i.e., health-protective).

Table 4-1. Non-Cancer Toxicity Data (Oral/Dermal) for COPCs

COPC[a]	Class	Oral RfD (mg/kg-day)	Critical Effect	UF	Source	Source Date[b]	Notes
Aluminum	metals	1	neurological effects	100	PPRTV	April 2009	
Antimony	metals	0.0004	longevity, blood glucose, and cholesterol	1,000	IRIS	7/20/2009	
Arsenic	metals	0.0003	hyperpigmentation, keratosis and possible vascular complications	3	IRIS	7/20/2009	based on inorganic arsenic
Barium	metals	0.2	nephropathy	300	IRIS	7/23/2009	
Cadmium	metals	0.001	significant proteinuria	10	IRIS	7/23/2009	selected RfD is applicable to exposure via food ingestion
Chromium	metals	1.5	none reported	100	IRIS	9/15/2011	based on chromium (III)[c]
Cobalt	metals	0.0003	decreased iodide uptake	300	PPRTV	April 2009	
Copper	metals	0.04	na	na	HEAST	April 2009	
Iron	metals	0.7	na	na	PPRTV	April 2009	
Manganese	metals	0.14	central nervous system effects (other effects include impairment of neurobehavioral function)	1	IRIS	7/20/2009	
Mercury	metals	0.0001	developmental neuropsychological impairment	10	IRIS	7/23/2009	based on methylmercury[d]
Nickel	metals	0.02	decreased body and organ weights	300	IRIS	7/23/2009	
Vanadium	metals	0.005	decreased hair cystine	na	EPA RSL user's guide	April 2009	RfD for vanadium and compounds; adapted from the RfD for vanadium pentoxide[e]
Zinc	metals	0.3	decrease in erythrocyte copper, zinc-superoxide dismutase activity in healthy adults	3	IRIS	7/23/09	
Naphthalene	PAHs	0.02	decreased mean terminal body weight in males	3,000	IRIS	7/21/2009	
1,4-Dichlorobenzene	other SVOCs	0.07	na	na	ATSDR	April 2009	

Table 4-1. Non-Cancer Toxicity Data (Oral/Dermal) for COPCs

COPC[a]	Class	Oral RfD (mg/kg-day)	Critical Effect	UF	Source	Source Date[b]	Notes
Total PCBs	PCBs	0.00002	ocular xudates, inflamed and prominent Meibomian glands, distorted growth; decreased antibody response	300	IRIS	7/20/2009	based on Aroclor 1254, the lowest and most protective RfD available for PCBs in IRIS
Total DDTs	pesticides	0.0005	liver lesions	100	IRIS	7/21/2009	
1,1-Dichloroethane	VOCs	0.2	increased urinary enzyme markers	3,000	PPRTV	April 2009	
1,2,4-Trimethylbenzene	VOCs	0.05	na	na	PPRTV	April 2009	provisional value
1,3,5-Trimethylbenzene	VOCs	0.05	na	na	PPRTV	April 2009	
Benzene	VOCs	0.004	decreased lymphocyte count	300	IRIS	7/20/2009	
Chlorobenzene	VOCs	0.02	histopathologic changes in liver	1,000	IRIS	7/20/2009	
cis-1,2-Dichloroethene	VOCs	0.01	na	na	PPRTV	April 2009	
Dichloromethane	VOCs	0.06	liver toxicity	100	IRIS	7/20/2009	
Ethylbenzene	VOCs	0.1	liver and kidney toxicity	1,000	IRIS	7/20/2009	
n-Propylbenzene	VOCs	0.1	liver and kidney toxicity	1,000	IRIS	7/20/2009	surrogate = ethylbenzene
Total xylenes	VOCs	0.2	decreased body weight, increased mortality	1,000	IRIS	7/20/2009	
trans-1,2-Dichloroethene	VOCs	0.02	na	na	IRIS	April 2009	
Vinyl chloride	VOCs	0.003	liver cell polymorphism	30	IRIS	7/20/2009	
TPH-gasoline (aliphatic)	TPH	0.3	reduced nerve connection velocity	na	PPRTV	Sept. 2009	EPA (2009f)
TPH-diesel (aliphatic)	TPH	0.01	liver, kidney, and hematologic effects	na	PPRTV	Sept. 2009	EPA (2009f)

[a] COPCs for which no RfD was available were excluded from this table. These COPCs include cPAH TEQ, tert-butyl methyl ether, and trichloroethene.

[b] The IRIS date is the date that the database was searched; the ATSDR, HEAST, EPA RSL table and PPRTV dates are the dates that the RSL tables or PPRTV reference documents (the sources of the ATSDR, HEAST, and PPRTV values) were updated.

[c] The toxicity value for trivalent chromium (chromium III), as opposed to hexavalent chromium (chromium VI), was used in this HHRA because there is no evidence to suggest that hexavalent chromium is present at the Study Area. Trivalent chromium occurs naturally in the environment and is an essential nutrient, while hexavalent chromium is produced as a result of industrial processes.

[d] Mercury is a COPC only for the Force Lake fish consumer scenario. The toxicity value for methylmercury was selected for use in this HHRA because the majority of mercury present in fish tissue is methylmercury (EPA 2000a).

[e] The RfD for vanadium and compounds was used in this HHRA. This RfD was adapted by EPA for use in the RSL tables by adjusting the vanadium pentaoxide RfD (0.009 mg/kg-day) by the difference in molecular weight. The molecular weight of vanadium is 56% of the molecular weight of vanadium pentoxide, and thus the RfD was scaled based on this factor (0.009 multiplied by 56%).

ATSDR – Agency for Toxic Substances and Disease Registry
COPC – contaminant of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
HEAST – Health Effects Assessment Summary Tables
IRIS – Integrated Risk Information System
na – not applicable or available
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PPRTV – Provisional Peer-Reviewed Toxicity Values
RfD – reference dose
RSL – regional screening level
SVOC – semivolatile organic compound
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons
UF – uncertainty factor
VOC – volatile organic compound

Table 4-2. Non-Cancer Toxicity Data (Inhalation) for COPCs

COPC[a]	Class	Inhalation RfC (mg/m^3)	Critical Effect	UF	Source	Source Date[b]	Notes
Arsenic	metals	0.000015	na	na	Cal EPA	April 2009	based on inorganic arsenic
Cobalt	metals	0.000006	respiratory tract irritation and decreased lung function	300	PPRTV	April 2009	
Manganese	metals	0.00005	impairment of neurobehavioral function	1,000	IRIS	7/20/2009	
Naphthalene	PAHs	0.003	nasal effects including hyperplasia and metaplasia in respiratory and olfactory epithelium	3,000	IRIS	7/21/2009	
1,4-Dichlorobenzene	other SVOCs	0.8	increased liver weights	100	IRIS	7/20/2009	
1,1-Dichloroethane	VOCs	0.5	kidney damage	1,000	RAIS	7/20/2009	
1,2,4-Trimethylbenzene	VOCs	0.007	decreased blood clotting time	3,000	IRIS	April 2009	
1,3,5-Trimethylbenzene	VOCs	0.006	na	na	PPRTV	April 2009	
Benzene	VOCs	0.03	decreased lymphocyte count	300	IRIS	7/20/2009	
Chlorobenzene	VOCs	0.05	na	na	PPRTV	April 2009	
Ethylbenzene	VOCs	1	developmental toxicity	300	IRIS	7/20/2009	
n-Propylbenzene	VOCs	1	developmental toxicity	300	IRIS	7/20/2009	surrogate = ethylbenzene
tert-Butyl methyl ether	VOCs	3	increased liver and kidney weights; increased severity of spontaneous renal lesions (females), and swollen periocular tissue (males and females)	100	IRIS	7/20/2009	
trans-1,2-Dichloroethene	VOCs	0.06	pulmonary capillary hyperemia, distention of the alveolar septum, and fatty degeneration of the liver	3,000	PPRTV	April 2009	
Vinyl chloride	VOCs	0.1	liver cell polymorphism	30	IRIS	7/20/2009	
Total xylenes	VOCs	0.1	impaired motor coordination (decreased rotarod performance)	300	IRIS	7/20/2009	
TPH-gasoline (aliphatic)	TPH	0.6	nasal epithelial cell hyperplasia	na	PPRTV	Sept. 2009	EPA (2009f)

[a] COPCs for which no RfC was available were excluded from this table. These COPCs include copper, cPAH TEQ, total PCBs, total DDTs, cis-1,2-dichloroethene, dichloromethane, and trichloroethene.

[b] The IRIS date is the date that the database was searched; the HEAST and PPRTV dates are the dates that the RSL tables or PPRTV reference documents (the sources of the HEAST and PPRTV values) were updated.

COPC – contaminant of potential concern
Cal EPA – California Environmental Protection Agency
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
HEAST – Health Effects Assessment Summary Tables
IRIS – Integrated Risk Information System
na – not applicable or available
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PPRTV – Provisional Peer-Reviewed Toxicity Values
RAIS – Risk Assessment Information System
RfC – reference concentration
RSL – regional screening level
SVOC – semivolatile organic compound
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons
UF – uncertainty factor
VOC – volatile organic compound

The SF and inhalation unit risk factor represent plausible upper-bound estimates of the probability of a carcinogenic response per unit intake of a COPC over a lifetime. EPA has recently updated the guidance for carcinogen risk assessment to emphasize consideration of the mode of action (e.g., mutagenesis) in the development of SFs (EPA 2005a). In general, the SF is based on a dose-response curve using available carcinogenic data for a given COPC. Mathematical models are used to extrapolate from high experimental doses to the low doses expected for human contact in the environment. The selection of the mathematical model for dose extrapolation (e.g., linear or nonlinear) is generally informed by the mode of action of the COPC (EPA 2005a).

As previously noted in Section 2.2.4, the cPAH TEQ is composed of individual compounds that have similar structures as well as a common mechanism of toxicity. Thus, the toxicity assessment is based on the group, rather than on an individual compound. The specific PAHs included in the cPAH group were presented in Table 2-5. The toxicity of multiple cPAHs is generally evaluated using the relative potency approach. This approach involves a comparison of the cancer-causing ability of a particular cPAH with a reference compound, benzo[a]pyrene (BaP), by means of a potency equivalency factor. A cPAH with a factor of 1.0 is assumed to have the same cancer-inducing potency as BaP. A cPAH with a factor of 0.5 would be assumed to have half the cancer-inducing potency of BaP, and so forth. Potency equivalency factors for cPAHs have been developed by Cal EPA (California EPA 1994) based on various toxicity endpoints and were presented in Table 2-5.

The cancer toxicity values used in this HHRA are summarized in Tables 4-3 and 4-4. In addition to toxicity values, Tables 4-3 and 4-4 present cancer weight-of-evidence descriptors, which are used to describe a chemical's cancer-causing potential in humans. EPA's 1986 guidelines (EPA 1986) used groups A through E to describe cancer-causing potential (i.e., group A for known human carcinogens through group E for evidence of non-carcinogenicity in humans). Under EPA's updated 2005 guidelines for carcinogen risk assessment, a narrative approach, rather than the 1986 alphanumeric categories, is used to characterize carcinogenicity. The five standard weight-of-evidence descriptors developed as part of the 2005 guidance are as follows: carcinogenic to humans, likely to be carcinogenic to humans, suggestive evidence of carcinogenic potential, inadequate information to assess carcinogenic potential, and not likely to be carcinogenic to humans. For COPCs for which no EPA descriptors are available, International Agency for Research on Cancer (IARC) carcinogen classifications were used when available.

Table 4-3. Cancer Toxicity Data (Oral/Dermal) for COPCs

COPC[a]	Class	Cancer Weight-of-Evidence Descriptor[b]	Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Source	Source Date[c]	Notes
Arsenic	metals	A	1.5	IRIS	7/20/2009	based on inorganic arsenic
Cobalt	metals	likely to be carcinogenic to humans	na	PPRTV	na	
Mercury	metals	C	na	IRIS	na	based on methylmercury[d]
Naphthalene	PAHs	C	na	IRIS	na	
cPAH TEQ	PAHs	B2	7.3	IRIS	7/20/2009	based on benzo(a)pyrene[e]
1,4-Dichlorobenzene	other SVOCs	2B (IARC)	0.0054	Cal EPA	April 2009	
Total PCBs	PCBs	B2	2	IRIS	7/20/2009	upper-bound slope factor used for this risk estimate
Total DDTs	pesticides	B2	0.34	IRIS	7/21/2009	
1,1-Dichloroethane	VOCs	C	0.0057	Cal EPA	April 2009	
Benzene	VOCs	A	0.055	IRIS	7/20/2009	
Dichloromethane	VOCs	B2	0.0075	IRIS	7/20/2009	
tert-Butyl methyl ether	VOCs	na	0.0018	Cal EPA	April 2009	
Trichloroethene	VOCs	2A (IARC)	0.13[f]	Cal EPA	April 2009	
Vinyl chloride (non-occupational exposure)	VOCs	A	1.5	IRIS	7/20/2009	based on continuous lifetime exposure from birth
Vinyl chloride (occupational exposure)	VOCs	A	0.72	IRIS	7/20/2009	based on continuous lifetime exposure during adulthood

[a] COPCs included in this table are either known, probable, or possible human carcinogens(see below). Cadmium and TPH, although considered to be potential carcinogens, are excluded from this table because they are carcinogens only via the inhalation pathway (see Table 4-4). In addition, n-propylbenzene was not evaluated for the carcinogenic oral or dermal pathways per EPA guidance (EPA 2009g).

[b] EPA's cancer weight-of-evidence descriptors (as presented in IRIS) were the primary classification used to describe carcinogenic potential. When available, the 2005 narrative descriptors were used; otherwise the 1986 alphanumeric descriptors were used. In addition, IARC classifications were used when no EPA descriptors were available. The 1986 alphanumeric EPA descriptors and IARC group classifications used in this table are as follows: A = known human carcinogen; B1 = probable human carcinogen (based on limited evidence of carcinogenicity in humans); B2 = probable human carcinogen (sufficient evidence in animals and inadequate or no evidence in humans); C = possible human carcinogen (limited evidence from animal studies and inadequate or no data in humans); D = not

classifiable as to human carcinogenicity; 2A = probably carcinogenic to humans; 2B = possibly carcinogenic to humans. The 2005 descriptors are narrative, and thus abbreviations are not used.

[c] The IRIS date is the date that the database was searched; the Cal EPA dates are the dates that the RSL tables (the sources of the Cal EPA values) were updated.

[d] Mercury is a COPC only for the Force Lake fish consumer scenario. The toxicity value for methylmercury was selected for use in this HHRA because the majority of mercury present in fish tissue is methylmercury (EPA 2000a).

[e] The cPAH TEQ sum was calculated based on potency equivalency factors, which relate the potency of the seven cPAHs in the Harbor Oil dataset to the most toxic of these PAHs (benzo(a)pyrene), as described in Section 2.2.4 and Cal EPA (1994). Thus, the benzo(a)pyrene toxicity value was used for cPAH TEQ.

[f] The inhalation unit risk factor for trichloroethene was adjusted upward by a factor of 10, as recommended by EPA Region 10 (EPA 2010c).

COPC – contaminant of potential concern
Cal EPA – California Environmental Protection Agency
cPAH – carcinogenic PAH
DDT – dichlorodiphenyltrichloroethane
EPA – US Environmental Protection Agency
IARC – International Agency for Research on Cancer
IRIS – Integrated Risk Information System na – not applicable or available
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RAIS – Risk Assessment Information System
RSL – regional screening level
SVOC – semivolatile organic compound
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

Table 4-4. Cancer Toxicity Data (Inhalation) for COPCs

COPC[a]	Class	Cancer Weight-of-Evidence Descriptor [b]	Inhalation Unit Risk Factor $(\mu g/m^3)^{-1}$	Source	Source Date[c]	Notes
Arsenic	metals	A	0.0043	IRIS	7/20/2009	based on inorganic arsenic
Cobalt	metals	likely to be carcinogenic to humans	0.009	PPRTV	April 2009	
Naphthalene	PAHs	C	3.4×10^{-5}	Cal EPA	April 2009	
cPAH TEQ	PAHs	B2	0.001	Cal EPA	April 2009	inhalation unit risk factor based on benzo(a)pyrene[d]
1,4-Dichlorobenzene	other SVOCs	2B (IARC)	1×10^{-5}	Cal EPA	April 2009	
Total PCBs	PCBs	B2	0.0001	IRIS	7/20/2009	Low risk and persistence; upper-bound unit risk factor
Total DDTs	pesticides	B2	9.7×10^{-5}	IRIS	7/21/2009	
1,1-Dichloroethane	VOCs	C	1.6×10^{-6}	Cal EPA	April 2009	
Benzene	VOCs	A	7.8×10^{-6}	IRIS	7/20/2009	
Dichloromethane	VOCs	B2	4.7×10^{-7}	IRIS	7/20/2009	
tert-Butyl methyl ether	VOCs	na	3×10^{-7}	Cal EPA	April 2009	
Trichloroethene	VOCs	2A (IARC)	2×10^{-5} [e]	Cal EPA	April 2009	
Vinyl chloride (non-occupational exposure)	VOCs	A	8.8×10^{-6}	IRIS	6/11/2010	based on continuous lifetime exposure from birth
Vinyl chloride (occupational exposure)	VOCs	A	4.4×10^{-6}	IRIS	6/11/2010	based on continuous lifetime exposure during adulthood
TPH-gasoline (aliphatic)	TPH	na	1.9×10^{-7}	PPRTV	Sept. 2009	EPA (2009f)

[a] COPCs included in this table are either known, probable, or possible human carcinogens (see below). In addition, ethylbenzene and n-propylbenzene were not evaluated for the carcinogenic inhalation pathway per EPA guidance (EPA 2009g).

[b] EPA's cancer weight-of-evidence descriptors (as presented in IRIS) were the primary classification used to describe carcinogenic potential. When available, the 2005 narrative descriptors were used; otherwise the 1986 alphanumeric descriptors were used. Additionally, IARC classifications were used when no EPA descriptors were available. The 1986 alphanumeric EPA descriptors and IARC group classifications used in this table are as follows: A = known human carcinogen; B1 = probable human carcinogen (based on limited evidence of carcinogenicity in humans); B2 = probable human carcinogen (sufficient evidence in animals and inadequate or no evidence in humans); C = possible human carcinogen (limited evidence from animal studies and inadequate or no data in humans); D = not classifiable as to human carcinogenicity; 2A = probably carcinogenic to humans; 2B = possibly carcinogenic to humans. The 2005 descriptors are narrative, and thus abbreviations are not used.

[c] The IRIS date is the date that the database was searched, the Cal EPA dates are the dates that the RSL tables (the sources of the Cal EPA values) were updated, and the PPRTV date is the date that the document was updated.

[d] The cPAH TEQ sum is calculated based on potency equivalency factors, which relate the potency of the seven cPAHs in the Harbor Oil dataset to the most toxic of these PAHs (benzo(a)pyrene), as described in Section 2.2.4 and Cal EPA (1994). Thus, the benzo(a)pyrene toxicity value was used for cPAH TEQ.

[e] The inhalation unit risk factor for trichloroethene was adjusted upward by a factor of 10, as recommended by EPA Region 10 (EPA 2010c).

COPC – contaminant of potential concern
Cal EPA – California Environmental Protection Agency
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
EPA – US Environmental Protection Agency
IARC – International Agency for Research on Cancer
IRIS – Integrated Risk Information System
na – not applicable or available
PCB – polychlorinated biphenyl
PPRTV – Provisional Peer-Reviewed Toxicity Value
RAIS – Risk Assessment Information System
RSL – regional screening level
SVOC – semivolatile organic compound
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

In addition, the non-cancer toxicological endpoints that were used to establish the RfDs and RfCs are summarized in Table 4-5. It should be noted that COPCs may have adverse effects other than the endpoints identified in Table 4-5 because these effects occur at higher doses than the doses represented by the RfD or RfC. For example, although not identified as a critical effect for the development of the RfD for PCBs (or PCB Aroclors) in IRIS (the critical endpoint for PCBs was the immune system), nervous system effects, particularly neurodevelopmental effects, are well documented across a range of PCB exposure levels (ATSDR 2000; Longnecker et al. 2003).

Table 4-5. Toxicological Endpoints by Exposure Pathway for COPCs with Non-Carcinogenic Effects

COPC	Body Weight	Cardiovascular System	Dermal	Development	Endocrine System	Eyes	Hematologic System	Immune System	Kidney	Liver	Nervous System	Nose	Reproductive System	Respiratory System
Metals														
Aluminum[a]											RfD			
Antimony[a]					O/D		O/D							
Arsenic[b]		O/D	O/D											
Barium[a]									O/D					
Cadmium[a]									O/D					
Chromium[c]														
Cobalt							O/D							I
Copper[c]														
Iron[a, c]														
Manganese											O/D, I			
Mercury[a]				O/D							O/D			
Nickel[a]	O/D				O/D				O/D	O/D				
Vanadium[a]			O/D											
Zinc[a]							O/D							
Other SVOCs														
1,4-Dichlorobenzene[c]										I				
PAHs														
Naphthalene	O/D											I		I
cPAH TEQ[d]														
PCBs														
Total PCBs				O/D				O/D						

Table 4-5. Toxicological Endpoints by Exposure Pathway for COPCs with Non-Carcinogenic Effects

COPC	Body Weight	Cardiovascular System	Dermal	Development	Endocrine System	Eyes	Hematologic System	Immune System	Kidney	Liver	Nervous System	Nose	Reproductive System	Respiratory System
Pesticides														
Total DDTs										O/D				
VOCs														
1,1-Dichloroethane									O/D, I					
1,4-Dichlorobenzene										I				
1,2,4-Trimethylbenzene[c]							I							
1,3,5-Trimethylbenzene[b,c]														
Benzene								O/D, I						
Chlorobenzene[b]										O/D,				
cis-1,2-Dichloroethene														
Dichloromethane										O/D				
Ethylbenzene				I					O/D	O/D				
n-Propylbenzene				I					O/D	O/D				
tert-Butyl methyl ether									I	I				
trans-1,2-Dichloroethene		I								I				I
Trichloroethene[d]														
Vinyl chloride										O/D, I				
Total xylenes	O/D										I			
Petroleum Hydrocarbons														
TPH-gasoline (aliphatic)											O/D	I		
TPH-diesel (aliphatic)[a]							O/D		O/D	O/D				

Note: Each of these COPCs will likely have additional toxic effect endpoints at exposures above the RfD or RfC. The toxicological profile section of the HHRA (Attachment 6) may be consulted by readers who desire more information on toxic effect endpoints.

[a] Not a COPC for the industrial (construction/trenching scenario) and thus not evaluated based on the inhalation pathway. Therefore, no RfC effects are noted for these COPCs in this table.

[b] No information was available regarding the RfC endpoint for this COPC.

[c] No information was available regarding the RfD endpoint for this COPC.

[d] No RfC or RfD was available for this COPC.

[e] Nervous system effects for PCBs were not identified in IRIS for development of the RfD, but such effects, particularly neurodevelopmental effects, are well documented (ATSDR 2000).

ATSDR – Agency for Toxic Substances and Disease Registry

COPC – contaminant of potential concern

cPAH – carcinogenic polycyclic aromatic hydrocarbon

DDT – dichlorodiphenyltrichloroethane

I – inhalation exposure; indicates the RfC for a particular COPC was based on the identified endpoint

O/D – oral and dermal exposure; indicates the RfD for a particular COPC was based on the identified endpoint

PAH – polycyclic aromatic hydrocarbon

PCB – polychlorinated biphenyl

SVOC – semivolatile organic compound

TEQ – toxic equivalent

TPH – total petroleum hydrocarbons

VOC – volatile organic compound

5.0 RISK CHARACTERIZATION

This section summarizes the approach for calculating risk estimates and presents the quantitative risk characterization results for the HHRA. In this step of the HHRA, risks were quantified by combining the results of the exposure assessment (Section 3) with the results of the toxicity assessment (Section 4).

These estimates characterize risks to people who could be exposed to COPCs present at the Study Area and identify contaminants of concern (COCs), which are defined here as COPCs with an excess cancer risk estimate greater than 1×10^{-6} or a non-cancer HQ greater than 1 for any RME scenario. 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 through exposure to COPCs at the Study Area averaged over a 70-year lifetime.

Excess cancer risks greater than 1×10^{-6} do not necessarily indicate unacceptable risks; EPA's target risk range is between 1×10^{-6} and 1×10^{-4}. However, as a health-protective approach consistent with EPA guidance, risks greater than the lower end of this target risk range (i.e., above 1×10^{-6}) were identified in this HHRA.

This section also identifies COCs with the greatest contributions to the total risk estimates. In addition to the scenarios summarized in this section, a screening level assessment was done to assess risks based on residential exposure. The screening assessment for hypothetical future residents indicated that excess cancer risks would likely be greater than the upper end of EPA's target risk range (10^{-4}) and some chemicals would have an HQ greater than 1 based on the comparison of Study Area concentrations with regional screening levels (Attachment 1).

5.1 Risk Estimate Calculations

This section presents the equations that were used to calculate risks for the baseline HHRA. Carcinogenic and non-carcinogenic risks were evaluated separately. In addition, risks from exposure to lead were estimated using the IEUBK (EPA 1994, 2007b) and the ALM (EPA 2003b), rather than the equations presented in this section.

5.1.1 Carcinogenic Risks

Cancer risks are expressed as an excess lifetime cancer risk (i.e., the increased risk that an individual will develop cancer in his or her lifetime based on exposure to concentrations at the Study Area). Excess cancer risks are expressed as a probability in scientific notation (e.g., 1×10^{-6},

which is equivalent to 0.000001 or 1 in 1,000,000). Per EPA guidance (1989), only one significant figure is used when presenting excess cancer risks because of the uncertainty in cancer SFs and the parameters used to quantify risk. Equation 5-1 presents the method used to calculate carcinogenic risks for oral and dermal exposure, and Equation 5-2 presents the method used to calculate carcinogenic risks for inhalation exposure.

$$\text{Risk} = \text{CDI} \times \text{SF}$$ **Equation 5-1**

Where:

Risk	unitless	COPC-specific lifetime excess cancer risk
CDI	mg/kg-day	COPC-specific chronic daily intake rate
SF	$(\text{mg/kg-day})^{-1}$	route- and COPC-specific cancer slope factor

$$\text{Risk} = \text{EC} \times \text{IUR}$$ **Equation 5-2**

Where:

Risk	unitless	COPC-specific lifetime excess cancer risk
EC	$\mu g/m^3$	time-weighted COPC-specific inhalation exposure concentration
IUR	$(\mu g/m^3)^{-1}$	COPC-specific inhalation unit risk

Cancer risks for individual COPCs are summed for each exposure pathway to determine the overall lifetime excess cancer risk associated with a given exposure scenario at the Study Area. For the recreational scenarios, which include exposure durations from birth to the age of 30, a calculation was performed to integrate risk estimates for three age groups (0 to 6, 7 to 16, and 17 to 30 years of age) to account for the different age-specific exposure parameters (e.g., body weight and surface area) for these age groups. Because excess cancer risk estimates are probabilities of an individual's increased cancer risk, the integrated lifetime risk estimate was calculated as the sum of risk estimates for the three age groups. Thus, the method used to calculate the cancer risk for the recreational scenarios is somewhat different than the method used to calculate excess cancer risk for the worker scenarios summarized in Sections 5.3.1, 5.3.2, and 5.3.3, which were all based on adult exposures only. For risks to children from COPCs with mutagenic modes of action,[11] EPA provides additional guidance because of the increased susceptibility of children and young adults to these contaminants (EPA 2005b). In this HHRA, cPAH TEQ is the only COPC that falls into this category. Risks to children from cPAH TEQ will be calculated as follows per EPA guidance: the slope factor will be multiplied by a factor of 10 for children aged 0 to 2, and by a factor of 3 for children aged 3 to 16. These factors account for the potentially higher susceptibility of young children to contaminants with mutagenic modes of action. Equation 5-3 presents the method used to calculate the excess cancer risk estimate for mutagens for oral and dermal exposure.

[11] A mutagen is a chemical that is capable of causing a mutation (i.e., a change in genetic structure).

$$\text{Risk} = \left(\text{CDI}_{\text{age0-2}} \times (\text{SF} \times 10)\right) + \left(\text{CDI}_{\text{age3-6}} \times (\text{SF} \times 3)\right) + \left(\text{CDI}_{\text{age7-16}} \times (\text{SF} \times 3)\right) + \left(\text{CDI}_{\text{age17-30}} \times \text{SF}\right)$$

Equation 5-3

Where:

Risk	unitless	COPC-specific lifetime excess cancer risk
CDI	mg/kg-day	COPC-specific chronic daily intake rate based on the exposure duration for each age group (i.e., 6 years for age 0 to 6, 10 years for age 7 to 16, and 14 years for age 17 to 30)
SF	$(\text{mg/kg-day})^{-1}$	route- and COPC-specific cancer slope factor

It should be noted that a similar equation to calculate risks via inhalation exposure is not presented because the scenarios evaluated for child and/or lifetime risks (i.e., the Force Lake recreational and Force Lake fish consumer scenarios) do not include exposure via inhalation (as discussed in Section 3.1). Only the worker scenarios, which are evaluated only for adults, include risks based on inhalation exposure.

5.1.2 Non-Carcinogenic Risks

Non-cancer risks are expressed as an HQ, which is the ratio of the exposure dose to the COPC-specific RfD or RfC. Non-cancer risks are exceedance ratios, not probabilities. An HQ greater than 1 indicates that the exposure dose is greater than the toxicity threshold, and thus adverse effects may occur. Equation 5-4 presents the method used to calculate non-carcinogenic risks for oral and dermal exposure, and Equation 5-5 presents the method used to calculate non-carcinogenic risks for inhalation exposure.

$$\text{HQ} = \frac{\text{CDI}}{\text{RfD}}$$

Equation 5-4

Where:

HQ	unitless	hazard quotient
CDI	mg/kg-day	COPC-specific chronic daily intake rate
RfD	mg/kg-day	route- and COPC-specific reference dose

$$\text{HQ} = \frac{\text{EC}}{\text{RfC} \times \text{CF}}$$

Equation 5-5

Where:

HQ	unitless	hazard quotient
EC	$\mu g/m^3$	time-weighted COPC-specific inhalation exposure concentration
RfC	mg/m^3	COPC-specific reference concentration
CF	µg/mg	conversion factor (equal to 1,000)

Unlike excess cancer risks, HQs were not summed across age groups because non-cancer risks are not expressed as probabilities. The recreational scenarios include an exposure duration of 30 years, from birth to the age of 30. There are important behavioral, physiological, and

toxicological differences between children and adults that may cause children, particularly children under the age of 6, to be more exposed to some environmental contaminants (EPA 2008b). Thus, it is important to present the non-cancer risks to young children separately from older children and adults. Because HQs for the 0 to 6 age group were higher than HQs for older children and adults, decisions on the need for remediation are typically based on the HQs for the 0 to 6 age group. For risk communication purposes, however, it is useful to also present non-cancer HQs for the entire 30-year exposure duration, reflecting both childhood and adult exposure. Because the HQs across different age groups are not additive, an integrated HQ was calculated using the age group-specific HQs (i.e., 0 to 6, 7 to 16, and 17 to 30 years). Equation 5-6 presents the method for calculating the combined 0-to-30 year HQ, where the averaging time used in the CDI equations for each age group is based on the total exposure duration of 30 years (365 days × 30 years = 10,950 days).[12]

$$HQ = \left(\frac{CDI_{age0\text{-}6} + CDI_{age7\text{-}16} + CDI_{age17\text{-}30}}{RfD} \right)$$ **Equation 5-6**

Where:

HQ	unitless	weighted average hazard quotient for age classes ranging from 0 to 30 years
CDI	mg/kg-day	COPC-specific chronic daily intake rate based on the exposure duration for each age group (i.e., 6 years for age 0 to 6, 10 years for age 7 to 16, and 14 years for age 17 to 30) using the overall scenario averaging time of 30 years
RfD	mg/kg-day	COPC-specific reference dose

As noted above, the HQs for the entire 30-year exposure duration are presented for risk communication purposes only, and are not typically used for risk management decisions.

HQs for COPCs with similar toxicological effects (e.g., neurological damage) can be summed to calculate endpoint-specific hazard indices (HIs). If the overall HI was greater than 1 for a given scenario or exposure area, endpoint-specific HIs were calculated by summing the HQs for COPCs with common toxicological endpoints (e.g., all HQs calculated for the developmental endpoint).

5.2 Risk Characterization Format

Excess cancer risks and HQs are presented according to the format recommended in EPA (1998). The primary purpose of the HHRA is to characterize risks from COPCs at the Study Area in support of risk management decisions and remedial options. Risk estimates also provide

[12] Note that the CDIs calculated for each age group (i.e., 0 to 6, 7 to 16, and 17 to 30) in Equation 5-6 use the overall scenario averaging time of 30 years (10,950 days), which allows for the calculation of the average weighted HQ. These CDIs are different than those used to calculate non-cancer HQs for individual age groups or to calculate excess cancer risks, for which the averaging time for each age group is used.

information to the public about what their health risks may be from engaging in different activities associated with the Study Area (e.g., worker scenarios and Force Lake recreation scenarios).

Excess cancer risks are summed for all COPCs within each exposure scenario. Exposure scenarios in which the same receptor is exposed via multiple pathways simultaneously were addressed by summing the RME estimates for those pathways. This approach was applied to all direct sediment exposure scenarios that involved dermal absorption, incidental ingestion, and inhalation. In addition, excess cancer risk estimates were summed across media for scenarios assuming exposure to multiple media (e.g., facility soil and groundwater for the industrial [construction/trenching] worker RME scenario). For some combinations of exposure media, the highest risk estimate may be several orders of magnitude higher than those for the other media. The resulting risk estimate for the combination of multiple scenarios may then differ only slightly or not at all from the risk estimate for the RME scenario alone.

In this section, CDIs are presented with two significant figures; excess cancer risks and HQs are presented with only one significant figure. Sums of excess cancer risk estimates are reported with one significant figure as well. For example, the sum of excess risk estimates of 2×10^{-4} and 3×10^{-5} would be reported as 2×10^{-4}, not 2.3×10^{-4}. The overall HI and endpoint-specific HIs (sums of HQs for individual COPCs with similar toxicological endpoints) are presented with one significant figure if they are less than 1, or to the nearest integer if they are greater than 1. This is to allow the reader to follow summations. For example, HQs of 4 and 10 would be summed to equal 14, not 10. However, HQs of 0.01 and 0.001 would be summed to equal 0.01, not 0.011.

5.3 Risk Characterization Results

This section presents the results for each exposure scenario quantified in the baseline HHRA for the Study Area:

- **Industrial (construction/trenching) worker RME scenario:** Cancer and non-cancer risks for exposure to Facility soil and groundwater are presented in Section 5.3.1.
- **Future outdoor worker RME scenario:** Cancer and non-cancer risks for exposure to Facility soil are presented in Section 5.3.2.
- **Industrial/commercial worker vapor intrusion scenario:** Per EPA direction, risks were calculated using EPA screening levels (2002c). These screening levels for the COPCs identified as part of this scenario are based on carcinogenic risks, and thus non-cancer HQs were not calculated.
- **Force Lake recreational user RME scenario:** Cancer and non-cancer risks for exposure to wetland soil, lake sediment, and lake surface water are presented in Section 5.3.4.

- **Force Lake fish consumer RME scenario:** Cancer and non-cancer risks for exposure to fish tissue are presented in Section 5.3.5.

For those scenarios with excess cancer risk estimates greater than 1×10^{-6} or with endpoint-specific HIs greater than 1, risks estimates based on background or reference area[13] concentrations are also discussed. In addition to these scenarios, Attachment 1 discusses the results of the screening assessment for hypothetical future residents.

5.3.1 Industrial (Construction/Trenching) Worker

This section presents cancer and non-cancer risks to workers through exposure to Facility soil and groundwater during construction or trenching activities (Tables 5-1 through 5-4). Excess cancer risks were greater than 1×10^{-6} for exposure to Facility soil, but not to groundwater. The total non-cancer HQ was less than 1 based on exposure to Facility soil or groundwater.

[13] 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 (i.e., urban areas in the vicinity of the Study Area) are presented for comparison with Study Area concentrations.

Table 5-1. Excess Cancer Risk Estimates for the Industrial (Construction/Trenching) Worker Scenario Based on Exposure to Facility Soil

Scenario timeframe: Current/future
Medium: Facility soil
Receptor population: Workers
Receptor age: Adult

COPC	EPC (mg/kg dw)	Cancer CDI (mg/kg-day)		Cancer EC (µg/m^3)	Cancer Slope Factor (mg/kg-day)$^{-1}$	Inhalation Unit Risk Factor (µg/m^3)$^{-1}$	Excess Cancer Risk			
		Incidental Ingestion	Dermal Absorption	Inhalation			Incidental Ingestion	Dermal Absorption	Inhalation	Total
Arsenic	8.3	3.8×10^{-7}	1.1×10^{-7}	5.1×10^{-9}	1.5	0.0043	6×10^{-7}	2×10^{-7}	2×10^{-11}	8×10^{-7}
Cobalt	13	6.0×10^{-7}	6.0×10^{-8}	8.0×10^{-9}	na	0.009	na[a]	na[a]	7×10^{-11}	7×10^{-11}
cPAH TEQ	0.95	4.4×10^{-8}	5.7×10^{-8}	5.9×10^{-10}	7.3	0.001	3×10^{-7}	4×10^{-7}	6×10^{-13}	7×10^{-7}
Naphthalene	2.0	9.2×10^{-8}	1.2×10^{-7}	6.1×10^{-7}	na	3.4×10^{-5}	na[a]	na[a]	2×10^{-11}	2×10^{-11}
Total PCBs	3.4	1.6×10^{-7}	2.2×10^{-7}	8.5×10^{-9}	2	0.0001	3×10^{-7}	4×10^{-7}	9×10^{-13}	7×10^{-7}
Total DDTs	11	5.1×10^{-7}	1.5×10^{-7}	6.8×10^{-9}	0.34	9.7×10^{-5}	2×10^{-7}	5×10^{-8}	7×10^{-13}	3×10^{-7}
1,1-Dichloroethane	0.68	3.1×10^{-8}	na[b]	1.4×10^{-4}	0.0057	1.6×10^{-6}	2×10^{-10}	na[b]	2×10^{-10}	4×10^{-10}
Benzene	0.33	1.5×10^{-8}	na[b]	4.9×10^{-5}	0.055	7.8×10^{-6}	8×10^{-10}	na[b]	4×10^{-10}	1×10^{-9}
Dichloromethane	0.02	9.2×10^{-10}	na[b]	4.2×10^{-6}	0.0075	4.7×10^{-7}	7×10^{-12}	na[b]	2×10^{-12}	9×10^{-12}
Ethylbenzene	1.9	8.8×10^{-8}	na[b]	na[c]	0.011	na	1×10^{-9}	na[b]	na[c]	1×10^{-9}
Trichloroethene	0.16	7.4×10^{-9}	na[b]	1.5×10^{-5}	0.13	2×10^{-5}	1×10^{-9}	na[b]	3×10^{-10}	1×10^{-9}
Vinyl chloride	1.2	5.5×10^{-8}	na[b]	1.7×10^{-3}	0.72	4.4×10^{-6}	4×10^{-8}	na[b]	8×10^{-9}	5×10^{-8}
TPH-gasoline (aliphatic)	430	2.0×10^{-5}	na[b]	1.5×10^{-1}	na	1.9×10^{-7}	na[a]	na[a]	3×10^{-8}	3×10^{-8}
Total excess cancer risk across exposure routes										**3×10^{-6}**

[a] No cancer slope factor is available, and thus the excess cancer risk based on incidental ingestion and dermal absorption cannot be calculated.
[b] No dermal absorption factor is available for this COPC. Dermal exposure for this COPC is discussed in the uncertainty analysis (Section 6.0).
[c] Per EPA guidance, the carcinogenic risk from the inhalation pathway was not assessed for ethylbenzene (EPA 2010c).

CDI – chronic daily intake
COPC – contaminant of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EC – exposure concentration
EPA – US Environmental Protection Agency
EPC – exposure point concentration
na – not applicable or available
PCB – polychlorinated biphenyl
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons

Table 5-2. Excess Cancer Risk Estimates for the Industrial (Construction/Trenching) Worker Scenario Based on Exposure to Groundwater

Scenario timeframe: Current/future
Medium: Groundwater
Receptor population: Workers
Receptor age: Adult

COPC	EPC (mg/kg dw)	Cancer CDI for Dermal Absorption (mg/kg-day)	Cancer EC for Inhalation ($\mu g/m^3$)	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Inhalation Unit Risk Factor $(\mu g/m^3)^{-1}$	Excess Cancer Risk		
						Dermal Absorption	Inhalation	Total
Arsenic (total)[a]	0.015	2.9×10^{-8}	na[b]	1.5	na[b]	4×10^{-8}	na[b]	4×10^{-8}
Naphthalene	0.00033	1.9×10^{-7}	2.8×10^{-10}	na	3.4×10^{-5}	na[d]	9×10^{-15}	9×10^{-15}
1,4-Dichlorobenzene	0.0014	1.9×10^{-7}	1.7×10^{-9}	0.0054	1×10^{-5}	1×10^{-9}	2×10^{-14}	1×10^{-9}
Total DDTs	0.000049	1.1×10^{-7}	1.5×10^{-12}	0.34	9.7×10^{-5}	4×10^{-8}	2×10^{-16}	4×10^{-8}
Benzene	0.039	na[c]	4.8×10^{-8}	0.055	7.8×10^{-6}	na[c]	4×10^{-13}	4×10^{-13}
tert-Butyl methyl ether	0.028	na[c]	2.9×10^{-8}	0.0018	3×10^{-7}	na[c]	9×10^{-15}	9×10^{-15}
Vinyl chloride	0.0005	na[c]	8.1×10^{-11}	0.72	4.4×10^{-6}	na[c]	4×10^{-16}	4×10^{-16}
Total excess cancer risk across exposure routes								**8×10^{-8}**

[a] Both the total and dissolved fraction were greater than the screening level. To be conservative, the total fraction was assessed in this HHRA because it is slightly higher than the dissolved fraction.

[b] This COPC is not expected to volatilize significantly because of its diffusivity in air or water, and thus risks based on inhalation are not assessed here.

[c] No dermal absorption factor is available for this COPC. Dermal exposure for this COPC is discussed in the uncertainty analysis (Section 6.0).

[d] No cancer slope factor is available for this COPC, and thus the excess cancer risk based on dermal absorption cannot be calculated.

CDI – chronic daily intake
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EC – exposure concentration
EPC – exposure point concentration
HHRA – human health risk assessment
na – not applicable or available

Table 5-3. Non-Cancer Hazard Estimates for the Industrial (Construction/Trenching) Worker Scenario Based on Exposure to Facility Soil

Scenario timeframe: Current/future
Medium: Facility soil
Receptor population: Workers
Receptor age: Adult

COPC	EPC (mg/kg dw)	Non-Cancer CDI (mg/kg-day)		Non-Cancer EC for Inhalation (µg/m^3)	Reference Dose (mg/kg-day)	Reference Concentration (mg/m^3)	Hazard Quotient			
		Incidental Ingestion	Dermal Absorption				Incidental Ingestion	Dermal Absorption	Inhalation	Total
Arsenic	8.3	2.7×10^{-5}	8.0×10^{-6}	3.6×10^{-7}	0.0003	0.000015	0.09	0.03	0.00002	0.1
Cobalt	13	4.2×10^{-5}	na[a]	5.6×10^{-7}	0.0003	0.000006	0.1	na[a]	0.00009	0.1
Copper	270	8.7×10^{-4}	na[a]	1.2×10^{-5}	0.04	na	0.02	na[a]	na[b]	0.02
Naphthalene	2.0	6.5×10^{-6}	8.4×10^{-6}	4.3×10^{-5}	0.02	0.003	0.0003	0.0004	0.00001	0.0007
Total PCBs	3.4	1.1×10^{-5}	1.5×10^{-5}	6.0×10^{-7}	0.00002	na	0.5	0.8	na[b]	1
Total DDTs	11	3.6×10^{-5}	1.1×10^{-5}	4.8×10^{-7}	0.0005	na	0.07	0.02	na[b]	0.09
1,1-Dichloroethane	0.68	2.2×10^{-6}	na[a]	9.7×10^{-3}	0.2	0.5	0.00001	na[a]	0.00002	0.00003
1,2,4-Trimethylbenzene	5.3	1.7×10^{-5}	na[a]	1.1×10^{-4}	0.05	0.007	0.0003	na[a]	0.00002	0.0003
1,3,5-Trimethylbenzene	1.3	4.2×10^{-6}	na[a]	2.8×10^{-5}	0.05	0.006	0.00008	na[a]	0.000005	0.00009
Benzene	0.33	1.1×10^{-6}	na[a]	3.4×10^{-3}	0.004	0.03	0.0003	na[a]	0.0001	0.0004
Chlorobenzene	0.22	7.1×10^{-7}	na[a]	2.7×10^{-3}	0.02	0.05	0.00004	na[a]	0.00005	0.00009
cis-1,2-Dichloroethene	8.7	2.8×10^{-5}	na[a]	8.6×10^{-2}	0.01	na	0.003	na[a]	na[b]	0.003
Dichloromethane	0.02	6.5×10^{-8}	na[a]	3.0×10^{-4}	0.06	na	0.000001	na[a]	na[b]	0.000001
Ethylbenzene	1.9	6.1×10^{-6}	na[a]	4.5×10^{-3}	0.1	1	0.00006	na[a]	0.000005	0.00007
trans-1,2-Dichloroethene	5.5	1.8×10^{-5}	na[a]	8.0×10^{-2}	0.02	0.06	0.0009	na[a]	0.001	0.002
Vinyl chloride	1.2	3.9×10^{-6}	na[a]	1.2×10^{-1}	0.003	0.1	0.001	na[a]	0.001	0.002
Total xylenes	10	3.2×10^{-5}	na[a]	3.0×10^{-2}	0.2	0.1	0.0002	na[a]	0.0003	0.0005
TPH-gasoline (aliphatic)	430	1.4×10^{-3}	na[a]	1.1×10^{1}	0.3	0.6	0.005	na[a]	0.02	0.02
Overall HI across all exposure routes/pathways[c]										**1**

[a] No dermal absorption factor is available for this COPC. Dermal exposure for this COPC is discussed in the uncertainty analysis (Section 6.0).

[b] No RfC is available for these COPCs, and thus HQs from inhalation cannot be calculated.

[c] The overall HI is equal to the sum of HQs for all COPCs across multiple endpoints and/or target organs. If the overall HI did not exceed 1, then endpoint-specific HIs were not calculated because they would be less than 1 as well.

CDI – chronic daily intake
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EC – exposure concentration
EPC – exposure point concentration
HI – hazard index
HQ – hazard quotient
na – not applicable or available
PCB – polychlorinated biphenyl
RfC – reference concentration
TPH – total petroleum hydrocarbons

Table 5-4. Non-Cancer Hazard Estimates for the Industrial (Construction/Trenching) Worker Scenario Based on Exposure to Groundwater

Scenario timeframe: Current/future
Medium: Groundwater
Receptor population: Workers
Receptor age: Adult

COPC	EPC (mg/kg dw)	Non-Cancer CDI for Dermal Absorption (mg/kg-day)	Non-Cancer EC for Inhalation (μg/m^3)	Reference Dose (mg/kg-day)	Reference Concentration (mg/m^3)	Hazard Quotient		
						Dermal Absorption	Inhalation	Total
Arsenic (total)[a]	0.015	2.1×10^{-6}	na[b]	0.0003	0.000015	0.007	na[b]	0.007
Manganese (total)[a]	4.0	na[c]	na[b]	0.14	0.000006	na[c]	na[b]	na
Naphthalene	0.00033	1.4×10^{-5}	1.9×10^{-8}	0.02	0.003	0.0007	0.000000006	0.0007
1,4-Dichlorobenzene	0.0014	1.4×10^{-5}	1.2×10^{-7}	0.07	0.8	0.0002	0.0000000001	0.0002
Total DDTs	0.000049	8.0×10^{-6}	1.1×10^{-10}	0.0005	na	0.02	na[b]	0.02
1,2,4-Trimethylbenzene	0.0072	na[c]	4.3×10^{-7}	0.05	0.007	na[c]	0.00000006	0.00000006
1,3,5-Trimethylbenzene	0.003	na[c]	1.8×10^{-7}	0.05	0.006	na[c]	0.00000003	0.00000003
Benzene	0.039	na[c]	3.4×10^{-6}	0.004	0.03	na[c]	0.0000001	0.0000001
Chlorobenzene	0.08	na[c]	6.3×10^{-6}	0.02	0.05	na[c]	0.0000001	0.0000001
n-Propylbenzene	0.011	na[c]	7.4×10^{-7}	0.1	1	na[c]	0.0000000007	0.0000000007
tert-Butyl methyl ether	0.028	na[c]	2.1×10^{-6}	na	3	na[c]	0.0000000007	0.0000000007
Vinyl chloride	0.0005	na[c]	5.7×10^{-9}	0.003	0.1	na[c]	0.00000000006	0.00000000006
Overall HI across all exposure routes/pathways[d]								**0.03**

[a] Both the total and dissolved fraction were greater than the screening level. As a conservative assumption, the total fraction was assessed in this HHRA because it is slightly higher than the dissolved fraction.

[b] This COPC is not expected to volatilize significantly because of its diffusivity in air or water, and thus risks based on inhalation are not assessed here.

[c] No dermal absorption factor is available for this COPC. Dermal exposure for this COPC is discussed in the uncertainty analysis (Section 6.0).

[d] The overall HI is equal to the sum of HQs for all COPCs across multiple endpoints and/or target organs. If the overall HI did not exceed 1, then endpoint-specific HIs were not calculated because they would be less than 1 as well.

CDI – chronic daily intake
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EC – exposure concentration
EPC – exposure point concentration
HHRA – human health risk assessment
HI – hazard index
HQ – hazard quotient
na – not applicable or available
RfC – reference concentration

While no individual COPCs had an excess cancer risk greater than 1×10^{-6}, the estimated total excess cancer risk was equal to 3×10^{-6}. Cancer risk estimates for arsenic, cPAH TEQ, and total PCBs together accounted for over 80% of the total excess cancer risk (Table 5-1). The total PCB HQ based on exposure to soil was equal to, but not greater than 1. No COPCs had non-cancer HQs greater than 1. Based on the risk estimates and HQs, no COCs were identified for this scenario.

In addition to evaluating risks separately by media, the risks presented in Tables 5-1 through 5-4 can be combined based on exposure to both soil and groundwater. Table 5-5 presents these total risk estimates for this scenario.

Table 5-5. Excess Cancer Risk Estimates Across Scenarios

Scenario	Excess Cancer Risk	Hazard Quotient
Exposure to Facility soil	3×10^{-6}	1
Exposure to groundwater	8×10^{-8}	0.03
Total risk estimate across media	**3×10^{-6}**	**1**

As shown in Table 5-5, the total excess cancer risk was equal to 3×10^{-6}, attributable almost entirely to exposure to Facility soil. The overall HI was equal to, but did not exceed 1, and thus endpoint-specific HIs were not calculated.

To further evaluate the total excess cancer risk based on exposure to Facility soil, background or reference area excess cancer risks for the industrial (construction/trenching) worker based on exposure to Facility soil were calculated (Table 5-6). Background or reference area risk estimates were calculated for those COPCs contributing the majority of the risk (shown as excess cancer risk in Table 5-6). The background soil concentrations used for this comparison were based on recommended DEQ default background concentrations for metals. For other organic compounds, reference area soil concentrations were based on concentrations reported at nearby sites (Attachment 7); specific regulatory background soil concentrations have not been established. Risks from groundwater are shown in this table for completeness, but an evaluation of background or reference area groundwater risks was not conducted because of the low risks calculated based on exposure to this medium.

Table 5-6. Comparison of Study Area and Background or Reference Area Soil Exposure Concentrations and Risk Estimates for the Industrial (Construction/Trenching) Worker RME Scenario

Media	COPC	Soil Exposure Concentration (mg/kg dw)		Excess Cancer Risk	
		Study Area	Background or Reference Area[a]	Study Area	Background or Reference Area[a]
Facility Soil	Arsenic	8.3	7	8×10^{-7}	6×10^{-7}
	cPAH TEQ	0.95	0.0082 to 0.056	7×10^{-7}	6×10^{-9} to 4×10^{-8}
	Total PCBs	3.4	0.023 to 0.024[b]	7×10^{-7}	5×10^{-9}
	Other COPCs	na	na	4×10^{-7}	ne
Ground-water	All COPCs	na	na	8×10^{-8}	ne
Total excess cancer risk				**3×10^{-6}**	**na**

[a] Background and reference area concentrations and sources are discussed in Attachment 7. Concentrations for metals are representative of background concentrations and concentrations for organic compounds are representative of reference area concentrations (i.e., concentrations in urban areas in the vicinity of the Study Area).

[b] No soil reference area concentrations were available. The concentrations presented here are sediment reference area concentrations, as discussed in Attachment 7.

cPAH – carcinogenic polycyclic aromatic hydrocarbon
na – not applicable
ne – not evaluated
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure
TEQ – toxic equivalent

As shown in Table 5-6, the Study Area excess cancer risk estimate for arsenic was less than 1×10^{-6} and was similar to the risk estimate based on background (8×10^{-7} vs. 6×10^{-7}). The reference area risks for total PCBs and cPAH TEQ were 18 to 140 times lower than Study Area risks.

5.3.2 Future Outdoor Worker

This section presents cancer and non-cancer risks to future outdoor workers associated with exposure to Facility soil. The estimated excess cancer risk was equal to 2×10^{-5} (Table 5-7). The sum of non-cancer HQs was less than 1 (equal to 0.6) (Table 5-8).

Table 5-7. Excess Cancer Risk Estimates for the Future Outdoor Worker RME Scenario

Scenario timeframe: Future
Medium: Facility soil
Receptor population: Workers
Receptor age: Adult

COPC	EPC (mg/kg dw)	Cancer CDI (mg/kg-day)		Cancer EC (µg/m^3)	Cancer Slope Factor (mg/kg-day)$^{-1}$	Inhalation Unit Risk Factor (µg/m^3)$^{-1}$	Excess Cancer Risk			
		Incidental Ingestion	Dermal Absorption	Inhalation			Incidental Ingestion	Dermal Absorption	Inhalation	Total
Arsenic	11	3.8×10^{-6}	3.8×10^{-7}	6.8×10^{-7}	1.5	0.0043	6×10^{-6}	6×10^{-7}	3×10^{-9}	7×10^{-6}
cPAH TEQ	1.1	3.8×10^{-7}	1.6×10^{-7}	6.8×10^{-8}	7.3	0.001	3×10^{-6}	1×10^{-6}	7×10^{-11}	4×10^{-6}
Total PCBs	5.2	1.8×10^{-6}	8.4×10^{-7}	1.3×10^{-6}	2	0.0001	4×10^{-6}	2×10^{-6}	1×10^{-10}	6×10^{-6}
Total DDTs	16	5.6×10^{-6}	5.5×10^{-7}	9.9×10^{-7}	0.34	0.000097	2×10^{-6}	2×10^{-7}	1×10^{-10}	2×10^{-6}
1,1-Dichloroethane	0.68	2.4×10^{-7}	na[b]	1.4×10^{-2}	0.0057	1.6×10^{-6}	1×10^{-9}	na[b]	2×10^{-8}	2×10^{-8}
Benzene	0.51	1.8×10^{-7}	na[b]	7.6×10^{-3}	0.055	7.8×10^{-6}	1×10^{-8}	na[b]	6×10^{-8}	7×10^{-8}
Dichloromethane	0.047	1.6×10^{-8}	na[b]	9.8×10^{-4}	0.0075	4.7×10^{-7}	1×10^{-10}	na[b]	5×10^{-10}	6×10^{-10}
Ethylbenzene	3.1	1.1×10^{-6}	na[b]	1.1×10^{-2}	0.011	na	1×10^{-8}	na[b]	na[c]	1×10^{-8}
Trichloroethene	0.27	9.4×10^{-8}	na[b]	2.5×10^{-3}	0.13	0.00002	1×10^{-8}	na[b]	5×10^{-8}	6×10^{-8}
Vinyl chloride	1.2	4.2×10^{-7}	na[b]	1.7×10^{-1}	0.72	4.4×10^{-6}	3×10^{-7}	na[b]	8×10^{-7}	1×10^{-6}
TPH-gasoline (aliphatic)	660	2.3×10^{-4}	na[b]	1.5×10^{1}	na	1.9×10^{-7}	na[a]	na[a]	3×10^{-6}	3×10^{-6}
Total excess cancer risk across exposure routes										**2×10^{-5}**

[a] No cancer slope factor is available for this COPC, and thus the excess cancer risk based on incidental ingestion and dermal absorption cannot be calculated.
[b] No dermal absorption factor is available for this COPC. Dermal exposure for this COPC is discussed in the uncertainty analysis (Section 6.0).
[c] Per EPA guidance, the carcinogenic risk from the inhalation pathway was not assessed for ethylbenzene (EPA 2010c).

CDI – chronic daily intake
COPC – contaminant of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
EC – exposure concentration
EPA – US Environmental Protection Agency
EPC – exposure point concentration
dw – dry weight
na – not applicable
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons

Table 5-8. Non-Cancer Hazard Estimates for the Future Outdoor Worker RME Scenario

Scenario timeframe: Future
Medium: Facility soil
Receptor population: Workers
Receptor age: Adult

COPC	EPC (mg/kg dw)	Non-Cancer CDI (mg/kg-day)		Non-Cancer EC for Inhalation ($\mu g/m^3$)	Reference Dose (mg/kg-day)	Reference Concentration (mg/m^3)	Hazard Quotient			
		Incidental Ingestion	Dermal Absorption				Incidental Ingestion	Dermal Absorption	Inhalation	Total
Arsenic	11	1.1×10^{-5}	1.1×10^{-6}	1.9×10^{-6}	0.0003	0.000015	0.04	0.004	0.0001	0.04
Cobalt	14	1.4×10^{-5}	na[a]	2.4×10^{-6}	0.0003	0.000006	0.05	na[a]	0.0004	0.05
Copper	150	1.5×10^{-4}	na[a]	2.6×10^{-5}	0.04	na	0.004	na[a]	na[b]	0.004
Naphthalene	2.6	2.5×10^{-6}	1.1×10^{-6}	2.2×10^{-4}	0.02	0.003	0.00013	0.00005	0.00007	0.0002
Total PCBs	5.2	5.1×10^{-6}	2.4×10^{-6}	3.6×10^{-6}	0.00002	na	0.3	0.12	na[b]	0.4
Total DDTs	16	1.6×10^{-5}	1.5×10^{-6}	2.8×10^{-6}	0.0005	na	0.03	0.003	na[b]	0.03
1,1-Dichloroethane	0.68	6.7×10^{-7}	na[a]	3.9×10^{-2}	0.2	0.5	0.000003	na[a]	0.00008	0.00008
1,2,4-Trimethylbenzene	13	1.3×10^{-5}	na[a]	1.1×10^{-3}	0.05	0.007	0.0003	na[a]	0.0002	0.0005
1,3,5-Trimethylbenzene	3	2.9×10^{-6}	na[a]	2.5×10^{-4}	0.05	0.006	0.00006	na[a]	0.00004	0.0001
Benzene	0.51	5.0×10^{-7}	na[a]	2.1×10^{-2}	0.004	0.03	0.0001	na[a]	0.0007	0.0008
cis-1,2-Dichloroethene	130	1.3×10^{-4}	na[a]	$5.0 \times 10^{+0}$	0.01	na	0.01	na[a]	na[b]	0.01
Dichloromethane	0.047	4.6×10^{-8}	na[a]	2.7×10^{-3}	0.06	na	0.0000008	na[a]	na[b]	0.0000008
Ethylbenzene	3.1	3.0×10^{-6}	na[a]	3.0×10^{-2}	0.1	1	0.00003	na[a]	0.00003	0.00006
trans-1,2-Dichloroethene	5.5	5.4×10^{-6}	na[a]	3.2×10^{-1}	0.02	0.06	0.0003	na[a]	0.005	0.005
Vinyl chloride	1.2	1.2×10^{-6}	na[a]	4.8×10^{-1}	0.003	0.1	0.0004	na[a]	0.005	0.005
Total xylenes	16	1.6×10^{-5}	na[a]	1.9×10^{-1}	0.2	0.1	0.00008	na[a]	0.002	0.002
TPH-gasoline (aliphatic)	660	6.5×10^{-4}	na[a]	4.3×10^{1}	0.3	0.6	0.002	na[a]	0.07	0.07
Overall HI across all exposure routes/pathways[c]										**0.6**

[a] No dermal absorption factor is available for this COPC. Dermal exposure for this COPC is discussed in the uncertainty analysis (Section 6.0).
[b] No RfC is available for these COPCs, and thus HQs from inhalation cannot be calculated.

[c] The overall HI is equal to the sum of HQs for all COPCs across multiple endpoints and/or target organs. If the overall HI did not exceed 1, then endpoint-specific HIs were not calculated because they would be less than 1 as well.

CDI – chronic daily intake
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EC – exposure concentration
EPC – exposure point concentration
HI – hazard index
HQ – hazard quotient
na – not applicable
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure
TPH – total petroleum hydrocarbons

Excess cancer risk estimates for arsenic, cPAH TEQ, total PCBs, total DDTs, and TPH-gasoline (aliphatic) individually were greater than 1×10^{-6}, and thus were identified as COCs. Together they accounted for nearly all of the total excess cancer risk. Arsenic, cPAH TEQ, and total PCBs, total DDTs, and TPH-gasoline (aliphatic) accounted for approximately 30, 17, 26, 9, and 13%, respectively, of the total excess cancer risk.

To further evaluate the total excess cancer risk, background or reference area excess cancer risks for the future outdoor worker based on exposure to soil were calculated (Table 5-9).

Table 5-9. Comparison of Study Area and Background or Reference Area Soil Exposure Concentrations and Excess Cancer Risk Estimates for the Future Outdoor Worker Scenario Based on Exposure to Facility Soil

COPC	Soil Exposure Concentration (mg/kg dw)		Excess Cancer Risk	
	Study Area	Background or Reference Area[a]	Study Area	Background or Reference Area[a]
Arsenic	11	7	7×10^{-6}	4×10^{-6}
cPAH TEQ	1.1	0.0082 to 0.056	4×10^{-6}	3×10^{-8} to 2×10^{-7}
Total PCBs	5.2	0.023 to 0.024[b]	6×10^{-6}	2×10^{-8}
Total DDTs	16	0.015 to 0.355	2×10^{-6}	2×10^{-9} to 5×10^{-8}
TPH-gasoline (aliphatic)	660	ne	3×10^{-6}	ne
Other COPCs	na	na	1×10^{-6}	na
Total risk			**2×10^{-5}**	**na**

[a] Background or reference area concentrations and sources are discussed in Attachment 7. Concentrations for metals are representative of background concentrations, and concentrations for organic compounds are representative of reference area concentrations (i.e., concentrations in urban areas in the vicinity of the Study Area).

[b] No soil reference area concentrations were available. The concentrations presented here are sediment reference area concentrations, as discussed in Attachment 7.

COPC – contaminant of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
na – not applicable
ne – not evaluated
PCB – polychlorinated biphenyl
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons

As shown in Table 5-9, the background arsenic concentration (7 mg/kg dw) was over half of the value of the Study Area exposure concentration (11 mg/kg dw) and was greater than 85% of the Facility soil concentrations included as part of the exposure area for this scenario. Thus the consideration of background is important when evaluating the excess cancer risk estimate associated with arsenic. For cPAH TEQ, total PCBs, and total DDTs, the excess cancer risks calculated using reference area concentrations were 6 to 1,000 times lower than Study Area risk estimates.

5.3.3 Industrial/Commercial Worker Vapor Intrusion

This section presents risks to workers at the Study Area associated with the intrusion of vapors into buildings at the Facility. Note that this scenario looks at exposure from COPCs via vapor intrusion, not overall risks associated with operations on the Facility.

5.3.3.1 Current Facility Buildings

Risks associated with vapor intrusion into buildings were calculated using groundwater screening levels provided in EPA's draft guidance (2002c). These screening levels were calculated using a target excess cancer risk of 1×10^{-6} (i.e., concentrations below these screening levels would equate to an excess cancer risk lower than 1×10^{-6}) and using default exposure parameters protective of residential exposure, even though this scenario is based worker exposure.[14] The main differences between residential and worker exposure parameters are the assumed exposure frequency and the duration (350 days/year for 30 years for residential exposure as compared with 250 days/year for 25 years for worker exposure). Thus, risks to workers would be lower than those presented here.

The groundwater vapor intrusion screening levels in EPA's guidance (2002c) were calculated based on the equations presented in EPA's *Supplemental Guidance for Developing Soil Screening Levels* (2002d). These calculations differ slightly from those presented in EPA's RAGS Part F: Supplemental Guidance for Inhalation Risk Assessment (2009j), which provides updated methodologies for the calculation of risks from inhalation. Specifically, exposure time (i.e., hours per day) was not considered in the 2002 methodology. Because no new vapor intrusion screening levels are available, the EPA (2002c) screening levels were used for this assessment.

Groundwater concentrations of all chemicals were less than the screening levels. Nevertheless, two COPCs (benzene and vinyl chloride) were identified for this scenario because of their status as Class A carcinogens, per EPA direction. Excess cancer risks for these two COPCs were derived by dividing the EPC by the screening level and multiplying the result by 1×10^{-6} (i.e., the target risk level used to calculate the screening levels) (Table 5-10).

[14] Default exposure parameters, as presented in EPA (2002c), include an exposure duration of 30 years, an exposure frequency of 350 days per year, an inhalation rate of 20 m^3/day, and a body weight of 70 kg. Toxicity values used in the calculation of these 2002 screening levels are consistent with toxicity values for benzene and vinyl chloride in IRIS.

Table 5-10. Risk Estimates for the Industrial/Commercial Worker Vapor Intrusion Scenario

COPC	EPC (µg/L)	EPA Vapor Intrusion SL (2002c) (µg/L)	Excess Cancer Risk
Benzene	3.1	5.0	6×10^{-7}
Vinyl chloride	0.5	2.0	3×10^{-7}
Total excess cancer risk			**9×10^{-7}**

COPC – contaminant of potential concern
EPA – US Environmental Protection Agency
EPC – exposure point concentration
RL – reporting limit
SL – screening level

As presented in Table 5-10, the total excess cancer risk was equal to 9×10^{-7}, less than the lower end of EPA's target risk range. Furthermore, as noted previously, risks to occupational workers would likely be lower than the risks presented in Table 5-10 because the screening levels used to calculate these risks were based on residential exposures, which assume a higher exposure potential than that for workers.

5.3.3.2 Hypothetical/Future Facility Buildings

In addition to the evaluation of risks associated with vapor intrusion to current Facility buildings (Section 5.3.3.1), risks to workers associated with hypothetical exposures in future buildings at the Facility were also examined. Because the sizes and locations of future buildings are unknown, all shallow groundwater samples not included in the current Facility building assessment were compared with the vapor intrusion screening levels. The same two COPCs (benzene and vinyl chloride) were identified based on their Class A carcinogen status, and concentrations were compared with screening levels. Concentrations were less than screening levels with one exception: benzene was detected at a concentration greater than the screening level at location MW-4s in 2008 (140 µg/L versus a screening level of 5.0 µg/L). In the sample collected at the same location a year later, benzene was detected at a concentration of 2.9 µg/L, less than the screening level. Thus, although the concentration based on the single sample from MW-4s in 2008 could result in a risk greater than 1×10^{-6} if a building were built and occupied at this location, risks are unlikely to be greater than 1×10^{-6} if multiple samples over a longer time period or covering the area of a hypothetical future building were considered.

Based on this analysis, risks would be expected to be low (less than 1×10^{-6}) for workers if additional buildings were to be constructed at the Facility. No COCs were identified for the Industrial/Commercial Worker Vapor Intrusion scenario.

5.3.4 Force Lake Recreational User

This section presents cancer and non-cancer risks associated with exposure to wetland soil, lake sediment, and lake surface water. Risks were calculated for the total exposure duration of 30 years, ranging from birth to age 30 to include the most sensitive life stage in a lifetime scenario (as discussed in Section 5.1). Excess cancer risks based on exposure to wetland soil, lake sediment, and lake surface water are presented in Tables 5-11 to 5-13.

The excess cancer risk based on exposure to wetland soil (9×10^{-6}) was higher than the lower end of EPA's target risk range (1×10^{-6}). The excess cancer risk based on exposures to lake sediment or lake surface water were less than or equal to 1×10^{-6}.

Table 5-11. Cumulative Lifetime Excess Cancer Risk Estimates for the Force Lake Recreational User RME Scenario Based on Exposure to Wetland Soil

Scenario timeframe: Current/future
Medium: Wetland soil
Receptor population: Visitors
Receptor age: Child and adult (aged 0 to 30)

COPC	EPC (mg/kg dw)	Cancer CDI (mg/kg-day)		Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Excess Cancer Risk		
		Incidental Ingestion	Dermal Absorption		Incidental Ingestion	Dermal Absorption	Total
Arsenic	9.6	1.3×10^{-6}	1.5×10^{-7}	1.5	2×10^{-6}	2×10^{-7}	2×10^{-6}
cPAH TEQ	1.1	1.5×10^{-7}	7.7×10^{-8}	7.3	4×10^{-6}	2×10^{-6}	6×10^{-6}
Total PCBs	0.77	1.0×10^{-7}	5.8×10^{-8}	2	2×10^{-7}	1×10^{-7}	3×10^{-7}
Total DDTs	9.1	1.2×10^{-6}	1.5×10^{-7}	0.34	4×10^{-7}	5×10^{-8}	5×10^{-7}
Benzene	0.0077	1.0×10^{-9}	na[a]	0.055	6×10^{-11}	na[a]	6×10^{-11}
Trichloroethene	0.0075	1.0×10^{-9}	na[a]	0.013	1×10^{-10}	na[a]	1×10^{-10}
Total excess cancer risk across exposure routes							**9×10^{-6}**

[a] No dermal absorption factor was available for this COPC. Dermal exposure for this COPC is discussed in the uncertainty analysis (Section 6.0).

CDI – chronic daily intake
COPC – contaminant of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPC – exposure point concentration
na – not applicable
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure
TEQ – toxic equivalent

Table 5-12. Cumulative Lifetime Excess Cancer Risk Estimates for the Force Lake Recreational User RME Scenario Based on Exposure to Lake Sediment

Scenario timeframe: Current/future
Medium: Lake sediment
Receptor population: Visitors
Receptor age: Child and adult (aged 0 to 30)

COPC	EPC (mg/kg dw)	Cancer CDI (mg/kg-day)		Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Excess Cancer Risk		
		Incidental Ingestion	Dermal Absorption		Incidental Ingestion	Dermal Absorption	Total
Arsenic	6.4	8.5×10^{-7}	1.0×10^{-7}	1.5	1×10^{-6}	2×10^{-7}	1×10^{-6}
cPAH TEQ	0.081	1.1×10^{-8}	5.6×10^{-9}	7.3	3×10^{-7}	1×10^{-7}	4×10^{-7}
Total excess cancer risk across exposure routes							**1×10^{-6}**

CDI – chronic daily intake
COPC – contaminant of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
dw – dry weight
EPC – exposure point concentration
RME – reasonable maximum exposure
TEQ – toxic equivalent

Table 5-13. Cumulative Lifetime Excess Cancer Risk Estimates for the Force Lake Recreational User RME Scenario Based on Exposure to Lake Surface Water

Scenario timeframe: Current/future
Medium: Lake surface water
Receptor population: Visitors
Receptor age: Child and adult (aged 0 to 30)

COPC	EPC (mg/L)	Cancer CDI (mg/kg-day)		Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Excess Cancer Risk		
		Incidental Ingestion	Dermal Absorption		Incidental Ingestion	Dermal Absorption	Total
Arsenic (total)[a]	0.0012	9.3×10^{-8}	8.1×10^{-9}	1.5	1×10^{-7}	1×10^{-8}	1×10^{-7}
Total excess cancer risk across exposure routes							**1×10^{-7}**

[a] Both the total and dissolved fractions were greater than the screening level. To be conservative, the total fraction was assessed in this HHRA because it is slightly higher than the dissolved fraction.

CDI – chronic daily intake
COPC – contaminant of potential concern
EPC – exposure point concentration
HHRA – human health risk assessment
RME – reasonable maximum exposure

HQs for child exposure (0 to 6 year age class) are presented in Tables 5-14 to 5-16 for the three recreational scenarios. For risk communication purposes, the weighted average HQs for the 30-yr exposure duration are also presented (Tables 5-17 to 5-19). These HQs are lower than those for the 0-to-6 year age group, and are not typically used for risk management decisions. They are presented here for risk communication purposes only.

The overall HI was less than 1 for all media for children aged 0 to 6 (the most sensitive age group). The overall HI for the 30-yr exposure duration, presented as a weighted average, was a factor of 3 to 4 times lower than the overall HI for children aged 0 to 6.

Table 5-14. Non-Cancer Hazard Estimates for the Force Lake Recreational User RME Scenario Based on the Exposure of Children Aged 0 to 6 to Wetland Soil

Scenario timeframe: Current/future
Medium: Wetland soil
Receptor population: Visitors
Receptor age: Child (aged 0 to 6)

COPC	EPC (mg/kg dw)	Non-Cancer CDI (mg/kg-day)		Reference Dose (mg/kg-day)	Hazard Quotient		
		Incidental Ingestion	Dermal Absorption		Incidental Ingestion	Dermal Absorption	Total
Aluminum	12,000	1.1×10^{-2}	na[a]	1	0.01	na[a]	0.01
Antimony	1.1	9.9×10^{-7}	na[a]	0.0004	0.002	na[a]	0.002
Arsenic	9.6	8.6×10^{-6}	5.2×10^{-7}	0.0003	0.03	0.002	0.03
Chromium	37	3.3×10^{-5}	na[a]	1.5	0.00002	na[a]	0.00002
Cobalt	12	1.1×10^{-5}	na[a]	0.0003	0.04	na[a]	0.04
Copper	160	1.4×10^{-4}	na[a]	0.04	0.004	na[a]	0.004
Iron	57,000	5.1×10^{-2}	na[a]	0.7	0.07	na[a]	0.07
Manganese	1,100	9.9×10^{-4}	na[a]	0.14	0.007	na[a]	0.007
Vanadium	76	6.8×10^{-5}	na[a]	0.005	0.01	na[a]	0.01
Naphthalene	0.64	5.7×10^{-7}	1.5×10^{-7}	0.02	0.00003	0.000007	0.00004
Total PCBs	0.77	6.9×10^{-7}	1.9×10^{-7}	0.00002	0.03	0.01	0.04
Total DDTs	9.1	8.2×10^{-6}	4.9×10^{-7}	0.0005	0.02	0.001	0.02
Benzene	0.0077	6.9×10^{-9}	na[a]	0.004	0.000002	na[a]	0.000002
TPH-gasoline (aliphatic)	25	2.2×10^{-5}	na[a]	0.3	0.00007	na[a]	0.00007
TPH-diesel (aliphatic)	780	7.0×10^{-4}	na[a]	0.01	0.07	na[a]	0.07
Overall HI across all exposure routes/pathways[b]							**0.3**

[a] No dermal absorption factor is available for this COPC. Dermal exposure for this COPC is discussed in the uncertainty analysis (Section 6.0).

[b] The overall HI is equal to the sum of HQs across multiple endpoints and/or target organs. The value indicates that the HI could not exceed 1 for individual endpoints. Therefore, HIs were not calculated for individual endpoints.

CDI – chronic daily intake
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPC – exposure point concentration
HI – hazard index
HQ – hazard quotient
na – not applicable
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure
TPH – total petroleum hydrocarbons

Table 5-15. Non-Cancer Hazard Estimates for the Force Lake Recreational User RME Scenario Based on the Exposure of Children Aged 0 to 6 to Lake Sediment

Scenario timeframe: Current/future
Medium: Lake sediment
Receptor population: Visitors
Receptor age: Child (aged 0 to 6)

COPC	EPC (mg/kg dw)	Non-Cancer CDI (mg/kg-day)		Reference Dose (mg/kg-day)	Hazard Quotient		
		Incidental Ingestion	Dermal Absorption		Incidental Ingestion	Dermal Absorption	Total
Arsenic	6.4	5.7×10^{-6}	3.4×10^{-7}	0.0003	0.02	0.001	0.02
Chromium	30	2.7×10^{-5}	na[a]	1.5	0.00002	na[a]	0.00002
Cobalt	14	1.3×10^{-5}	na[a]	0.0003	0.04	na[a]	0.04
Vanadium	67	6.0×10^{-5}	na[a]	0.005	0.01	na[a]	0.01
TPH-gasoline (aliphatic)	34	3.1×10^{-5}	na[a]	0.3	0.0001	na[a]	0.0001
Overall HI across all exposure routes/pathways[b]							**0.07**

[a] No dermal absorption factor is available for this COPC. Dermal exposure for this COPC is discussed in the uncertainty analysis (Section 6.0).

[b] The overall HI is equal to the sum of HQs across multiple endpoints and/or target organs. The value indicates that the HI could not exceed 1 for individual endpoints. Therefore, HIs were not calculated for individual endpoints.

CDI – chronic daily intake
COPC – contaminant of potential concern
dw – dry weight
EPC – exposure point concentration
HI – hazard index
HQ – hazard quotient
na – not applicable
RME – reasonable maximum exposure
TPH – total petroleum hydrocarbons

Table 5-16. Non-Cancer Hazard Estimates for the Force Lake Recreational User RME Scenario Based on the Exposure of Children Aged 0 to 6 to Lake Surface Water

Scenario timeframe: Current/future
Medium: Lake surface water
Receptor population: Visitors
Receptor age: Child (aged 0 to 6)

COPC	EPC (mg/L)	Non-Cancer CDI (mg/kg-day)		Reference Dose (mg/kg-day)	Hazard Quotient		
		Incidental Ingestion	Dermal Absorption		Incidental Ingestion	Dermal Absorption	Total
Arsenic (total)[a]	0.0012	4.6×10^{-7}	1.8×10^{-8}	0.0003	0.002	0.00006	0.002

[a] Both the total and dissolved fraction were greater than the screening level. To be conservative, the total fraction was assessed in this HHRA because it is slightly higher than the dissolved fraction.

CDI – chronic daily intake
COPC – contaminant of potential concern
EPC – exposure point concentration
HHRA – human health risk assessment
HI – hazard index
HQ – hazard quotient

Table 5-17. Weighted Non-Cancer Hazard Estimates for 0 to 30-yr Exposure Duration for the Force Lake Recreational User RME Scenario Based on Exposure to Wetland Soil

Scenario timeframe: Current/future
Medium: Wetland soil
Receptor population: Visitors
Receptor age: Child and adult (aged 0 to 30)

COPC	EPC (mg/kg dw)	Non-Cancer CDI (mg/kg-day)		Reference Dose (mg/kg-day)	Hazard Quotient		
		Incidental Ingestion	Dermal Absorption		Incidental Ingestion	Dermal Absorption	Total
Aluminum	12,000	3.7×10^{-3}	na[a]	1	0.004	na[a]	0.004
Antimony	1.1	3.4×10^{-7}	na[a]	0.0004	0.0009	na[a]	0.0009
Arsenic	9.6	3.0×10^{-6}	3.6×10^{-7}	0.0003	0.01	0.001	0.01
Chromium	37	1.1×10^{-5}	na[a]	1.5	0.000008	na[a]	0.000008
Cobalt	12	3.7×10^{-6}	na[a]	0.0003	0.01	na[a]	0.01
Copper	160	5.0×10^{-5}	na[a]	0.04	0.001	na[a]	0.001
Iron	57,000	1.8×10^{-2}	na[a]	0.7	0.03	na[a]	0.03
Manganese	1,100	3.4×10^{-4}	na[a]	0.14	0.002	na[a]	0.002
Vanadium	76	2.4×10^{-5}	na[a]	0.005	0.005	na[a]	0.005
Naphthalene	0.64	2.0×10^{-7}	1.0×10^{-7}	0.02	0.00001	0.000005	0.00002
Total PCBs	0.77	2.4×10^{-7}	1.3×10^{-7}	0.00002	0.01	0.007	0.02
Total DDTs	9.1	2.8×10^{-6}	3.4×10^{-7}	0.0005	0.006	0.0007	0.007
Benzene	0.0077	2.4×10^{-9}	na[a]	0.004	0.0000006	na[a]	0.0000006
TPH-gasoline (aliphatic)	25	7.8×10^{-6}	na[a]	0.3	0.00003	na[a]	0.00003
TPH-diesel (aliphatic)	780	2.4×10^{-4}	na[a]	0.01	0.02	na[a]	0.02
Overall HI across all exposure routes/pathways[b]							**0.1**

[a] No dermal absorption factor was available for this COPC. Dermal exposure for this COPC is discussed in the uncertainty analysis (Section 6.0).

[b] The overall HI is equal to the sum of HQs across multiple endpoints and/or target organs. The value indicates that the HI could not exceed 1 for individual endpoints. Therefore, HIs were not calculated for individual endpoints.

CDI – chronic daily intake
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPC – exposure point concentration
HI – hazard index
HQ – hazard quotient
na – not applicable
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure
TPH – total petroleum hydrocarbons

Table 5-18. Weighted Non-Cancer Hazard Estimates for 0 to 30-yr Exposure Duration for the Force Lake Recreational User RME Scenario Based on Exposure to Lake Sediment

Scenario timeframe: Current/future
Medium: Lake sediment
Receptor population: Visitors
Receptor age: Child and adult (aged 0 to 30)

COPC	EPC (mg/kg dw)	Non-Cancer CDI (mg/kg-day)		Reference Dose (mg/kg-day)	Hazard Quotient		
		Incidental Ingestion	Dermal Absorption		Incidental Ingestion	Dermal Absorption	Total
Arsenic	6.4	2.0×10^{-6}	2.4×10^{-7}	0.0003	0.007	0.0008	0.008
Chromium	30	9.3×10^{-6}	na[a]	1.5	0.000006	na[a]	0.000006
Cobalt	14	4.3×10^{-6}	na[a]	0.0003	0.01	na[a]	0.01
Vanadium	67	2.1×10^{-5}	na[a]	0.005	0.004	na[a]	0.004
TPH-gasoline (aliphatic)	34	1.1×10^{-5}	na[a]	0.3	0.00004	na[a]	0.00004
Overall HI across all exposure routes/pathways[b]							**0.02**

[a] No dermal absorption factor was available for this COPC. Dermal exposure for this COPC is discussed in the uncertainty analysis (Section 6.0).

[b] The overall HI is equal to the sum of HQs across multiple endpoints and/or target organs. The value indicates that the HI could not exceed 1 for individual endpoints. Therefore, HIs were not calculated for individual endpoints.

CDI – chronic daily intake
COPC – contaminant of potential concern
dw – dry weight
EPC – exposure point concentration
HI – hazard index
HQ – hazard quotient
na – not applicable
RME – reasonable maximum exposure
TPH – total petroleum hydrocarbons

Table 5-19. Weighted Non-Cancer Hazard Estimates for 0 to 30-yr Exposure Duration for the Force Lake Recreational User RME Scenario Based on Exposure to Lake Surface Water

Scenario timeframe: Current/future
Medium: Lake surface water
Receptor population: Visitors
Receptor age: Child and adult (aged 0 to 30)

COPC	EPC (mg/L)	Non-Cancer CDI (mg/kg-day)		Reference Dose (mg/kg-day)	Hazard Quotient		
		Incidental Ingestion	Dermal Absorption		Incidental Ingestion	Dermal Absorption	Total
Arsenic (total)[a]	0.0012	2.2×10^{-7}	1.9×10^{-8}	0.0003	0.0007	0.00006	0.0008

[a] Both the total and dissolved fractions were greater than the screening level. To be conservative, the total fraction was assessed in this HHRA because it was slightly higher than the dissolved fraction.

CDI – chronic daily intake
COPC – contaminant of potential concern
EPC – exposure point concentration
HHRA – human health risk assessment
HI – hazard index
HQ – hazard quotient
RME – reasonable maximum exposure

In addition to evaluating risks separately by media, the risks presented in Tables 5-11 through 5-19 can be combined based on exposure to multiple media (i.e., wetland soil, lake sediment, and lake water). Table 5-20 presents these total risk estimates.

Table 5-20. Total Risk Estimates Across Media for the Force Lake Recreational User RME Scenario

Exposure Media	Child and Adult Exposure (aged 0 to 30)	Child Exposure (aged 0 to 6)
Excess Cancer Risk		
Exposure to wetland soil	9×10^{-6}	ne[a]
Exposure to lake sediment	1×10^{-6}	ne[a]
Exposure to lake water	1×10^{-7}	ne[a]
Total risk estimate across media	**1×10^{-5}**	ne[a]
Sum of Non-Cancer HQs		
Exposure to wetland soil	0.1	0.3
Exposure to lake sediment	0.02	0.08
Exposure to lake water	0.0008	0.002
Total risk estimate across media	**0.1**	**0.4**

[a] The child age 0 to 6 excess cancer risks are not presented separately because they are lower than those for the integrated child and adult exposure.

HQ – hazard quotient

ne – not evaluated

RME – reasonable maximum exposure

As can be seen in Table 5-20, the total lifetime excess cancer risk across exposure media (1×10^{-5}) was greater than 1×10^{-6}. The overall HI was less than 1 for both age groups and for all exposure media.

Two COPCs had individual excess cancer risks greater than 1×10^{-6}: arsenic and cPAH TEQ based on exposure to wetland soil. Thus, arsenic and cPAH TEQ were identified as COCs for this scenario. No COCs were identified based on exposure to lake sediment or lake surface water.

To further evaluate the total excess cancer risk, background or reference area excess cancer risks for the Force Lake recreational user RME scenario were calculated for arsenic and cPAH TEQ because together they accounted for the majority of the total excess cancer risk (over 90%) for wetland soil and lake sediment (Table 5-21).

Table 5-21. Comparison of Study Area and Background or Reference Area Soil or Sediment Exposure Concentrations and Lifetime Excess Cancer Risk Estimates for the Force Lake Recreational User RME Scenario

Media	COPC	Soil or Sediment Exposure Concentration (mg/kg dw)		Lifetime Excess Cancer Risk	
		Study Area	Background or Reference Area[a]	Study Area	Background or Reference Area[a]
Wetland soil	Arsenic	9.6	7	2×10^{-6}	2×10^{-6}
	cPAH TEQ	1.1	0.0082 to 0.056	6×10^{-6}	4×10^{-8} to 3×10^{-7}
	Other COPCs	na	na	8×10^{-7}	ne
Lake sediment	Arsenic	6.4	7 to 7.9	1×10^{-6}	2×10^{-6}
	cPAH TEQ	0.081	0.134 to 0.149	4×10^{-7}	7×10^{-7} to 8×10^{-7}
Lake water	All COPCs	na	na	1×10^{-7}	ne
Total risk				**1×10^{-5}**	**na**

[a] Background and reference area concentrations and sources are discussed in Attachment 7. Concentrations for metals are representative of background concentrations and concentrations for organic compounds are representative of reference area concentrations (i.e., concentrations in urban areas in the vicinity of the Study Area).

COPC – contaminant of potential concern

cPAH – carcinogenic polycyclic aromatic hydrocarbon

na – not applicable

ne – not evaluated

TEQ – toxic equivalent

As shown in Table 5-21, the excess cancer risk estimates for arsenic were the same for both Study Area and background concentrations (2×10^{-6}). For cPAH TEQ, the Study Area risk estimate based on exposure to wetland soil was greater than that calculated from reference area soil concentrations, while the Study Area risk estimate based on lake sediment was less than that calculated from reference area sediment concentrations.

5.3.5 Force Lake Fish Consumer

The excess cancer risk estimate for the Force Lake fish consumer scenario was greater than 1×10^{-6} for each of the three COPCs with carcinogenic effects (arsenic, total PCBs, total DDTs) (Tables 5-22 to 5-24). Thus, arsenic, total PCBs, and total DDTs were identified as COCs for this scenario. The total excess cancer risk for individuals consuming 6 meals per year of fish from Force Lake was equal to 2×10^{-5} (Table 5-22). As with the Force Lake recreational user RME scenario, HQs were calculated based on a child (0 to 6 years of age) age class and also as a weighted average over a 30-yr exposure duration (including both child and adult exposure from birth to age 30). As noted above, the integrated 0-to-30 year exposure duration HQs are presented for risk communication purposes only, and are not typically used for risk management decisions. No COPCs had HQs greater than 1 for either age

group, and no endpoint-specific HIs were greater than 1 (Tables 5-23 and 5-24).

Table 5-22. Integrated Lifetime Excess Cancer Risk Estimate for the Force Lake Fish Consumer RME Scenario

Scenario timeframe: Current/future
Medium: Fish tissue
Receptor population: Recreational fishermen or individuals supplementing their diets (transient individuals or individuals from ethnic populations)
Receptor age: Child and adult (aged 0 to 30)

COPC	EPC (mg/kg ww)[a]	Cancer CDI (mg/kg-day)	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Excess Cancer Risk
Arsenic	0.22	5.0×10^{-6}	1.5	7×10^{-6}
Total PCBs	0.33	7.5×10^{-6}	2	1×10^{-5}
Total DDTs	0.30	6.8×10^{-6}	0.34	2×10^{-6}
Total excess cancer risk				**2×10^{-5}**

[a] EPCs are estimated based on sediment concentrations and BSAFs (see Attachment 2).

BSAF – biota-sediment accumulation factor
CDI – chronic daily intake
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
EPC – exposure point concentration
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure
ww – wet weight

Table 5-23. Non-Cancer Hazard Estimate for the Force Lake Fish Consumer RME Scenario Based on the Exposure of Children Aged 0 to 6 Years

Scenario timeframe: Current/future
Medium: Fish tissue
Receptor population: Recreational fishermen or individuals supplementing their diets (transient individuals or individuals from ethnic populations)
Receptor age: Child (aged 0 to 6)

COPC	EPC (mg/kg ww)[a]	Non-Cancer CDI (mg/kg-day)	Reference Dose (mg/kg-day)	Hazard Quotient
Arsenic	0.22	1.7×10^{-5}	0.0003	0.06
Barium	57	4.5×10^{-3}	0.2	0.02
Cadmium	0.44	3.4×10^{-5}	0.001	0.03
Cobalt	3.9	3.1×10^{-4}	0.0003	1
Copper	22	1.7×10^{-3}	0.04	0.04
Mercury	0.021	1.6×10^{-6}	0.0001	0.02
Nickel	7.7	6.0×10^{-4}	0.02	0.03
Vanadium	19	1.5×10^{-3}	0.005	0.3
Zinc	100	7.8×10^{-3}	0.3	0.03
Total PCBs	0.33	2.6×10^{-5}	0.00002	1
Total DDTs	0.30	2.3×10^{-5}	0.0005	0.05
Hazard indices by effect:				
Hazard index for body weight endpoint (nickel)				**0.03**
Hazard index for cardiovascular endpoint (arsenic)				**0.06**
Hazard index for dermal endpoint (arsenic, vanadium)				**0.4**
Hazard index for developmental endpoint (mercury, PCBs)				**1**
Hazard index for endocrine system endpoint (nickel)				**0.03**
Hazard index for hematologic endpoint (cobalt, zinc)				**1**
Hazard index for immune system endpoint (PCBs)				**1**
Hazard index for kidney endpoint (barium, cadmium, nickel)				**0.08**
Hazard index for liver endpoint (nickel, DDTs)				**0.08**
Hazard index for nervous system endpoint (mercury)				**0.02**

[a] EPCs are estimated based on sediment concentrations and BSAFs (see Attachment 2).

BSAF – biota-sediment accumulation factor
CDI – chronic daily intake
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
EPC – exposure point concentration
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure
ww – wet weight

Table 5-24. Weighted Non-Cancer Hazard Estimate for 0 to 30-yr Exposure Duration for the Force Lake Fish Consumer RME Scenario

Scenario timeframe: Current/future
Medium: Fish tissue
Receptor population: Recreational fishermen or individuals supplementing their diets (transient individuals or individuals from ethnic populations)
Receptor age: Child and adult (aged 0 to 30)

COPC	EPC (mg/kg ww)[a]	Non-Cancer CDI (mg/kg-day)	Reference Dose (mg/kg-day)	Hazard Quotient
Arsenic	0.22	1.2×10^{-5}	0.0003	0.04
Barium	57	3.0×10^{-3}	0.2	0.02
Cadmium	0.44	2.3×10^{-5}	0.001	0.02
Cobalt	3.9	2.1×10^{-4}	0.0003	0.7
Copper	22	1.2×10^{-3}	0.04	0.03
Mercury	0.021	1.1×10^{-6}	0.0001	0.01
Nickel	7.7	4.1×10^{-4}	0.02	0.02
Vanadium	19	1.0×10^{-3}	0.005	0.2
Zinc	100	5.3×10^{-3}	0.3	0.02
Total PCBs	0.33	1.7×10^{-5}	0.00002	0.9
Total DDTs	0.30	1.6×10^{-5}	0.0005	0.03
Hazard indices by effect:				
Hazard index for body weight endpoint (nickel)				**0.02**
Hazard index for cardiovascular endpoint (arsenic)				**0.04**
Hazard index for dermal endpoint (arsenic, vanadium)				**0.2**
Hazard index for developmental endpoint (mercury, PCBs)				**0.9**
Hazard index for endocrine system endpoint (nickel)				**0.02**
Hazard index for hematologic endpoint (cobalt, zinc)				**0.7**
Hazard index for immune system endpoint (PCBs)				**0.9**
Hazard index for kidney endpoint (barium, cadmium, nickel)				**0.06**
Hazard index for liver endpoint (nickel, DDTs)				**0.05**
Hazard index for nervous system endpoint (mercury)				**0.01**

[a] EPCs are estimated based on sediment concentrations and BSAFs (see Attachment 2).

BSAF – biota-sediment accumulation factor
CDI – chronic daily intake
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
EPC – exposure point concentration
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure
ww – wet weight

The majority of the total excess cancer risk based on fish consumption was attributable to total PCBs (53%), with approximately 37% attributable to arsenic, and 11% attributable to total DDTs. Endpoint-specific HIs were less than or equal to 1 for both the child exposure scenario (0 to 6 years of age) and the integrated (i.e., combined) child and adult exposure scenario (0 to 30 years of age).

To evaluate the effect of background or reference area concentrations on the risk estimates for these COPCs, background or reference area fish tissue concentrations and risks were calculated for comparison (Table 5-25).

Table 5-25. Comparison of Study Area and Background or Reference Area Exposure Concentrations and Lifetime Excess Cancer Risk Estimates for the Force Lake Fish Consumer Scenario

COPC	Exposure Concentration in Fish Tissue (mg/kg ww)		Excess Cancer Risk	
	Study Area	Background or Reference Area[a]	Study Area	Background or Reference Area[a]
Arsenic	0.22	0.24 – 0.27	7×10^{-6}	8×10^{-6} to 9×10^{-6}
Total PCBs	0.33	0.077 – 0.081	1×10^{-5}	3×10^{-6} to 4×10^{-6}
Total DDTs	0.30	0.025 – 0.030	2×10^{-6}	2×10^{-7}
Total risk			**2×10^{-5}**	**na**

[a] Background and reference area concentrations and sources are discussed in Attachment 7. 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 in the vicinity of the Study Area).

COPC – contaminant of potential concern

DDT – dichlorodiphenyltrichloroethane

PCB – polychlorinated biphenyl

na – not applicable

ww – wet weight

As shown in Table 5-25, the excess cancer risk estimate for arsenic based on the regional background concentration was slightly greater than the Study Area risk estimate. For both total PCBs and total DDTs, the reference area risk estimates were approximately 3 to 10 times lower than those calculated using Study Area concentrations.

In addition to the risks presented here for the Force Lake fish consumer RME scenario, cumulative risks, which account for the possibility that individuals may be exposed to lake sediment, lake water, or wetland soil while fishing at Force Lake, are presented in Section 5.5.

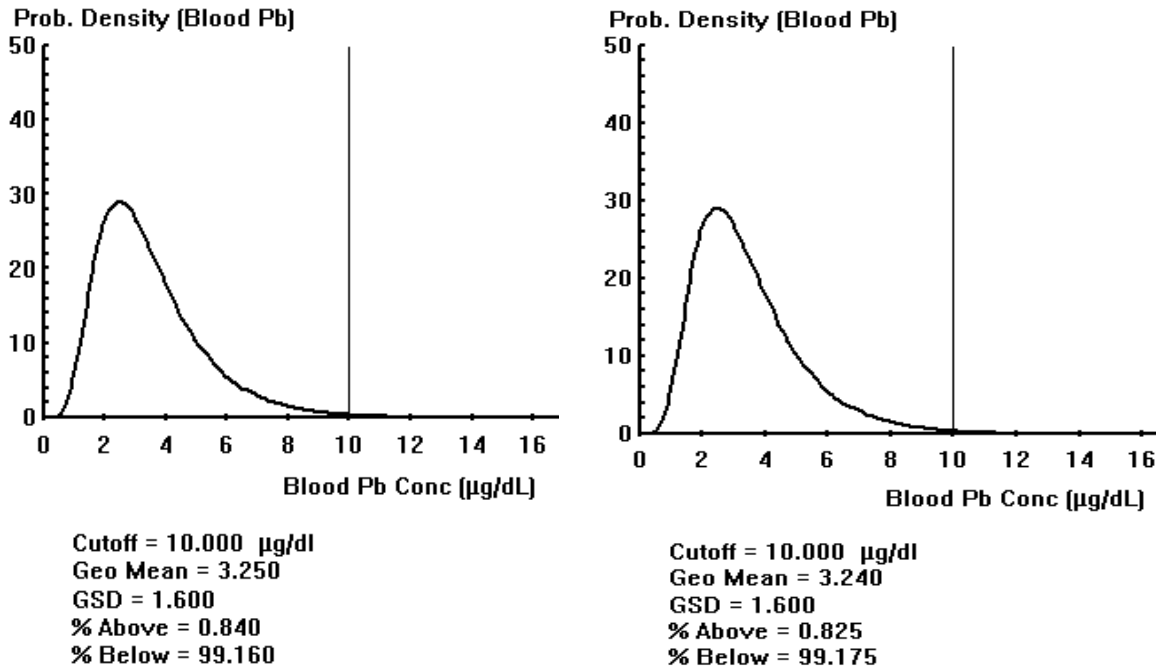
5.4 Lead Modeling Results

As described in Section 3.3.6, risks from exposure to lead were not quantified following the exposure model used for other COPCs. Because the toxicokinetics (absorption, distribution, metabolism, and excretion) of lead are well understood, health risks from lead exposure were evaluated based on blood lead concentration, which can be modeled. The results of blood lead modeling for children (IEUBK) and adults (ALM) are presented in the subsections below.

5.4.1 Children (IEUBK)

The IEUBK lead model was run using default parameters, except for the inclusion of site-specific sediment, soil, and fish tissue concentration data, as described earlier in Section 3.3.6.1. Model output is provided in the form of a probability density curve that describes the probability of blood lead concentrations occurring in a hypothetical population of children. The CDC has established a blood lead concentration of 10 µg/dL as a level of concern threshold for children above which adverse health effects may occur. The probability density curves designate the percent of children that were predicted to have blood lead levels that may exceed the threshold.

Probability density curves were generated for the Study Area using time-weighted average EPCs (Figure 5-1). For information regarding the time-weighted average approach to calculating EPC values, see Section 3.3.6.1. Note that these concentrations are less than the default soil concentration of 200 mg/kg dw in the model. However, based on this range of exposures, fewer than 0.9% of the modeled child population would have blood lead levels that exceed the CDC level of concern (shown in both graphs in Figure 5-1 as the area under the curve to the right of the vertical line, which represents 10 µg/dL). EPA's risk reduction goal for contaminated sites is that no more than 5% of the population of children exposed to lead will have blood lead levels greater than 10 µg/dL Based on the results of the IEUBK model for the Study Area, lead was not considered to be a COC.



a) Wetland soil and fish consumption **b) Force Lake sediment and fish consumption**

Figure 5-1. Probability Density Curves for Predicted Blood Lead Concentrations Using Input Data from the Children's Force Lake Recreational User RME Scenario and Force Lake Fish Consumer RME Scenario

5.4.2 Adults (ALM)

The ALM was run to estimate risks from lead exposure to the most sensitive population, which is a developing fetus. Lead risks were assessed by estimating the probability of exceeding the threshold blood lead level of 10 µg/dL in the fetus through evaluation of exposure of a pregnant mother. Results for the worker and recreational scenarios are presented in Table 5-26. As described in Section 3.3.6.2, the model was run in two modes for the Force Lake recreational user (with and without fish consumption) so that the incremental effects of fish consumption could be evaluated.

Table 5-26. Risk Estimates for Predicted Fetal and Adult Lead Levels Using the Adult Lead Model

Results	Unit	Scenario Name			
		Industrial (Construction/ Trenching) RME Worker	Future Outdoor RME Worker	Force Lake RME Recreational User	
				Wetland Soil	Force Lake Sediment
Estimates for Soil and Sediment Incidental Ingestion Only					
Predicted adult blood lead levels, CTE[a]	µg/dL	2.0	1.7	1.6	1.5
Predicted fetal blood lead levels, 95th percentile[b]	µg/dL	6.0	5.3	4.8	4.7
Probability of fetal blood lead level exceeding 10 µg/dL (lognormal)[c]	%	1.0	0.63	0.41	0. 40
Estimates Including Fish Consumption					
Predicted adult blood lead levels, CTE[d]	µg/dL	na	na	1.9	1.9
Predicted fetal blood lead levels, 95th percentile[b]	µg/dL	na	na	5.9	5.8
Probability of fetal blood lead level exceeding 10 µg/dL (lognormal)[c]	%	na	na	0.91	0.90

[a] Central tendency estimate of adult blood lead concentration for sediment intake only.

[b] Estimate of 95th percentile fetal blood lead concentration.

[c] Probability of exceeding EPA's threshold for fetal exposure, a blood lead level of 10 µg/dL (EPA 2003b).

[d] Central tendency estimate of adult blood lead concentration for sediment ingestion and fish consumption.

CTE – central tendency estimate

EPA – US Environmental Protection Agency

na – not applicable

RME – reasonable maximum exposure

The 95th percentiles of predicted blood lead concentrations for the developing fetus were 6.0 and 5.3 µg/dL for the industrial (construction/trenching) worker RME scenario and for the future outdoor worker RME scenarios, respectively (Table 5-26). For the Force Lake

recreational user RME scenario based on exposure to either wetland soil or lake sediment, the 95th percentile of predicted blood lead concentration for the developing fetus was 4.8 µg/dL or 4.7 µg/dL, respectively, without the inclusion of fish consumption from Force Lake. The 95th percentiles of blood lead concentrations and probabilities of exceeding the 10 µg/dL threshold were slightly higher for the recreational user RME scenarios when fish consumption is included (5.9 µg/dL or 5.8 µg/dL, respectively). The probability of exceeding the 10 µg/dL blood lead threshold was less than or equal to 1.0% for all scenarios, regardless of the inclusion or exclusion of fish tissue consumption. These results indicate that lead should not be considered a COC for human health at the Study Area.

5.5 Risk Characterization Summary

This section provides a summary of excess cancer risk and non-cancer hazard estimates calculated previously in this section. Risks were evaluated for a number of different types of exposure scenarios to describe different types and intensities of site use. RME scenarios such as those evaluated in this document represent the highest exposures that are reasonably expected to occur at a site, and are generally used by EPA to evaluate remedial actions at a site (EPA 1989). In addition, it should be noted that RME, by definition, likely overestimates exposure for many individuals. The total excess cancer risks and non-cancer HQs are presented for all scenarios in Table 5-27.

Table 5-27. Summary of Total Excess Cancer Risks and Non-Cancer HQs

Scenario Name	Total Excess Cancer Risk	Overall HI[a]
Industrial (construction/trenching) worker RME scenario		
Facility soil	3×10^{-6}	1
Groundwater	8×10^{-8}	0.03
Cumulative risk across media	**3×10^{-6}**	**1**
Future outdoor worker RME scenario		
Facility soil	2×10^{-5}	0.6
Industrial/commercial worker vapor intrusion scenario		
Vapor intrusion	9×10^{-7}	ne[b]
Force Lake recreational user RME scenario		
Wetland soil	9×10^{-6}	0.3[c]
Lake sediment	1×10^{-6}	0.08[c]
Lake water	1×10^{-7}	0.002[c]
Cumulative risk across media	**1×10^{-5}**	**0.4**[c]
Force Lake fish consumer RME scenario		
Fish tissue consumption	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 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 (i.e., combined) 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 is equal to 3. Because this value is greater than 1, endpoint-specific HIs were calculated per EPA guidance (EPA 1989). No endpoint-specific HIs were greater than 1 (see Section 5.3.5 for details).

HI – hazard index

HQ – hazard quotient

ne – not evaluated

RME – reasonable maximum exposure

As shown in Table 5-27, the following RME scenarios had excess cancer risks greater than or equal to 1×10^{-6} and/or non-cancer HQs greater than or equal to 1:

- **Industrial (construction/trenching) worker RME scenario:** The total excess cancer risk was equal to 3×10^{-6} based on exposure to Facility soil, although no risk estimate for an individual COPC exceeded 1×10^{-6}.
- **Future outdoor worker RME scenario:** The total excess cancer risk was equal to 2×10^{-5} based on exposure to Facility soil.
- **Industrial/Commercial Worker Vapor Intrusion Scenario:** The total excess cancer risk (9×10^{-7} based on conservative published screening levels using residential exposure parameters) was less than the lower end of EPA's target risk range of 10^{-6} to 10^{-4}.
- **Force Lake recreational user RME scenario (cumulative lifetime exposure):** The total excess cancer risk was 1×10^{-5} for exposure across media, based predominantly on exposure to wetland soil (9×10^{-6}). Risks from exposure to surface water in Force Lake were less than 1×10^{-6}, indicating low risk from surface water exposure and also indicating that the concentrations in stormwater did not elevate concentrations in the lake to those that would result in risks greater than EPA's target risk range.
- **Force Lake fish consumer RME scenario (integrated lifetime exposure):** The excess cancer risk was greater than 1×10^{-6} based on the consumption of fish tissue (equal to 2×10^{-5}). No endpoint-specific HIs were greater than 1 based on either integrated lifetime exposure or on child exposure.

The excess cancer risk estimates for the scenarios listed above that were greater than 1×10^{-6} are summarized in Table 5-28. No endpoint-specific HIs were greater than 1, so for the purpose of brevity, these risks are not summarized here Table 5-28.

Table 5-28. Summary of Excess Cancer Risks for Scenarios with Total Excess Cancer Risks Greater than or Equal to 1×10^{-6}

COPC	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 and reference area concentrations and sources are discussed in Attachment 7. 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).

COPC – contaminant of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
na – not applicable
nc – not calculated
PCB – polychlorinated biphenyl
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons

As shown in Table 5-28, arsenic, cPAHs, total PCBs, total DDTs, and TPH-gasoline (aliphatic) accounted for nearly all of the risk across scenarios.

For both worker RME scenarios, the majority (over 70%) of the total excess cancer risk was attributable to arsenic, cPAH TEQ, and total PCBs, with a lesser contribution from total DDTs and TPH-gasoline (aliphatic). However, for both worker scenarios, risk estimates calculated based on the DEQ background concentration for arsenic were comparable to (although somewhat less than) those based on Study Area concentrations, indicating that the regional background concentration for arsenic is an important consideration when evaluating the Study Area risk estimate. Risk estimates based on reference area soil concentrations for cPAH TEQ, total PCBs, and total DDTs were less than Study Area risk estimates.

For the Force Lake recreational user RME scenario, the majority (over 90%) of the total excess cancer risk (equal to 9×10^{-6} for exposure to wetland soil and equal to 1×10^{-6} for exposure to lake sediment) was attributable to arsenic and cPAH TEQ. However, risks calculated based on background concentrations for arsenic were similar to (wetland soil) or higher than (lake sediment) risk estimates based on Study Area concentrations. Reference area risk estimates for cPAH TEQ were less than Study Area risk estimates for scenarios based on exposure to soil but were less for scenarios based on exposure to sediment.

For the Force Lake fish consumer RME scenario, the majority of the risk was attributable to total PCBs (53%), with lower percentages attributable to arsenic (37%) and total DDTs (11%). Risks calculated based on background concentrations for arsenic were higher than those based on Study Area concentrations and the Study Area risk estimate for total DDTs was within the range of risks calculated using reference area fish tissue concentrations. No endpoint-specific HIs were greater than 1 for any scenario.

In addition, per EPA guidance (EPA 1989), risks for multiple scenarios were summed to represent possible cumulative risk for individuals who engage in several different activities. For this HHRA, it is possible for individuals fishing at Force Lake to also be exposed to wetland soil, lake sediment, and lake water (i.e., the Force Lake recreational user). The sum of the excess cancer risks for the Force Lake recreational user and the Force Lake fish consumer is presented in Table 5-29 for both adults and children. No other multiple scenario combinations are expected for the Study Area.

Table 5-29. Excess Cancer Risk Estimates Across Scenarios

Scenario	Cumulative Lifetime Excess Cancer Risk[a]
Force Lake recreational user RME scenario	
Exposure to wetland soil	9×10^{-6}
Exposure to lake sediment	1×10^{-6}
Exposure to lake water	1×10^{-7}
Force Lake fish consumer RME scenario	
Exposure via fish consumption	2×10^{-5}
Cumulative risk across scenarios	**3×10^{-5}**

[a] Cumulative lifetime excess cancer risks were calculated for the total exposure duration of 30 years, ranging from birth to age 30 to include the most sensitive life stage.

As shown in Table 5-29, the cumulative risk based on the Force Lake recreational user RME scenario and the Force Lake fish consumer RME scenario was based largely on the risks associated with the consumption of fish from Force Lake (approximately 67% of the total). This analysis demonstrates that direct exposure to wetland soil, lake sediment, and lake surface water contributed relatively little to recreational risk estimates when both direct exposure and fish consumption were assessed.

6.0 UNCERTAINTY ANALYSIS

In any risk assessment, there is always some uncertainty regarding the resulting risk estimates. Despite using the best available information to parameterize the scenarios evaluated in this baseline HHRA and to represent the toxicity of the COPCs, these estimates are inherently uncertain. Table 6-1 presents a summary of the uncertainties inherent in the risk estimates presented in this document.

Table 6-1 Summary of Uncertainties Identified in the Baseline HHRA

Parameter	Level of Uncertainty	Effect of Uncertainty on Risk Estimate	Potential Means to Reduce Uncertainty	Potential Impact on Risk Estimates	Comments
Exposure assessment					
EPCs for small datasets or infrequently detected COPCs (Section 6.1.1)	low to medium	For COPCs where fewer than six detected concentrations were available, the higher of either the maximum detect or half the maximum RL was used as the EPC. This value may under- or over-estimate the true mean.	Collect additional data with lower reporting limits	low	The majority of datasets (including all COCs) had 6 or more detected values and thus it was possible to calculate a UCL. All COCs had 6 or more detects, and thus UCLs could be calculated.
COPCs lacking guidance on dermal absorption fractions (Section 6.1.2)	medium	The underestimation of dermal risks from metals lacking absorption factors is expected to have small effect on overall risk estimates.	Evaluate risks based on a range of absorption assumptions	low	Dermal absorption is dependent on the speciation of metals, but is typically low. Risk calculations in this uncertainty assessment were done assuming that dermal absorption ranged from 0.001 to 0.03 (the range of available for metals). These risk estimates indicate this pathway likely does not contribute significantly to underestimation.
Exposure frequency for the Force Lake recreational user scenario (Section 6.1.3)	medium	Total risk estimates may be overestimated.	Further evaluation of recreational activities at the Study Area	low	The exposure frequency used for the Force Lake recreational user was likely overestimated given the conditions at the Study Area. This, risks to recreational users are likely to be lower than those presented in Section 5.
Use of BSAFs to estimate fish tissue concentrations (Section 6.1.4)	high	Total risk estimate may be over- or underestimated, although overestimation is more likely.	Collect fish tissue from Force Lake	medium to low	Based on the analysis performed in Section 6.1.3, uncertainty in the BSAF value can increase or decrease risk estimates. The total excess cancer risk is unlikely to increase significantly if fish tissue was collected, but could decrease.

Table 6-1 Summary of Uncertainties Identified in the Baseline HHRA

Parameter	Level of Uncertainty	Effect of Uncertainty on Risk Estimate	Potential Means to Reduce Uncertainty	Potential Impact on Risk Estimates	Comments
Fish consumption rate (Section 6.1.5)	high	May over- or underestimate the risks associated with the consumption of fish tissue.	Conduct a creel study or formal fishing survey	unknown	Risk estimates have a one-to-one relationship with consumption rates, and thus are sensitive to changes in this value. However, based on the number of fish present in Force Lake, a consumption rate higher than six meals per year is unlikely, as discussed in Section 6.1.4.
Toxicity Assessment					
Chemicals without RSLs (Section 6.2.1)	low	Total risk estimate may be somewhat underestimated.	Develop RSLs and/or toxicity values for these COPCs	low	Chemicals without RSLs are listed in Section 6.2.1.
COPCs without toxicity values (Section 6.2.2)	low	total risk estimate may be somewhat underestimated.	Develop toxicity values for these COPCs	low	The few COPCs without toxicity values for a given pathway are listed in Section 6.2.2.
Risk Characterization					
Risks from non-detected COPCs (Section 6.3.1)	low	May have no effect, or may mean that risks estimates are underestimated if COPC is present.	Achieve lower reporting limits	low for total risk estimates	Reporting limits for non-detected COPC are compared to RSLs in Section 6.3.1.
Risks to current Facility workers from soil berm and soil stockpile (Section 6.3.2)	low	Likely has no effect because of the low exposure potential of current outdoor workers to this soil	Interview workers	low for total risk estimates	The soil berm and soil stockpile are both located in areas away from the everyday activities of workers at the Facility, and thus risk from the exposure to this soil is low.

BSAF – biota sediment accumulation factor
EPC – exposure point concentration
HHRA – human health risk assessment
RSL – regional screening level

The following subsections further discuss the uncertainties summarized in Table 6-1, divided into sections on the exposure assessment, toxicity assessment, and risk characterization.

6.1 Exposure Assessment

For most HHRAs, including this assessment of risks to people at the Study Area, assumptions made during the exposure assessment contribute a high level of uncertainty and variability to the risk estimates. Alternative exposure values are possible for the parameters described in Section 3.0, which would in turn affect the risk estimates presented in Section 5.0.

This section addresses uncertainties related to the exposure assessment, including exposure point concentrations, dermal absorption factors, BSAFs used to calculate fish tissue concentrations, and the fish consumption rate used in the HHRA.

6.1.1 Exposure Point Concentrations

For all COPCs, ProUCL 4.00.04 software was used to develop UCLs on the mean. This software first evaluates the distribution of the data, then recommends a statistical approach and provides an estimated UCL (EPA 2009d). The UCLs were intended to provide reasonably health-protective estimates of the EPCs for the infrequently detected COPCs present in soil, sediment, and water at the Study Area. However, when fewer than six detected concentrations were available for a given dataset, the higher of either the maximum detect of half of the maximum RL was used as the EPC. The following subsections address cases when ProUCL could not be used to calculate a UCL.

6.1.1.1 EPC Estimates for Small Datasets

This section discusses the uncertainties associated with datasets with fewer than six samples. As described above, a UCL was not calculated for datasets with fewer than six samples. For datasets with fewer than six samples, the higher of either the maximum detected concentration or half the maximum RL was used as the EPC. The uncertainty related to potential EPC under- or over-estimation is greater for EPCs derived for small datasets with fewer than six samples because it was not possible to use ProUCL.

For this HHRA, less than 10% of the EPCs had fewer than 6 samples in the dataset, none of which were for COCs. Thus, the uncertainty related to the calculation of EPCs for small samples sizes is low.

6.1.1.2 EPC Estimates for Infrequently Detected COPCs

ProUCL 4.00.04 was used to calculate a UCL when there were six or more detected values because it provides defensible statistical methods for UCL calculations, and does not rely on simple substitutions for the non-detected data points. ProUCL software allows for parametric and non-parametric analysis of both uncensored datasets (i.e., all detected concentrations) and those that contain non-detects to determine a distribution from which a UCL may be calculated. Some of the statistical methods (e.g., Kaplan-Meier method) are able to handle datasets that have multiple detection levels (EPA 2009d). These more accurate methods for identifying distributions make it possible to better define the appropriate UCL value for use in risk assessment.

Approximately 35% of the datasets for which EPCs were needed had detection frequencies of less than 50%. For those datasets where more than six detected values were available, ProUCL was used to calculate a UCL, thus reducing some of the uncertainty associated with the low detection frequency. However, approximately half of these datasets also had less than six detected values, and thus ProUCL could not be used. For these datasets, the higher of either the maximum detect of half of the maximum RL was used as the EPC. While the use of the maximum value here may under- or overestimate the EPC, the low number of EPCs that are maximum values helps to reduce this uncertainty. Additionally, none of the COPCs that fall into this category were identified as COCs.

6.1.2 Dermal Absorption Fractions

Dermal exposure to nine metals identified as COPCs for the direct sediment exposure scenarios was not evaluated because these COPCs lacked dermal absorption factors. EPA guidance states that “for inorganics, the speciation of the compound is critical to the dermal absorption and there are too little data to extrapolate a reasonable default value” (EPA 2004). Therefore, only incidental ingestion and/or inhalation for these 9 COPCs was considered in the risk characterization. Note that dermal exposure was not evaluated for an additional 14 VOCs because, as stated in EPA guidance (2004), no default dermal absorption values are available for VOCs because they “would tend to be volatilized from the soil on skin and should be accounted for via inhalation routes in combined exposure pathways.”

Although it is not possible to estimate the dermal absorption for the nine metals, a sensitivity analysis was conducted to evaluate the importance of the dermal portion of the total risk estimate (i.e., whether risks were likely to be significantly underestimated because of the absence of dermal absorption calculations). For metals, DEQ (1998) has recommended a default dermal absorption value of 0.01 (EPA 1995). For this exercise, dermal absorption fractions that were an order of magnitude on either side of this default value were evaluated. Alternate risk estimates using these default dermal absorption values were calculated. No additional excess cancer risk exceedances of 1×10^{-6} or HQ exceedances of 1 occurred for any scenario.

In addition, risks were calculated for one metal assuming several different absorption factors to assess the impacts on risk estimates of different assumptions for dermal absorption values. Cobalt was selected because of its higher toxicity relative to other metals and the higher risks estimated using default dermal absorption values. Therefore, the inclusion of dermal exposure would be expected to have a more significant impact on risk estimates than the inclusion of dermal exposure for other metals without ABS.

Table 6-2 presents non-cancer risk estimates for cobalt using a range of dermal absorption values for several scenarios.

Table 6-2. Risk Estimates Using a Range of Dermal Absorption Values for Cobalt

Dermal Absorption Factor[a]	Hazard Quotient			
	Incidental Ingestion	Dermal Absorption	Inhalation	Total
Industrial (Construction/Trenching) Worker RME Scenario: Facility Soil				
0.1	0.1	0.1	0.00009	0.2
0.01	0.1	0.01	0.00009	0.1
0.001	0.1	0.001	0.00009	0.1
none	0.1	none	0.00009	0.1
Future Outdoor Worker RME Scenario: Facility Soil				
0.1	0.05	0.02	0.0004	0.07
0.01	0.05	0.002	0.0004	0.05
0.001	0.05	0.0002	0.0004	0.05
none	0.05	none	0.0004	0.05
Force Lake Recreational User RME Scenario: Exposure of Children Aged 0 to 6 to Wetland Soil[b]				
0.1	0.04	0.007	na	0.05
0.01	0.04	0.0007	na	0.04
0.001	0.04	0.00007	na	0.04
none	0.04	none	na	0.04
Force Lake Recreational User RME Scenario: Exposure of Children Aged 0 to 6 to Lake Sediment[b]				
0.1	0.04	0.008	na	0.05
0.01	0.04	0.0008	na	0.04
0.001	0.04	0.00008	na	0.04
none	0.04	none	na	0.04

Note – The incidental ingestion and inhalation HQs were presented in the risks characterization (Section 5.3) and are presented here for completeness.

[a] EPA guidance provides a dermal absorption value for only two metals (0.03 for arsenic and 0.001 for cadmium). The hypothetical range of dermal absorption factors included in this table (0.1, 0.01, and 0.001) is inclusive of the values available for these metals.

[b] Risks to children aged 0 to 6 presented in Section 5.3 were higher than or equal to those for cumulated lifetime exposure, and thus the Force Lake recreational user scenario based on the exposure of children aged 0 to 6 is shown here.

EPA – US Environmental Protection Agency

na – not applicable or available
RME – reasonable maximum exposure

As can be seen in Table 6-2, the HQs for cobalt change only slightly (if at all) across the range of ABS used. Thus, it can be concluded that the lack of dermal absorption factors for metals (and the absence of significant risks based on dermal exposure for these COPCs) is unlikely to affect overall conclusions from this HHRA.

6.1.3 Force Lake Recreational User Exposure Frequency

The exposure frequency (22 days per year) used to evaluate risks to individuals exposed to wetland soil, Force Lake sediment, and Force Lake surface water was based on the assumption that individuals visit the Study Area once per week during the summer (13 weeks) and once per month during the rest of the year (9 months). However, given the conditions at the Study Area (i.e., limited public access and lack or recreational facilities), the exposure frequency is likely to be less than the 22 days per year assumed in this HHRA. Thus, risks would be expected to be lower than those presented in Section 5. Exposure frequency represents a relatively low source of uncertainty for this HHRA because risks from sediment and soil were relatively low (i.e., equal to 1×10^{-6} to 9×10^{-6}).

6.1.4 Calculation of Contaminant Concentrations in Fish Tissue Using BSAFs

Fish tissue samples were not analyzed for contaminant concentrations in Force Lake because of the low level of concentrations found in Force Lake sediments. Thus, to evaluate the risks to humans from the consumption of fish, contaminant concentrations in fish tissue were estimated using BSAFs (see Attachment 2). As discussed in Section 5.0, arsenic, total PCBs and total DDTs were the main COPCs contributing to the total excess cancer risk exceeding 1×10^{-6}. No COPCs had an HQ greater than 1. This section discusses the BSAFs for arsenic, total PCBs, and total DDTs in more detail. Table 6-3 presents the BSAFs used in the HHRA along with a discussion of the selected values used in this HHRA.

Table 6-3. Fish BSAFs Used in the HHRA

COPC	BSAF	Source	Discussion of Selected Value
Arsenic	0.12 dw/dw	PTI (1995b)	Only one fish BSAF value (0.12) was presented in the PTI report for arsenic (1995b). The average invertebrate BSAF from this source was 0.12, with a range of BSAFs from 0.022 to 0.71.
Total PCBs	6.45 lipid/OC	mean of BSAFs in EPA database (2008a)[a]	The dataset contains 285 BSAFs, ranging from 0.0038 to 258, with a median value of 2.07 and a mean value of 6.45. The standard deviation is 21 and the standard error is 1.2.

Table 6-3. Fish BSAFs Used in the HHRA

COPC	BSAF	Source	Discussion of Selected Value
Total DDTs	3.01 lipid/OC	weighted average of the mean BSAFs for components detected in Force Lake (16% 2,4′-DDD, 29% 4,4′-DDD, and 55% 4,4′-DDE)	2,4′-DDD: A geometric mean of 0.045 was selected from PTI (1995a). The range of BSAFs reported was 0.006 to 0.12, with a median of 0.084.
			4,4′-DDD: A mean BSAF of 0.83 was calculated from EPA's BSAF database (2008a). The dataset contains 28 BSAFs, ranging from 0.10 to 2.23, with a median value of 0.74. The standard deviation is 0.61 and the standard error is 0.12.
			4,4′-DDE: A mean BSAF of 5.00 was calculated from EPA's BSAF database (2008a). The dataset contains 34 BSAFs, ranging from 0.070 to 35, with a median value of 1.2. The standard deviation is 7.9 and the standard error is 1.3.

[a] BSAF is the average BSAF reported in EPA's BSAF database for all fish species.

BSAF – biota sediment accumulation factor
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPA – US Environmental Protection Agency
HHRA – human health risk assessment
OC – organic carbon
PCB – polychlorinated biphenyl

As can be seen in Table 6-3, considerable variability exists regarding available BSAF values. The minimum to maximum range of BSAFs can span several orders of magnitude (although often because of the presence of outliers in the dataset). Table 6-4 presents excess cancer risks for the Force Lake fish consumer RME scenarios for a range of BSAFs to determine the impact of BSAF uncertainty on risk estimates.

Table 6-4. Risk Calculations Across a Range of BSAFs

Description of BSAF Value	BSAF Value	Lifetime Excess Cancer Risks
Arsenic		
Selected value for HHRA	0.12 dw/dw	7×10^{-6}
Median value for invertebrates[a]	0.064 dw/dw	4×10^{-6}
10th Percentile for invertebrates[a]	0.045 dw/dw	2×10^{-6}
90th Percentile for invertebrates[a]	0.41 dw/dw	2×10^{-5}
Total PCBs		
Selected value for HHRA	6.45 lipid/OC	1×10^{-5}
Median BSAF	2.07 lipid/OC	4×10^{-6}
10th Percentile of BSAFs	0.17 lipid/OC	4×10^{-7}
90th Percentile of BSAFs	12.6 lipid/OC	3×10^{-5}
Total DDTs		
Selected value for HHRA	3.01 lipid/OC	2×10^{-6}
Median BSAF	0.89 lipid/OC	7×10^{-7}
10th Percentile of BSAFs[b]	0.10 lipid/OC	8×10^{-8}
90th Percentile of BSAFs[b]	11.5 lipid/OC	9×10^{-6}

Table 6-4. Risk Calculations Across a Range of BSAFs

Description of BSAF Value	BSAF Value	Lifetime Excess Cancer Risks
Total Excess Cancer Risk		
Selected value for HHRA	na	2×10^{-5}
Median BSAF	na	8×10^{-6}
10th Percentile of BSAFs	na	2×10^{-6}
90th Percentile of BSAFs	na	6×10^{-5}

[a] As discussed in Table 6-3, only one fish BSAF was available for arsenic. Invertebrate BSAFs were used in this table to provide a range of possible BSAFs.

[b] No 10th and 90th percentiles could be calculated for 2,4′-DDD because only summary statistics were presented by PTI (1995a). Thus, the minimum and maximum values were used to calculate the total DDT BSAF for 2,4′-DDD.

BSAF – biota sediment accumulation factor
DDT – dichlorodiphenyltrichloroethane
HHRA – human health risk assessment
OC – organic carbon
PCB – polychlorinated biphenyl

As can be seen in Table 6-4, excess cancer risk estimates changed significantly compared to the original risk estimates when the high-end (maximum or 90th percentile) and low-end (minimum or 10th percentile) BSAFs were used.

Based on this assessment, the use of BSAFs (rather than actual fish tissue data) to estimate fish tissue concentrations is unlikely to result in a significant underestimation of the total excess cancer risk. Because conservative (i.e., health protective) BSAFs were used, the total excess cancer risk is more likely to be overestimated.

6.1.5 Fish Consumption Rate

In order to characterize risks to people based on the consumption of fish from Force Lake, it was necessary to estimate the number of meals of fish consumed by people who fish at the lake (see Section 3.3.3). Based on the available information, a rate of six meals per year was selected to conservatively represent various types of individuals who may fish at Force Lake, including recreational anglers, ethnic populations using fish collected from Force Lake to supplement their diet, or transient individuals collecting fish from Force Lake as they move around the area. However, because of the lack of creel studies or formal fishing surveys regarding fish consumption for Force Lake, the consumption rate used in this HHRA is uncertain. This section discusses this source of uncertainty in relation to the total excess cancer risk of 2×10^{-5} estimated in Section 5.3.

Because the consumption rate has a one-to-one relationship with the estimated risk based on fish consumption, the risk estimate is highly sensitive to consumption rate assumptions. Alternate excess cancer risk estimates were calculated for a range of consumption rates for the adult Force Lake fish consumer scenario because risks to adults were higher than those to children. The following three rates are discussed in this section:

- **3 meals per year (1.88 g/day):** Half of the selected fish consumption rate for the Study Area. This rate may be more realistic based on the results of the 2009 and late 1980s fish surveys (see Section 3.3.3).
- **6 meals per year (3.75 g/day):** The selected fish consumption rate for the Study Area.
- **28 meals per year (17.5 g/day):** The current EPA default fish consumption rate for the protection of water quality (EPA 2000b).

Table 6-5 presents the risk estimates associated with these consumption rates. In addition, these fish consumption rates are shown in Figure 6-1, which illustrates the relationship between the fish consumption rate and the excess cancer risk.

Table 6-5. Risk Estimates Across Fish Consumption Rates

Consumption Rate	Meals per Year	Lifetime Excess Cancer Risk
Half of the Harbor Oil fish consumption rate	3	1×10^{-5}
Harbor Oil HHRA consumption rate	6	2×10^{-5}
DEQ default fish consumption rate	28	1×10^{-4}

DEQ – Oregon Department of Environmental Quality
HHRA – human health risk assessment

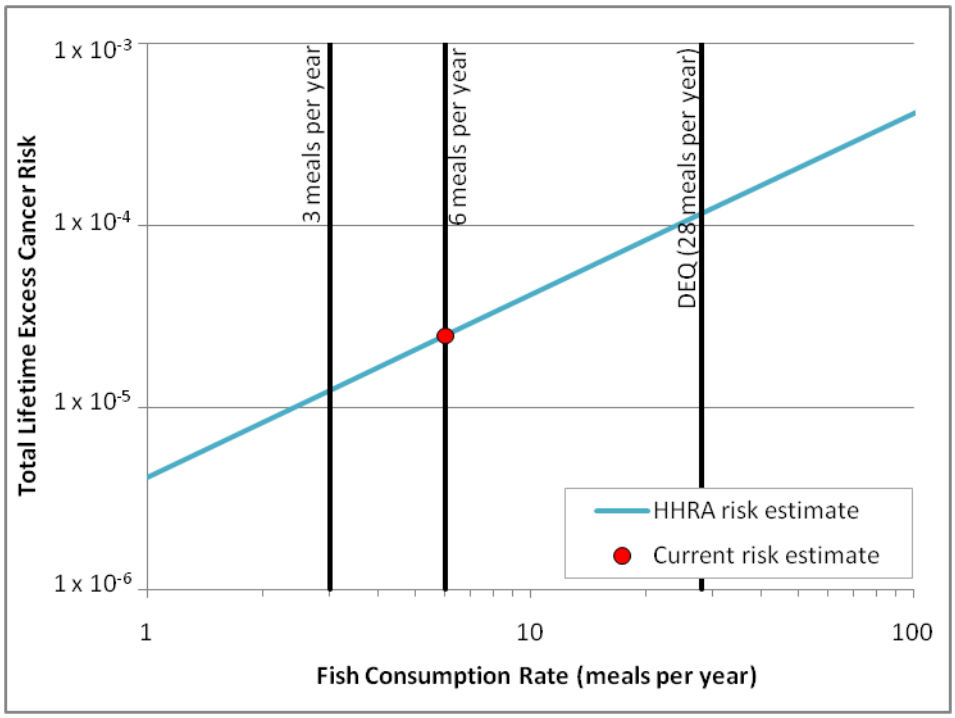


Figure 6-1. Excess Cancer Risk Estimates across Fish Consumption Rates

As can be seen in Figure 6-1, the selection of a consumption rate is important in the estimation of risks to people from the consumption of fish from Force Lake. At the selected rate of six meals per year, the integrated lifetime excess cancer risk was 2×10^{-5}. A decrease in the fish consumption rate to three meals per year (half of the rate used in this HHRA) would have resulted in an integrated lifetime excess cancer risk of 1×10^{-5}. An increase in the fish consumption rate to the EPA default rate of 28 meals per year would have resulted in an integrated lifetime excess cancer risk of 1×10^{-4}.

To estimate the feasibility of various fish consumption rates, the number of fish collected during the 2009 Force Lake fish survey was compared to the number of fish that would be needed to support six anglers at each of these rates (Table 6-6). This comparison was done assuming only adult anglers and assuming each adult angler was also feeding one young child (aged 0 to 6).

Table 6-6. Number of Fish Needed for Six Anglers Consuming Fish from Force Lake Under Various Consumption Rate Scenarios

Fish Size Category	Fish Collected During the 2009 Survey[a]	Number of Fish Needed per Year to Support Various Consumption Rates for Six Anglers		
		Half of the Harbor Oil Fish CR (3 meals per year)	Harbor Oil HHRA CR (6 meals per year)	EPA Default Fish CR (28 meals per year)
Adults Only				
Small fish (less than 15 cm in length)	76	180 – 270	360 – 540	1,680 – 2,520
Medium-sized fish (15 to 25 cm in length)	12	36 – 54	72 – 108	336 – 504
Large fish (over 50 cm in length)	1 – 2[b]	18	36	168
Adults and Children				
Small fish (less than 15 cm in length)	76	230 – 346	461 – 691	2,150 – 3,226
Medium-sized fish (15 to 25 cm in length)	12	46 – 69	92 – 138	430 – 645
Large fish (over 50 cm in length)	1 – 2[b]	23	46	215

Note: One adult meal (8 oz or 228 g) was assumed to be equal to either 1 large fish (over 50 cm in length), 2 to 3 medium-sized fish (15 to 25 cm in length), or 10 to 15 small fish (less than 15 cm in length). The number of fish per adult meal was scaled based on the young child meal size of 64 g (for children aged 0 to 6).

[a] Source: Windward (2009b)

[b] The large fish (carp) were observed during the fish survey but were not captured.

CR – consumption rate

EPA – US Environmental Protection Agency

HHRA – human health risk assessment

As can be seen in Table 6-6, the population of fish in the lake is small, particularly when compared to the numbers of fish that would be needed to support fishing at the default EPA consumption rate of 28 meals per year and even compared to the rate proposed corresponding to consumption of six meals per year. Given the survey methods that were used and conditions under which the survey was conducted, it is unlikely that Force Lake contains the numbers of fish needed to support six anglers at the EPA default consumption rate, which would require that each year anglers catch several hundred more fish than were observed during the 2009 survey. As can be seen from Table 6-6, it is even unlikely that the lake would support the consumption rate of six meals per year assumed for the HHRA.

6.2 Toxicity Assessment

This section addresses uncertainties related to the toxicity assessment of chemicals for the Study Area, including chemicals without RSLs (Section 6.3.1) and COPCs without toxicity information (Section 6.2.2).

6.2.1 Chemicals without RSLs

The toxicity benchmarks used in this baseline HHRA are based on the most recent guidance provided by EPA (see Section 3.2). They are health-protective in that they include uncertainty factors or extrapolations to account for sensitive sub-populations or other limitations of the toxicity data on which they are based. However, for some chemicals, no screening levels (e.g., RSLs) are available. Table 6-7 presents a list of those chemicals without soil or sediment RSLs, Table 6-8 presents a list of those chemicals without water RSLs, and Table 6-9 presents a list of those chemicals without fish RSLs. More information on the results of the analysis of these chemicals is available in Attachment 3.

Table 6-7. Chemicals Without Soil RSLs

Detected Chemicals	Non-Detected Chemicals
Metals	**Other SVOCs**
Calcium	2-Nitrophenol
Manganese	3-Nitroaniline
Sodium	4-Bromophenyl phenyl ether
Other SVOCs	4-Chloro-3-methylphenol
Carbazole	4-Chlorophenyl phenyl ether
PAHs	4-Nitrophenol
Benzo(g,h,i)perylene	**Phthalates**
Dibenzofuran	Dimethyl phthalate
Phenanthrene	Di-n-octyl phthalate
VOCs	**VOCs**
Methyl ethyl ketone	1,1-Dichloropropene
Methyl isobutyl ketone	1,2,3-Trichlorobenzene
Methylcyclohexane	2,2-Dichloropropane
n-Butylbenzene	2-Hexanone

Table 6-7. Chemicals Without Soil RSLs

Detected Chemicals	Non-Detected Chemicals
p-Cymene tert-Butylbenzene	Bromochloromethane

Note: No sediment RSLs are available, and thus soil RSLs were used in this risk assessment, as discussed in Section 3.2.1.

PAH – polycyclic aromatic hydrocarbon
RSL – regional screening level
SVOC – semivolatile organic compound
VOC – volatile organic compound

Table 6-8. Chemicals Without Water RSLs

Detected Chemicals	Non-Detected Chemicals	
Metals	**Other SVOCs**	**Pesticides**
Aluminum	1,2,4-Trichlorobenzene	beta-BHC
Antimony	2,4,5-Trichlorophenol	delta-BHC
Cadmium	2,4-Dichlorophenol	gamma-Chlordane
Calcium	2,4-Dimethylphenol	Methoxychlor
Cobalt	2,4-Dinitrophenol	beta-BHC
Iron	2,4-Dinitrotoluene	delta-BHC
Magnesium	2-Methylphenol	gamma-Chlordane
Potassium	2-Nitroaniline	Methoxychlor
Selenium	2-Nitrophenol	**Phthalates**
Sodium	3-Nitroaniline	Butyl benzyl phthalate
Thallium	4,6-Dinitro-o-cresol	Dimethyl phthalate
Vanadium	4-Bromophenyl phenyl ether	Di-n-octyl phthalate
Zinc	4-Chloro-3-methylphenol	**VOCs**
Other SVOCs	4-Chloroaniline	1,1,1,2-Tetrachloroethane
2-Chlorophenol	4-Chlorophenyl phenyl ether	1,1,2,2-Tetrachloroethane
Acetophenone	4-Methylphenol	1,1,2-Trichlorotrifluoroethane
Benzaldehyde	4-Nitroaniline	1,1-Dichloropropene
Phenol	4-Nitrophenol	1,2,3-Trichlorobenzene
PAHs	Atrazine	1,2,3-Trichloropropane
2-Methylnaphthalene	Biphenyl	1,2-Dibromo-3-chloropropane
Dibenzofuran	bis(2-chloroethoxy)methane	1,2-Dichloropropane
Phenanthrene	bis(2-chloroethyl)ether	1,3-Dichloropropane
Phthalates	bis(2-chloroisopropyl)ether	2,2-Dichloropropane
Di-n-butyl phthalate	Caprolactam	2-Chlorotoluene
Diethyl phthalate	Carbazole	2-Hexanone
VOCs	Hexachlorobutadiene	4-Chlorotoluene
Acetone	Hexachlorocyclopentadiene	Bromobenzene
n-Butylbenzene	Isophorone	Bromochloromethane
p-Cymene	Nitrobenzene	Carbon disulfide
	N-Nitroso-di-n-propylamine	cis-1,3-Dichloropropene
	N-Nitrosodiphenylamine	Cyclohexane
	Hexachlorobutadiene	Dibromochloromethane
	PAHs	Dibromomethane
	2-Chloronaphthalene	Dichlorodifluoromethane
	Benzo(g,h,i)perylene	Methyl acetate
		Methyl ethyl ketone
		Methyl isobutyl ketone
		Methylcyclohexane
		tert-Butylbenzene
		Tetrachloroethene
		trans-1,3-Dichloropropene
		Vinyl acetate
		1,2-Dichloroethene

BHC – benzene hexachloride
PAH – polycyclic aromatic hydrocarbon
RSL – regional screening level
SVOC – semivolatile organic compound
VOC – volatile organic compound

Table 6-9. Chemicals Without Fish RSLs

Detected Chemicals	Non-Detected Chemicals
PAHs	**Other SVOCs**
Benzo(g,h,i)perylene	1,3-Dichlorobenzene
Dibenzofuran	**Pesticides**
Phenanthrene	delta-BHC
	VOCs
	1,1,2-Trichlorotrifluoroethane
	1,1-Dichloroethene
	1,1-Dichloropropene
	1,2,3-Trichlorobenzene
	1,2,4-Trimethylbenzene
	1,2-Dibromoethane (EDB)
	2,2-Dichloropropane
	2-Chlorotoluene
	2-Hexanone
	4-Chlorotoluene
	Bromochloromethane
	Chloroethane
	Chloromethane
	cis-1,2-Dichloroethene
	cis-1,3-Dichloropropene
	p-Cymene
	Dibromomethane
	Dichloromethane
	Isopropylbenzene
	Methyl isobutyl ketone
	n-Butylbenzene
	n-Propylbenzene
	sec-Butylbenzene
	tert-Butyl methyl ether
	tert-Butylbenzene
	Tetrachloroethene
	trans-1,2-Dichloroethene
	trans-1,3-Dichloropropene

EDB – ethylene dibromide
BHC – benzene hexachloride
PAH – polycyclic aromatic hydrocarbon
RSL – regional screening level
SVOC – semivolatile organic compound
VOC – volatile organic compound

Toxicity information for these chemicals is not provided in the EPA, DEQ, EPA AWQC, or EPA Region 3 sources identified for use in this HHRA (see Section 3.2). Because these chemicals were not identified as COPCs through screening, they were not included in risk estimates. Overall risks may have been underestimated if there are significant toxic effects associated with these chemicals. However, the fact that toxicity values have not been developed for these chemicals provides some indication that the toxicity of these chemicals is generally lower than that

of chemicals for which toxicity values have been developed because scientists conducting toxicity studies tend to prioritize chemicals suspected to be the most toxic.

6.2.2 COPCs without Toxicity Values

Four types of toxicity values were used in this HHRA, including two non-cancer toxicity values (an oral RfD and an inhalation RfC) and two carcinogenic toxicity values[15] (an oral cancer SF and an inhalation unit risk factor). For each of these types of toxicity values, it was not possible to find a value for several COPCs:

- COPCs lacking a oral/dermal RfD: cPAH TEQ, tert-butyl methyl ether, and trichloroethene
- COPCs lacking an inhalation RfC: copper, cPAH TEQ, total DDTs, dichloromethane, and trichloroethene
- COPCs lacking an oral/dermal cancer SF: cobalt, mercury and naphthalene, TPH-gasoline (aliphatic), TPH-diesel (aliphatic)
- COPCs lacking an inhalation unit risk factor: naphthalene

As can be seen from this list, there were relatively few COPC-toxicity value combinations where a value could not be determined, indicating that the level of uncertainty associated with the lack of toxicity values is low. In addition, it should be noted that there was at least one toxicity value available for each COPC. For each COPC, either COPC-specific toxicity information was available or a suitable surrogate was available for at least one of the four types of toxicity values used in this HHRA (see Section 4.0).

When a surrogate was used, efforts were made to select the most toxic surrogate of those available to ensure that this HHRA is sufficiently health-protective. However, it is important to recognize that the use of a surrogate could result in the over- or under-estimation of risk estimates. Because surrogates were used for relatively few COPCs, and health-protective surrogates were selected, this issue does not represent a significant source of uncertainty in this HHRA.

6.3 Risk Characterization

This section addresses uncertainties related to the calculated risk estimates for the Study Area, including risks associated with non-detected COPCs (Section 6.3.1) and current outdoor workers (Section 6.3.2).

[15] Carcinogenic toxicity values were only compiled for those chemicals classified as carcinogens (see Section 4 for additional information).

6.3.1 Non-Detected COPCs

As indicated in Section 3.2.2, risks were characterized only for those COPCs that were detected in the medium specific to that exposure scenario. Some COPCs in each scenario were never detected, but a sufficient number of sample RLs exceeded the applicable RSLs, and thus were identified as COPCs (see Section 3.2).

To provide a brief assessment of the hypothetical risks associated with these COPCs, half of the maximum RLs were compared with the applicable RSLs for each scenario-media combination (Tables 6-10 to 6-17).

Table 6-10. Summary of COPCs with Non-Detected Concentrations for the Industrial (Construction/Trenching) Worker RME Scenario Based on Exposure to Facility Soil

Non-Detected COPC	Unit	Detection Frequency Ratio	RL or Range of RLs	Mean Detect	Mean Value	Worker Soil RSL[a]	No. of Non-Detected Concentrations > RSL[a]	Maximum EF (half RL)[b]
Other SVOCs								
2,6-Dinitrotoluene	µg/kg dw	0/46	98 U – 8,830 U	nd	590	1,700	9	2.6
3,3'-Dichlorobenzidine	µg/kg dw	0/44	98 U – 4,420 U	nd	380	200	30	11
N-Nitroso-di-n-propylamine	µg/kg dw	0/46	98 U – 2,200 U	nd	190	250	16	4.4
Pesticides								
Dieldrin	µg/kg dw	0/115	0.6 U – 9,600 U	nd	90	110	17	44
alpha-BHC	µg/kg dw	0/115	0.6 U – 4,800 U	nd	40	35	22	69
Toxaphene	µg/kg dw	0/115	96 UJ – 480,000 U	nd	9,000	1,600	53	150
VOCs								
1,2-Dibromo-3-chloropropane	µg/kg dw	0/113	3 UJ – 5,600 U	nd	80	73	12	38
1,2-Dibromoethane (EDB)	µg/kg dw	0/113	0.9 U – 1,100 U	nd	10	0.44	113	1,250
1,2-Dichloroethane	µg/kg dw	0/113	0.9 U – 1,100 U	nd	10	7.4	12	74
Bromodichloromethane	µg/kg dw	0/113	0.9 U – 1,100 U	nd	10	23	12	24
Bromomethane	µg/kg dw	0/113	0.9 U – 1,100 U	nd	10	39	12	14
Carbon tetrachloride	µg/kg dw	0/113	0.9 U – 1,100 U	nd	10	70	12	7.9
Chloroform	µg/kg dw	0/113	0.9 U – 1,100 U	nd	10	18	12	31

[a] The worker soil RSL is the lowest of EPA industrial screening levels (2009i) and DEQ human health occupational, construction worker, or excavation worker RBCs for the following four exposure routes: soil ingestion, dermal absorption, and inhalation; volatilization to outdoor air; and leaching to groundwater (2007b).

[b] The EF provides a comparison of half of the maximum RL and the RSL and was calculated by dividing the half RL by the RSL. An EF greater than 1 indicates that the half RL is greater than the RSL.

BHC – benzene hexachloride
COPC – contaminant of potential concern
dw – dry weight
EDB – ethylene dibromide
EF – exceedance factor
EPA – US Environmental Protection Agency
nd – not detected
RBC – risk-based concentration
RL – reporting limit
RME – reasonable maximum exposure
RSL – regional screening level
SVOC – semivolatile organic compound
U – not detected at given concentration
VOC – volatile organic compound

Table 6-11. Summary of COPCs with Non-Detected Concentrations for the Industrial (Construction/Trenching) Worker RME Scenario Based on Exposure to Groundwater

Non-Detected COPC	Unit	Detection Frequency Ratio	RL or Range of RLs	Mean Detect	Mean Value	Worker Water RSL[a]	No. of Non-Detected Concentrations > RSL	Maximum EF (half RL)[b]
PAHs								
cPAH TEQ	µg/L	0/28	0.0910 U – 1.50 U	nd	0.186	0.0029	28	260
Other SVOCs								
2,6-Dinitrotoluene	µg/L	0/6	3.7 U – 4 U	nd	2	3.7	3	0.5
3,3'-Dichlorobenzidine	µg/L	0/6	1.8 U – 2 U	nd	0.9	0.13	6	7.7
Hexachlorobenzene	µg/L	0/28	0.0050 U – 0.4 U	nd	0.04	0.035	6	5.7
Pentachlorophenol	µg/L	0/6	1.8 U – 2 U	nd	0.9	0.47	6	2.1
PCBs								
Total PCBs	µg/L	0/28	0.10 U – 0.96 U	nd	0.14	0.028	28	17
Pesticides								
Aldrin (total)[c]	µg/L	0/28	0.0050 U – 0.019 U	nd	0.0039	0.0033	28	2.9
Dieldrin (total)[c]	µg/L	0/28	0.010 U – 0.019 U	nd	0.0059	0.0035	28	2.7
alpha-BHC	µg/L	0/28	0.0050 U – 0.019 U	nd	0.0039	0.009	6	1.1
Heptachlor	µg/L	0/28	0.0050 U – 0.024 U	nd	0.0043	0.013	7	0.9
Heptachlor epoxide	µg/L	0/28	0.0050 U – 0.019 U	nd	0.0039	0.0062	6	1.5
Toxaphene (total)[v]	µg/L	0/28	0.50 U – 4.8 U	nd	0.69	0.052	28	46
VOCs								
1,2-Dibromoethane (EDB)	µg/L	0/28	0.20 U – 1.0 U	nd	0.5	0.0057	28	88
1,2-Dichloroethane	µg/L	0/28	0.20 U – 1.0 U	nd	0.5	0.13	28	3.8
Bromodichloromethane	µg/L	0/28	0.20 U – 1.0 U	nd	0.5	0.18	28	2.8
Bromomethane	µg/L	0/28	0.50 U – 1.0 U	nd	0.5	0.85	25	0.6
Carbon tetrachloride	µg/L	0/28	0.20 U – 1.0 U	nd	0.5	0.17	28	2.9
Chloroform	µg/L	0/28	0.20 U – 1.0 U	nd	0.5	0.18	28	2.8
Trichloroethene	µg/L	0/28	0.20 U – 1.0 U	nd	0.5	0.029	28	17

[a] The worker water RSL is the lowest of EPA water screening levels (2009i) and DEQ human health occupational RBCs for the following four exposure pathways: ingestion and inhalation from tap water, volatilization to outdoor air, and exposure to groundwater during excavation (2007b).

[b] The EF provides a comparison of half of the maximum RL and the RSL and was calculated by dividing the half RL by the RSL. An EF greater than 1 indicates that the half RL is greater than the RSL.

[c] For this COPC, both total and dissolved concentrations were analyzed. To be conservative, the total fraction was assessed in this HHRA because it is slightly higher than the dissolved fraction.

BHC – benzene hexachloride
COPC – contaminant of potential concern
cPAH – carcinogenic PAH
dw – dry weight
EDB – ethylene dibromide
EF – exceedance factor
EPA – US Environmental Protection Agency
nd – not detected
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RBC – risk-based concentration
RL – reporting limit
RME – reasonable maximum exposure
RSL – regional screening level
SVOC – semivolatile organic compound
TEQ – toxic equivalent
U – not detected at given concentration
VOC – volatile organic compound

Table 6-12. Summary of COPCs with Non-Detected Concentrations for the Future Outdoor Worker RME Scenario Based on Exposure to Facility Soil

Non-Detected COPC	Unit	Detection Frequency Ratio	RL or Range of RLs	Mean Detect	Mean Value	Worker Soil RSL[a]	No. of Non-Detected Concentrations > RSL	Maximum EF (half RL)[b]
Other SVOCs								
2,6-Dinitrotoluene	µg/kg dw	0/37	98 U – 8,830 U	nd	660	1,700	7	2.6
3,3'-Dichlorobenzidine	µg/kg dw	0/36	98 U – 4,420 U	nd	420	200	27	11
N-Nitroso-di-n-propylamine	µg/kg dw	0/37	98 U – 2,200 U	nd	220	250	16	4.4
Pesticides								
Aldrin	µg/kg dw	0/72	0.6 U – 4,800 U	nd	60	100	8	24
Dieldrin	µg/kg dw	0/72	0.6 U – 9,600 U	nd	100	110	16	44
alpha-BHC	µg/kg dw	0/72	0.6 U – 4,800 U	nd	60	35	19	69
gamma-BHC	µg/kg dw	0/72	0.6 U – 4,800 U	nd	60	100	8	24
Heptachlor epoxide	µg/kg dw	0/72	0.6 U – 4,800 U	nd	80	190	8	13
Toxaphene	µg/kg dw	0/72	97 UJ – 480,000 U	nd	12,000	1,600	39	150
VOCs								
1,2-Dibromoethane (EDB)	µg/kg dw	0/69	0.9 U – 1,100 U	nd	20	0.44	69	1,250

[a] The worker soil RSL is the lowest of EPA industrial screening levels (2009i) and DEQ human health occupational, construction worker, or excavation worker RBCs for the following four exposure routes: soil ingestion, dermal absorption, and inhalation; volatilization to outdoor air; and leaching to groundwater (2007b).

[b] The EF provides a comparison of half of the maximum RL and the RSL and was calculated by dividing the half RL by the RSL. An EF greater than 1 indicates that the half RL is greater than the RSL.

BHC –benzene hexachloride
COPC – contaminant of potential concern
dw – dry weight
EDB – ethylene dibromide
EF – exceedance factor
EPA – US Environmental Protection Agency
nd – not detected
RBC –risk-based concentration
RL – reporting limit
RME – reasonable maximum exposure
RSL – regional screening level
SVOC – semivolatile organic compound
U– not detected at given concentration
VOC –volatile organic compound

Table 6-13. Summary of COPCs with Non-Detected Concentrations for the Industrial/Commercial Worker Vapor Intrusion Scenario Based on Exposure to Groundwater

Non-Detected COPC	Unit	Detection Frequency Ratio	RL or Range of RLs	Mean Detect	Mean Value	EPA SL[a]	No. of Non-Detected Concentrations > RSL	Maximum EF (half RL)[b]
Other SVOCs								
Hexachlorobutadiene	µg/L	0/6	0.0050 U – 0.4 U	nd	0.07	0.33	2	0.6
VOCs								
1,1-Dichloropropene	µg/L	0/4	1.0 U	nd	0.5	0.84	4	0.6
1,2-Dibromoethane (EDB)	µg/L	0/6	1.0 U	nd	0.5	0.36	6	1.4
Bromoform	µg/L	0/6	1.0 U	nd	0.5	0.0083	6	60
cis-1,2- Dichloropropene	µg/L	0/6	1.0 U	nd	0.5	0.84	6	0.6
trans-1,2- Dichloropropene	µg/L	0/6	0.94 U – 1.0 U	nd	0.5	0.84	6	0.6

[a] The EPA SL is from EPA's *Guidance for evaluating the vapor intrusion to indoor air pathway from groundwater and soils* (EPA 2002c).

[b] The EF provides a comparison of half of the maximum RL and the RSL and was calculated by dividing the half RL by the RSL. An EF greater than 1 indicates that the half RL is greater than the RSL.

COPC – contaminant of potential concern
dw – dry weight
EDB – ethylene dibromide
EF – exceedance factor
EPA – US Environmental Protection Agency
nd – not detected
RBC –risk-based concentration
RL – reporting limit
RSL – regional screening level
SL – screening level
SVOC – semivolatile organic compound
TEQ – toxic equivalent
U – not detected at given concentration
VOC –volatile organic compound

Table 6-14. Summary of COPCs with Non-Detected Concentrations for the Force Lake Recreational User RME Scenario Based on Exposure to Wetland Soil

Non-Detected COPC	Unit	Detection Frequency Ratio	Detect or Range of Detects	RL or Range of RLs	Mean Detect	Mean Value	Residential/ Recreational Soil RSL[a]	No. of Non-Detected Concentrations > RSL	Maximum EF (half RL)[b]
Metals									
Thallium	mg/kg dw	0/5	nd	0.3 U – 0.75 U	nd	0.3	0.51	3	0.7
Other SVOCs									
2,4-Dinitrophenol	µg/kg dw	0/14	nd	200 U – 17,700 U	nd	2,500	12000	3	0.7
2,4-Dinitrotoluene	µg/kg dw	0/15	nd	98 U – 5,200 U	nd	430	1600	2	1.6
2,6-Dinitrotoluene	µg/kg dw	0/15	nd	98 U – 8,830 U	nd	1,200	420	8	11
3,3'-Dichlorobenzidine	µg/kg dw	0/14	nd	98 U – 5,200 U	nd	760	28	14	93
4,6-Dinitro-o-cresol	µg/kg dw	0/14	nd	200 U – 10,000 U	nd	1,500	610	8	8.2
Atrazine	µg/kg dw	0/5	nd	973 U – 4,420 U	nd	1,440	2100	3	1.1
bis(2-chloroethyl)ether	µg/kg dw	0/15	nd	20 U – 1,000 U	nd	140	190	6	2.6
N-Nitroso-di-n-propylamine	µg/kg dw	0/15	nd	98 U – 5,200 U	nd	330	69	15	38
Pentachlorophenol	µg/kg dw	1/15	80 J	98 U – 5,200 U	80	720	480	7	5.4
Pesticides									
Aldrin	µg/kg dw	0/61	nd	0.92 U – 490 U	nd	12	29	7	8.4
Dieldrin	µg/kg dw	0/61	nd	0.97 U – 980 U	nd	23	23	32	21
alpha-BHC	µg/kg dw	0/61	nd	0.92 U – 490 U	nd	12	4.8	35	51
gamma-BHC	µg/kg dw	0/61	nd	0.92 U – 490 U	nd	12	14	21	18
Toxaphene	µg/kg dw	0/61	nd	96 U – 49,000 U	nd	2,900	440	48	56
VOCs									
1,2-Dibromo-3-chloropropane	µg/kg dw	0/52	nd	3 UJ – 150 UJ	nd	8	5.6	44	13
1,2-Dibromoethane (EDB)	µg/kg dw	0/52	nd	0.9 U – 15 U	nd	1	0.073	52	100
1,2-Dichloroethane	µg/kg dw	0/52	nd	0.9 U – 15 U	nd	1	1.2	43	6.3
Bromodichloromethane	µg/kg dw	0/52	nd	0.9 U – 15 U	nd	1	3.9	10	1.9

Table 6-14. Summary of COPCs with Non-Detected Concentrations for the Force Lake Recreational User RME Scenario Based on Exposure to Wetland Soil

Non-Detected COPC	Unit	Detection Frequency Ratio	Detect or Range of Detects	RL or Range of RLs	Mean Detect	Mean Value	Residential/ Recreational Soil RSL[a]	No. of Non-Detected Concentrations > RSL	Maximum EF (half RL)[b]
Chloroform	µg/kg dw	0/52	nd	0.9 U – 15 U	nd	1	3.1	13	2.4
Vinyl chloride	µg/kg dw	0/52	nd	0.9 U – 15 U	nd	1	0.5	52	15

[a] The residential/recreational soil RSL is the lowest of EPA residential screening levels (2009i) and DEQ RBCs through soil ingestion, dermal contact, and inhalation; residential exposure through volatilization to outdoor air; and residential exposure through leaching to groundwater (2007b).

[b] The EF provides a comparison of half of the maximum RL and the RSL and was calculated by dividing the half RL by the RSL. An EF greater than 1 indicates that the half RL is greater than the RSL.

BHC –benzene hexachloride
COPC – contaminant of potential concern
dw – dry weight
EDB – ethylene dibromide
EF – exceedance factor
EPA – US Environmental Protection Agency
J – estimated concentration
nd – not detected
RBC –risk-based concentration
RL – reporting limit
RME – reasonable maximum exposure
RSL – regional screening level
SVOC – semivolatile organic compound
U – not detected at given concentration
VOC –volatile organic compound

Table 6-15. Summary of COPCs with Non-Detected Concentrations for the Force Lake Recreational User RME Scenario Based on Exposure to Lake Sediment

Non-Detected COPC	Unit	Detection Frequency Ratio	RL or Range of RLs	Mean Detect	Mean Value	Residential/ Recreational Soil RSL[a]	No. of Non-Detected Concentrations > RSL	Maximum EF (half RL)[b]
Pesticides								
Dieldrin	µg/kg dw	0/11	4.8 U – 25 U	nd	11	23	9	0.5
alpha-BHC	µg/kg dw	0/11	2.4 U – 12 U	nd	5.1	4.8	9	1.3
Toxaphene	µg/kg dw	0/11	970 U – 5,000 U	nd	2,100	440	11	5.7
VOCs								
1,2-Dibromo-3-chloropropane	µg/kg dw	0/11	5.3 U – 41 U	nd	15	5.6	9	3.7
1,2-Dibromoethane (EDB)	µg/kg dw	0/11	1.1 U – 8.2 U	nd	3.0	0.073	11	56
1,2-Dichloroethane	µg/kg dw	0/11	1.1 U – 8.2 U	nd	3.0	1.2	9	3.4
Benzene	µg/kg dw	0/11	1.1 U – 8.2 U	nd	3.0	8.4	0	0.49
Bromodichloromethane	µg/kg dw	0/11	1.1 U – 8.2 U	nd	3.0	3.9	8	1.1
Chloroform	µg/kg dw	0/11	1.1 U – 8.2 U	nd	3.0	3.1	9	1.3
Trichloroethene	µg/kg dw	0/11	1.1 U – 8.2 U	nd	3.0	1.7	9	2.4
Vinyl chloride	µg/kg dw	0/11	1.1 U – 8.2 U	nd	3.0	0.5	11	8.2

[a] The residential/recreational sediment RSL is the lowest of EPA residential screening levels (2009i) and DEQ RBCs through soil ingestion, dermal contact, and inhalation; residential exposure through volatilization to outdoor air; and residential exposure through leaching to groundwater (2007b). Soil RSLs are used because no sediment-specific RSLs are available.

[b] The EF provides a comparison of half of the maximum RL and the RSL and was calculated by dividing the half RL by the RSL. An EF greater than 1 indicates that the half RL is greater than the RSL.

BHC –benzene hexachloride
dw – dry weight
EDB – ethylene dibromide
EF – exceedance factor
EPA – US Environmental Protection Agency
nd – not detected
RBC –risk-based concentration
RL – reporting limit
RME – reasonable maximum exposure
RSL – regional screening level
U – not detected at given concentration
VOC –volatile organic compound

Table 6-16. Summary of COPCs with Non-Detected Concentrations for the Force Lake Recreational User RME Scenario Based on Exposure to Lake Surface Water

Non-Detected COPC	Unit	Detection Frequency Ratio	RL or Range of RLs	Mean Detect	Mean Value	Residential/ Recreational Water RSL[a]	No. of Non-Detected Concentrations > RSL	Maximum EF (half RL)[b]
Metals								
Cobalt (total)[c]	µg/L	0/3	3 U	nd	2	1.1	3	1.4
PAHs								
cPAH TEQ	µg/L	0/3	0.0910 U	nd	0.0455	0.0029	3	16
Other SVOCs								
1,2,4-Trichlorobenzene	µg/L	0/3	5.0 U	nd	2.5	0.82	3	3.0
1,4-Dichlorobenzene	µg/L	0/3	1.0 U	nd	0.50	0.43	3	1.2
Hexachlorobenzene	µg/L	0/3	0.0050 U	nd	0.0025	0.00028	3	8.9
PCBs								
Total PCBs	µg/L	0/3	0.10 UJ	nd	0.050	0.000064	3	780
Pesticides								
Aldrin	µg/L	0/3	0.0050 U	nd	0.0025	0.000049	3	51
Dieldrin	µg/L	0/3	0.010 U	nd	0.0050	0.000052	3	96
alpha-BHC	µg/L	0/3	0.0050 U	nd	0.0025	0.0026	3	1.0
beta-BHC	µg/L	0/3	0.0050 U – 0.024 U	nd	0.0057	0.0091	1	1.3
gamma-Chlordane	µg/L	0/3	0.0050 U	nd	0.0025	0.0008	3	3.1
Total chlordane	µg/L	0/3	0.0050 U	nd	0.0025	0.0008	3	3.1
Heptachlor	µg/L	0/3	0.0050 U	nd	0.0025	0.000079	3	32
Heptachlor epoxide	µg/L	0/3	0.0050 U	nd	0.0025	0.000039	3	64
Toxaphene	µg/L	0/3	0.50 U	nd	0.25	0.00028	3	890
VOCs								
1,1,1,2-Tetrachloroethane	µg/L	0/3	1.0 U	nd	0.50	0.52	3	1.0
1,1,2,2-Tetrachloroethane	µg/L	0/3	1.0 U	nd	0.50	0.067	3	7.5
1,1,2-Trichloroethane	µg/L	0/3	1.0 U	nd	0.50	0.24	3	2.1
1,2,3-Trichloropropane	µg/L	0/3	2.0 U	nd	1.0	0.0096	3	100

Table 6-16. Summary of COPCs with Non-Detected Concentrations for the Force Lake Recreational User RME Scenario Based on Exposure to Lake Surface Water

Non-Detected COPC	Unit	Detection Frequency Ratio	RL or Range of RLs	Mean Detect	Mean Value	Residential/ Recreational Water RSL[a]	No. of Non-Detected Concentrations > RSL	Maximum EF (half RL)[b]
1,2-Dibromo-3-chloropropane	µg/L	0/3	5.0 U	nd	2.5	0.00032	3	7,800
1,2-Dibromoethane (EDB)	µg/L	0/3	1.0 U	nd	0.50	0.0057	3	88
1,2-Dichloroethane	µg/L	0/3	1.0 U	nd	0.50	0.13	3	3.8
1,2-Dichloropropane	µg/L	0/3	1.0 U	nd	0.50	0.39	3	1.3
Benzene	µg/L	0/3	1.0 U	nd	0.50	0.35	3	1.4
Bromodichloromethane	µg/L	0/3	1.0 U	nd	0.50	0.12	3	4.2
Bromomethane	µg/L	0/3	1.0 U	nd	0.50	0.85	3	0.6
Carbon tetrachloride	µg/L	0/3	1.0 U	nd	0.50	0.17	3	2.9
Chloroform	µg/L	0/3	1.0 U	nd	0.50	0.18	3	2.8
cis-1,3-Dichloropropene	µg/L	0/3	1.0 U	nd	0.50	0.34	3	1.5
Dibromochloromethane	µg/L	0/3	1.0 U	nd	0.50	0.15	3	3.3
Tetrachloroethene	µg/L	0/3	1.0 U	nd	0.50	0.11	3	4.5
trans-1,3-Dichloropropene	µg/L	0/3	1.0 U	nd	0.50	0.34	3	1.5
Trichloroethene	µg/L	0/3	1.0 U	nd	0.50	0.029	3	17
Vinyl chloride	µg/L	0/3	1.0 U	nd	0.50	0.016	3	31

[a] The residential/recreational water RSL is the lowest of EPA AWQC for human water/ organism consumption and organism consumption (2009c), EPA water screening levels (2009i), and DEQ human health occupational RBCs for the following four pathways: ingestion and inhalation from tap water, volatilization to outdoor air, and exposure to groundwater during excavation (2007b).

[b] The EF provides a comparison of half of the maximum RL and the RSL and was calculated by dividing the half RL by the RSL. An EF greater than 1 indicates that the half RL is greater than the RSL.

[c] For this COPC, both total and dissolved concentrations were analyzed. To be conservative, the total fraction was assessed in this HHRA because it is slightly higher than the dissolved fraction.

AWQC – ambient water quality criteria
BHC –benzene hexachloride
COPC – contaminant of potential concern
cPAH – carcinogenic PAH
dw – dry weight
EDB – ethylene dibromide
EF – exceedance factor
EPA – US Environmental Protection Agency
nd – not detected
PAH – polycyclic aromatic hydrocarbon
PCB –polychlorinated biphenyl
RBC –risk-based concentration
RL – reporting limit
RME – reasonable maximum exposure
RSL – regional screening level
SVOC – semivolatile organic compound
TEQ – toxic equivalent
U – not detected at given concentration
VOC –volatile organic compound

Table 6-17. Summary of COPCs with Non-Detected Concentrations for the Force Lake Fish Consumer RME Scenario Based on Exposure to Calculated Fish Tissue

Non-Detected COPC	Unit	Detection Frequency Ratio	Sediment Concentrations (dw)		BSAF[a]	Calculated Fish Tissue Concentrations (ww)[b]		Fish RSL (mg/kg ww)[c]	No. of Non-Detected Concentrations > RSL	Maximum EF (half RL)[d]
			Range of RLs	Mean Value		Range of RLs	Mean Value			
Metals										
Antimony	mg/kg	0/11	0.3 UJ – 1 UJ	0.4	1	0.06 UJ – 0.2 UJ	0.08	0.0541	9	1.8
Selenium	mg/kg	0/11	0.7 U – 4 U	2	1	0.14 U – 0.8 U	0.4	0.676	0	0.6
Pesticides										
Aldrin	µg/kg	0/11	2.4 U – 12 U	5.1	1	0.0014 U – 0.0068 U	0.0029	0.000186	11	18
Dieldrin	µg/kg	0/11	4.8 U – 25 U	11	2.2	0.0060 U – 0.031 U	0.014	0.000197	11	80
alpha-BHC	µg/kg	0/11	2.4 U – 12 U	5.1	1	0.0014 U – 0.0068 U	0.0029	0.000501	11	6.7
beta-BHC	µg/kg	0/11	2.4 U – 23 U	5.7	1	0.0014 U – 0.013 U	0.0032	0.00175	9	3.7
gamma-BHC	µg/kg	0/11	2.4 U – 12 U	5.1	1	0.0014 U – 0.0068 U	0.0029	0.00287	9	1.2
alpha-Chlordane	µg/kg	0/11	2.4 U – 12 U	5.1	1.5	0.0020 U – 0.0099 U	0.0042	0.00901	0	0.5
Total chlordane	µg/kg	0/11	2.4 U – 12 U	5.1	26	0.035 U – 0.18 U	0.075	0.00901	11	10
Heptachlor	µg/kg	0/11	2.4 U – 12 U	5.1	0.13	0.00018 U – 0.00088 U	0.00070	0.000701	0	0.6
Heptachlor epoxide	µg/kg	0/11	2.4 U – 12 U	5.1	29	0.039 U – 0.20 U	0.83	0.000347	11	280
Toxaphene	µg/kg	0/11	970 U – 5,000 U	2,100	1	0.55 U – 2.8 U	1.2	0.00287	11	490
VOCs										
1,2,3-Trichloropropane	µg/kg	0/11	2.1 U – 16 U	5.8	1	0.0012 U – 0.0090 U	0.0033	0.000451	11	10
1,2-Dibromo-3-chloropropane	µg/kg	0/11	5.3 U – 41 U	15	1	0.0030 U – 0.023 U	0.0085	0.00394	9	2.9
Benzene	µg/kg	0/11	1.1 U – 8.2 U	3.0	1	0.00062 U – 0.0046 U	0.0017	0.0574	0	0.04
Vinyl chloride	µg/kg	0/11	1.1 U – 8.2 U	3.0	1	0.00062 U – 0.0046 U	0.0017	0.00438	0	0.5

[a] BSAF units are dw/dw for metals, and are lipid/OC for all other COPCs.

[b] Fish tissue concentrations are estimated based on the sediment concentrations and BSAFs presented in this table (see Attachment 2 for additional information regarding the methodology used to calculate tissue concentrations).

[c] Fish RSLs are taken from EPA Region 3 RBC tables (2009h).

[d] The EF provides a comparison of half of the maximum RL and the RSL and was calculated by dividing the half RL by the RSL. An EF greater than 1 indicates that the half RL is greater than the RSL.

BHC –benzene hexachloride
COPC – contaminant of potential concern
dw – dry weight
EF – exceedance factor
EPA – US Environmental Protection Agency
J – estimated concentration
RL – reporting limit
RME – reasonable maximum exposure
RSL – regional screening level
U – not detected at given concentration
VOC –volatile organic compound

As can be seen in Tables 6-10 to 6-17, the EFs based on half of the maximum RL ranged from 0.5 up to 7,800. Of the EFs presented in these tables, most were less than 100 (92%), and the majority were less than 10 (62%). Because these EFs were based on reporting limits, not detected concentrations, they are highly uncertain and do not necessarily indicate the level of risk associated with these COPCs. Despite the uncertainty surrounding the risks associated with non-detected COPCs (i.e., because of the uncertainty in the exposure concentrations for non-detected COPCs), this analysis indicates that high risks from these COPCs are unlikely. Thus, the potential impact of this uncertainty on the risk estimates in this HHRA is low.

6.3.2 Risks to Current Outdoor Workers

The soil berm surrounding the Facility and the soil stockpile on the northern portion of the Facility are not covered in gravel or pavement and are thus accessible to current outdoor workers (see Figure 1-2 and 2-1 for the location of these samples). The exposure potential for current workers at the Facility to contact the soil berm or soil stockpile is low based on activities conducted at the Facility and based on the location of this soil (i.e., not in normal work areas).

Despite this low exposure potential, risks associated with the soil berm and soil stockpile were evaluated by screening contaminant concentrations in soil against worker RSLs. Six contaminants were detected in the soil berm at concentrations greater than the industrial RSL (arsenic, copper, lead, cPAH TEQ, total PCBs, and total DDTs), and two contaminants were detected in the soil stockpile at concentrations greater than the industrial RSL (arsenic and lead). These contaminants are discussed further below:

- **Arsenic**: eight of the nine soil berm and all of the three soil stockpile samples had arsenic concentrations greater than the industrial RSL. However, of these samples, only one soil berm sample had an arsenic concentration that was greater than the regional soil background concentration of 7 mg/kg dw (see Attachment 7).
- **Copper**: one of the nine soil berm samples and none of the soil stockpile samples had copper concentrations that were greater than the industrial RSL. The one soil berm sample with a copper concentration that was greater than the RSL had an exceedance factor of 1.1, while the average soil berm exceedance factor was well below 1 (equal to 0.2).
- **Lead**: All of the nine soil berm and all of the three soil stockpile samples had lead concentrations that were greater than the industrial RSL. However, all of these samples had concentrations that were within a factor of 3 of the regional soil background concentration of 17 mg/kg dw (see Attachment 7), and most were within a factor of 2 of this background concentration.

- **cPAH TEQ**: three of the nine soil berm and none of the soil stockpile samples had cPAH TEQs that were greater than the industrial RSL. Exceedance factors for these samples were 1.6, 1.7, and 23, with a mean exceedance factor across the nine berm samples of 3.0. The high exceedance factor of 23 was for location SB-06 in the northwest corner of the Facility.
- **Total PCBs**: one of the nine soil berm and none of the soil stockpile samples had total PCB concentrations that were greater than the industrial RSL. The one soil berm sample with a concentration greater than the RSL had an exceedance factor of 1.0, while the average soil berm exceedance factor was below 1 (equal to 0.5).
- **Total DDTs**: one of the nine soil berm and none of the soil stockpile samples had total DDT concentrations greater than the industrial RSL. The one soil berm sample with a concentration greater than the RSL had an exceedance factor of 1.6, while the average soil berm exceedance factor was below 1 (equal to 0.3).

The exceedances of the industrial RSLs for contaminants detected in the soil berm and soil stockpile samples indicate that there could be some risk to current outdoor workers at the Facility. However, as previously noted, the low exposure potential of workers to this soil combined with the generally low contaminants concentrations indicates that risks associated with the soil berm and soil stockpile are low.

7.0 CONCLUSIONS

This baseline HHRA characterizes human health risks from site-related exposures in support of risk management decisions and the evaluation of remedial options. In addition, this HHRA serves to inform the public of health risks from exposures to contaminants at the Study Area. Scenarios evaluated in this HHRA included worker scenarios based on activities conducted at the Facility, recreational user scenarios associated with activities in Force Lake or the nearby wetlands, and a fish consumer scenario based on the consumption of fish from Force Lake.

Additionally, a screening level assessment was conducted to assess risks based on residential exposure. This screening assessment for hypothetical future residents indicated that the total excess cancer risks would be greater than the upper end of EPA's target risk range (10^{-4}), and that some chemicals would have an HQ greater than 1 based on a comparison of Study Area with regional screening levels (Attachment 1) if the land use designation for this area changed in the future. However, 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 a natural resource management planning area established under the City of Portland planning code, these designations are not likely to change in the future.

This variety of exposure scenarios were evaluated to provide a range of risk estimates. Individuals can evaluate their own risks by comparing their behavior with the assumptions included in each of the exposure scenarios. A summary of the risk estimates is provided in Table 7-1. Additional summary information regarding the risk estimates and uncertainties associated with these estimates is provided in Section 5.5 (risk estimates) and Table 6-1 (uncertainties).

In Section 5, all COPCs with risk estimates for one or more scenarios greater than an excess cancer risk of 1×10^{-6} or a non-cancer HQ of 1 were identified as COCs (Table 7-1).

Table 7-1. Summary of Total Excess Cancer Risks and Non-Cancer HQs

Scenario Name	Total Excess Cancer Risk	Overall HI[a]	COCs
Facility Scenarios			
Industrial (construction/ trenching) worker RME scenario: Facility soil	3×10^{-6}	1	none
Future outdoor worker RME scenario: Facility soil	2×10^{-5}	0.6	arsenic, cPAH TEQ, total PCBs, total DDTs, TPH-gasoline (aliphatic)
Industrial/commercial worker vapor intrusion scenario	9×10^{-7}	ne[b]	none
Non-Facility Scenarios			
Force Lake recreational user RME scenario: Wetland soil	9×10^{-6}	0.3[c]	arsenic, cPAH TEQ
Force Lake recreational user RME scenario: Lake sediment	1×10^{-6}	0.08[c]	none
Force Lake fish consumer RME scenario	2×10^{-5}	3 (endpoint-specific HIs were less than 1)[c, d]	arsenic, total PCBs, total DDTs

[a] The overall HI is equal to the sum of HQs for all COPCs across multiple endpoints and/or target organs.

[b] Risks for this scenario were calculated using the vapor intrusion screening levels, which are based on the more stringent of the cancer or non-cancer risks (i.e., whichever 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 for the 0 to 6-yr age group. These HQs are higher than HQs 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 is equal to 3. Because this value is greater than 1, endpoint-specific HIs were calculated per EPA guidance (EPA 1989). No endpoint-specific HIs were greater than 1 (see Section 5.3.5 for details).

COCs – contaminants of concern
COPC – contaminants of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
HI – hazard index
HQ – hazard quotient
ne – not evaluated
RME – reasonable maximum exposure
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons

Table 7-2 presents a summary of the excess cancer risks and the percent contributions of each COC relative to the total excess cancer risk, based on Study Area concentrations and on background or reference area concentrations. No individual COPC non-cancer HQs or endpoint-specific HIs were greater than 1. The following subsections discuss each COC in greater detail.

Table 7-2. Summary of Risk Estimates and Percent Contribution of Total Risk for each COC

COC	Scenarios with Excess Cancer Risks Greater than 1×10^{-6}	Excess Cancer Risk (Percent Contribution to Total)	
		Study Area	Background or Reference Area[a]
Arsenic	future outdoor worker: Facility soil	7×10^{-6} (30%)	4×10^{-6}
	Force Lake recreational user: wetland soil	2×10^{-6} (23%)	2×10^{-6}
	Force Lake fish consumer	7×10^{-6} (37%)	8×10^{-6} to 9×10^{-6}
cPAH TEQ	future outdoor worker: Facility soil	4×10^{-6} (17%)	3×10^{-8} to 2×10^{-7}
	Force Lake recreational user: wetland soil	6×10^{-6} (68%)	4×10^{-8} to 3×10^{-7}
Total PCBs	future outdoor worker: Facility soil	6×10^{-6} (26%)	2×10^{-8}
	Force Lake fish consumer	1×10^{-5} (53%)	3×10^{-6} to 4×10^{-6}
Total DDTs	future outdoor worker: Facility soil	2×10^{-6} (9%)	2×10^{-9} to 5×10^{-8}
	Force Lake fish consumer	2×10^{-6} (11%)	2×10^{-7}
TPH-gasoline (aliphatic)	future outdoor worker: Facility soil	3×10^{-6} (13%)	ne

[a] Background and reference area concentrations and sources are discussed in Attachment 7.

COC – contaminant of concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDT – dichlorodiphenyltrichloroethane
ne – not evaluated
PCB – polychlorinated biphenyl
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons

7.1 Arsenic

Arsenic was selected as a COC based on: 1) exposure to Facility soil for the outdoor worker scenario, 2) exposure to wetland soil for the recreational user scenario, and 3) exposure to lake sediment for the fish consumer scenario (Table 7-2). Arsenic made up 30, 23, and 37% of the estimated total excess cancer risks for these three scenarios, respectively. However, risk estimates based on background concentrations for arsenic were similar to those based on Study Area concentrations, and thus the consideration of background concentrations is important for arsenic. Arsenic concentrations in soil across much of the Study Area were less than or equal to the regional background soil concentration of 7 mg/kg dw (DEQ 2002, 2007a), although six soil samples collected in the former drainage ditch area to the northwest of the Facility and four samples in the west corner of the Facility had concentrations greater than this value.

7.2 cPAH TEQ

cPAH TEQ was selected as a COC based on exposure to Facility soil for the future outdoor worker scenario and based on exposure to wetland soil for the Force Lake recreational user scenario (Table 7-2). The excess cancer risk associated with cPAH TEQ was 17 and 68% of the total excess cancer risk for these two scenarios, respectively. Risk estimates based on reference area soil concentrations for cPAH TEQ were generally much less than those based on Study Area soil concentrations, indicating that reference area concentrations are not an important consideration for cPAH TEQ. The highest cPAH TEQs were detected in samples collected from the central portion of the Facility and at several locations in the former drainage ditch area to the northwest of the Facility.

7.3 Total PCBs

Total PCBs were selected as a COC based on exposure to Facility soil for the future outdoor worker RME scenario and based on exposure to lake sediment for the Force Lake fish consumer RME scenario (Table 7-2). The excess cancer risk associated with total PCBs was 26 and 53% of the total excess cancer risk estimates for these two scenarios, respectively. Risk estimates based on reference area concentrations for total PCBs were much less than those based on Study Area concentrations, indicating that reference area concentrations are not an important consideration for total PCBs.

Total PCB concentrations were highest (greater than 10,000 µg/kg dw) near the Facility entrance in the east corner of the Facility. Total PCB concentrations were also relatively high (greater than 1,000 µg/kg dw) in the central portion of the Facility and at several locations in the former drainage ditch area to the northwest of the Facility. Total PCB concentrations in Force Lake were much lower, ranging from non-detect to 131 µg/kg dw.

7.4 Total DDTs

Total DDTs were selected as a COC based on exposure to Facility soil for the future outdoor worker RME scenario and based on exposure to lake sediment for the Force Lake fish consumer RME scenario (Table 7-2). The excess cancer risks associated with total DDTs were less than the estimates for the other COCs and represented 11% or less of the total excess cancer risk for the future outdoor worker and Force Lake fish consumer RME scenarios. Risk estimates based on reference area concentrations for total DDTs were much less than those based on Study Area concentrations, indicating that reference area concentrations are not an important consideration for total DDTs.

Total DDT concentrations were highest in samples collected from the central portion of the Facility and along the southwest Facility boundary with the wetlands.

7.5 TPH-gasoline (aliphatic)

TPH-gasoline (aliphatic) was selected as a COC for the future outdoor worker RME scenario based on exposure to Facility soil. The excess cancer risk was equal to 3×10^{-6} for this scenario, which was 13% of the total.

No background concentrations were available from the sources evaluated for TPH-gasoline (aliphatic). At the Study Area, gasoline-range TPH was generally highest in the central portion of the Facility. In off-Facility portions of the Study Area, concentrations were highest in the wetlands near the southwest corner of the Facility and in Force Lake.

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