JACOBS

US Army Corps of Engineers®

Prepared for:

Department of the Army
Nashville District, Corps of Engineers
Nashville, Tennessee

Final Baseline Human Health Risk Assessment Acid Area 3

Former Plum Brook Ordnance Works
Sandusky, Ohio

Contract DACW62-03-D-0004-0004

February, 2008

Prepared by:

Jacobs Engineering Group Inc.
125 Broadway Avenue
Oak Ridge, Tennessee 37830

200.1e
G05OH001823_03.11_0500_a

COMPLETION OF INDEPENDENT TECHNICAL REVIEW

Jacobs Engineering Group, Inc. has completed the Final Baseline Human Health Risk Assessment for Acid Area 3 at the Former Plum Brook Ordnance Works, Sandusky, Ohio. Notice is hereby given that an independent technical review has been conducted that is appropriate to the level of risk and complexity inherent in the project, as defined in the Quality Control Plan. During the independent technical review, compliance with established policy principles and procedures, utilizing justified and valid assumptions, was verified. This included review of assumptions; methods, procedures, and material used in analyses; alternatives evaluated; the appropriateness of data used and level of data obtained; and reasonableness of the results, including whether the product meets the customer's needs consistent with law and existing Corps policy.

(Signature)	(Discipline)	(Date)
	Defense/Environmental Security	2/15/08

Independent Technical Review Team Leader and Team Members

(Signature)	(Discipline)	(Date)

Independent Technical Review Team Leader and Team Members

(Signature)	(Discipline)	(Date)

Independent Technical Review Team Leader and Team Members

(Signature)	(Discipline)	(Date)
	Risk Assessment	2/15/08

Jacobs BHHRA Report Author

CERTIFICATION OF INDEPENDENT TECHNICAL REVIEW

Significant concerns and the explanation of the resolution are as follows (Describe the major technical concerns, possible impact, and resolution):

Comment: See Appendix F for responses to PBOW team member review comments on the draft report.

Comment: Ensure that comments addressing specific sections or text are applied to all other relevant sections/text within the document.

Comment: Ensure that comments received on the Draft Baseline Human Health Risk Assessment, Acid Area 2 from Paul Jayko, Ohio Environmental Protection Agency, Site Coordinator, DERR-NWDO, are also applied to the Draft Baseline Human Health Risk Assessment, Acid Area 3.

Comment:

Comment:

All concerns resulting from independent technical review of the project have been considered.

Al Hardesty (Signature) 2/15/08 (Date)

(Project Manager)

Final
Baseline Human Health Risk Assessment

Acid Area 3

Former Plum Brook Ordnance Works
Sandusky, Ohio

Prepared for:

DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
NASHVILLE, TENNESSEE
CONTRACT DACW62-03-D-0004-0004

Prepared by:

JACOBS ENGINEERING GROUP, INC.
125 BROADWAY AVENUE
OAK RIDGE, TN 37830

February 2008

Table of Contents

Section ..... **Page**

List of Appendices iii

List of Figures iii

List of Tables iii

List of Acronyms and Abbreviations iv

Executive Summary ES-1

1.0 INTRODUCTION 1-1

1.1 FACILITY DESCRIPTION 1-1

1.2 BACKGROUND 1-2

1.3 SITE USE AND GROUNDWATER USE 1-2

1.3.1 Acid Areas Land Use 1-3

1.3.2 Groundwater Use 1-3

1.4 PROTOCOL FOR THE BASELINE HUMAN HEALTH RISK ASSESSMENT 1-4

1.5 ORGANIZATION OF THE BASELINE HUMAN HEALTH RISK ASSESSMENT 1-5

2.0 DATA EVALUATION 2-1

2.1 IDENTIFICATION OF COPCS 2-1

2.1.1 Evaluation of Data Quality 2-2

2.1.2 Frequency of Detection 2-3

2.1.3 Risk-Based Screening 2-3

2.1.4 Evaluating Essential Nutrients 2-3

2.1.5 Background Screening 2-4

2.2 DEVELOPING EXPOSURE-POINT CONCENTRATIONS 2-4

2.3 RESULTS OF THE DATA EVALUATION 2-7

3.0 EXPOSURE ASSESSMENT 3-1

3.1 CONCEPTUAL SITE EXPOSURE MODEL 3-1

3.1.1 Physical Setting 3-2

3.1.2 Contaminant Sources, Release Mechanisms, and Migration Pathways 3-3

3.1.3 Receptors and Exposure Pathways 3-3

3.2 QUANTIFICATION OF EXPOSURE-POINT CONCENTRATIONS 3-12
3.2.1 COPC Concentrations from Dust 3-12
3.2.2 Concentrations in Household Air from Groundwater Use 3-14
3.2.3 Concentrations of VOCs in Groundwater: Resident Dermal Uptake 3-15
3.2.4 Concentrations of COPCs in Venison 3-15
3.3 QUANTIFICATION OF CHEMICAL INTAKES 3-17
3.3.1 Inhalation of COPCs in Air 3-18
3.3.2 Incidental Ingestion of COPCs in Soil and Sediment 3-18
3.3.3 Dermal Contact with COPCs in Soil, Sediment, or Water 3-19
3.3.4 Consumption of Venison 3-20
3.3.5 Ingestion of COPCs in Groundwater and Surface Water 3-21
4.0 TOXICITY ASSESSMENT 4-1
4.1 EVALUATION OF CARCINOGENICITY 4-1
4.2 EVALUATION OF NONCARCINOGENIC EFFECTS 4-2
4.3 DERMAL TOXICITY VALUES 4-3
4.4 TARGET ORGAN TOXICITY 4-4
4.5 SOURCES OF TOXICITY INFORMATION USED IN THE RISK ASSESSMENT ... 4-4
5.0 RISK CHARACTERIZATION 5-1
5.1 CANCER RISK 5-1
5.2 NONCANCER HAZARDS 5-2
5.3 RISK-BASED REMEDIATION LEVEL DEVELOPMENT 5-4
5.4 RISK CHARACTERIZATION RESULTS AND DISCUSSION 5-6
6.0 UNCERTAINTY ANALYSIS 6-1
7.0 SUMMARY AND CONCLUSIONS 7-1
7.1 SAMPLING AND ANALYSIS 7-1
7.2 RISK ASSESSMENT RESULTS 7-2
7.3 CONCLUSIONS 7-3
8.0 REFERENCES 8-1

List of Appendices

APPENDIX A	Dermal Absorbed Dose Calculations
APPENDIX B	Risk Calculations
APPENDIX C	Risk-Based Remediation Levels
APPENDIX D	Toxicological Profiles for Chemicals of Concern
APPENDIX E	ProUCL Calculations for Exposure-Point Concentrations
APPENDIX F	Responses to Comments on the Draft Baseline Human Health Risk Assessment

List of Figures

Figure 1-1	Location Map, Plum Brook Ordnance Works, Sandusky, Ohio
Figure 1-2	Location Map, Acid Area 3, Plum Brook Ordnance Works, Sandusky, Ohio
Figure 2-1	Sampling Locations, Acid Area 3, Plum Brook Ordnance Works, Sandusky, Ohio
Figure 3-1	Human Health Conceptual Site Exposure Model, Acid Area 3, Plum Brook Ordnance Works, Sandusky, Ohio
Figure 5-1	Distribution of COCs Exceeding Background and EPC in Surface Soil - Acid Area 3, Plum Brook Ordnance Works, Sandusky, Ohio
Figure 5-2	Distribution of COCs Exceeding Background and EPC in Bedrock Groundwater - Acid Area 3, Plum Brook Ordnance Works, Sandusky, Ohio

List of Tables

Table 2-1	Summary Statistics and Identification of COPCs for Constituents Detected in Environmental Media, Acid Area 3, Plum Brook Ordnance Works, Sandusky, Ohio
Table 3-1	Receptor/Exposure Scenarios, Acid Area 3, Plum Brook Ordnance Works, Sandusky, Ohio
Table 3-2	Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors, Acid Area 3, Plum Brook Ordnance Works, Sandusky, Ohio
Table 3-3	Variables Used to Estimate Potential Chemical Intake and Contact Rates from Groundwater at Acid Area 3, Plum Brook Ordnance Works, Sandusky, Ohio
Table 4-1	Toxicity Values used in the BHHRA
Table 5-1	Summary of Noncancer Hazards and Cancer Risk Estimates from Potential Exposures at Acid Area 3, Plum Brook Ordnance Works, Sandusky, Ohio

List of Acronyms and Abbreviations

5x, 10x	five-times, ten-times
µg/dL	microgram/deciliter
ABS	dermal absorption factor
AF	adherence factor
amsl	above mean sea level
ATSDR	Agency for Toxic Substances and Disease Registry
AT	averaging time
bgs	below ground surface
BHHRA	baseline human health risk assessment
BSC	background screening concentration
BW	body weight
cm^2	square centimeter
COC	chemical of concern
COPC	chemical of potential concern
CSEM	conceptual site exposure model
CT	central tendency
DA	dose absorbed per unit body surface area per event
DERP	Defense Environmental Restoration Program
DM	dry matter
DNT	dinitrotoluene
DOE	U.S. Department of Energy
ED	exposure duration
EF	exposure frequency
EPA	U.S. Environmental Protection Agency
EPC	exposure-point concentration
ET	exposure time
FI	fraction of intake
ft	foot/feet
FUDS	Formerly Used Defense Sites
g	gram
g/m^3	grams per cubic meter
g/kg-day	grams per kilogram of body weight per day
GAF	gastrointestinal absorption factor
gpm	gallons per minute
HHEM	human health evaluation manual
HI	hazard index
HQ	hazard quotient
Jacobs	Jacobs Engineering Group
IEUBK	integrated exposure-uptake biokinetic
ILCR	incremental lifetime cancer risk
IR	ingestion rate
IRIS	Integrated Risk Information System
IT	IT Corporation
kg	kilogram
L	liter

m^3	cubic meter
MDC	maximum detected concentration
mg	milligram
mg/cm^2	milligrams per square centimeter
NASA	National Aeronautics and Space Administration
NCRPM	National Council on Radiation Protection and Measurements
OEPA	Ohio Environmental Protection Agency
PAH	polynuclear aromatic hydrocarbon
PBOW	Plum Brook Ordnance Works
PC	permeability coefficient
PCB	polychlorinated biphenyl
PEF	particulate emission factor
PRG	preliminary remediation goal
RA	Risk Assessment
RBC	Risk Based Criteria
RBRL	risk-based remediation level
RBSC	risk-based screening concentration
RfC	reference concentration
RfD	reference dose
RI	Remedial Investigation
RME	reasonable maximum exposure
SA	surface area
SAIC	Science Applications International Corporation
SF	slope factor
Shaw	Shaw Environmental, Inc.
SI	Site Investigation
SVOC	semivolatile organic compound
TAL	target analyte list
TNT	trinitrotoluene
TRW	Technical Review Workgroup
UCL	upper confidence limit
UCL_{95}	95th percent upper confidence limit on the arithmetic mean
UF	uncertainty factor
USACE	U.S. Army Corps of Engineers
VOC	volatile organic compound

EXECUTIVE SUMMARY

This baseline human health risk assessment (BHHRA) report presents the human health risks from potential exposure to soil, groundwater, surface water, and sediment associated with Acid Area 3 located at the former Plum Brook Ordnance Works (PBOW), Sandusky, Erie County, Ohio. This BHHRA was prepared in accordance with the Baseline Human Health Risk Assessment and Ecological Risk Assessment Work Plans (Jacobs, 2007). It is consistent with U.S. Environmental Protection Agency (EPA) and Ohio EPA guidance and with the procedures established in the BHHRA Work Plan for TNT Areas A & C soil (IT Corporation, 2001a) and the BHHRA work plan for groundwater at PBOW (Shaw Environmental, Inc., 2005a).

Acid Area 3 site is located near the western boundary of the northern portion of PBOW. The site was used to produce oleum, sulfuric acid, and nitric acid for the manufacture of trinitrotoluene (TNT). Investigations have identified chemical contamination in site media. The site's current physical features include an open field with a drainage ditch running north to south on the western perimeter of the site. Several rail lines are still present at the site oriented in a north–south direction. The ground surface is relatively flat. The majority of the site is currently covered with tall grass and frequent low shrubs. Some small wooded areas have developed along the former railroad tracks. Much of the area outside of the site boundary is also open terrain with tall grass or small shrubs and occasional wooded areas.

The objective of this BHHRA is to evaluate potential for cancer and noncancer human health effects posed to current and potential future receptors. This objective was met through the process of data evaluation, exposure assessment, toxicity assessment, risk characterization, and uncertainty analysis.

Data evaluation consists of identification of data sources, evaluation of data quality, identification of chemicals of potential concern, and background screening. The exposure assessment consists of development of the conceptual site exposure model including definition of contaminant sources, contaminant release mechanisms, receptors, and exposure pathways; description of exposure-point concentrations; and identification of the methods for calculating chemical intake and contact rates. The toxicity assessment defines the potential for cancer and/or noncancer human health effects; provides an estimate of the quantitative relationship between the magnitude of dose or contact rate and the probability and/or severity of adverse effects; and identifies the toxicity values that are used in the BHHRA. The risk characterization combines the output of the exposure assessment and toxicity assessment to quantify the risk to each receptor. The uncertainty analysis identifies uncertainties in all phases of the BHHRA and discusses their individual effects on the risk assessment results.

PBOW is currently classified for industrial use, but future residential use was considered in the risk assessment to support evaluation of all plausible receptor scenarios. Groundskeeper, construction worker and hunter scenarios were evaluated under the current site-use assumptions. Groundskeeper, construction worker, indoor worker, hunter (including a child venison consumer) and on-site residential scenarios were evaluated as plausible future exposure scenarios.

The groundskeeper, hunter, and child venison consumer were evaluated for exposure only to surface soil. The total hazard index (HI) estimate for the groundskeeper receptor was less than the threshold value of 1 for noncancer effects. The total ILCR estimate for the groundskeeper receptor was 2E-5. The chemicals of concern (COCs) for the ILCR were arsenic, polychlorinated biphenyl- (PCB-) 1254, benzo(a)anthracene, and benzo(a)pyrene. Total HI estimates for the adult hunter, and adult and child venison consumer receptors were below 1. The total incremental lifetime cancer risk (ICLR) for the adult hunter was 2E-6. The COC for the ILCR was benzo(a)pyrene. Total ILCR estimates for the adult and child venison consumer receptors were below 1E-6, defined as the point of departure for significant contribution to cancer risk.

The construction worker was evaluated for exposure to surface and subsurface soil, surface water and sediment. Total HI estimates summed across all media for the construction worker receptor was 4. The total HI summed across surface water and sediment was less than 1. The total HI summed across surface and subsurface soil was 4. The COCs for the HI were arsenic, iron, thallium and PCB-1254 in surface soil and antimony, arsenic, iron, and thallium in subsurface soil. The total ILCR estimate summed across all media for the construction worker receptor was 3E-6. ILCR sums for surface water and sediment were less than 1E-6. ILCR summed for surface and subsurface soil was 3E-6. The COC for the ILCR was benzo(a)pyrene in surface soil. There were no COCs in subsurface soil.

The indoor worker was evaluated for exposure to surface soil and groundwater. The total HI estimate summed across all media for the indoor worker receptor was 2. The HI for groundwater and surface soil were 1 and 0.2, respectively. The COCs for the groundwater HI were arsenic, benzene, and thallium. The total ILCR estimate summed across all media for the indoor worker receptor was 3E-4. The ILCR for groundwater and surface soil were 3E-4 and 9E-6, respectively. The COCs for the ILCR were 2-nitrotoluene, arsenic, benzene, methylene chloride, and tetrachloroethene in groundwater. The COCs for the ILCR were arsenic, PCB-1254, and benzo(a)pyrene in surface soil. There were no COCs in subsurface soil. Vapor intrusion into buildings from subsurface soil was not evaluated as there were no volatile organic compounds (VOCs) detected in the subsurface soil.

The adult and child residential receptors were evaluated for exposure to surface and subsurface soil, groundwater, surface water and sediment. Total HI estimates summed across all media for the adult and child residential receptors were 5 and 15, respectively. HI sums for surface water and sediment were below 1. HI sums for groundwater and surface and subsurface soil were 5 and 15 for the adult and child, respectively. The groundwater COCs for the HI were arsenic, barium, benzene, and thallium for the adult, and arsenic, barium, 2-methylnaphthalene, benzene, methylene choride, naphthalene, thallium, and total xylenes for the child. The surface soil COCs were PCB-1254 for the adult, and arsenic, iron, manganese, thallium, and PCB-1254 for the child. The subsurface COCs were aluminum, antimony, arsenic, iron, manganese, and thallium for the child. There were no HI drivers for adult exposures to subsurface soil.

The total ILCR estimates summed across all media for the adult and child residential receptors were 9E-4 and 5E-4, respectively. ILCR sums for surface water and sediment were 1E-6 and 2E-6 for the adult and child, respectively. ILCR sums for groundwater and surface and subsurface soil were 9E-4 and 5E-4, respectively. The groundwater COCs for the ILCR were 2-

nitrotoluene, arsenic, benzene, bis(2-ethylhexyl)phthalate, methylene chloride, and tetrachloroethene for the adult and 2-nitrotoluene, arsenic, benzene, bis(2-ethylhexyl)phthalate, methylene chloride, and tetrachloroethene for the child. The surface soil COCs were arsenic, PCB-1254, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, and dibenz(a,h)anthracene for the adult, and arsenic, PCB-1254, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, and dibenz(a,h)anthracene for the child. The subsurface COC was arsenic for the adult and child residential receptors. Vapor intrusion into dwellings from subsurface soil was not evaluated, as there were no VOCs detected in the subsurface soil.

Based on analytical results, metals, polynuclear aromatic hydrocarbons (PAHs), and PCBs appear to be widespread but generally at low concentrations in environmental media at Acid Area 3. All inorganic constituents detected in environmental media were carried through the risk assessment to provide a conservative estimate of potential risks associated with exposure to site media. However, the maximum detected concentrations for arsenic, iron, and manganese in surface soil and aluminum, antimony, arsenic, and iron in subsurface soil were lower than their respective background criteria. There are no site-specific background data for the PAHs, and several were selected as COCs. PAH concentrations at Acid Area 3 all fall within global background levels for urban areas compiled by the Agency for Toxic Substances and Disease Registry (1997).

HIs for contamination in soil were less than 1 for a groundskeeper or hunter, including an adult or child who consumes venison from deer harvested on site, suggesting that adverse effects from exposure are unlikely. Cancer risk for a groundskeeper or hunter, including an adult or child who consumes venison from deer harvested on site, were within or below the cancer risk range of 1E-6 to 1E-4.

HIs for the indoor workers and adult resident were below 1. HIs exceeded 1 for the construction worker and child residential receptors for exposure to surface soil. The primary contributor to the HIs was PCB-1254. Cancer risk estimates were within the cancer risk range of 1E-6 to 1E-4 for the construction worker but exceeded 1E-4 for the indoor worker, and adult and child residential receptors. The primary contributor to the ILCRs was benzo(a)pyrene.

HIs for construction workers and adult and child residential receptors were equal to or below 1 for exposure to subsurface soil. Cancer risk estimates were below or within the cancer risk range of 1E-6 to 1E-4 for the construction worker and the adult and child residential receptors. The primary contributor to the ILCRs was arsenic.

HIs for the indoor workers and adult and child residential receptors exceed 1 for exposure to groundwater. The primary contributor to the HIs was thallium. Cancer risk estimates were just above 1E-4 for the indoor worker and the adult and child residential receptors. The primary contributor to the ILCRs was arsenic.

HIs for exposure to contamination in surface water were below 1 for all receptors evaluated. Cancer risk estimates were below or at the low end of the cancer risk range of 1E-6 to 1E-4 for the construction worker, and adult and child residential receptors for exposures to sediment.

Accounting for natural background concentrations of metals in all media, the sporadic detections of organic compounds in groundwater, surface water, and sediment, potential risks from exposure to contaminants detected in site environmental media appear to be limited.

1.0 INTRODUCTION

This baseline human health risk assessment (BHHRA) report presents the human health risks from potential exposure to soil, groundwater, surface water, and sediment associated with Acid Area 3 located at the former Plum Brook Ordnance Works (PBOW), Sandusky, Erie County, Ohio.

This BHHRA was prepared by Jacobs Engineering Group (Jacobs) under contract DACW62-03-D-0004, Delivery Order #4. This work is being conducted for the U.S. Army Corp of Engineers (USACE) under the Defense Environmental Restoration Program (DERP) – Formerly Used Defense Sites (FUDS). The Army is the executive agent for the FUDS program and the USACE manages and directs the program's administration. Investigations at PBOW under DERP-FUDS are being managed by the USACE Huntington District and technically overseen by the USACE Nashville District.

This BHHRA was prepared in accordance with the *Baseline Human Health Risk Assessment and Ecological Risk Assessment Work Plans* (Jacobs, 2007). It is consistent with U.S. Environmental Protection Agency (EPA) and Ohio EPA (OEPA) guidance and with the procedures established in the BHHRA Work Plan for TNT Areas A & C soil (IT Corporation [IT], 2001a) and the BHHRA work plan for groundwater at PBOW (Shaw Environmental, Inc. [Shaw], 2005a).

1.1 Facility Description

PBOW is located approximately 4 miles south of Sandusky, Ohio, and 59 miles west of Cleveland (Figure 1-1). Although located primarily in Perkins and Oxford Townships, the eastern edge of the facility extends into Huron and Milan Townships. PBOW is bounded on the north by Bogart Road, on the south by Mason Road, on the west by Patten Tract Road, and on the east by U.S. Highway 250. The area surrounding PBOW is mostly agricultural and residential (IT, 2001b). The facility is currently surrounded by a chain-link fence, and the perimeter is regularly patrolled. Access by authorized personnel is limited to established checkpoints. Public access is restricted, except during the annual deer hunting season. The Acid Area 3 site is located approximately 1 mile east of Acid Area 2, northwest of the intersection of Ransom Road and Maintenance Road (Figure 1-2).

The Acid Area 3 site physical features include an open field with a drainage ditch running north to south on the western perimeter of the site. A storm sewer system was constructed at the site, as evidenced by existing drainage grates, manhole covers, and open holes with brick lining. A large diameter concrete culvert discharges into the ditch on the east side of the bank near the center of the site. Running water was heard through the drainage grates during the Round 1 groundwater sampling effort. Several rail lines are still present at the site, oriented in a north–south direction. A paved service road borders the northern and western perimeter of the site, while Ransom Road and Maintenance Road serve as boundaries for the eastern and southern perimeter, respectively. Acid Area 3 covers approximately 40 acres. The ground surface is relatively flat, with elevations ranging from 632.6 to 637.0 ft amsl. The majority of the site is currently an open field with tall grass and frequent low shrubs. Some small wooded areas have developed along the former railroad tracks. Much of the area outside of the site boundary is also open terrain with tall grass or small shrubs and occasional wooded areas.

1.2 Background

The 9,009-acre PBOW site was built in early 1941 as a manufacturing plant for trinitrotoluene (TNT), dinitrotoluene (DNT), and pentolite. Production of explosives began in December 1941 and continued until 1945. It is estimated that more than one billion pounds of explosives were manufactured during the four-year operating period.

The National Aeronautics and Space Administration (NASA) acquired PBOW in 1963 and presently utilizes about 6,400 acres for conducting space research. The site is operated by NASA as the Plum Brook Station of the John Glenn Research Center, which is headquartered in Cleveland, Ohio. In 1978 NASA declared approximately 2,152 acres of land as excess (IT, 1997). The Perkins Township Board of Education acquired 46 acres of the excess property for use as a bus transportation center. The Ohio National Guard has an agreement with the U.S. Army's General Services Administration to use 604 acres of the facility.

Acid Area 3 was used to produce oleum, sulfuric acid, and nitric acid for the manufacture of TNT. The Acid Area 3 site contained 10 buildings, 46 above-ground tanks, and a rail line. A review of the 1958 and 1968 aerial photos indicates that the above-ground features including buildings and storage tanks were dismantled between these dates. The Acid Area 3 site is not currently being utilized, with the exception of storage use at the remaining building.

Recent investigation at Acid Area 3 have identified chemical contamination in the soil and sediment, which is related to former U.S. Department of Defense activities. Concentrations of polychlorinated biphenyls (PCBs) and semivolatile organic compounds (SVOCs) exceed the screening criteria.

1.3 Site Use and Groundwater Use

Prior to acquisition of the site for construction of the PBOW, the area was largely agricultural. Most of the forested areas were cleared during construction of the PBOW. Today, second generation forests have returned to large portions of the site that are not actively used by NASA. Other undeveloped areas of the site are maintained as open fields. The surrounding area is mostly agricultural and residential.

Potential future uses of portions or all of the facility property include:

1. The continuation of NASA activities at PBOW.
2. Recreational uses such as hunting and fishing. PBOW is open to deer hunters during the hunting season.
3. Selling of portions of the site by the General Services Administration to other parties (state or local government or private individuals).
4. Agricultural uses.
5. Residential uses.

6. Training area for use by National Guard Units.

7. Construction activities.

Items 3 through 7 are speculative and no negotiations have been scheduled to define future land use.

1.3.1 Acid Areas Land Use

Acid Area 3 was used as early as 1941. Acid production likely ceased in 1945 when TNT production was discontinued. Previous investigation reports and records searches do not indicate dates for construction, operation, or dismantlement. Removal of buildings and above-ground tanks occurred between 1958 and 1968 based on aerial photography. The only remaining building at Acid Area 3 is the northernmost building adjacent to the rail line, which is locked and used by NASA for storage of unknown materials. No specific future uses of this site have been identified.

1.3.2 Groundwater Use

Two aquifers are utilized for drinking water in the area surrounding PBOW: a carbonate aquifer outcropping in the western portion of Erie County and a shale aquifer outcropping in the eastern portion. PBOW is located within the transition of the two aquifers. Both aquifers are overlain by a veneer of glacial drift, generally less than 20 ft thick, that is considered a poor source of groundwater except in areas of sand and gravel lenses. The shallow overburden at Acid Area 3 is limited to silt and clay deposits, with occasional discontinuous lenses of silty fine-grained sand. Well yields from the shallow monitoring wells at Acid Area 3 ranged from 20 to 350 ml per minute. Because of the low yields shallow groundwater could not realistically be used as a potable water source and does not represent a point of exposure for future residents.

Most of PBOW is mapped by the Ohio Department of Natural Resources as an area in which well yields seldom exceed 3 gpm from the shale aquifer and overlying discontinuous sand and gravel deposits. The northwest portion of PBOW, including most or all of Acid Area 3, is mapped as an area in which yields of 100 to 500 gpm may be developed from depths of less than 200 ft from cavernous limestone and dolomite. A wedged-shape area extending from the northwest boundary of PBOW and pinching out just south of Acid Area 3 is mapped as an area in which yields of 5 to 25 gpm may be developed from wells drilled in limestone. The boundary of this area runs near to or includes the southeastern-most extent of Acid Area 3 (Ohio Department of Natural Resources, 2007).

Residences to the north and east of PBOW are served by city, county, and rural water departments. Residences south and west of PBOW are supplied by wells. As of 1991, a total of 179 permitted private drinking water wells listed at the Erie County Health Department were within a 4-mile radius of PBOW (Science Applications International Corporation [SAIC], 1991). The nearest recorded well is at 6115 Schenk Road, approximately 3600 ft west of Acid Area 3; however, a closer well was observed at 1810 Schenk Road, located approximately 2700 ft west of Acid Area 3.

1.4 Protocol for the Baseline Human Health Risk Assessment

This BHHRA was prepared based on EPA, USACE, and OEPA guidance, including, but not limited to, the following:

- OEPA, 2004a, *Technical Decision Compendium, Methodology for Evaluating Site-specific Background Concentrations of Chemicals* Ohio EPA Division of Emergency and Remedial Response Remedial Response Program 14 April 2004.

- OEPA, 2004b, *Technical Decision Compendium, Human Health Cumulative Carcinogenic Risk and Non-carcinogenic Hazard Goals for DERR Remedial Response and Office of Federal Facility Oversight* Ohio EPA Division of Emergency and Remedial Response 28 April 2004

- OEPA, 2005a, *Use of Risk-Based Numbers in the Remedial Response Process Overview* DERR-00-RR-038, June 28, 2005.

- OEPA, 2005b, *Technical Decision Compendium, Assessing Compounds without Formal Toxicity Values Available for Use in Human Health Risk Assessment* Ohio EPA Division of Emergency and Remedial Response Remedial Response Program August 2005.

- U.S. EPA, 1989a, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A)*, Interim Final, Office of Emergency and Remedial Response, Washington, D.C., EPA/540/1-89/002.

- U.S. EPA, 1991a, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors*, Interim Final, Office of Solid Waste and Emergency Response, OSWER Directive: 9285.6-03.

- U.S. EPA, 1991b, *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual Part B – Development of Risk-Based Preliminary Remediation Goals*, Interim, Office of Emergency and Remedial Response, Washington, D.C., EPA/540/R-92/003, December.

- U.S. EPA, 1992a, *Supplemental Guidance to RAGS: Calculating the Concentration Term*, Office of Solid Waste and Emergency Response, Washington, D.C., Publication 9285.7-081.

- U.S. EPA, 1992b, *Dermal Exposure Assessment: Principles and Applications*, Interim Report, Office of Research and Development, Washington, D.C., EPA/600/891/011B, including Supplemental Guidance dated August 18, 1992.

- U.S. EPA, 1992c, "Guidance on Risk Characterization for Risk Managers and Risk Assessors," Memorandum from F. Henry Habicht II, Deputy Administrator, to Assistant Administrators, Regional Administrators, February 26.

- U.S. EPA, 1997a, *Exposure Factors Handbook*, Office of Research and Development, National Center for Environmental Assessment, Washington, D.C., EPA/600/P95/002F, August.

- USACE, 1999, *Risk Assessment Handbook, Volume I: Human Health Evaluation*, Engineer Manual EM 200-1-4.

- U.S. EPA, 2004a, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part E - Supplemental Guidance for Dermal Risk Assessment)*, Final, Office of Superfund Remediation and Technology Innovation, Washington, D.C., EPA/540/R-99/005, July.

1.5 Organization of the Baseline Human Health Risk Assessment

This BHHRA report presents the methods used, results generated, and the interpretation of these results. The remainder of this report is organized as follows:

Section 2.0, Data Evaluation: Identifies data sources, evaluates data quality, identifies chemicals of potential concern (COPCs), and provides the background screening.

Section 3.0, Exposure Assessment: Presents the conceptual site exposure model (CSEM), including contaminant sources, contaminant release mechanisms, receptors, and exposure pathways; describes exposure-point concentrations (EPCs); and presents methods for calculating chemical intake and contact rates.

Section 4.0, Toxicity Assessment: Describes the potential for cancer and/or noncancer human health effects; provides an estimate of the quantitative relationship between the magnitude of dose or contact rate and the probability and/or severity of adverse effects; identifies the toxicity values that are used in the BHHRA; and describes the development of dermal toxicity values.

Section 5.0, Risk Characterization: Combines the output of the exposure assessment and toxicity assessment to quantify the risk to each receptor. Risks associated with exposure to all appropriate media were evaluated. This section includes the derivation of risk-based remediation levels (RBRLs), which describes their development based on the methods of the BHHRA and discussion between OEPA and USACE.

Section 6.0, Uncertainty Analysis: Identifies uncertainties in all phases of the BHHRA and discusses their individual effects on the risk assessment results, focusing on those issues that are most likely to have the greatest effect on risk estimates and/or risk management decisions.

Section 7.0, Summary and Conclusions: Provides a brief summary of the BHHRA, including quantitative results, uncertainties, and pertinent site information. The summary focuses those results and issues that are most likely to directly affect site management decisions.

Section 8.0, References: Provides a complete list of all references used and cited in the BHHRA.

The text of this document is supported by the following appendices:

Appendix A, Dermal Absorbed Dose Calculations

Appendix B, Risk Calculations

Appendix C, Risk-Based Remediation Levels

Appendix D, Toxicological Profiles for Chemicals of Concern

Appendix E, ProUCL Calculations for Exposure-Point Concentrations

Appendix F, Responses to Comments on the Draft Baseline Human Health Risk Assessment

2.0 DATA EVALUATION

A Site Investigation (SI) was performed at Acid Areas 2 and 3 in 1998 (IT, 1998), which identified surface and subsurface soil contamination above EPA Region 3 Risk Based Criteria (RBC). Thirty-eight soil samples were collected at 20 locations at Acid Area 3. Organic contaminants in surface and subsurface soil exceeding the RBCs included PCBs and SVOCs.

Groundwater monitoring wells were installed at Acid Area 3 as part of a site-wide groundwater investigation beginning as early as 1993. Two wells installed at Acid Area 3 were sampled from 1997 through 2002. These wells were included in the 2005 investigation (Jacobs, 2006), summarized below.

A Remedial Investigation (RI) was performed in 2004 – 2005, which involved additional surface and subsurface soil sampling, surface water and sediment sampling, and groundwater sampling from shallow and bedrock monitoring wells. Soil samples were collected from 14 locations in Acid Area 3. Surface soil samples were collected from 0.5 to 1.5 ft below ground surface (bgs) at all locations. Subsurface samples were collected from 3 to 5 ft bgs at all locations and from 8 to 10 ft bgs at specific locations. All samples were analyzed for volatile organic compounds (VOCs), SVOCs, nitroaromatics, target analyte list (TAL) metals, and PCBs.

Three shallow overburden monitoring wells and 2 bedrock monitoring wells were installed at Acid Area 3 in December 2004. All newly installed wells were developed and slug tested. Two rounds of groundwater samples were collected from the newly installed wells and existing wells in January and April 2005. In addition to the collection of unfiltered samples, samples for metals analysis were filtered in the field during the January 2005 sampling round. Based on the BHHRA technical memorandum submitted 23 May 2005 (Shaw, 2005) no filtered data were used in risk assessment.

Three surface water and sediment samples were collected from the drainage ditch along the western perimeter of Acid Area 3. Sediment samples were collected 27 October 2004. Surface water samples were collected at the same locations 29 April 2005, once sufficient discharge was present at all locations. Sample locations included one upstream location, one location adjacent to the site, and one downstream location. Ten additional surface water and sediment samples were collected in the spring of 2006, including 7 locations adjacent to the site and three downstream locations.

RI sample collection and data evaluation are discussed in detail in the Interim Final Site Characterization Report (Jacobs, 2006). Sufficient data have been collected for Acid Area 3 to support a risk assessment.

2.1 Identification of COPCs

COPCs are the chemicals that are identified as site-related and potentially capable of contributing significantly to risk, and are carried forward to quantitative evaluation in the risk assessment (RA). The following subsections describe the process for their identification. Prior to initiation of the RA, a list of chemicals present in site samples was compiled. This initial list included all chemicals detected in any site medium. COPCs were selected from this list as discussed in the following sections.

2.1.1 Evaluation of Data Quality

The quality of the analytical data was evaluated to select data for inclusion in the BHHRA. Data quality is expressed by the assignment of qualifier codes during the analytical laboratory quality control process or during data validation that reflect the level of confidence in the data. The following are some of the more common qualifiers and their meanings (EPA, 1989a):

U Chemical was analyzed for but not detected; the associated value is the sample quantitation limit.

J Value is estimated, probably below the contract-required quantitation limit.

N The analysis indicates an analyte for which there is presumptive evidence to make a tentative identification.

NJ The analysis indicates a "tentatively identified analyte," and the reported value represents its approximate concentration.

UJ The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

R Quality control indicates that the data are unusable (chemical may or may not be present).

B Inorganic chemicals: the concentration is less than the contract-required detection limit but greater than the instrument detection limit. Organic chemicals: the concentration in the sample is not sufficiently higher than the concentration in the blank, using the five-times, ten-times (5x, 10x) rule, whereby a chemical is considered a nondetect unless its concentration exceeds 5 or 10 times the blank concentration. For common laboratory contaminants (acetone, 2-butanone [methyl ethyl ketone], methylene chloride, toluene, and the phthalate esters), the sample concentration must exceed 10 times the blank concentration to be considered a detection.

"J", "N", and "NJ" qualified data were used in the BHHRA; "R" data and "B" qualified data were not. The handling of "U" qualified data (nondetects) in the BHHRA is described in Section 3.2. Data for which the identity of the chemical was unclear were not used in the BHHRA. When confidence was reasonably high that the chemical was present but the actual concentration was somewhat in question, the data generally were used.

Some chemicals were analyzed under two different analytical programs. For example, the DNT isomers were analyzed by EPA Method 8330 for nitroaromatics as well as EPA Method 8270C for SVOCs. Analytical results from EPA Method 8330 were used to quantify risks. The potential uncertainties associated with analytical results obtained by EPA Method 8270c are discussed in the uncertainty analysis (Section 6.0).

2.1.2 Frequency of Detection

As stated above, if confidence was high that a given chemical was present, the data generally were used in the RA. For most chemicals, their identification at concentrations above levels in blanks (considering the 5x, 10x rule) was presumptive evidence of their presence. However, chemicals that were reported infrequently (i.e., in less than 5 percent of the samples) may be artifacts in the data that do not reflect the presence of the chemical in question. Chemicals that were reported only at low concentrations in less than 5 percent of the samples from a given medium were dropped from further consideration unless their presence would be expected based on site historical information.

2.1.3 Risk-Based Screening

Risk-based screening for human health focuses the assessment on the chemicals that may contribute significantly to overall risk and to remove from quantification those chemicals whose contribution is clearly inconsequential. In this screening, the maximum detected concentration (MDC) was compared to the appropriate risk-based screening concentration (RBSC). The units of the MDC and RBSC are the same for each chemical in a given medium.

If the MDC of a chemical was less than or equal to its RBSC, then the chemical in this medium was not considered further in the BHHRA because it is unlikely that chemical concentrations at or below the RBSC would contribute significantly to risk. An analyte was identified as a COPC if its MDC exceeded its RBSC. RBSCs used in this BHHRA were derived from the EPA Region 9 preliminary remediation goal (PRG) tables (EPA, 2004b).

PRG values are based on a concentration equal to either an incremental lifetime cancer risk (ILCR) of 1E-6 or a noncancer hazard quotient (HQ) of 1, the threshold at or below which adverse noncancer effects are regarded as unlikely to occur. For this BHHRA, the noncancer values listed in the PRG tables were multiplied by a factor of 0.1 to provide additional protection for simultaneous exposure to multiple chemicals resulting in RBSC values associated with an HQ of 0.1. For cancer risk, the PRG values were used directly as RBSCs in the BHHRA, as they are based on an ILCR of 1E-6. Acceptable exposure levels are generally concentration levels that represent an increased upper bound lifetime cancer risk to an individual of 1E-6 to 1E-4 (EPA, 1990), referred to as the “risk management range.” Cancer risks associated with PRG values represent the lower end of this range. For this BHHRA, the RBSC for a chemical that elicited both cancer and noncancer health effects was selected based on either a cancer risk of 1E-6 or an HQ of 0.1, whichever associated concentration was lower.

2.1.4 Evaluating Essential Nutrients

Evaluating essential nutrients is a special form of risk-based screening applied to certain ubiquitous elements that are generally considered to be required human nutrients. Essential nutrients such as calcium, iron, magnesium, potassium, and sodium are usually eliminated as COPCs because they are generally considered innocuous in environmental media. Other essential nutrients including chloride, iodine, and phosphorus, may be eliminated as COPCs, provided that their presence in a particular medium is shown to be unlikely to cause adverse effects on-human health. No members of this latter group were selected as site-related chemicals. Therefore, an exposure analysis was not performed.

2.1.5 Background Screening

For background screening, the MDC was compared to the PBOW chemical-specific background screening concentration (BSC) for groundwater or soil. The derivation of groundwater BSCs was described in the 2004 groundwater report (Shaw, 2005c). BSCs were calculated for use at PBOW based on concentrations found in background bedrock monitoring wells installed upgradient of PBOW sources. Each groundwater BSC is either the MDC or the calculated 95 percent upper tolerance limit of the background groundwater data set based on unfiltered samples collected using low-flow sampling, whichever value is lower (Shaw, 2005c). BSCs for soil established as part of the acid areas investigation (IT, 1998) were used for this RA. BSCs for soil were reported as the 95 percent upper tolerance limit for lognormal data sets or the 95th percentile for datasets with a nonparametric distribution.

Background screening also applies to certain organic compounds that are part of normal background concentrations. Such chemicals may include VOCs and polycyclic aromatic hydrocarbons (PAHs), a class of organic compounds that form from natural or anthropogenic combustion of organic matter including fossil fuels, and are generally ubiquitous in the environment. Airborne PAHs associated with non-Department of Defense sources may be deposited on soil and leach to groundwater. Benzene, toluene, ethylbenzene, and xylenes (BTEX) compounds may also be associated with background due to the presence of natural petroleum-derived compounds present in the vicinity of PBOW.

Background screening was applied to each inorganic constituent whose MDC exceeded the RBSC and that could not be characterized as an infrequently detected analyte. Background screening consisted of comparing the MDC of the site data set to the BSC. Background screening was not used to eliminate COPCs. Comparison of COPC concentrations to background levels are discussed in Section 6.0.

2.2 Developing Exposure-Point Concentrations

The EPC is a conservative estimate of the average concentration of a COPC, statistically calculated from the analytical results of all samples for a particular environmental medium within an exposure unit.

Because of the uncertainty associated with characterizing contamination in environmental media, both the mean and the upper confidence limit (UCL) on the mean are usually estimated for each COPC in each medium of interest. The upper 95 percent confidence limit on the mean is generally referred to as the UCL_{95}.

The EPA statistical software package ProUCL Version 3 was used to compute estimated mean and UCL_{95} concentrations for all data sets containing fewer than 15 percent nondetects. ProUCL Version 3 is inappropriate for data sets containing more than 15 percent nondetects.

For data sets with 15 percent or more nondetects, a combination of the following procedures was used:

- Most statistical computations were made using a FoxPro based statistical package developed by Jacobs and based on a large number of published guidance manuals.

- Kaplan-Meier computations were confirmed using Minitab Version 14 (commercial statistical software from Minitab Inc.).

Data sets consisting of 5 or more data points were tested for normality and lognormality with the Shapiro-Wilk test. Statistical analysis was performed only on those chemicals identified COPCs. The UCL_{95} was calculated for a normal distribution as follows (EPA, 1992a):

$$UCL_{95} = \bar{x} + t_{1-a,n-1}\left(\frac{s}{\sqrt{n}}\right) \qquad \textbf{Eq. 2.1}$$

where:

UCL_{95} = upper 95th confidence limit on the arithmetic mean concentration (calculated)

$\bar{x}$ = sample arithmetic mean

t_1 = critical value for Student's *t*-test

α= 0.05 (95 percent confidence limit for a one-tailed test)

n = number of samples in the data set

s = sample standard deviation.

The UCL_{95} was calculated for a lognormal distribution as follows (Gilbert, 1987):

$$UCL_{95} = e^{\left(\bar{Y}+0.5s_y^2+\left[H_{0.95}\frac{s_y}{(n-1)^{0.5}}\right]\right)} \qquad \textbf{Eq. 2.2}$$

where:

UCL_{95} = 95 percent upper confidence limit on the arithmetic mean (calculated)

$\bar{Y}$ = Σy/n = sample arithmetic mean of the log-transformed data,

s_y = ln x = sample standard deviation of the log-transformed data

n = number of samples in the data set

$H_{0.95}$ = value for computing the one-sided upper 95 percent confidence limit on a lognormal mean from standard statistical tables.

If the data distribution was nonparametric, the UCL_{95} was estimated using three different methods: Kaplan-Meier (Kaplan and Meier, 1958), simple bootstrap with replacement (Helsel, 2005), and rank order based on the binomial distribution.

The Kaplan-Meier method for UCL_{95} calculation has been used for many years in the medical industry and in manufacturing to estimate summary statistics for censored data sets (data sets with nondetect results). The Kaplan-Meier method estimates the survival probability function for the evaluated data set. The survival function is the probability that any given data value will exceed any specific quantile of the data set. The UCL_{95} is computed by integrating the area under the stair-step survival function curve.

The simple bootstrap UCL_{95} is computed by resampling the data set with replacement a large number of times, computing the mean of each resampling, and computing the UCL_{95} from these computed means using the Students-t approach.

The UCL_{95} rank order on the arithmetic mean of the data set was estimated by ranking the data observations from smallest to largest. The arithmetic mean was converted to a percentile by interpolation. The rank order of the data point selected as the UCL_{95} was estimated from the following equation (Gilbert, 1987):

$$u = p(n+1) + Z_{1-\alpha}\sqrt{np(1-p)} \qquad \textbf{Eq. 2.3}$$

where:

u = rank order of value selected as UCL_{95}, calculated

p = percentile corresponding to the arithmetic mean

n = number of samples in the data set

α= confidence limit (95 percent)

$Z_{1-\alpha}$ = normal deviate variable.

Analytical data from field duplicates were averaged with original sample results to yield one result for use in the statistical manipulations.

Generally, the detection limit is the lowest concentration of a chemical that can be "seen" above the normal, random noise of an analytical instrument or method. Analytical results are presented as nondetects ("U" qualifier) whenever chemical concentrations in samples do not exceed the reporting limits for the analytical procedures for those samples. To apply the statistical procedures described above, a concentration value must be assigned to nondetects. Generally, nondetects were assumed to be present at one-half the reporting limit (EPA, 1989a). However, professional judgment was used in those cases where the detection limit was unusually high. For example, elevated detection limits that exceed the MDC due to matrix interference or sample dilution may be eliminated from the data set and not used in the estimation of the EPC; however, no data points were eliminated from use in EPC estimation in this evaluation.

The UCL_{95} or MDC, whichever is smaller, was selected as the EPC and is understood to represent a conservative estimate of average for use in the RA or in various transport models used to estimate exposure.

2.3 Results of the Data Evaluation

Previous investigations at Acid Area 3 confirmed the presence of soil contamination from former PBOW operations. The sampling locations for these investigations are provided in Figure 2-1. The objective of the soil investigation conducted under the RI (Jacobs, 2006) was to evaluate the presence of soil contamination at additional former site facilities not previously sampled. The objective of the groundwater investigation was to characterize the shallow and bedrock aquifers and to evaluate the presence of chemical contamination in groundwater in the vicinity of Acid Area 3. Two rounds of groundwater samples were collected from the shallow and bedrock monitoring wells. Data from samples collected January 2005 are presented in the Round 1 Quarterly Groundwater Monitoring Report (Jacobs, 2005). Data from samples collected April 2005 are presented in the Final Round 2 Quarterly Groundwater Monitoring Report (Jacobs, 2006). Thirteen surface water and sediment samples were collected from the drainage ditch at Acid Area 3.

Table 2-1 provides the following information for each detected chemical for each medium at Acid Area 3:

- Chemical name,
- Frequency of detection,
- Range of detected concentrations,
- Range of detection limits,
- Arithmetic mean of site concentrations,
- 95 percent upper confidence limit (UCL) on the arithmetic mean,
- Appropriate RBSC,
- Appropriate BSC, and
- Selection/exclusion of chemical as a COPC.

Surface Soil. A total of 34 surface soil samples have been collected at Acid Area 3, which includes 20 samples collected during the 1998 SI and 14 samples collected during the RI. Contaminants detected include VOCs, nitroaromatics, SVOCs, PCBs, and metals. Specific compounds exceeding the USEPA Region 9 Residential PRGs (EPA, 2004b) are identified in Table 2-1.

Subsurface Soil. A total of 40 subsurface soil samples have been collected from 32 locations at Acid Area 3, which includes 18 samples from 18 locations during the 1998 SI and 22 samples from 14 locations during the RI (Jacobs, 2006). Sample depths for the 1998 SI ranged from 2 to 10 ft bgs. Sample depths for the RI were limited to the 3 to 5 ft interval and the 8 to 10 foot interval. Contaminants detected include VOCs, nitroaromatics, SVOCs, PCBs, and metals. Specific compounds exceeding the USEPA Region 9 Residential PRGs (EPA, 2004b) are identified in Table 2-1.

Shallow Groundwater: Contaminants detected in shallow groundwater at Acid Area 3 during two rounds of sampling in 2005 include VOCs and metals. Specific compounds exceeding the USEPA Region 9 residential PRGs (EPA, 2004b) for drinking water are identified in Table 2-1. The organic detections were limited to a few locations and a few compounds. The two VOCs (cyclohexane and methylcyclohexane) detected in monitoring wells AA3-GW-004 and AA3-GW-005 during Round 2 were J-flagged because the detections were between the reporting limit and the detection limit, indicating that the detections are estimated and the associated numerical values are the approximate concentrations of the respective analytes in the samples. These contaminants were not detected during Round 1 sampling.

Methylene chloride, which is a common lab artifact, was reported in the sample from monitoring well AA3-GW-002 during Round 2 only.

Bedrock Groundwater. Contaminants detected in bedrock groundwater during two rounds of sampling include VOCs, nitroaromatics, SVOCs, and metals. Specific compounds exceeding the USEPA Region 9 residential PRGs (EPA, 2004b) for drinking water are identified in Table 2-1. The organic compounds are present at all bedrock locations and include numerous VOCs associated with naturally occurring petroleum. Benzene and xylene have been detected in other background monitoring wells completed in the Columbus Limestone and are compounds found in naturally occurring petroleum. The Columbus Limestone is known to contain naturally occurring petroleum in the region. Further characterization of the organic compounds is to be performed by NASA in an attempt to confirm the source of these compounds.

PCE, detected in AA3-BEDGW-001 and AA3-BEDGW-002, was not detected during 5 prior sampling events dating back to 1997. The PCE detections were J-flagged because they were between the reporting limit and the detection limit, indicating that they were estimated and the associated numerical values are the approximate concentrations of the respective analytes in the sample.

Surface Water. Contaminants detected in surface water at Acid Area 3 are limited to metals and very few organic compounds. All but one of the organic compound detections were J-flagged because they were between the reporting limit and the detection limit, indicating that the detections are estimated and the associated numerical values are the approximate concentrations of the respective analytes in the samples. Specific compounds exceeding the USEPA Region 9 residential PRGs (EPA, 2004b) for drinking water are identified in Table 2-1.

Sediment. Contaminants detected in sediment at Acid Area 3 include VOCs, SVOCs, PAHs, nitroaromatics, PCBs, and metals. Specific compounds exceeding the USEPA Region 9 Residential PRGs (EPA, 2004b) for soil are identified in Table 2-1.

3.0 EXPOSURE ASSESSMENT

Exposure is the contact by a receptor with a chemical or physical agent. An exposure assessment estimates the type and magnitude of potential exposure of a receptor to COPCs found at or migrating from a site (EPA, 1989a). The following steps are included in an exposure assessment:

- Characterize the physical setting,
- Identify the contaminant sources, release mechanisms, and migration pathways,
- Identify the potentially exposed receptors,
- Identify the potential exposure pathways,
- Estimate EPCs, and
- Estimate chemical intakes or contact rates.

This BHHRA characterizes potential exposures to COPCs in soil, groundwater, surface water and sediment associated with Acid Area 3. Estimation of risk from potential exposure is described in the risk characterization for each COPC (Section 5.0). The Scope of Work (USACE, 2001) requires the summation of potential risks from all environmental media evaluated in the risk characterization.

3.1 Conceptual Site Exposure Model

The CSEM provides the basis for identifying and evaluating the potential risks to human health in the BHHRA. The CSEM was constructed from plausible site-use scenarios and the potential exposure pathways. The elements of the CSEM include:

- Source,
- Source media (i.e., initially contaminated environmental media),
- Contaminant release mechanisms,
- Contaminant transport pathways,
- Intermediate or transport media,
- Exposure media,
- Plausible receptors, and
- Routes of exposure.

Contaminant release mechanisms and transport pathways are not relevant for direct receptor contact with a contaminated source medium (e.g., ingestion of or dermal contact with groundwater).

Figure 3-1 depicts the CSEM used for Acid Area 3. The receptors and pathways on the figure reflect plausible scenarios developed from information on site background and history, topography, climate, and demographics as presented by the site-wide groundwater investigation (IT, 1997). Exposure pathways that were identified as complete on the CSEM are addressed in the BHHRA. Additional potential receptors not listed on the CSEM figures were briefly discussed in Section 3.1.3.2 of the Work Plan (Jacobs, 2007).

No current or future exposures by off-site residents were evaluated. The majority of the off-site residents are serviced by municipal water. There are numerous private groundwater wells in the vicinity, including 8 within one mile of the facility boundary. Although natural hydrocarbons are known to be present within the bedrock limestone and shale formations, groundwater underlying the sites cannot be summarily excluded for consideration as a tap water source based on natural water quality parameters. Therefore, given the presence of numerous off-site wells and the assumption of unrestricted future land use on site, the development of groundwater for on-site residential (or on-site worker) use as tap water was regarded as plausible.

3.1.1 Physical Setting

The Acid Area 3 site physical features include an open field with a drainage ditch running north to south on the western perimeter of the site. A storm sewer system was constructed at the site, as evidenced by existing drainage grates, manhole covers, and open holes with brick lining. A large diameter concrete culvert discharges into the ditch on the east side of the bank, near the center of the site. Running water was heard through the drainage grates during the Round 1 groundwater sampling effort. Several rail lines are still present at the site oriented in a north–south direction. A paved service road borders the northern and western perimeter of the site, while Ransom Road and Maintenance Road serve as boundaries for the eastern and southern perimeter, respectively. Acid Area 3 covers approximately 40 acres. The ground surface is relatively flat, ranging from 632.6 to 637.0 ft amsl. The majority of the site is currently an open field, with tall grass and frequent low shrubs. Some small wooded areas have developed along the former railroad tracks. Much of the area outside of the site boundary is also open terrain with tall grass or small shrubs and occasional wooded areas.

Geology. Overburden thickness at Acid Area 3 ranges from 21.0 to 25.9 ft. The overburden consists of clay and silty clay, with frequent discontinuous zones of silt in the upper 10 feet of the overburden. The lower 5 to 7 ft of overburden consists of a fairly continuous layer of highly plastic clay, which is present at most locations. There are deposits of sandy silt and silty sand on the east side of the site at depths ranging from 8 to 18 ft, with a maximum thickness of 5 ft. The Plum Brook Shale subcrops beneath these unconsolidated deposits over the entire site. The thickness of this shale ranges from 4.5 to 14 ft, with thickness decreasing to the northwest. The Delaware Limestone underlies the Plum Brook Shale; the Delaware Limestone is underlain by the Columbus Limestone.

Surface Water. The only surface water feature within Acid Area 3 is a drainage ditch on the western perimeter of the site, which flows from north to south. The drainage ditch is approximately 1800 ft on-site, discharging to Pipe Creek approximately one-half mile downgradient of the site. The drainage ditch makes a 90-degree bend at the southwest corner of the site and then flows westward toward Pipe Creek. The channel is approximately 6 to 8 ft wide and 4 to 5 ft deep at the upstream end north of the site, increasing to 15 ft wide and 8 ft

deep at the downstream location. The upstream portion of the drainage ditch is ephemeral and flows only during the wet season and following precipitation events, remaining dry from mid-summer through the fall. The lower half of the drainage ditch maintains 6 to 12 inches of water on a continuous basis. A 24-inch culvert discharges into the drainage ditch on the east side of the channel near the center of the site. An underground drainage system is present within the interior of the Acid Area 3 site, which likely discharges shallow groundwater through the 24-inch culvert. A series of drainage grates are present on the east side of the easternmost rail line.

Groundwater. Groundwater at PBOW includes the shallow overburden and the bedrock aquifers. Numerous wells have been installed across the site to characterize these two water-bearing units (Shaw, 2003). The shallow overburden generally has low yields over most of the site due to the high percentage of silt and clay. Water levels in the shallow overburden range from less than 1 ft bgs to 6 ft bgs during wet season and fluctuate up to 4 ft on a seasonal basis. Shallow water levels generally mirror the local topography and flow is typically toward the local surface drainage features with a general northerly trend. Shallow groundwater at Acid Area 3 generally flows toward the center of the site, where underground drainage tiles divert shallow groundwater directly to the drainage ditch west of the site.

Bedrock groundwater has been subdivided into two separate units at PBOW: 1) the Plum Brook Shale and Ohio Shale, and 2) the Delaware Limestone and Columbus Limestone. Water levels in the Plum Brook Shale and Ohio Shale closely match those of the shallow overburden suggesting good vertical communication between the two units. Water levels in the Delaware and Columbus Limestones are on average 30 ft bgs. Water in the limestone typically occurs in fractures, along bedding planes, or in solutionally enlarged openings. The conceptual model indicates that bedrock groundwater flow in the Delaware and Columbus Limestones is dependant on the frequency, orientation, density, and connectivity of the fractures. Groundwater flow in the limestone is generally to the north; however, there are major fracture zones transecting the site, which influence groundwater flow in several areas (Shaw, 2003). Groundwater from the Columbus Limestone at Acid Area 3 is unsuitable as a potable water source due to the presence of naturally occurring hydrogen sulfide gas and petroleum.

3.1.2 Contaminant Sources, Release Mechanisms, and Migration Pathways

Numerous buildings, process facilities, and storage tanks were constructed at Acid Area 3 to support the production of oleum, sulfuric acid, and nitric acid used in manufacturing TNT. Contamination resulted from the inadvertent release of oleum, sulfuric acid, nitric acid, contaminants, and residues. Releases occurred to the surface soil as spills and to the subsurface soil from leaking or damaged underground pipes. Releases may also have occurred during decontamination or during the building and equipment removal processes. Runoff and erosion may have spread contamination over the surrounding surface soil and may have carried contaminants to nearby streams. Infiltration and leaching may have carried contaminants into the subsurface soil and groundwater.

3.1.3 Receptors and Exposure Pathways

Receptors, selected to represent the upper bound on exposure from all plausibly exposed groups of people at Acid Area 3, and the pathways by which they may be exposed to chemicals are summarized in Figure 3-1 and Table 3-1. The exposure variable values used in the contaminant intake models for soil, surface water, and sediment are compiled in Table 3-2. The

exposure variable values used in the contaminant intake models for groundwater are compiled in Table 3-3. The receptors evaluated in this BHHRA are:

- Current and future groundskeeper,
- Current and future construction worker,
- Future on-site resident,
- Future indoor worker, and
- Current and future hunter.

Most RAs are based on a reasonable maximum exposure (RME) assumption. The intent of the RME assumption is to estimate the highest exposure level that could reasonably be expected to occur, but not necessarily the worst possible case (EPA, 1989a, 1991a). It is interpreted as reflecting the 90th to 95th percentile on exposure. In keeping with EPA (1991a) guidance, variables chosen for the baseline RME scenario for ingestion rate (IR), exposure frequency (EF) and exposure duration (ED) were generally upper bounds. Other variables such as body weight (BW) and exposed skin surface area (SA), were generally central or average values. In the case of contact rates consisting of multiple components (e.g., dermal contact with soil or water, which consists of a dermal absorption factor [ABS] and soil-to-skin adherence factor [AF] for soil, and permeability coefficient [PC] and exposure time [ET] for water), only one variable, ABS or PC, needs to be an upper bound. The conservatism built into the individual variables ensures that the entire estimate for contact rate is sufficiently conservative.

The averaging time (AT) for the noncancer evaluation was computed as the product of ED (years) times 365 days per year (days/year), to estimate an average daily dose over the entire exposure period (EPA, 1989a). For cancer evaluation, AT was computed as the product of 70 years, the assumed human lifetime, times 365 days/year, to estimate an average daily dose prorated over a lifetime regardless of the frequency or duration of exposure. This methodology assumes that the risk from short-term exposure to a high dose of a given carcinogen is equivalent to long-term exposure to a correspondingly lower dose, provided that the total lifetime doses are equivalent. This approach is consistent with the EPA (1986) policy of carcinogen evaluation, although it introduces uncertainty into the cancer RA.

The chemical intake equations contain a fraction of intake (FI) parameter to account for scenarios in which exposure to a potentially contaminated medium associated with the site was less than total daily exposure to that medium. For example, if the site of interest is small enough such that a groundskeeper may spend only one-half of his working time there, an FI of 0.5 was applied to the soil ingestion and dermal intake equations. An FI was also used if a receptor's exposure was split between two comparable media. For example, if a construction worker is exposed to both soil and sediment, FIs are introduced that apportion his exposure between the two media. The default value of FI is 1.

3.1.3.1 Overburden Groundwater

Shallow groundwater in the vicinity of Acid Area 3 is not regarded as a potential source of potable water because of the high clay content and limited discontinuous permeable zones,

resulting in low yields. It is possible that a construction worker may be exposed to shallow groundwater via direct contact; however, such exposure would likely be sporadic and of short duration. Therefore, the BHHRA did not quantitatively evaluate exposure to perched groundwater.

3.1.3.2 Bedrock Groundwater

The following receptors were evaluated to represent the upper bound on bedrock groundwater exposure for all plausibly exposed groups of people at Acid Area 3.

Current on-site. No current on-site exposure to bedrock groundwater exists.

Future on-site. The evaluation of future on-site exposure to bedrock groundwater was based on measured concentrations at Acid Area 3 described in this report. Future receptors were the on-site worker and on-site resident.

If on-site groundwater were to be developed as a tap water source, other potential future groundwater receptors may include short-term (e.g., construction) workers or site visitors. However, the levels of exposure to these would be shorter in duration and/or frequency than that of an on-site worker or resident. Therefore, the on-site worker and resident receptor represent an upper bound on exposure for all potential receptors.

The potential exposure scenarios evaluated for groundwater were the future on-site resident and the future on-site worker. Exposure assumptions and parameter values specific to the resident and worker are described in the paragraphs that follow. The fraction of tap water intake/exposure attributed to groundwater was 1.0 for each receptor. Exposure parameters and parameter values are summarized in Table 3-1.

Resident. The resident was assumed to be exposed to groundwater as household tap water and, for volatile compounds, to air concentrations associated with groundwater use in the residence. Cancer and noncancer assessments were performed for both an adult and child. The evaluations assumed 30 years of exposure: 24 years as a 70-kilogram (kg) adult (EPA, 1991a) and 6 years as a 15-kg child (EPA, 1991a). For cancer effects, the adult and child effects were summed together; for noncancer effects, the child and adult were evaluated separately. An EF of 350 days per year (EPA, 1991a) was used for adult and child residential pathways.

Drinking water ingestion rates for the adult of 2 liters per day (L/day) (EPA, 1991a) and for the child of 1 L/day (EPA, 1991a) were assumed. Both the child and adult resident were assumed to be dermally exposed to COPCs in groundwater while bathing/showering. The child was assumed to bathe for 20 minutes per day (0.333 hour/day) (EPA, 2004a). The adult was assumed to shower for 35 minutes per day (0.6 hour/day) (EPA, 2004a). Inhalation rates of 0.833 m^3/hour for the adult (EPA, 1991a) and 0.416 m^3/hour for the child (EPA, 2004a) were used. Because the *Exposure Factors Handbook* (EPA, 1997a) lists a 90th percentile for time spent in a residence as over 23 hours per day, it was conservatively assumed that the resident spends 24 hours per day in the house.

On-Site Worker. Under the future land-use scenario, a site worker may be exposed to groundwater, which theoretically could be developed as a source of drinking water. His drinking water ingestion rate was assumed to be 1 L/day (EPA, 1991a). He could also experience dermal contact with groundwater used to clean equipment and to rinse dust or perspiration from his body. For this evaluation, it was assumed that the head, forearms, and hands, approximately 3,300 square centimeters (cm^2) (EPA, 2004a), would be exposed intermittently for up to 1 hour per day. Dermal absorbed dose was calculated using the spreadsheet model developed by EPA in conjunction with RAGS Part E (EPA, 2004a) (Appendix A).

3.1.3.3 Surface Soil

The following receptors were evaluated to represent the upper bound on surface soil exposure for all plausibly exposed groups of people at Acid Area 3. Exposure assumptions and parameter values specific to the potential current and future receptors are described in the paragraphs that follow. Exposure parameters and parameter values are summarized in Table 3-1.

Current on-site. Potential current on-site receptors are construction workers, groundskeepers, and hunters. The evaluation of current on-site exposure to surface soil was based on current measured concentrations.

Future on-site. Potential future receptors are construction workers, on-site indoor workers, on-site residents, groundskeepers and hunters. The evaluation of future on-site exposure to surface soil was based on current measured concentrations.

Groundskeeper. Under the current and future land-use scenarios, a groundskeeper may be exposed to surface soil. The groundskeeper scenario was designed to evaluate the upper bound for site worker exposure to surface soil in the current and future site-use scenario. Direct exposure pathways include incidental ingestion and dermal contact. Inhalation of dust raised by operating lawn mowers or other equipment was also evaluated because relatively high dust concentrations may be produced within the groundskeeper's breathing zone, with little opportunity for dilution by ambient air. The groundskeeper was assumed to be a 70-kg adult who works 8 hours per day (hours/day), approximately 5 days per week (days/week) year-round on site for a total of 250 days/year for 25 years (EPA, 1991a). The respiratory rate for the groundskeeper was assumed to be 20 m^3/8-hour workday (2.5 m^3/hour), and the soil incidental ingestion rate was assumed to be 100 milligrams per day (mg/day), comparable to that for an agricultural worker.

Recent studies evaluating soil adherence that consider the nature of the activity performed and the different body regions were reviewed by EPA (1997a). Measurements of soil adherence to hands, arms, legs, feet, and face for 29 groundskeepers revealed AFs ranging from 8E-4 milligrams per square centimeters (mg/cm^2) (legs) to 1.5E-1 mg/cm^2 (hands). The AF weight averaged across these body regions (i.e., adjusted to reflect the different SAs of the different body regions) for males and females is 9E-3 mg/cm^2. The SA of body regions evaluated for groundskeepers includes approximately 11,300 cm^2 (EPA, 1997a).

Hunter. Under the current and future land-use scenarios, a hunter may be exposed to surface soil. The hunter was assumed to be a 70-kg adult nearby resident (exposure duration of 30 years) (EPA, 1991a). Small children would be unlikely to accompany the hunter afield.

Therefore, the direct exposure pathways evaluated for the hunter (incidental ingestion and dermal contact with soil) were not evaluated for the small child. It was assumed that the hunter would spend his entire 2-week vacation hunting on PBOW; i.e., his EF for incidental soil ingestion and dermal contact was 14 days/year. His incidental soil ingestion rate was assumed to be 100 mg/day (EPA, 1991a). It was assumed that approximately 25 percent of his body SA, or 4,550 cm^2, would be available for exposure to soil (EPA, 2004a). A soil AF of 0.2 mg/cm^2 was assumed. Inhalation of airborne dust would be a potential exposure pathway, however, vegetation would reduce dust emissions to insignificant levels, and it was assumed that the hunter would spend virtually all of his time on vegetated rather than bare soil. Therefore, it was assumed that inhalation exposure would contribute much less than incidental ingestion and the inhalation exposure pathway was not evaluated.

Future On-Site Resident. It was assumed that the future on-site resident would be exposed to surface soil. The on-site residential scenario was evaluated using both an adult and a child. Lifetime cancer risk was estimated as the sum of the risks calculated for the adult and the child.

The adult resident was assumed to be a 70-kg person with an incidental soil ingestion rate of 100 mg/day, and an inhalation rate of 20 m^3/day (0.83 m^3/hour) (EPA, 1991a). Approximately 25 percent of his body SA, or 4,500 cm^2, was assumed as available for exposure to soil (EPA, 2004a). The adult resident was assumed to be exposed 350 days/year for 24 years (EPA, 1991a).

The child resident was assumed to be a 1- through 6-year-old with an average BW of 15 kg, a soil ingestion rate of 200 mg/day, and an inhalation rate of 10 m^3/day (EPA, 1991a). Approximately 25 percent of his body SA, or 1,750 cm^2, was assumed to be available for exposure to soil (EPA, 2004a). The child resident was assumed to be exposed for 350 days/year for 6 years (EPA, 1991a).

An average soil AF of 0.2 mg/cm^2 was adopted for the on-site resident (EPA, 2004a).

Evaluation of exposure to VOCs from soil by the future on-site resident was addressed during evaluation of airborne dust as described for the groundskeeper, above. It was assumed that 80 percent of the soil surface would be covered with pavement or vegetation for evaluating inhalation to airborne dust. Inhalation of VOCs released from subsurface soil and entrapped in indoor air was not evaluated as there were no VOCs detected in the subsurface soil. Inhalation rates of 20 m^3/day for the adult (EPA, 1991a) and 10 m^3/day for the child (EPA, 1991a) were used.

Future On-Site Indoor Worker. Under the future land-use scenario, an on-site worker may be exposed to surface soil. This receptor scenario was developed to evaluate exposure to indoor airborne VOCs entrapped in a building. However, as there were no VOCs detected in the subsurface soil, this pathway was not evaluated. The indoor worker would also be potentially exposed to surface soil via incidental ingestion. Dermal exposure to surface soil and inhalation of airborne dust and VOCs from surface soil, although plausible, were expected to be less significant than incidental ingestion because he would spend his work time indoors. Therefore, dermal contact and inhalation of dust and airborne VOCs from surface soil was not quantified.

The indoor worker was assumed to be a 70-kg adult who works 8 hours/day, approximately 5 days/week year-round on the site for a total of 250 days/year for 25 years (EPA, 1991a). His soil incidental ingestion rate was assumed to be 50 mg/day, and his inhalation rate was assumed to be 20 m^3/8-hour workday.

Construction Worker. Under the current and future land-use scenarios, a construction worker may be exposed to surface soil. The construction worker scenario was developed to evaluate short-term exposure to surface and subsurface soil (total soil) in either the current or future site-use scenario. Construction projects were expected to be infrequent. It was assumed that the construction worker would participate in only one construction project on the site. Relevant exposure pathways include incidental ingestion and dermal contact, inhalation of dust raised by operating construction equipment, and inhalation of airborne VOCs released from subsurface soil during excavation and grading.

The construction worker was assumed to be a 70-kg adult who works 8 hours per day (hours/day), approximately 5 days per week (days/week) for 6 months. Potential exposure pathways were incidental ingestion and dermal contact, inhalation of dust raised by operating construction equipment, and inhalation of airborne VOCs released from subsurface soil during excavation and grading. However, as there were no VOCs detected in the subsurface soil, inhalation of airborne VOCs released from subsurface soil during excavation and grading was not evaluated. Excavation and soil grading activities, which result in intensive soil contact, were assumed to last for 3 months; for the remaining 3 months, construction activities were assumed to result in less intensive soil contact. Soil ingestion rates of 480 mg/day (EPA, 1991a) and 100 mg/day, similar to an agricultural worker, were assumed for the intensive and less intensive contact periods, respectively. The resulting time-weighted average soil ingestion rate was 290 mg/day.

Construction workers would also experience dermal contact with soil adhered as dust or from direct contact with the soil. An AF for soil for the construction worker of 8E-2 mg/cm^2 was estimated using the same method as previously described for the groundskeeper, combining EPA (1997a) data for construction workers, utility workers, and equipment operators to capture the full range of activities likely to be performed by this receptor. The body regions evaluated for construction workers total approximately 11,300 cm^2. An inhalation rate of 20 m^3/day (EPA, 1991a) for potential exposures to VOCs and air borne dust was assumed.

3.1.3.4 Subsurface Soil

The following receptors were evaluated to represent the upper bound on subsurface soil exposure for all plausibly exposed groups of people at Acid Area 3. Exposure assumptions and parameter values specific to the potential current and future receptors are described in the paragraphs that follow. Exposure parameters and parameter values are summarized in Table 3-1.

Current on-site. The only potential current on-site receptors are construction workers. The evaluation of current on-site exposure to surface soil was based on current measured concentrations.

Future on-site. Potential future receptors are construction workers and on-site residents. The evaluation of future on-site exposure to surface soil was based on current measured concentrations.

Groundskeeper. Under the current and future land-use scenarios, contact with subsurface soil would be infrequent and sporadic, since such contact would not be part of the groundskeeper's regular duties or activities. Therefore, exposure to subsurface soil was not evaluated.

Future On-Site Resident. Exposure parameters for the future on-site resident are identical to those described above for surface soil (Section 3.1.3.3). Future on-site residents were assumed to be exposed to subsurface soil as a result of residential development that would involve excavation and grading, which would bring subsurface soil to the surface.

Future On-Site Indoor Worker. Under the future land-use scenario, an on-site worker may be exposed to indoor airborne VOCs entrapped in a building. VOCs released from subsurface soil may enter a building through joints or cracks in the foundation or slab. However, as there were no VOCs retained as COPCs in the subsurface soil, this pathway was not evaluated. The exposure parameters for the on-site indoor worker are the same as described above for surface soil (Section 3.1.3.3).

Construction Worker. Under the current and future land-use scenarios, a construction worker may be exposed to subsurface soil. Exposure parameters for the construction worker were identical to those described above for surface soil (Section 3.1.3.3).

3.1.3.5 Surface Water

The following receptors were evaluated to represent the upper bound on surface water exposure for all plausibly exposed groups of people at Acid Area 3. Exposure assumptions and parameter values specific to the potential current and future receptors are described in the paragraphs that follow. Exposure parameters and parameter values are summarized in Table 3-1.

Current on-site. The only potential current on-site receptors are construction workers. The evaluation of current on-site exposure to surface water was based on current measured concentrations.

Future on-site. Potential future receptors are construction workers and on-site residents. The evaluation of future on-site exposure to surface water was based on current measured concentrations.

Groundskeeper. Under the current and future land-use scenarios, a groundskeeper may be exposed to surface water. However, such exposure would be infrequent and sporadic, since such contact would not be part of the groundskeeper’s regular duties or activities. Therefore, exposure to surface water was not quantified.

Hunters. Under the current and future land-use scenarios, a hunter may be exposed to surface water. However, such exposure would be infrequent and sporadic, since such contact would not be part of the hunter’s regular or activities. Therefore, exposure to surface water was not quantified.

Future On-Site Resident. The future on-site resident was assumed to be exposed to surface water. The resident could have access to the surface water bodies associated with Acid Area 3. It was assumed that the resident would visit the streams for 8 hours/day, 2 days/week during the warmer half of the year. The resident was assumed to wade for 3 hours/day on 52 days/year. The exposure pathway evaluated was dermal contact with surface water. Approximately 30 percent of the adult's and child's total body SAs, 5,450 cm^2 and 2,100 cm^2, respectively, were assumed to be available for exposure to surface water. The dermal absorbed dose was calculated using the spreadsheet model developed by EPA in conjunction with RAGS Part E (EPA, 2004a) (Appendix A). Incidental ingestion of surface water in a wading scenario was considered to be less significant than dermal contact and was not quantified. Inhalation of VOC emissions from surface water is also possible, but the large volume of outdoor ambient air and natural air currents would be expected to dilute airborne concentrations such that this pathway would be less significant than dermal contact, which was quantified. For these reasons, inhalation of VOC emissions from surface water was not quantified.

On-Site Indoor Worker. Under the future land-use scenario, an on-site indoor worker would not be expected to be exposed to surface water. Therefore, exposure to surface water was not quantified.

Construction Worker. Under the current and future land-use scenarios, a construction worker may be exposed to subsurface soil. The construction worker may also be exposed to surface water during projects such as installation of underground utilities or rerouting stream flow. Dermal contact would be the most significant pathway for exposure to surface water. Incidental ingestion of surface water would also be possible, but would be expected to be much less significant than dermal contact. Dermal exposure to surface water was assumed to occur for 4 hours/day, or one-half the normal workday. It was assumed that the arms, forearms and hands (an SA of approximately 3,100 cm^2 [EPA, 1997a]) would be exposed to surface water. Dermal absorbed dose was calculated using the spreadsheet model developed by EPA in conjunction with RAGS Part E (EPA, 2004a) (Appendix A). Inhalation of VOCs from surface water is also possible, but the large volume of outdoor ambient air and natural air currents would be expected to dilute airborne concentrations, so that this pathway would be less significant than dermal contact, which was quantified. For these reasons incidental ingestion and inhalation of VOCs from surface water were not quantified.

3.1.3.6 Sediment

The following receptors were evaluated to represent the upper bound on sediment exposure for all plausibly exposed groups of people at Acid Area 3. Exposure assumptions and parameter values specific to the potential current and future receptors are described in the paragraphs that follow. Exposure parameters and parameter values are summarized in Table 3-1.

Current on-site. The only potential current on-site receptors are construction workers. The evaluation of current on-site exposure to sediment was based on current measured concentrations.

Future on-site. Potential future receptors are construction workers and on-site residents. The evaluation of future on-site exposure to sediment was based on current measured concentrations.

Groundskeeper. Under the current and future land-use scenarios, a groundskeeper may be exposed to sediment. However, such exposure would be infrequent and sporadic since contact would not be part of the groundskeeper's regular duties or activities. Therefore, exposure to sediment was not quantified.

Hunters. Under the current and future land-use scenarios, a hunter may be exposed to sediment. However, such exposure would be infrequent and sporadic since contact would not be part of the hunter's regular or activities. Therefore, exposure to sediment was not quantified.

Future On-Site Resident. The future on-site resident was assumed to be exposed to sediment. The resident could have access to sediments associated with Acid Area 3 and could be exposed to sediment. It was assumed that the resident would visit the streams for 8 hours/day, 2 days/week during the warmer half of the year. The resident was assumed to wade for 3 hours/day on 52 days/year. The exposure pathway evaluated was dermal contact with sediment. The mechanisms of exposure to soil and sediment are likely to be similar; therefore, the incidental soil ingestion rate of 100 mg/day was also applied to sediment. Approximately 25 percent of the adults and child's total body SAs, 4,500 cm^2 and 1,750 cm^2, respectively, were used.

On-Site Indoor Worker. Under the future land-use scenario, an on-site indoor worker would not be expected to be exposed to sediment. Therefore, exposure to sediment was not quantified.

Construction Worker. Under the current and future land-use scenarios, a construction worker may be exposed to sediment. The construction worker may be exposed to sediment during projects such as installation of underground utilities or rerouting stream flow. Dermal contact would be the most significant pathway for exposure to sediment. Incidental ingestion of sediment would also be possible, but would be expected to be much less significant than dermal contact. Dermal exposure to sediment was assumed to occur for 4 hours/day, or one-half the normal work day. It was assumed that the arms, forearms and hands, an SA of approximately 3,100 cm^2 (EPA, 1997a), would be exposed to sediment. Inhalation of VOCs from sediment would also be possible; but the large volume of outdoor air and natural air currents would be expected to dilute airborne concentrations such that this pathway would be less significant than dermal contact, which was quantified. For these reasons incidental ingestion and inhalation of VOCs from sediment were not quantified.

3.1.3.7 Game Animals

The following receptors were evaluated to represent the upper bound on exposure via ingestion of game animals taken at Acid Area 3.

Current and future on-site. The potential current and future on-site receptors are hunters. The evaluation of current on-site exposure to game animals was based on current measured concentrations.

Exposure assumptions and parameter values specific to the potential current and future receptors are described in the paragraphs that follow. Exposure parameters and parameter values are summarized in Table 3-1.

Hunters. This scenario was developed to evaluate the potential for contaminants in soil to affect food-chain pathways. Acid Area 3 provides habitat for deer and other wildlife, and deer hunting is permitted on the PBOW facility. Therefore, a hunter who consumes his game is a plausible scenario requiring evaluation. Many kinds of game animals may be hunted and consumed including squirrel, pheasant and other upland birds, turkey and deer; however, the deer is the species most likely to contribute meaningfully to the diet. Therefore, the evaluation was limited to a deer hunter.

Data were not located regarding the rate of venison ingestion; therefore, a hypothetical scenario was adapted from the assumptions applied to a similar site in West Virginia (IT, 2000c). A highly conservative but plausible scenario consists of a hunter who kills a deer each year. It was assumed that the hunter eats 10 pounds (4.5 kg) of venison per year (Sharp, 1995). This consumption rate corresponds to 0.013 kg/day (0.186 g/kg-day) of venison for each of the 350 days per year (EPA, 1991a) that the hunter spends at home.

It is likely that the successful hunter would share his venison with the rest of the family, which may include small children. The hunter's child was referred to as a child venison consumer for the purposes of this evaluation. Data regarding the rate of venison ingestion by small children were not located. It was assumed that venison replaced beef in the diet, and the differences in beef consumption between adults and children were used to estimate a venison ingestion rate for children. EPA (1997a) provides per capita beef intake data for less than 1- to 5-year-old children ranging from 0.941 to 1.46 g/kg-day (time-weighted average of 1.296 g/kg-day). EPA (1997a) provides per capita beef intake data for 12- to 70+-year-old adults ranging from 0.568 to 0.83 g/kg-day (time-weighted average of 0.727 g/kg-day). From these data, it was estimated that the beef consumption of small children, expressed on a BW basis, would be approximately 1.8 times that of an adult. Therefore, a venison ingestion rate of 0.335 g/kg-day was estimated for the young child from the venison ingestion rate of 0.186 g/kg-day for the adult. Assuming that the child is 0 to 6 years old with an average BW of 15 kg (EPA, 1991a), the child venison ingestion rate may be expressed as 0.005 kg/day.

3.2 Quantification of Exposure-Point Concentrations

The EPC is a conservative estimate of the average concentration of a COPC, statistically calculated from the analytical results of all samples for a particular environmental medium to which a receptor may be exposed over the duration of the exposure. An EPC may be based on media concentrations that have been directly measured or it may be derived based on environmental medium-to-medium transport modeling. The EPCs of COPCs in soil, groundwater, surface water and sediment were statistically derived values based on measured analytical data. Concentrations of COPCs in air were not measured (and in the case of groundwater volatilization or future exposure scenarios, cannot reasonably be measured), but were based on models that use the EPCs of COPCs in groundwater as input values.

3.2.1 COPC Concentrations from Dust

Inhalation exposure to particulate (dust) emissions from soil for the groundskeeper and construction worker evaluations results from activities that raise dust. Therefore, the most appropriate approach to estimating chemical concentrations in ambient air is through the use of an activity-based dust loading equation (U.S. Department of Energy [DOE], 1989):

$$C_a = (D)(C_{so})(CF_1) \quad \textbf{Eq. 3.1}$$

where:

C_a=contaminant concentration in air (mg/m^3, calculated)

D = dust loading factor (g of soil/m^3 of air)

C_{so} = contaminant concentration in soil (mg/kg)

CF_1 = conversion factor (1E-3 kg/g).

Plausible values for D include 2E-4 grams per cubic meter (g/m^3) for agricultural activity (DOE, 1989), 6E-4 g/m^3 for construction work (DOE, 1983), and 1E-4 g/m^3 for other activity (National Council on Radiation Protection and Measurements [NCRPM], 1984). The value for D of 1E-4 g/m^3 for other activity was used for the groundskeeper. It was assumed that construction activities requiring intimate contact with soil, for which D = 6E-4 g/m^3 is appropriate, may last for one-half of a construction period. The remaining one-half of the time is more realistically characterized by D = 1E-4 g/m^3. Therefore, a time-weighted average dust loading factor for construction work of 3.5E-4 g/m^3 was estimated for the construction worker.

Airborne concentrations of VOCs estimated by the dust loading model was assumed to sufficiently estimate levels of VOCs that may arise from volatilization, because the dust loading model treats the VOCs as if they were located at the ground surface.

The resident would be more likely to be exposed to dust arising from wind erosion than from dust-raising activities on the site. EPA (1996a) derived a model for estimating a dust particulate emission factor based on an "unlimited reservoir" model and the assumption that the source area is square:

$$PEF = Q/C \times \frac{3600}{0.036 \times (1-V) \times \left(U_m / U_t\right)^3 \times F(x)} \quad \textbf{Eq. 3.2}$$

where:

PEF = particulate emission factor (m^3/kg, calculated)

Q/C = inverse of the mean concentration at center of square source (43.08 g/m^{3}second per kg/m^3, site-specific value from Table 3 in EPA [1996a] [Zone 7, Cleveland, 30-acre site])

3600 = seconds/hour

V = fraction of surface covered with vegetation (0.8, unitless, assumed)

U_m = mean annual wind speed (default, 4.69 m/second)

U_t = equivalent threshold value of wind speed at 7 m (default, 11.32 m/second)

F(x) = function dependent on U_m/U_t (default, 0.194).

The concentration of COPCs in air are calculated as follows:

$$C_a = \frac{C_{so}}{PEF} \qquad \textbf{Eq. 3.3}$$

where:

C_a = contaminant concentration in air (mg/m^3, calculated)

C_{so} = contaminant concentration in soil (mg/kg)

PEF = particulate emission factor (m^3/kg).

Airborne concentrations of VOCs estimated by the wind erosion model were assumed to sufficiently estimate levels of VOCs that may arise from volatilization, because the wind erosion model treats the VOCs as if they were located at the ground surface.

3.2.2 Concentrations in Household Air from Groundwater Use

Inhalation of VOCs released from groundwater was evaluated, as applicable, for the on-site resident scenario. Chemicals that have a Henry's Law value exceeding 1E-05 atmospheres per cubic meter (m^3) per mole and a molecular weight less than 200 grams per mole are considered to be VOCs and are subject to evaluation via this pathway. Other groundwater contaminants may be evaluated on a case-by-case basis for their potential contribution to risk via the inhalation pathway based on the degree of departure from the Henry's Law and molecular weight criteria, groundwater concentration, and toxicity.

The simple whole-house tap water-to-air model described in Part B of the human health evaluation manual (HHEM) (EPA, 1991b) was used in the BHHRA. This model was selected based on correspondence between the OEPA (2004) and the USACE. Part B of the HHEM recommends a volatilization constant of 0.0005 for the total concentrations of all VOCs detected in groundwater; the conversion is characterized by the following equation:

$$C_a = C_{gw} x 0.001 \, {}^{mg}\!/_{\mu g} \, x K_{wa} \, x 1{,}000 \, {}^{L}\!/_{m^3} \qquad \textbf{Eq. 3.4}$$

where:

C_a = Modeled concentration in air (mg/m^3)

C_{gw} = Groundwater EPC (µg/L)

K_{wa} = tap water-to-air volatilization constant (0.0005 [unitless]; [EPA, 1991b])

Implicit in HHEM Part B application of this model are the following: 1) a family of four uses the groundwater as the sole source of household tap water; 2) the volume of the house is 150 m^3; 3) the daily groundwater use is 720 L/day; 4) 50 percent of VOCs in tap water volatilize to household air; and 5) the exchange rate of the house is 0.25 m^3/hour (EPA, 1991b). The EPA (1997a) *Exposure Factors Handbook* lists values different from some of these assumed by HHEM Part B. As appropriate, this pathway was evaluated in the BHHRA using alternate values from the *Exposure Factors Handbook*.

3.2.3 Concentrations of VOCs in Groundwater: Resident Dermal Uptake

Volatilization of VOCs from household water reduces the concentration remaining available for dermal contact. As mentioned in Section 3.2.2, the HHEM Part B whole-house tap water-to-air model assumes that 50 percent of the VOC concentrations are released to household air. Thus, the concentrations of VOCs remaining in the water after volatilization occurs are calculated by difference as follows:

$$C_d = C_{gw} x (1 - F_v) \qquad \textbf{Eq. 3.5}$$

where:

C_d = concentration of VOC in household water available for dermal exposure (mg/L, calculated)

C_{gw} = concentration of VOC in groundwater (mg/L)

F_v = fraction of VOCs volatilized to air (0.5, unitless).

Only the concentration remaining in tap water after volatilization (C_d), as applicable, was assumed to be available for contact with the skin during bathing/showering.

3.2.4 Concentrations of COPCs in Venison

The hunter was assumed to harvest and consume game and share it with his family, including small children. The game was assumed to be venison because deer is the species hunted most widely and most likely to provide a regular contribution to the diet. Data do not exist to reliably estimate contaminant concentrations in venison, but the following simplifying assumptions permit estimates sufficient for an RA:

- Deer are small ruminants and as such are not unlike cattle; thus, it is reasonable to assume they may have similar physiological processes that could yield similar biotransfer factors. Unlike beef, however, deer meat does not undergo marbling with fat, and deer fat is quite unpalatable and is likely to be trimmed rather than consumed. Therefore, the biotransfer factors for edible venison were derived by adjusting biotransfer factors for beef to account for differences in the fat content of table-ready beef (cooked choice retail cuts trimmed to 0 inches of fat: average 14.4 percent fat) and venison (cooked boneless muscle meats: average 2.9 percent fat) (Nutrient Database, 1997).

- Deer are expected to browse a much larger area than that encompassed by Acid Area 3; therefore the fraction of total browse consumed from the contaminated site would be expected to be small.

- Indirect food-chain pathways may be significant for metals and for those SVOCs that persist in the environment and have the tendency to bioaccumulate. VOCs are generally mobile in the environment and unstable in biological systems and do not tend to bioaccumulate.

To reflect the assumptions previously noted, venison biotransfer factors are estimated by multiplying beef biotransfer factors by 2.9/14.4 (or 0.20), and by a fraction, FI_e. FI_e reflects the areal portion of the site compared to a deer's home range area. These assumptions are captured in the following equation:

$$B_v = 0.20(FI_e)(B_b) \qquad \textbf{Eq. 3.6}$$

where:

B_v = biotransfer factor for venison (unitless, calculated)

0.20 = factor to reflect differences in fat content between beef and venison (0.20, unitless, see above)

FI_e = areal portion of site compared to a deer's home range (0.06, unitless, see below)

B_b = biotransfer factor for beef.

Values for B_b for metals are provided in the toxicity profiles in Appendix D. Toxicity profiles were prepared for each of the COCs. The toxicity profiles briefly describe the uses of the chemical, its physical properties, behavior in environmental media, biotransfer capability, and toxicity values.

The Acid Area 3 sites cover approximately 40 acres, respectively. The home range of a deer is approximately 630 acres. Therefore, FI_e was set equal to 0.06.

Deer were assumed to be exposed to contaminants by ingesting browse growing on contaminated soil. It was assumed that deer consume approximately 1.74 kg of browse per day (Sample, et al., 1996), which is approximately 50 percent dry matter (DM), or 0.87 kg browse DM per day (Mautz, et al., 1976). The contaminant concentration in browse was estimated from the following equation, which was originally developed for estimating the contaminant concentration in forage to which cattle may be exposed (EPA, 1994a):

$$C_p = (CF_7)(C_{so})(B_p) \quad \textbf{Eq. 3.7}$$

where:

C_p = concentration of contaminant in (plant) forage DM (mg/kg, calculated)

CF_7 = conversion factor to adjust for soil containing 20 percent moisture (1.25 unitless).

C_{so} = concentration of contaminant in soil (mg/kg)

B_p = soil-to-forage biotransfer factor (mg of chemical per kg of dry plant/mg of chemical per kg of dry soil).

Values for B_p were taken from the toxicity profiles in Appendix D. B_p values for the vegetative parts of plants rather than the reproductive parts of plants were selected, where possible, because deer browse year-round, and the vegetative parts are more available for the greater part of the year.

The concentration of COPC in venison can be estimated from the following equation (adapted from EPA, 1994a):

$$C_v = (Q_p)(C_p)(B_v) \quad \textbf{Eq. 3.8}$$

where:

C_v = contaminant concentration in venison (mg/kg, calculated)

Q_p = browse ingestion rate (0.87 kg DM/day)

C_p = contaminant concentration in browse DM (mg/kg)

B_v = biotransfer factor for venison (days/kg).

3.3 Quantification of Chemical Intakes

This section describes the models used to quantify doses or intakes of the COPC by the exposure pathways identified in Section 3.1.3, using the exposure parameter values described in Section 3.1.3. Models are taken or modified from EPA (1989a) unless otherwise indicated. Intakes were calculated for both cancer and noncancer evaluations. Therefore, the AT variable shown in the following equations is replaced with AT_n for noncancer calculations (365 × ED), and with AT_c (25,550 days) for the cancer calculations. Intake values were based on the EPCs (Section 2.2) and the equations discussed below for the respective exposure pathways.

3.3.1 Inhalation of COPCs in Air

The following equation was used to estimate the inhaled dose of COPC in air (groundskeeper, construction worker, on-site resident - inhalation of dust and VOCs in ambient air from surface or total soil; construction worker - inhalation of VOCs in ambient air from subsurface soil; indoor worker and on-site resident - inhalation of VOCs in indoor air from subsurface soil and tap water):

$$I_a = \frac{(C_a)(FI_a)(IR_a)(ET_a)(EF)(ED)}{(BW)(AT)} \qquad \textbf{Eq. 3.9}$$

where:

I_a = inhaled dose of COPC (mg/kg-day, calculated)

C_a = concentration of COPC in air (mg/m^3)

FI_a = fraction of exposure attributed to site media (unitless)

IR_a = inhalation rate (m^3/hour)

ET_a = exposure time (hours/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days).

3.3.2 Incidental Ingestion of COPCs in Soil and Sediment

The ingested dose of COPCs in soil (groundskeeper, construction worker, on-site resident, indoor worker, hunter) were estimated from the equation:

$$\mathrm{I_{so}} = \frac{(\mathrm{C_{so}})(\mathrm{FI_{so}})(\mathrm{IR_{so}})(\mathrm{EF})(\mathrm{ED})(\mathrm{CF_2})}{(\mathrm{BW})(\mathrm{AT})} \qquad \textbf{Eq. 3.10}$$

where:

I_{so} = ingested dose of COPC in soil (mg/kg-day, calculated)

C_{so} = concentration of COPC in soil (mg/kg)

FI_{so} = fraction of exposure attributed to site soil or sediment (unitless)

IR_{so} = ingestion rate of soil or sediment (mg/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

CF_2 =conversion factor (1E-6 kg/mg)

BW = body weight (kg)

AT = averaging time (days).

3.3.3 Dermal Contact with COPCs in Soil, Sediment, or Water

Unlike the methodologies for estimating inhaled or ingested doses of COPCs, which quantify the dose presented to the barrier membrane (the pulmonary or gastrointestinal mucosa, respectively), dermal dose is estimated as the dose that crosses the skin and is systemically absorbed. For this reason, dermal toxicity values are also based on absorbed dose. The absorbed dose of a COPC is estimated from the equation (EPA, 2004a):

$$DAD = \frac{(DA)(SA)(EF)(ED)}{(BW)(AT)} \qquad \textbf{Eq. 3.11}$$

where:

DAD = average dermal absorbed dose of COPC (mg/kg-day, calculated)

DA = dose absorbed per unit body surface area per day (mg/cm^2-day)

SA = SA_{so} for soil, SA_{sd} for sediment, SA_w for water = surface area of the skin exposed (cm^2)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days).

DA is calculated differently for dermal uptake from soil or sediment and from water. Dermal uptake of constituents from soil (groundskeeper, construction worker, on-site resident, hunter) or sediment (construction worker, on-site resident) assumes that absorption is a function of the fraction of a dermally applied dose that is absorbed. It is calculated from the equation (EPA, 2004a):

$$DA = (C)(FI)(CF_2)(AF)(ABS) \quad \textbf{Eq. 3.12}$$

where:

DA = dose absorbed per unit body surface area per day (mg/cm^2-day, calculated)

C = C_{so} for soil, C_{sd} for sediment = concentration of COPC in medium (mg/kg)

FI = FI_{so} for soil, FI_{sd} for sediment = fraction of exposure attributed to site medium (unitless)

CF_2 = conversion factor (1E-6 kg/mg)

AF = AF_{so} for soil, AF_{sd} for sediment = soil- or sediment-to-skin adherence factor (mg/cm^2-day)

ABS = absorption fraction (unitless, chemical-specific).

ABS values are provided in the toxicity profiles for each COC.

Quantification of dermal absorbed dose was modeled using the spreadsheet model developed by EPA in conjunction with RAGS Part E (EPA, 2004a) (Appendix C).

3.3.4 Consumption of Venison

Consumption of venison by the hunter or his child is evaluated by the following equation:

$$I_v = \frac{(C_v)(IR_v)(EF)(ED)}{(BW)(AT)} \quad \textbf{Eq. 3.13}$$

where:

I_v = ingested dose of COPC in venison (mg/kg-day, calculated)

C_v = concentration of COPC in venison (mg/kg)

IR_v =venison ingestion rate (kg/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days).

3.3.5 Ingestion of COPCs in Groundwater and Surface Water

The ingested dose of COPCs in groundwater and surface water is estimated from the equation:

$$I_w = \frac{(C_w)(IR_w)(EF)(ED)}{(BW)(AT)} \qquad \textbf{Eq. 3.14}$$

where:

I_w = ingested dose of COPC in groundwater (mg/kg-day, calculated)

C_w = concentration of COPC in groundwater (mg/L)

IR_w = drinking water ingestion rate (L/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days)

4.0 TOXICITY ASSESSMENT

Toxicity is defined as the ability of a chemical to induce adverse effects in biological systems. The purpose of the toxicity assessment is two-fold:

- Identify the cancer and noncancer effects that may arise from exposure of humans to the COPC (hazard assessment).

- Provide an estimate of the quantitative relationship between the magnitude and duration of exposure and the probability or severity of adverse effects (dose response assessment).

The latter is accomplished by the derivation of cancer and noncancer toxicity values, as described in the following section.

4.1 Evaluation of Carcinogenicity

A few chemicals are known, and many more are suspected, to be human carcinogens. The carcinogenic slope factors (SFs), inhalation unit risks, and the accompanying weight-of-evidence classification are used to evaluate potential human carcinogenic risks associated with exposures.

In defining the potential carcinogenicity of a chemical to humans, EPA first evaluates the sufficiency of evidence of carcinogenicity from available animal and human data. If there are sufficient quantitative data and adequate understanding of the carcinogenic process, a biologically based model may be developed to relate dose and response data on an agent-specific basis. Otherwise, as a default procedure, a standard model can be used to curve-fit the data. Once the data are evaluated, the chemical is assigned a weight-of-evidence classification. The EPA recognizes 6 weight-of-evidence group classifications for carcinogenicity, which are as follows:

- Group A – Human Carcinogenic: human data are sufficient to identify the chemical as a human carcinogen.

- Group B1 – Probable Human Carcinogen: human data indicate that a causal association is credible, but alternative explanations cannot be dismissed.

- Group B2 – Probable Human Carcinogen: human data are insufficient to support a causal association, but testing data in animals support a causal association.

- Group C – Possible Human Carcinogen: human data are inadequate or lacking, but animal data suggest a causal association, although the studies have deficiencies that limit interpretation.

- Group D – Not Classifiable as to Human Carcinogenicity: human and animal data are lacking or inadequate.

- Group E – Evidence of Non-Carcinogenicity to Humans: human data are negative or lacking, and adequate animal data indicate no association with cancer.

The weight-of-evidence narrative developed to characterize potential carcinogenic hazard summarizes the results of the hazard assessment and provides a conclusion with regard to human carcinogenic potential. The weight-of-evidence narrative includes both a conclusion about the weight of evidence of carcinogenic potential and a summary of the data on which the conclusion rests. The narrative explains the kinds of evidence available and how they fit together in drawing conclusions, and points out significant issues/strengths/limitations of the data and conclusions.

EPA derives SF and unit risk values for carcinogens. SFs generally represent an upper bound on the average risk in a population or the risk for a randomly selected individual, but not the risk for a highly susceptible individual or group. Some individuals face a higher risk and some face a lower risk. The use of upper bounds generally is considered to be a health-protective approach for covering the risk to susceptible individuals, although the calculation of upper bounds is not based on susceptibility data. The SF defines quantitatively the relationship between dose and response as the plausible upper-bound estimate of the probability of a response (i.e., development of cancer) per unit intake of a potential carcinogen over a lifetime. In general, an inhalation unit risk is developed directly from a dose response analysis using equivalent human concentrations already expressed in units of $\mu g/m^3$.

The SF is derived by EPA by selecting the most appropriate data set, extrapolating to lower doses, and determining equivalent human doses for the appropriate route of exposure. A nonlinear extrapolation method can be used for cases with sufficient data to ascertain the mode of action and to conclude that it is not linear at low doses but with insufficient data to support a toxicodynamic model that may be either nonlinear or linear at low doses. Nonlinear extrapolation having a significant biological support may be presented in addition to a linear approach when the available data and a weight of evidence evaluation support a nonlinear approach, but the data are not strong enough to ascertain the mode of action. The SF is expressed in terms of risk per unit concentration of the chemical (mg) per unit body weight (kg) per unit time (day) or $(mg/kg/day)^{-1}$. Inhalation unit risk estimates express the SF in terms of $\mu g/m^3$ or ppm air.

Cancer toxicity values and sources are provided in Table 4-1.

4.2 Evaluation of Noncarcinogenic Effects

Many chemicals, whether or not associated with carcinogenicity, are associated with noncarcinogenic effects. The evaluation of noncancer effects (EPA, 1989b) involves:

- Qualitative identification of the adverse effect(s) associated with the chemical, which may differ depending on the duration (acute or chronic) or route (oral or inhalation) of exposure.
- Identification of the critical effect for each duration of exposure (i.e., the first adverse effect that occurs as dose is increased).
- Estimation of the threshold dose for the critical effect for each duration of exposure.
- Development of an uncertainty factor (UF); i.e., quantification of the uncertainty associated with interspecies extrapolation, intraspecies variation in sensitivity, severity of

the critical effect, slope of the dose-response curve, and deficiencies in the database, in regard to developing a reference dose (RfD) for human exposure.

- Identification of the target organ(s) for the critical effect for each route of exposure.

These information points are used to derive an exposure route- and duration-specific toxicity value called an RfD, expressed as mg/kg-day, which is considered to be the dose for humans at which adverse effects are not expected to occur, and includes uncertainty of an order of magnitude or greater. Mathematically, it is estimated as the ratio of the threshold dose to the UF. For purposes of risk assessment, chronic exposure is defined as equal to or greater than 7 years, or at least 10 percent of expected lifespan; subchronic exposure is defined as 2 weeks to 7 years.

The EPA Integrated Risk information System (IRIS) expresses the inhalation noncancer reference value as a reference concentration (RfC) in units of mg/m^3. Because noncancer risk characterization requires a reference value expressed as mg/kg-day, the RfC must be converted to an inhalation RfD. Since the inhalation RfC is based on continuous exposure of an adult human (assumed to inhale 20 m^3 of air per day and to weigh 70 kg), the mathematical conversion consists of multiplying the RfC (mg/m^3) by 20 m^3/day and dividing the result by 70 kg.

RfD and RfC values are derived for both chronic and subchronic exposure. Under the assumption of monotonicity (incidence, intensity, or severity of effects can increase, but cannot decrease, with increasing magnitude or duration of exposure), a chronic RfD may be considered sufficiently protective for subchronic exposure, but a subchronic RfD may not be protective for chronic exposure. Currently, subchronic RfD values exist for few chemicals. Subchronic RfD values can be derived from chronic RfD values as follows:

- If the UF applied in the derivation of the chronic RfD does not provide for expansion from subchronic to chronic exposure (e.g., if the chronic RfD was derived from a chronic study), the chronic RfD is adopted as being sufficiently protective for subchronic exposure.

- If the UF applied in the derivation of the chronic RfD contains a component to expand from subchronic to chronic exposure, the subchronic RfD is derived by multiplying the chronic RfD by the factor used to expand from subchronic to chronic exposure (e.g., if a factor of 10 was used to expand from subchronic to chronic exposure, the subchronic RfD will be 10 times larger than the chronic RfD).

Oral and dermal RfDs (discussed in Section 4.3) as well as RfCs and inhalation RfDs are provided in the Table 4-1.

4.3 Dermal Toxicity Values

Dermal RfDs and SFs are derived from the corresponding oral values, provided there is no evidence to suggest that dermal exposure induces exposure route-specific effects that are not appropriately modeled by oral exposure data. In the derivation of a dermal RfD, the oral RfD is multiplied by the gastrointestinal absorption factor (GAF), expressed as a decimal fraction. The resulting dermal RfD, therefore, is based on absorbed dose. The RfD based on absorbed dose

is the appropriate value with which to compare a dermal dose, because dermal doses are expressed as absorbed rather than exposure doses. The dermal SF is derived by dividing the oral SF by the GAF. The oral SF is divided, rather than multiplied, by the GAF because the SF is expressed as a reciprocal dose.

4.4 Target Organ Toxicity

As a matter of science policy, EPA assumes dose and effect to be additive for noncarcinogenic effects (EPA, 1989a). This assumption provides the justification for adding the HQs or hazard indices (HIs) in the risk characterization for noncancer effects (Section 5.2) resulting from exposure to multiple chemicals, pathways, or media. However, EPA (1989a) acknowledges that adding all HQ or HI values may overestimate hazard because the assumption of additivity is probably appropriate only for those chemicals that exert their toxicity by the same mechanism.

Mechanisms of toxicity data sufficient for predicting additivity with a high level of confidence are available for very few chemicals. In the absence of such data, EPA (1989a) assumes that chemicals that act on the same target organ may do so by the same mechanism of toxicity; that is, the target organ serves as a surrogate for mechanism of toxicity. When total HI for all media for a receptor exceeds 1 due to the contributions of several chemicals, it is appropriate to segregate the chemicals by route of exposure and mechanism of toxicity (i.e., target organ) and estimate separate HI values for each target organ.

As a practical matter, since human environmental exposures are likely to involve near- or sub-threshold doses, the target organ chosen for a given chemical is the one associated with the critical effect. If more than one organ is affected by a given chemical at the threshold, then the affected target organs are selected for this chemical. The target organ is also selected on the basis of duration of exposure (i.e., the target organ for chronic or subchronic exposure to low or moderate doses is selected rather than the target organ for acute exposure to high doses) and route of exposure. Because dermal RfD values are derived from oral RfD values, the oral target organ is adopted as the dermal target organ. For some chemicals, no target organ is identified. This occurs when no adverse effects are observed or when adverse effects such as reduced longevity or growth rate are not accompanied by recognized organ- or system-specific functional or morphologic alteration. Target organs for the oral and inhalation pathway are provided in the toxicity profiles.

4.5 Sources of Toxicity Information Used in the Risk Assessment

Toxicity values were selected for use in this BHHRA based on the EPA Office of Solid Waste and Emergency Response Directive 9285.7-53 (EPA, 2003b) which prescribes the following hierarchy:

- **Tier 1 values**: IRIS (EPA, 2005) database.
- **Tier 2 values**: EPA's provisional peer-reviewed toxicity values. The provisional peer-reviewed toxicity values are developed by the Office of Research and Development, the National Center for Environmental Assessment, and the Superfund Health Risk Technical Support Center on a chemical-specific basis when requested by the Superfund program.

- **Tier 3 values**: Other toxicity values from additional EPA and non-EPA sources of toxicity information. As stated in the EPA Office of Solid Waste and Emergency Response directive, "priority should be given to those sources of information that are the most current, the basis for which is transparent and publicly available, and which have been peer reviewed." Two common examples of Tier 3 values are the EPA's Health Effects Assessment Summary Tables (EPA, 1997b) and the California Environmental Protection Agency (2005) Office of Environmental Health Hazard Assessment Toxicity Criteria Database.

GAFs, used to derive dermal RfD values and SFs from the corresponding oral toxicity values, are obtained from the following sources:

- Oral absorption efficiency data compiled by the National Center for Environmental Assessment for the Superfund Health Risk Technical Support Center of EPA.

- Federal agency reviews of the empirical data, such as Agency for Toxic Substances and Disease Registry Toxicological Profiles and various EPA criteria documents.

- Other published reviews of the empirical data.

- The primary literature.

GAFs obtained from reviews are compared to empirical (especially more recent) data, when possible, and are evaluated for suitability for use for deriving dermal toxicity values from oral toxicity values. The suitability of the GAF increases when the following similarities are present in the oral pharmacokinetic study from which the GAF is derived and in the key toxicity study from which the oral toxicity value is derived:

- The same strain, sex, age, and species of test animal were used.

- The same chemical form (e.g., the same salt or complex of an inorganic element or organic compound) was used.

- The same mode of administration (e.g., diet, drinking water, or gavage vehicle) was used.

- Similar dose rates were used.

The most defensible GAF for each chemical was used in the BHHRA.

5.0 RISK CHARACTERIZATION

Risk characterization is the combination of the results of the exposure assessment and toxicity assessment to yield a quantitative expression of risk. Quantitative estimates are developed for individual chemicals, exposure pathways and exposure media for each receptor. The risk characterization is used to guide risk management decisions.

Generally, the risk characterization follows the methodology prescribed by the EPA (1989a), as modified by more recent information and guidance. The EPA methods are, appropriately, designed to be health-protective and tend to overestimate rather than underestimate risk. The risk results are generally conservative, because risk characterization involves multiplication of the conservatisms built into the estimation of source-term and exposure-point concentrations, the exposure (intake) estimates, and the toxicity dose-response assessments.

Risk characterization is limited to those site-related chemicals selected as COPCs, i.e., present at concentrations that exceed RBSCs (Section 2.1.3).

Up to this point, the term “risk” has been used generically to mean the potential for the occurrence of adverse effects, either cancer or noncancer, to arise from exposure to chemicals. However, at this point in the discussion, it is helpful to define terms more precisely. Therefore, in this section of the document, “risk” is used to describe the likelihood or probability of the occurrence of cancer. The potential for the occurrence of noncancer effects is referred to as noncancer hazard.

5.1 Cancer Risk

The risk from exposure to potential chemical carcinogens is estimated as the probability of an individual developing cancer over a lifetime, and is called the ILCR. In the low-dose range, which would be expected for most environmental exposures, cancer risk is estimated from the following linear equation (EPA, 1989a):

$$ILCR = (CDI)(SF) \qquad \textbf{Eq. 5.1}$$

where:

$ILCR$ = incremental lifetime cancer risk, a unitless expression of the probability of developing cancer, adjusted for background incidence, calculated

CDI = chronic daily intake, averaged over 70 years (mg/kg-day)

SF = cancer slope factor (risk per mg/kg-day).

The use of Equation 5.1 assumes that chemical carcinogenesis does not exhibit a threshold and that the dose-response relationship is linear in the low-dose range. Because this equation could generate theoretical cancer risks greater than 1 for high-dose levels, it is considered to be inaccurate at cancer risks greater than 1 E-2. In these cases, cancer risk may be estimated by the one-hit model (EPA, 1989a):

$$ILCR = 1 - e^{[(CDI)(SF)]} \qquad \textbf{Eq. 5.2}$$

where:

$ILCR$ = incremental lifetime cancer risk, a unitless expression of the probability of developing cancer, adjusted for background incidence, calculated

$e^{[(CDI)(SF)]}$ = the exponential of the risk calculated using Equation 5.1

As a matter of policy, the EPA (1986) considers the carcinogenic potency of simultaneous exposure to low doses of carcinogenic chemicals to be additive, regardless of the chemicals' mechanisms of toxicity or sites (organs of the body) of action. Cancer risk arising from exposure to a given chemical in a given medium by multiple pathways is estimated from the following equation:

$$ILCR_p = ILCR_{chem1} + ILCR_{chem2} + ...ILCR_i \qquad \textbf{Eq. 5.3}$$

where:

$ILCR_p$ = total pathway risk of cancer incidence, calculated

$ILCR_{chemi}$ = individual chemical cancer risk for the pathway.

Cancer risk for a given receptor across chemicals and across media is summed in the same manner. For risk management purposes, OEPA considers a total ILCR of 1E-6 to be a point of departure below which cancer risks are considered to be insignificant. ILCR estimates between 1E-6 and 1E-4 are considered to fall within the risk management range. ILCR estimates above 1E-4 are considered to be unacceptable. The OEPA (2004b) policy is consistent with the EPA (1990) policy of risk management.

5.2 Noncancer Hazards

The noncancer hazards associated with chemicals are evaluated by comparing an exposure level or intake with an RfD. The HQ, defined as the ratio of intake to RfD, is estimated as (EPA, 1989a):

$$HQ = I / RfD \qquad \textbf{Eq. 5.4}$$

where:

HQ = hazard quotient (unitless, calculated)

I = intake of chemical averaged over subchronic or chronic exposure period (mg/kg-day)

RfD = reference dose (mg/kg-day).

Chemical noncancer hazards are evaluated using chronic RfD values. This approach is different from the probabilistic approach used to evaluate cancer risks. An HQ of 0.01 does not imply a 1 in 100 chance of an adverse effect, but indicates that the estimated intake is 100 times lower than the RfD. An HQ of unity (1) indicates that the estimated intake equals the RfD. If the HQ is greater than unity, there may be concern for potential adverse health effects.

In the case of simultaneous exposure of a receptor to multiple chemicals, or to a given chemical by multiple pathways, an HI is calculated as the sum of the HQs by:

$$HI = HQ_1 + HQ_2 + HQ_i \qquad \textbf{Eq. 5.5}$$

where:

HI = hazard index (unitless, calculated)

HQ_i = hazard quotient for the Ith chemical, or for the Ith pathway.

An HI may be calculated across all exposure pathways for a given chemical, across all chemicals for a given exposure pathway, across all chemicals and exposure pathways for a given exposure medium, or across all media to yield the total HI for a given receptor.

HQ or HI values below or equal to the threshold value of 1 are interpreted to mean that adverse noncancer effects are unlikely. HQ or HI values greater than 1 are interpreted to mean that there is a likelihood of adverse noncancer effects.

Calculating a total HI as the sum of HQ values is based on the assumption that the potential for noncancer effects is additive. EPA (1989a), however, acknowledges that the assumption of additivity is probably appropriate only for chemicals that induce adverse effects by the same mechanism (Section 4.2). Therefore, if the total HI for a receptor exceeds 1, individual HI values may be calculated for each target organ as follows:

$$Total\ HI_a = HI_{p1-a} + HI_{p2-a} + ...HI_{pi-a} \qquad \textbf{Eq. 5.6}$$

where:

$Total\ HI_a$ = total hazard index for target organ “a” (unitless, calculated)

HI_{pi-a} = hazard index for target organ “a” via pathway “i”.

Toxicity values are not available for the evaluation of lead. Risk assessment of lead generally consists of estimating blood lead levels in children associated with exposure to the environmental media at the site in question, and comparing the estimate with the threshold level of 10 µg/dL. Two common exposure scenarios are routinely evaluated. The first is residential, which involves direct exposure of a young child. The EPA (1994b) integrated exposure-uptake biokinetic (IEUBK) blood lead model for young children is used to predict blood lead levels for children hypothetically exposed at the site. The IEUBK is a self-contained DOS-based computer program. Average lead concentrations in the various media are input in the model; default

values provided by the IEUBK are used when site-specific data are not available. Arithmetic mean values, rather than conservative estimates of average, are used because the IEUBK contains a statistical module that addresses individual variation in exposure and physiological parameters. The output is a probability density histogram of predicted blood lead levels. The risk assessment is considered to "pass" if the IEUBK predicts that not more than 5 percent of young children exposed in this manner would experience a mean blood lead level above the 10.4 µg/dL threshold.

An alternative risk assessment for lead in soil for residential site use may consist of comparing the average concentration with the RBRL of 400 mg/kg. The risk assessment is considered to pass if the average concentration of lead in soil does not exceed 400 mg/kg. Development of the RBRL of 400 mg/kg is described in the next section.

The second common exposure scenario addresses adult exposures to lead in soil in nonresidential exposure scenarios (EPA, 1996b). The method focuses on the estimation of blood lead concentrations in fetuses carried by women exposed to average concentrations of lead in soil (EPA, 1999). The method is based on a probability model for blood lead levels in adult women exposed to lead in soil coupled with an estimated constant of proportionality between fetal and maternal blood lead levels, a geometric mean fetal blood lead concentration and empirically determined geometric standard deviation (EPA, 1999). The statistical terms used in the method permit an equation to be used to establish an average adult blood lead concentration such that a fetus has not more than a 5 percent probability of blood lead concentrations exceeding 10 µg/dL (EPA, 1996b). The risk assessment is considered to pass if the average adult blood lead level does not predict an excess of 5 percent probability that fetal blood lead levels exceed 10 µg/dL, as interpreted by the Technical Review Workgroup (TRW) for the established cleanup goal to limit childhood risk of exceeding 10 µg/dL to 5 percent (EPA, 1994c, 1996b).

An alternative risk assessment for lead in soil for industrial site use may consist of comparing the average concentration with the RBRL of 750 mg/kg. The risk assessment is considered to pass if the average concentration of lead in soil does not exceed 750 mg/kg. Development of the RBRL of 750 mg/kg is described in the following section.

5.3 Risk-Based Remediation Level Development

RBRLs are derived to provide support for risk management decisions. They are developed only for the COCs in media that are associated with unacceptable risk that may potentially warrant corrective action. RBRLs are site-specific risk-based concentrations that reflect the exposure and toxicity assumptions applied in the baseline RA. Consequently, RBRLs are source medium-, receptor-, and chemical-specific. The development of RBRLs involves a balance of cancer risk and noncancer hazard estimates. The development of RBRLs is an iterative process with on-going discussion between OEPA and the USACE.

The first step in RBRL development is selection of COCs. Either of two conditions results in designation of a COPC as a COC:

- The concentration of the COPC exceeds its medium-specific ARAR, provided one is available.

- The COPC contributes significantly to cancer risk or hazard as described below.

As presented in EPA 1991b, COCs based on cancer risks are selected for any medium for which the total ILCR for a given receptor (summed across chemicals and exposure pathways) exceeds 1E-4. For an individual COPC in a given medium to be selected as a cancer-based COC, it must have an ILCR (summed across exposure pathways) exceeding 1E-6. COCs based on noncancer hazards are selected for any receptor for which the total HI (summed across chemicals and exposure pathways) exceeds 1. For an individual COPC in any medium to be selected as a noncancer-based COC, it must have an HI (summed across exposure pathways) exceeding 0.1.

RBRLs are risk- or hazard-specific concentrations of chemicals developed only for the COCs in media selected by the criteria described above. RBRLs for cancer COCs are estimated for a given medium from the following equation (EPA, 2000):

$$RBRL_{coc} = \frac{ST_{coc} TR}{ILCR_{coc}} \qquad \textbf{Eq. 5.7}$$

where:

$RBRL_{coc}$ = risk-based remediation level for a given COC, receptor and source medium (calculated)

ST_{coc} = source-term concentration of the COC in the given medium

TR = target risk level (1E-6, 1E-5)

$ILCR_{coc}$ = total incremental lifetime cancer risk for a given COC, receptor and source medium.

RBRLs for noncancer COCs are estimated as follows (EPA, 2000):

$$RBRL_{coc} = \frac{ST_{coc} THI}{HI_{coc}} \qquad \textbf{Eq. 5.8}$$

where:

$RBRL_{coc}$ = risk-based remediation level for a given COC, receptor and source medium (calculated)

ST_{coc} = source-term concentration of the COC in the given medium

THI = target hazard index (0.1, 1)

HI_{coc} = total hazard index for a given COC, receptor and source medium.

Concentration units are not provided in Equations 5.7 or 5.8; the RBRL units are the same as the concentration units of the EPC. RBRLs are not final remedial concentrations. RBRLs are to be used by risk managers as approximate values to give an idea of the magnitude of remediation that may be needed. Final remedial goals based on toxicity, carcinogenicity, number and variety of COCs, and other factors as appropriate would be developed before a feasibility study were initiated.

The procedure described above is not suitable for developing an RBRL for lead. EPA (1994c,d, 1998, 2001) has considerable experience using the IEUBK to develop screening levels for lead in soil. The concentration of 400 mg/kg in soil has stood the test of time as a screening level. EPA (1998) recommends applying site-specific data to the IEUBK to develop site-specific cleanup levels or RBRLs. In general, cleanup levels developed with the IEUBK do not exceed the screening level of 400 mg/kg unless site-specific exposure parameters are available that differ substantially from the defaults provided by the model. The residential scenario developed in this BHHRA was based on standard exposure assumptions. Site-specific information is not available that would permit refinement of these assumptions. Therefore, the IEUBK was not used to develop a site-specific RBRL for lead in soil for residential use. Instead, the 400 mg/kg screening level confirmed by EPA (1998) is adopted as the RBRL.

EPA (2004b) provides a PRG of 750 mg/kg for lead in soil for industrial sites, based on the recommendations of the TRW for lead. The PRG is appropriately considered a screening value for lead for industrial site use.

Plausible receptor scenarios for industrial site use include the groundskeeper, the indoor worker and the construction worker. Theoretically, the EPA (1996b) adult blood lead model could be used to develop RBRLs for lead in soil for these exposure scenarios. However, central tendency (CT) or mid-range exposure variable values, including estimates for incidental soil ingestion rate, are not available for these receptors. Therefore, any attempt to refine the screening level or develop a site-specific RBRL would introduce an inordinate amount of uncertainty. Largely for this reason, the EPA (2004b) PRG of 750 mg/kg for lead in industrial soil is adopted as the RBRL for the groundskeeper, indoor worker, and construction worker for this BHHRA.

5.4 Risk Characterization Results and Discussion

ILCR and HQ estimates for each receptor, medium and COPC, including sums across exposure routes for each COPC, are compiled in tables in Appendix B.

Considerable uncertainty is associated with ILCR, HQ and HI estimates; therefore, EPA (1989a) recommends that they be rounded to one significant figure for presentation in an RA. For example, an HI of 1.49E+0 is rounded to 1 and interpreted to mean that the HI does not exceed the threshold level of 1 and that occurrence of adverse noncancer effects is unlikely. An HI of 1.49E+1, for example, is rounded to 15.

COCs are defined as the chemicals that contribute significantly to an ILCR exceeding 1E-4 or an HI exceeding 1. For this discussion, an individual chemical is considered to contribute significantly to the cancer risk estimate if its ILCR summed across all exposure routes exceeds 1E-6. Similarly, an individual chemical is considered to contribute significantly to the noncancer hazard if its HI summed across all exposure routes exceeding 0.1.

When total HI summed across chemicals and/or media exceeds the threshold limit of 1, consideration is given to possible benefit of segregating HI values by target organ, as suggested by EPA (1989a). Target organ specific HIs were not developed in this BHHRA.

Total HI and ILCR estimates for each receptor and each source medium for Acid Area 3 are summarized in Table 5-1 and discussed below; detailed results are provided in Appendix B. The uncertainties associated with the HI and ILCR estimates are discussed in Section 6.0.

The groundskeeper, hunter, and child venison consumer were evaluated for exposure only to surface soil. Total HI estimate for the groundskeeper receptor was less than 1. The HI was below the threshold for noncancer effects. The total ILCR estimate for the groundskeeper receptor was 2E-5. The COCs for the ILCR were arsenic, PCB-1254, benzo(a)anthracene, and benzo(a)pyrene. Total HI estimates for the adult hunter, and adult and child venison consumer receptors were below the threshold limit of 1. The total ICLR for the adult hunter was 2E-6. The COC for the ILCR was benzo(a)pyrene. Total ILCR estimates for the adult and child venison consumer receptors were 1E-6, defined as the point of departure for significant contribution to cancer risk.

The construction worker was evaluated for exposure to surface and subsurface soil, surface water and sediment. Total HI estimates summed across all media for the construction worker receptor was 4 (Table 5-1). The total HI summed across surface water and sediment was less than 1. The total HI summed across surface and subsurface soil was 4. The COCs for the HI were arsenic, iron, thallium and PCB-1254 in surface soil and antimony, arsenic, iron, and thallium in subsurface soil. The total ILCR estimate summed across all media for the construction worker receptor was 3E-6. ILCR sums for surface water and sediment are less than 1E-6. ILCR summed for surface and subsurface soil was 3E-6. The COC for the ILCR was benzo(a)pyrene in surface soil. There were no COCs in subsurface soil.

The indoor worker was evaluated for exposure to surface soil and groundwater. The total HI estimate summed across all media for the indoor worker receptor was 2 (Table 5-1). The HI for groundwater and surface soil were 1 and 0.2, respectively. The COCs for the groundwater HI were arsenic, benzene, and thallium. The total ILCR estimate summed across all media for the indoor worker receptor was 3E-4. The ILCR for groundwater and surface soil were 3E-4 and 9E-6, respectively. The COCs for the ILCR were 2-nitrotoluene, arsenic, benzene, methylene chloride, and tetrachloroethene in groundwater. The COCs for the ILCR were arsenic, PCB-1254, and benzo(a)pyrene in surface soil. There were no COCs in subsurface soil. Vapor intrusion into buildings from subsurface soil was not evaluated, as there were no VOCs detected in the subsurface soil.

The adult and child residential receptors were evaluated for exposure to surface and subsurface soil, groundwater, surface water and sediment. Total HI estimates summed across all media for the adult and child residential receptors were 5 and 15, respectively (Table 5-1). HI sums for surface water and sediment were below 1. HI sums for groundwater and surface and subsurface soil were 5 and 15 for the adult and child, respectively. The groundwater COCs for the HI were arsenic, barium, benzene, and thallium for the adult, and arsenic, barium, 2-methylnaphthalene, benzene, methylene choride, naphthalene, thallium, and total xylenes for the child. The surface soil COCs were PCB-1254 for the adult, and arsenic, iron, manganese, thallium, and PCB-1254 for the child. The subsurface COCs were aluminum, antimony, arsenic,

iron, manganese, and thallium for the child. There were no HI COCs for adult exposures to subsurface soil.

The total ILCR estimates summed across all media for the adult and child residential receptors were 9E-4 and 5E-4, respectively. ILCR sums for surface water and sediment were 1E-6 and 2E-6 for the adult and child, respectively. ILCR sums for groundwater and surface and subsurface soil were 9E-4 and 5E-4, respectively. The groundwater COCs for the ILCR were 2-nitrotoluene, arsenic, benzene, bis(2-ethylhexyl)phthalate, methylene chloride, and tetrachloroethene for the adult and 2-nitrotoluene, arsenic, benzene, bis(2-ethylhexyl)phthalate, methylene chloride, and tetrachloroethene for the child. The surface soil COCs were arsenic, PCB-1254, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, and dibenz(a,h)anthracene for the adult, and arsenic, PCB-1254, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, and dibenz(a,h)anthracene for the child. The subsurface soil COC was arsenic for the adult and child residential receptors. Vapor intrusion into dwellings from subsurface soil was not evaluated, as there were no VOCs detected in the subsurface soil.

RBRLs for total soil for cancer risk and noncancer effects for all receptors are compiled in Appendix C. The RBRLs should be considered as average concentrations, rather than not-to-exceed concentrations, for the COCs.

Figures 5-1 and 5-2 show the distribution of COCs (based on the adult and child residential exposure scenarios) exceeding the EPC and background concentration for surface soil and groundwater.

6.0 UNCERTAINTY ANALYSIS

This section evaluates the uncertainties inherent in the RA process. Uncertainty is a factor in each step of the data evaluation and exposure and toxicity assessments presented in the preceding sections. Uncertainties associated with early stages of the RA become magnified when they are concatenated with other uncertainties in the latter stages. It is not possible to eliminate all uncertainty, and sometimes not even to reduce it; however, a recognition of the uncertainties is fundamental to the understanding and reasonable use of the RA results.

Generally, risk assessments carry two types of uncertainty. Measurement uncertainty refers to the usual variance that accompanies scientific measurements such as instrument uncertainty (accuracy and precision) associated with contaminant concentrations. The results of the RA incorporate the accumulated variances of the individual measured values. A different kind of uncertainty stems from data gaps, i.e., additional information needed to complete the database for the assessment. Often the data gap is significant, such as imprecision regarding the number of days that a hunter might visit the site or the absence of information on the effects of human exposure to a chemical (EPA, 1992c).

EPA (1992c) guidance urges risk assessors to address or provide descriptions of individual risk to include the "high end" portions and "central tendency" of the risk distribution. One way of fulfilling this preference, if either cancer or noncancer risk exceeds generally acceptable limits (cancer risk greater than 1 E-4 or target organ-specific HI greater than 1) is to re-calculate the ILCRs or HIs using CT values for as many intake model variables as possible. In contrast to the RME evaluation, which prevails in RAs and uses upper-end values for intake or contact rates, exposure frequency and exposure duration, the CT evaluation uses average or midrange values for these variables (EPA, 1991a). The intent is to present a quantified risk/hazard estimate more typical for the receptor of interest.

Another method of quantifying uncertainty, called Monte Carlo simulation, provides a more graphic illustration of the uncertainty associated with a risk/hazard estimate, because it presents the risk as a range with probability densities. To be meaningful, however, Monte Carlo simulation requires that the nature of the distributions of the variables that drive the risk assessment be well characterized. However, well characterized distributions are available for few exposure or toxicological variables, in which case the Monte Carlo simulation provides an incomplete or potentially misleading illustration of the magnitude or the distribution of the uncertainty.

Because of the limitations of the CT and Monte Carlo procedures, the uncertainty analysis consists of a qualitative discussion of the sources of uncertainty and their impact on the estimated risk results and their interpretation, as described below.

Sampling and Analytical Limitations. It is not possible to completely characterize the nature and extent of contamination on any site. Uncertainties arise from limits on the number of locations that can be sampled. The sampling protocol used at Acid Area 3, however, was designed to optimize efficiency of the sampling effort and reduce uncertainty by focusing on areas around former process buildings, storage structures, and potential transfer piping. Furthermore, the sampling appears to be sufficient to show that the contamination is largely limited to the soil. Specifically, the data show that surface water is not a medium of concern.

There appears to be little uncertainty regarding the media affected by chemical releases at Acid Area 3.

The sampling and analytical data are sufficient to identify PCB-1254 as the major contaminant in soil. Metals and PAHs were also identified. Analyses were not performed for pesticides and herbicides, or dioxins/dibenzofurans. Pesticides and herbicides may have been used to control insects and discourage overgrowth of weeds. These classes of compounds, however, are commonly identified in agricultural and formerly agricultural areas, and lack of analysis for these chemicals is not considered to impart significant uncertainty to the assessment. Dioxins/dibenzofurans are commonly associated with incineration, but their formation generally requires a source of chlorine, such as chlorinated solvents. There is no record or other reason to believe that chlorinated organics were present when the former buildings were demolished therefore, lack of analysis for the dioxins/dibenzofurans is not viewed as a significant source of uncertainty.

The major contaminants in deep groundwater are metals, benzene, and tetrachloroethene. Detection of metals in groundwater appears to be associated with sediment entrained in the samples. Specifically, samples with elevated turbidity had higher metals concentrations, while concentrations of metals in samples with low turbidity levels and filtered samples had low concentrations or were nondetect. Benzene may also be associated with background due to the presence of natural petroleum-derived compounds present in the vicinity of PBOW. Tetrachloroethene is not naturally occurring in the environment. It is used as a solvent or degreaser. Tetrachloroethene was detected in two samples from different monitoring wells. Both results were "J" flagged, indicating the detected results were between the detection limit and the reporting limit. Tetrachloroethene was not detected in any samples from other media at Acid Area 3. The presence of tetrachloroethene in deep groundwater is most likely attributable to laboratory contamination, given the low frequency of detection.

Selection and Quantification of Chemicals of Potential Concern. Uncertainty associated with the processes used to identify COPCs and estimate EPCs arises from the following:

1. Identifying background chemicals. Metals are judged to be present at concentrations comparable to background if the MDC does not exceed the BSC, or if statistical testing demonstrates that the site data and background data are drawn from the same population. Statistical testing of site data versus background was not performed for this RA. All inorganic constituents detected in environmental media were carried through the risk assessment to provide a conservative estimate of potential risks associated with exposure to site media. The MDCs for arsenic, iron, and manganese in surface soil and aluminum, antimony, arsenic, and iron in subsurface soil were lower than their respective background criteria. Detected concentrations of thallium in surface and subsurface soil exceeded its background criterion. The maximum concentration of lead detected in surface was 13 times greater than background. There was no background criterion for thallium in deep groundwater. Some organic chemicals, such as PAHs, may be considered to be anthropogenic background. PAHs were identified in soil and sediment at Acid Area 3, possibly from of asphalt contained in roofing material and in roads and parking areas, or associated with the rail line traversing the site. There are no site-specific background data for the PAHs, and several were selected as COCs. PAH concentrations at Acid Area 3 all fall within global background levels for urban areas compiled by the Agency for Toxic Substances and Disease Registry (ATSDR) (1997). Given the rationale for their presence,

PAHs may be considered site-related compounds in soil at Acid Area 3. The PAH benzo(a)pyrene contributes approximately 50 percent of the adult residential risk at Acid Area 3. However, the total risk is within the cancer risk range of 1E-6 to 1E-4.

2. Estimated EPCs are uncertain. For statistical purposes, if a constituent was positively identified at a site and had at least a single positive hit, all the samples with nondetects were assumed to have a value equal to half the reporting limit and were included in the data set. These procedures may introduce a conservative bias into the risk assessment. Computed UCL values are only estimates of the actual upper confidence limits associated with each data set. Examples of factors affecting the uncertainty of these estimates include number of samples, proportion of nondetects, conformance with an assumed mathematical distribution, imprecision of laboratory data, elevated detection limits (from dilutions, matrix interference, etc.), statistical methodology, etc. The confidence of computed UCLs for this project have been qualitatively evaluated and identified as high, moderate, low and indeterminate. For indeterminate data sets, the maximum detected concentration was used for the UCL. Uncertainties associated with the statistical determination of EPCs for the COCs in each medium are:

- Groundwater
    - 2-methylnaphthalene: Indeterminate confidence – elevated detection limits for nondetects, 80% nondetects
    - 2-nitrotoluene: Indeterminate confidence – elevated detection limits for nondetects, 90% nondetects
    - Arsenic (total): Indeterminate confidence – all nondetects
    - Barium (total): Moderate confidence – non-parametric, 10 samples
    - Benzene: Indeterminate confidence – elevated detection limits for nondetects
    - bis(2-ethylhexyl)phthalate: Indeterminate confidence – elevated detection limits for nondetects, 90% nondetects
    - Methylene Chloride: Moderate confidence – non-parametric, 10 samples
    - Naphthalene: Indeterminate confidence – elevated detection limits for nondetects, 70% nondetects
    - Tetrachloroethene (PCE): Indeterminate confidence – elevated detection limits for nondetects, 80% nondetects
    - Thallium (total): Indeterminate confidence – elevated detection limits for nondetects, 80% nondetect
    - Xylenes (total): Moderate confidence – non-parametric, 10 samples

- Surface Soil
    - Arsenic: High confidence – no nondetects, good fit to normal distribution
    - Benzo(a)anthracene: Indeterminate confidence – elevated detection limits for nondetects, 59% nondetects
    - Benzo(a)pyrene: Indeterminate confidence – elevated detection limits for nondetects, 53% nondetects
    - Dibenz(a,h)anthracene: Indeterminate confidence – elevated detection limits for nondetects, 88% nondetects
    - Iron: High confidence – no nondetects, good fit to normal distribution
    - Manganese: High confidence – no nondetects, good fit to gamma distribution
    - PCB-1254: Indeterminate confidence– elevated detection limits for nondetects, 76% nondetects

- PCB-1260: Moderate confidence – non-parametric
- Thallium: Indeterminate confidence – elevated detection limits for nondetects, 71% nondetects

- Subsurface Soil
  - Aluminum: High confidence – no nondetects, good fit to normal distribution
  - Antimony: Indeterminate confidence – elevated detection limits for nondetects, 85% nondetects
  - Arsenic: High confidence – good fit to gamma distribution
  - Benzo(a)pyrene: Indeterminate confidence – elevated detection limits for nondetects, 98% nondetects
  - Iron: High confidence – no nondetects, good fit to normal distribution
  - Manganese: High confidence – no nondetects, good fit to gamma distribution
  - Thallium: Indeterminate confidence – elevated detection limits for nondetects, 83% nondetects

3. A limited number of samples may not completely characterize the site because they provide less information about the population from which they are drawn than do larger sample sets. Accordingly, small sets tend to have a greater variability, which results in the calculation of wide confidence intervals on the mean concentration and high EPCs. In some cases, the UCL_{95} was greater than the maximum value; thus, the maximum value was chosen as the EPC. High confidence limits may introduce a conservative bias into the risk assessment.

4. Laboratory analytical techniques have a degree of uncertainty associated with them. These uncertainties are documented by using data qualifiers to reflect the degree of certainty of measurement. For example, some data were estimated (e.g., J-qualified), while other data were rejected (i.e., R-qualified) . The direction of bias is unclear.

5. Per EPA (1992a) guidance, the UCL_{95} was used for EPCs. Therefore, the exposure assessment is likely to underestimate the EPCs in 5 percent of the cases, and overestimate exposures in 95 percent of cases, imparting an overall conservative bias to the risk assessment.

Selection of Hypothetical Receptors and Potential Exposure Pathways. The exposure scenarios chosen for evaluation address plausible receptors for the current and projected future site uses previously described. Although the specific uses to which the sites may be put are not entirely certain, the general categories (industrial, recreational, residential) are comprehensive and fairly standard. The receptor scenarios selected for evaluation include the most intensely exposed for each general site-use category; therefore, uncertainty regarding the specific uses has no meaningful effect on interpretation of the RA. For example, the groundskeeper represents the upper bound on exposure for any industrial application. The indoor worker represents the upper bound on any indoor worker exposure. The construction worker represents the upper bound on short-term exposure to soil, regardless of the nature of a construction project. The hunter represents a plausible scenario for recreational site use and indirect (food-chain) exposure. Finally, the on-site resident represents the upper bound for residential site use. The resident is generally considered to represent the upper bound for any standard site use.

Another source of uncertainty in the receptor scenarios was the decision not to quantify intake or uptake from certain exposure routes. For example, inhalation of VOCs in outdoor air that volatilized from subsurface soil by the groundskeeper, indoor worker and hunter was not

quantified. It was assumed that overlying soil would attenuate emissions and that the large volume of outdoor air and natural air currents would dilute concentrations in the breathing zone to toxicologically insignificant levels. This assumption was based on considerable experience with volatilization models, and was consistent with the assumption applied by EPA (2004c) in developing PRGs for soil. VOCs were generally not detected in surface or subsurface soil at Acid Area 3. Where VOCs were detected, their concentrations were below the Region 9 PRGs and none were selected as COPCs, further reducing concern that a potentially significant exposure pathway was not evaluated.

As another example, the groundskeeper and hunter were not evaluated for exposure to surface water or sediment, even though these receptors spend most of their time outdoors. Since contact with surface water would not be part of their normal activities, it was assumed that any exposure would be sporadic and would not readily lend itself to quantification. Also, such exposures should be viewed as repeated acute rather than chronic, which does not fit the EPA (1989a) paradigm or the toxicity values developed for an RA. Finally, exposure to surface water was evaluated for the construction worker and on-site resident, who were expected to be more regularly exposed. Therefore, the decision not to evaluate surface water exposure for the groundskeeper and hunter was not seen as a significant source of uncertainty affecting the results or interpretation of the RA.

The indoor worker was not evaluated for inhalation of airborne dust or VOCs from surface soil or for dermal contact with surface soil because these exposure routes were expected to be less significant than incidental ingestion, which was quantified. The decision not to quantify inhalation and dermal exposure imparts a non-conservative bias to the RA. However, inhalation and dermal contact were quantified for the groundskeeper, who would be more intensely exposed by these routes. Risk estimates for the groundskeeper from inhalation exposure were negligible. Similarly, as stated above, VOCs were generally not detected in surface or subsurface soil at Acid Area 3. Where VOCs were detected, their concentrations were below the Region 9 PRGs and none were selected as COPCs, further reducing the possibility that a potentially significant exposure pathway was not evaluated. Therefore, it was assumed that inhalation exposure would be negligible for the indoor worker, as well, and that the decision not to quantify this route had no meaningful effect on the outcome of the RA or its interpretation.

Other plausible receptors include office workers, delivery personnel, and resident farmers. These receptors would be less intensively exposed to soil than the groundskeeper; therefore, their exposures were not evaluated. Much of the land around PBOW is used for agriculture, and it is possible that areas of PBOW could be farmed in the future. However, experience has shown that risk from ingestion of home-grown grains, fruits, meat, poultry, eggs, or milk is generally insignificant compared with direct exposure pathways, except for dioxin/furan compounds; therefore, indirect food-chain exposures are not evaluated. Additionally, the increased exposure to soil and ingestion of beef are adequately represented by the evaluations of groundskeeper and ingestion of venison scenarios, respectively.

The uncertainty associated with dermal exposure is not as clear. Dermal risk estimates for the groundskeeper were at the low end of the cancer risk range of 1E-6 to 1E-4 at Acid Area 3. It is expected that the intensity of dermal exposure to soil would be much less for an indoor worker than an outdoor worker; however, dermal exposure parameters were not developed for the indoor worker to test this assumption. Therefore, the decision not to evaluate dermal exposure represents a source of uncertainty that has not been quantified. The construction worker and

on-site resident were not evaluated for inhalation of VOCs from surface water or incidental ingestion of surface water, because these exposure routes were expected to be less significant than dermal exposure, which was quantified.

The decision not to quantify inhalation of VOCs from surface water imparts a non-conservative bias to the RA; however, VOCs were not detected in surface water samples from Acid Area 3. The uncertainty associated with incidental ingestion is not as clear. It is expected that the potential for incidental ingestion would be very low in a wading scenario, and far less significant than dermal uptake; however, exposure parameters for incidental ingestion were not developed to test this assumption. Therefore, the decision not to evaluate incidental ingestion represents a source of uncertainty that has not been quantified.

The hunter was not evaluated for inhalation of dust from surface soil because this receptor would be expected to spend most of his time on vegetated soil, and because inhalation exposure would be expected to be far less than incidental ingestion of soil, which was quantified. However, inhalation was quantified for the groundskeeper, who would be more intensely exposed. Estimated risk for the groundskeeper from inhalation exposure was negligible. Therefore, it was assumed that inhalation exposure would be negligible for the hunter as well, and that the decision not to quantify this route had no meaningful effect on the outcome of the RA or its interpretation.

Quantification of Intakes. Ingestion rates, inhalation rates, EDs, and EFs were based on upper-bound values (EPA, 1989a, 1991a), even though it is likely that serial multiplication of conservative variable values leads to gross overestimation of COPC intakes (Cogliano, 1997).

Toxicity Assessment. Considerable uncertainty is associated with the qualitative (hazard assessment) and quantitative (dose-response) evaluations of a toxicity assessment. Hazard assessment of carcinogenicity is evaluated as a weight-of-evidence determination (EPA, 1986). Positive animal cancer test data suggest that humans also contain tissue(s) that may manifest a carcinogenic response; however, the animal data cannot necessarily be used to predict the target tissue in humans. In the hazard assessment of noncancer effects, positive animal data suggest the nature of the effects (i.e., the target tissues and type of effects) anticipated in humans (EPA, 1989b).

There are many sources of uncertainty in the dose-response evaluation for cancer (i.e., computation of an SF or unit risk) and noncancer effects (i.e., computation of an RfD). First, there is uncertainty regarding interspecies (animal-to-human) extrapolation which, in the absence of quantitative pharmacokinetic, dosimetric, or mechanistic data, is usually based on consideration of interspecies differences in basal metabolic rate. Second, there is uncertainty regarding intraspecies or individual variation. Most toxicity experiments are performed with animals that are very similar in age and genotype, so that intragroup biological variation is minimal, but the human population of concern may reflect wide heterogeneity including unusual sensitivity to the COPC. Even toxicity data from human occupational exposure reflect a bias because only those individuals sufficiently healthy to attend work regularly and those not unusually sensitive to the COPC are likely to be occupationally exposed. Third, uncertainty arises from expansion from short-term to lifetime exposure such as the construction worker and child on-site resident. Additional uncertainty arises from the potential for children to be more sensitive than adults. Finally, the quality of the key study from which the quantitative estimate is derived and the database contributes to uncertainty. For cancer studies, the uncertainty

associated with some quality factors (e.g., study group size) is expressed within the 95 percent upper-bound of the SF. For noncancer effects, additional uncertainty factors may be applied in the derivation of the RfD to reflect poor quality of the key study or gaps in the database.

Another source of uncertainty regarding quantitative risk estimation for carcinogenicity is the method by which data from high doses in animal studies are extrapolated to the dose range expected for environmentally exposed humans. The linearized multistage model, which is used in most quantitative estimates of human cancer risk from animal data (PAHs, PCBs), is based on a non-threshold assumption of carcinogenesis. An impressive body of evidence, however, suggests that epigenetic carcinogens as well as many genotoxic carcinogens, have a threshold below which they are noncarcinogenic (Gold, et al., 1992); therefore, the use of the linearized multistage model is ultraconservative for chemicals that exhibit a threshold for carcinogenicity.

A further source of uncertainty for noncancer effects arises from use of an effect level in the estimation of an RfD or RfC, because this estimation is predicated on the assumption of a threshold below which adverse effects are not expected. Therefore, an additional uncertainty factor is usually applied to estimate a no-effect level. Additional uncertainty arises from estimating RfD values for chronic exposure from less-than-chronic data. Unless empirical data indicate that effects do not worsen with increasing duration of exposure, an additional uncertainty factor is applied to the no-effect level in the less-than-chronic study. Uncertainty also arises from the presence of chemicals (e.g., lead) for which there are no EPA-approved toxicity values, and for which quantitative risk characterization is not possible. However, the adult blood-lead model and the IEUBK are supported by a considerable body of empirical data, and are considered to be among the best validated of the various models used in risk assessment. In summary, the EPA methodology for both cancer and noncancer toxicity evaluation is intentionally designed to be protective. However, the extent to which toxicity values may overestimate toxic potency is not clear, and it is possible that the toxicity values for some compounds may not be adequately protective.

Risk Characterization. Risk characterization is the process of quantifying the risk of cancer due to exposure to carcinogens, as well as quantitatively evaluating hazards potentially posed by exposure to noncarcinogenic toxicants. Cancer risk is assumed to be additive for all carcinogens. Noncancer risk is assumed to be additive for chemicals with similar sites of toxicological action. In the event that any combination of these chemicals results in synergistic effects, risk might be underestimated. Conversely, the assumption of additivity would overestimate risk if a combination of these chemicals acted antagonistically or had no combined toxic effect at all.

7.0 SUMMARY AND CONCLUSIONS

This section briefly summarizes the RA protocol and results and interprets the results, in light of the uncertainty associated with their estimation, to draw realistic conclusions regarding risk to human health.

PBOW is currently classified for industrial use, but future residential use was considered in the risk assessment to support evaluation of all plausible receptor scenarios. Groundskeeper, construction worker and hunter scenarios were evaluated under the current site-use assumptions. Groundskeeper, construction worker, indoor worker, hunter (including a child venison consumer) and on-site residential scenarios were evaluated as plausible future exposure scenarios. The groundskeeper was evaluated for exposure to surface soil. The construction worker was evaluated for exposure to surface and subsurface soil, surface water and sediment. The adult hunter was evaluated for exposure to surface soil by direct contact and indirectly by ingestion of venison (deer graze vegetation growing on contaminated soil). The indoor worker was evaluated for exposure to surface and subsurface soil, and groundwater. The on-site resident was evaluated as the upper bound on exposure to surface and subsurface soil, groundwater, surface water and sediment.

7.1 Sampling and Analysis

Surface and subsurface soil samples were taken from the areas around each of the former process buildings where contamination was thought to have been possible. Surface water and sediment samples were taken from the drainage ditches that border the site. Groundwater samples were collected from monitoring wells at the site.

The analytical results revealed that the soil contains metals, PCBs, and PAHs at concentrations exceeding the Region 9 PRGs; consequently, they were selected as COPCs. PAHs possibly result from asphalt contained in roofing material and in roads and parking areas, or associated with the rail line traversing the site.

Contaminants detected in deep groundwater were metals, VOCs, and SVOCs. Detection of metals in groundwater appears to be associated with sediment entrained in the samples. Specifically, samples with elevated turbidity had higher metals concentrations while samples with low turbidity levels and filtered samples had low concentrations or were nondetects. Certain VOCs may be associated with background due to the presence of natural petroleum-derived compounds present in the vicinity of PBOW. Other VOCs and SVOCs may be artifacts of the analytical process at the laboratory, but they could not be eliminated during data validation.

Metals, PCBs and benzo(a)pyrene were selected as COPCs in sediment. Metals concentrations were consistently below or less than 5 times their respective background concentrations.

Manganese was the only COPCs in surface water. Only one concentration of manganese exceeded the Region 9 PRG for tap water.

7.2 Risk Assessment Results

The groundskeeper, hunter, and child venison consumer were evaluated for exposure only to surface soil. Total HI estimate for the groundskeeper receptor was less than the threshold value of 1 for noncancer effects. The total ILCR estimate for the groundskeeper receptor was 2E-5. The COCs for the ILCR were arsenic, PCB-1254, benzo(a)anthracene, and benzo(a)pyrene. Total HI estimates for the adult hunter, and adult and child venison consumer receptors were below the threshold limit of 1. The total ICLR for the adult hunter was 2E-6. The COC for the ILCR was benzo(a)pyrene. Total ILCR estimates for the adult and child venison consumer receptors were below 1E-6, defined as the point of departure for significant contribution to cancer risk.

The construction worker was evaluated for exposure to surface and subsurface soil, surface water and sediment. Total HI estimates summed across all media for the construction worker receptor was 4 (Table 5-1). The total HI summed across surface water and sediment was less than 1. The total HI summed across surface and subsurface soil was 4. The COCs for the HI were arsenic, iron, thallium and PCB-1254 in surface soil and antimony, arsenic, iron, and thallium in subsurface soil. The total ILCR estimate summed across all media for the construction worker receptor was 3E-6. ILCR sums for surface water and sediment were less than 1E-6. ILCR summed for surface and subsurface soil was 3E-6. The COC for the ILCR was benzo(a)pyrene in surface soil. There were no COCs in subsurface soil.

The indoor worker was evaluated for exposure to surface soil and groundwater. The total HI estimate summed across all media for the indoor worker receptor was 2 (Table 5-1). The HI for groundwater and surface soil were 1 and 0.2, respectively. The COCs for the groundwater HI were arsenic, benzene, and thallium. The total ILCR estimate summed across all media for the indoor worker receptor was 3E-4. The ILCR for groundwater and surface soil were 3E-4 and 9E-6, respectively. The COCs for the ILCR were 2-nitrotoluene, arsenic, benzene, methylene chloride, and tetrachloroethene in groundwater. The COCs for the ILCR were arsenic, PCB-1254, and benzo(a)pyrene in surface soil. There were no COCs in subsurface soil. Vapor intrusion into buildings from subsurface soil was not evaluated as there were no VOCs detected in the subsurface soil.

The adult and child residential receptors were evaluated for exposure to surface and subsurface soil, groundwater, surface water and sediment. Total HI estimates summed across all media for the adult and child residential receptors were 5 and 15, respectively (Table 5-1). HI sums for surface water and sediment were below 1. HI sums for groundwater and surface and subsurface soil were 5 and 15 for the adult and child, respectively. The groundwater COCs for the HI were arsenic, barium, benzene, and thallium for the adult, and arsenic, barium, 2-methylnaphthalene, benzene, methylene choride, naphthalene, thallium, and total xylenes for the child. The surface soil COCs were PCB-1254 for the adult, and arsenic, iron, manganese, thallium, and PCB-1254 for the child. The subsurface COCs were aluminum, antimony, arsenic, iron, manganese, and thallium for the child. There were no HI drivers for adult exposures to subsurface soil.

The total ILCR estimates summed across all media for the adult and child residential receptors were 9E-4 and 5E-4, respectively. ILCR sums for surface water and sediment were 1E-6 and 2E-6 for the adult and child, respectively. ILCR sums for groundwater and surface and subsurface soil were 9E-4 and 5E-4, respectively. The groundwater COCs for the ILCR were

2-nitrotoluene, arsenic, benzene, bis(2-ethylhexyl)phthalate, methylene chloride, and tetrachloroethene for the adult and 2-nitrotoluene, arsenic, benzene, bis(2-ethylhexyl)phthalate, methylene chloride, and tetrachloroethene for the child. The surface soil COCs were arsenic, PCB-1254, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, and dibenz(a,h)anthracene for the adult, and arsenic, PCB-1254, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, and dibenz(a,h)anthracene for the child. The subsurface COC was arsenic for the adult and child residential receptors. Vapor intrusion into dwellings from subsurface soil was not evaluated, as there were no VOCs detected in the subsurface soil.

7.3 Conclusions

Based on analytical results, metals, PAHs, and PCBs appear to be widespread but generally at low concentrations in environmental media at Acid Area 3. HIs for contamination in soil were less than 1 for a groundskeeper or hunter, including an adult or child who consumes venison from deer harvested on site, suggesting that adverse effects from exposure are unlikely. Cancer risk for a groundskeeper or hunter, including an adult or child who consumes venison from deer harvested on site, were within or below the cancer risk range of 1E-6 to 1E-4.

HIs for the indoor workers and adult resident were below 1. HIs exceeded 1 for the construction worker and child residential receptors for exposure to surface soil. The primary contributor to the HIs was PCB-1254. Cancer risk estimates were within the cancer risk range of 1E-6 to 1E-4 for the construction worker but exceeded 1E-4 for the indoor worker, and adult and child residential receptors. The primary contributor to the ILCRs was benzo(a)pyrene.

HIs for construction workers and adult and child residential receptors equal to or below 1 for exposure to subsurface soil. Cancer risk estimates were below or within the cancer risk range of 1E-6 to 1E-4 for the construction worker and the adult and child residential receptors. The primary contributor to the ILCRs was arsenic.

HIs for the indoor workers and adult and child residential receptors exceed 1 for exposure to groundwater. The primary contributor to the HIs was thallium. Cancer risk estimates were just above 1E-4 for the indoor worker and the adult and child residential receptors. The primary contributor to the ILCRs was arsenic.

HIs for exposure to contamination in surface water were below 1 for all receptors evaluated. Cancer risk estimates were below or at the low end of the cancer risk range of 1E-6 to 1E-4 for the construction worker, and adult and child residential receptors for exposures to sediment.

Accounting for natural background concentrations of metals in all media, the sporadic detections of organics in groundwater, surface water, and sediment, potential risks from exposure to contaminants detected in site environmental media appear to be limited.

8.0 REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR), 1997, Update Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs), U.S. Department of Health and Human Services, Atlanta, GA.

California Environmental Protection Agency, 2005, *Toxicity Criteria Database*, Office of Environmental Health Hazard Assessment, Sacramento, California, http://www.oehha.co.gov/risk/ChemicalDB/index.asp.

Cogliano, V. J., 1997, "Plausible Upper Bounds: Are Their Sums Plausible?" Risk Analysis 17(1): 77-84.

Gilbert, R. O., 1987, *Statistical Methods for Environmental Pollution Monitoring*, New York, New York: Van Nostrand Reinhold.

Gold, L. S., N. B. Manley and B. N. Ames, 1992, "Quantitative and Qualitative Extrapolation of Carcinogenesis Between Species," Proceedings of Conference on Chemical Risk Assessment in the Department of Defense (DoD): Science, Policy and Practice, 9 to 1 I April 1991, Dayton, OH, published by American Conference of Governmental Industrial Hygienists, Inc.

Helsel, Dennis R. 2005, *Nondetects and Data Analysis: Statistics for Censored Environmental Data*, John Wiley & Sons, Inc.

IT Corporation (IT), 2001a, TNT Areas A and C Remedial Investigation, Volume II – Human Health Risk Assessment, Final, Former Plum Book Ordnance Works, Sandusky, Ohio, November

IT, 2001b, *TNT Areas A and C Remedial Investigation, Volume I – Report of Findings, Final, Former Plum Book Ordnance Works, Sandusky, Ohio,* November.

IT, 2000c, *Draft Baseline Human Health Risk Assessment Work Plan for the Former TNT Manufacturing Area, West Virginia Ordnance Works, Mason Count, West Virginia, January.*

IT, 1998, *Site Investigation of Acid Areas, Former Plum Brook Ordnance Works, Sandusky, Ohio*.

IT, 1997, *Site-Wide Groundwater Investigation Report, Plum Brook Ordnance Works, Sandusky, Ohio,* September.

Jacobs, 2007, *Final Baseline Human Health Risk Assessment and Ecological Risk Assessment Work Plan, Acid Areas 2 and 3, April*

Jacobs, 2006, *Interim Final Site Characterization Report, Remedial Investigation Part 1, at Acid Areas 2 & 3 Former Plum Brook Ordnance Works, Sandusky, Ohio*, September.

Kaplan, E. L., and Paul Meier, June 1958, *Nonparametric Estimation from Incomplete Observations*, American Statistical Association Journal

Mautz, W. W., H. Silver, and J. B. Holter, 1976, "Digestibility and Related Nutritional Data for Seven Northern Deer Browse Species," *Journal of Wildlife Management*, 40(4): 630-638.

National Council on Radiation Protection and Measurements (NCRPM), 1984, *Radiological Assessment: Predicting the Transport, Bioaccumulation, and Uptake by Man of Radionuclides Released to the Environment*, NCRP Report No. 76.

Nutrient Database, 1997, Data compiled from U.S. Department of Agriculture releases, and published nutrient information from 71 chain references, on line, http://www.nutribase.com.)

Ohio Department of Natural Resources, map showing Ground-Water Resources of Erie County by Alfred C. Walker, http://www.dnr.state.oh.us/water/gwrmaps/counties/Erie.htm, accessed April 2007.

Ohio Environmental Protection Agency (OEPA), 2005a, *Use of Risk-Based Numbers in the Remedial Response Process Overview DERR-00-RR-038, June 28, 2005.*

OEPA, 2005b, *Technical Decision Compendium Assessing Compounds without Formal Toxicity Values Available for Use in Human Health Risk Assessment Ohio EPA Division of Emergency and Remedial Response Remedial Response Program August 2005.*

OEPA, 2004a, *Technical Decision Compendium Methodology for Evaluating Site-specific Background Concentrations of Chemicals Ohio EPA Division of Emergency and Remedial Response Remedial Response Program 14 April 2004*.

OEPA, 2004b, *Technical Decision Compendium Human Health Cumulative Carcinogenic Risk And Non-Carcinogenic Hazard Goals For DERR Remedial Response And Office Of Federal Facility Oversight Ohio EPA Division Of Emergency And Remedial Response 28 April 2004*

Sample, B. E., D. M. Opresko, and G. W. Suter II, 1996, *Toxicological Benchmarks for Wildlife: 1996 Revision*, Prepared for the U.S. Department of Energy by Health Sciences Research Division, Oak Ridge National Laboratory.

Science Applications International Corporation (SAIC), 1991, *NASA Plum Brook Station, Preliminary Assessment*, Volume I, Sandusky, Ohio, June.

Sharp, G., 1995, Personal Communication: Telephone conversation between P. Goetchius, IT Corp. and Gary Sharp, Wildlife Biologist, West Virginia Division of Natural Resources, Point Pleasant, West Virginia, 17 February.

Shaw Environmental, Inc. (Shaw), 2003, *2002 Groundwater Data Summary and Evaluation Report, Former Plum Brook Ordnance Works, Sandusky, Ohio*, June.

Shaw, 2005a, *Baseline Human Health Risk Assessment of Groundwater Work Plan, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio*, October.

Shaw, 2005b, *Technical Memorandum for the Baseline Human Health Risk Assessment for Groundwater at the West Area Red Water Pond, Former Plum Brook Ordnance Works, Sandusky, Ohio*, May.

Shaw, 2005c, *2004 Groundwater Data Summary and Evaluation Report, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio*, April.

U.S. Army Corps of Engineers (USACE), 2001, *Scope of Work, Phase II Groundwater Remedial Investigation (RI), TNT and Red Water Ponds Area, Former Plum Brook Ordnance Works, Sandusky, Ohio*, December 10.

USACE, 1999, *Risk Assessment Handbook, Volume I: Human Health Evaluation*, Engineer Manual EM 200-1-4.

U.S. Department of Energy (DOE), 1989, A Manual for Implementing Residual Radioactive Material Guidelines, Argonne National Laboratory, Argonne, IL, ANL/ES-160, DOE/CH/8901.

DOE, 1983, Pathway Analysis and Radiation Dose Estimates for Radioactive Residues at Formerly Utilized MED/AEC Sites, U.S. Dept. of Energy, Oak Ridge Operations Office, Oak Ridge, TN, DOE ORO-832.

U.S. Environmental Protection Agency (EPA), 2005, *Integrated Risk Information System (IRIS)*, National Center for Environmental Assessment, Cincinnati, Ohio, http://www.epa.gov/iris/index.html.

EPA, 2004a, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part E - Supplemental Guidance for Dermal Risk Assessment),* Final, Office of Superfund Remediation and Technology Innovation, Washington, D.C., EPA/540/R-99/005, July.

EPA, 2004b, *Region 9 Preliminary Remediation Goals (PRG) Table*, Region 9, San Francisco, California, October, http://www.epa.gov/region09/waste/sfund/prg/files/prgtable.pdf.

EPA, 2004c, *User's Guide and Background Technical Document for Region 9 Preliminary Remediation Goals (PRG) Table*, Region 9, San Francisco, California, October, http://www.epa.gov/region09/waste/sfund /prg/files/04usersguide.pdf.

EPA, 2003b, *Human Health Toxicity Values in Superfund Risk Assessments*, Office of Solid Waste and Emergency Response, Washington, D.C., OSWER Directive 9285.7-53, December.

EPA, 2001, 40 CFR Part 745, "Lead Identification of Dangerous Levels of Lead; Final Rule," *Federal Register* 66(4): 1206-1240.

EPA, 2000. Supplemental Guidance to RAGS: Region 4 Bulletins, Human Health Risk Assessment Bulletins. EPA Region 4, originally published November 1995, Website version last updated May 2000: http://www.epa.gov/region4/waste/ots/healtbul.htm.

EPA, 1999. Use of the TRW Interim Adult Lead Methodology in Risk Assessment. Pat Van Leeuwen, EPA Region 5, Paul White ORD/NCEA.

EPA, 1998, "Clarification to the 1994 Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities," Memorandum from T. Fields, Jr. to regional administrators I-X, 27 August.

EPA, 1997a, *Exposure Factors Handbook*, Office of Research and Development, National Center for Environmental Assessment, Washington, D.C., EPA/600/P-95/002F, August.

EPA, 1997b, *Health Effects Assessment Summary Tables, FY 1997 Update,* Office of Solid Waste and Emergency Response, 9200.6-303 (97-1), EPA-540-R-97-036, NTIS No. PB97-921197.

EPA, 1996a, *Soil Screening Guidance: Technical Background Document*, Office of Solid Waste and Emergency Response, EPA/540/R-95/128, NTIS No. PB96-963502.

EPA, 1996b, *Recommendations of the Technical Review Workgroup for Lead for an Interim Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil*, Technical Review Workgroup for Lead, December.

EPA, 1994a, *Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities,* Office of Solid Waste and Emergency Response, Draft, April, EPA530-R-94-021, including Errata, "Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes," October, and "Modification of Screening Guidance Fate and Transport Equations," November.

EPA, 1994b, *Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children*, Office of Emergency and Remedial Response, Washington, DC, EPA/540/R-93/081. PB93-963510.

EPA, 1994c, "Guidance on Residential Lead-Based Paint, Lead-Contaminated Dust, and Lead-Contaminated Soil," Memorandum from L.R. Goldman to regional directors, 14 July.

EPA, 1994d, "Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities," Memorandum from E.P. Laws to regional administrators I-X, 14 July.

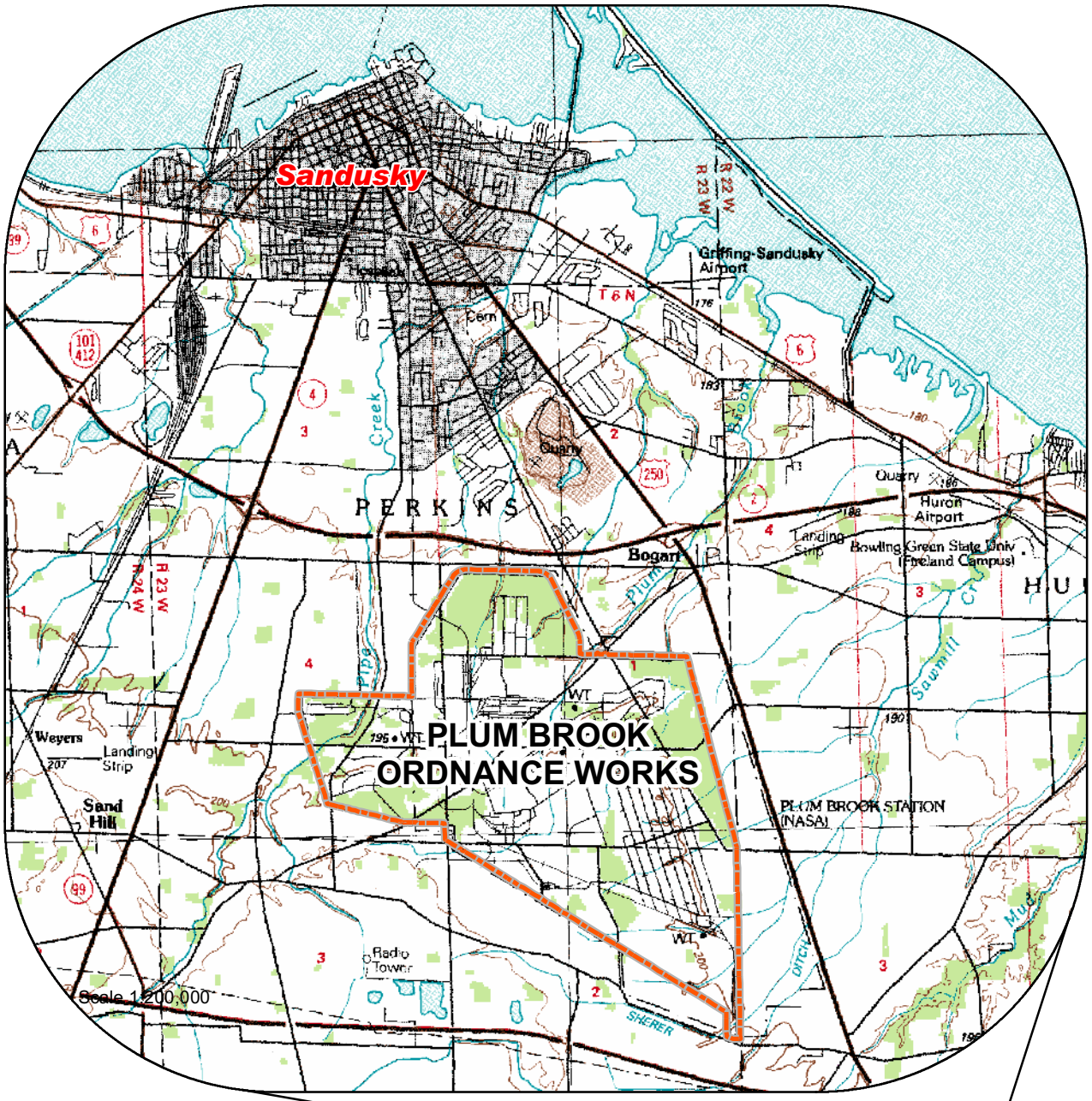
EPA, 1993, *Superfund's Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure,* Preliminary Review Drag (5/5/93).

EPA, 1992a, *Supplemental Guidance to RAGS: Calculating the Concentration Term*, Office of Solid Waste and Emergency Response, Washington, D.C., Publication 9285.7-081.

EPA, 1992b, *Dermal Exposure Assessment: Principles and Applications*, Interim Report, Office of Research and Development, Washington, D.C., EPA/600/8-91/011B, including Supplemental Guidance dated August 18, 1992.

EPA, 1992c, "Guidance on Risk Characterization for Risk Managers and Risk Assessors," Memorandum from F. Henry Habicht II, Deputy Administrator, to Assistant Administrators, Regional Administrators, February 26.

EPA, 1991, Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors, Interim Final, Office of Solid Waste and Emergency Response, OSWER Directive: 9285.6-03.



0 0.5 1 2 Miles

Legend

Plum Brook Ordnance Works Boundary

N

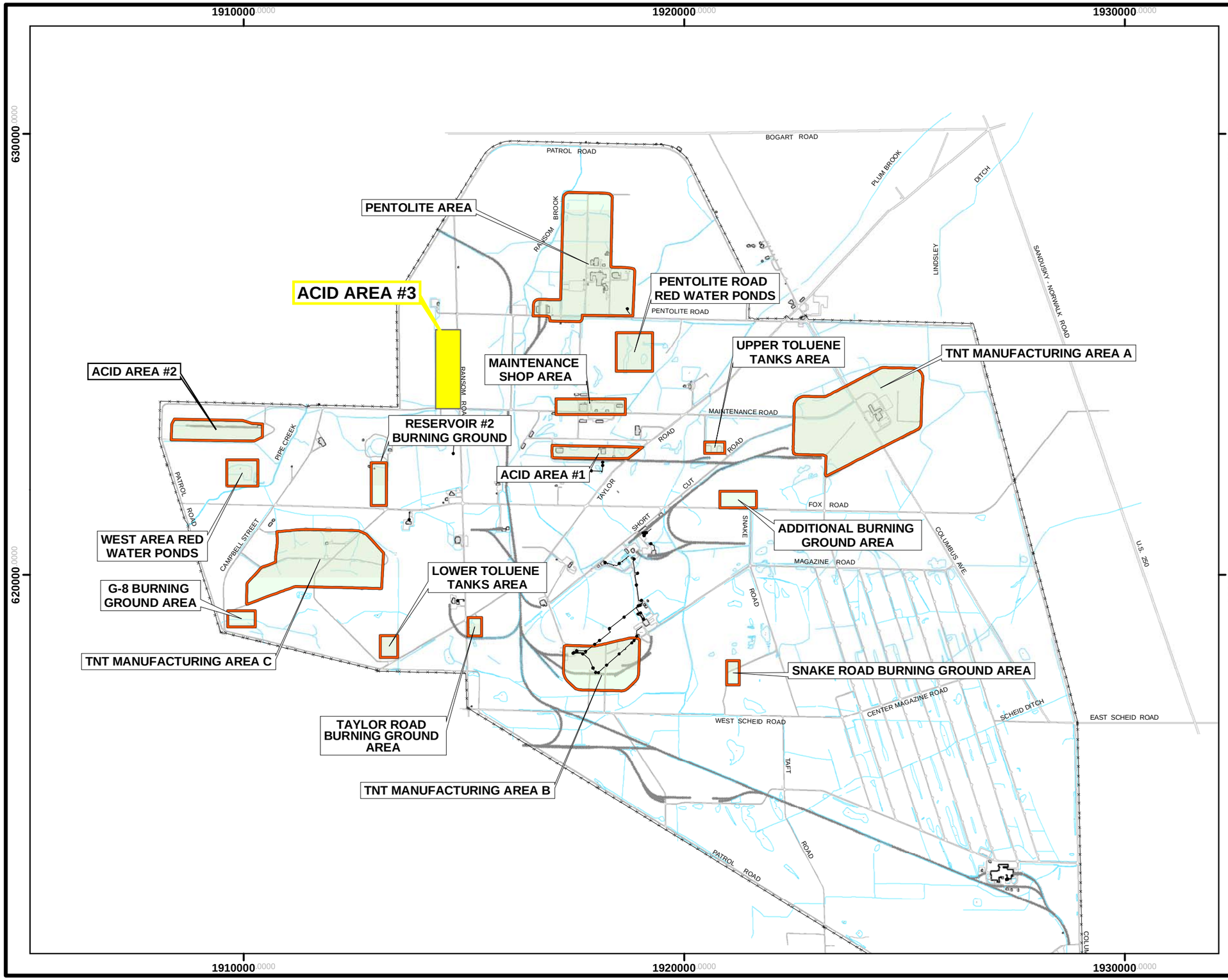
JACOBS

Location Map,
Plum Brook Ordnance Works
Sandusky, Ohio

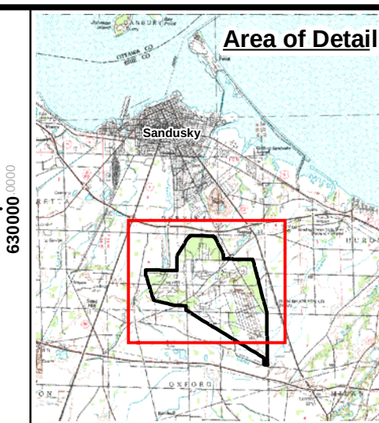
Plumbrook Ordnance Works
Sandusky, Ohio

08/04/06 NZ D:/GIS/Plumbrook/Projects/
Final_AA2_3_RI/ArcGIS/PBOW_Site_Location.mxd

Figure 1-1



Area of Detail



Legend

Area of Concern

Creek, Ditch, Conveyance

N

0 2,000 4,000 Feet

Sources

Data mapped to Ohio State Plane North NAD83, map grid units in feet.

JACOBS

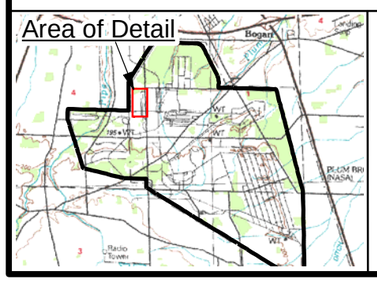
Location Map, Acid Area 3

Plum Brook Ordnance Works
Sandusky, Ohio

07/19/07 LD S:/GIS/Projects/Plumbrook/Projects/AA2_3 HHRA/ArcGIS/Acid_Areas3_LocMap.mxd

Figure 1-2

Area of Detail



Legend

- Storage Tank Areas from Engineering Drawings
- Creek, Ditch, Conveyance
- Buildings
- Railway
- 1998 SI Soil Borings
- 2004 Soil Borings (1 surface sample and 2 subsurface samples)
- 2004 Soil Borings (1 surface sample and 1 subsurface sample)
- Monitoring Wells
- Piezometers
- Surface Water Sediment Sampling Locations

0 50 100 200
Feet

N

Notes: *Aerial Photography from 1958.*
Data mapped to Ohio State Plane North NAD83, map units are feet.

JACOBS

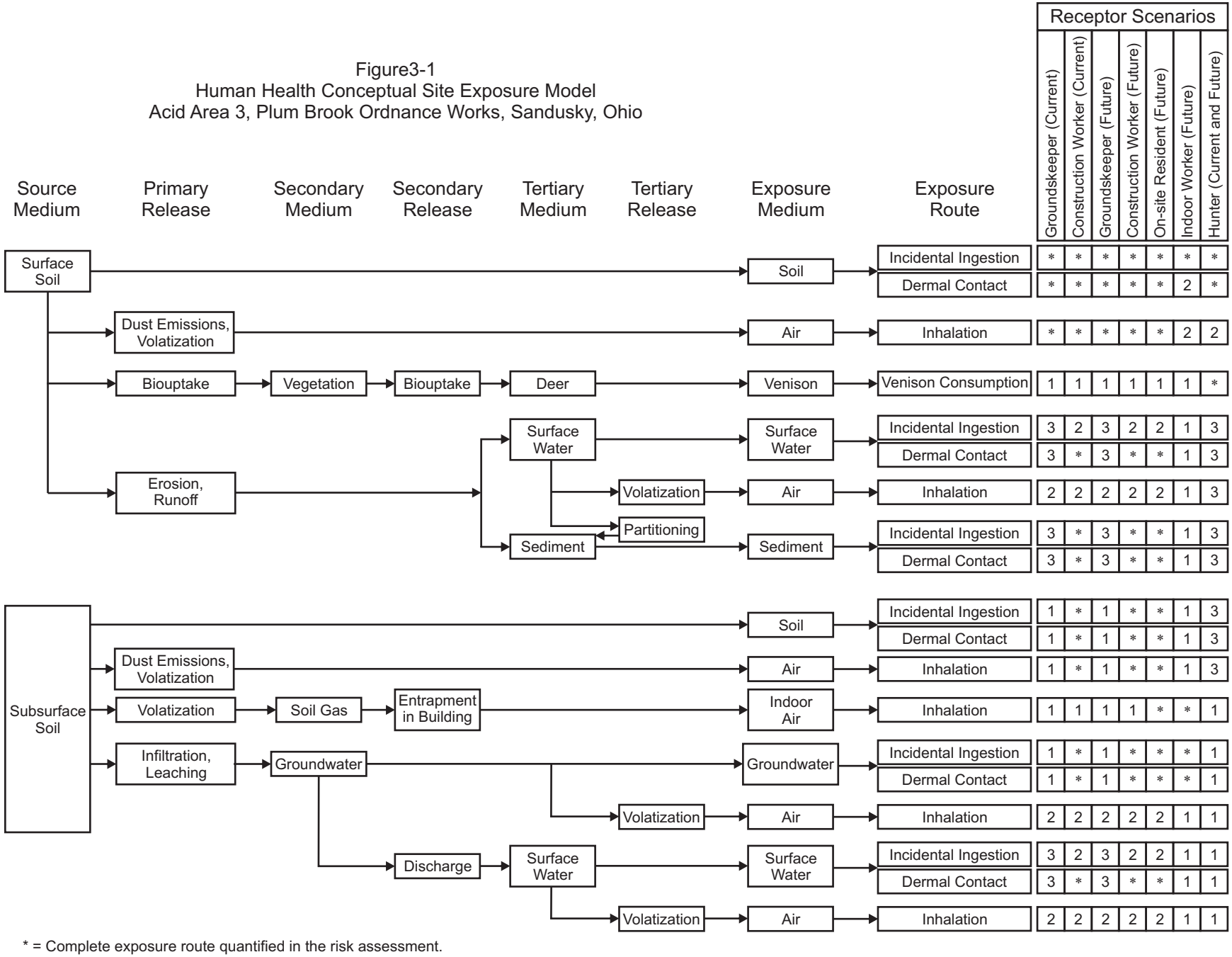
Sampling Locations — Acid Area 3

Plum Brook Ordnance Works
Sandusky, Ohio

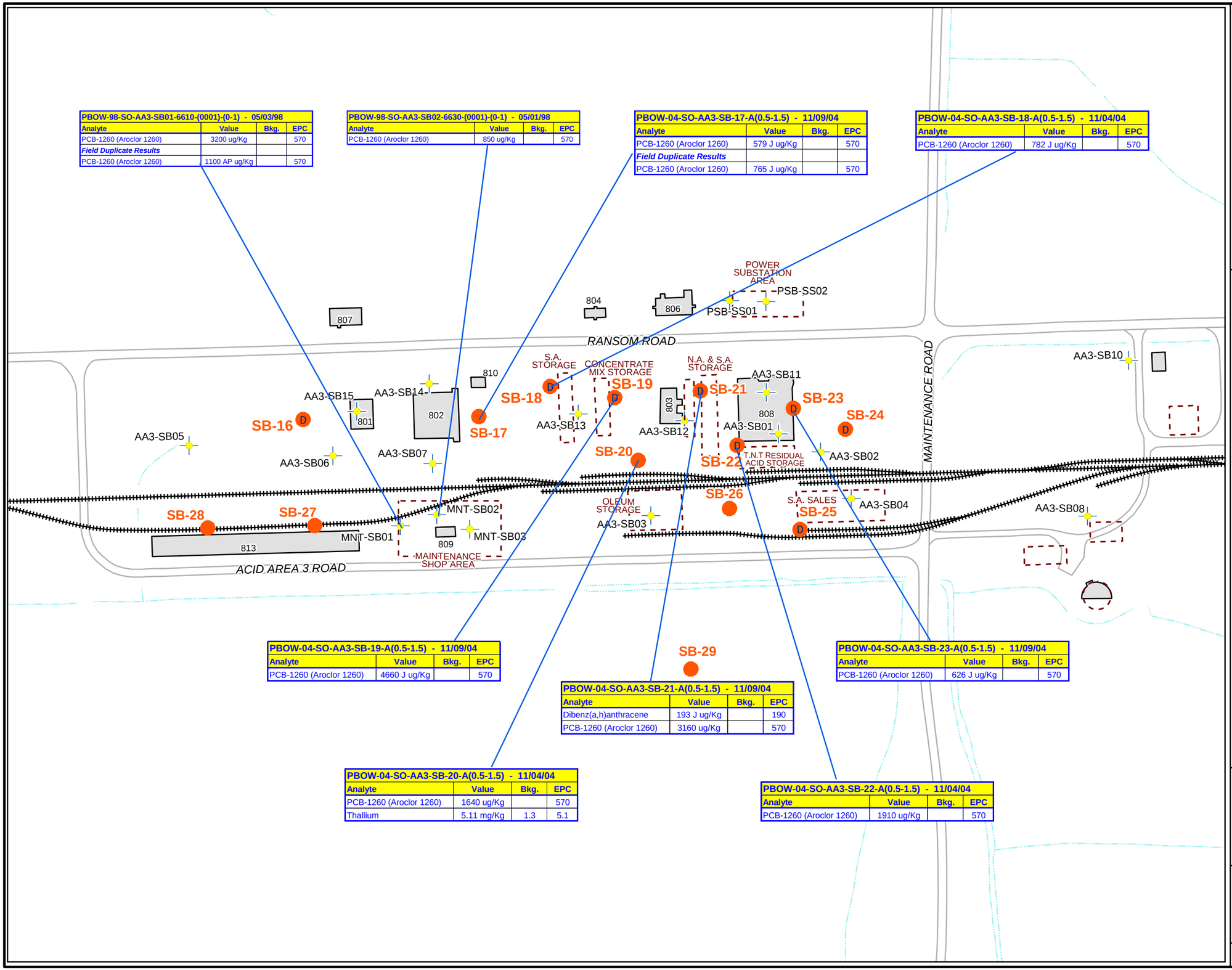
09/20/06 JD D:/GIS/Plumbrook/Projects/Baseline Human Health Risk Assessment/ArcGIS/AA3_Sampling_Locs.mxd

Figure 2-1

Figure3-1
Human Health Conceptual Site Exposure Model
Acid Area 3, Plum Brook Ordnance Works, Sandusky, Ohio



* = Complete exposure route quantified in the risk assessment.
1 = There is no plausible pathway for exposure in this medium.
2 = Although theoretically complete, this pathway in not quantified as explained in text.
3 = Contact with this medium, although plausible, is not part of this receptor's normal or expected activities; therefore, contact would be sporadic and is not quantified.



PBOW-98-SO-AA3-SB01-6610-(0001)-(0-1) - 05/03/98			
Analyte	Value	Bkg.	EPC
PCB-1260 (Aroclor 1260)	3200 ug/Kg		570
Field Duplicate Results			
PCB-1260 (Aroclor 1260)	1100 AP ug/Kg		570

PBOW-98-SO-AA3-SB02-6630-(0001)-(0-1) - 05/01/98			
Analyte	Value	Bkg.	EPC
PCB-1260 (Aroclor 1260)	850 ug/Kg		570

PBOW-04-SO-AA3-SB-17-A(0.5-1.5) - 11/09/04			
Analyte	Value	Bkg.	EPC
PCB-1260 (Aroclor 1260)	579 J ug/Kg		570
Field Duplicate Results			
PCB-1260 (Aroclor 1260)	765 J ug/Kg		570

PBOW-04-SO-AA3-SB-18-A(0.5-1.5) - 11/04/04			
Analyte	Value	Bkg.	EPC
PCB-1260 (Aroclor 1260)	782 J ug/Kg		570

PBOW-04-SO-AA3-SB-19-A(0.5-1.5) - 11/09/04			
Analyte	Value	Bkg.	EPC
PCB-1260 (Aroclor 1260)	4660 J ug/Kg		570

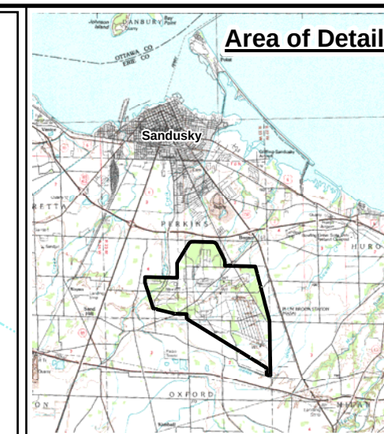
PBOW-04-SO-AA3-SB-21-A(0.5-1.5) - 11/09/04			
Analyte	Value	Bkg.	EPC
Dibenz(a,h)anthracene	193 J ug/Kg		190
PCB-1260 (Aroclor 1260)	3160 ug/Kg		570

PBOW-04-SO-AA3-SB-23-A(0.5-1.5) - 11/09/04			
Analyte	Value	Bkg.	EPC
PCB-1260 (Aroclor 1260)	626 J ug/Kg		570

PBOW-04-SO-AA3-SB-20-A(0.5-1.5) - 11/04/04			
Analyte	Value	Bkg.	EPC
PCB-1260 (Aroclor 1260)	1640 ug/Kg		570
Thallium	5.11 mg/Kg	1.3	5.1

PBOW-04-SO-AA3-SB-22-A(0.5-1.5) - 11/04/04			
Analyte	Value	Bkg.	EPC
PCB-1260 (Aroclor 1260)	1910 ug/Kg		570

Area of Detail



Legend

- 1998 SI Soil Borings
- 2004 Soil Borings to 10 ft bgs
- 2004 Soil Borings to 5 ft bgs

Note:
bgs = below ground surface
Bkg. = Background Sample
PRG = Preliminary Remediation Goal

- Storage Tank Areas from Engineering Drawings
- Creek, Ditch, Conveyance
- Buildings
- Railway

N

0 50 100 200 Feet

Sources
Data mapped to Ohio State Plane North NAD83, map grid units in feet.

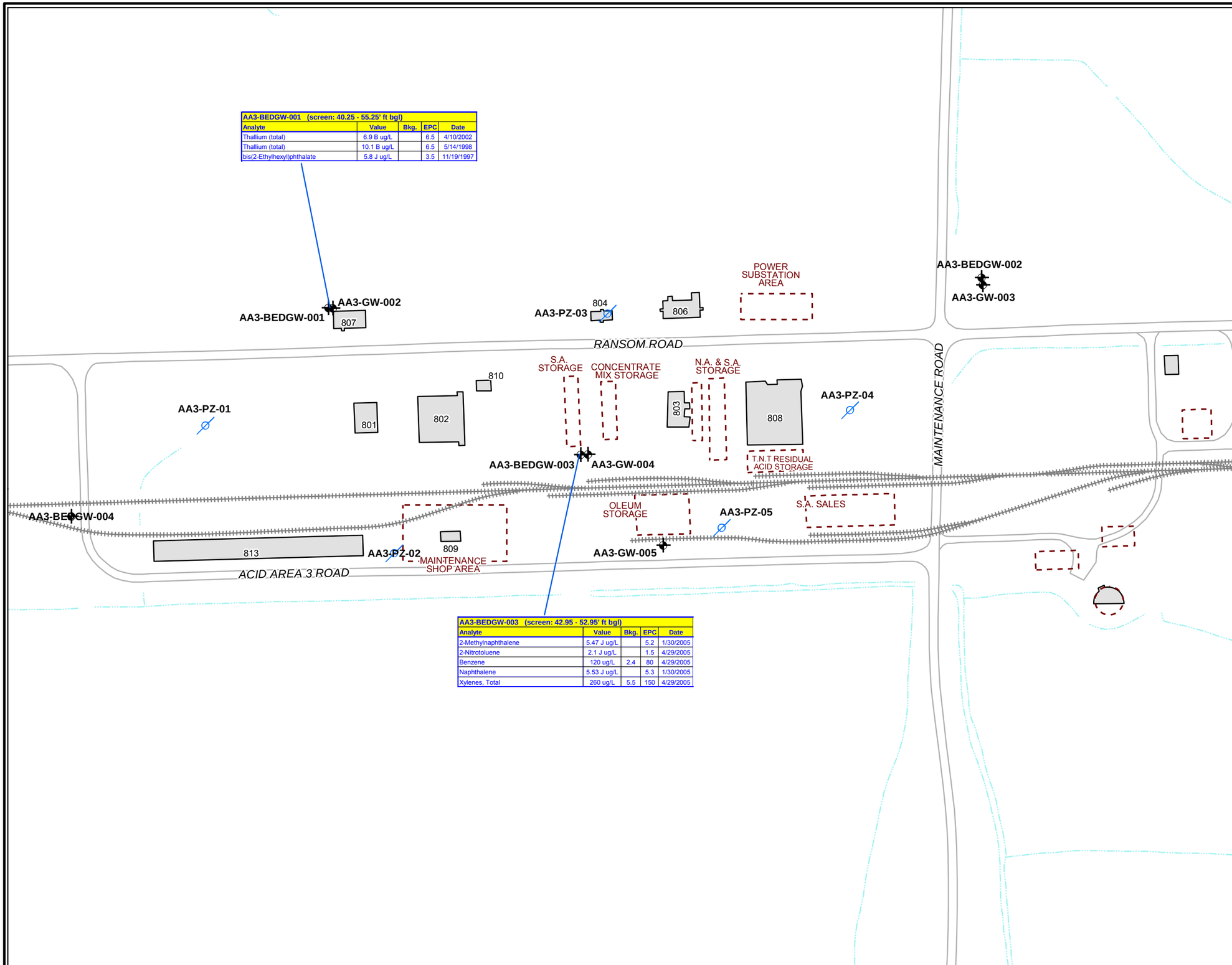
JACOBS

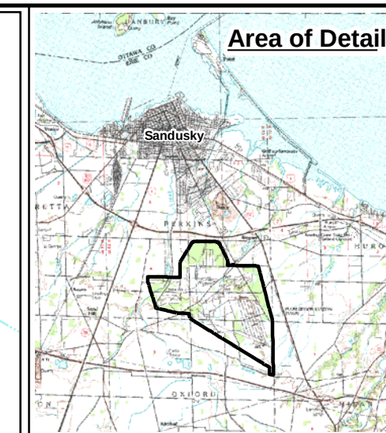
Distribution of COCs Exceeding Background and EPC in Surface Soil — Acid Area 3

Plum Brook Ordnance Works
Sandusky, Ohio

07/19/07 JD S:/GIS/Plumbrook/Projects/AA2_3 HHRA/ArcGIS/AA3_Surface_Soil.mxd

Figure 5-1





Legend

- Monitoring Wells
- Piezometers

Note:
bgs = below ground surface
Bkg. = Background Sample
PRG = Preliminary Remediation Goal

- Storage Tank Areas from Engineering Drawings
- Creek, Ditch, Conveyance
- Buildings
- Railway

N

0 50 100 200 Feet

Sources
Data mapped to Ohio State Plane North NAD83, map grid units in feet.

JACOBS

Distribution of COCs Exceeding Background and EPC in Bedrock Groundwater — Acid Area 3

Plum Brook Ordnance Works
Sandusky, Ohio

07/19/07 JD S:/GIS/Plumbrook/Projects/AA2_3 HHRA/ArcGIS/AA3_Deep_GW.mxd

Figure 5-2

Table 2-1 Summary Statistics and Identification of COPCs for Constituents Detected in Environmental Media at Acid Area 3 Plum Brook Ordnance Works, Sandusky, Ohio.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	BKG	Toxicity Screening Level[1]	COPCs
Surface Soil												
HE	2,4-Dinitrotoluene	mg/Kg	4	0.0646 - 0.622	0.81	5.6	0.906	Poisson	5.6		12.22	
HE	2,6-Dinitrotoluene	mg/Kg	2	0.0595 - 0.842	0.87	0.87	0.256	Poisson	0.87		6.11	
MET	Aluminum	mg/Kg	100		2430	14000	7305	ProUCL: Normal	8097	15500	7614.20	Yes
MET	Antimony	mg/Kg	18	0.492 - 8.20	0.666	2.28	0.968	Non Parametric - Indeterminate	1.31	9.3	3.13	
MET	Arsenic	mg/Kg	100		2.29	13.3	6.34	ProUCL: Normal	7.07	36.5	0.39	Yes
MET	Barium	mg/Kg	97	24.0 - 24.0	18.1	115	50.6	Normal	56.9	826	537.49	
MET	Beryllium	mg/Kg	32	0.0454 - 0.690	0.0998	0.902	0.321	Non Parametric - Kaplan-Meier	0.58	1	15.44	
MET	Cadmium	mg/Kg	32	0.0378 - 0.690	0.106	0.674	0.31	Non Parametric - Kaplan-Meier	0.576		3.70	
MET	Calcium	mg/Kg	100	0.0000 - 0.0000	1210	291000		NOT normal	291000		NA	
MET	Chromium	mg/Kg	100		5.48	19.6	11.3	Normal	12.3	29	30.10	
MET	Cobalt	mg/Kg	91	5.70 - 6.00	1.9	22.3	8.58	Lognormal - ROS	8.82	116	902.89	
MET	Copper	mg/Kg	100		3.95	23.4	13.2	Normal	14.8	56.2	312.86	
MET	Iron	mg/Kg	100		6810	26600	15145	ProUCL: Normal	16935	234000	2346.32	Yes
MET	Lead	mg/Kg	100		3.6	653	38.7	ProUCL: 95% Chebyshev (Mean, Sd)	121	48.6	40.00	Yes
MET	Magnesium	mg/Kg	100	0.0000 - 0.0000	864	30600		NOT normal	30600		NA	
MET	Manganese	mg/Kg	100		51.9	922	359	ProUCL: Approximate Gamma	426	3506	176.24	Yes
MET	Mercury	mg/Kg	59	0.0047 - 0.041	0.0076	0.19	0.0298	Non Parametric - Kaplan-Meier	0.19	0.1	2.35	
MET	Nickel	mg/Kg	100		5.38	36.5	15.8	Lognormal	16.2	55.1	156.43	
MET	Potassium	mg/Kg	71	574. - 649.	251	1190	655	Non Parametric - Indeterminate	1190	3390	NA	
MET	Selenium	mg/Kg	24	0.570 - 2.27	0.6	1.75	0.716	Non Parametric - Indeterminate	1.75	2	39.11	
MET	Sodium	mg/Kg	41	574.0000 - 686.0000	27.6	180		NON PARAMETRIC	180		NA	
MET	Thallium	mg/Kg	29	0.934 - 4.81	1.84	5.11	1.61	Non Parametric - Indeterminate	5.11	1.3	0.52	Yes
MET	Vanadium	mg/Kg	100		9.06	31.1	20.1	ProUCL: Normal	21.6	40.9	7.82	Yes
MET	Zinc	mg/Kg	100		6.48	238	53.9	Non Parametric - Kaplan-Meier	63.5	322	2346.32	
PCB	PCB-1254	ug/Kg	24	17.5 - 2300	45.8	4180	396	Non Parametric - Indeterminate	4180		221.86	Yes
PCB	PCB-1260	ug/Kg	62	5.18 - 41.	18.5	4660	567	Non Parametric - Kaplan-Meier	570		221.86	Yes

Table 2-1 Continued.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	BKG	Region 9 Residential PRG	COPCs
SVO	2-Methylnaphthalene	ug/Kg	9	29.0000 - 450.0000	80.2	240		Poisson	240		5591.61	
SVO	Acenaphthene	ug/Kg	6	12.8000 - 450.0000	51	52		Poisson	52		368170.57	
SVO	Acenaphthylene	ug/Kg	24	40.6 - 400.	64	750	151	Non Parametric - Indeterminate	750		NA	
SVO	Anthracene	ug/Kg	29	29.6000 - 400.0000	40	790		NON PARAMETRIC	790		2189612.06	
SVO	Benzaldehyde	ug/Kg	100	0.0000 - 0.0000	94.3	94.3		NORMAL	94.3		611030.97	
SVO	Benzo(a)anthracene	ug/Kg	41	21.6 - 400	59	3500	326	Non Parametric - Indeterminate	3500		621.46	Yes
SVO	Benzo(a)pyrene	ug/Kg	47	29.3 - 400	26	3300	317	Non Parametric - Indeterminate	3300		62.15	Yes
SVO	Benzo(b)fluoranthene	ug/Kg	44	28.2 - 400	59.3	3400	340	Non Parametric - Kaplan-Meier	382		621.46	Yes
SVO	Benzo(g,h,i)perylene	ug/Kg	44	26.6 - 400.	41	1300	238	Non Parametric - Indeterminate	1300		NA	
SVO	Benzo(k)fluoranthene	ug/Kg	41	31.7000 - 400.0000	67.7	3300		NON PARAMETRIC	3300		6214.57	
SVO	Benzyl butyl phthalate	ug/Kg	9	143.0000 - 765.0000	390	560		Poisson	560		1222061.94	
SVO	bis(2-Ethylhexyl)phthalate	ug/Kg	15	366. - 1960.	41	524	84.7	Non Parametric - Kaplan-Meier	85.1		34741.47	
SVO	Carbazole	ug/Kg	6	48.2000 - 450.0000	120	200		Poisson	200		24319.03	
SVO	Chrysene	ug/Kg	41	17.1000 - 400.0000	91	3400		NON PARAMETRIC	3400		62145.67	
SVO	Dibenz(a,h)anthracene	ug/Kg	12	22.0 - 450	24	193	128	Non Parametric - Indeterminate	193		62.15	Yes
SVO	Dibenzofuran	ug/Kg	3	270.0000 - 1440.0000	61	61		Poisson	61		14526.31	
SVO	Di-n-butylphthalate	ug/Kg	3	380. - 2390.	464	464	249	Poisson	464		611030.97	
SVO	Fluoranthene	ug/Kg	53	18.6000 - 400.0000	44	5500		?NOT normal	5500		229361.02	
SVO	Fluorene	ug/Kg	12	10.8000 - 450.0000	69.5	190		NON PARAMETRIC	190		274710.66	
SVO	Indeno(1,2,3-cd)pyrene	ug/Kg	41	27.9 - 400	43	1400	218	Non Parametric - Kaplan-Meier	230		621.46	Yes
SVO	Naphthalene	ug/Kg	9	10.5 - 450.	59.7	78.6	66.4	Poisson	78.6		5591.61	
SVO	Phenanthrene	ug/Kg	38	20.8 - 400.	85.3	2400	283	Non Parametric - Indeterminate	2400		NA	
SVO	Pyrene	ug/Kg	53	16.1000 - 400.0000	39	4600		?NOT normal	4600		231595.11	
VOC	2-Butanone (Methyl ethyl ketone)	ug/Kg	12	1.0800 - 27.0000	5.59	14.3		NON PARAMETRIC	14.3		2231119.78	
VOC	Acetone	ug/Kg	6	1.5800 - 27.0000	7.4	154		Poisson	154		1412657.06	
VOC	Benzene	ug/Kg	15	0.8300 - 6.9000	2.58	5.29		NON PARAMETRIC	5.29		643.15	
VOC	Carbon Disulfide	ug/Kg	15	1.3600 - 6.9000	1.6	36.2		NON PARAMETRIC	36.2		35534.04	
VOC	Cyclohexane	ug/Kg	36	1.5600 - 1.9500	5.82	9.76		NON PARAMETRIC	9.76		140000.00	
VOC	Ethylbenzene	ug/Kg	15	0.6310 - 6.9000	1.56	3.06		NON PARAMETRIC	3.06		395000.00	
VOC	Methyl Acetate	ug/Kg	14	3.3100 - 4.1600	14.2	30		NON PARAMETRIC	30		2208674.40	
VOC	Methylcyclohexane	ug/Kg	57	0.7300 - 0.8500	1.44	10.9		?NOT normal	10.9		259105.52	
VOC	Toluene	ug/Kg	26	0.7440 - 6.2000	1.61	12.2		NON PARAMETRIC	12.2		520000.00	
VOC	Xylenes, Total	ug/Kg	15	1.0600 - 6.9000	3.81	7.68		NON PARAMETRIC	7.68		27063.05	

Table 2-1 Continued.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	BKG	Region 9 Residential PRG	COPCs
Subsurface Soil												
HE	2,4-Dinitrotoluene	mg/Kg	3	0.0643 - 0.420	1.3	2.1	0.231	Poisson	2.1		12.22	
HE	2,6-Dinitrotoluene	mg/Kg	2	0.0593 - 0.420	0.06	0.06	0.195	Poisson	0.06		6.11	
MET	Aluminum	mg/Kg	100		2650	11900	8156	ProUCL: Normal	8712	15500	7614.20	Yes
MET	Antimony	mg/Kg	15	0.481 - 7.60	0.771	8	2.1	Non Parametric - Indeterminate	8	9.3	3.13	Yes
MET	Arsenic	mg/Kg	95	0.627 - 0.662	0.718	32.2	8.29	ProUCL: Approximate Gamma	8.5	36.5	0.39	Yes
MET	Barium	mg/Kg	98	24.2 - 24.2	23.3	126	61.3	Normal	67.3	826	537.49	
MET	Beryllium	mg/Kg	50	0.0444 - 0.630	0.147	0.75	0.355	Normal - ROS	0.433	1	15.44	
MET	Cadmium	mg/Kg	43	0.0370 - 0.630	0.154	0.917	0.358	Non Parametric - Kaplan-Meier	0.569		3.70	
MET	Calcium	mg/Kg	100	0.0000 - 0.0000	1600	64200		NOT normal	64200		NA	
MET	Chromium	mg/Kg	100		4.5	19.3	13.4	Normal	14.3	29	30.10	
MET	Cobalt	mg/Kg	98	6.00 - 6.00	4.58	20.2	10.4	Normal	11.5	116	902.89	
MET	Copper	mg/Kg	98	3.00 - 3.00	10	31.6	19.4	Normal	21	56.2	312.86	
MET	Iron	mg/Kg	100		5720	34800	19676	ProUCL: Normal	21160	234000	2346.32	Yes
MET	Lead	mg/Kg	100		2.5	15.3	10.4	Normal	11	48.6	40.00	
MET	Magnesium	mg/Kg	100	0.0000 - 0.0000	744	23500		NOT normal	23500		NA	
MET	Manganese	mg/Kg	100		93.4	1180	463	ProUCL: Appriximate Gamma	623	3506	176.24	Yes
MET	Mercury	mg/Kg	30	0.0045 - 0.042	0.0087	0.0623	0.0185	Non Parametric - Kaplan-Meier	0.0623	0.1	2.35	
MET	Nickel	mg/Kg	100		6.2	45	23.8	Normal	26	55.1	156.43	
MET	Potassium	mg/Kg	93	578. - 604.	439	2550	1190	Normal	1350	3390	NA	
MET	Selenium	mg/Kg	28	0.580 - 2.90	0.64	2.81	0.788	Non Parametric - Kaplan-Meier	0.981	2	39.11	
MET	Silver	mg/Kg	18	0.0708 - 1.30	0.104	0.278	0.177	Non Parametric - Kaplan-Meier	0.278	11.1	39.11	
MET	Sodium	mg/Kg	55	578.0000 - 635.0000	39.8	173		?NOT normal	173		NA	
MET	Thallium	mg/Kg	18	0.806 - 1.47	1.5	5.45	1.02	Non Parametric - Indeterminate	5.45	1.3	0.52	Yes
MET	Vanadium	mg/Kg	100		8.2	31.5	22.7	ProUCL: Normal	24.8	40.9	7.82	Yes
MET	Zinc	mg/Kg	100		16.9	84.4	53	Normal	56.7	322	2346.32	
PCB	PCB-1254 (Aroclor 1254)	ug/Kg	5	16.8000 - 99.9000	47.6	47.6		Poisson	47.6		221.86	
PCB	PCB-1260 (Aroclor 1260)	ug/Kg	5	4.7000 - 27.9000	115	115		Poisson	115		221.86	
SVO	2-Methylnaphthalene	ug/Kg	3	28.9000 - 420.0000	81	81		Poisson	81		5591.61	

Table 2-1 Continued.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	BKG	Region 9 Residential PRG	COPCs
SVO	Acenaphthene	ug/Kg	3	12.7000 - 420.0000	100	100		Poisson	100		368170.57	
SVO	Acenaphthylene	ug/Kg	3	40.4000 - 420.0000	120	120		Poisson	120		NA	
SVO	Anthracene	ug/Kg	3	29.4000 - 420.0000	280	280		Poisson	280		2189612.06	
SVO	Benzo(a)anthracene	ug/Kg	3	21.2000 - 420.0000	360	360		Poisson	360		621.46	
SVO	Benzo(a)pyrene	ug/Kg	3	28.8 - 420	340	340	103	Poisson	340		62.15	
SVO	Benzo(b)fluoranthene	ug/Kg	3	27.4000 - 420.0000	340	340		Poisson	340		621.46	
SVO	Benzo(g,h,i)perylene	ug/Kg	3	26.1000 - 420.0000	170	170		Poisson	170		NA	
SVO	Benzo(k)fluoranthene	ug/Kg	3	31.1000 - 420.0000	320	320		Poisson	320		6214.57	
SVO	Benzyl butyl phthalate	ug/Kg	8	143.0000 - 420.0000	196	901		Poisson	901		1222061.94	
SVO	bis(2-Ethylhexyl)phthalate	ug/Kg	15	365.0000 - 426.0000	45	521		NON PARAMETRIC	521		34741.47	
SVO	Chrysene	ug/Kg	5	16.8000 - 420.0000	26	360		Poisson	360		62145.67	
SVO	Dibenzofuran	ug/Kg	3	269.0000 - 420.0000	280	280		Poisson	280		14526.31	
SVO	Di-n-butylphthalate	ug/Kg	5	380. - 521.	1440	20700	1920	Poisson	20700		611030.97	
SVO	Fluoranthene	ug/Kg	5	18.3000 - 420.0000	50	1000		Poisson	1000		229361.02	
SVO	Fluorene	ug/Kg	3	10.7000 - 420.0000	410	410		Poisson	410		274710.66	
SVO	Indeno(1,2,3-cd)pyrene	ug/Kg	3	27.4000 - 420.0000	170	170		Poisson	170		621.46	
SVO	Naphthalene	ug/Kg	3	10.5 - 420.	140	140		Poisson	140		5591.61	
SVO	Phenanthrene	ug/Kg	3	20.5000 - 420.0000	1300	1300		Poisson	1300		NA	
SVO	Pyrene	ug/Kg	5	15.8000 - 420.0000	35	730		Poisson	730		231595.11	
VOC	2-Butanone (Methyl ethyl ketone)	ug/Kg	15	1.0700 - 25.0000	5.5	20		NON PARAMETRIC	20		2231119.78	
VOC	Acetone	ug/Kg	15	1.5700 - 25.0000	19	250		NON PARAMETRIC	250		1412657.06	
VOC	Benzene	ug/Kg	35	0.8220 - 6.3000	1.22	9.11		NON PARAMETRIC	9.11		643.15	
VOC	Carbon Disulfide	ug/Kg	10	1.3400 - 6.3000	2.3	13		NON PARAMETRIC	13		35534.04	
VOC	Cyclohexane	ug/Kg	64	1.5500 - 1.9800	4.33	11.3		?NOT normal	11.3		140000.00	
VOC	Methylene Chloride	ug/Kg	5	0.9250 - 6.3000	6.1	40		Poisson	40		9106.99	
VOC	Toluene	ug/Kg	40	0.7380 - 6.3000	1.6	22.8		NON PARAMETRIC	22.8		520000.00	
VOC	Xylenes, Total	ug/Kg	35	1.0500 - 6.3000	1.37	13.6		NON PARAMETRIC	13.6		27063.05	

Table 2-1 Continued.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	BKG	Region 9 Residential PRG	COPCs
Bedrock Groundwater												
GC2	Cyanide	mg/L	22	0.0030 - 0.010	0.0086	0.0268					73.00	
GC2	Nitrogen, Nitrate (as N)	mg/L	20	0.005 - 10.0	0.225	0.413					1000.00	
GC2	Sulfate (as SO4)	mg/L	70	.005 - 0.280	1.21	31.1					NA	
HE	2-Nitrotoluene	ug/L	10	0.0900 - 0.2020	2.1	2.1	0.283	NON PARAMETRIC	1.54		0.05	Yes
HE	3-Nitrotoluene	ug/L	20	0.0960 - 0.3720	0.43	0.44					12.17	
HE	RDX	ug/L	10	0.0822 - 0.5000	0.32	0.32					0.61	
MET	Aluminum (total)	ug/L	40	45.4000 - 200.0000	59.6	397					3649.87	
MET	Aluminum_FILT	ug/L	29	45.4000 - 200.0000	49.2	50.2					NA	
MET	Barium (total)	ug/L	80	200.0000 - 200.0000	74.1	967	271.995	NON PARAMETRIC	734.89		255.50	Yes
MET	Barium_FILT	ug/L	71	200.0000 - 200.0000	76.2	806					NA	
MET	Calcium (total)	ug/L	100	0.0000 - 0.0000	58700	189000					NA	
MET	Calcium_FILT	ug/L	100	0.0000 - 0.0000	57500	160000					NA	
MET	Chromium (total)	ug/L	10	0.2360 - 10.0000	1.6	1.6					10.95	
MET	Cobalt_FILT	ug/L	14	0.8980 - 50.0000	1.13	1.13					NA	
MET	Copper (total)	ug/L	10	1.9000 - 25.0000	12.5	12.5					146.00	
MET	Iron (total)	ug/L	60	22.9000 - 30.0000	58.4	450					1094.99	
MET	Magnesium (total)	ug/L	100	0.0000 - 0.0000	30100	108000					NA	
MET	Magnesium_FILT	ug/L	100	0.0000 - 0.0000	30400	96300					NA	
MET	Manganese (total)	ug/L	100	0.0000 - 0.0000	10.2	83.8					87.60	
MET	Manganese_FILT	ug/L	100	0.0000 - 0.0000	12.9	57.6					NA	
MET	Mercury (total)	mg/L	10	0.0584 - 0.200	0.091	0.091					1.09	
MET	Potassium (total)	ug/L	100	0.0000 - 0.0000	10800	49600					NA	
MET	Potassium_FILT	ug/L	100	0.0000 - 0.0000	11100	44700					NA	
MET	Sodium (total)	ug/L	100	0.0000 - 0.0000	35700	368000					NA	
MET	Sodium_FILT	ug/L	100	0.0000 - 0.0000	41600	331000					NA	
MET	Thallium (total)	ug/L	20	3.0000 - 14.1000	6.9	10.1	4.78	Normal	6.53		0.24	Yes
MET	Thallium_FILT	ug/L	14	4.8000 - 14.1000	6.4	6.4					NA	
MET	Zinc (total)	ug/L	30	1.4600 - 5.0000	11.8	67.6					1094.99	
MET	Zinc_FILT	ug/L	29	1.4600 - 2.6000	23	42.8					NA	

Table 2-1 Continued.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	BKG	Region 9 Residential PRG	COPCs
SVO	2-Methylnaphthalene	ug/L	20	0.8700 - 10.0000	4.6	5.47	2.42	NON PARAMETRIC	5.195		0.62	Yes
SVO	bis(2-Ethylhexyl)phthalate	ug/L	10	0.8000 - 10.0000	5.8	5.8	1.88575	Gamma	3.51		4.80	Yes
SVO	Naphthalene	ug/L	30	0.5400 - 10.0000	0.7	5.53	2.33	NON PARAMETRIC	5.3		0.62	Yes
SVO	Phenol	ug/L	10	0.8200 - 10.0000	3.1	3.1					1094.99	
VOC	Acetone	ug/L	25	1.7300 - 2.0000	22	36					547.50	
VOC	Benzene	ug/L	80	5.0000 - 200.0000	0.763	120	30.9	Gamma	80.17		0.35	Yes
VOC	Carbon Disulfide	ug/L	50	0.1180 - 200.0000	0.45	4.2					104.29	
VOC	Chloromethane	ug/L	10	0.1420 - 400.0000	11.4	11.4					15.82	
VOC	Cyclohexane	ug/L	100	0.0000 - 0.0000	16.7	160					1034.17	
VOC	Ethylbenzene	ug/L	80	5.0000 - 200.0000	0.353	31					133.99	
VOC	Isopropylbenzene (Cumene)	ug/L	83	0.1010 - 0.1010	0.423	7.6					65.82	
VOC	Methylcyclohexane	ug/L	100	0.0000 - 0.0000	7.16	62					521.72	
VOC	Methylene Chloride	ug/L	40	0.1280 - 0.9000	2.1	160	17.46	Lognormal	160		4.28	Yes
VOC	Tetrachloroethene (PCE)	ug/L	20	0.1410 - 200.0000	0.42	0.5	10.5	NON PARAMETRIC	0.5		0.10	Yes
VOC	Toluene	ug/L	90	5.0000 - 5.0000	1.28	68					72.34	
VOC	Xylenes, Total	ug/L	80	5.0000 - 200.0000	2.56	260	60.6	Gamma	147.8		20.57	Yes

Table 2-1 Continued.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	BKG	Region 9 Residential PRG	COPCs
Shallow Groundwater												
GC2	Nitrogen, Nitrate (as N)	mg/L	30	0.005 - 0.100	0.062	0.076	0.0647				1000.00	
GC2	Sulfate (as SO4)	mg/L	100	0.0000 - 0.0000	37.0000	268					NA	
MET	Aluminum (total)	ug/L	40	45.4000 - 200.0000	103	11600		NON PARAMETRIC	11600		3649.87	Yes
MET	Arsenic (total)	ug/L	30	3.0000 - 10.0000	8.1	12.1		NON PARAMETRIC	12.1		0.04	Yes
MET	Arsenic_FILT	ug/L	17	4.5900 - 10.0000	12.5	12.5					NA	
MET	Barium (total)	ug/L	80	200.0000 - 200.0000	55.3	237					255.50	
MET	Barium_FILT	ug/L	67	200.0000 - 200.0000	53.4	198					NA	
MET	Calcium (total)	ug/L	100	0.0000 - 0.0000	88800	205000					NA	
MET	Calcium_FILT	ug/L	100	0.0000 - 0.0000	89600	164000					NA	
MET	Chromium (total)	ug/L	20	0.2360 - 10.0000	0.695	22.8		NON PARAMETRIC	22.8		10.95	Yes
MET	Cobalt (total)	ug/L	30	0.8980 - 50.0000	1.66	2.6					73.00	
MET	Cobalt_FILT	ug/L	50	0.8980 - 50.0000	1.03	2.79					NA	
MET	Copper (total)	ug/L	10	2.5500 - 25.0000	33.6	33.6					146.00	
MET	Copper_FILT	ug/L	17	2.5500 - 25.0000	44.2	44.2					NA	
MET	Iron (total)	ug/L	50	22.9000 - 100.0000	38.2	27300		?NOT normal	27300		1094.99	Yes
MET	Iron_FILT	ug/L	33	22.9000 - 100.0000	39.9	64.9					NA	
MET	Lead (total)	ug/L	10	1.5000 - 3.0000	16.6	16.6		NON PARAMETRIC	16.6		0.00	Yes
MET	Magnesium (total)	ug/L	100	0.0000 - 0.0000	24900	56500					NA	
MET	Magnesium_FILT	ug/L	100	0.0000 - 0.0000	25400	54700					NA	
MET	Manganese (total)	ug/L	80	0.4190 - 3.0000	51.3	816		?NOT normal	816		87.60	Yes
MET	Manganese_FILT	ug/L	100	0.0000 - 0.0000	0.567	295					NA	
MET	Mercury (total)	ug/L	10	0.0584 - 0.2000	0.091	0.091					1.09	
MET	Nickel (total)	ug/L	10	0.7450 - 40.0000	5.2	5.2					73.00	
MET	Nickel_FILT	ug/L	17	0.7450 - 40.0000	3.06	3.06					NA	
MET	Potassium (total)	ug/L	70	500.0000 - 5000.0000	469	2410					NA	
MET	Potassium_FILT	ug/L	50	175.0000 - 5000.0000	470	2330					NA	
MET	Sodium (total)	ug/L	100	0.0000 - 0.0000	6120	36300					NA	
MET	Sodium_FILT	ug/L	100	0.0000 - 0.0000	6290	36000					NA	
MET	Zinc (total)	ug/L	90	20.0000 - 20.0000	11.5	128					1094.99	
MET	Zinc_FILT	ug/L	100	0.0000 - 0.0000	13.8	109					NA	
VOC	Cyclohexane	ug/L	13	0.0999 - 0.6000	0.44	0.44					1034.17	
VOC	Methylcyclohexane	ug/L	25	0.1070 - 0.5000	0.49	0.6					521.72	
VOC	Methylene Chloride	ug/L	10	0.1280 - 1.0000	0.49	0.49					4.28	

Table 2-1 Continued.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	BKG	Region 9 Residential PRG	COPCs
Surface Water												
MET	Aluminum	ug/L	38	100. - 100.	118	404	171	Non Parametric - Indeterminate	404		3649.87	
MET	Barium	ug/L	100		31	43.1	36.6	Normal	38.3		255.50	
MET	Calcium	ug/L	100		88600	116000	104000	Normal	109000		NA	
MET	Iron	ug/L	100		62.6	644	220	Lognormal	251		1094.99	
MET	Magnesium	ug/L	100		17300	26300	22400	Normal	23600		NA	
MET	Manganese	ug/L	100		19	147	44.4	ProUCL: Approximate Gamma	52.6		87.60	Yes
MET	Potassium	ug/L	77	500. - 500.	536	1820	867	Lognormal - ROS	975		NA	
MET	Sodium	ug/L	100		2530	5490	3750	Normal	4180		NA	
SVO	bis(2-Ethylhexyl)phthalate	ug/L	77	1.10 - 1.10	2	3	0.0394	Non Parametric - Kaplan-Meier	0.354		4.80	
SVO	Naphthalene	ug/L	62	1.00 - 1.10	0.034	0.043	2.5	Non Parametric - Kaplan-Meier	0.043		0.62	
VOC	1,1,1-Trichloroethane	ug/L	54	0.15 - 0.30	0.19	3.8	0.693	Normal - ROS	1.28		317.17	
VOC	1,1-Dichloroethane	ug/L	8	0.15 - 0.30	0.89	0.89	0.155	Poisson	0.89		81.11	

Table 2-1 Continued.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	BKG	Region 9 Residential PRG	COPCs
Sediment												
GC2	Cyanide	mg/Kg	10	0.160 - 0.370	0.42	0.42	0.42	Non Parametric - Indeterminate	0.42		122.21	
HE	HMX	mg/Kg	8	0.0273 - 0.095	0.12	0.12		Poisson	0.12		305.52	
HE	RDX	mg/Kg	8	0.035 - 0.095	0.098	0.098	0.098	Poisson	0.098		4.42	
MET	Aluminum	mg/Kg	100		5730	10200	8216	ProUCL: Normal	8936	15500	7614.20	Yes
MET	Arsenic	mg/Kg	92	1.16	2.53	15.4	8.23	ProUCL: Normal	10.3	36.5	0.39	Yes
MET	Barium	mg/Kg	100		41.6	79	67.8	Non Parametric	72.7	826	537.49	
MET	Beryllium	mg/Kg	92	0.570 - 0.570	0.32	0.66	0.48	Normal	0.541	1	15.44	
MET	Cadmium	mg/Kg	38	0.2900 - 0.5700	0.33	0.699		NON PARAMETRIC	0.699		3.70	
MET	Calcium	mg/Kg	100	0.0000 - 0.0000	28700	77700		NORMAL	77700		NA	
MET	Chromium	mg/Kg	100		9	16.3	13.7	Normal	14.7	29	30.10	
MET	Cobalt	mg/Kg	100		4.9	9.8	7.91	Normal	8.67	116	902.89	
MET	Copper	mg/Kg	100		12.3	24.6	18.9	Normal	22.2	56.2	312.86	
MET	Iron	mg/Kg	100		12400	23300	18731	ProUCL: Normal	20528	234000	2346.32	Yes
MET	Lead	mg/Kg	100		12.6	84.1	26	ProUCL: 95% Chebyshev (Mean, Sd)	52.5	48.6	40.00	Yes
MET	Magnesium	mg/Kg	100	0.0000 - 0.0000	5800	18500		NORMAL	18500		NA	
MET	Manganese	mg/Kg	100		207	586	399	ProUCL: Normal	462	3506	176.24	Yes
MET	Mercury	mg/Kg	100		0.028	0.084	0.044	Lognormal	0.049	0.1	2.35	
MET	Nickel	mg/Kg	100		13.7	26	19.6	Normal	23.1	55.1	156.43	
MET	Potassium	mg/Kg	100		649	1830	1050	Normal	1270	3390	NA	
MET	Silver	mg/Kg	23	0.260 - 0.570	0.222	0.355	0.306	Non Parametric - Kaplan-Meier	0.355	11.1	39.11	
MET	Sodium	mg/Kg	23	264.0000 - 568.0000	71.6	105		NON PARAMETRIC	105		NA	
MET	Thallium	mg/Kg	15	0.33 - 1.1	3.56	5.33	0.889	Non Parametric - Indeterminate	3.7		0.52	Yes
MET	Vanadium	mg/Kg	100		14.7	25.7	20.6	ProUCL: Normal	22.4	40.9	7.82	Yes
MET	Zinc	mg/Kg	100		35.6	99.6	63.9	Normal	71.4	322	2346.32	
PCB	PCB-1254	ug/Kg	8	5.4 - 22.4	473	473	40.6	Poisson	473		221.86	Yes
PCB	PCB-1260	ug/Kg	77	5.8 - 6.2	8.6	1130	133	Non Parametric - Kaplan-Meier	135		221.86	Yes

Table 2-1 Continued.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	BKG	Region 9 Residential PRG	COPCs
SVO	Acenaphthylene	ug/Kg	15	42.4 - 120.	91.8	387	190	Non Parametric - Indeterminate	387		NA	
SVO	Anthracene	ug/Kg	8	30.9 - 120.	197	197	197	Poisson	197		2189612.06	
SVO	Benzaldehyde	ug/Kg	100		97	325	238	Normal	325		611030.97	
SVO	Benzo(a)anthracene	ug/Kg	31	22.3 - 72.0	45	298	167	Non Parametric - Indeterminate	298		621.46	
SVO	Benzo(a)pyrene	ug/Kg	23	30.2 - 72	130	510	101	Non Parametric - Indeterminate	246		62.15	Yes
SVO	Benzo(b)fluoranthene	ug/Kg	54	28.8 - 72.0	29	619	151	Non Parametric - Indeterminate	619		621.46	
SVO	Benzo(g,h,i)perylene	ug/Kg	15	27.4 - 72.0	192	230	211	Non Parametric - Indeterminate	230		NA	
SVO	Benzo(k)fluoranthene	ug/Kg	38	32.7 - 72.0	33	626	192	Non Parametric - Indeterminate	626		6214.57	
SVO	Benzoic acid	ug/Kg	33	556. - 872.	1220	1220	1220	Non Parametric - Indeterminate	1220		100000000.00	
SVO	bis(2-Ethylhexyl)phthalate	ug/Kg	15	130.0000 - 695.0000	170	260		NON PARAMETRIC	260		34741.47	
SVO	Chrysene	ug/Kg	46	17.7 - 72.0	40	520	169	Non Parametric - Indeterminate	520		62145.67	
SVO	Fluoranthene	ug/Kg	69	19.2 - 72.0	35	1180	228	Non Parametric - Indeterminate	1180		229361.02	
SVO	Indeno(1,2,3-cd)pyrene	ug/Kg	15	28.8 - 72.0	140	270	205	Non Parametric - Indeterminate	270		621.46	
SVO	Phenanthrene	ug/Kg	15	21.5 - 72.0	150	222	186	Non Parametric - Indeterminate	222		NA	
SVO	Pyrene	ug/Kg	62	16.6 - 72.0	36	504	138	Lognormal - ROS	141		231595.11	
VOC	2-Butanone (Methyl ethyl ketone)	ug/Kg	15	1.1200 - 3.9000	36.1	62.5		NON PARAMETRIC	62.5		2231119.78	
VOC	Acetone	ug/Kg	92	1.65 - 1.65	6.4	295	66.5	Non Parametric - Kaplan-Meier	66.8		1412657.06	
VOC	Benzene	ug/Kg	100	0.0000 - 0.0000	0.78	5.86		NORMAL	5.86		643.15	
VOC	Carbon Disulfide	ug/Kg	54	1.4100 - 2.0000	1.9	48		?NOT normal	48		35534.04	
VOC	Cyclohexane	ug/Kg	92	0.6200 - 0.6200	2.6	13		NORMAL	13		140000.00	
VOC	Methylcyclohexane	ug/Kg	100	0.0000 - 0.0000	3.2	17		NORMAL	17		259105.52	
VOC	Toluene	ug/Kg	100	0.0000 - 0.0000	1	12.8		NOT normal	12.8		520000.00	
VOC	Xylenes, Total	ug/Kg	31	0.7700 - 1.9000	2.18	8.2		NON PARAMETRIC	8.2		27063.05	
VOC	Ethylbenzene	ug/Kg	38	0.8200 - 1.5000	0.91	2.96		NON PARAMETRIC	2.96		395000.00	

1 Toxicity screening levels are obtained from the EPA Region 9 PRG tables for residential exposures and tap water and are concentrations equal to either an incremental lifetime cancer risk (ILCR) of 1E-6 or a noncancer hazard quotient (HQ) of 0.1.

mg/kg miligram/kilogram
ug/kg microgram/kilogram
mg/L miligram/Liter
ug/L microgram/Liter
BKG Background Concentration
UCL Upper Confidence Limit - Calculated based on the recommended distribution.

EPC Exposure Point Concentration - Lesser of the UCL or the maximum detected concentration.
PRG Preliminary Remediation Goal - PRGs based on noncancer effects were multiplied by 0.1.
COPC Contaminant of Potential Concern
nc noncancer
ca cancer

Table 3-1
Receptor/Exposure Scenarios
Acid Area 3
Plum Brook Ordnance Works, Sandusky, Ohio

Source Medium	Model	Exposure Medium	Exposure Pathway
	Groundskeeper		
Surface soil	None	Soil	Incidental ingestion Dermal contact
	Volatilization from soil	Ambient air	Inhalation
	Dust emissions based on activity	Ambient air	Inhalation
Total soil	Not quantified[a]		
Groundwater	Not quantified[a]		
Surface water	Not quantified[b]		
Sediment	Not quantified[b]		
	Indoor Worker		
Surface soil	None	Soil	Incidental ingestion Dermal contact
Subsurface soil	Volatilization from soil	Indoor air	Inhalation
Total soil	Not quantified[a]		
Groundwater	None	Groundwater	Ingestion Dermal contact
Surface water	Not quantified[a]		
Sediment	Not quantified[a]		
	Construction Worker		
Total soil	None	Soil	Incidental ingestion Dermal contact
	Volatilization from soil	Ambient air	Inhalation
	Dust emissions based on activity	Ambient air	Inhalation
Groundwater	Not quantified[b]		
Surface water	None	Surface water	Incidental ingestion Dermal contact
	Volatilization from water	Ambient air	Inhalation
Sediment	None	Sediment	Incidental ingestion Dermal contact

Table 3-1 (continued)

Source Medium	Model	Exposure Medium	Exposure Pathway
	On-Site Resident		
Total soil	None	Soil	Incidental ingestion Dermal contact
	Volatilization from soil	Ambient air	Inhalation
	Dust emissions based on wind erosion	Ambient air	Inhalation
Subsurface soil	Volatilization from soil	Indoor air	Inhalation
Groundwater	None	Groundwater	Ingestion Dermal contact
	Volatilization from groundwater	Ambient air	Inhalation
Surface water	None	Surface water	Incidental Ingestion Dermal contact
	Volatilization from water	Ambient air	Inhalation
Sediment	None	Sediment	Incidental ingestion Dermal contact
	Hunter		
Surface soil	None	Soil	Incidental ingestion Dermal contact
	Dust, volatilization	Ambient air	Inhalation
	Bio uptake	Venison	Venison consumption
Groundwater	Not quantified[a]		

a There is no plausible pathway for exposure to this medium.

b Although contact with this medium is possible, exposure would be sporadic rather than continuous or predictable. Such exposures do not lend themselves to evaluation under the chronic toxicity paradigm used in a baseline risk assessment. Although theoretically complete, this pathway is not quantified as explained in text.

Table 3-2
Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors
Acid Area 3, Plum Brook Ordnance Works, Sandusky, Ohio

Pathway Variable	Grounds-keeper	Construction Worker	On-Site Resident	Indoor Worker	Hunter
General Variables Used in All Intake Models					
Body weight (BW), kg	70[a]	70[a]	Child: 15[b] Adult: 70[a]	70[a]	Child: 15[b] Adult: 70[a]
Averaging time, noncancer (AT), day_{sd}	9125	183	Child: 2190 Adult: 8760	9125	Child: 2190 Adult: 10950
Averaging time, cancer (AT), day_{se}	25550	25550	25550	25550	25550
Inhalation of VOCs and Resuspended Dust from Surface Soil, Total Soil or Subsurface Soil					
Fraction exposed to contaminated medium(FI_a), unitless	1[c]	1[c]	1[c]	NA	NA
Inhalation rate (IR_a), m^3/day	20[a]	20[a]	Child: 10[b] Adult: 20[a]	NA	NA
Exposure frequency (EF), days/year	250[a]	250[a]	350[a]	NA	NA
Exposure duration (ED), years	25[a]	0.5[b]	Child: 6[b] Adult: 24[b]	NA	NA
Inhalation of VOCs in Indoor Air from Subsurface Soil					
Fraction exposed to contaminated medium(FI_a), unitless	NA	NA	1[c]	1[c]	NA
Inhalation rate (IR_a), m^3/day	NA	NA	Child: 6.8[c] Adult: 13.7[c]	20[a]	NA
Exposure frequency (EF), days/year	NA	NA	350[a]	250[a]	NA
Exposure duration (ED), years	NA	NA	Child: 6[b] Adult: 24[b]	25[a]	NA
Incidental Ingestion of Soil					
Fraction exposed to contaminated medium(FI_{so}), unitless	1[c]	1[c]	0.9[c]	1[c]	1[c]
Soil incidental ingestion rate (IR_{so}), mg/day	100[a]	290[c]	Child: 200[b] Adult: 100[a]	50[a]	Child: NA Adult: 100[a]
Exposure frequency (EF), days/year	250[a]	250[a]	350[a]	250[a]	14[c]
Exposure duration (ED), years	25[a]	0.5[c]	Child: 6[b] Adult: 24[b]	25[a]	30[a]

Table 3-2 (Continued)

Pathway Variable	Grounds-keeper	Construction Worker	On-Site Resident	Indoor Worker	Hunter
Incidental Ingestion of Sediment					
Fraction exposed to contaminated medium(FI_{sd}), unitless	NA	1[c]	0.1[c]	NA	NA
Sediment incidental ingestion rate (IR_{sd}),mg/day	NA	290[c]	Child: 200[b] Adult: 100[a]	NA	NA
Exposure frequency (EF), days/year	NA	250[a]	350[a]	NA	NA
Exposure duration (ED), years	NA	0.5[c]	Child: 6[b] Adult: 24[b]	NA	NA
Dermal Contact with Soil					
Fraction exposed to contaminated medium (FI_{so}), unitless	1[c]	1[c]	0.9[c]	NA	1[c]
Body surface area exposed to soil (SA_{so}), cm^2	11,300[f]	11,300[f]	Child: 1750[g] Adult: 4550[g]	NA	Child: NA Adult: 4550[g]
Soil-to-skin adherence factor (AF_{so}),mg/cm^2	0.009[f]	0.08[f]	0.2[g]	NA	0.2[g]
Dermal absorption factor (ABS), unitless	csv	csv	csv	NA	csv
Exposure frequency (EF), days/year	250[a]	250[a]	350[a]	NA	14[c]
Exposure duration (ED), years	25a	0.5[c]	Child: 6[b] Adult: 24[b]	NA	30[a]
Dermal Contact with Sediment					
Fraction exposed to contaminated medium(FI_{sd}), unitless	NA	1[c]	0.1[c]	NA	NA
Body surface area exposed to sediment(SA_{sd}), cm^2	NA	3100[f]	Child: 1750[g] Adult: 4550[g]	NA	NA
Sediment-to-skin adherence factor (AF_{sd}),mg/cm^2	NA	0.24[f]	0.2[g]	NA	NA
Dermal absorption factor (ABS), unitless	NA	csv	csv	NA	NA
Exposure frequency (EF), days/year	NA	250[a]	350[a]	NA	NA
Exposure duration (ED), years	NA	0.5[c]	Child: 6[b] Adult: 24[b]	NA	NA

Table 3-2 (Continued)

Pathway Variable	Grounds-keeper	Construction Worker	On-Site Resident	Indoor Worker	Hunter
Dermal Contact with Surface Water					
Body surface area exposed to surface water (SA_{sw}), cm^2	NA	3100[f]	Child: 2100[g] Adult: 5450[g]	NA	NA
Permeability coefficient (PC), cm/hour	NA	csv	csv	NA	NA
Exposure time (ET_{sw}), hour/day	NA	4[c]	3[c]	NA	NA
Exposure frequency (EF), days/year	NA	250[a]	52[c]	NA	NA
Exposure duration (ED), years	NA	0.5[c]	Child: 6[b] Adult: 24[b]	NA	NA
Venison Consumption					
Venison ingestion rate (IR_v), kg/day	NA	NA	NA	NA	Child: 0.005[c] Adult: 0.013[c]
Exposure frequency (EF), days/year	NA	NA	NA	NA	350[a]
Exposure duration (ED), years	NA	NA	NA	NA	Child: 6[b] Adult: 30[a]

a U.S. Environmental Protection Agency (EPA), 1991, Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors, Interim Final, Office of Solid Waste and Emergency Response, OSWER Directive: 9285.603.

b U.S. Environmental Protection Agency (EPA), 1999, *EPA Region 9: Preliminary Remediation Goals (PRGs) 1999*, 3 December, on-line.

c Assumed; see text.

d Calculated as the product of ED (years) x 365 days/year.

e Calculated as the product of 70 years (assumed human lifetime) x 365 days/year.

f U.S. Environmental Protection Agency (EPA), 1997b, *Exposure Factors Handbook*, Final, National Center for Environmental Assessment, Washington, DC, EPA/600/P-95/002Fa, August.

g U.S. Environmental Protection Agency (EPA), 1992b, *Dermal Exposure Assessment: Principles and Applications*, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91/011B, including Supplemental Guidance dated August 18, 1992.

NA = not applicable to this receptor; csv = chemical-specific value.

Table 3-3
Variables Used to Estimate Potential Chemical Intake and Contact Rates from Groundwater
Acid Area 3 Plum Brook Ordnance Works, Sandusky, Ohio

Pathway Variable	On-site Worker	Resident
General Variables		
Exposure duration (ED), years	25[a]	Child: 6[b] Adult: 24[b]
Body weight (BW), kg	70[a]	Child: 15[b] Adult: 70[a]
Averaging time, noncancer (AT), days[c]	9125	Child: 2190 Adult: 8760
Averaging time, cancer (AT), days[c]	25550	25550
Inhalation of VOCs from Groundwater		
Exposure time (ET), hours/day	NA	24[d]
Inhalation rate (IR_a), m^3/hour	NA	Child: 0.416[b] Adult: 0.833[b]
Exposure frequency (EF), days/year	250[a]	350[a]
Drinking Water Ingestion of Groundwater		
Fraction exposed to contaminated medium (FI_{gw}), unitless	1[f]	1[f]
Drinking water ingestion rate (IR_{gw}), L/day	1[a]	Child: 1[b] Adult: 2[a]
Exposure frequency (EF), days/year	250[a]	350[a]
Dermal Contact with Groundwater		
Fraction exposed to contaminated medium (FI_{gw}), unitless	1[e]	1[e]
Body surface area exposed to water (Sa_{gw}), cm^2	3300[g]	Child: 6600[f] Adult: 20000[f]
Permeability coefficient (PC), cm/hour	csv	csv
Exposure time (ET_{gw}), hours/day	1[f]	Child: 0.333[g] Adult: 0.2[d]
Exposure frequency (EF), days/year	250[a]	350[a]

cm - Centimeter.
cm^2 - Square centimeter.
csv - Chemical-specific value.
kg - Kilogram.
L - Liters.
m^3 - Cubic meters.
NA - Not applicable to this receptor.
VOC - Volatile organic compound.

[a] U.S. Environmental Protection Agency (EPA), 1991a, *Risk Assessment Guidance for Superfund Volume 1: Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors* , Interim Final, Office of Solid Waste and Emergency Response, OSWER Directive: 9285.603.

[b] U.S. Environmental Protection Agency (EPA), 2004c, *User's Guide and Background Technical Document for EPA Region 9 Preliminary Remediation Goals (PRG) Table* , Region 9, San Francisco, California, October.

[c] Calculated as the product of ED (years) x 365 days/year.

[d] The *Exposure Factors Handbook* (see reference g) indicates that the 90th percentile for the amount of

time spent at a residence is more than 23 hours per day.

[e] Assumed; see text.

[f] U.S. Environmental Protection Agency (EPA), 2004a, *Risk Assessment Guidance for Superfund Volume 1: Human Health Evaluation Manual (Part E - Supplemental Guidance for Dermal Risk Assessment)* , Final, Office of Superfund Remediation and Technology Innovation, Washington, D.C., July, EPA/540/R-99/005.

[g] U.S. Environmental Protection Agency, (EPA), 1997a, *Exposure Factors Handbook* , Final, National Center for Environmental Assessment, Washington, D.C., EPA/600/P-95/002Fa, August.

References

Foster, S. A. and P. C. Chrostowski, 1987, "Inhalation Exposures to Volatile Organic Contaminants in the Shower," Presentation at the ***80th Annual Meeting of the Air Pollution Control Association***, June 21-28.

Ohio Environmental Protection Agency (OEPA), 2004, e-mail correspondence from L. Moore (OEPA Risk Assessor) to L. Long (USACE Risk Assessor), December 15.

U.S. Environmental Protection Agency (EPA), 2004a, ***Risk-Based Concentration Table***, memorandum from Jennifer Hubbard (Region 3 Toxicologist) to RBC Table users, Philadelphia, Pennsylvania, April, <http://www.epa.gov/reg3hwmd/risk/human/index.htm>.

U.S. Environmental Protection Agency (EPA), 2004b, ***User's Guide and Background Technical Document for Region 9 Preliminary Remediation Goals (PRG) Table***, Region 9, San Francisco, California, October, <http://www.epa.gov/region09/waste/sfund/prg/files/04usersguide.pdg>.

U.S. Environmental Protection Agency (EPA), 1995, ***Supplemental Guidance to RAGS: Region 4 Bulletins Human Health Risk Assessment***, Waste Management Division, Atlanta, Georgia, November.

U.S. Environmental Protection Agency (EPA), 1991b, ***Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim***, Office of Emergency and Remedial Response, Washington, D.C., December (EPA/540/R-92/003).

Table 4-1. Toxicity Values Used in the BHHRA.

Analyte	Reference Doses			Cancer Slope Factors		
	Oral	Dermal	Inhalation	Oral	Dermal	Inhalation
1,1,2-Trichloroethane	4.00E-03	4.00E-03	4.00E-03	5.70E-02	5.70E-02	5.60E-02
1,3-Dinitrobenzene	1.00E-04	1.00E-04	1.00E-04	--	--	--
2-Methylnaphthalene	2.00E-02	2.00E-02	8.57E-04	--	--	--
2-Nitrotoluene	1.00E-02	1.00E-02	--	2.30E-01	2.30E-01	--
Aluminum	1.00E+00	1.00E+00	1.43E-03	--	--	--
Arsenic	3.00E-04	3.00E-04	--	1.50E+00	1.50E+00	1.51E+01
Barium	2.00E-01	2.00E-01	2.00E-01	--	--	--
Benzene	4.00E-03	4.00E-03	8.57E-03	5.50E-02	5.50E-02	2.70E-02
Benz[a]anthracene	--	--	--	7.30E-01	7.30E-01	3.10E-01
Benzo[a]pyrene	--	--	--	7.30E+00	7.30E+00	3.10E+00
Benzo[b]fluoranthene	--	--	--	7.30E-01	7.30E-01	3.10E-01
Benzo[k]fluoranthene	--	--	--	7.30E-02	7.30E-02	3.10E-02
Bis(2-ethylhexyl)phthalate	2.00E-02	2.00E-02	2.00E-02	1.40E-02	1.40E-02	1.40E-02
Bromomethane	1.40E-03	1.40E-03	1.43E-03	--	--	--
Chlorobenzene	2.00E-02	2.00E-02	1.43E-02	--	--	--
Chloromethane	--	--	2.57E-02	--	--	6.30E-03
Chromium	3.00E-03	3.00E-03	2.85E-05	--	--	2.94E+02
Cyanide	2.00E-02	2.00E-02	--	--	--	--
Dibenz[ah]anthracene	--	--	--	7.30E+00	7.30E+00	3.10E+00
Indeno[1,2,3-cd]pyrene	--	--	--	7.30E-01	7.30E-01	3.10E-01
Iron	7.00E-01	7.00E-01	--	--	--	--
Lead	--	--	--	--	--	--
Manganese	4.67E-02	4.67E-02	1.40E-05	--	--	--
Methylene chloride	6.00E-02	6.00E-02	8.57E-01	7.50E-03	7.50E-03	1.65E-03
Naphthalene	2.00E-02	2.00E-02	8.57E-04	--	--	--
Nickel	2.00E-02	2.00E-02	--	--	--	--
Nitrobenzene	5.00E-04	5.00E-04	5.71E-04	--	--	--
N-Nitroso di-n-propylamine	--	--	--	7.00E+00	7.00E+00	7.00E+00
PCB-1254	2.00E-05	2.00E-05	2.00E-05	2.00E+00	2.00E+00	2.00E+00
PCB-1260	--	--	--	2.00E+00	2.00E+00	2.00E+00
Tetrachloroethene (PCE)	1.00E-02	1.00E-02	1.14E-01	5.40E-01	5.40E-01	2.07E-02
Thallium	7.00E-05	7.00E-05	--	--	--	--
Trichloroethylene (TCE)	3.00E-04	3.00E-04	1.14E-02	4.00E-01	4.00E-01	4.00E-01
Vanadium	5.00E-03	5.00E-03	--	--	--	--
Xylenes, total	2.00E-01	2.00E-01	2.86E-02	--	--	--

-- = Toxicity value not available

Table 5-1. Summary of Noncancer Hazards and Cancer Risk Estimates from Potential Exposures at Acid Area 3, Plum Brook Ordnance Works, Sandusky, OH

Groundskeeper Risks From Exposure to Surface Soil		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	3.E-01	2.E-05
Dermal Contact	3.E-02	2.E-06
Inhalation	2.E-03	2.E-09
Total	4.E-01	2.E-05

Adult Hunter Risks From Exposure to Surface Soil		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	2.E-02	1.E-06
Dermal Contact	1.E-02	1.E-06
Inhalation	NA	NA
Total	3.E-02	2.E-06

Adult Hunter Risks From Ingestion of Venison		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	3.E-04	2.E-09
Dermal Contact	NA	NA
Inhalation	NA	NA
Total	3.E-04	2.E-09

Child Risks From Ingestion of Venison		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	5.E-04	9.E-10
Dermal Contact	NA	NA
Inhalation	NA	NA
Total	5.E-04	9.E-10

Construction Worker Risks From Exposure to Surface Soil		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	2.E+00	2.E-06
Dermal Contact	5.E-01	7.E-07
Inhalation	3.E-03	8.E-11
Total	3.E+00	3.E-06

Construction Worker Risks From Exposure to Subsurface Soil		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	1.E+00	5.E-07
Dermal Contact	2.E-02	5.E-08
Inhalation	NA	NA
Total	1.E+00	6.E-07

Construction Worker Risks From Exposure to Surface Water		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	NA	NA
Dermal Contact	1.E-04	NA
Inhalation	NA	NA
Total	1.E-04	NA

Construction Worker Risks From Exposure to Sediment		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	5.E-01	1.E-07
Dermal Contact	1.E-02	2.E-08
Inhalation	NA	NA
Total	5.E-01	1.E-07

Indoor Worker Risks From Exposure to Groundwater		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	1.E+00	4.E-05
Dermal Contact	3.E-02	2.E-06
Inhalation	NA	NA
Total	1.E+00	4.E-05

Indoor Worker Risks From Exposure to Surface Soil		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	2.E-01	9.E-06
Dermal Contact	NA	NA
Inhalation	NA	NA
Total	2.E-01	9.E-06

Table 5-1. Continued

Adult Residential Risks From Exposure to Groundwater		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	4.E+00	1.E-04
Dermal Contact	9.E-02	6.E-06
Inhalation	2.E-01	5.E-06
Total	4.E+00	1.E-04

Child Residential Risks From Exposure to Groundwater		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	9.E+00	7.E-05
Dermal Contact	2.E-01	3.E-06
Inhalation	4.E-01	3.E-06
Total	9.E+00	7.E-05

Adult Residential Risks From Exposure to Surface Soil		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	9.E-03	2.E-05
Dermal Contact	3.E-01	2.E-05
Inhalation	2.E-03	3.E-09
Total	3.E-01	4.E-05

Child Residential Risks From Exposure to Surface Soil		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	4.E+00	5.E-05
Dermal Contact	6.E-01	9.E-06
Inhalation	5.E-03	1.E-09
Total	5.E+00	6.E-05

Adult Residential Risks From Exposure to Subsurface Soil		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	5.E-03	5.E-06
Dermal Contact	1.E-02	1.E-06
Inhalation	NA	NA
Total	1.E-02	7.E-06

Child Residential Risks From Exposure to Subsurface Soil		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	2.E+00	1.E-05
Dermal Contact	2.E-02	7.E-07
Inhalation	NA	NA
Total	2.E+00	1.E-05

Adult Recreational Risks From Exposure to Surface Water		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	NA	NA
Dermal Contact	4.E-05	NA
Inhalation	NA	NA
Total	4.E-05	NA

Child Recreational Risks From Exposure to Surface Water		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	NA	NA
Dermal Contact	7.E-05	NA
Inhalation	NA	NA
Total	7.E-05	NA

Adult Recreational Risks From Exposure to Sediment		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	2.E-02	9.E-07
Dermal Contact	5.E-03	4.E-07
Inhalation	NA	NA
Total	3.E-02	1.E-06

Child Recreational Risks From Exposure to Sediment		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	2.E-01	2.E-06
Dermal Contact	1.E-02	2.E-07
Inhalation	NA	NA
Total	2.E-01	2.E-06

APPENDIX A

DERMAL ABSORBED DOSE CALCULATIONS

Cancer Dermal Absorbed Dose Calculations
for Adult Residential Exposures to Organics in Acid Area 3 Groundwater.

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells I8-I18
The default exposure conditions used in this spreadsheet assume exposure duration for carcinogenic effects of chemicals in water through showering

Concentration (mg/L*L/1000 cm3):	Conc =	1E-03 mg/cm3 (default value for purpose of illustration)
Input site specific concentrations in Column marked "Conc"		= 1 mg/L (1 pj = 1 ug/cm3 = 1000 ppb)
Area exposed (cm2):	SA =	20000 cm2
Event time (hr/event):	t_event =	0.20 hr/event (35 minutes/event)
Event frequency (events/day):	EV =	1 event/day
Exposure frequency (days/year):	EF =	350 days/yr
Exposure duration (years):	ED =	24 years
for carcinogenic effects, ED = 30 years (used in this spreadsheet)		
for noncarcinogenic effects, ED = 9 years		
Body weight (kg):	BW =	70.0 kg
Averaging time (days):	AT =	25550 days
for carcinogenic effects, AT=70 years (25,550 days)		
for noncarcinogenic effects, AT=ED (in days)		
Skin thickness (assumed to be 10 um):	lsc =	1.00E-03 cm

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV	IR =	2000 (cm3/day = L/day * 1000 cm3/L)
Drinking (mg/day) = Conc * IR * ABSIG	ABSGI =	1.0 (assumed 100% GI absorption)

IR: Ingestion rate of drinking water
ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min) Q = 1135500.0 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data as evaluated using MLAB (Civilized Software, Bethesda, MD)
95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.
Note:

	CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp (cm/hr) predicted	Kp (cm/hr) measured	Kp 95% UCI	Special Chemicals (*) or (**)	Derm/ Drink	Chem Assess	Derm/ Total Dose	B	tau (hr)	t_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Ds/lsc)	Dsc/lsc	Dsc
17	Benzene	71432	78.1	2.13	5.9E-04	1.5E-02		3.7E-01		10%	N	0%	0.1	0.29	0.70	1.0	8.02E-05	1.5E-02	8.0E-07	7.5E-05	-3.2E+00	5.71E-04	5.71E-07
58	bis(2-Ethylhexyl)phthalate	117817	391.0	5.11	9.4E-04	2.5E-02		6.6E-01		101%	Y	1%	0.2	16.64	39.93	0.8	3.51E-06	2.5E-02	3.5E-07	3.3E-05	-5.0E+00	1.00E-05	1.00E-08
92	2-Nitrotoluene	88722	137.1	2.45		1.1E-02		7.5E-02		11%	Y	0%	0.1	0.63	1.50	1.0	1.54E-06	1.1E-02	1.7E-08	1.6E-06	-3.6E+00	2.66E-04	2.66E-07
** 139	Methylene chloride	75092	84.9	1.25	1.4E-04	3.5E-03		8.8E-02 **		2%	N	0%	0.0	0.32	0.76	1.0	1.60E-04	3.5E-03	4.0E-07	3.7E-05	-3.3E+00	5.23E-04	5.23E-07
143	2-Methylnaphthalene	91576	142.2	3.90		9.7E-02		1.2E+00		98%	Y	1%	0.4	0.67	1.60	1.0	5.20E-06	9.7E-02	5.1E-07	4.8E-05	-3.6E+00	2.49E-04	2.49E-07
143	Naphthalene	91203	128.2	3.30	1.8E-03	4.7E-02		1.2E+00		43%	Y	0%	0.2	0.56	1.34	1.0	5.30E-06	4.7E-02	2.3E-07	2.1E-05	-3.5E+00	2.99E-04	2.99E-07
** 187	Tetrachloroethene (PCE)	127184	165.8	3.40	1.3E-03	3.3E-02		8.4E-01 **		39%	Y	0%	0.2	0.91	2.18	1.0	5.00E-07	3.3E-02	2.0E-08	1.8E-06	-3.7E+00	1.84E-04	1.84E-07
209	Xylenes, total	1330207	106.2	3.15		4.9E-02		1.4E+00		39%	Y	0%	0.2	0.42	1.01	1.0	1.48E-04	4.9E-02	5.8E-06	5.5E-04	-3.4E+00	3.97E-04	3.97E-07

Noncancer Dermal Absorbed Dose Calculations
for Adult Residential Exposures to Organics in Acid Area 3 Surface Water.

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells I8-I18
The default exposure conditions used in this spreadsheet assume exposure duration for carcinogenic effects of chemicals in water through showering

Concentration (mg/L*L/1000 cm3):	Conc =	1E-03 mg/cm3 (default value for purpose of illustration)
Input site specific concentrations in Column marked "Conc"		= 1 mg/L (1 pl= 1 ug/cm3 = 1000 ppb)
Area exposed (cm2):	SA =	5450 cm2
Event time (hr/event):	t_event =	3.00 hr/event (35 minutes/event)
Event frequency (events/day):	EV =	1 event/day
Exposure frequency (days/year):	EF =	52 days/yr
Exposure duration (years):	ED =	24 years
for carcinogenic effects, ED = 30 years (used in this spreadsheet)		
for noncarcinogenic effects, ED = 9 years		
Body weight (kg):	BW =	70.0 kg
Averaging time (days):	AT =	8760 days
for carcinogenic effects, AT=70 years (25,550 days)		
for noncarcinogenic effects, AT=ED (in days)		
Skin thickness (assumed to be 10 um):	lsc =	1.00E-03 cm

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV	IR =	2000 (cm3/day = L/day * 1000 cm3/L)
Drinking (mg/day) = Conc * IR * ABSIG	ABSGI =	1.0 (assumed 100% GI absorption)

IR: Ingestion rate of drinking water
ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min) Q = 1135500.0 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data as evaluated using MLAB (Civilized Software, Bethesda, MD)
95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.
Note:

CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp (cm/hr) predicted	Kp (cm/hr) measured	Kp 95% UCI	Special Chemicals (*) or (**)	Derm/ Drink	Chem Assess	Derm/ Total Dose	B	tau (hr)	t_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Ds/lsc)	Dsc/lsc	Dsc

No Organic COPCs

Cancer Dermal Absorbed Dose Calculations
for Adult Residential Exposures to Inorganics in Acid Area 3 Groundwater.

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc =	1.00E-03	mg/cm3 (default value for purpose of illustration)
SA=	2.00E+04	cm2
t_event =	2.00E-01	hr/event (35 minutes/event)
EV =	1.00E+00	event/day
EF =	3.50E+02	days/yr
ED =	2.40E+01	years
BW =	7.00E+01	kg
AT =	2.56E+04	days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water IR = 2.00E+03 (cm3/day = L/day * 1000 cm3/L)
ABSIG: Absorption fraction in GI tract Chemical specific
Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/ Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSGI (chemical specific)	Screening	Chemicals to be assessed	Derm/ Total Dose
Arsenic (total)	1.0E-03	default	3.87E-06	7.7E-10	7.3E-08	95%	0.21%	N	0.00%
Barium (total)	1.0E-03	default	7.35E-04	1.5E-07	1.4E-05	7%	2.86%	N	0.00%

Noncancer Dermal Absorbed Dose Calculations
for Adult Residential Exposures to Inorganics in Acid Area 3 Groundwater.

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc =	1.00E-03	mg/cm3 (default value for purpose of illustration)
SA=	2.00E+04	cm2
t_event =	2.00E-01	hr/event (35 minutes/event)
EV =	1.00E+00	event/day
EF =	3.50E+02	days/yr
ED =	2.40E+01	years
BW =	7.00E+01	kg
AT =	8.76E+03	days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water	IR =	2.00E+03	(cm3/day = L/day * 1000 cm3/L)
ABSIG: Absorption fraction in GI tract	Chemical specific		

Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/ Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSGI (chemical specific)	Screening	Chemicals tc be assessed	Derm/ Total Dose
Arsenic (total)	1.0E-03	default	3.87E-06	7.7E-10	2.1E-07	95%	0.21%	N	0.00%
Barium (total)	1.0E-03	default	7.35E-04	1.5E-07	4.0E-05	7%	2.86%	N	0.00%
Thallium (total)	1.0E-03	default	6.53E-06	1.3E-09	3.6E-07	100%	0.20%	N	0.00%

Cancer Dermal Absorbed Dose Calculations
for Adult Residential Exposures to Organics in Acid Area 3 Groundwater.

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells I8-I18
The default exposure conditions used in this spreadsheet assume exposure duration for carcinogenic effects of chemicals in water through showering

Concentration (mg/L*L/1000 cm3):	Conc =	1E-03 mg/cm3 (default value for purpose of illustration)
Input site specific concentrations in Column marked "Conc"		= 1 mg/L (1 pl = 1 ug/cm3 = 1000 ppb)
Area exposed (cm2):	SA =	5450 cm2
Event time (hr/event):	t_event =	3.00 hr/event (35 minutes/event)
Event frequency (events/day):	EV =	1 event/day
Exposure frequency (days/year):	EF =	52 days/yr
Exposure duration (years):	ED =	24 years
for carcinogenic effects, ED = 30 years (used in this spreadsheet)		
for noncarcinogenic effects, ED = 9 years		
Body weight (kg):	BW =	70.0 kg
Averaging time (days):	AT =	25550 days
for carcinogenic effects, AT=70 years (25,550 days)		
for noncarcinogenic effects, AT=ED (in days)		
Skin thickness (assumed to be 10 um):	lsc =	1.00E-03 cm

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV	IR =	2000 (cm3/day = L/day * 1000 cm3/L)
Drinking (mg/day) = Conc * IR * ABSIG	ABSGI =	1.0 (assumed 100% GI absorption)

IR: Ingestion rate of drinking water
ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min) Q = 1135500.0 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data as evaluated using MLAB (Civilized Software, Bethesda, MD)
95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.
Note:

CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp (cm/hr) predicted	Kp (cm/hr) measured	Kp 95% UCI	Special Chemicals (*) or (**)	Derm/ Drink	Chem Assess	Derm/ Total Dose	B	tau (hr)	t_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Ds/lsc)	Dsc/lsc	Dsc

No Organic COPCs

Noncancer Dermal Absorbed Dose Calculations
for Adult Residential Exposures to Organics in Acid Area3 Groundwater.

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells I8-I18
The default exposure conditions used in this spreadsheet assume exposure duration for
carcinogenic effects of chemicals in water through showering

Concentration (mg/L*L/1000 cm3):	Conc =	1E-03 mg/cm3 (default value for purpose of illustration)
input site specific concentrations in Column marked "Conc"		= 1 mg/L (1 pl= 1 ug/cm3= 1000 ppb)
Area exposed (cm2):	SA =	20000 cm2
Event time (hr/event):	t_event =	0.20 hr/event (35 minutes/event)
Event frequency (events/day):	EV =	1 event/day
Exposure frequency (days/year):	EF =	350 days/yr
Exposure duration (years):	ED =	24 years
for carcinogenic effects, ED = 30 years (used in this spreadsheet)		
for noncarcinogenic effects, ED = 9 years		
Body weight (kg):	BW =	70 kg
Averaging time (days):	AT =	8760 days
for carcinogenic effects, AT=70 years (25,550 days)		
for noncarcinogenic effects, AT=ED (in days)		
Skin thickness (assumed to be 10 um):	lsc =	1.00E-03 cm

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV	IR =	2000 (cm3/day = L/day * 1000 cm3/L)
Drinking (mg/day) = Conc * IR * ABSIG	ABSGI =	1.0 (assumed 100% GI absorption)

IR: Ingestion rate of drinking water
ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min) Q = 1135500.0 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data
as evaluated using MLAB (Civilized Software, Bethesda, MD)
95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.
Note:

	CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp (cm/hr) predicted	Kp (cm/hr) measured	Kp 95% UCI	Special Chemicals (*) or (**)	Derm/ Drink	Chem Assess	Derm/ Total Dose	B	tau (hr)	t_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Ds/lsc)	Dsc/lsc	Dsc
17	Benzene	71432	78.1	2.13	5.9E-04	1.5E-02		3.7E-01		10%	N	0%	0.1	0.29	0.70	1.0	8.02E-05	1.5E-02	8.0E-07	2.2E-04	-3.2E+00	5.71E-04	5.71E-07
58	bis(2-Ethylhexyl)phthalate	117817	391.0	5.11	9.4E-04	2.5E-02		6.6E-01		101%	Y	1%	0.2	16.64	39.93	0.8	3.51E-06	2.5E-02	3.5E-07	9.7E-05	-5.0E+00	1.00E-05	1.00E-08
92	2-Nitrotoluene	88722	137.1	2.45		1.1E-02		7.5E-02		11%	Y	0%	0.1	0.63	1.50	1.0	1.54E-06	1.1E-02	1.7E-08	4.7E-06	-3.6E+00	2.66E-04	2.66E-07
** 139	Methylene chloride	75092	84.9	1.25	1.4E-04	3.5E-03		8.8E-02 **		2%	N	0%	0.0	0.32	0.76	1.0	1.60E-04	3.5E-03	4.0E-07	1.1E-04	-3.3E+00	5.23E-04	5.23E-07
143	2-Methylnaphthalene	91576	142.2	3.90		9.7E-02		1.2E+00		98%	Y	1%	0.4	0.67	1.60	1.0	5.20E-06	9.7E-02	5.1E-07	1.4E-04	-3.6E+00	2.49E-04	2.49E-07
143	Naphthalene	91203	128.2	3.30	1.8E-03	4.7E-02		1.2E+00		43%	Y	0%	0.2	0.56	1.34	1.0	5.30E-06	4.7E-02	2.3E-07	6.2E-05	-3.5E+00	2.99E-04	2.99E-07
** 187	Tetrachloroethene (PCE)	127184	165.8	3.40	1.3E-03	3.3E-02		8.4E-01 **		39%	Y	0%	0.2	0.91	2.18	1.0	5.00E-07	3.3E-02	2.0E-08	5.4E-06	-3.7E+00	1.84E-04	1.84E-07
209	Xylenes, total	1330207	106.2	3.15		4.9E-02		1.4E+00		39%	Y	0%	0.2	0.42	1.01	1.0	1.48E-04	4.9E-02	5.8E-06	1.6E-03	-3.4E+00	3.97E-04	3.97E-07

Cancer Dermal Absorbed Dose Calculations
for Adult Residential Exposures to Inorganics in Acid Area 3 Surface Water.

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc =	1.00E-03	mg/cm3 (default value for purpose of illustration)
SA=	5.45E+03	cm2
t_event =	3.00E+00	hr/event (35 minutes/event)
EV =	1.00E+00	event/day
EF =	5.20E+01	days/yr
ED =	2.40E+01	years
BW =	7.00E+01	kg
AT =	2.56E+04	days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water	IR =	2.00E+03	(cm3/day = L/day * 1000 cm3/L)
ABSIG: Absorption fraction in GI tract	Chemical specific		

Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/r Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSGI (chemical specific)	Screening	Chemicals to be assessed	Derm/ Total Dose
Manganese	1.0E-03	default	5.26E-05	1.6E-07	6.0E-07	6%	13.63%	Y	0.00%

Noncancer Dermal Absorbed Dose Calculations
for Adult Residential Exposures to Inorganics in Acid Area 3 Surface Water.

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc =	1.00E-03	mg/cm3 (default value for purpose of illustration)
SA=	5.45E+03	cm2
t_event =	3.00E+00	hr/event (35 minutes/event)
EV =	1.00E+00	event/day
EF =	5.20E+01	days/yr
ED =	2.40E+01	years
BW =	7.00E+01	kg
AT =	8.76E+03	days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water	IR =	2.00E+03	(cm3/day = L/day * 1000 cm3/L)
ABSIG: Absorption fraction in GI tract	Chemical specific		

Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/ Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSGI (chemical specific)	Screening	Chemicals to be assessed	Derm/ Total Dose
Manganese	1.0E-03	default	5.26E-05	1.6E-07	1.7E-06	6%	13.63%	Y	0.00%

Cancer Dermal Absorbed Dose Calculations
for Child Residential Exposures to Organics in Acid Area 3 Groundwater.

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells I8-I18
The default exposure conditions used in this spreadsheet assume exposure duration for carcinogenic effects of chemicals in water through showering

Concentration (mg/L*L/1000 cm3):	Conc =	1E-03 mg/cm3 (default value for purpose of illustration)
Input site specific concentrations in Column marked "Conc"		= 1 mg/L (1 pl= 1 ug/cm3 = 1000 ppb)
Area exposed (cm2):	SA =	6600 cm2
Event time (hr/event):	t_event =	0.33 hr/event (35 minutes/event)
Event frequency (events/day):	EV =	1 event/day
Exposure frequency (days/year):	EF =	350 days/yr
Exposure duration (years):	ED =	6 years
for carcinogenic effects, ED = 30 years (used in this spreadsheet)		
for noncarcinogenic effects, ED = 9 years		
Body weight (kg):	BW =	15 kg
Averaging time (days):	AT =	25550 days
for carcinogenic effects, AT=70 years (25,550 days)		
for noncarcinogenic effects, AT=ED (in days)		
Skin thickness (assumed to be 10 um):	Isc =	1.00E-03 cm

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV	IR =	2000 (cm3/day = L/day * 1000 cm3/L)
Drinking (mg/day) = Conc * IR * ABSIG	ABSGI =	1.0 (assumed 100% GI absorption)

IR: Ingestion rate of drinking water
ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min) Q = 1135500.0 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data as evaluated using MLAB (Civilized Software, Bethesda, MD)
95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.
Note:

	CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp (cm/hr) predicted	Kp (cm/hr) measured	Kp 95% UCI	Special Chemicals (*) or (**)	Derm/ Drink	Chem Assess	Derm/ Total Dose	B	tau (hr)	t_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Ds/Isc)	Dsc/Isc	Dsc
17	Benzene	71432	78.1	2.13	5.9E-04	1.5E-02		3.7E-01		4%	N	0%	0.1	0.29	0.70	1.0	8.02E-05	1.5E-02	1.0E-06	3.7E-05	-3.2E+00	5.71E-04	5.71E-07
58	bis(2-Ethylhexyl)phthalate	117817	391.0	5.11	9.4E-04	2.5E-02		6.6E-01		43%	Y	0%	0.2	16.64	39.93	0.8	3.51E-06	2.5E-02	4.6E-07	1.6E-05	-5.0E+00	1.00E-05	1.00E-08
92	2-Nitrotoluene	88722	137.1	2.45		1.1E-02		7.5E-02		5%	N	0%	0.1	0.63	1.50	1.0	1.54E-06	1.1E-02	2.2E-08	8.0E-07	-3.6E+00	2.66E-04	2.66E-07
** 139	Methylene chloride	75092	84.9	1.25	1.4E-04	3.5E-03		8.8E-02 **		1%	N	0%	0.0	0.32	0.76	1.0	1.60E-04	3.5E-03	5.1E-07	1.8E-05	-3.3E+00	5.23E-04	5.23E-07
143	2-Methylnaphthalene	91576	142.2	3.90		9.7E-02		1.2E+00		42%	Y	0%	0.4	0.67	1.60	1.0	5.20E-06	9.7E-02	6.6E-07	2.4E-05	-3.6E+00	2.49E-04	2.49E-07
143	Naphthalene	91203	128.2	3.30	1.8E-03	4.7E-02		1.2E+00		18%	Y	0%	0.2	0.56	1.34	1.0	5.30E-06	4.7E-02	2.9E-07	1.1E-05	-3.5E+00	2.99E-04	2.99E-07
** 187	Tetrachloroethene (PCE)	127184	165.8	3.40	1.3E-03	3.3E-02		8.4E-01 **		17%	Y	0%	0.2	0.91	2.18	1.0	5.00E-07	3.3E-02	2.5E-08	9.2E-07	-3.7E+00	1.84E-04	1.84E-07
209	Xylenes, total	1330207	106.2	3.15		4.9E-02		1.4E+00		17%	Y	0%	0.2	0.42	1.01	1.0	1.48E-04	4.9E-02	7.5E-06	2.7E-04	-3.4E+00	3.97E-04	3.97E-07

Noncancer Dermal Absorbed Dose Calculations
for Child Residential Exposures to Organics in Acid Area 3 Groundwater.

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells I8-I18
The default exposure conditions used in this spreadsheet assume exposure duration for carcinogenic effects of chemicals in water through showering

Concentration (mg/L*L/1000 cm3):	Conc =	1E-03 mg/cm3 (default value for purpose of illustration)
Input site specific concentrations in Column marked "Conc"		= 1 mg/L (1 pj= 1 ug/cm3 = 1000 ppb)
Area exposed (cm2):	SA =	6600 cm2
Event time (hr/event):	t_event =	0.33 hr/event (35 minutes/event)
Event frequency (events/day):	EV =	1 event/day
Exposure frequency (days/year):	EF =	350 days/yr
Exposure duration (years):	ED =	6 years
for carcinogenic effects, ED = 30 years (used in this spreadsheet)		
for noncarcinogenic effects, ED = 9 years		
Body weight (kg):	BW =	15.0 kg
Averaging time (days):	AT =	2190 days
for carcinogenic effects, AT=70 years (25,550 days)		
for noncarcinogenic effects, AT=ED (in days)		
Skin thickness (assumed to be 10 um):	lsc =	1.00E-03 cm

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV	IR =	2000 (cm3/day = L/day * 1000 cm3/L)
Drinking (mg/day) = Conc * IR * ABSIG	ABSGI =	1.0 (assumed 100% GI absorption)

IR: Ingestion rate of drinking water
ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min) Q = 1135500.0 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data as evaluated using MLAB (Civilized Software, Bethesda, MD)
95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.
Note:

	CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp (cm/hr) predicted	Kp (cm/hr) measured	Kp 95% UCI	Special Chemicals (*) or (**)	Derm/ Drink	Chem Assess	Derm/ Total Dose	B	tau (hr)	t_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Ds/lsc)	Dsc/lsc	Dsc
17	Benzene	71432	78.1	2.13	5.9E-04	1.5E-02		3.7E-01		4%	N	0%	0.1	0.29	0.70	1.0	8.02E-05	1.5E-02	1.0E-06	4.3E-04	-3.2E+00	5.71E-04	5.71E-07
58	bis(2-Ethylhexyl)phthalate	117817	391.0	5.11	9.4E-04	2.5E-02		6.6E-01		43%	Y	0%	0.2	16.64	39.93	0.8	3.51E-06	2.5E-02	4.6E-07	1.9E-04	-5.0E+00	1.00E-05	1.00E-08
92	2-Nitrotoluene	88722	137.1	2.45		1.1E-02		7.5E-02		5%	N	0%	0.1	0.63	1.50	1.0	1.54E-06	1.1E-02	2.2E-08	9.3E-06	-3.6E+00	2.66E-04	2.66E-07
** 139	Methylene chloride	75092	84.9	1.25	1.4E-04	3.5E-03		8.8E-02 **		1%	N	0%	0.0	0.32	0.76	1.0	1.60E-04	3.5E-03	5.1E-07	2.2E-04	-3.3E+00	5.23E-04	5.23E-07
143	2-Methylnaphthalene	91576	142.2	3.90		9.7E-02		1.2E+00		42%	Y	0%	0.4	0.67	1.60	1.0	5.20E-06	9.7E-02	6.6E-07	2.8E-04	-3.6E+00	2.49E-04	2.49E-07
143	Naphthalene	91203	128.2	3.30	1.8E-03	4.7E-02		1.2E+00		18%	Y	0%	0.2	0.56	1.34	1.0	5.30E-06	4.7E-02	2.9E-07	1.2E-04	-3.5E+00	2.99E-04	2.99E-07
** 187	Tetrachloroethene (PCE)	127184	165.8	3.40	1.3E-03	3.3E-02		8.4E-01 **		17%	Y	0%	0.2	0.91	2.18	1.0	5.00E-07	3.3E-02	2.5E-08	1.1E-05	-3.7E+00	1.84E-04	1.84E-07
209	Xylenes, total	1330207	106.2	3.15		4.9E-02		1.4E+00		17%	Y	0%	0.2	0.42	1.01	1.0	1.48E-04	4.9E-02	7.5E-06	3.2E-03	-3.4E+00	3.97E-04	3.97E-07

Cancer Dermal Absorbed Dose Calculations
for Child Residential Exposures to Inorganics in Acid Area 3 Groundwater.

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc =	1.00E-03	mg/cm3 (default value for purpose of illustration)
SA=	6.60E+03	cm2
t_event =	3.33E-01	hr/event (35 minutes/event)
EV =	1.00E+00	event/day
EF =	3.50E+02	days/yr
ED =	6.00E+00	years
BW =	1.50E+01	kg
AT =	2.56E+04	days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water IR = 2.00E+03 (cm3/day = L/day * 1000 cm3/L)
ABSIG: Absorption fraction in GI tract Chemical specific
Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/ Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSGI (chemical specific)	Screening	Chemicals tc be assessed	Derm/ Total Dose
Arsenic (total)	1.0E-03	default	3.87E-06	1.3E-09	4.7E-08	95%	0.12%	N	0.00%
Barium (total)	1.0E-03	default	7.35E-04	2.4E-07	8.9E-06	7%	1.57%	N	0.00%
Thallium (total)	1.0E-03	default	6.53E-06	2.2E-09	7.9E-08	100%	0.11%	N	0.00%

Noncancer Dermal Absorbed Dose Calculations
for Child Residential Exposures to Inorganics in Acid Area 3 Groundwater.

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc =	1.00E-03	mg/cm3 (default value for purpose of illustration)
SA=	6.60E+03	cm2
t_event =	3.33E-01	hr/event (35 minutes/event)
EV =	1.00E+00	event/day
EF =	3.50E+02	days/yr
ED =	6.00E+00	years
BW =	1.50E+01	kg
AT =	2.19E+03	days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water IR = 2.00E+03 (cm3/day = L/day * 1000 cm3/L)
ABSIG: Absorption fraction in GI tract Chemical specific
Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/ Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSGI (chemical specific)	Screening	Chemicals tc be assessed	Derm/ Total Dose
Arsenic (total)	1.0E-03	default	3.87E-06	1.3E-09	5.4E-07	95%	0.12%	N	0.00%
Barium (total)	1.0E-03	default	7.35E-04	2.4E-07	1.0E-04	7%	1.57%	N	0.00%
Thallium (total)	1.0E-03	default	6.53E-06	2.2E-09	9.2E-07	100%	0.11%	N	0.00%

Cancer Dermal Absorbed Dose Calculations
for Child Residential Exposures to Organics in Acid Area 3 Surface Water.

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells I8-I18
The default exposure conditions used in this spreadsheet assume exposure duration for carcinogenic effects of chemicals in water through showering

Concentration (mg/L*L/1000 cm3):	Conc =	1E-03 mg/cm3 (default value for purpose of illustration)
Input site specific concentrations in Column marked "Conc"		= 1 mg/L (1 pj= 1 ug/cm3= 1000 ppb)
Area exposed (cm2):	SA =	2100 cm2
Event time (hr/event):	t_event =	3.00 hr/event (35 minutes/event)
Event frequency (events/day):	EV =	1.0 event/day
Exposure frequency (days/year):	EF =	52.0 days/yr
Exposure duration (years):	ED =	6.0 years
for carcinogenic effects, ED = 30 years (used in this spreadsheet)		
for noncarcinogenic effects, ED = 9 years		
Body weight (kg):	BW =	15.0 kg
Averaging time (days):	AT =	25550 days
for carcinogenic effects, AT=70 years (25,550 days)		
for noncarcinogenic effects, AT=ED (in days)		
Skin thickness (assumed to be 10 um):	Isc =	1.00E-03 cm

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV	IR =	2000 (cm3/day = L/day * 1000 cm3/L)
Drinking (mg/day) = Conc * IR * ABSIG	ABSGI =	1.0 (assumed 100% GI absorption)

IR: Ingestion rate of drinking water
ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min) Q = 1135500.0 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data as evaluated using MLAB (Civilized Software, Bethesda, MD)
95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.
Note:

CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp (cm/hr) predicted	Kp (cm/hr) measured	Kp 95% UCI	Special Chemicals (*) or (**)	Derm/ Drink	Chem Assess	Derm/ Total Dose	B	tau (hr)	t_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Ds/Isc)	Dsc/Isc	Dsc

No Organic COPCs

Noncancer Dermal Absorbed Dose Calculations
for Child Residential Exposures to Organics in Acid Area 3 Surface Water.

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells I8-I18
The default exposure conditions used in this spreadsheet assume exposure duration for carcinogenic effects of chemicals in water through showering

Concentration (mg/L*L/1000 cm3):	Conc =	1E-03 mg/cm3 (default value for purpose of illustration)
Input site specific concentrations in Column marked "Conc"		= 1 mg/L (1 pj= 1 ug/cm3 = 1000 ppb)
Area exposed (cm2):	SA =	2100 cm2
Event time (hr/event):	t_event =	3.00 hr/event (35 minutes/event)
Event frequency (events/day):	EV =	1 event/day
Exposure frequency (days/year):	EF =	52 days/yr
Exposure duration (years):	ED =	24 years
for carcinogenic effects, ED = 30 years (used in this spreadsheet)		
for noncarcinogenic effects, ED = 9 years		
Body weight (kg):	BW =	70.0 kg
Averaging time (days):	AT =	8760 days
for carcinogenic effects, AT=70 years (25,550 days)		
for noncarcinogenic effects, AT=ED (in days)		
Skin thickness (assumed to be 10 um):	lsc =	1.00E-03 cm

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV	IR =	2000 (cm3/day = L/day * 1000 cm3/L)
Drinking (mg/day) = Conc * IR * ABSIG	ABSGI =	1.0 (assumed 100% GI absorption)

IR: Ingestion rate of drinking water
ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min) Q = 1135500.0 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data as evaluated using MLAB (Civilized Software, Bethesda, MD)
95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.
Note:

CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp (cm/hr)	Kp (cm/hr)	Kp 95% UCI	Special Chemicals	Derm/ Drink	Chem Assess	Derm/ Total Dose	B	tau (hr)	t_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Ds/lsc)	Dsc/lsc	Dsc

No Organic COPCs

Cancer Dermal Absorbed Dose Calculations
for Child Residential Exposures to Inorganics in Acid Area 3 Surface Water.

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc =	1.00E-03	mg/cm3 (default value for purpose of illustration)
SA=	2.10E+03	cm2
t_event =	3.00E+00	hr/event (35 minutes/event)
EV =	1.00E+00	event/day
EF =	5.20E+01	days/yr
ED =	6.00E+00	years
BW =	1.50E+01	kg
AT =	2.56E+04	days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water IR = 2.00E+03 (cm3/day = L/day * 1000 cm3/L)
ABSIG: Absorption fraction in GI tract Chemical specific
Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/r Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSGI (chemical specific)	Screening	Chemicals to be assessed	Derm/ Total Dose
Manganese	1.0E-03	default	5.26E-05	1.6E-07	2.7E-07	6%	5.25%	N	0.00%

Noncancer Dermal Absorbed Dose Calculations
for Child Residential Exposures to Inorganics in Acid Area 3 Surface Water.

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc =	1.00E-03	mg/cm3 (default value for purpose of illustration)
SA=	2.10E+03	cm2
t_event =	3.00E+00	hr/event (35 minutes/event)
EV =	1.00E+00	event/day
EF =	5.20E+01	days/yr
ED =	6.00E+00	years
BW =	1.50E+01	kg
AT =	2.19E+03	days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water	IR =	2.00E+03	(cm3/day = L/day * 1000 cm3/L)
ABSIG: Absorption fraction in GI tract	Chemical specific		
Condition for screening: "Y" when Dermal is 10% of Drinking			

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/ı Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSGI (chemical specific)	Screening	Chemicals to be assessed	Derm/ Total Dose
Manganese	1.0E-03	default	5.26E-05	1.6E-07	3.1E-06	6%	5.25%	N	0.00%

Cancer Dermal Absorbed Dose Calculations
for Indoor Worker Exposures to Organics in Acid Area 3 Groundwater.

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells I8-I18
The default exposure conditions used in this spreadsheet assume exposure duration for carcinogenic effects of chemicals in water through showering

Concentration (mg/L*L/1000 cm3):	Conc =	1E-03 mg/cm3 (default value for purpose of illustration)
Input site specific concentrations in Column marked "Conc"		= 1 mg/L (1 pi = 1 ug/cm3 = 1000 ppb)
Area exposed (cm2):	SA =	3300 cm2
Event time (hr/event):	t_event =	1.00 hr/event (35 minutes/event)
Event frequency (events/day):	EV =	1 event/day
Exposure frequency (days/year):	EF =	250 days/yr
Exposure duration (years):	ED =	25 years
for carcinogenic effects, ED = 30 years (used in this spreadsheet)		
for noncarcinogenic effects, ED = 9 years		
Body weight (kg):	BW =	70.0 kg
Averaging time (days):	AT =	25550 days
for carcinogenic effects, AT=70 years (25,550 days)		
for noncarcinogenic effects, AT=ED (in days)		
Skin thickness (assumed to be 10 um):	Isc =	1.00E-03 cm

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV	IR =	2000 (cm3/day = L/day * 1000 cm3/L)
Drinking (mg/day) = Conc * IR * ABSIG	ABSGI =	1.0 (assumed 100% GI absorption)

IR: Ingestion rate of drinking water
ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min) Q = 1135500.0 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data as evaluated using MLAB (Civilized Software, Bethesda, MD)
95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.
Note:

	CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp (cm/hr) predicted	Kp (cm/hr) measured	Kp 95% UCI	Special Chemicals (*) or (**)	Derm/ Drink	Chem Assess	Derm/ Total Dose	B	tau (hr)	t_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Ds/Isc)	Dsc/Isc	Dsc
17	Benzene	71432	78.1	2.13	5.9E-04	1.5E-02		3.7E-01		4%	N	0%	0.1	0.29	0.70	1.0	8.02E-05	1.5E-02	1.9E-06	2.2E-05	-3.2E+00	5.71E-04	5.71E-07
58	bis(2-Ethylhexyl)phthalate	117817	391.0	5.11	9.4E-04	2.5E-02		6.6E-01		37%	Y	0%	0.2	16.64	39.93	0.8	3.51E-06	2.5E-02	7.9E-07	9.1E-06	-5.0E+00	1.00E-05	1.00E-08
92	2-Nitrotoluene	88722	137.1	2.45		1.1E-02		7.5E-02		4%	N	0%	0.1	0.63	1.50	1.0	1.54E-06	1.1E-02	3.8E-08	4.4E-07	-3.6E+00	2.66E-04	2.66E-07
** 139	Methylene chloride	75092	84.9	1.25	1.4E-04	3.5E-03		8.8E-02 **		1%	N	0%	0.0	0.32	0.76	1.0	1.60E-04	3.5E-03	9.3E-07	1.1E-05	-3.3E+00	5.23E-04	5.23E-07
143	2-Methylnaphthalene	91576	142.2	3.90		9.7E-02		1.2E+00		36%	Y	0%	0.4	0.67	1.60	1.0	5.20E-06	9.7E-02	1.1E-06	1.3E-05	-3.6E+00	2.49E-04	2.49E-07
143	Naphthalene	91203	128.2	3.30	1.8E-03	4.7E-02		1.2E+00		16%	Y	0%	0.2	0.56	1.34	1.0	5.30E-06	4.7E-02	5.1E-07	5.9E-06	-3.5E+00	2.99E-04	2.99E-07
** 187	Tetrachloroethene (PCE)	127184	165.8	3.40	1.3E-03	3.3E-02		8.4E-01 **		15%	Y	0%	0.2	0.91	2.18	1.0	5.00E-07	3.3E-02	4.4E-08	5.1E-07	-3.7E+00	1.84E-04	1.84E-07
209	Xylenes, total	1330207	106.2	3.15		4.9E-02		1.4E+00		15%	Y	0%	0.2	0.42	1.01	1.0	1.48E-04	4.9E-02	1.3E-05	1.5E-04	-3.4E+00	3.97E-04	3.97E-07

Noncancer Dermal Absorbed Dose Calculations
for Indoor Worker Exposures to Organics in Acid Area 3 Groundwater.

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells I8-I18
The default exposure conditions used in this spreadsheet assume exposure duration for
carcinogenic effects of chemicals in water through showering

Concentration (mg/L*L/1000 cm3):	Conc =	1E-03 mg/cm3 (default value for purpose of illustration)
Input site specific concentrations in Column marked "Conc"		= 1 mg/L (1 p = 1 ug/cm3 = 1000 ppb)
Area exposed (cm2):	SA =	3300 cm2
Event time (hr/event):	t_event =	1.00 hr/event (35 minutes/event)
Event frequency (events/day):	EV =	1 event/day
Exposure frequency (days/year):	EF =	250 days/yr
Exposure duration (years):	ED =	25 years
for carcinogenic effects, ED = 30 years (used in this spreadsheet)		
for noncarcinogenic effects, ED = 9 years		
Body weight (kg):	BW =	70.0 kg
Averaging time (days):	AT =	9125 days
for carcinogenic effects, AT=70 years (25,550 days)		
for noncarcinogenic effects, AT=ED (in days)		
Skin thickness (assumed to be 10 um):	lsc =	1.00E-03 cm

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV	IR =	2000 (cm3/day = L/day * 1000 cm3/L)
Drinking (mg/day) = Conc * IR * ABSIG	ABSGI =	1.0 (assumed 100% GI absorption)

IR: Ingestion rate of drinking water
ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min) Q = 1135500.0 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data
as evaluated using MLAB (Civilized Software, Bethesda, MD)
95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.
Note:

	CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp (cm/hr) predicted	Kp (cm/hr) measured	Kp 95% UCI	Special Chemicals (*) or (**)	Derm/ Drink	Chem Assess	Derm/ Total Dose	B	tau (hr)	t_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Ds/lsc)	Dsc/lsc	Dsc
17	Benzene	71432	78.1	2.13	5.9E-04	1.5E-02		3.7E-01		4%	N	0%	0.1	0.29	0.70	1.0	8.02E-05	1.5E-02	1.9E-06	6.0E-05	-3.2E+00	5.71E-04	5.71E-07
58	bis(2-Ethylhexyl)phthalate	117817	391.0	5.11	9.4E-04	2.5E-02		6.6E-01		37%	Y	0%	0.2	16.64	39.93	0.8	3.51E-06	2.5E-02	7.9E-07	2.5E-05	-5.0E+00	1.00E-05	1.00E-08
92	2-Nitrotoluene	88722	137.1	2.45		1.1E-02		7.5E-02		4%	N	0%	0.1	0.63	1.50	1.0	1.54E-06	1.1E-02	3.8E-08	1.2E-06	-3.6E+00	2.66E-04	2.66E-07
** 139	Methylene chloride	75092	84.9	1.25	1.4E-04	3.5E-03		8.8E-02 **		1%	N	0%	0.0	0.32	0.76	1.0	1.60E-04	3.5E-03	9.3E-07	3.0E-05	-3.3E+00	5.23E-04	5.23E-07
143	2-Methylnaphthalene	91576	142.2	3.90		9.7E-02		1.2E+00		36%	Y	0%	0.4	0.67	1.60	1.0	5.20E-06	9.7E-02	1.1E-06	3.7E-05	-3.6E+00	2.49E-04	2.49E-07
143	Naphthalene	91203	128.2	3.30	1.8E-03	4.7E-02		1.2E+00		16%	Y	0%	0.2	0.56	1.34	1.0	5.30E-06	4.7E-02	5.1E-07	1.6E-05	-3.5E+00	2.99E-04	2.99E-07
** 187	Tetrachloroethene (PCE)	127184	165.8	3.40	1.3E-03	3.3E-02		8.4E-01 **		15%	Y	0%	0.2	0.91	2.18	1.0	5.00E-07	3.3E-02	4.4E-08	1.4E-06	-3.7E+00	1.84E-04	1.84E-07
209	Xylenes, total	1330207	106.2	3.15		4.9E-02		1.4E+00		15%	Y	0%	0.2	0.42	1.01	1.0	1.48E-04	4.9E-02	1.3E-05	4.2E-04	-3.4E+00	3.97E-04	3.97E-07

Cancer Dermal Absorbed Dose Calculations
for Indoor Worker Exposures to Inorganics in Acid Area 3 Groundwater.

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc =	1.00E-03	mg/cm3 (default value for purpose of illustration)
SA=	3.30E+03	cm2
t_event =	1.00E+00	hr/event (35 minutes/event)
EV =	1.00E+00	event/day
EF =	2.50E+02	days/yr
ED =	2.50E+01	years
BW =	7.00E+01	kg
AT =	2.56E+04	days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water IR = 2.00E+03 (cm3/day = L/day * 1000 cm3/L)
ABSIG: Absorption fraction in GI tract Chemical specific
Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/ Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSGI (chemical specific)	Screening	Chemicals tc be assessed	Derm/ Total Dose
Arsenic (total)	1.0E-03	default	3.87E-06	3.9E-09	4.5E-08	95%	0.17%	N	0.00%
Barium (total)	1.0E-03	default	7.35E-04	7.3E-07	8.5E-06	7%	2.36%	N	0.00%
Thallium (total)	1.0E-03	default	6.53E-06	6.5E-09	7.5E-08	100%	0.17%	N	0.00%

Noncancer Dermal Absorbed Dose Calculations
for Indoor Worker Exposures to Inorganics in Acid Area 3 Groundwater.

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc =	1.00E-03	mg/cm3 (default value for purpose of illustration)
SA=	3.30E+03	cm2
t_event =	1.00E+00	hr/event (35 minutes/event)
EV =	1.00E+00	event/day
EF =	2.50E+02	days/yr
ED =	2.50E+01	years
BW =	7.00E+01	kg
AT =	9.13E+03	days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water	IR =	2.00E+03	(cm3/day = L/day * 1000 cm3/L)
ABSIG: Absorption fraction in GI tract	Chemical specific		

Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/ Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSGI (chemical specific)	Screening	Chemicals tc be assessed	Derm/ Total Dose
Arsenic (total)	1.0E-03	default	3.87E-06	3.9E-09	1.2E-07	95%	0.17%	N	0.00%
Barium (total)	1.0E-03	default	7.35E-04	7.3E-07	2.4E-05	7%	2.36%	N	0.00%
Thallium (total)	1.0E-03	default	6.53E-06	6.5E-09	2.1E-07	100%	0.17%	N	0.00%

Cancer Dermal Absorbed Dose Calculations
for Construction Worker Exposures to Organics in Acid Area 3 Surface Water.

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells I8-I18
The default exposure conditions used in this spreadsheet assume exposure duration for carcinogenic effects of chemicals in water through showering

Concentration (mg/L*L/1000 cm3):	Conc =	1E-03 mg/cm3 (default value for purpose of illustration)
Input site specific concentrations in Column marked "Conc"		= 1 mg/L (1 pl= 1 ug/cm3 = 1000 ppb)
Area exposed (cm2):	SA =	3100 cm2
Event time (hr/event):	t_event =	4.00 hr/event (35 minutes/event)
Event frequency (events/day):	EV =	1.0 event/day
Exposure frequency (days/year):	EF =	250.0 days/yr
Exposure duration (years):	ED =	0.5 years
for carcinogenic effects, ED = 30 years (used in this spreadsheet)		
for noncarcinogenic effects, ED = 9 years		
Body weight (kg):	BW =	70.0 kg
Averaging time (days):	AT =	25550 days
for carcinogenic effects, AT=70 years (25,550 days)		
for noncarcinogenic effects, AT=ED (in days)		
Skin thickness (assumed to be 10 um):	lsc =	1.00E-03 cm

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV	IR =	2000 (cm3/day = L/day * 1000 cm3/L)
Drinking (mg/day) = Conc * IR * ABSIG	ABSGI =	1.0 (assumed 100% GI absorption)

IR: Ingestion rate of drinking water
ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min) Q = 1135500.0 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data as evaluated using MLAB (Civilized Software, Bethesda, MD)
95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.
Note:

CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp (cm/hr) predicted	Kp (cm/hr) measured	Kp 95% UCI	Special Chemicals (*) or (**)	Derm/ Drink	Chem Assess	Derm/ Total Dose	B	tau (hr)	t_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Ds/lsc)	Dsc/lsc	Dsc

No Organic COPCs

Noncancer Dermal Absorbed Dose Calculations
for Construction Worker Exposures to Organics in Acid Area 3 Surface Water.

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells I8-I18
The default exposure conditions used in this spreadsheet assume exposure duration for carcinogenic effects of chemicals in water through showering

Concentration (mg/L*L/1000 cm3):	Conc =	1E-03	mg/cm3 (default value for purpose of illustration)
Input site specific concentrations in Column marked "Conc"		= 1 mg/L	(1 pj = 1 ug/cm3 = 1000 ppb)
Area exposed (cm2):	SA =	3100	cm2
Event time (hr/event):	t_event =	4.00	hr/event (35 minutes/event)
Event frequency (events/day):	EV =	1.0	event/day
Exposure frequency (days/year):	EF =	250.0	days/yr
Exposure duration (years):	ED =	0.5	years
for carcinogenic effects, ED = 30 years (used in this spreadsheet)			
for noncarcinogenic effects, ED = 9 years			
Body weight (kg):	BW =	70.0	kg
Averaging time (days):	AT =	183	days
for carcinogenic effects, AT=70 years (25,550 days)			
for noncarcinogenic effects, AT=ED (in days)			
Skin thickness (assumed to be 10 um):	isc =	1.00E-03	cm

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV	IR =	2000	(cm3/day = L/day * 1000 cm3/L)
Drinking (mg/day) = Conc * IR * ABSIG	ABSGI =	1.0	(assumed 100% GI absorption)

IR: Ingestion rate of drinking water
ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min) Q = 1135500.0 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data as evaluated using MLAB (Civilized Software, Bethesda, MD)
95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.
Note:

CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp (cm/hr) predicted	Kp (cm/hr) measured	Kp 95% UCI	Special Chemicals (*) or (**)	Derm/ Drink	Chem Assess	Derm/ Total Dose	B	tau (hr)	t_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Ds/isc)	Dsc/isc	Dsc	b	c	t_star1 B>0.6	t_star3 B<=0.6

No Organic COPCs

Cancer Dermal Absorbed Dose Calculations
for Construction Worker Exposures to Inorganics in Acid Area 3 Surface Water.

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc =	1.00E-03	mg/cm3 (default value for purpose of illustration)
SA=	3.10E+03	cm2
t_event =	4.00E+00	hr/event (35 minutes/event)
EV =	1.00E+00	event/day
EF =	2.50E+02	days/yr
ED =	5.00E-01	years
BW =	7.00E+01	kg
AT =	2.56E+04	days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water IR = 2.00E+03 (cm3/day = L/day * 1000 cm3/L)
ABSIG: Absorption fraction in GI tract Chemical specific
Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/r Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSGI (chemical specific)	Screening	Chemicals to be assessed	Derm/ Total Dose
Manganese	1.0E-03	default	5.26E-05	2.1E-07	4.6E-08	6%	10.33%	Y	0.00%

Noncancer Dermal Absorbed Dose Calculations
for Construction Worker Exposures to Inorganics in Acid Area 3 Surface Water.

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc =	1.00E-03	mg/cm3 (default value for purpose of illustration)
SA=	3.10E+03	cm2
t_event =	4.00E+00	hr/event (35 minutes/event)
EV =	1.00E+00	event/day
EF =	2.50E+02	days/yr
ED =	5.00E-01	years
BW =	7.00E+01	kg
AT =	1.83E+02	days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water IR = 2.00E+03 (cm3/day = L/day * 1000 cm3/L)
ABSIG: Absorption fraction in GI tract Chemical specific
Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/r Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSGI (chemical specific)	Screening	Chemicals to be assessed	Derm/ Total Dose
Manganese	1.0E-03	default	5.26E-05	2.1E-07	6.4E-06	6%	10.33%	Y	0.00%

APPENDIX B

RISK CALCULATIONS

Table B-1. Risks and Hazards from Ingestion of Surface Soil at Acid Area 3 for Groundskeeper Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.10E+03	1.00E+00	7.92E-03	7.92E-03	2.83E-03	No toxicity value	NA
Arsenic	7.07E+00	3.00E-04	6.92E-06	2.31E-02	2.47E-06	1.50E+00	3.71E-06
Iron	1.69E+04	7.00E-01	1.66E-02	2.37E-02	5.92E-03	No toxicity value	NA
Lead	1.21E+02	No toxicity value	1.18E-04	NA	4.23E-05	No toxicity value	NA
Manganese	4.26E+02	4.67E-02	4.17E-04	8.93E-03	1.49E-04	No toxicity value	NA
Thallium	5.11E+00	7.00E-05	5.00E-06	7.14E-02	1.79E-06	No toxicity value	NA
Vanadium	2.16E+01	5.00E-03	2.11E-05	4.23E-03	7.55E-06	No toxicity value	NA
PCB-1254	4.18E+00	2.00E-05	4.09E-06	2.05E-01	1.46E-06	2.00E+00	2.92E-06
PCB-1260	5.70E-01	No toxicity value	5.58E-07	NA	1.99E-07	2.00E+00	3.98E-07
Benzo(a)anthracene	3.50E+00	No toxicity value	3.42E-06	NA	1.22E-06	7.30E-01	8.93E-07
Benzo(a)pyrene	3.40E+00	No toxicity value	3.33E-06	NA	1.19E-06	7.30E+00	8.67E-06
Benzo(b)fluoranthene	3.82E-01	No toxicity value	3.74E-07	NA	1.33E-07	7.30E-01	9.74E-08
Dibenz(a,h)anthracene	1.93E-01	No toxicity value	1.89E-07	NA	6.74E-08	7.30E+00	4.92E-07
Indeno(1,2,3-cd)pyrene	2.30E-01	No toxicity value	2.25E-07	NA	8.04E-08	7.30E-01	5.87E-08
Hazard Index				3.44E-01			
Total Cancer Risk							1.72E-05

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-2. Risks and Hazards from Dermal contact with Surface Soil at Acid Area 3 for Groundskeeper Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.10E+03	1.00E+00	ND	NA	ND	No toxicity value	NA
Arsenic	7.07E+00	3.00E-04	2.11E-07	7.04E-04	7.54E-08	1.50E+00	1.13E-07
Iron	1.69E+04	7.00E-01	ND	NA	ND	No toxicity value	NA
Lead	1.21E+02	No toxicity value	ND	NA	ND	No toxicity value	NA
Manganese	4.26E+02	4.67E-02	ND	NA	ND	No toxicity value	NA
Thallium	5.11E+00	7.00E-05	ND	NA	ND	No toxicity value	NA
Vanadium	2.16E+01	5.00E-03	ND	NA	ND	No toxicity value	NA
PCB-1254	4.18E+00	2.00E-05	5.82E-07	2.91E-02	2.08E-07	2.00E+00	4.16E-07
PCB-1260	5.70E-01	No toxicity value	7.94E-08	NA	2.84E-08	2.00E+00	5.67E-08
Benzo(a)anthracene	3.50E+00	No toxicity value	4.53E-07	NA	1.62E-07	7.30E-01	1.18E-07
Benzo(a)pyrene	3.40E+00	No toxicity value	4.40E-07	NA	1.57E-07	7.30E+00	1.15E-06
Benzo(b)fluoranthene	3.82E-01	No toxicity value	4.94E-08	NA	1.76E-08	7.30E-01	1.29E-08
Dibenz(a,h)anthracene	1.93E-01	No toxicity value	2.50E-08	NA	8.92E-09	7.30E+00	6.51E-08
Indeno(1,2,3-cd)pyrene	2.30E-01	No toxicity value	2.98E-08	NA	1.06E-08	7.30E-01	7.76E-09
Hazard Index				2.98E-02			
Total Cancer Risk							1.94E-06

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-3. Risks and Hazards from Inhalation of Particulates from Surface Soil at Acid Area 3 for Groundskeeper Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.10E+03	1.43E-03	3.70E-07	2.59E-04	1.32E-07	No toxicity value	NA
Arsenic	7.07E+00	No toxicity value	3.23E-10	NA	1.15E-10	1.51E+01	1.74E-09
Iron	1.69E+04	No toxicity value	7.74E-07	NA	2.77E-07	No toxicity value	NA
Lead	1.21E+02	No toxicity value	5.53E-09	NA	1.98E-09	No toxicity value	NA
Manganese	4.26E+02	1.40E-05	1.95E-08	1.39E-03	6.96E-09	No toxicity value	NA
Thallium	5.11E+00	No toxicity value	2.34E-10	NA	8.34E-11	No toxicity value	NA
Vanadium	2.16E+01	No toxicity value	9.88E-10	NA	3.53E-10	No toxicity value	NA
PCB-1254	4.18E+00	2.00E-05	1.91E-10	9.56E-06	6.83E-11	2.00E+00	1.37E-10
PCB-1260	5.70E-01	No toxicity value	2.61E-11	NA	9.31E-12	2.00E+00	1.86E-11
Benzo(a)anthracene	3.50E+00	No toxicity value	1.60E-10	NA	5.72E-11	3.10E-01	1.77E-11
Benzo(a)pyrene	3.40E+00	No toxicity value	1.55E-10	NA	5.55E-11	3.10E+00	1.72E-10
Benzo(b)fluoranthene	3.82E-01	No toxicity value	1.75E-11	NA	6.24E-12	3.10E-01	1.93E-12
Dibenz(a,h)anthracene	1.93E-01	No toxicity value	8.82E-12	NA	3.15E-12	3.10E+00	9.77E-12
Indeno(1,2,3-cd)pyrene	2.30E-01	No toxicity value	1.05E-11	NA	3.76E-12	3.10E-01	1.16E-12
Hazard Index				1.66E-03			
Total Cancer Risk							2.10E-09

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-4. Risks and Hazards from Ingestion of Surface Soil at Acid Area 3 for Adult Hunter Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.10E+03	1.00E+00	4.44E-04	4.44E-04	1.90E-04	No toxicity value	NA
Arsenic	7.07E+00	3.00E-04	3.87E-07	1.29E-03	1.66E-07	1.50E+00	2.49E-07
Iron	1.69E+04	7.00E-01	9.28E-04	1.33E-03	3.98E-04	No toxicity value	NA
Lead	1.21E+02	No toxicity value	6.63E-06	NA	2.84E-06	No toxicity value	NA
Manganese	4.26E+02	4.67E-02	2.33E-05	5.00E-04	1.00E-05	No toxicity value	NA
Thallium	5.11E+00	7.00E-05	2.80E-07	4.00E-03	1.20E-07	No toxicity value	NA
Vanadium	2.16E+01	5.00E-03	1.18E-06	2.37E-04	5.07E-07	No toxicity value	NA
PCB-1254	4.18E+00	2.00E-05	2.29E-07	1.15E-02	9.82E-08	2.00E+00	1.96E-07
PCB-1260	5.70E-01	No toxicity value	3.12E-08	NA	1.34E-08	2.00E+00	2.68E-08
Benzo(a)anthracene	3.50E+00	No toxicity value	1.92E-07	NA	8.22E-08	7.30E-01	6.00E-08
Benzo(a)pyrene	3.40E+00	No toxicity value	1.86E-07	NA	7.98E-08	7.30E+00	5.83E-07
Benzo(b)fluoranthene	3.82E-01	No toxicity value	2.09E-08	NA	8.97E-09	7.30E-01	6.55E-09
Dibenz(a,h)anthracene	1.93E-01	No toxicity value	1.06E-08	NA	4.53E-09	7.30E+00	3.31E-08
Indeno(1,2,3-cd)pyrene	2.30E-01	No toxicity value	1.26E-08	NA	5.40E-09	7.30E-01	3.94E-09
Hazard Index				1.92E-02			
Total Cancer Risk							1.16E-06

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-5. Risks and Hazards from Dermal Contact with Surface Soil at Acid Area 3 for Adult Hunter Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.10E+03	1.00E+00	ND	NA	ND	No toxicity value	NA
Arsenic	7.07E+00	3.00E-04	1.05E-07	3.49E-04	4.48E-08	1.50E+00	6.72E-08
Iron	1.69E+04	7.00E-01	ND	NA	ND	No toxicity value	NA
Lead	1.21E+02	No toxicity value	ND	NA	ND	No toxicity value	NA
Manganese	4.26E+02	4.67E-02	ND	NA	ND	No toxicity value	NA
Thallium	5.11E+00	7.00E-05	ND	NA	ND	No toxicity value	NA
Vanadium	2.16E+01	5.00E-03	ND	NA	ND	No toxicity value	NA
PCB-1254	4.18E+00	2.00E-05	2.89E-07	1.44E-02	1.24E-07	2.00E+00	2.47E-07
PCB-1260	5.70E-01	No toxicity value	3.94E-08	NA	1.69E-08	2.00E+00	3.37E-08
Benzo(a)anthracene	3.50E+00	No toxicity value	2.24E-07	NA	9.62E-08	7.30E-01	7.02E-08
Benzo(a)pyrene	3.40E+00	No toxicity value	2.18E-07	NA	9.34E-08	7.30E+00	6.82E-07
Benzo(b)fluoranthene	3.82E-01	No toxicity value	2.45E-08	NA	1.05E-08	7.30E-01	7.66E-09
Dibenz(a,h)anthracene	1.93E-01	No toxicity value	1.24E-08	NA	5.30E-09	7.30E+00	3.87E-08
Indeno(1,2,3-cd)pyrene	2.30E-01	No toxicity value	1.47E-08	NA	6.32E-09	7.30E-01	4.61E-09
Hazard Index				1.48E-02			
Total Cancer Risk							1.15E-06

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-6. Risks and Hazards from Ingestion of Venison Harvested from Acid Area 3 for Adult Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Venison (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	1.58E-04	1.00E+00	2.82E-08	2.82E-08	1.21E-08	No toxicity value	NA
Arsenic	2.46E-07	3.00E-04	4.38E-11	1.46E-07	1.88E-11	1.50E+00	2.82E-11
Iron	5.89E-02	7.00E-01	1.05E-05	1.50E-05	4.50E-06	No toxicity value	NA
Lead	9.47E-08	No toxicity value	1.69E-11	NA	7.23E-12	No toxicity value	NA
Manganese	5.93E-07	4.67E-02	1.06E-10	2.26E-09	4.53E-11	No toxicity value	NA
Thallium	7.11E-05	7.00E-05	1.27E-08	1.81E-04	5.43E-09	No toxicity value	NA
Vanadium	1.17E-06	5.00E-03	2.09E-10	4.18E-08	8.96E-11	No toxicity value	NA
PCB-1254	1.16E-05	2.00E-05	2.07E-09	1.03E-04	8.86E-10	2.00E+00	1.77E-09
PCB-1260	4.48E-07	No toxicity value	7.98E-11	NA	3.42E-11	2.00E+00	6.84E-11
Benzo(a)anthracene	5.76E-07	No toxicity value	1.03E-10	NA	4.40E-11	7.30E-01	3.21E-11
Benzo(a)pyrene	6.80E-07	No toxicity value	1.21E-10	NA	5.19E-11	7.30E+00	3.79E-10
Benzo(b)fluoranthene	9.45E-08	No toxicity value	1.68E-11	NA	7.21E-12	7.30E-01	5.27E-12
Dibenz(a,h)anthracene	1.86E-07	No toxicity value	3.30E-11	NA	1.42E-11	7.30E+00	1.03E-10
Indeno(1,2,3-cd)pyrene	4.71E-08	No toxicity value	8.38E-12	NA	3.59E-12	7.30E-01	2.62E-12
Hazard Index				3.00E-04			
Total Cancer Risk							2.39E-09

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-7. Risks and Hazards from Ingestion of Venison Harvested from Acid Area 3 for Child Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Venison (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	1.58E-04	1.00E+00	5.07E-08	5.07E-08	4.34E-09	No toxicity value	NA
Arsenic	2.46E-07	3.00E-04	7.86E-11	2.62E-07	6.74E-12	1.50E+00	1.01E-11
Iron	5.89E-02	7.00E-01	1.88E-05	2.69E-05	1.61E-06	No toxicity value	NA
Lead	9.47E-08	No toxicity value	3.03E-11	NA	2.60E-12	No toxicity value	NA
Manganese	5.93E-07	4.67E-02	1.90E-10	4.06E-09	1.62E-11	No toxicity value	NA
Thallium	7.11E-05	7.00E-05	2.27E-08	3.25E-04	1.95E-09	No toxicity value	NA
Vanadium	1.17E-06	5.00E-03	3.75E-10	7.51E-08	3.22E-11	No toxicity value	NA
PCB-1254	1.16E-05	2.00E-05	3.71E-09	1.86E-04	3.18E-10	2.00E+00	6.36E-10
PCB-1260	4.48E-07	No toxicity value	1.43E-10	NA	1.23E-11	2.00E+00	2.45E-11
Benzo(a)anthracene	5.76E-07	No toxicity value	1.84E-10	NA	1.58E-11	7.30E-01	1.15E-11
Benzo(a)pyrene	6.80E-07	No toxicity value	2.17E-10	NA	1.86E-11	7.30E+00	1.36E-10
Benzo(b)fluoranthene	9.45E-08	No toxicity value	3.02E-11	NA	2.59E-12	7.30E-01	1.89E-12
Dibenz(a,h)anthracene	1.86E-07	No toxicity value	5.93E-11	NA	5.08E-12	7.30E+00	3.71E-11
Indeno(1,2,3-cd)pyrene	4.71E-08	No toxicity value	1.50E-11	NA	1.29E-12	7.30E-01	9.41E-13
Hazard Index				5.38E-04			
Total Cancer Risk							8.58E-10

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-8. Risks and Hazards from Ingestion of Surface Soil at Acid Area 3 for Construction Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.10E+03	1.00E+00	4.60E-02	4.60E-02	3.28E-04	No toxicity value	NA
Arsenic	7.07E+00	3.00E-04	4.01E-05	1.34E-01	2.87E-07	1.50E+00	4.30E-07
Iron	1.69E+04	7.00E-01	9.61E-02	1.37E-01	6.86E-04	No toxicity value	NA
Lead	1.21E+02	No toxicity value	6.87E-04	NA	4.90E-06	No toxicity value	NA
Manganese	4.26E+02	4.67E-02	2.42E-03	5.18E-02	1.73E-05	No toxicity value	NA
Thallium	5.11E+00	7.00E-05	2.90E-05	4.14E-01	2.07E-07	No toxicity value	NA
Vanadium	2.16E+01	5.00E-03	1.23E-04	2.45E-02	8.76E-07	No toxicity value	NA
PCB-1254	4.18E+00	2.00E-05	2.37E-05	1.19E+00	1.69E-07	2.00E+00	3.39E-07
PCB-1260	5.70E-01	No toxicity value	3.23E-06	NA	2.31E-08	2.00E+00	4.62E-08
Benzo(a)anthracene	3.50E+00	No toxicity value	1.99E-05	NA	1.42E-07	7.30E-01	1.04E-07
Benzo(a)pyrene	3.40E+00	No toxicity value	1.93E-05	NA	1.38E-07	7.30E+00	1.01E-06
Benzo(b)fluoranthene	3.82E-01	No toxicity value	2.17E-06	NA	1.55E-08	7.30E-01	1.13E-08
Dibenz(a,h)anthracene	1.93E-01	No toxicity value	1.10E-06	NA	7.82E-09	7.30E+00	5.71E-08
Indeno(1,2,3-cd)pyrene	2.30E-01	No toxicity value	1.31E-06	NA	9.32E-09	7.30E-01	6.81E-09
Hazard Index				1.99E+00			
Total Cancer Risk							2.00E-06

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-9. Risks and Hazards from Dermal Contact with Surface Soil at Acid Area 3 for Construction Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.10E+03	1.00E+00	ND	NA	ND	No toxicity value	NA
Arsenic	7.07E+00	3.00E-04	3.75E-06	1.25E-02	2.68E-08	1.50E+00	4.02E-08
Iron	1.69E+04	7.00E-01	ND	NA	ND	No toxicity value	NA
Lead	1.21E+02	No toxicity value	ND	NA	ND	No toxicity value	NA
Manganese	4.26E+02	4.67E-02	ND	NA	ND	No toxicity value	NA
Thallium	5.11E+00	7.00E-05	ND	NA	ND	No toxicity value	NA
Vanadium	2.16E+01	5.00E-03	ND	NA	ND	No toxicity value	NA
PCB-1254	4.18E+00	2.00E-05	1.04E-05	5.18E-01	7.39E-08	2.00E+00	1.48E-07
PCB-1260	5.70E-01	No toxicity value	1.41E-06	NA	1.01E-08	2.00E+00	2.02E-08
Benzo(a)anthracene	3.50E+00	No toxicity value	8.05E-06	NA	5.75E-08	7.30E-01	4.20E-08
Benzo(a)pyrene	3.40E+00	No toxicity value	7.82E-06	NA	5.59E-08	7.30E+00	4.08E-07
Benzo(b)fluoranthene	3.82E-01	No toxicity value	8.79E-07	NA	6.28E-09	7.30E-01	4.58E-09
Dibenz(a,h)anthracene	1.93E-01	No toxicity value	4.44E-07	NA	3.17E-09	7.30E+00	2.31E-08
Indeno(1,2,3-cd)pyrene	2.30E-01	No toxicity value	5.29E-07	NA	3.78E-09	7.30E-01	2.76E-09
Hazard Index				5.30E-01			
Total Cancer Risk							6.88E-07

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-10. Risks and Hazards from inhalation of Surface Soil at Acid Area 3 for Construction Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.10E+03	1.43E-03	7.40E-07	5.18E-04	5.29E-09	No toxicity value	NA
Arsenic	7.07E+00	No toxicity value	6.47E-10	NA	4.62E-12	1.51E+01	6.95E-11
Iron	1.69E+04	No toxicity value	1.55E-06	NA	1.11E-08	No toxicity value	NA
Lead	1.21E+02	No toxicity value	1.11E-08	NA	7.90E-11	No toxicity value	NA
Manganese	4.26E+02	1.40E-05	3.90E-08	2.78E-03	2.78E-10	No toxicity value	NA
Thallium	5.11E+00	No toxicity value	4.67E-10	NA	3.34E-12	No toxicity value	NA
Vanadium	2.16E+01	No toxicity value	1.98E-09	NA	1.41E-11	No toxicity value	NA
PCB-1254	4.18E+00	2.00E-05	3.82E-10	1.91E-05	2.73E-12	2.00E+00	5.46E-12
PCB-1260	5.70E-01	No toxicity value	5.21E-11	NA	3.72E-13	2.00E+00	7.45E-13
Benzo(a)anthracene	3.50E+00	No toxicity value	3.20E-10	NA	2.29E-12	3.10E-01	7.09E-13
Benzo(a)pyrene	3.40E+00	No toxicity value	3.11E-10	NA	2.22E-12	3.10E+00	6.88E-12
Benzo(b)fluoranthene	3.82E-01	No toxicity value	3.49E-11	NA	2.50E-13	3.10E-01	7.74E-14
Dibenz(a,h)anthracene	1.93E-01	No toxicity value	1.76E-11	NA	1.26E-13	3.10E+00	3.91E-13
Indeno(1,2,3-cd)pyrene	2.30E-01	No toxicity value	2.10E-11	NA	1.50E-13	3.10E-01	4.66E-14
Hazard Index				3.32E-03			
Total Cancer Risk							8.38E-11

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-11. Risks and Hazards from Ingestion of Subsurface Soil at Acid Area 3 for Construction Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.71E+03	1.00E+00	4.94E-02	4.94E-02	3.53E-04	No toxicity value	NA
Antimony	8.00E+00	4.00E-04	4.54E-05	1.14E-01	3.24E-07	No toxicity value	NA
Arsenic	8.50E+00	3.00E-04	4.82E-05	1.61E-01	3.45E-07	1.50E+00	5.17E-07
Iron	2.12E+04	7.00E-01	1.20E-01	1.72E-01	8.58E-04	No toxicity value	NA
Manganese	6.23E+02	4.67E-02	3.54E-03	7.58E-02	2.53E-05	No toxicity value	NA
Thallium	5.45E+00	7.00E-05	3.09E-05	4.42E-01	2.21E-07	No toxicity value	NA
Vanadium	2.48E+01	5.00E-03	1.41E-04	2.81E-02	1.01E-06	No toxicity value	NA
0.00E+00	0.00E+00	#N/A	0.00E+00	NA	0.00E+00	#N/A	NA
Hazard Index				1.04E+00			
Total Cancer Risk							5.17E-07

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-12. Risks and Hazards from Dermal contact with Subsurface Soil at Acid Area 3 for Construction Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.71E+03	1.00E+00	ND	NA	ND	No toxicity value	NA
Antimony	8.00E+00	4.00E-04	ND	NA	ND	No toxicity value	NA
Arsenic	8.50E+00	3.00E-04	4.51E-06	1.50E-02	3.22E-08	1.50E+00	4.83E-08
Iron	2.12E+04	7.00E-01	ND	NA	ND	No toxicity value	NA
Manganese	6.23E+02	4.67E-02	ND	NA	ND	No toxicity value	NA
Thallium	5.45E+00	7.00E-05	ND	NA	ND	No toxicity value	NA
Vanadium	2.48E+01	5.00E-03	ND	NA	ND	No toxicity value	NA
0.00E+00	0.00E+00	#N/A	#N/A	NA	#N/A	#N/A	NA

Hazard Index	1.50E-02

Total Cancer Risk		4.83E-08

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-13. Risks and Hazards from Dermal Contact with Surface Water at Acid Area 3 for Construction Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Water (mg/L) RME	Reference Dose 1/(mg/kg-day)	Dermal Absorbed Dose RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Dermal Absorbed Dose RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Manganese	5.26E-02	4.67E-02	6.36E-06	1.36E-04	4.56E-08	No toxicity value	NA
Hazard Index				1.36E-04			
Total Cancer Risk							

RME = reasonable maximum exposure
RfD = reference dose
Sf = slope factor

Table B-14. Risks and Hazards from Ingestion of Sediment at Acid Area 3 for Construction Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Sediment (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.94E+03	1.00E+00	2.54E-02	2.54E-02	6.23E-05	No toxicity value	NA
Arsenic	1.03E+01	3.00E-04	2.92E-05	9.74E-02	7.18E-08	1.50E+00	1.08E-07
Iron	2.05E+04	7.00E-01	5.82E-02	8.32E-02	1.43E-04	No toxicity value	NA
Lead	5.25E+01	No toxicity value	1.49E-04	NA	3.66E-07	No toxicity value	NA
Manganese	4.62E+02	4.67E-02	1.31E-03	2.81E-02	3.22E-06	No toxicity value	NA
Thallium	3.70E+00	7.00E-05	1.05E-05	1.50E-01	2.58E-08	No toxicity value	NA
Vanadium	2.24E+01	5.00E-03	6.36E-05	1.27E-02	1.56E-07	No toxicity value	NA
PCB-1254	4.73E-01	2.00E-05	1.34E-06	6.71E-02	3.30E-09	2.00E+00	6.60E-09
PCB-1260	1.35E-01	No toxicity value	3.83E-07	NA	9.41E-10	2.00E+00	1.88E-09
Benzo(a)pyrene	2.46E-01	No toxicity value	6.98E-07	NA	1.72E-09	7.30E+00	1.25E-08
Hazard Index				4.64E-01			
Total Cancer Risk							1.29E-07

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-15. Risks and Hazards from Dermal Contact with Sediment at Acid Area 3 for Construction Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Sediment (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.94E+03	1.00E+00	ND	NA	ND	No toxicity value	NA
Arsenic	1.03E+01	3.00E-04	7.74E-07	2.58E-03	5.53E-09	1.50E+00	8.29E-09
Iron	2.05E+04	7.00E-01	ND	NA	ND	No toxicity value	NA
Lead	5.25E+01	No toxicity value	ND	NA	ND	No toxicity value	NA
Manganese	4.62E+02	4.67E-02	ND	NA	ND	No toxicity value	NA
Thallium	3.70E+00	7.00E-05	ND	NA	ND	No toxicity value	NA
Vanadium	2.24E+01	5.00E-03	ND	NA	ND	No toxicity value	NA
PCB-1254	4.73E-01	2.00E-05	1.66E-07	8.29E-03	1.18E-09	2.00E+00	2.37E-09
PCB-1260	1.35E-01	No toxicity value	4.73E-08	NA	3.38E-10	2.00E+00	6.76E-10
Benzo(a)pyrene	2.46E-01	No toxicity value	8.01E-08	NA	5.72E-10	7.30E+00	4.18E-09

Hazard Index	1.09E-02	
Total Cancer Risk		1.55E-08

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-16. Risks and Hazards from Ingestion of Bedrock Groundwater at Acid Area 3 for Indoor Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Groundwater (mg/L) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
2-Methylnaphthalene	5.20E-03	2.00E-02	5.08E-05	2.54E-03	1.82E-05	No toxicity value	NA
2-Nitrotoluene	1.54E-03	1.00E-02	1.51E-05	1.51E-03	5.40E-06	2.30E-01	1.24E-06
Arsenic (total)	3.87E-03	3.00E-04	3.78E-05	1.26E-01	1.35E-05	1.50E+00	2.03E-05
Barium (total)	7.35E-01	2.00E-01	7.19E-03	3.60E-02	2.57E-03	No toxicity value	NA
Benzene	8.02E-02	4.00E-03	7.85E-04	1.96E-01	2.80E-04	5.50E-02	1.54E-05
bis(2-Ethylhexyl)phthalate	3.51E-03	2.00E-02	3.43E-05	1.72E-03	1.23E-05	1.40E-02	1.72E-07
Methylene Chloride	1.60E-01	6.00E-02	1.57E-03	2.61E-02	5.59E-04	7.50E-03	4.19E-06
Naphthalene	5.30E-03	2.00E-02	5.19E-05	2.59E-03	1.85E-05	No toxicity value	NA
Tetrachloroethene (PCE)	5.00E-04	1.00E-02	4.89E-06	4.89E-04	1.75E-06	5.40E-01	9.44E-07
Thallium (total)	6.53E-03	7.00E-05	6.39E-05	9.12E-01	2.28E-05	No toxicity value	NA
Xylenes, total	1.48E-01	2.00E-01	1.45E-03	7.23E-03	5.17E-04	No toxicity value	NA
Hazard Index				1.31E+00			
Total Cancer Risk							4.22E-05

RME = reasonable maximum exposure
Sf = slope factor
RfD = reference dose

Table B-17. Risks and Hazards from Dermal Contact with Bedrock Groundwater at Acid Area 3 for Indoor Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Groundwater (mg/L) RME	Reference Dose 1/(mg/kg-day)	Dermal Absorbed Dose RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Dermal Absorbed Dose RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
2-Methylnaphthalene	5.20E-03	2.00E-02	3.69E-05	1.85E-03	1.32E-05	No toxicity value	NA
2-Nitrotoluene	1.54E-03	1.00E-02	1.23E-06	1.23E-04	4.41E-07	2.30E-01	1.01E-07
Arsenic (total)	3.87E-03	3.00E-04	1.25E-07	4.16E-04	4.46E-08	1.50E+00	6.69E-08
Barium (total)	7.35E-01	2.00E-01	2.37E-05	1.19E-04	8.47E-06	No toxicity value	NA
Benzene	8.02E-02	4.00E-03	6.02E-05	1.51E-02	2.15E-05	5.50E-02	1.18E-06
bis(2-Ethylhexyl)phthalate	3.51E-03	2.00E-02	2.55E-05	1.27E-03	9.10E-06	1.40E-02	1.27E-07
Methylene Chloride	1.60E-01	6.00E-02	2.99E-05	4.98E-04	1.07E-05	7.50E-03	8.00E-08
Naphthalene	5.30E-03	2.00E-02	1.65E-05	8.23E-04	5.88E-06	No toxicity value	NA
Tetrachloroethene (PCE)	5.00E-04	1.00E-02	1.42E-06	1.42E-04	5.07E-07	5.40E-01	2.74E-07
Thallium (total)	6.53E-03	7.00E-05	2.11E-07	3.01E-03	7.53E-08	No toxicity value	NA
Xylenes, total	1.48E-01	2.00E-01	4.21E-04	2.10E-03	1.50E-04	No toxicity value	NA

Hazard Index	2.54E-02

Total Cancer Risk		1.83E-06

RME = reasonable maximum exposure
RfD = reference dose
Sf = slope factor

Table B-18. Risks and Hazards from Ingestion of Surface Soil at Acid Area 3 for Indoor Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.10E+03	1.00E+00	3.96E-03	3.96E-03	1.41E-03	No toxicity value	NA
Arsenic	7.07E+00	3.00E-04	3.46E-06	1.15E-02	1.24E-06	1.50E+00	1.85E-06
Iron	1.69E+04	7.00E-01	8.29E-03	1.18E-02	2.96E-03	No toxicity value	NA
Lead	1.21E+02	No toxicity value	5.92E-05	NA	2.11E-05	No toxicity value	NA
Manganese	4.26E+02	4.67E-02	2.08E-04	4.47E-03	7.44E-05	No toxicity value	NA
Thallium	5.11E+00	7.00E-05	2.50E-06	3.57E-02	8.93E-07	No toxicity value	NA
Vanadium	2.16E+01	5.00E-03	1.06E-05	2.11E-03	3.77E-06	No toxicity value	NA
PCB-1254	4.18E+00	2.00E-05	2.05E-06	1.02E-01	7.30E-07	2.00E+00	1.46E-06
PCB-1260	5.70E-01	No toxicity value	2.79E-07	NA	9.96E-08	2.00E+00	1.99E-07
Benzo(a)anthracene	3.50E+00	No toxicity value	1.71E-06	NA	6.12E-07	7.30E-01	4.46E-07
Benzo(a)pyrene	3.40E+00	No toxicity value	1.66E-06	NA	5.94E-07	7.30E+00	4.34E-06
Benzo(b)fluoranthene	3.82E-01	No toxicity value	1.87E-07	NA	6.67E-08	7.30E-01	4.87E-08
Dibenz(a,h)anthracene	1.93E-01	No toxicity value	9.44E-08	NA	3.37E-08	7.30E+00	2.46E-07
Indeno(1,2,3-cd)pyrene	2.30E-01	No toxicity value	1.13E-07	NA	4.02E-08	7.30E-01	2.93E-08
Hazard Index				1.72E-01			
Total Cancer Risk							8.62E-06

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure

SF = slope factor

Table B-19. Risks and Hazards from Ingestion of Bedrock Groundwater at Acid Area 3 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Groundwater (mg/L) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
2-Methylnaphthalene	5.20E-03	2.00E-02	1.42E-04	7.12E-03	4.88E-05	No toxicity value	NA
2-Nitrotoluene	1.54E-03	1.00E-02	4.23E-05	4.23E-03	1.45E-05	2.30E-01	3.34E-06
Arsenic (total)	3.87E-03	3.00E-04	1.06E-04	3.53E-01	3.63E-05	1.50E+00	5.45E-05
Barium (total)	7.35E-01	2.00E-01	2.01E-02	1.01E-01	6.90E-03	No toxicity value	NA
Benzene	8.02E-02	4.00E-03	2.20E-03	5.49E-01	7.53E-04	5.50E-02	4.14E-05
bis(2-Ethylhexyl)phthalate	3.51E-03	2.00E-02	9.61E-05	4.80E-03	3.29E-05	1.40E-02	4.61E-07
Methylene Chloride	1.60E-01	6.00E-02	4.38E-03	7.31E-02	1.50E-03	7.50E-03	1.13E-05
Naphthalene	5.30E-03	2.00E-02	1.45E-04	7.26E-03	4.98E-05	No toxicity value	NA
Tetrachloroethene (PCE)	5.00E-04	1.00E-02	1.37E-05	1.37E-03	4.70E-06	5.40E-01	2.54E-06
Thallium (total)	6.53E-03	7.00E-05	1.79E-04	2.55E+00	6.13E-05	No toxicity value	NA
Xylenes, total	1.48E-01	2.00E-01	4.05E-03	2.03E-02	1.39E-03	No toxicity value	NA
Hazard Index				3.68E+00			
Total Cancer Risk							1.14E-04

RME = reasonable maximum exposure
Sf = slope factor
RfD = reference dose

Table B-20. Risks and Hazards from Dermal Contact with Bedrock Groundwater at Acid Area 3 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Groundwater (mg/L) RME	Reference Dose 1/(mg/kg-day)	Dermal Absorbed Dose RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Dermal Absorbed Dose RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
2-Methylnaphthalene	5.20E-03	2.00E-02	1.40E-04	7.01E-03	4.81E-05	No toxicity value	NA
2-Nitrotoluene	1.54E-03	1.00E-02	4.68E-06	4.68E-04	1.61E-06	2.30E-01	3.69E-07
Arsenic (total)	3.87E-03	3.00E-04	2.12E-07	7.06E-04	7.26E-08	1.50E+00	1.09E-07
Barium (total)	7.35E-01	2.00E-01	4.03E-05	2.01E-04	1.38E-05	No toxicity value	NA
Benzene	8.02E-02	4.00E-03	2.18E-04	5.45E-02	7.48E-05	5.50E-02	4.11E-06
bis(2-Ethylhexyl)phthalate	3.51E-03	2.00E-02	9.66E-05	4.83E-03	3.31E-05	1.40E-02	4.64E-07
Methylene Chloride	1.60E-01	6.00E-02	1.08E-04	1.81E-03	3.71E-05	7.50E-03	2.79E-07
Naphthalene	5.30E-03	2.00E-02	6.25E-05	3.12E-03	2.14E-05	No toxicity value	NA
Tetrachloroethene (PCE)	5.00E-04	1.00E-02	5.39E-06	5.39E-04	1.85E-06	5.40E-01	9.98E-07
Thallium (total)	6.53E-03	7.00E-05	3.58E-07	5.11E-03	1.23E-07	No toxicity value	NA
Xylenes, total	1.48E-01	2.00E-01	1.60E-03	7.99E-03	5.48E-04	No toxicity value	NA

Hazard Index	8.63E-02

Total Cancer Risk		6.33E-06

RME = reasonable maximum exposure
RfD = reference dose
Sf = slope factor

Table B-21. Risks and Hazards from Inhalation of Volatiles from Bedrock Groundwater at Acid Area 3 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Groundwater (mg/L) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
2-Methylnaphthalene	5.20E-03	8.57E-04	2.96E-05	3.46E-02	1.02E-05	No toxicity value	NA
2-Nitrotoluene	1.54E-03	No toxicity value	8.81E-06	NA	3.02E-06	No toxicity value	NA
Arsenic (total)	3.87E-03	No toxicity value	2.21E-05	NA	7.56E-06	1.51E+01	NA
Barium (total)	7.35E-01	2.00E-01	4.19E-03	NA	1.44E-03	No toxicity value	NA
Benzene	8.02E-02	8.57E-03	4.57E-04	5.34E-02	1.57E-04	2.70E-02	4.23E-06
bis(2-Ethylhexyl)phthalate	3.51E-03	2.00E-02	2.00E-05	1.00E-03	6.86E-06	1.40E-02	9.61E-08
Methylene Chloride	1.60E-01	8.57E-01	9.13E-04	1.07E-03	3.13E-04	1.65E-03	5.15E-07
Naphthalene	5.30E-03	8.57E-04	3.02E-05	3.53E-02	1.04E-05	No toxicity value	NA
Tetrachloroethene (PCE)	5.00E-04	1.14E-01	2.85E-06	2.50E-05	9.78E-07	2.07E-02	2.02E-08
Thallium (total)	6.53E-03	No toxicity value	3.72E-05	NA	1.28E-05	No toxicity value	NA
Xylenes, total	1.48E-01	2.86E-02	8.44E-04	2.95E-02	2.89E-04	No toxicity value	NA

Hazard Index	1.55E-01

Total Cancer Risk	4.87E-06

RME = reasonable maximum exposure
Sf = slope factor
RfD = reference dose

Table B-22. Risks and Hazards from Ingestion of Surface Soil at Acid Area 3 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.10E+03	1.00E+00	2.00E-04	2.00E-04	3.42E-03	No toxicity value	NA
Arsenic	7.07E+00	3.00E-04	1.74E-07	5.81E-04	2.99E-06	1.50E+00	4.48E-06
Iron	1.69E+04	7.00E-01	4.18E-04	5.97E-04	7.16E-03	No toxicity value	NA
Lead	1.21E+02	No toxicity value	2.98E-06	NA	5.11E-05	No toxicity value	NA
Manganese	4.26E+02	4.67E-02	1.05E-05	2.25E-04	1.80E-04	No toxicity value	NA
Thallium	5.11E+00	7.00E-05	1.26E-07	1.80E-03	2.16E-06	No toxicity value	NA
Vanadium	2.16E+01	5.00E-03	5.33E-07	1.07E-04	9.13E-06	No toxicity value	NA
PCB-1254	4.18E+00	2.00E-05	1.03E-07	5.15E-03	1.77E-06	2.00E+00	3.53E-06
PCB-1260	5.70E-01	No toxicity value	1.41E-08	NA	2.41E-07	2.00E+00	4.82E-07
Benzo(a)anthracene	3.50E+00	No toxicity value	8.63E-08	NA	1.48E-06	7.30E-01	1.08E-06
Benzo(a)pyrene	3.40E+00	No toxicity value	8.38E-08	NA	1.44E-06	7.30E+00	1.05E-05
Benzo(b)fluoranthene	3.82E-01	No toxicity value	9.42E-09	NA	1.61E-07	7.30E-01	1.18E-07
Dibenz(a,h)anthracene	1.93E-01	No toxicity value	4.76E-09	NA	8.16E-08	7.30E+00	5.96E-07
Indeno(1,2,3-cd)pyrene	2.30E-01	No toxicity value	5.67E-09	NA	9.72E-08	7.30E-01	7.10E-08
Hazard Index				8.66E-03			
Total Cancer Risk							2.09E-05

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-23. Risks and Hazards from Dermal Contact with Surface Soil at Acid Area 3 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.10E+03	1.00E+00	ND	NA	ND	No toxicity value	NA
Arsenic	7.07E+00	3.00E-04	2.38E-06	7.93E-03	8.16E-07	1.50E+00	1.22E-06
Iron	1.69E+04	7.00E-01	ND	NA	ND	No toxicity value	NA
Lead	1.21E+02	No toxicity value	ND	NA	ND	No toxicity value	NA
Manganese	4.26E+02	4.67E-02	ND	NA	ND	No toxicity value	NA
Thallium	5.11E+00	7.00E-05	ND	NA	ND	No toxicity value	NA
Vanadium	2.16E+01	5.00E-03	ND	NA	ND	No toxicity value	NA
PCB-1254	4.18E+00	2.00E-05	6.57E-06	3.28E-01	2.25E-06	2.00E+00	4.50E-06
PCB-1260	5.70E-01	No toxicity value	8.95E-07	NA	3.07E-07	2.00E+00	6.14E-07
Benzo(a)anthracene	3.50E+00	No toxicity value	5.10E-06	NA	1.75E-06	7.30E-01	1.28E-06
Benzo(a)pyrene	3.40E+00	No toxicity value	4.96E-06	NA	1.70E-06	7.30E+00	1.24E-05
Benzo(b)fluoranthene	3.82E-01	No toxicity value	5.57E-07	NA	1.91E-07	7.30E-01	1.39E-07
Dibenz(a,h)anthracene	1.93E-01	No toxicity value	2.81E-07	NA	9.65E-08	7.30E+00	7.05E-07
Indeno(1,2,3-cd)pyrene	2.30E-01	No toxicity value	3.35E-07	NA	1.15E-07	7.30E-01	8.40E-08
Hazard Index				3.36E-01			
Total Cancer Risk							2.10E-05

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-24. Risks and Hazards from Inhalation of Particulates from Surface Soil at Acid Area 3 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/L) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.10E+03	1.43E-03	4.66E-07	3.27E-04	1.60E-07	No toxicity value	NA
Arsenic	7.07E+00	No toxicity value	4.07E-10	NA	1.40E-10	1.51E+01	2.10E-09
Iron	1.69E+04	No toxicity value	9.76E-07	NA	3.35E-07	No toxicity value	NA
Lead	1.21E+02	No toxicity value	6.97E-09	NA	2.39E-09	No toxicity value	NA
Manganese	4.26E+02	1.40E-05	2.45E-08	1.75E-03	8.41E-09	No toxicity value	NA
Thallium	5.11E+00	No toxicity value	2.94E-10	NA	1.01E-10	No toxicity value	NA
Vanadium	2.16E+01	No toxicity value	1.24E-09	NA	4.27E-10	No toxicity value	NA
PCB-1254	4.18E+00	2.00E-05	2.41E-10	1.20E-05	8.26E-11	2.00E+00	1.65E-10
PCB-1260	5.70E-01	No toxicity value	3.28E-11	NA	1.13E-11	2.00E+00	2.25E-11
Benzo(a)anthracene	3.50E+00	No toxicity value	2.02E-10	NA	6.91E-11	3.10E-01	2.14E-11
Benzo(a)pyrene	3.40E+00	No toxicity value	1.96E-10	NA	6.72E-11	3.10E+00	2.08E-10
Benzo(b)fluoranthene	3.82E-01	No toxicity value	2.20E-11	NA	7.55E-12	3.10E-01	2.34E-12
Dibenz(a,h)anthracene	1.93E-01	No toxicity value	1.11E-11	NA	3.81E-12	3.10E+00	1.18E-11
Indeno(1,2,3-cd)pyrene	2.30E-01	No toxicity value	1.33E-11	NA	4.54E-12	3.10E-01	1.41E-12
Hazard Index				2.09E-03			
Total Cancer Risk							2.53E-09

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-25. Risks and Hazards from Ingestion of Subsurface Soil at Acid Area 3 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/L) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.71E+03	1.00E+00	2.15E-04	2.15E-04	3.68E-03	No toxicity value	NA
Antimony	8.00E+00	4.00E-04	1.97E-07	4.93E-04	3.38E-06	No toxicity value	NA
Arsenic	8.50E+00	3.00E-04	2.10E-07	6.99E-04	3.59E-06	1.50E+00	5.39E-06
Iron	2.12E+04	7.00E-01	5.22E-04	7.45E-04	8.94E-03	No toxicity value	NA
Manganese	6.23E+02	4.67E-02	1.54E-05	3.29E-04	2.63E-04	No toxicity value	NA
Thallium	5.45E+00	7.00E-05	1.34E-07	1.92E-03	2.30E-06	No toxicity value	NA
Vanadium	2.48E+01	5.00E-03	6.12E-07	1.22E-04	1.05E-05	No toxicity value	NA
0.00E+00	0.00E+00	#N/A	0.00E+00	NA	0.00E+00	#N/A	NA

Hazard Index	4.52E-03	
Total Cancer Risk		5.39E-06

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-26. Risks and Hazards from Dermal Contact with Subsurface Soil at Acid Area 3 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.71E+03	1.00E+00	ND	NA	ND	No toxicity value	NA
Antimony	8.00E+00	4.00E-04	ND	NA	ND	No toxicity value	NA
Arsenic	8.50E+00	3.00E-04	2.86E-06	9.54E-03	9.81E-07	1.50E+00	1.47E-06
Iron	2.12E+04	7.00E-01	ND	NA	ND	No toxicity value	NA
Manganese	6.23E+02	4.67E-02	ND	NA	ND	No toxicity value	NA
Thallium	5.45E+00	7.00E-05	ND	NA	ND	No toxicity value	NA
Vanadium	2.48E+01	5.00E-03	ND	NA	ND	No toxicity value	NA
0.00E+00	0.00E+00	#N/A	#N/A	NA	#N/A	#N/A	NA

Hazard Index	9.54E-03	
Total Cancer Risk		1.47E-06

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-27. Risks and Hazards from Dermal Contact with Surface Water at Acid Area 3 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Water (mg/L) RME	Reference Dose 1/(mg/kg-day)	Dermal Absorbed Dose RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Dermal Absorbed Dose RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Manganese	5.26E-02	4.67E-02	1.75E-06	3.75E-05	6.00E-07	No toxicity value	NA
Hazard Index				3.75E-05			
Total Cancer Risk							

RME - Reasonable Maximum Exposure
RfD - Reference Dose
Sf-Slope factor

Table B-28. Risks and Hazards from Ingestion of Sediment at Acid Area 3 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Sediment (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.94E+03	1.00E+00	1.22E-03	1.22E-03	4.20E-04	No toxicity value	NA
Arsenic	1.03E+01	3.00E-04	1.41E-06	4.70E-03	4.84E-07	1.50E+00	7.26E-07
Iron	2.05E+04	7.00E-01	2.81E-03	4.02E-03	9.64E-04	No toxicity value	NA
Lead	5.25E+01	No toxicity value	7.19E-06	NA	2.47E-06	No toxicity value	NA
Manganese	4.62E+02	4.67E-02	6.33E-05	1.36E-03	2.17E-05	No toxicity value	NA
Thallium	3.70E+00	7.00E-05	5.07E-07	7.24E-03	1.74E-07	No toxicity value	NA
Vanadium	2.24E+01	5.00E-03	3.07E-06	6.14E-04	1.05E-06	No toxicity value	NA
PCB-1254	4.73E-01	2.00E-05	6.48E-08	3.24E-03	2.22E-08	2.00E+00	4.44E-08
PCB-1260	1.35E-01	No toxicity value	1.85E-08	NA	6.34E-09	2.00E+00	1.27E-08
Benzo(a)pyrene	2.46E-01	No toxicity value	3.37E-08	NA	1.16E-08	7.30E+00	8.43E-08

Hazard Index	2.24E-02

Total Cancer Risk		8.67E-07

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-29. Risks and Hazards from Dermal Contact with Sediment at Acid Area 3 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Sediment (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.94E+03	1.00E+00	ND	NA	ND	No toxicity value	NA
Arsenic	1.03E+01	3.00E-04	3.85E-07	1.28E-03	1.32E-07	1.50E+00	1.98E-07
Iron	2.05E+04	7.00E-01	ND	NA	ND	No toxicity value	NA
Lead	5.25E+01	No toxicity value	ND	NA	ND	No toxicity value	NA
Manganese	4.62E+02	4.67E-02	ND	NA	ND	No toxicity value	NA
Thallium	3.70E+00	7.00E-05	ND	NA	ND	No toxicity value	NA
Vanadium	2.24E+01	5.00E-03	ND	NA	ND	No toxicity value	NA
PCB-1254	4.73E-01	2.00E-05	8.25E-08	4.13E-03	2.83E-08	2.00E+00	5.66E-08
PCB-1260	1.35E-01	No toxicity value	2.36E-08	NA	8.08E-09	2.00E+00	1.62E-08
Benzo(a)pyrene	2.46E-01	No toxicity value	3.99E-08	NA	1.37E-08	7.30E+00	9.98E-08
Hazard Index				5.41E-03			
Total Cancer Risk							3.71E-07

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-30. Risks and Hazards from Ingestion of Bedrock Groundwater at Acid Area 3 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Groundwater (mg/L) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
2-Methylnaphthalene	5.20E-03	2.00E-02	3.32E-04	1.66E-02	2.85E-05	No toxicity value	NA
2-Nitrotoluene	1.54E-03	1.00E-02	9.87E-05	9.87E-03	8.46E-06	2.30E-01	1.95E-06
Arsenic (total)	3.87E-03	3.00E-04	2.47E-04	8.24E-01	2.12E-05	1.50E+00	3.18E-05
Barium (total)	7.35E-01	2.00E-01	4.70E-02	2.35E-01	4.03E-03	No toxicity value	NA
Benzene	8.02E-02	4.00E-03	5.13E-03	1.28E+00	4.39E-04	5.50E-02	2.42E-05
bis(2-Ethylhexyl)phthalate	3.51E-03	2.00E-02	2.24E-04	1.12E-02	1.92E-05	1.40E-02	2.69E-07
Methylene Chloride	1.60E-01	6.00E-02	1.02E-02	1.70E-01	8.77E-04	7.50E-03	6.58E-06
Naphthalene	5.30E-03	2.00E-02	3.39E-04	1.69E-02	2.90E-05	No toxicity value	NA
Tetrachloroethene (PCE)	5.00E-04	1.00E-02	3.20E-05	3.20E-03	2.74E-06	5.40E-01	1.48E-06
Thallium (total)	6.53E-03	7.00E-05	4.17E-04	5.96E+00	3.58E-05	No toxicity value	NA
Xylenes, total	1.48E-01	2.00E-01	9.45E-03	4.73E-02	8.10E-04	No toxicity value	NA
Hazard Index				8.58E+00			
Total Cancer Risk							6.62E-05

RME = reasonable maximum exposure
Sf = slope factor
RfD = reference dose

Table B-31. Risks and Hazards from Dermal Contact with Bedrock Groundwater at Acid Area 3 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Groundwater (mg/L) RME	Reference Dose 1/(mg/kg-day)	Dermal Absorbed Dose RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Dermal Absorbed Dose RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
2-Methylnaphthalene	5.20E-03	2.00E-02	2.79E-04	1.39E-02	2.39E-05	No toxicity value	NA
2-Nitrotoluene	1.54E-03	1.00E-02	9.30E-06	9.30E-04	7.97E-07	2.30E-01	1.83E-07
Arsenic (total)	3.87E-03	3.00E-04	5.43E-07	1.81E-03	4.66E-08	1.50E+00	6.98E-08
Barium (total)	7.35E-01	2.00E-01	1.03E-04	5.16E-04	8.85E-06	No toxicity value	NA
Benzene	8.02E-02	4.00E-03	4.33E-04	1.08E-01	3.71E-05	5.50E-02	2.04E-06
bis(2-Ethylhexyl)phthalate	3.51E-03	2.00E-02	1.92E-04	9.60E-03	1.65E-05	1.40E-02	2.30E-07
Methylene Chloride	1.60E-01	6.00E-02	2.15E-04	3.59E-03	1.85E-05	7.50E-03	1.38E-07
Naphthalene	5.30E-03	2.00E-02	1.24E-04	6.21E-03	1.06E-05	No toxicity value	NA
Tetrachloroethene (PCE)	5.00E-04	1.00E-02	1.07E-05	1.07E-03	9.18E-07	5.40E-01	4.96E-07
Thallium (total)	6.53E-03	7.00E-05	9.17E-07	1.31E-02	7.86E-08	No toxicity value	NA
Xylenes, total	1.48E-01	2.00E-01	3.17E-03	1.59E-02	2.72E-04	No toxicity value	NA

Hazard Index	1.75E-01	
Total Cancer Risk		3.16E-06

RME = reasonable maximum exposure
RfD = reference dose
Sf = slope factor

Table B-32. Risks and Hazards from Inhalation of Volatiles from Bedrock Groundwater at Acid Area 3 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Groundwater (mg/L) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
2-Methylnaphthalene	5.20E-03	8.57E-04	6.91E-05	8.06E-02	5.92E-06	No toxicity value	NA
2-Nitrotoluene	1.54E-03	No toxicity value	2.05E-05	NA	1.76E-06	No toxicity value	NA
Arsenic (total)	3.87E-03	No toxicity value	5.14E-05	NA	4.41E-06	1.51E+01	NA
Barium (total)	7.35E-01	2.00E-01	9.77E-03	NA	8.38E-04	No toxicity value	NA
Benzene	8.02E-02	8.57E-03	1.07E-03	1.24E-01	9.14E-05	2.70E-02	2.47E-06
bis(2-Ethylhexyl)phthalate	3.51E-03	2.00E-02	4.66E-05	2.33E-03	4.00E-06	1.40E-02	5.60E-08
Methylene Chloride	1.60E-01	8.57E-01	2.13E-03	2.48E-03	1.82E-04	1.65E-03	3.00E-07
Naphthalene	5.30E-03	8.57E-04	7.05E-05	8.22E-02	6.04E-06	No toxicity value	NA
Tetrachloroethene (PCE)	5.00E-04	1.14E-01	6.65E-06	5.83E-05	5.70E-07	2.07E-02	1.18E-08
Thallium (total)	6.53E-03	No toxicity value	8.68E-05	NA	7.44E-06	No toxicity value	NA
Xylenes, total	1.48E-01	2.86E-02	1.97E-03	6.88E-02	1.69E-04	No toxicity value	NA

Hazard Index	3.61E-01

Total Cancer Risk		2.84E-06

RME = reasonable maximum exposure
Sf = slope factor
RfD = reference dose

Table B-33. Risks and Hazards from Ingestion of Surface Soil at Acid Area 3 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/L) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.10E+03	1.00E+00	9.32E-02	9.32E-02	7.99E-03	No toxicity value	NA
Arsenic	7.07E+00	3.00E-04	8.14E-05	2.71E-01	6.97E-06	1.50E+00	1.05E-05
Iron	1.69E+04	7.00E-01	1.95E-01	2.78E-01	1.67E-02	No toxicity value	NA
Lead	1.21E+02	No toxicity value	1.39E-03	NA	1.19E-04	No toxicity value	NA
Manganese	4.26E+02	4.67E-02	4.90E-03	1.05E-01	4.20E-04	No toxicity value	NA
Thallium	5.11E+00	7.00E-05	5.88E-05	8.40E-01	5.04E-06	No toxicity value	NA
Vanadium	2.16E+01	5.00E-03	2.49E-04	4.97E-02	2.13E-05	No toxicity value	NA
PCB-1254	4.18E+00	2.00E-05	4.81E-05	2.40E+00	4.12E-06	2.00E+00	8.25E-06
PCB-1260	5.70E-01	No toxicity value	6.56E-06	NA	5.62E-07	2.00E+00	1.12E-06
Benzo(a)anthracene	3.50E+00	No toxicity value	4.03E-05	NA	3.45E-06	7.30E-01	2.52E-06
Benzo(a)pyrene	3.40E+00	No toxicity value	3.91E-05	NA	3.35E-06	7.30E+00	2.45E-05
Benzo(b)fluoranthene	3.82E-01	No toxicity value	4.40E-06	NA	3.77E-07	7.30E-01	2.75E-07
Dibenz(a,h)anthracene	1.93E-01	No toxicity value	2.22E-06	NA	1.90E-07	7.30E+00	1.39E-06
Indeno(1,2,3-cd)pyrene	2.30E-01	No toxicity value	2.65E-06	NA	2.27E-07	7.30E-01	1.66E-07
Hazard Index				4.04E+00			
Total Cancer Risk							4.87E-05

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-34. Risks and Hazards from Dermal Contact with Surface Soil at Acid Area 3 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.10E+03	1.00E+00	ND	NA	ND	No toxicity value	NA
Arsenic	7.07E+00	3.00E-04	4.27E-06	1.42E-02	3.66E-07	1.50E+00	5.49E-07
Iron	1.69E+04	7.00E-01	ND	NA	ND	No toxicity value	NA
Lead	1.21E+02	No toxicity value	ND	NA	ND	No toxicity value	NA
Manganese	4.26E+02	4.67E-02	ND	NA	ND	No toxicity value	NA
Thallium	5.11E+00	7.00E-05	ND	NA	ND	No toxicity value	NA
Vanadium	2.16E+01	5.00E-03	ND	NA	ND	No toxicity value	NA
PCB-1254	4.18E+00	2.00E-05	1.18E-05	5.89E-01	1.01E-06	2.00E+00	2.02E-06
PCB-1260	5.70E-01	No toxicity value	1.61E-06	NA	1.38E-07	2.00E+00	2.75E-07
Benzo(a)anthracene	3.50E+00	No toxicity value	9.16E-06	NA	7.85E-07	7.30E-01	5.73E-07
Benzo(a)pyrene	3.40E+00	No toxicity value	8.90E-06	NA	7.63E-07	7.30E+00	5.57E-06
Benzo(b)fluoranthene	3.82E-01	No toxicity value	1.00E-06	NA	8.57E-08	7.30E-01	6.26E-08
Dibenz(a,h)anthracene	1.93E-01	No toxicity value	5.05E-07	NA	4.33E-08	7.30E+00	3.16E-07
Indeno(1,2,3-cd)pyrene	2.30E-01	No toxicity value	6.02E-07	NA	5.16E-08	7.30E-01	3.77E-08
Hazard Index				6.03E-01			
Total Cancer Risk							9.40E-06

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-35. Risks and Hazards from Inhalation of Particulates from Surface Soil at Acid Area 3 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.10E+03	1.43E-03	1.09E-06	7.62E-04	9.33E-08	No toxicity value	NA
Arsenic	7.07E+00	No toxicity value	9.50E-10	NA	8.15E-11	1.51E+01	1.23E-09
Iron	1.69E+04	No toxicity value	2.28E-06	NA	1.95E-07	No toxicity value	NA
Lead	1.21E+02	No toxicity value	1.63E-08	NA	1.39E-09	No toxicity value	NA
Manganese	4.26E+02	1.40E-05	5.73E-08	4.09E-03	4.91E-09	No toxicity value	NA
Thallium	5.11E+00	No toxicity value	6.87E-10	NA	5.89E-11	No toxicity value	NA
Vanadium	2.16E+01	No toxicity value	2.90E-09	NA	2.49E-10	No toxicity value	NA
PCB-1254	4.18E+00	2.00E-05	5.62E-10	2.81E-05	4.82E-11	2.00E+00	9.63E-11
PCB-1260	5.70E-01	No toxicity value	7.66E-11	NA	6.57E-12	2.00E+00	1.31E-11
Benzo(a)anthracene	3.50E+00	No toxicity value	4.70E-10	NA	4.03E-11	3.10E-01	1.25E-11
Benzo(a)pyrene	3.40E+00	No toxicity value	4.57E-10	NA	3.92E-11	3.10E+00	1.21E-10
Benzo(b)fluoranthene	3.82E-01	No toxicity value	5.14E-11	NA	4.40E-12	3.10E-01	1.36E-12
Dibenz(a,h)anthracene	1.93E-01	No toxicity value	2.59E-11	NA	2.22E-12	3.10E+00	6.89E-12
Indeno(1,2,3-cd)pyrene	2.30E-01	No toxicity value	3.09E-11	NA	2.65E-12	3.10E-01	8.22E-13
Hazard Index				4.88E-03			
Total Cancer Risk							1.48E-09

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-36. Risks and Hazards from Ingestion of Subsurface Soil at Acid Area 3 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.71E+03	1.00E+00	1.00E-01	1.00E-01	8.59E-03	No toxicity value	NA
Antimony	8.00E+00	4.00E-04	9.21E-05	2.30E-01	7.89E-06	No toxicity value	NA
Arsenic	8.50E+00	3.00E-04	9.78E-05	3.26E-01	8.38E-06	1.50E+00	1.26E-05
Iron	2.12E+04	7.00E-01	2.43E-01	3.48E-01	2.09E-02	No toxicity value	NA
Manganese	6.23E+02	4.67E-02	7.17E-03	1.54E-01	6.14E-04	No toxicity value	NA
Thallium	5.45E+00	7.00E-05	6.27E-05	8.96E-01	5.38E-06	No toxicity value	NA
Vanadium	2.48E+01	5.00E-03	2.85E-04	5.71E-02	2.45E-05	No toxicity value	NA
0.00E+00	0.00E+00	#N/A	0.00E+00	NA	0.00E+00	#N/A	NA

Hazard Index	2.11E+00

Total Cancer Risk		1.26E-05

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-37. Risks and Hazards from Dermal Contact with Subsurface Soil at Acid Area 3 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.71E+03	1.00E+00	ND	NA	ND	No toxicity value	NA
Antimony	8.00E+00	4.00E-04	ND	NA	ND	No toxicity value	NA
Arsenic	8.50E+00	3.00E-04	5.13E-06	1.71E-02	4.40E-07	1.50E+00	6.60E-07
Iron	2.12E+04	7.00E-01	ND	NA	ND	No toxicity value	NA
Manganese	6.23E+02	4.67E-02	ND	NA	ND	No toxicity value	NA
Thallium	5.45E+00	7.00E-05	ND	NA	ND	No toxicity value	NA
Vanadium	2.48E+01	5.00E-03	ND	NA	ND	No toxicity value	NA
0.00E+00	0.00E+00	#N/A	#N/A	NA	#N/A	#N/A	NA

Hazard Index	1.71E-02	
Total Cancer Risk		6.60E-07

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-38. Risks and Hazards from Dermal Contact with Surface Water at Acid Area 3 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Water (mg/L) RME	Reference Dose 1/(mg/kg-day)	Dermal Absorbed Dose RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Dermal Absorbed Dose RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Manganese	5.26E-02	4.67E-02	3.15E-06	6.74E-05	2.70E-07	No toxicity value	NA
Hazard Index				6.74E-05			
Total Cancer Risk							

RME - Reasonable Maximum Exposure
RfD - Reference Dose
Sf-Slope factor

Table B-39. Risks and Hazards from Ingestion of Sediment at Acid Area 3 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Sediment (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.94E+03	1.00E+00	1.14E-02	1.14E-02	9.79E-04	No toxicity value	NA
Arsenic	1.03E+01	3.00E-04	1.32E-05	4.39E-02	1.13E-06	1.50E+00	1.69E-06
Iron	2.05E+04	7.00E-01	2.62E-02	3.75E-02	2.25E-03	No toxicity value	NA
Lead	5.25E+01	No toxicity value	6.71E-05	NA	5.75E-06	No toxicity value	NA
Manganese	4.62E+02	4.67E-02	5.91E-04	1.27E-02	5.06E-05	No toxicity value	NA
Thallium	3.70E+00	7.00E-05	4.73E-06	6.76E-02	4.05E-07	No toxicity value	NA
Vanadium	2.24E+01	5.00E-03	2.86E-05	5.73E-03	2.45E-06	No toxicity value	NA
PCB-1254	4.73E-01	2.00E-05	6.05E-07	3.02E-02	5.18E-08	2.00E+00	1.04E-07
PCB-1260	1.35E-01	No toxicity value	1.73E-07	NA	1.48E-08	2.00E+00	2.96E-08
Benzo(a)pyrene	2.46E-01	No toxicity value	3.15E-07	NA	2.70E-08	7.30E+00	1.97E-07
Hazard Index				2.09E-01			
Total Cancer Risk							2.02E-06

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-40. Risks and Hazards from Dermal Contact with Sediment at Acid Area 3 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Sediment (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Noncarcinogenic Effects: Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	8.94E+03	1.00E+00	ND	NA	ND	No toxicity value	NA
Arsenic	1.03E+01	3.00E-04	6.91E-07	2.30E-03	5.93E-08	1.50E+00	8.89E-08
Iron	2.05E+04	7.00E-01	ND	NA	ND	No toxicity value	NA
Lead	5.25E+01	No toxicity value	ND	NA	ND	No toxicity value	NA
Manganese	4.62E+02	4.67E-02	ND	NA	ND	No toxicity value	NA
Thallium	3.70E+00	7.00E-05	ND	NA	ND	No toxicity value	NA
Vanadium	2.24E+01	5.00E-03	ND	NA	ND	No toxicity value	NA
PCB-1254	4.73E-01	2.00E-05	1.48E-07	7.41E-03	1.27E-08	2.00E+00	2.54E-08
PCB-1260	1.35E-01	No toxicity value	4.23E-08	NA	3.62E-09	2.00E+00	7.25E-09
Benzo(a)pyrene	2.46E-01	No toxicity value	7.16E-08	NA	6.13E-09	7.30E+00	4.48E-08
Hazard Index				9.71E-03			
Total Cancer Risk							1.66E-07

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

APPENDIX C

RISK-BASED REMEDIATION LEVELS

Risk-Based Remediation Criteria for Groundskeeper Exposures to Surface Soil at Acid Area 3,					
Analyte	**Units**	**THI = 0.1**	**TILCR 10^{-6}**	**THI = 1.0**	**TILCR 10^{-5}**
Arsenic	mg/Kg	3.E+01	2.E+00	3.E+02	2.E+01
PCB-1254	mg/Kg	2.E+00	1.E+00	2.E+01	1.E+01
Benzo(a)anthracene	mg/Kg	NA	3.E+00	NA	3.E+01
Benzo(a)pyrene	mg/Kg	NA	3.E-01	NA	3.E+00

Risk-Based Remediation Criteria for Adult Hunter Exposures to Surface Soil at Acid Area 3,					
Analyte	**Units**	**THI = 0.1**	**TILCR 10^{-6}**	**THI = 1.0**	**TILCR 10^{-5}**
Benzo(a)pyrene	mg/Kg	NA	3.E+00	NA	3.E+01

Risk-Based Remediation Criteria for Indoor Worker Exposures to Bedrock Groundwater at Acid Area 3,					
Analyte	**Units**	**THI = 0.1**	**TILCR 10^{-6}**	**THI = 1.0**	**TILCR 10^{-5}**
2-Nitrotoluene	mg/L	9.E-02	1.E-03	9.E-01	1.E-02
Arsenic (total)	mg/L	3.E-03	2.E-04	3.E-02	2.E-03
Benzene	mg/L	4.E-02	5.E-03	4.E-01	5.E-02
Methylene Chloride	mg/L	6.E-01	4.E-02	6.E+00	4.E-01
Tetrachloroethene (PCE)	mg/L	8.E-02	4.E-04	8.E-01	4.E-03
Thallium (total)	mg/L	7.E-04	NA	7.E-03	NA

Risk-Based Remediation Criteria for Indoor Worker Exposures to Surface Soil at Acid Area 3,					
Analyte	**Units**	**THI = 0.1**	**TILCR 10^{-6}**	**THI = 1.0**	**TILCR 10^{-5}**
Arsenic	mg/Kg	6.E+01	4.E+00	6.E+02	4.E+01
Iron	mg/Kg	1.E+05	NA	1.E+06	NA
PCB-1254	mg/Kg	4.E+00	3.E+00	4.E+01	3.E+01
Benzo(a)pyrene	mg/Kg	NA	8.E-01	NA	8.E+00

Risk-Based Remediation Criteria for Construction Worker Exposures to Surface Soil at Acid Area 3,					
Analyte	**Units**	**THI = 0.1**	**TILCR 10^{-6}**	**THI = 1.0**	**TILCR 10^{-5}**
Arsenic	mg/Kg	5.E+00	2.E+01	5.E+01	2.E+02
Iron	mg/Kg	1.E+04	NA	1.E+05	NA
Thallium	mg/Kg	1.E+00	NA	1.E+01	NA
PCB-1254	mg/Kg	2.E-01	9.E+00	2.E+00	9.E+01
Benzo(a)pyrene	mg/Kg	NA	2.E+00	NA	2.E+01

Risk-Based Remediation Criteria for Construction Worker Exposures to Subsurface Soil at Acid Area 3,					
Analyte	**Units**	**THI = 0.1**	**TILCR 10^{-6}**	**THI = 1.0**	**TILCR 10^{-5}**
Antimony	mg/Kg	7.E+00	NA	7.E+01	NA
Arsenic	mg/Kg	5.E+00	2.E+01	5.E+01	2.E+02
Iron	mg/Kg	1.E+04	NA	1.E+05	NA
Thallium	mg/Kg	1.E+00	NA	1.E+01	NA

Risk-Based Remediation Criteria for Construction Worker Exposures to Sediment at Acid Area 3,					
Analyte	**Units**	**THI = 0.1**	**TILCR 10^{-6}**	**THI = 1.0**	**TILCR 10^{-5}**
Arsenic	mg/Kg	1.E+01	9.E+01	1.E+02	9.E+02
Thallium	mg/Kg	2.E+00	NA	2.E+01	NA

Risk-Based Remediation Criteria for Adult Residential Exposures to Bedrock Groundwater at Acid Area 3,					
Analyte	**Units**	**THI = 0.1**	**TILCR 10^{-6}**	**THI = 1.0**	**TILCR 10^{-5}**
2-Nitrotoluene	mg/L	3.E-02	4.E-04	3.E-01	4.E-03
Arsenic (total)	mg/L	1.E-03	7.E-05	1.E-02	7.E-04
Barium (total)	mg/L	7.E-01	NA	7.E+00	NA
Benzene	mg/L	1.E-02	2.E-03	1.E-01	2.E-02
bis(2-Ethylhexyl)phthalate	mg/L	3.E-02	3.E-03	3.E-01	3.E-02
Methylene Chloride	mg/L	2.E-01	1.E-02	2.E+00	1.E-01
Tetrachloroethene (PCE)	mg/L	3.E-02	1.E-04	3.E-01	1.E-03
Thallium (total)	mg/L	3.E-04	NA	3.E-03	NA

Risk-Based Remediation Criteria for Adult Residential Exposures to Surface Soil at Acid Area 3,					
Analyte	**Units**	**THI = 0.1**	**TILCR 10^{-6}**	**THI = 1.0**	**TILCR 10^{-5}**
Arsenic	mg/Kg	8.E+01	1.E+00	8.E+02	1.E+01
PCB-1254	mg/Kg	1.E+00	5.E-01	1.E+01	5.E+00
PCB-1260	mg/Kg	NA	5.E-01	NA	5.E+00
Benzo(a)anthracene	mg/Kg	NA	1.E+00	NA	1.E+01
Benzo(a)pyrene	mg/Kg	NA	1.E-01	NA	1.E+00
Dibenz(a,h)anthracene	mg/Kg	NA	1.E-01	NA	1.E+00

Risk-Based Remediation Criteria for Adult Residential Exposures to Subsurface Soil at Acid Area 3,					
Analyte	**Units**	**THI = 0.1**	**TILCR 10^{-6}**	**THI = 1.0**	**TILCR 10^{-5}**
Arsenic	mg/Kg	8.E+01	1.E+00	8.E+02	1.E+01
Benzo(a)pyrene	mg/Kg	NA	1.E-01	NA	1.E+00

Risk-Based Remediation Criteria for Child Residential Exposures to Bedrock Groundwater at Acid Area 3,					
Analyte	**Units**	**THI = 0.1**	**TILCR 10^{-6}**	**THI = 1.0**	**TILCR 10^{-5}**
2-Methylnaphthalene	mg/L	5.E-03	NA	5.E-02	NA
2-Nitrotoluene	mg/L	1.E-02	7.E-04	1.E-01	7.E-03
Arsenic (total)	mg/L	5.E-04	1.E-04	5.E-03	1.E-03
Barium (total)	mg/L	3.E-01	NA	3.E+00	NA
Benzene	mg/L	5.E-03	3.E-03	5.E-02	3.E-02
Methylene Chloride	mg/L	9.E-02	2.E-02	9.E-01	2.E-01
Naphthalene	mg/L	5.E-03	NA	5.E-02	NA
Tetrachloroethene (PCE)	mg/L	1.E-02	3.E-04	1.E-01	3.E-03
Thallium (total)	mg/L	1.E-04	NA	1.E-03	NA
Xylenes, total	mg/L	1.E-01	NA	1.E+00	NA

Risk-Based Remediation Criteria for Child Residential Exposures to Surface Soil at Acid Area 3,					
Analyte	**Units**	**THI = 0.1**	**TILCR 10^{-6}**	**THI = 1.0**	**TILCR 10^{-5}**
Arsenic	mg/Kg	2.E+00	6.E-01	2.E+01	6.E+00
Iron	mg/Kg	6.E+03	NA	6.E+04	NA
Manganese	mg/Kg	4.E+02	NA	4.E+03	NA
Thallium	mg/Kg	6.E-01	NA	6.E+00	NA
PCB-1254	mg/Kg	1.E-01	4.E-01	1.E+00	4.E+00
PCB-1260	mg/Kg	NA	4.E-01	NA	4.E+00
Benzo(a)anthracene	mg/Kg	NA	1.E+00	NA	1.E+01
Benzo(a)pyrene	mg/Kg	NA	1.E-01	NA	1.E+00
Dibenz(a,h)anthracene	mg/Kg	NA	1.E-01	NA	1.E+00

Risk-Based Remediation Criteria for Child Residential Exposures to Subsurface Soil at Acid Area 3,					
Analyte	**Units**	**THI = 0.1**	**TILCR 10^{-6}**	**THI = 1.0**	**TILCR 10^{-5}**
Aluminum	mg/Kg	9.E+03	NA	9.E+04	NA
Antimony	mg/Kg	3.E+00	NA	3.E+01	NA
Arsenic	mg/Kg	2.E+00	6.E-01	2.E+01	6.E+00
Iron	mg/Kg	6.E+03	NA	6.E+04	NA
Manganese	mg/Kg	4.E+02	NA	4.E+03	NA
Thallium	mg/Kg	6.E-01	NA	6.E+00	NA
Benzo(a)pyrene	mg/Kg	NA	1.E-01	NA	1.E+00

Risk-Based Remediation Criteria for Child Residential Exposures to Sediment at Acid Area 3, Plum Brook Ordnance Works, Sandusky, Ohio					
Analyte	**Units**	**THI = 0.1**	**TILCR 10^{-6}**	**THI = 1.0**	**TILCR 10^{-5}**
Arsenic	mg/Kg	2.E+01	6.E+00	2.E+02	6.E+01

APPENDIX D

TOXICOLOGICAL PROFILES FOR CHEMICALS OF CONCERN

TOXICOLOGICAL PROFILES
FOR THE CHEMICALS OF CONCERN

INTRODUCTION

Toxicological profiles are presented for each chemical of concern. The doubly hyphenated number in parentheses following the chemical name is its unique Chemical Abstract Service (CAS) registration number. The CAS number may be located in the profile title, or, in the case of multiple isomers or members of a chemical class, in the introductory text or the table that provides the physical properties.

Toxicological profiles contain brief descriptions of the nature of the potential adverse effects associated with the chemical. It is important to note that a discussion of adverse effects without a discussion of dose is incomplete and potentially misleading, because virtually any chemical may be toxic at some dose, and many chemicals (e.g., nutritionally required minerals, vitamins, amino acids, etc.) enhance human health at some low dose. An ever growing and compelling body of evidence suggests that many environmental contaminants also enhance health at low doses (Hart and Frame, 1996).

When sufficient data are available, the EPA Integrated Risk Information System (IRIS) presents the EPA's verified chronic toxicity values for noncancer effects, and for cancer risk (EPA, 2001). The toxicity values for noncancer effects include a reference dose (RfD) expressed in milligrams per kilogram per day (mg/kg-day) for chronic oral exposure, and a reference concentration (RfC), in milligrams per cubic meter (mg/m^3), for chronic inhalation exposure. The inhalation RfC in units of mg/m^3 may be converted to an equivalent inhalation RfD by assuming continuous chronic exposure of humans with a body weight of 70 kg and an inhalation rate of 20 m^3/day. In other words, the RfC expressed as mg/m^3 is multiplied by the inhalation rate of 20 m^3/day, and the result is divided by the body weight of 70 kg to yield an inhalation RfD expressed as mg/kg-day.

RfDs and RfCs are usually derived from empirical benchmark doses (BMD) or concentrations called no-observed-effect levels (NOEL) or no-observed-adverse-effect levels (NOAEL) from animal toxicity or human epidemiology studies. If the data do not permit identifying a NOEL or NOAEL, a lowest-observed-adverse-effect level (LOAEL) or lowest-effect level (LEL) may be used. A frank-effect level (FEL), e.g., mortality, shortened life span or serious physiologic, neurologic or behavioral disturbances, is generally considered an inappropriate benchmark from which to develop an RfD or RfC. Some RfD and RfC derivations employ a BMD that is a statistically estimated dose for humans at which some low proportion of the population may experience some minimally adverse effect. A BMD at which 10 percent of the population may be expected to respond is expressed as BMD_{10}. The RfD or RfC is derived by dividing the benchmark level (e.g., NOAEL or BMD_{10}) by a series of uncertainty and modifying factors, which collectively are designated the uncertainty factor (UF).

For cancer effects, IRIS presents a verified EPA cancer weight-of-evidence group classification that reflects qualitatively the likelihood that the chemical is carcinogenic to humans. IRIS also presents a slope factor (SF) for oral exposure, expressed as the risk per mg/kg-day ingested dose, and a unit risk factor (URF) for inhalation exposure, expressed as the risk per microgram per cubic meter ($\mu g/m^3$) in ambient air. These quantitative estimates are generally provided for chemicals in EPA weight-of-evidence Groups A and B and C, if the data are adequate. The SF or URF is usually estimated as an upper bound on the slope of the dose- or concentration response curve from animal

toxicity or human epidemiology studies. The inhalation URF in units of risk per ~ig/m3 may be converted to an equivalent inhalation SF in units of risk per mg/kg-day by assuming continuous lifetime exposure of humans with a body weight to 70 kg and an inhalation rate of 20 m^3/day. In other words, the URF expressed as risk per µg/m^3 is divided by the inhalation rate of 20 m^3/day, and multiplied by the assumed body weight of 70 kg and a conversion factor of 1000 µg/mg .

Toxicity values are not estimated for acute toxicity and acute exposure is not evaluated in the risk assessment. Nonetheless, the levels associated with acute lethality and data regarding the effects of acute exposure to levels higher than ordinarily observed in chronic environmental exposure provide additional perspective regarding the toxicity of the chemical. Therefore, information regarding acute toxicity, when available, is included in the profiles. Lethality data for laboratory animals are generally expressed as the oral dose associated with lethality of 50 percent of an exposed population (LD50) or the concentration in air associated with lethality of 50 percent of an exposed population (LC_{50}). Occasionally the dose associated with lethality in a low percentage of an exposed population (LD_{LO}) is presented.

The toxicity profiles also provide documentation for physical constants that are important for chemical transport modeling, such as molecular weight (MW) in grams per mole (g/mole), the log of the octanol/water partition coefficient (log K_{ow}), Henry's law constant (H) in atmosphere-cubic meter/mole (atm-m^3/mole), the soil/water partition coefficient (K_d) in liters per kilogram (L/kg) for metals, the log of the soil/organic carbon partition coefficient (log K_{oc} (unitless) for organic chemicals, diffusivity in air (D_a) in square centimeters per second (cm^2/s), diffusivity in water (D_w) in cm^2/s, vapor pressure (VP) in atmospheres (atm), and solubility in water (S) in milligrams per liter (mg/L) . In addition, organic chemicals are designated as volatile organic compounds (VOC) or semivolatile organic compounds (SVOC) based on their propensity to volatilize from environmental media. Chemicals designated as VOCs generally have a MW less than 200 g/mole and H greater than 1 E-5 atm-m^3/mole (EPA, 1991).

The physical constants generally are taken from the most reliable source (i.e., the source that provides the highest level of documentation). Values for interrelated properties are usually taken from the same source (e.g., H is often estimated from VP and S; therefore, the same source is generally used for all three property values). When one source provides several values for a given property, professional judgment is used to select the most appropriate. Obvious outliers may be dropped from consideration. The average or the midpoint of a range of values may be selected. K_d values for metals and K_{oc} values for ionizing organic compound are based on a default pH of 6.8 (EPA, 1996) if the data are available. VP, S and H values are limited to those provided for normal ambient temperatures (0 to 30°C), but the temperatures reported in the original sources are not presented in the toxicity profile, nor is any attempt made to extrapolate K, VP or S to any default temperature.

When values for H were not located, they were calculated as follows, provided the requisite information was available (EPA, 1998):

$$H = \frac{VP \cdot MW}{S} \qquad \text{Eq. 1}$$

where :

H = Henry's law constant (atm-m^3/mole, calculated)

VP = vapor pressure (atm)
MW = molecular weight (g/mole)
S = solubility in water (mg/L).

When values for Da were not located, they were calculated as follows (EPA, 1998):

$$D_s = \frac{1.9}{MW^{2/3}} \qquad \text{Eq. 2}$$

where:

D_a = diffusivity in air (cm2/s, calculated)
MW = molecular weight (g/mole) .

When values for DW were not located, they were calculated as follows (EPA, 1998):

$$D_w = \frac{22E-5}{MW^{2/3}} \qquad \text{Eq. 3}$$

where :

D_W = diffusivity in water (cm'/s, calculated)
MW = molecular weight (g/mole).

When values for Koc were not located, they were calculated as follows for phthalates and polyaromatic aromatic hydrocarbons (PAH) provided log K.,, was available (EPA, 1998):

$$\log K_{oc} = 0.97 \log K_{ow} - 0.094 \qquad \text{Eq. 4}$$

where:

K_{oc} = soil/organic carbon partition coefficient (unitless, calculated)
K_{ow} = octanol/water partition coefficient (unitless).

K_{oc}, for other organic chemicals was calculated as follows provided $\log K_{ow}$ was available (EPA, 1998):

$$\log K_{oc} = 0.18 \log K_{ow} + 0.151 \qquad \text{Eq. 5}$$

where:

K_{oc} = soil/organic carbon partition coefficient (unitless, calculated)
K_{ow} = octanol/water partition coefficient (unitless).

The toxicity profiles also present the predominant sources of release to the environment as well as a qualitative description of the fate of the chemical in air, surface water and sediment, and soil. No attempt is made to present quantitative data because environmental fate is usually highly dependent on climatic conditions and the characteristics of the medium to which the chemical is released, which may differ from location to location and change from time to time. The source and fate information may provide perspective regarding the likelihood that the chemical's presence is related to site activities, that the chemical will migrate across media, or that the chemical will persist at toxicologically significant levels.

Biotransfer factors are provided for chemicals for which food-chain pathways may be significant, which includes many inorganic chemicals and those organic chemicals that are highly lipophilic and persist in the environment. High lipophilicity is indicated by a log

K_{ow} greater than 3 (Lyman et al., 1990). Lipophilicity enhances partitioning to biomedia and passage across biological membranes. Persistence in the environment is evidence that the chemical might resist biotransformation and, therefore, remain in edible tissues at toxicologically significant concentrations. VOCs tend to be mobile and labile (i.e., subject to rapid and extensive biotransformation and excretion), and generally do not participate significantly in food-chain pathways. Therefore, biotransfer factors are not estimated for VOCs. Some of the SVOCs, however, are highly lipophilic. They may persist or yield metabolites that are significant toxicants in their own right. For example, the organochlorine pesticide DDT is metabolized by mammals to DDE, which is similar in carcinogenic potency to the parent compound. Biotransfer factors are generally estimated for SVOCs that have log K_{ow} values greater than 3.

The biotransfer factors of interest are soil-to-plant biotransfer factors (B_p) and cattle ingestion-to-beef factors (B_b). Separate soil-to-plant biotransfer factors are available for the reproductive parts of plants (e.g., fruits, seeds) and the vegetative parts of plants (e.g., stems, leaves) for inorganic and some organic chemicals. Soil-to-plant factors for the reproductive parts of plants are designated B_{pr}; soil-to-plant factors for the vegetative parts of plants are designated B_{pv}.

Soil-to-plant biotransfer factors (Bp) for SVOCs are estimated by a simple model by Travis and Arms (1988), which is based only on log K_{ow}:

$$\log B_p = 1.588 - 0.578 \log K_{ow} \qquad \text{Eq. 6}$$

where:

B_p = soil-to-plant biotransfer factor (unitless, calculated)
K_{ow} = octanol/water partition coefficient (unitless) .

Separate biotransfer factors are not estimated for the reproductive parts of plants (B_{pr}) and the vegetative parts of plants (B_{pv}).

Cattle ingestion-to-beef factors (Bb) for SVOCs are estimated by a simple model by Travis and Arms (1988), which is based only on log K.W:

$$\log B_p = 7.6 + \log K_{ow} \qquad \text{Eq. 7}$$

where:

B_b = cattle ingestion-to-beef biotransfer factor (days/kg, calculated)
K_{ow} = octanol/water partition coefficient (unitless).

This risk assessment followed EPA's *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part E - Supplemental Guidance for Dermal Risk Assessment)* (EPA 2004a). Therefore, oral RfDs and slope factors were used without modification. Additionally, only those constituents identified in the guidance as having sufficient data for dermal uptake from soil were evaluated for soil and sediment. Dermal absorbed doses for surface water and sediment were calculated using the spreadsheet model developed by EPA that accompanies the guidance.

References for Introduction

Bintein, S. and J. Devillers, 1993, "Nonlinear Dependence of Fish Bioconcentration on n-Octanol/Water Partition Coefficient," SAR and QSAR in Environmental Research, 1 : 29-39.

Devillers, J., S . Bintein and D. Domine, 1996, "Comparison of BCF Models Based on Log P,"Chemosphere, 33(6) : 1047-1065.

Hart, R.W. and L.T. Frame, 1996, "Toxicological Defense Mechanisms and How They May Affect the Nature of Dose-Response Relationships," Biological Effects of Low Level Exposure (BELLE) Newsletter, 5(1): 1-16.

Lyman, W. J., W. F. Reehl and D. H. Rosenblatt, 1990, Handbook of Chemical Property Estimation Methods, Environmental Behavior of Organic Compounds, American Chemical Society, Washington, DC.

Travis, C.C. and A.D . Arms, 1988, "Bioconcentration of Organics in Beef, Milk and Vegetation," Environmental Science and Technology, 22(3): 271-274.

U.S. Environmental Protection Agency (EPA), 1991, Risk Assessment Guidancefor Superfund: Volume I-Human Health Evaluation Manual (Part B, Development ofRisk-Based Preliminary Remediation Goals), Interim, Office of Emergency and Remedial Response, Washington, DC, OSWER Publication 9285 .7-01B.

U.S. Environmental Protection Agency (EPA), 1992, Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91/01 1 B, January.

U.S. EPA, 2004a, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part E - Supplemental Guidance for Dermal Risk Assessment)*, Final, Office of Superfund Remediation and Technology Innovation, Washington, D.C., EPA/540/R-99/005, July.

U.S. Environmental Protection Agency (EPA), 1996, Soil Screening Guidance: Users Guide, Office of Solid Waste and Emergency Response, Washington, DC, Publication 9355.4-23, April.

U.S. Environmental Protection Agency (EPA), 2001, Integrated Risk Information System (IRIS), National Center for Environmental Assessment, Cincinnati, OH, on line.

INORGANIC CHEMICALS

ARSENIC (7440-38-2)

Arsenic is a natural metalloid that occurs in both inorganic and organic forms (ATSDR, 1998). Inorganic arsenic is more toxic than organic forms. Major uses in the U.S. include its incorporation into wood preservatives and other agricultural chemicals. Relevant physical properties are compiled below:

MW (g/mole)	log K_{ow} (unitless)	H (atm-m3/mole)	Kd (L/kg)	Da (cm2/s)	Dw (cm2/s)	VP (atm)	S (mg/L)
74.92 (element)	NA	NA	2.9e+1[a]	NA	NA	Note 1[b]	Note 2[b]

NA = not applicable
Note 1 : Variable : inorganic arsenic compounds are not likely to volatilize ; some organic arsenic compounds are low-boiling liquids or gases at normal temperatures .
Note 2 : Variable: inorganic arsenic compounds range from practically insoluble to freely miscible in water; most organic arsenic compounds are not readily soluble, most arsenic acid compounds are soluble to freely miscible.
a U.S . Environmental Protection Agency (EPA), 1996, Soil Screening Guidance: Users Guide, Office of Solid Waste and Emergency Response, Washington, DC, Publication 9355 .4-23, April.
b Agency for Toxic Substances and Disease Registry, (ATSDR), 1998, Update Toxicological Profile for Arsenic, U.S. Public Health Service, Atlanta, Georgia, April.

The major source of arsenic release to the environment is from copper, zinc and lead smelting operations (HSDB, 2001). Releases also occur from several other industries that use arsenic. Most (approximately 80 percent) anthropogenic releases are initially to soil (ATSDR, 1998).

Arsenic occurs in the air as a combination of trivalent and pentavalent forms almost entirely adsorbed to small particles that permit dispersion over long distances (ATSDR, 1998). Residence time in the atmosphere averages approximately nine days. Removal is largely by wet and dry deposition. Arsenic in surface water can undergo a variety of transformations and exist in several soluble forms. Sorption to sediment is often an important removal process, but biotransformation in sediment may return soluble forms to the water. Arsenic in soil generally exists as insoluble forms sorbed to clay or organic matter or complexed with calcium or iron. Mobility is low and leaching is not generally significant, except that increasing soil pH can dramatically increase mobility.

Biotransfer factors for arsenic are compiled below:

BCF (L/kg)	Bpr (unitless)	BPV (Unitless)	Bb (days/kg)
20[a]	6.0E-3[b]	4.0E-2[b]	2.0E-3[b]

a U .S. Environmental Protection Agency (EPA), 1998, Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities, Volume Two, Peer Review Draft, Office of Solid Waste and Emergency Response, Washington, DC, EPA530-D-98-001 B, July.
b Baes, C.F., R.D. Sharp, A.L . Sjoreen, R.W. Shor, 1984,AReview and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture, Health and Safety Division, Oak Ridge National Laboratory, ORNL-5786, September.

Data regarding the dermal uptake of arsenic were not located. The default ABS of 0 .01 for metals (OEPA, 1998) is used herein.

Inorganic arsenic may be an essential nutrient, exerting beneficial effects on growth, health and feed conversion efficiency (Underwood, 1977). A lethal dose of arsenic trioxide in humans is 70-180 mg (=50-140 mg arsenic (Ishinishi et al., 1986). Acute oral exposure of humans to high doses of arsenic produces liver swelling, skin lesions, disturbed heart function and neurological effects. The only noncancer effects in humans clearly attributable to chronic oral exposure to arsenic are dermal hyperpigmentation and keratosis, as revealed by studies of several hundred Chinese exposed to naturally occurring arsenic in well water (EPA, 2001). Similar effects were observed in persons exposed to high levels of arsenic in water in Utah and the northern part of Mexico . EPA (2001) verified an RfD of 3E-4 mg/kg-day for chronic oral exposure, based on a NOAEL of 8E-4 mg/kg-day for hyperpigmentation and kertatosis of the skin from the Chinese data. An uncertainty factor of 3 was applied. An increased incidence of Blackfoot disease was also observed, which may not be related to arsenic alone. Goyer (1991) describes black-foot disease as a peripheral vascular disorder manifested as acrocyanosis and Raynaud's disease, which may progress to gangrene. Confidence in the RfD is medium. EPA (2001) notes that the skin is the more sensitive target organ. Nonetheless, in keeping with EPA (1989) guidance regarding selection of target organ, both the skin and peripheral vascular system are selected as target organs for prolonged oral exposure to arsenic.

Occupational (predominantly inhalation) exposure is also associated with neurological deficits, anemia, and vascular effects (Ishinishi et al., 1986), but concomitant exposure to other chemicals cannot be ruled out. The data are not sufficient for estimation of an inhalation RfC. Inorganic arsenic is clearly a carcinogen in humans. Inhalation exposure is associated with increased risk of lung cancer in persons employed as smelter workers, in arsenical pesticide applicators, and in a population residing near a pesticide manufacturing plant (EPA, 2001). Oral exposure to high levels in well water is associated with increased risk of skin cancer. Extensive animal testing with various forms of arsenic given by many routes of exposure to several species, however, has not demonstrated the carcinogenicity of arsenic. EPA (2001) classified inorganic arsenic in cancer weight-of-evidence Group A (human carcinogen), and recommended an oral SF of 1.5E+0 per mg/kg-day, based on the incidence of skin cancer in the Chinese study. EPA (2001) noted that the uncertainties associated with the oral unit risk are considerably less than those for most carcinogens, so that the unit risk might be reduced an order of magnitude. An inhalation URF of 4E-3 per pg/m3, equivalent to an inhalation SF of 1.5E+1 per mg/kg-day, was derived for inorganic arsenic from the incidence of lung cancer in occupationally exposed men.

References for Arsenic

Agency for Toxic Substances and Disease Registry, (ATSDR), 1998, Update Toxicological Profile for Arsenic, Draft for Public Comment, U.S. Public Health Service, Atlanta, Georgia, August.

Goyer, R.A., 1991, "Toxic Effects of Metals," in Casarett and DoullIs Toxicology, The Basic Science of Poisons, Fourth Edition, Amdur, M.O., J. Doull and C.D. Klaassen, Eds., Pergamon Press, New York, pp. 623-680.

Ishinishi, N., K. Tsuchiya, M. Vahter and B.A. Fowler, 1986, "Arsenic," In: Friberg, L., G.F. Nordberg and V.B. Vouk, Eds., Handbook on the Toxicology of Metals, Volume 11, Second Edition, New York: Elsevier Science Publishers B.V., pp. 43-83.

Ohio Environmental Protection Agency (OEPA), 1998, U.S. NASA Plum Brook, Erie County, Ohio LD#: 322-0552, Risk Assessment Work Plans, letter from R.E. Nabors, Site Coordinator, to L.S. Ingram, Department of the Army, June 22.

Underwood, E.J., 1977, Trace Elements in Human and Animal Nutrition, Fourth Edition, New York: Academic Press, pp. 424-429.

U.S. Environmental Protection Agency (EPA), 1989, Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part A), Interim Final, Office of Emergency and Remedial Response, Washington, DC, EPA/540/1-89/002, December.

U.S. Environmental Protection Agency (EPA), 1992, Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91 /011 B, January.

U.S. Environmental Protection Agency (EPA), 1993, "Oral and Dermal Absorption Factors for Multiple Chemicals (FEMP O.U. #4/Fernald, OH)," Memorandum from Joan Dollarhide, ECAO, to Pat Van Leeuwen, Region V, dated July 21.

U.S. Environmental Protection Agency (EPA), 2001, Integrated Risk Information System (IRIS), On-line, Environmental Criteria and Assessment Office, Cincinnati, OH.

LEAD (7439-92-1)

Lead is a naturally occurring metal used in the manufacture of batteries, ammunition, and other metal products (ATSDR, 1997). Relevant physical properties are compiled below:

MW (g/mole)	log K_{ow} (unitless)	H (atm-m3/mole)	Kd (L/kg)	Da (cm2/s)	Dw (cm2/s)	VP (atm)	S (mg/L)
207.2 (element)	NA	NA	ND	NA	NA	ND	9.9E-3[a]

NA = not applicable, ND = do data
a Value for lead chloride as a typical lead salt (Agency for Toxic Substances and Disease Registry, [ATSDR], 1997, Update Toxicological Profile for Lead, Draft for Public Comment, U.S . Public Health Service, Atlanta, Georgia, August .)

Lead may enter the environment during mining, ore processing, smelting, refining, use, recycling or disposal (ATSDR, 1997; HSDB, 2001). Emission from automobile exhaust was at one time the largest source of atmospheric lead. Natural sources are minor compared with anthropogenic sources. Generally the form of lead that enters the atmosphere is not known. However, metallic lead may be released from smelting and refining plants. Lead in air exists attached to small particles that may travel great distances before removal by wet or dry deposition. Lead deposited on or released to soil generally remains in the top 2 to 5 cm where it remains relatively immobile, although a small percentage may be present in soluble forms that are subject to leaching. Acid conditions increase the potential for leaching. Lead released to surface water tends to form salts that are only sparingly soluble. Deposition in bed sediment is the primary removal mechanism, although biomethylation may mobilize lead and return it to the water column. Soil and sediment act as sinks for anthropogenic releases of lead.

Lead in fish is localized in the mucus on the epidermis, the dermis, and scales so that the edible portions generally do not pose a hazard to human health (HSDB, 2001). Therefore, the BCF listed below probably overstates the danger to humans. Lead does not biomagnify through the aquatic or terrestrial food chains (ATSDR, 1997). Biotransfer factors for lead are compiled below:

BCF (L/kg)	Bpr (unitless)	BPV (Unitless)	Bb (days/kg)
49[a]	9.0E-3[b]	4.5E-2[b]	3.0E-4[b]

a U.S. Environmental Protection Agency (EPA), 1986, Superfund Public Health Evaluation Manual, Office of Emergency and Remedial Response, Washington, DC, OSWER Directive 9285-4-1, EPA/540/1-86/060, PB87-183125, October .
b Baes, C.F., R.D. Sharp, A.L. Sjoreen, R.W. Shor, 1984, A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture, Health and Safety Division, Oak Ridge National Laboratory, ORNL-5786, September .

The noncancer toxicity of lead to humans has been well characterized through decades of medical observation and scientific research (EPA, 2001). The principal effects of acute oral exposure are gastrointestinal colic with diffuse paroxysmal abdominal pain (probably due to vagal irritation), anemia, and, in severe cases, acute encephalopathy, particularly in children (Tsuchiya, 1986). The primary effects of long-term exposure are neurological and hematological. Limited occupational data indicate that long-term exposure to lead may induce kidney damage. The principal target organs of lead toxicity are the nervous system and the erythrocyte. Some of the effects on the blood, particularly changes in levels of certain blood enzymes, and subtle neurobehavioral changes in children, appear to occur at levels so low as to be considered non-threshold

effects. In part for this reason the EPA (1990, 2001) considered inappropriate the derivation of an RfD for chronic oral exposure.

The Integrated Exposure, Uptake Biokinetic Model (IEUBK) Version 0.99D (EPA, 1994a) is generally used to evaluate lead in children, the most sensitive receptor under a residential exposure scenario. The IEUBK model integrates lead uptake from inhalation, drinking water, diet, soil and dust ingestion, and ingestion of incidental sources such as chips of lead-based paint, and estimates blood lead concentrations over the first seven years of a child's life. Generally, it is considered that childhood blood lead levels below 10 µg/dL reflect minimal likelihood of adverse effects from exposure to lead. Since it is plausible that children could be present under most residential site-use scenarios, it is appropriate to use the IEUBK to establish target levels for lead in soil for residential use. EPA (1994b) used the IEUBK to estimate a lead concentration of 400 mg/kg in bare soil to which children might be regularly exposed as the level below which further evaluation and exposure-reduction action is not necessary.

The IEUBK, however, does not address lead concentrations in media to which adults may be exposed in a non-residential site-use scenario. EPA (1996) adopted a model similar to the IEUBK to estimate blood lead concentrations in adult women in an occupational exposure scenario. The pregnant woman is assumed to be the member of the adult population most sensitive to exposure to lead because of the potential for developmental effects on the fetus. The EPA (1996) adult blood lead model estimates a lead concentration in soil of approximately 750 mg/kg (EPA, 2001) as the level below which the 95' percentile fetal blood lead concentration would not exceed 10 µg/dL.

EPA (2001) classified lead in cancer weight-of-evidence Group B2 (probable human carcinogen), based on inadequate evidence in humans and sufficient animal evidence. The human data consist of several epidemiologic occupational studies that yield confusing results. All the studies lacked quantitative exposure date and failed to control for smoking and concomitant exposure to other possibly carcinogenic metals. Rat and mouse bioassays showed statistically significant increases in renal tumors following dietary and subcutaneous exposure to several soluble lead salts. Various lead compounds were observed to induce chromosomal alterations in vivo and in vitro, sister chromatid exchange in exposed workers and cell transformation in Syrian hamster embryo cells, to enhance simian adenovirus induction, and to alter molecular processes that regulate gene expression. EPA (2001) declined to estimate risk for oral exposure to lead because many factors (e.g., age, general health, nutritional status, existing body burden and duration of exposure) influence the bioavailability of ingested lead, introducing a great deal of uncertainty into any estimate of risk.

References for Lead

Agency for Toxic Substances and Disease Registry, (ATSDR), 1997, Update Toxicological Profile for Lead, Draft for Public Comment, U.S. Public Health Service, Atlanta, GA, August.

Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.

Ohio Environmental Protection Agency (OEPA), 1998, U.S. NASA Plum Brook, Erie County, Ohio LD#: 322-0552, Risk Assessment Work Plans, letter from R.E. Nabors, Site Coordinator, to L.S. Ingram, Department of the Army, June 22.

Tsuchiya, K., 1986, "Lead," In: Friberg, L., G.F. Nordberg and V.B. Vouk, Eds., Handbook on the Toxicology of Metals, Volume 11, Second Edition, New York: Elsevier Science Publishers B.V. pp. 298-353.

U.S. Environmental Protection Agency (EPA), 1990, Technical Support Document for Lead, Prepared by the Chemical Hazard Assessment Division, Syracuse Research Corporation, under contract to the Environmental Criteria and Assessment Office, Cincinnati, OH.

U.S. Environmental Protection Agency (EPA), 1992, Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91 /011 B, January.

U.S. Environmental Protection Agency (EPA), 1993, "Oral and Dermal Absorption Factors for Multiple Chemicals (FEMP O.U. #4/Femald, OH)," Memorandum from Joan Dollarhide, ECAO, to Pat Van Leeuwen, Region V, dated July 21.

U.S. Environmental Protection Agency (EPA), 1994a, Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children, Office of Emergency and Remedial Response, Publ. No. 9285-7-15-1, EPA/540/R-93/081, NTIS No. PB93-963510.

U.S. Environmental Protection Agency (EPA), 1994b, "Guidance on Residential Lead-Based Paint, Lead-Contaminated Dust, and Lead-Contaminated Soil," Memorandum from L.R. Goldman to regional directors, 14 July.

U.S. Environmental Protection Agency (EPA), 1996, Recommendations of the Technical Review Workgroup for Lead for an Interim Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil, Technical Review Workgroup for Lead, December.

U.S. Environmental Protection Agency (EPA), 2004, Region 9 Preliminary Remediation Goals (PRGs) 2004 Update, online, 1 November.

U.S. Environmental Protection Agency (EPA), 2001, Integrated Risk Information System (IRIS), On-line, Environmental Criteria and Assessment Office, Cincinnati, OH.

MANGANESE (7439-96-5)

Manganese is a naturally occurring metal used in the manufacture of steel, and in other metallurgical processes, batteries, and various manganese-containing chemicals including matches, glass and porcelain, fireworks, varnishes, ceramics and fungicides (ATSDR, 1997; Keen and Leach, 1988). Relevant physical properties are compiled below:

MW (g/mole)	log K_{ow} (unitless)	H (atm-m3/mole)	Kd (L/kg)	Da (cm2/s)	Dw (cm2/s)	VP (atm)	S (mg/L)
54.94 (element)	NA	NA	ND	NA	NA	ND	Note 1[a]

NA = not applicable, ND = do data
Note 1: Metallic manganese decomposes in the presence ofwater. Manganous chloride as a typical manganese salt: 7.23E+5.
a Agency for Toxic Substances and Disease Registry, (ATSDR), 1997, Update Toxicological Profle for Manganese, Draft for Public Comment, U.S. Public Health Service, Atlanta, Georgia, September.

Anthropogenic sources of atmospheric manganese include metal processing, disposal of manganese-containing materials, resuspension of manganese-containing soil dust, fly ash emissions from incinerators, and the combustion of gasoline containing manganese anti-knock ingredients (ATSDR, 1997; HSDB, 2001). Manganese may be released to water by discharge from industrial facilities or in leachate from landfills and soil. Landfill disposal of manganese-containing wastes is the predominant source of manganese release to soil.

Manganese exists in the air bound to particles; dry deposition is the primary removal mechanism, although wet deposition may also be significant (ATSDR, 1997). Manganese in fly ash exists as chlorides and oxides that are relatively soluble and mobile in the environment.

Manganese in water exists as any number of sparingly soluble salts that attach to suspended sediment (ATSDR, 1977). Sedimentation is the primary removal process. Soluble forms also exist, depending on pH of the water, and may be released from sediment. The extent of absorption to constituents of soil is highly variable. Low concentrations may occur in an irreversibly "fixed" form to clay, but higher concentrations often manifest considerable mobility.

Biotransfer factors for manganese are compiled below:

BCF (L/kg)	Bpr (unitless)	BPV (Unitless)	Bb (days/kg)
See Below	5.0E-2[a]	2.5E-1[a]	4.0E-4[a]

a Baes, C.F ., R.D. Sharp, A.L . Sjoreen, R.W. Shor, 1984, A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture, Health and Safety Division, Oak Ridge National Laboratory, ORNL-5786, September.

Manganese in aquatic systems tends to bioaccumulate more strongly in plants and lower trophic levels, and less strongly in edible fish. ATSDR (1997) reports BCFs of 10,000 to 20, 000 L/kg for marine and freshwater plants, 2500 to 6300 L/kg for phytoplankton, 300 to 5500 L/kg for marine algae, 800 to 830 L/kg for intertidal mussels, and 100 to 600 L/kg reported for fin fish. The midpoint of the BCF range for intertidal mussels of 815 L/kg is used herein for shellfish. The midpoint of the BCF range for fin fish of 350 L/kg is used herein for fin fish.

Keen and Leach (1988) and ATSDR (1997) reviewed the empirical data and reported that approximately three to five percent of dietary manganese is absorbed, regardless of the amount present in the diet. EPA (2001) selected five percent as a rough approximation of the extent of GI absorption. This value (0.05) is selected as the GAF for manganese.

The ABS of 0.01 is an OEPA (1998) default for metals for which empirical data are lacking.

Manganese is nutritionally required in humans for normal growth and health (EPA, 2001). Humans exposed to approximately 0.8 mg manganese/kg-day in drinking water (28 mg/L) exhibited lethargy, increased muscle tonus, tremor and mental disturbances. The elderly appeared to be more sensitive than children. Oral treatment of laboratory rodents induces biochemical changes in the brain, but rodents do not exhibit the neurological signs exhibited by humans. Occupational exposures to high concentrations in air induce a generally typical spectrum of neurological effects, and increased incidence of pneumonia (ACGIH, 1991).

EPA (2001) derived an oral RfD for manganese of 1.4E-1 mg/kg-day from a NOAEL of I .4E-1 mg/kg-day for neurologic effects from human dietary studies and an uncertainty factor of 1. Confidence in the RfD is medium. The oral RfD of 1 .4E-1 mg/kg-day will be used for dietary items other than drinking water. EPA (2001) recommends that a modifying factor of 3 should be used to adjust the RfD for use when oral exposure involves drinking water and non-dietary ingestion. The oral RfD resulting from application of the modifying factor, 4 .7E-2 mg/kg-day, will be used for drinking water and incidental ingestion of non-dietary items, and will serve as the basis for developing the dermal RfD. The CNS is the target organ for chronic oral exposure to manganese. EPA (2001) presents a verified chronic inhalation RfC of 5E-5 mg/m3 (equivalent to an inhalation RfD of 1 .4E-5 mg/kg-day) based on a LOAEL for neurological effects in occupationally exposed humans and an uncertainty factor of 1000. Confidence in the RfC is medium. The CNS is the target organ for inhalation exposure to manganese.

EPA (2001) classified manganese in cancer weight-of-evidence Group D (not classifiable as to carcinogenicity to humans). Quantitative cancer risk estimates are not derived for Group D chemicals.

References for Manganese

Agency for Toxic Substances and Disease Registry, (ATSDR), 1992, Toxicological Profile for Acetone, Draft for Public Comment, U.S. Public Health Service, Atlanta, Georgia.

American Conference of Governmental Industrial Hygienists (ACGIH), 1991, Documentation of the Threshold Limit Values and Biological Exposure Indices, Sixth Edition, ACGIH, Cincinnati, OH, pp. 10-11.

Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.

Ohio Environmental Protection Agency (OEPA), 1998, U.S. NASA Plum Brook, Erie County, Ohio LD#: 322-0552, Risk Assessment Work Plans, letter from R.E. Nabors, Site Coordinator, to L.S. Ingram, Department of the Army, June 22.

U.S. Environmental Protection Agency (EPA), 1992, Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91 /011B, January.

U.S. Environmental Protection Agency (EPA), 2001, Integrated Risk Information System(IRIS), National Center for Environmental Assessment, Cincinnati, OH, on line.

Benzene (71-43-2)

Benzene is a naturally occurring VOC, present in low levels in many plants and animals, as well as a synthetic compound derived from petroleum (ATSDR, 1995). Benzene is widely used as a solvent and in the manufacturing of other organic compounds such as styrene, phenol, detergents, pesticides, explosives, polychlorinated biphenyls, flavors, perfumes, paints and coatings, nylon intermediates and photographic chemicals, among others. It is also used in food processing and leather tanning and occurs a component of gasoline. Relevant physical properties are compiled below:

MW (g/mole)	log K_{ow} (unitless)	H (atm-m3/mole)	Kd (L/kg)	Da (cm2/s)	Dw (cm2/s)	VP (atm)	S (mg/L)
78.1	2.13[a]	5.56E-3[b]	1.77[b]	8.8E-2[b]	9.8E-6[b]	1.25E-1[c]	1.75E+3[b]

a U.S . Environmental Protection Agency (EPA), 1992, Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91/01113, January.
b U.S . Environmental Protection Agency (EPA), 1996, Soil Screening Guidance: Users Guide, Office of Solid Waste and Emergency Response, Washington, DC, Publication 9355 .4-23, April.
c U. S. Environmental Protection Agency (EPA), 1994, Technical Background Document for Soil Screening Guidance, Review Draft, Office of Solid Waste and Emergency Response, Washington, DC, Publication No. 9355.4-17, EPA540/R-94/106, PB95-963532, November.

Benzene will enter the atmosphere primarily from fugitive emissions and exhaust connected with its use in gasoline (ATSDR, 1995 ; HSDB, 2001) . Other important sources are emissions associated with its production and use as a solvent, as an industrial intermediate in the production of materials mentioned above, and coke oven blast furnaces and coke by-product recovery plants. In addition, there are discharges into water from industrial effluents and losses during spills. Sources of release to soil include land disposal of benzene-containing wastes, industrial discharge and leaks from underground storage tanks.

Benzene released to the atmosphere will exist almost exclusively in the vapor phase (ATSDR, 1995; HSDB, 2001). It is not subject to direct photolysis but it will react with photochemically produced hydroxyl radicals with a half-life of approximately 13 days. The reaction time in polluted atmospheres which contain nitrogen oxides or sulfur dioxide is accelerated with the half-life being reported as 4-6 hours. Products ofphotooxidation include phenol, nitrophenols, nitrobenzene, formic acid, and peroxyacetyl nitrate. Benzene is fairly soluble in water and is removed from the atmosphere in rain.

Benzene released to soil will be subject to rapid volatilization near the surface; that which does not evaporate will be highly to very highly mobile in the soil and may leach to groundwater (ATSDR, 1995; HSDB, 2001). Benzene may be subject to biodegradation under aerobic conditions. Microbial transformation proceeds through formation of cis-dihydrodiols to catechols, which lead to fission of the aromatic ring.

Benzene may be subject to photooxidation and biodegradation in shallow, aerobic groundwaters, but probably not significantly under deeper or anaerobic conditions (ATSDR, 1995; HSDB, 12001). Benzene released to surface water will be subject to rapid volatilization. It is not expected to sorb to sediment or to hydrolyze significantly. It may be subject to biodegradation, but this is unlikely to be a significant fate process in sediment.

Benzene is not expected to participate significantly in food-chain pathways (HSDB, 2001); therefore, biotransfer factors are not provided.

The OEPA (1998) default ABS of 0.1 for organic chemicals is adopted for this evaluation.

Short-term exposure to benzene induces central nervous system (CNS) effects such as drowsiness, dizziness and headaches; long-term exposure may induce anemia (ATSDR, 1995). Oral dosing in animals induces hematopoietic and immune effects. EPA (1996) derived a provisional RfD for chronic oral exposure of 3E-3 mg/kg-day, based on a LOAEL of 8 mg/kg-day in a 28-day drinking water study in mice. The LOAEL was associated with minor hematologic effects (erythrocytopenia, leucopenia, lymphocytopenia), all associated with decreased cell counts, and increased response in several tests of immunologic activity. Depressed immunologic activity was observed at higher dose levels. An uncertainty factor of 3000 was applied to derive the provisional RfD from the LOAEL. Confidence in the RfD is medium. The hematopoietic mechanism and the immune system are the target organs for chronic oral exposure to benzene.

A provisional chronic inhalation RfC of 6E-3 mg/m^3 for benzene was based on a LOAEL of 32 mg/m^3 for depressed hematopoiesis in a study in which mice were exposed intermittently for up to 178 days (EPA, 1994). The exposure concentration was adjusted to an equivalent human continuous exposure concentration of 5.7 mg/m^3. Application of an uncertainty factor of 1000 to the LOAEL of 5 .7 mg/m^3 yields the RfC of 6E-3. The RfC is equivalent to an RfD of 1.7E-3 mg/kg-day. Confidence in the inhalation RfC is low. The hematopoietic mechanism and the immune system are the target organs for chronic inhalation exposure to benzene.

Benzene is classified as an EPA cancer weight-of-evidence Group A chemical (known human carcinogen) based on epidemiologic studies and case studies that provide clear evidence of a causal association between exposure to benzene and acute nonlymphocytic leukemia, and that also provide supportive evidence for chronic nonlymphocytic leukemia and chronic lymphocytic leukemia (EPA, 2001). Other neoplastic conditions that are associated with an increased risk in humans are hematologic neoplasms, blood disorders such as preleukemia and aplastic anemia, Hodgkin's lymphoma, and myelodysplastic syndrome. Experimental animal data add to the weight of evidence that exposure to benzene increases the risk of cancer in multiple species at multiple organ sites (hematopoietic, oral and nasal, liver, forestomach, preputial gland, lung, ovary, and mammary gland).

A verified URF for inhalation exposure of 2.2E-6 to 7.8E-6 per µg/m^3 was based on the incidence of leukemia in humans exposed to benzene while employed in the Pliofilm industry (EPA, 2001). A low-dose linearity model utilizing maximum likelihood estimates was used to estimate the URF. The range reflects differences in the exposure assumptions estimated from the study. EPA (2001) concluded that neither any specific URF value nor either end of the range is more defensible than the other. Therefore, the upper end of the range, 7.8E-6 per 4g/m3, is conservatively selected for this evaluation. The URF of 7.8E-6 per ~Lg/m3 is equivalent to an inhalation SF of 2.7E-2 per mg/kg/day.

The occupational data that serve as the basis for the inhalation URF also serve as the basis for a verified oral SF for benzene (EPA, 2001). The inhalation URF range was mathematically converted to an equivalent oral SF range by applying standard inhalation rate and body weight assumptions, and by adjusting for route-specific differences in absorption. EPA (2001) assumed that GI absorption is 100 percent and that respiratory tract uptake is 50 percent. The oral SF range so derived is 1 .5E-2 to 5.5E-2 per mg/kg-

day. The upper end of the range, 5.5E-2 per mg/kg-day, is selected as the oral SF for this evaluation.

References for Benzene

Agency for Toxic Substances and Disease Registry, (ATSDR), 1995, Update Toxicological Profile for Benzene, Draft for Public Comment, U.S . Public Health Service, Atlanta, Georgia, August.

Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.

Jones, T.D. and BA Owen, 1989, Health Risks from Mixtures of Radionuclides and Chemicals in Drinking Water, Oak Ridge National Laboratory, Oak Ridge, TN, ORNL-6533.

Ohio Environmental Protection Agency (OEPA), 1998, U.S. NASA Plum Brook, Erie County, Ohio LD#: 322-0552, Risk Assessment Work Plans, letter from R.E. Nabors, Site Coordinator, to L.S. Ingram, Department of the Army, June 22 .

U.S. Environmental Protection Agency (EPA), 1992, Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91/01 1 B, January.

U.S. Environmental Protection Agency (EPA), 1994, Risk Assessment Issue Paper for: Derivation of a Provisional Chronic Inhalation RfC for Benzene (CASRN 71-43-2), National Center for Environmental Assessment, Cincinnati, OH, March 23.

U.S. Environmental Protection Agency (EPA), 1996, Risk Assessment Issue Paper for: Derivation of a Provisional Oral RfD for Benzene (CASRN 71-43-2), National Center for Environmental Assessment, Cincinnati, OH, July 2.

U.S. Environmental Protection Agency (EPA), 2001, Integrated Risk Information System (IRIS), National Center for Environmental Assessment, Cincinnati, OH, on line.

NITROTOLUENES

The nitrotoluenes consist of three isomers: o-nitrotoluene (2-nitrotoluene), m-nitrotoluene (3-nitrotoluene) and p-nitrotoluene (4-nitrotoluene) (Lewis, 1997). All behave in the environment as VOCs. The nitrotoluenes, especially the o- and p-isomers, are used as intermediates in the synthesis of other organic chemicals, particularly toluidine, tolidine, fuchsine and other synthetic dyes, explosives, petrochemicals, pesticides, pharmaceuticals, rubber and agricultural chemicals, dyes and pigments (HSDB, 2001). Relevant physical properties are compiled below:

MW (g/mole)	log K_{ow} (unitless)	H (atm-m^3/mole)	Kd (L/kg)	Da (cm2/s)	Dw (cm2/s)	VP (atm)	S (mg/L)
o-nitrotoluene (88-72-2)							
137.13	2.3[a]	5.56E-5[a]	2.44[a]	7.14E-2[b]	8.0E-6[c]	1.32E-4[c]	6.52E+2[a]
m-nitrotoluene (99-08-1)							
137.13	2.45[a]	7.5E-5[a]	2.16[a]	7.14E-2[b]	8.0E-6[c]	2.72E-4[c]	4.98E+2[c]
p-nitrotoluene (99-99-0							
137.13	2.37[a]	5.0E-5[a]	2.49[a]	7.14E-2[b]	8.1E-6[c]	1.22E-4[c]	4.22E+2[c]

a Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.
b Calculated as described in Introduction to the Toxicity Profiles.
c Montgomery, J .H., 1996, Groundwater Chemicals Desk Reference, Second Edition, Lewis Publishers, New York, pp. 790-795 .

The major sources of release of nitrotoluenes to the environment appear to be production and use facilities and plants which produce these compounds as by-products (HSDB, 2001). These include manufacturers of dinitrotoluene, trinitrotoluene, intermediates for rubber and agricultural chemicals, and various azo and sulfur dye intermediates. Nitrotoluenes may also enter the environment from the disposal of waste products which contain these compounds.

Nitrotoluenes released to soil are expected to be resistant to oxidation and chemical hydrolysis (HSDB, 2001). The nitrotoluenes are reported to biodegrade under anaerobic conditions to form toluidine; one study under aerobic conditions in a mixed culture of soil microorganisms resulted in persistence exceeding 64 days. The nitrotoluenes are expected to be moderately to highly mobile in soil and volatilize slowly from dry soil surfaces.

Nitrotoluenes released to water are expected to be susceptible to photolysis, volatilization and aerobic biodegradation, provided suitable acclimation has been achieved (HSDB, 2001). Oxidation, chemical hydrolysis, adsorption to suspended solids and sediments and bioaccumulation in aquatic organisms are not expected to be significant fate processes. Insufficient data were available to indicate the significance of anaerobic biodegradation as a possible removal mechanism. Nitrotoluenes released to the atmosphere are expected to exist entirely in the vapor phase (HSDB, 2001). The dominant removal mechanism is expected to be reaction with photochemically generated hydroxyl radicals (estimated half-life 8 hours) and direct photolysis. Photoproducts include 2-methyl-6-nitrophenol and 2-methyl-4-nitrophenol (o-isomer), 3-methyl- 4-nitrophenol, 3-methyl-2-nitrophenol and 3-methyl-6-nitrophenol (m-isomer) and 2-methyl-6- nitrophenol (p-isomer).

The nitrotoluenes are not expected to bioconcentrate or bioaccumulate significantly (HSDB, 2001); therefore, biotransfer factors are not estimated.

Data regarding the dermal uptake of the nitrotoluenes from soil were not located in the available literature; the OEPA (1998) default ABS of 0.1 for organic chemicals is selected for this evaluation.

Data regarding the acute toxicity of oral exposure to the nitrotoluenes were not located. A 13- week dietary study with the three nitrotoluene isomers in rats and mice indicated that effects were most notable with o-nitrotoluene (ACGIH, 1991). Effects included biochemical evidence of altered liver function, and splenic and renal lesions. EPA (1997) derived a provisional RfD of 1 E-2 mg/kg-day for chronic oral exposure to all three nitrotoluene isomers from data for o-nitrotoluene. In the key study, rats were treated by gavage for 6 months. The LOAEL was 200 mg/kg-day associated with lesions in the spleen. An uncertainty factor of 10,000 was applied to the LOAEL. The derivation of the provisional RfD is unclear, because dividing the LOAEL of 200 mg/kg-day by an uncertainty factor of 10,000 would be expected to yield an RfD of 2E-2 mg/kg-day, not I E-2 mg/kg-day as reported by EPA (1997). The liver, spleen and kidney are considered to be the target organs for chronic oral exposure to the nitrotoluenes.

Data regarding the toxicity of inhalation exposure to the nitrotoluenes were not located in the available literature. The data are inadequate for developing an inhalation RfC.

Data regarding the potential carcinogenicity of the nitrotoluenes were not located in the available literature. The nitrotoluenes are not assigned to a cancer weight-of-evidence group and URFs and SFs are not available.

References for Nitrotoluenes

Agency for Toxic Substances and Disease Registry, (ATSDR), 1990, Toxicological Profile for Nitrobenzene, U.S. Department of Health and Human Services, Atlanta, GA.

Agency for Toxic Substances and Disease Registry, (ATSDR), 1997, Update Toxicological Profile for 2,4-Dinitrotoluene and 2,6-Dinitrotoluene, Draft for Public Comment, U.S. Department of Health and Human Services, Atlanta, GA, September.

American Conference of Governmental Industrial Hygienists (ACGIH), 1991, Documentation of the Threshold Limit Values and Biological Exposure Indices, Sixth Edition, ACGIH, Cincinnati, OH, pp. 1131-1133.

Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.

Lewis, R.J., Sr., 1997, Hawley's Condensed Chemical Dictionary, Thirteenth Edition, John Wiley & Sons, Inc., New York, pp. 800-801.

Ohio Environmental Protection Agency (OEPA), 1998, U.S. NASA Plum Brook, Erie County, Ohio LD#: 322-0552, Risk Assessment Work Plans, letter from R.E. Nabors, Site Coordinator, to L.S. Ingram, Department of the Army, June 22.

Environmental Protection Agency (EPA), 1992a, Health Advisory for 2,4- and 2,6-Dinitrotoluene (DNT), Health and Ecological Criteria Division, Office of Water, Washington, DC.

U.S. Environmental Protection Agency (EPA), 1992b, Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91/01 1 B, January.

U.S. Environmental Protection Agency (EPA), 1997, Health Effects Assessment Summary Tables, FY1997 Update, Office of Solid Waste and Emergency Response, Washington, DC, 9200.6-303(97-1), EPA 540/R-97-036, PB97-921199.

POLYAROMATIC HYDROCARBONS (PAHs)

The PAHs COCs are benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene. All are SVOCs. PAHs are the products of incomplete combustion of fossil fuels or other organic matter, hence include both natural and anthropogenic sources (ATSDR, 1993a). Relevant physical properties are compiled below:

MW (g/mole)	log K_{ow} (unitless)	H (atm-m^3/mole)	Kd (L/kg)	Da (cm2/s)	Dw (cm2/s)	VP (atm)	S (mg/L)
benzo(a)anthracene (56-55-3)							
228.29	5.66[a]	1.6E-6[a]	5.30[a]	5.10E-2[d]	9.0E-6[d]	2.9E-11[c]	I[a]
Benzo(a)pyrene (50-32-8)							
252.3	6.16[e]	4.9E-7[a]	6.74[a]	4.30E-2[d]	9.0E-6[d]	7.4E-12[a]	3.8E+3[a]
Benzo(b)fluoranthene (99-99-0)							
252.3	6.12[e]	1.22-5[a]	5.74[a]	2.26E-2[d]	5.56E-6[d]	1.3E-9[a]	I[a]
Benzo(k)fluoranthene (207-08-9)							
252.3	6.06[a]	3.87-5[a]	5.74[a]	2.26E-2[d]	5.56E-6[d]	6.6E-10[a]	I[a]
Dibenz(a,h)anthracene (53-70-3)							
278.35	6.84[e]	7.3-8[a]	6.52[a]	2.02E-2[d]	5.18E-6[d]	8.2E-12[a]	5E-7[a]
Indeno(1,2,3-cd)pyrene (193-39-5)							
276.3	6.58[e]	6.95-8[a]	6.20[a]	1.90E-2[d]	5.66E-6[d]	1.3E-12[a]	6.23E-2[a]

a Agency for Toxic Substances and Disease Registry (ATSDR), 1993a, Update Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs), Draft for Public Comment, U.S. Department of Health and Human Services, Atlanta, Georgia, October.
b Montgomery, J.H ., 1996, Groundwater Chemicals Desk Reference, Second Edition, Lewis Publishers, New York.
c Calculated as described in Introduction to the Toxicity Profiles. 'U.S. Environmental Protection Agency (EPA), 1996,
d Soil Screening Guidance: Users Guide, Office of Solid Waste and Emergency Response, Washington, DC, Publication 9355 .4-23, April.
e U.S. Environmental Protection Agency (EPA), 1992, Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91/01113, January.
f U .S. Environmental Protection Agency (EPA), 1994, Technical Background Document for Soil Screening Guidance, Review Draft, Office of Solid Waste and Emergency Response, Washington, DC, Publication No . 9355 .4-17, EPA540/R-94/106, PB95-963532, November. 9
g Agency for Toxic Substances and Disease Registry, (ATSDR), 1993b, Update Toxicological Profile for Naphthalene, Draft for Public Comment, U.S. Public Health Service, Atlanta, Georgia, October.

The PAHs are ubiquitous products of incomplete combustion; natural sources include volcanoes and forest fires (ATSDR, 1993a, b; HSDB, 2001). There is some evidence for biosynthesis by plants, bacteria and algae. Some of the PAHs occur naturally in fossil fuels. Anthropogenic releases to the environment, primarily to the atmosphere, greatly outweigh the natural sources and include any processes that involve incomplete combustion of fossil fuels and organic matter, including wood-burning for home heat (the predominant source), cigarette smoke, internal combustion engine exhaust, and fuel oil emissions. Other sources include various crude oils, fresh and used motor oils,

gasolines, charcoal-broiled foods, processed foods, various oils, margarine, butter and fats, fruits, vegetables, and cereals, roasted coffee and tea. Naphthalene is released during its manufacture and processes that involve its use (e.g., vaporization from moth balls).

PAHs exist in the atmosphere as bothgases and particulates, the proportion depending on the vapor pressure of the individual chemical (ATSDR, 1993a, b; HSDB, 2001). They may travel short or long distances before removal from the air. Wet and dry deposition accounts for removal of the particulates. Vapor forms are subject to chemical oxidation processes in the air.

The predominant sources of PAHs in surface water are deposition from the atmosphere, industrial and sewage effluent and oil spills (ATSDR, 1993x, b). Runoff and erosion can also contribute PAHs to surface water bodies. Depending on solubility and vapor pressure, volatilization is a significant fate process for some of the PAHs in surface water. Adsorption to sediment is another significant removal process. Low molecular weight PAHs (acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene) are subject to chemical degradation and biodegradation. Naphthalene is relatively water soluble and may remain largely in solution. PAHs in sediment may biodegrade or accumulate in living organisms.

Deposition from the atmosphere is the principal source of PAHs in soil (ATSDR, 1993a, b). Other sources include industrial activities, disposal of sewage sludge, and leaching from coal storage sites. Most PAHs sorb to soil constituents because of their low solubility and high affinity for organic matter. Volatilization is an important removal process for the low molecular weight compounds. Some of the low molecular weight compounds, particularly naphthalene, may leach fairly rapidly to groundwater.

The propensity for the PAHs to participate in food-chain pathways is chemical specific, depending largely on the tendency for biodegradation or biotransformation (ATSDR, 1993a, b; HSDB, 2001). Biotransfer factors for the PAHs are compiled below:

BCF (L/kg)	B_{pr}[a,b] (unitless)	B_{pv}[a,b] (unitless)	B_b (days/kg)
benzo(a)anthracene (56-55-3)			
350[e]	2.07E-2	2.07E-2	1.15E-2
Benzo(a)pyrene (50-32-8)			
480[c]	1.07E-2	1.07E-2	3.63E-2
Benzo(b)fluoranthene (99-99-0)			
2800[f]	1.12E-2	1.12-2	3.31E-2
Benzo(k)fluoranthene (207-08-9)			
17,100[a]	6.78E-3	6.78E-3	2.88E-2
Dibenz(a,h)anthracene (53-70-3)			
10[e]	5.33E-2	5.33E-2	2.24E-3
Indeno(1,2,3-cd)pyrene (193-39-5)			
12,800[a]	6.09E-3	6.09E-3	9.55E-2

a Calculated as described in Introduction to the Toxicity Profiles.
b The methodology for estimating biotransfer of organic chemicals to plants does not differentiate vegetative and reproductive portions .
c Empirical data in Bluegill Sunfish (Lepomis macrochirus) from Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.
d Estimated value from Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.
e Empirical data in golden ide fish (Leuciscus idus melanotus) from Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line .

f Empirical data in clams from Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.
f Empirical data in guppies (Poecilia reticulata), from Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.
f Empirical data in fathead minnows, from Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line .

The BCF for indeno(1,2,3-cd)pyrene may be overestimated because the PAHs are generally readily metabolized by vertebrates, reducing the potential for bioconcentration (ATSDR, 1993a; HSDB, 2001). The BCF for benzo(b)fluoranthene is probably overestimated for fin fish because fin fish biotransform and eliminate PAHs much more readily than invertebrates.

Toxicokinetic studies of several PAHs summarized by ATSDR (1993a) provide limited quantitative information regarding the extent of GI absorption. Qualitatively, these studies indicate that absorption is incomplete. A study of benzo(a)pyrene in rats suggested that GI absorption ranges from 38 to 58 percent. The GAF of 0.5 (Jones and Owen, 1989), near the midpoint of the range from the rat study, is selected for benzo(a)pyrene and the other PAHs for which quantitative data are not available. GI absorption of dibenzo(a,h)anthracene is described as high; a GAF of 0 .8 is assumed for this compound.

Empirical data with pure compound dissolved or suspended in vehicles suggest that dermal uptake of benzo(a)pyrene is extensive (ATSDR, 1993x), but data regarding absorption from soil were not located. Lacking suitable empirical data for dermal uptake from soil, the OEPA (1998) Region IV default ABS of 0.1 for organic chemicals is chosen for the PAHs.

The PAHs are generally divided into two EPA cancer weight-of-evidence groups: Group D - not classifiable as to carcinogenicity to humans, and Group B2 - probable human carcinogens. No Group D PAHs were retained as COCs.

Cancer SFs and URFs are available for the Group B2 compounds but noncancer RfDs or RfCs are not. Therefore, evaluation and RGO development for these compounds are limited to cancer risk. These compounds have the morphologic requirements for carcinogenicity; therefore, it has been thought that cancer risk is the driver, and that noncancer effects are relatively insignificant, although empirical data were lacking.

Recent data, however, support this assumption. De Jong et al. (1999) reported a study in which male rats were treated by gavage with benzo(a)pyrene 5 days per week for 35 days at dose rates of 0 (control), 3, 10, 30 or 90 mg/kg. Significantly reduced rate of body weight gain and altered organ weights were observed in the 90 mg/kg group. Forestomach lesions were found in the 30 and 90 mg/kg group. Decreased thymus weights and hematological evidence of erythrocyte toxicity were observed in a dose-related manner in rats treated with 10 mg/kg and above. Subtle alterations in measures of immune function were also observed in these groups, establishing 10 mg/kg as the LOAEL and 3 mg/kg as the NOAEL for this study. The 3 mg/kg dose is equivalent to an adjusted NOAEL of 2.1 mg/kg-day. Application of an uncertainty factor of 1000 (factor of 10 to expand from subchronic to chronic exposure, and factors of 10 each to provide additional protection for intra- and interspecies variation) allows development of a preliminary oral RfD of 2E-3 mg/kg-day. Uncertainty surrounding the preliminary oral RfD is very high because the data base for benzo(a)pyrene is essentially limited to one study and several toxicological endpoints (e.g., developmental, reproductive, neurological) were not investigated .

Benzo(a)pyrene is the most extensively studied member of the class, inducing tumors in tissues at the point of contact of virtually all laboratory species tested by all routes of exposure. Although epidemiology studies suggested that complex mixtures that contain PAHs (coal tar, soots, coke oven emissions, cigarette smoke) are carcinogenic to humans, the carcinogenicity cannot be attributed to PAHs alone because of the presence of other potentially carcinogenic substances in these mixtures (ATSDR, 1993a) . In addition, recent investigations showed that the PAH fraction of roofing tar, cigarette smoke and coke oven emissions accounted for only 0.1-8% of the total mutagenic activity in Salmonella of the unfractionated complex mixture (Lewtas, 1988). Aromatic amines, nitrogen heterocyclic compounds, highly oxygenated quinones, diones, and nitrooxygenated compounds, none ofwhich would be expected to arise from in vivo metabolism of PAHs, probably accounts for the majority of the mutagenicity of coke oven emissions and cigarette smoke. Furthermore, coal tar, which contains a mixture of many PAHs, has a long history of use in the clinical treatment of a variety of skin disorders in humans (ATSDR, 1993a).

Because of the lack of human cancer data, assignment of individual PAHs to EPA cancer weight of-evidence groups is based largely on the results of animal studies with large doses of purified compound (EPA, 2001). Frequently, unnatural routes of exposure, including implants of the test chemical in beeswax and trioctanoin in the lungs of female rats, intratracheal instillation, and subcutaneous or intraperitoneal injection, were used.

EPA (2001) verified a SF for oral exposure to benzo(a)pyrene of 7 .3E+0 per mg/kg-day, based on several dietary studies in mice and rats. Recent reevaluations of the carcinogenicity and mutagenicity of the Group B2 PAHs suggest that there are large differences between individual PAHs in cancer potency (Krewski et al., 1989). Based on the available cancer and mutagenicity data, and assuming that there is a constant relative potency between different carcinogens across different bioassay systems and that the PAHs under consideration have similar dose-response curves, EPA (1993b) adopted relative potency values for several PAHs.

Although the EPA has not verified SFs for Group B2 PAHs other than benzo(a)pyrene, the SFs above represent reasonable estimates based on the data available. The relative potency approach employed here meets criteria considered to be desirable for this type of analysis (Lewtas, 1988). For example, the chemicals compared have similar chemical structures and would be expected to have similar toxicokinetic fate in mammalian systems. In addition, the available data suggest that the Group B2 PAHs have a similar mechanism of action, inducing frameshift mutations in Salmonella and tumor initiation in the mouse skin painting assay. Similar noncancer effects (minor changes in the blood, liver, kidneys) of the Group D PAHs support the hypothesis of a common mechanism of toxicity. Finally, the same endpoints of toxicity, i.e., potency in various cancer assays, and related data, were used to derive the relative potency values (Krewski et al., 1989). The oral SF for benzo(a)pyrene of 7.3E+0 per mg/kg-day, and the SFs presented above for the other Group B2 PAHs are adopted for the purposes of this evaluation.

An EPA (1994) evaluation of the inhalation cancer data suggests adoption of an inhalation SF for benzo(a)pyrene of 3 .1 E+0 per mg/kg-day, based on the incidence ofupper respiratory and digestive tract tumors in hamsters. Applying the relative potency estimates presented above yield the inhalation SFs for the other Group B2 PAHs presented above.

References for PAHs

Agency for Toxic Substances and Disease Registry, (ATSDR), 1993a, Update Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs), Draft for Public Comment, U.S. Public Health Service, Atlanta, Georgia, October.

De Jong, W.H., E.D. Kroes, J .G . Vos and H. Van Loveren, 1999, "Detection of Immunotoxicity of Benzo[a]pyrene in a Subacute Toxicity Study after Oral Exposure in Rats," Toxicological Sciences 50: 214-220.

Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.

Jones, TD. and BA Owen, 1989, Health Risks from Mixtures of Radionuclides and Chemicals in Drinking Water, Oak Ridge National Laboratory, Oak Ridge, TN, ORNL-6533.

U.S. Environmental Protection Agency (EPA), 1986, "Guidelines for Carcinogen Risk Assessment," Federal Register 51(185): 33992-34003.

Krewski, D., T. Thorslund and J. Withey, 1989, "Carcinogenic Risk Assessment of Complex Mixtures," Toxicology and Industrial Health, 5: 851-867.

Lewtas, J., 1988, "Genotoxicity of Complex Mixtures: Strategies for the Identification and Comparative Assessment of Airborne Mutagens and Carcinogens from Combustion Sources," Fundamental and Applied Toxicology, 10: 571-589.

Ohio Environmental Protection Agency (OEPA), 1998, U.S. NASA Plum Brook, Erie County, Ohio LD#: 322-0552, Risk Assessment Work Plans, letter from R.E. Nabors, Site Coordinator, to L.S. Ingram, Department of the Army, June 22.

U.S. Environmental Protection Agency (EPA), 1986, "Guidelines for Carcinogen Risk Assessment," Federal Register, 51(185): 33992-3400. U.S. Environmental Protection Agency (EPA), 1990, "National Oil and Hazardous Substances Pollution Contingency Plan," Federal Register 55(46): 8666-8865.

U.S. Environmental Protection Agency (EPA), 1992, Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91/01 1 B, January.

U.S. Environmental Protection Agency (EPA), 1993b, Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons, Office of Health and Environmental Assessment, Cincinnati, OH, EPA/600/R-93/089.

U.S. Environmental Protection Agency (EPA), 1994, Risk Assessment Issue Paper: Status of Inhalation Cancer Unit Risk for Benzo(a)Pyrene (CAS No. 50-32-8), National Center for Environmental Assessment, Cincinnati, OH, November 18.

U.S. Environmental Protection Agency (EPA), 1997, Health Effects Assessment Summary Tables, FY 1997 Update, Office of Solid Waste and Emergency Response, Washington, DC, 9200.6-303(97-1), EPA 540/R-97-036, PB97-921199.

U.S. Environmental Protection Agency (EPA), 2001, Integrated Risk Information System (IRIS), National Center for Environmental Assessment, Cincinnati, OH, on line.

POLYCHLORINATED BIPHENYLS (PCBs)

The PCBs are a class of SVOCs including 209 possible individual congeners, each consisting of a biphenyl structure and 1 to 10 chlorine atoms (ATSDR, 1995). The PCBs manufactured and used in the U.S. are called Aroclors. The Aroclors are mixtures of several PCB congeners and related compounds. Aroclors were used as dielectric and heat exchange agents in several open and closed systems, but since the middle 1970s, use has been restricted largely to electrical transformers and capacitors.

Analysis of PCBs in environmental media frequently involves "fingerprinting" the mixture, and reporting the result as the Aroclor(s) that most closely reflect the fingerprint(s) (ATSDR, 1995). Recently, however, more attention has been paid to analyzing and reporting individual congeners, because of the possibility that certain congeners may be dioxin-like in their mechanism of toxicity. The Aroclors most commonly identified in environmental media include Aroclor-1016, -1221, -1232, -1242, -1248, -1254, -1260, -1262, and -1268. Relevant physical properties are compiled below:

MW (g/mole)	log K_{ow} (unitless)	H (atm-m^3/mole)	Kd (L/kg)	Da (cm2/s)	Dw (cm2/s)	VP (atm)	S (mg/L)
Aroclor-1254 (11097-69-1)							
328[a,b]	6.5[b]	2.0E-3[b]	5.00[c]	3.99E-2[d]	5.6E-6[c]	1.01E-7[b]	3.5E-2[b]
Aroclor-1260 (11096-82-5)							
375.7[a,b]	6.8[b]	4.6E-3[b]	6.42[c]	3.65E-2[d]	5.3E-6[c]	5.33E-8[a]	4.1E-2[b]

a Average molecular mass for the proportions of individual congeners in the commercial product.
b Agency for Toxic Substances and Disease Registry (ATSDR), 1995, Update Toxicological Profile for Polychorinted Biphenyls, Draft for Public Comment, U.S . Department of Health and Human Services, Atlanta, Georgia, August.
c Montgomery, J.H., 1996, Groundwater Chemicals Desk Reference, Second Edition, Lewis Publishers, New York.
d Calculated as described in Introduction to the Toxicity Profiles.

Former PCB releases occurred as a result of their manufacture, use, disposal, and leakage from damaged PCB-containing equipment (ATSDR, 1995) . Currently the major source of PCB release to the environment is recycling of PCBs previously introduced into the environment, which involves volatilization from ground surfaces (water, soil) into the atmosphere with subsequent removal from the atmosphere via wet/dry deposition, followed by volatilization (HSDB, 2001). PCBs are also currently released to the environment from landfills containing PCB waste materials and products, incineration of municipal refuse and sewage sludge, and improper (or illegal) disposal of PCB materials, such as waste transformer fluid, to open areas. Major sources to air include emissions from the overhaul, repair or reuse of PCB-containing items, and the recycling of previously released PCBs described above (ATSDR, 1995; HSDB, 2001). The vapor pressures of the PCBs indicate that they would exist primarily in the vapor phase in the atmosphere; monitoring data have shown that between 87 and 100% of the PCBs in air are in the vapor-phase. Vapor pressure of the PCBs generally decreases with an increase in the extent of chlorination; therefore, the more highly chlorinated PCBs are more likely to be associated with the particulate-adsorption-phase in air than are the lesser chlorinated PCBs. Physical removal of PCBs in the atmosphere is accomplished by wet and dry deposition; dry deposition occurs only for PCBs in the particulate phase.

Major sources to soil include leaks or discharges from PCB-containing items and deposition from the atmosphere (ATSDR, 1995). PCBs sorb tightly to constituents of soil with adsorption generally increasing with the degree of chlorination. Although the lesser chlorinated biphenyls may exhibit low mobility in soil, PCBs will generally not leach significantly in most aqueous soil systems. In the presence of organic solvents, PCBs may leach quite rapidly through soil. Vapor loss of PCBs from soil surfaces appears to be an important loss mechanism with the rate of volatilization decreasing with increasing chlorination. Although the volatilization rate may be low, the total loss by volatilization over time may be significant because of the persistence and stability of PCBs. In general, the persistence of PCBs increases with an increase in the degree of chlorination (HSDB, 2001). Mono-, di- and trichlorinated biphenyls (Aroclors-1221 and -1232) biodegrade relatively rapidly, tetrachlorinated biphenyls (Aroclors-1016 and -1242) biodegrad slowly, and higher chlorinated biphenyls (Aroclors-1248, 1-254 and -1260) are resistant to biodegradation. The position of chlorination in the isomeric classes also determines the extent of biodegradation. Although biodegradation of higher chlorinated congeners may occur very slowly on an environmental basis, no other degradation mechanisms have been shown to be important in soil systems; therefore, biodegradation may be the ultimate degradation process in soil.

Former sources of PCBs to surface water include waste streams and discharges from waste water treatment plants (ATSDR, 1995). Currently, direct deposition, runoff and erosion probably predominate. Removal from water involves sorption to particles and sedimentation, as well as volatilization.

The PCBs are among the compounds that bioaccumulate in food chain pathways and are of special concern for biomagnification from sediment in benthic fish. Biotransfer factors for the PCBs are compiled below:

BCF (L/kg)	B_{pr}[a,b] (unitless)	B_{pv}[a,b] (unitless)	B_b[a] (days/kg)
Aroclor-1254 (11097-69-1)			
See below	6.78E-3	6.78E-3	7.94E-2
Aroclor-1260 (11096-82-5)			
See below	4.55E-3	4.55E-3	1.58E-1

a Calculated as described in Introduction to the Toxicity Profiles.
b The methodology for estimating biotransfer oforganic chemicals to plants does not differentiate vegetative and reproductive portions .

The acute oral toxicity of the PCBs is low to moderate, as indicated by LD_{50} values in laboratory animals ranging from 750 mg/kg (mink) to 4250 mg/kg (rats) (ATSDR, 1995). Mink appear to be unusually sensitive. Death appears to be due to respiratory depression and dehydration from diarrhea

The best known incident involving oral exposure by humans is the "Yusho" incident in Japan, in which persistent chloracne, gastrointestinal irritation and central nervous symptoms followed ingestion of cooking oil contaminated with PCBs (Gaffey, 1983). Further investigation, however, revealed that concentrations of polychlorinated dibenzofurans (PCDF) and polychlorinated quaterphenyls in the cooking oil were similar to those of PCBs, which confounds interpretation of the reported observations and symptoms.

Prolonged oral exposure of laboratory animals leads to liver damage, signs of chloracne, immunological effects, and neurological impairment, particularly of the young. A verified oral RfD for Aroclor-1254 of 2E-5 mg/kg-day for chronic oral exposure is based on a

LOAEL of 5E-3 mg/kg-day associated with chloracne and related signs and immunological effects in monkeys treated with the test material in gelatin capsules for over five years (EPA, 2001). An uncertainty factor of 300 was applied. Confidence in the RfD is medium. The immune system and skin are considered the target organs for prolonged oral exposure to Aroclor-1254.

Occupational exposure to PCBs, which involved both inhalation and dermal exposure, was associated with upper respiratory tract and ocular irritation, loss of appetite, liver enlargement and increased serum concentrations of liver enzymes, skin irritation, rashes and chloracne, and, in heavily exposed female workers, decreased birth weight oftheir infants (ATSDR, 1995). Concurrent exposure to PCB contaminants, such as PCDFs, confounds the interpretation of the occupational exposure studies. Rats, mice, rabbits and guinea pigs intermittently exposed to Aroclor-1254 vapors exhibit moderate liver degeneration, decreased body weight gain and slight renal tubular degeneration; however, the accuracy of the reported exposure concentration is in doubt. Neither verified nor provisional chronic inhalation RfC values arc available.

EPA (2001) classified PCBs in cancer weight-of-evidence Group B2 (probable human carcinogen) based on adequate evidence for liver tumors in laboratory animals and inadequate data in humans. EPA (2001) established a tiered approach for estimating the cancer potency of exposure to the PCBs. For the high risk tier, A SF of 2.0E+0 per mg/kg-day is verified as an upper-bound for exposure to PCBs via ingestion in the food chain, ingestion of soil or sediment, inhalation of dust or aerosol, or dermal contact with soil or sediment if an absorption factor is applied. In addition, the SF of 2.0E+0 per mg/kg-day is used for any congeners considered to be persistent or acting in a dioxin-like manner, and for any early life exposures. The high risk tier SF for central tendency (CT) analyses is 1.0E+0 per mg/kg-day. EPA (2001) verified an upperbound SF of 4.0E-1 per mg/kg-day for the low risk tier, which includes ingestion of watersoluble congeners, inhalation of evaporated congeners, and dermal exposure if no absorption factor is applied. A SF of 3E-1 per mg/kg-day is recommended for the low risk CT evaluation. The SF of 2.0E+0 per mg/kg-day is used for all exposure scenarios and exposure routes in this evaluation because analytical data that demonstrate the absence of dioxin-like or persistent congeners are not available, and the exposure of children or youths is plausible.

References for PCBs

Agency for Toxic Substances and Disease Registry, (ATSDR), 1995, Update Toxicological Profile for Polychlorinated Biphenyls, Draft for Public Comment, U.S. Public Health Service, Atlanta, Georgia, August.

Gaffey, W.R., 1983, "The epidemiology of PCBs," In: PCBs: Human and Environmental Hazards, F.M. D'itri and M.A. Kamrin, Eds., Boston: Butterworth Publishers.

Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.

U.S. Environmental Protection Agency (EPA), 1992, Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91/01 1B, January

U.S. Environmental Protection Agency (EPA), 1995, Great Lakes Water Quality Initiative, Technical Support Document for the Procedure to Determine Bioaccumulation Factors, EPA.820.8.95 .CC5, P1395-187290.

U.S. Environmental Protection Agency (EPA), 2001, Integrated Risk Information System (IRIS), National Center for Environmental Assessment, Cincinnati, OH, on line.

XYLENES, TOTAL

The xylenes (1330-20-7), also known as dimethylbenzenes, are synthetic VOCs derived from coal tar, coal gas, and petroleum distillation (ATSDR, 1993; HSDB, 2001). Natural sources include petroleum, forest fires and volatiles from plants.

Xylenes are used in the manufacture of other organic compounds, dyes, insecticides and pharmaceuticals, and as solvents (ATSDR, 1993; HSDB, 2001). They are components of aviation gasoline, asphalt and naphtha, and automobile exhaust. Technical xylene consists of approximately 44 percent m-xylene (1,3-dimethylbenzene [108-38-3]), 20 percent o-xylene (1,2- dimethylbenzene [95-47-6]), 20 percent p-xylene (1,4-dimethylbenzene [106-42-3]), and 15 percent ethylbenzene. Laboratory analyses of environmental media often report values for total xylenes (1330-20-7), mixed xylenes or m- and p- xylene. The xylene isomers have similar physical property values and are toxicologically similar; therefore, the relevant physical properties for m-xylene, presented below, may be applied to the mixed xylenes, total xylene or any of the three isomers:

MW (g/mole)	log K_{ow} (unitless)	H (atm-m^3/mole)	Kd (L/kg)	Da (cm2/s)	Dw (cm2/s)	VP (atm)	S (mg/L)
106.2	3.20[a]	7.34E-3[b]	2.61[b]	7.00E-2[b]	7.8E-6[b]	1.06E-2[c]	1.61E+2[b]

a U.S. Environmental Protection Agency (EPA), 1992, Dermal Exposure Assessment: Principles andApplications, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91 /011 B, January. '
b U.S. Environmental Protection Agency (EPA), 1996, Soil Screening Guidance: Users Guide, Office of Solid Waste and Emergency Response, Washington, DC, Publication 9355 .4-23, April.
c U.S. Environmental Protection Agency (EPA), 1994, Technical Background Document for Soil Screening Guidance, Review Draft, Office of Solid Waste and Emergency Response, Washington, DC, Publication No. 9355 .4-17, EPA540/R-94/106, PB95-963532, November.

Naturally occurring sources of xylenes are petroleum, forest fires and volatiles from plants (ATSDR, 1993; HSDB, 2001). The production and use of xylenes in petroleum products and as chemical solvents and intermediates may result in their release to the environment through various waste streams. Outgassing from landfills and automobile exhaust are other significant sources. Spills, leaking underground storage tanks, and leaching from landfills may release xylenes to soil and groundwater.

Xylenes will exist solely in the vapor phase in the ambient atmosphere, where they are subject to degradation by reaction with photochemically-produced hydroxyl radicals as the only significant removal process (ATSDR, 1993; HSDB, 2001). The atmospheric lifetime of xylenes is about 1 to 2 days. Products of photooxidation include a wide variety of ring hydroxylation and ring cleavage products.

Volatilization is expected to be the major removal mechanism for xylenes released to surface soil, but, depending on the size and rate of release, the majority of the release may infiltrate to subsurface soil (ATSDR, 1993). Photooxidation may degrade a significant part of the small amount that remains at the surface. Biodegradation is probably the only significant subsurface removal mechanism, but it is expected to be slow. A wide range of experimental K., values have been reported in soil samples with differing pH and organic carbon content (HSDB, 2001), suggesting a wide range in the extent to which the xylenes adsorb to soil particles. Generally, however, xylene is fairly mobile and may readily leach to groundwater.

Volatilization is probably the most significant removal mechanism for xylenes in surface water (ATSDR, 1993). Biodegradation may occur in surface water, groundwater and

landfill leachate, although quite slowly. Oxidative reactions are expected to be insignificant. Xylenes are expected to adsorb somewhat to suspended solids and sediment in water (HSDB, 2001).

Xylenes are not expected to participate significantly in food-chain pathways (ATSDR, 1993; HSDB, 2001); therefore, biotransfer factors are not provided.

Oral LD50 values for xylenes include 3.5 to 8 .6 g/kg in rats and 1 .6 to 5 .6 g/kg in mice (HSDB, 2001), suggesting that the acute toxicity is low, but that mice may be slightly more sensitive than rats to the acute effects of ingested xylenes. Prolonged oral exposure of animals to xylenes is associated with CNS signs and increased mortality without histopathological alterations in the internal organs (EPA, 2001). EPA (2001) presents a verified chronic oral RfD for total xylenes of 2E+0 mg/kg-day based on a NOAEL for hyperactivity and decreased body weight and increased mortality in male rats in chronic gavage studies with mixed xylenes. An uncertainty factor of 100 was used. Confidence in the chronic oral RfD is medium. EPA (1997) presents provisional RfDs for o-xylene and m-xylene of 2E+0 mg/kg-day based on the same study. The CNS is considered the target organ for prolonged oral exposure to the xylenes. The oral RfD of 2E+0 mg/kg-day is applied to total or mixed xylenes, and to each of the xylene isomers.

Occupational exposure to xylenes induces CNS effects and GI disturbances (ACGIH, 1991). Other effects attributed to occupational exposure to xylene (blood dyscrasias, and heart, liver and kidney damage) may arise from concurrent exposure to other chemicals. The data are not sufficient for derivation of an inhalation RfC. The CNS is the principal target organ for inhalation exposure to the xylenes.

Xylene is classified as a cancer weight-of-evidence Group D compound (not classifiable as to carcinogenicity to humans) (EPA, 2001). There are no reported human cancer data, and gavage studies in rat and mice of both sexes did not result in significant increases in tumor incidence.

References for Xylenes, Total

American Conference of Governmental Industrial Hygienists (ACGIH), 1991, Documentation of the Threshold Limit Values and Biological Exposure Indices, Sixth Edition, Cincinnati, OH, pp. 1732-1740.

Agency for Toxic Substances and Disease Registry, (ATSDR), 1993, Toxicological Profile for Xylenes, Draft for Public Comment, U.S. Department of Health and Human Services, Atlanta, GA.

Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.

Jones, TD. and BA Owen, 1989, Health Risksfrom Mixtures ofRadionuclides and Chemicals in Drinking Water, Oak Ridge National Laboratory, Oak Ridge, TN, ORNL-6533.

Ohio Environmental Protection Agency (OEPA), 1998, U.S. NASA Plum Brook, Erie County, Ohio LD#: 322-0552, Risk Assessment Work Plans, letter from R.E. Nabors, Site Coordinator, to L.S. Ingram, Department of the Army, June 22.

U.S. Environmental Protection Agency (EPA), 1992, Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91 /011 B, January.

U.S. Environmental Protection Agency (EPA), 1997, Health Effects Assessment Summary Tables, FY1997 Update, Office of Solid Waste and Emergency Response, 9200.6-303 (97-1), EPA-540-R-97-036, NTIS No. PB97-921199.

U.S. Environmental Protection Agency (EPA), 2001, Integrated Risk Information System (IRIS), National Center for Environmental Assessment, Cincinnati, OH, on line.

APPENDIX E

PROUCL CALCULATIONS FOR EXPOSURE-POINT CONCENTRATIONS

Data File AA3 Surface Soil

Variable: Aluminum

Raw Statistics	
Number of Valid Samples	34
Number of Unique Samples	32
Minimum	2430
Maximum	14000
Mean	7305
Median	7225
Standard Deviation	2271
Variance	4468503
Coefficient of Variation	0.282483
Skewness	0.64

Gamma Statistics	
k hat	13.4477
k star (bias corrected)	12.28075
Theta hat	556.4696
Theta star	609.347
nu hat	914.4435
nu star	835.0907
Approx.Chi Square Value (.05)	769.0113
Adjusted Level of Significance	0.0422
Adjusted Chi Square Value	765.8873

Log-transformed Statistics	
Minimum of log data	8.180321
Maximum of log data	9.546813
Mean of log data	8.882779
Standard Deviation of log data	0.280062
Variance of log data	0.078435

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.946926
Shapiro-Wilk 5% Critical Value	0.933
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	7964

Gamma Distribution Test	
A-D Test Statistic	0.347268
A-D 5% Critical Value	0.747206
K-S Test Statistic	0.096278
K-S 5% Critical Value	0.15081
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	8126.253
Adjusted Gamma UCL	8159.399

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.977258
Shapiro-Wilk 5% Critical Value	0.933
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	8173.504
95% Chebyshev (MVUE) UCL	9076.792
97.5% Chebyshev (MVUE) UCL	9765.092
99% Chebyshev (MVUE) UCL	11117.12

95% Non-parametric UCLs	
CLT UCL	8079.541
Adj-CLT UCL (Adjusted for skewness)	8140.733
Mod-t UCL (Adjusted for skewness)	8106.308
Jackknife UCL	8096.763
Standard Bootstrap UCL	7705
Bootstrap-t UCL	8147.229
Hall's Bootstrap UCL	8252.707
Percentile Bootstrap UCL	8089.118
BCA Bootstrap UCL	8123.088
95% Chebyshev (Mean, Sd) UCL	9063.458
97.5% Chebyshev (Mean, Sd) UCL	9747.222
99% Chebyshev (Mean, Sd) UCL	11090.34

Data File AA3 Surface Soil

Variable: Arsenic

Raw Statistics	
Number of Valid Samples	34
Number of Unique Samples	30
Minimum	2.29
Maximum	13.3
Mean	6.420294
Median	5.95
Standard Deviation	2.607934
Variance	6.801318
Coefficient of Variation	0.406202
Skewness	0.548969

Gamma Statistics	
k hat	6.031167
k star (bias corrected)	5.518613
Theta hat	1.064519
Theta star	1.163389
nu hat	410.1194
nu star	375.2657
Approx.Chi Square Value (.05)	331.3599
Adjusted Level of Significance	0.0422
Adjusted Chi Square Value	329.3253

Log-transformed Statistics	
Minimum of log data	0.828552
Maximum of log data	2.587764
Mean of log data	1.774277
Standard Deviation of log data	0.431273
Variance of log data	0.185996

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.966139
Shapiro-Wilk 5% Critical Value	0.933
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	7.177214

Gamma Distribution Test	
A-D Test Statistic	0.173143
A-D 5% Critical Value	0.748794
K-S Test Statistic	0.069772
K-S 5% Critical Value	0.151206
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	7.270995
Adjusted Gamma UCL	7.315916

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.973696
Shapiro-Wilk 5% Critical Value	0.933
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	7.446271
95% Chebyshev (MVUE) UCL	8.60333
97.5% Chebyshev (MVUE) UCL	9.534441
99% Chebyshev (MVUE) UCL	11.36343

95% Non-parametric UCLs	
CLT UCL	7.155966
Adj-CLT UCL (Adjusted for skewness)	7.200959
Mod-t UCL (Adjusted for skewness)	7.184232
Jackknife UCL	7.177214
Standard Bootstrap UCL	7.136366
Bootstrap-t UCL	7.266414
Hall's Bootstrap UCL	7.201939
Percentile Bootstrap UCL	7.176471
BCA Bootstrap UCL	7.222353
95% Chebyshev (Mean, Sd) UCL	8.369842
97.5% Chebyshev (Mean, Sd) UCL	9.213413
99% Chebyshev (Mean, Sd) UCL	10.87044

Data File AA3 Surface Soil

Variable: Iron

Raw Statistics	
Number of Valid Samples	34
Number of Unique Samples	31
Minimum	6810
Maximum	26600
Mean	15486.76
Median	15540
Standard Deviation	4990.909
Variance	24909168
Coefficient of Variation	0.322269
Skewness	0.321407

Gamma Statistics	
k hat	9.511051
k star (bias corrected)	8.691449
Theta hat	1628.292
Theta star	1781.839
nu hat	646.7515
nu star	591.0185
Approx.Chi Square Value (.05)	535.6153
Adjusted Level of Significance	0.0422
Adjusted Chi Square Value	533.0159

Log-transformed Statistics	
Minimum of log data	8.826147
Maximum of log data	10.18867
Mean of log data	9.59425
Standard Deviation of log data	0.339708
Variance of log data	0.115401

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.973094
Shapiro-Wilk 5% Critical Value	0.933
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	16935.31

Gamma Distribution Test	
A-D Test Statistic	0.1916
A-D 5% Critical Value	0.747847
K-S Test Statistic	0.07522
K-S 5% Critical Value	0.150934
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	17088.69
Adjusted Gamma UCL	17172.03

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.97215
Shapiro-Wilk 5% Critical Value	0.933
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	17310.28
95% Chebyshev (MVUE) UCL	19552.67
97.5% Chebyshev (MVUE) UCL	21295.73
99% Chebyshev (MVUE) UCL	24719.64

95% Non-parametric UCLs	
CLT UCL	16894.65
Adj-CLT UCL (Adjusted for skewness)	16945.06
Mod-t UCL (Adjusted for skewness)	16943.18
Jackknife UCL	16935.31
Standard Bootstrap UCL	16871.54
Bootstrap-t UCL	16953.12
Hall's Bootstrap UCL	16991.8
Percentile Bootstrap UCL	16953.53
BCA Bootstrap UCL	16904.71
95% Chebyshev (Mean, Sd) UCL	19217.69
97.5% Chebyshev (Mean, Sd) UCL	20832.07
99% Chebyshev (Mean, Sd) UCL	24003.2

Data File AA3 Surface Soil

Variable: Lead

Raw Statistics	
Number of Valid Samples	34
Number of Unique Samples	30
Minimum	3.6
Maximum	653
Mean	38.72103
Median	13.55
Standard Deviation	110.7123
Variance	12257.21
Coefficient of Variation	2.859229
Skewness	5.504054

Gamma Statistics	
k hat	0.701831
k star (bias corrected)	0.659513
Theta hat	55.17143
Theta star	58.71158
nu hat	47.72452
nu star	44.84686
Approx.Chi Square Value (.05)	30.48327
Adjusted Level of Significance	0.0422
Adjusted Chi Square Value	29.89681

Log-transformed Statistics	
Minimum of log data	1.280934
Maximum of log data	6.481577
Mean of log data	2.7956
Standard Deviation of log data	0.986155
Variance of log data	0.972502

RECOMMENDATION

Data are Non-parametric (0.05)

Use 95% Chebyshev (Mean, Sd) UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.287557
Shapiro-Wilk 5% Critical Value	0.933
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	70.85387

Gamma Distribution Test	
A-D Test Statistic	4.011272
A-D 5% Critical Value	0.792311
K-S Test Statistic	0.279597
K-S 5% Critical Value	0.157409
Data do not follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	56.96621
Adjusted Gamma UCL	58.08367

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.873182
Shapiro-Wilk 5% Critical Value	0.933
Data not lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	40.1289
95% Chebyshev (MVUE) UCL	48.26044
97.5% Chebyshev (MVUE) UCL	57.8554
99% Chebyshev (MVUE) UCL	76.70285

95% Non-parametric UCLs	
CLT UCL	69.95187
Adj-CLT UCL (Adjusted for skewness)	89.10237
Mod-t UCL (Adjusted for skewness)	73.84096
Jackknife UCL	70.85387
Standard Bootstrap UCL	69.62528
Bootstrap-t UCL	277.3244
Hall's Bootstrap UCL	206.4358
Percentile Bootstrap UCL	75.73324
BCA Bootstrap UCL	103.2137
95% Chebyshev (Mean, Sd) UCL	121.4835
97.5% Chebyshev (Mean, Sd) UCL	157.2948
99% Chebyshev (Mean, Sd) UCL	227.6393

Data File AA3 Surface Soil

Variable: Manganese

Raw Statistics	
Number of Valid Samples	34
Number of Unique Samples	34
Minimum	51.9
Maximum	922
Mean	360.7471
Median	309.5
Standard Deviation	200.9561
Variance	40383.36
Coefficient of Variation	0.557055
Skewness	1.163662

Gamma Statistics	
k hat	3.492843
k star (bias corrected)	3.204259
Theta hat	103.2818
Theta star	112.5836
nu hat	237.5133
nu star	217.8896
Approx.Chi Square Value (.05)	184.7201
Adjusted Level of Significance	0.0422
Adjusted Chi Square Value	183.2127

Log-transformed Statistics	
Minimum of log data	3.949319
Maximum of log data	6.826545
Mean of log data	5.738251
Standard Deviation of log data	0.578689
Variance of log data	0.334881

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.906557
Shapiro-Wilk 5% Critical Value	0.933
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	419.072

Gamma Distribution Test	
A-D Test Statistic	0.252147
A-D 5% Critical Value	0.752719
K-S Test Statistic	0.07294
K-S 5% Critical Value	0.151805
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	425.5251
Adjusted Gamma UCL	429.0262

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.969097
Shapiro-Wilk 5% Critical Value	0.933
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	448.2729
95% Chebyshev (MVUE) UCL	532.4727
97.5% Chebyshev (MVUE) UCL	604.9189
99% Chebyshev (MVUE) UCL	747.2254

95% Non-parametric UCLs	
CLT UCL	417.4348
Adj-CLT UCL (Adjusted for skewness)	424.7838
Mod-t UCL (Adjusted for skewness)	420.2183
Jackknife UCL	419.072
Standard Bootstrap UCL	415.9373
Bootstrap-t UCL	433.5631
Hall's Bootstrap UCL	430.4006
Percentile Bootstrap UCL	416.6912
BCA Bootstrap UCL	420.4559
95% Chebyshev (Mean, Sd) UCL	510.9708
97.5% Chebyshev (Mean, Sd) UCL	575.9727
99% Chebyshev (Mean, Sd) UCL	703.6564

Data File AA3 Surface Soil

Variable: Vanadium

Raw Statistics	
Number of Valid Samples	34
Number of Unique Samples	34
Minimum	10.7
Maximum	31.1
Mean	20.49059
Median	20.35
Standard Deviation	4.839629
Variance	23.42201
Coefficient of Variation	0.236188
Skewness	0.164203

Gamma Statistics	
k hat	17.79861
k star (bias corrected)	16.24775
Theta hat	1.151246
Theta star	1.261134
nu hat	1210.306
nu star	1104.847
Approx.Chi Square Value (.05)	1028.665
Adjusted Level of Significance	0.0422
Adjusted Chi Square Value	1025.044

Log-transformed Statistics	
Minimum of log data	2.370244
Maximum of log data	3.437208
Mean of log data	2.991611
Standard Deviation of log data	0.245792
Variance of log data	0.060414

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.979896
Shapiro-Wilk 5% Critical Value	0.933
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	21.89523

Gamma Distribution Test	
A-D Test Statistic	0.268601
A-D 5% Critical Value	0.746564
K-S Test Statistic	0.106204
K-S 5% Critical Value	0.150703
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	22.00812
Adjusted Gamma UCL	22.08585

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.974708
Shapiro-Wilk 5% Critical Value	0.933
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	22.13415
95% Chebyshev (MVUE) UCL	24.3219
97.5% Chebyshev (MVUE) UCL	25.97139
99% Chebyshev (MVUE) UCL	29.21148

95% Non-parametric UCLs	
CLT UCL	21.8558
Adj-CLT UCL (Adjusted for skewness)	21.88077
Mod-t UCL (Adjusted for skewness)	21.89912
Jackknife UCL	21.89523
Standard Bootstrap UCL	21.81312
Bootstrap-t UCL	21.99763
Hall's Bootstrap UCL	21.83421
Percentile Bootstrap UCL	21.85588
BCA Bootstrap UCL	21.87441
95% Chebyshev (Mean, Sd) UCL	24.10843
97.5% Chebyshev (Mean, Sd) UCL	25.67387
99% Chebyshev (Mean, Sd) UCL	28.74888

Data File AA3 Subsurface Soil

Variable: Aluminum

Raw Statistics	
Number of Valid Samples	40
Number of Unique Samples	40
Minimum	2650
Maximum	11900
Mean	8156
Median	8320
Standard Deviation	2088
Variance	3923482
Coefficient of Variation	0.239663
Skewness	-0.606

Gamma Statistics	
k hat	14.28658
k star (bias corrected)	13.08106
Theta hat	578.5051
Theta star	631.8187
nu hat	1000.06
nu star	915.6741
Approx.Chi Square Value (.05)	846.4246
Adjusted Level of Significance	0.0425
Adjusted Chi Square Value	843.2794

Log-transformed Statistics	
Minimum of log data	7.882315
Maximum of log data	9.384294
Mean of log data	8.984362
Standard Deviation of log data	0.291002
Variance of log data	0.084682

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.970831
Shapiro-Wilk 5% Critical Value	0.934
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	8712

Gamma Distribution Test	
A-D Test Statistic	0.764396
A-D 5% Critical Value	0.747606
K-S Test Statistic	0.139747
K-S 5% Critical Value	0.148527
Data follow approximate gamma distibution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	8941.04
Adjusted Gamma UCL	8974.387

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.868812
Shapiro-Wilk 5% Critical Value	0.934
Data not lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	9096.307
95% Chebyshev (MVUE) UCL	10123.01
97.5% Chebyshev (MVUE) UCL	10906.67
99% Chebyshev (MVUE) UCL	12446.01

95% Non-parametric UCLs	
CLT UCL	8815.575
Adj-CLT UCL (Adjusted for skewness)	8775.158
Mod-t UCL (Adjusted for skewness)	8824.696
Jackknife UCL	8831
Standard Bootstrap UCL	8486
Bootstrap-t UCL	8814.017
Hall's Bootstrap UCL	8761.122
Percentile Bootstrap UCL	8770.143
BCA Bootstrap UCL	8785.286
95% Chebyshev (Mean, Sd) UCL	9724.271
97.5% Chebyshev (Mean, Sd) UCL	10355.76
99% Chebyshev (Mean, Sd) UCL	11596.2

Data File AA3 Subsurface Soil

Variable: Arsenic

Raw Statistics	
Number of Valid Samples	40
Number of Unique Samples	38
Minimum	0.718
Maximum	32.2
Mean	9.252179
Median	8.29
Standard Deviation	6.880172
Variance	6.715
Coefficient of Variation	0.743627
Skewness	1.922641

Gamma Statistics	
k hat	2.378499
k star (bias corrected)	2.193675
Theta hat	3.889923
Theta star	4.217661
nu hat	166.4949
nu star	153.5573
Approx.Chi Square Value (.05)	125.9072
Adjusted Level of Significance	0.0425
Adjusted Chi Square Value	124.7213

Log-transformed Statistics	
Minimum of log data	0.083192
Maximum of log data	3.471966
Mean of log data	2.000154
Standard Deviation of log data	0.687089
Variance of log data	0.472092

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.80575
Shapiro-Wilk 5% Critical Value	0.934
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	10.6

Gamma Distribution Test	
A-D Test Statistic	0.492474
A-D 5% Critical Value	0.757426
K-S Test Statistic	0.110793
K-S 5% Critical Value	0.150278
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	11.28402
Adjusted Gamma UCL	11.39132

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.981604
Shapiro-Wilk 5% Critical Value	0.934
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	11.94901
95% Chebyshev (MVUE) UCL	14.37087
97.5% Chebyshev (MVUE) UCL	16.57306
99% Chebyshev (MVUE) UCL	20.89885

95% Non-parametric UCLs	
CLT UCL	11.16508
Adj-CLT UCL (Adjusted for skewness)	11.56892
Mod-t UCL (Adjusted for skewness)	11.28165
Jackknife UCL	11.21866
Standard Bootstrap UCL	9.73
Bootstrap-t UCL	11.82557
Hall's Bootstrap UCL	12.17068
Percentile Bootstrap UCL	11.17375
BCA Bootstrap UCL	11.42232
95% Chebyshev (Mean, Sd) UCL	14.32141
97.5% Chebyshev (Mean, Sd) UCL	16.51487
99% Chebyshev (Mean, Sd) UCL	20.8235

Data File AA3 Subsurface Soil

Variable: Iron

Raw Statistics	
Number of Valid Samples	40
Number of Unique Samples	40
Minimum	5720
Maximum	34800
Mean	19676
Median	18600
Standard Deviation	5568
Variance	28565740
Coefficient of Variation	0.265351
Skewness	0.634

Gamma Statistics	
k hat	12.58249
k star (bias corrected)	11.52304
Theta hat	1600.796
Theta star	1747.976
nu hat	880.7744
nu star	806.6128
Approx.Chi Square Value (.05)	741.6901
Adjusted Level of Significance	0.0425
Adjusted Chi Square Value	738.7489

Log-transformed Statistics	
Minimum of log data	8.651724
Maximum of log data	10.4429
Mean of log data	9.870299
Standard Deviation of log data	0.308102
Variance of log data	0.094927

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.982355
Shapiro-Wilk 5% Critical Value	0.934
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	21160

Gamma Distribution Test	
A-D Test Statistic	0.442806
A-D 5% Critical Value	0.74787
K-S Test Statistic	0.10525
K-S 5% Critical Value	0.148568
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	21905.1
Adjusted Gamma UCL	21992.31

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.890446
Shapiro-Wilk 5% Critical Value	0.934
Data not lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	22301.34
95% Chebyshev (MVUE) UCL	24941.29
97.5% Chebyshev (MVUE) UCL	26967.38
99% Chebyshev (MVUE) UCL	30947.25

95% Non-parametric UCLs	
CLT UCL	21627.99
Adj-CLT UCL (Adjusted for skewness)	21647.58
Mod-t UCL (Adjusted for skewness)	21672.67
Jackknife UCL	21669.61
Standard Bootstrap UCL	20600
Bootstrap-t UCL	21651.23
Hall's Bootstrap UCL	21812.11
Percentile Bootstrap UCL	21567.71
BCA Bootstrap UCL	21560
95% Chebyshev (Mean, Sd) UCL	24079.91
97.5% Chebyshev (Mean, Sd) UCL	25783.84
99% Chebyshev (Mean, Sd) UCL	29130.9

Data File AA3 Subsurface Soil

Variable: Manganese

Raw Statistics	
Number of Valid Samples	35
Number of Unique Samples	35
Minimum	93.4
Maximum	1763.5
Mean	526.7471
Median	454
Standard Deviation	330.9397
Variance	109521.1
Coefficient of Variation	0.628271
Skewness	1.960565

Gamma Statistics	
k hat	3.271863
k star (bias corrected)	3.010465
Theta hat	160.993
Theta star	174.972
nu hat	229.0304
nu star	210.7326
Approx.Chi Square Value (.05)	178.1325
Adjusted Level of Significance	0.0425
Adjusted Chi Square Value	176.7136

Log-transformed Statistics	
Minimum of log data	4.536891
Maximum of log data	7.475056
Mean of log data	6.106188
Standard Deviation of log data	0.576401
Variance of log data	0.332238

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.829855
Shapiro-Wilk 5% Critical Value	0.934
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	621.3358

Gamma Distribution Test	
A-D Test Statistic	0.457519
A-D 5% Critical Value	0.753377
K-S Test Statistic	0.10863
K-S 5% Critical Value	0.149582
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	623.1475
Adjusted Gamma UCL	628.1507

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.985354
Shapiro-Wilk 5% Critical Value	0.934
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	644.0611
95% Chebyshev (MVUE) UCL	764.0371
97.5% Chebyshev (MVUE) UCL	866.6842
99% Chebyshev (MVUE) UCL	1068.314

95% Non-parametric UCLs	
CLT UCL	618.7586
Adj-CLT UCL (Adjusted for skewness)	638.5667
Mod-t UCL (Adjusted for skewness)	624.4254
Jackknife UCL	621.3358
Standard Bootstrap UCL	615.111
Bootstrap-t UCL	657.4893
Hall's Bootstrap UCL	673.7877
Percentile Bootstrap UCL	623.5257
BCA Bootstrap UCL	640.9857
95% Chebyshev (Mean, Sd) UCL	770.5797
97.5% Chebyshev (Mean, Sd) UCL	876.0862
99% Chebyshev (Mean, Sd) UCL	1083.333

Data File AA3 Subsurface Soil

Variable: Vanadium

Raw Statistics	
Number of Valid Samples	40
Number of Unique Samples	40
Minimum	8.2
Maximum	31.5
Mean	23.30429
Median	24.2
Standard Deviation	4.792432
Variance	22.96741
Coefficient of Variation	0.205646
Skewness	-0.930436

Gamma Statistics	
k hat	19.09308
k star (bias corrected)	17.47558
Theta hat	1.220562
Theta star	1.333535
nu hat	1336.515
nu star	1223.29
Approx.Chi Square Value (.05)	1143.067
Adjusted Level of Significance	0.0425
Adjusted Chi Square Value	1139.405

Log-transformed Statistics	
Minimum of log data	2.104134
Maximum of log data	3.449988
Mean of log data	3.122221
Standard Deviation of log data	0.252096
Variance of log data	0.063553

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.948787
Shapiro-Wilk 5% Critical Value	0.934
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	24

Gamma Distribution Test	
A-D Test Statistic	0.919739
A-D 5% Critical Value	0.746861
K-S Test Statistic	0.134338
K-S 5% Critical Value	0.148412
Data follow approximate gamma distibution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	24.93984
Adjusted Gamma UCL	25.02

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.827727
Shapiro-Wilk 5% Critical Value	0.934
Data not lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	25.2838
95% Chebyshev (MVUE) UCL	27.8087
97.5% Chebyshev (MVUE) UCL	29.71304
99% Chebyshev (MVUE) UCL	33.45373

95% Non-parametric UCLs	
CLT UCL	24.63673
Adj-CLT UCL (Adjusted for skewness)	24.5006
Mod-t UCL (Adjusted for skewness)	24.65282
Jackknife UCL	24.67405
Standard Bootstrap UCL	23.4
Bootstrap-t UCL	24.51819
Hall's Bootstrap UCL	24.56038
Percentile Bootstrap UCL	24.53571
BCA Bootstrap UCL	24.45286
95% Chebyshev (Mean, Sd) UCL	26.83529
97.5% Chebyshev (Mean, Sd) UCL	28.36316
99% Chebyshev (Mean, Sd) UCL	31.36437

Data File AA3 Sediment

Variable: Aluminum

Raw Statistics	
Number of Valid Samples	13
Number of Unique Samples	13
Minimum	5730
Maximum	10200
Mean	8283.846
Median	8440
Standard Deviation	1319.46
Variance	1740976
Coefficient of Variation	0.159281
Skewness	-0.316624

Gamma Statistics	
k hat	40.50153
k star (bias corrected)	31.20631
Theta hat	204.5317
Theta star	265.4542
nu hat	1053.04
nu star	811.364
Approx.Chi Square Value (.05)	746.2469
Adjusted Level of Significance	0.03009
Adjusted Chi Square Value	737.3432

Log-transformed Statistics	
Minimum of log data	8.653471
Maximum of log data	9.230143
Mean of log data	9.009667
Standard Deviation of log data	0.166511
Variance of log data	0.027726

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.966305
Shapiro-Wilk 5% Critical Value	0.866
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	8936.079

Gamma Distribution Test	
A-D Test Statistic	0.262123
A-D 5% Critical Value	0.732776
K-S Test Statistic	0.168509
K-S 5% Critical Value	0.236172
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	9006.69
Adjusted Gamma UCL	9115.45

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.950138
Shapiro-Wilk 5% Critical Value	0.866
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	9049.29
95% Chebyshev (MVUE) UCL	9960.551
97.5% Chebyshev (MVUE) UCL	10684.67
99% Chebyshev (MVUE) UCL	12107.06

95% Non-parametric UCLs	
CLT UCL	8885.784
Adj-CLT UCL (Adjusted for skewness)	8851.446
Mod-t UCL (Adjusted for skewness)	8930.723
Jackknife UCL	8936.079
Standard Bootstrap UCL	8868.755
Bootstrap-t UCL	8902.93
Hall's Bootstrap UCL	8860.957
Percentile Bootstrap UCL	8864.615
BCA Bootstrap UCL	8862.308
95% Chebyshev (Mean, Sd) UCL	9878.996
97.5% Chebyshev (Mean, Sd) UCL	10569.22
99% Chebyshev (Mean, Sd) UCL	11925.03

Data File AA3 Sediment

Variable: Arsenic

Raw Statistics	
Number of Valid Samples	12
Number of Unique Samples	13
Minimum	2.53
Maximum	15.4
Mean	8.143077
Median	7.4
Standard Deviation	4.36667
Variance	19.06781
Coefficient of Variation	0.536243
Skewness	-0.01889

Gamma Statistics	
k hat	2.289072
k star (bias corrected)	1.812107
Theta hat	3.557371
Theta star	4.493708
nu hat	59.51587
nu star	47.11477
Approx.Chi Square Value (.05)	32.3602
Adjusted Level of Significance	0.03009
Adjusted Chi Square Value	30.62488

Log-transformed Statistics	
Minimum of log data	-0.544727
Maximum of log data	2.734368
Mean of log data	1.863115
Standard Deviation of log data	0.875937
Variance of log data	0.767266

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.981876
Shapiro-Wilk 5% Critical Value	0.866
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	10.3016

Gamma Distribution Test	
A-D Test Statistic	0.447532
A-D 5% Critical Value	0.741985
K-S Test Statistic	0.166881
K-S 5% Critical Value	0.239062
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	11.8559
Adjusted Gamma UCL	12.5277

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.813621
Shapiro-Wilk 5% Critical Value	0.866
Data not lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	18.47638
95% Chebyshev (MVUE) UCL	19.37554
97.5% Chebyshev (MVUE) UCL	23.81981
99% Chebyshev (MVUE) UCL	32.54973

95% Non-parametric UCLs	
CLT UCL	10.13515
Adj-CLT UCL (Adjusted for skewness)	10.12837
Mod-t UCL (Adjusted for skewness)	10.30054
Jackknife UCL	10.3016
Standard Bootstrap UCL	10.0438
Bootstrap-t UCL	10.38185
Hall's Bootstrap UCL	10.22651
Percentile Bootstrap UCL	10.00385
BCA Bootstrap UCL	10.11923
95% Chebyshev (Mean, Sd) UCL	13.42212
97.5% Chebyshev (Mean, Sd) UCL	15.70637
99% Chebyshev (Mean, Sd) UCL	20.19333

Data File AA3 Sediment

Variable: Iron

Raw Statistics	
Number of Valid Samples	13
Number of Unique Samples	13
Minimum	12400
Maximum	23300
Mean	18826.92
Median	19500
Standard Deviation	3441.694
Variance	11845256
Coefficient of Variation	0.182807
Skewness	-0.170285

Gamma Statistics	
k hat	30.84232
k star (bias corrected)	23.77614
Theta hat	610.425
Theta star	791.8409
nu hat	801.9004
nu star	618.1798
Approx.Chi Square Value (.05)	561.4909
Adjusted Level of Significance	0.03009
Adjusted Chi Square Value	553.7887

Log-transformed Statistics	
Minimum of log data	9.425452
Maximum of log data	10.09617
Mean of log data	9.826744
Standard Deviation of log data	0.190975
Variance of log data	0.036471

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.978088
Shapiro-Wilk 5% Critical Value	0.866
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	20528.21

Gamma Distribution Test	
A-D Test Statistic	0.208386
A-D 5% Critical Value	0.733037
K-S Test Statistic	0.139532
K-S 5% Critical Value	0.236143
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	20727.71
Adjusted Gamma UCL	21016

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.962486
Shapiro-Wilk 5% Critical Value	0.866
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	20860.24
95% Chebyshev (MVUE) UCL	23203.57
97.5% Chebyshev (MVUE) UCL	25093.16
99% Chebyshev (MVUE) UCL	28804.9

95% Non-parametric UCLs	
CLT UCL	20397.02
Adj-CLT UCL (Adjusted for skewness)	20348.85
Mod-t UCL (Adjusted for skewness)	20520.7
Jackknife UCL	20528.21
Standard Bootstrap UCL	20304.25
Bootstrap-t UCL	20546.73
Hall's Bootstrap UCL	20353.67
Percentile Bootstrap UCL	20323.08
BCA Bootstrap UCL	20326.92
95% Chebyshev (Mean, Sd) UCL	22987.73
97.5% Chebyshev (Mean, Sd) UCL	24788.11
99% Chebyshev (Mean, Sd) UCL	28324.62

Data File AA3 Sediment

Variable: Lead

Raw Statistics	
Number of Valid Samples	13
Number of Unique Samples	13
Minimum	12.6
Maximum	84.1
Mean	26.01154
Median	15.1
Standard Deviation	21.90247
Variance	479.7184
Coefficient of Variation	0.842029
Skewness	2.151085

Gamma Statistics	
k hat	2.518342
k star (bias corrected)	1.988468
Theta hat	10.32884
Theta star	13.0812
nu hat	65.47689
nu star	51.70017
Approx.Chi Square Value (.05)	36.18308
Adjusted Level of Significance	0.03009
Adjusted Chi Square Value	34.33999

Log-transformed Statistics	
Minimum of log data	2.533697
Maximum of log data	4.432007
Mean of log data	3.047051
Standard Deviation of log data	0.605019
Variance of log data	0.366048

RECOMMENDATION

Data are Non-parametric (0.05)

Use 95% Chebyshev (Mean, Sd) UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.642097
Shapiro-Wilk 5% Critical Value	0.866
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	36.83832

Gamma Distribution Test	
A-D Test Statistic	1.529391
A-D 5% Critical Value	0.741077
K-S Test Statistic	0.293632
K-S 5% Critical Value	0.238794
Data do not follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	37.16657
Adjusted Gamma UCL	39.16136

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.778766
Shapiro-Wilk 5% Critical Value	0.866
Data not lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	37.4356
95% Chebyshev (MVUE) UCL	43.73814
97.5% Chebyshev (MVUE) UCL	51.89864
99% Chebyshev (MVUE) UCL	67.92834

95% Non-parametric UCLs	
CLT UCL	36.00345
Adj-CLT UCL (Adjusted for skewness)	39.87592
Mod-t UCL (Adjusted for skewness)	37.44234
Jackknife UCL	36.83832
Standard Bootstrap UCL	35.51699
Bootstrap-t UCL	66.70127
Hall's Bootstrap UCL	81.89793
Percentile Bootstrap UCL	36.51154
BCA Bootstrap UCL	39.26154
95% Chebyshev (Mean, Sd) UCL	52.49034
97.5% Chebyshev (Mean, Sd) UCL	63.94774
99% Chebyshev (Mean, Sd) UCL	86.45358

Data File AA3 Sediment

Variable: Manganese

Raw Statistics	
Number of Valid Samples	13
Number of Unique Samples	13
Minimum	207
Maximum	586
Mean	404.3077
Median	452
Standard Deviation	116.9932
Variance	13687.4
Coefficient of Variation	0.289367
Skewness	-0.411124

Gamma Statistics	
k hat	11.29
k star (bias corrected)	8.735899
Theta hat	35.81113
Theta star	46.28118
nu hat	293.5401
nu star	227.1334
Approx.Chi Square Value (.05)	193.2422
Adjusted Level of Significance	0.03009
Adjusted Chi Square Value	188.7885

Log-transformed Statistics	
Minimum of log data	5.332719
Maximum of log data	6.37332
Mean of log data	5.957236
Standard Deviation of log data	0.324724
Variance of log data	0.105445

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.910787
Shapiro-Wilk 5% Critical Value	0.866
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	462.1395

Gamma Distribution Test	
A-D Test Statistic	0.759536
A-D 5% Critical Value	0.733687
K-S Test Statistic	0.288795
K-S 5% Critical Value	0.236624
Data do not follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	475.216
Adjusted Gamma UCL	486.4268

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.880545
Shapiro-Wilk 5% Critical Value	0.866
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	488.4601
95% Chebyshev (MVUE) UCL	566.89
97.5% Chebyshev (MVUE) UCL	636.6158
99% Chebyshev (MVUE) UCL	773.5785

95% Non-parametric UCLs	
CLT UCL	457.68
Adj-CLT UCL (Adjusted for skewness)	453.7266
Mod-t UCL (Adjusted for skewness)	461.5228
Jackknife UCL	462.1395
Standard Bootstrap UCL	456.2875
Bootstrap-t UCL	456.726
Hall's Bootstrap UCL	452.1612
Percentile Bootstrap UCL	455.3077
BCA Bootstrap UCL	451.8462
95% Chebyshev (Mean, Sd) UCL	545.7455
97.5% Chebyshev (Mean, Sd) UCL	606.9458
99% Chebyshev (Mean, Sd) UCL	727.1618

Data File AA3 Sediment

Variable: Vanadium

Raw Statistics	
Number of Valid Samples	13
Number of Unique Samples	12
Minimum	14.7
Maximum	25.7
Mean	20.73077
Median	20.8
Standard Deviation	3.455523
Variance	11.94064
Coefficient of Variation	0.166686
Skewness	-0.400432

Gamma Statistics	
k hat	36.68315
k star (bias corrected)	28.26909
Theta hat	0.565131
Theta star	0.733337
nu hat	953.7619
nu star	734.9964
Approx.Chi Square Value (.05)	673.0763
Adjusted Level of Significance	0.03009
Adjusted Chi Square Value	664.6283

Log-transformed Statistics	
Minimum of log data	2.687847
Maximum of log data	3.246491
Mean of log data	3.017927
Standard Deviation of log data	0.175265
Variance of log data	0.030718

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.94447
Shapiro-Wilk 5% Critical Value	0.866
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	22.4389

Gamma Distribution Test	
A-D Test Statistic	0.408942
A-D 5% Critical Value	0.73288
K-S Test Statistic	0.187301
K-S 5% Critical Value	0.23616
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	22.63791
Adjusted Gamma UCL	22.92566

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.925198
Shapiro-Wilk 5% Critical Value	0.866
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	22.76149
95% Chebyshev (MVUE) UCL	25.15053
97.5% Chebyshev (MVUE) UCL	27.05874
99% Chebyshev (MVUE) UCL	30.80704

95% Non-parametric UCLs	
CLT UCL	22.30718
Adj-CLT UCL (Adjusted for skewness)	22.19345
Mod-t UCL (Adjusted for skewness)	22.42116
Jackknife UCL	22.4389
Standard Bootstrap UCL	22.23202
Bootstrap-t UCL	22.31386
Hall's Bootstrap UCL	22.19555
Percentile Bootstrap UCL	22.22308
BCA Bootstrap UCL	22.15385
95% Chebyshev (Mean, Sd) UCL	24.90829
97.5% Chebyshev (Mean, Sd) UCL	26.71591
99% Chebyshev (Mean, Sd) UCL	30.26663

APPENDIX F

RESPONSES TO COMMENTS ON THE DRAFT BASELINE HUMAN HEALTH RISK ASSESSMENT

Comments received on the Draft Baseline Human Health Risk Assessment, Acid Area 2 from Paul Jayko, Ohio Environmental Protection Agency, Site Coordinator, DERR-NWDO, were also applied to the Draft Baseline Human Health Risk Assessment, Acid Area 3; therefore, these comments and responses are included in this appendix.

State of Ohio Environmental Protection Agency

Interoffice Memorandum

To: Paul Jayko, Site Coordinator, DERR-NWDO

From: John Weaver through Tim Fishbaugh, Manager, DDAGW-NWDO

Date: October 23, 2007

Facility: NASA Plum Brook Ordnance Works, Erie County, RR 322-0552.

Subject: Draft Baseline Human Health Risk Assessment Acid Area 2, document dated September 2007.

INTRODUCTION

The NASA Plum Brook Station (NPBS) is a formerly used defense site and is being investigated by the U.S. Army Corps of Engineers (USACE) under the Defense Environmental Restoration Program. The USACE Nashville, TN district contracted Jacobs Engineering Group, Inc. (Jacobs) to prepare a baseline human health risk assessment for Acid Area 2. The ERA was prepared as an element of a remedial investigation (RI) completed at Acid Area 2 during a period of time from approximately November 2004 to April 2005. For reference, Acid Area 2 was formerly used to produce materials for the manufacture of trinitrotoluene (TNT) including sulfuric and nitric acid. Constituents of concern (COCs) detected in soil samples include semivolatile organic compounds, polynuclear aromatic hydrocarbons, and PCBs.

NPBS/Jacobs submitted a Draft Baseline Human Health Risk Assessment Acid Area 2 to Ohio EPA on September 27, 2007. The Division of Emergency and Remedial Response (DERR) has requested that the Division of Drinking and Ground Waters (DDAGW) review the aforementioned risk assessment to determine its adequacy and completeness in support of the RI at Acid Area 2.

COMMENTS

1. **Ohio EPA requests that USACE Nashville, TN district (USACE) and/or Jacobs Engineering Group, Inc. (Jacobs) provide a technical/regulatory reference for the equation to calculate risk-based remediation levels ($RBRL_{coc}$); equation 5.7 (Eq. 5.7) on page 5-5 of the September 2007 Draft Baseline Human Health Risk Assessment Acid Area 2 (HHRA).**

   Ohio EPA is unclear as to how the equation for $RBRL_{coc}$ is developed using the variables of ST_{coc} (source term concentration, TR (target risk level of $1x10^{-6}$), and $ILCR_{coc}$ (incremental lifetime cancer risk [CDIxSF]).

   Response: The basis of the equation is that risks and remediation levels are proportional; as the concentration of a chemical rises, the risk will rise proportionally. Therefore, for a calculated level of risk (ILCRcoc) at a known concentration (STcoc), the remediation level may be calculated for any specified risk level (TR; such as 1X10-6).

The equation in the document has been referenced in the document USEPA. 2000. Supplemental Guidance to RAGS: Region 4 Bulletins, Human Health Risk Assessment Bulletins. EPA Region 4, originally published November 1995, Website version last updated May 2000: http://www.epa.gov/region4/waste/ots/healtbul.htm.

2. **The HHRA should have included an appendix containing ProUCL calculations for all constituents of concern (COCs) for each media type for cross-referencing purposes.**

   The exposure point concentration (EPC) column found on Table 2.1 of the HHRA is represented by the lesser of the ProUCL value or the maximum detected concentration of the COC in a particular media. The maximum detected concentration of each COC is provided but not the derivation of the ProUCL value.

   Response: ProUCL Version 3 was only used to calculate EPCs for data sets containing fewer than 15 percent nondetects. This is consistent with the documentation for ProUCL Version 3 which indicates that it is not suited for data sets with greater than 15 percent nondetects. The data sets calculated using ProUCL for Acid Areas 2 and 3 were all metal constituents. The ProUCL output has been added as an Appendix to the document.

   As detailed in Section 2.2 of the BHHRAs, statistical computations for data sets with greater than 15 percent nondetects were made using a FoxPro based statistical package developed by Jacobs. This software package was developed based on EPA and other statistical guidance and documentation. The operations performed by the software include: 1) Data distribution evaluations using Shapiro-Wilk and Shapiro-Francia methods, 2) Data distribution evaluations using box-plots and probability plots, 3) Outlier evaluation using ASTM E178-75, 4) Summary statistics computed using classical methods as described section 4-7 of the USEPA QA/G-9 publication and in Richard Gilbert's textbook "Statistical Methods for Environmental Pollution Monitoring", and 5) Calculations of UCLs as described in Gilbert, using Kaplan-Meier, using simple bootstrap with replacement, and by MLE (maximum likelihood estimation).

3. **Ohio EPA is unclear as to what USACE/Jacobs intend to do with the human health risk assessment conclusions found in Section 7.3 of the HHRA.**

   Response: The results will be used to determine the need for additional investigation or any remediation at the site.

ec: Archie Lunsey, DERR-NWDO
Paul Jayko, DHWM-NWDO
pc: Jeff Patzke, DDAGW-CO

ID: 5000007254

OhioEPA

inter-office communication

To:	Paul Jayko, **NWDO-DERR**	Date: 28 November 2007
From:	Janusz Z. Byczkowski, DERR, CO	
Subject:	**Draft Baseline Human Health Risk Assessment, Acid Area 3, Former Plum Brook Ordnance Works Sandusky, Ohio,** April 2007. Site: US NASA PLUM BROOK, TAYLOR & COLUMBUS Rds., SANDUSKY, OH 44870; ERIE Cnt.; OHID# 322-0552.	

The following memo is about the document *"Draft **Baseline Human Health Risk Assessment, Acid Area 3", Former Plum Brook Ordnance Works Sandusky, Ohio,*** dated September, 2007.

If you have any questions or need further technical support, please call me at: 614-644-3070 or e-mail at jbyczkowski@epa.state.oh.us.

DOCUMENT TITLE: *Draft* ***Baseline Human Health Risk Assessment, Acid Area 3***	
SITE: US NASA PLUM BROOK, TAYLOR & COLUMBUS Rds., SANDUSKY, OH 44870; ERIE Cnt.; OHID# 322-0552.	**DOCUMENT/DATE**: Draft /September 2007
Ohio EPA – Division of Emergency and Remedial Response COMMENTS	
REVIEWER: Dr. Janusz Z. Byczkowski, DERR, CO; Tel: 614-644-3070; e-mail: jbyczkowski@epa.state.oh.us.	
Review/DATE: 11/28/2007	

1. S 1.4, P 1-3, L# 36
Comment:
General Remark:
This Document should be revised to include some of the current Ohio EPA – Division of Emergency and Remedial Response (OEPA-DERR) remedial investigation/feasibility study (RI/FS) programmatic guidelines.

If you have any questions or need further technical support, please give me a call at: 614-644-3070 or e-mail at jbyczkowski@epa.state.oh.us.

For example, this Document states:
"*...This BHHRA was prepared based on [...] Ohio Environmental Protection Agency guidance...*"

However, the one and only OEPA guidance listed on the next page 1-4 and in the Reference section on page 8-2: OEPA (1993) "*Closure Plan Review Guidance for RCRA Facilities,*" is already obsolete.

Recommendation: I suggest a **revision** of the Document:
(i) to include OEPA-DERR - RI/FS programmatic recommendations available on-line at: http://www.epa.state.oh.us/derr/rules/guidance.html, and
(ii) to follow the suggestions and resolve the specific issues listed below.

Response: The document has been revised to include an expanded list of OEPA-DERR Guidance documents. The obsolete guidance document cited in the comment has been removed from the list of references.

2. 5.4, P 5-7, L# 36
Comment:
Specific Issues:

This Document states:
"*...Total ILCR estimates for the adult and child venison consumer receptors were below the risk management range...*" This statement is repeated in Section 7.2 (P. 7-2, L# 14) and the expression "*risk management range*" appears in numerous places (e.g., in S. 7.3 on P. 7-3).

Essentially, the description of baseline human health risk should be kept separate from risk management decisions, e.g., from setting "*risk management range*" or "*unacceptable risk*" levels (see: NRC, 1983). Risk management statements, are premature at a Baseline Risk

Assessment phase of the project. However, they may be discussed later, during the Feasibility Study (FS).

In this document, the results of quantitative baseline risk assessment should be objectively communicated as numerical values. They may be interpreted regarding their significance, health protection, and compared to the regulatory goals (e.g., OEPA, 2004, cumulative excess lifetime carcinogenic risk goal of 1E-5).

References:

NRC (1983) Commission on Life Sciences. "Risk Assessment in the Federal Government: Managing the Process". On line: http://books.nap.edu/books/0309033497/html/index.html .
OEPA (2004) Human Health Cumulative Carcinogenic Risk and Non-carcinogenic Hazard Goals for DERR Remedial Response and Office of Federal Facility Oversight. On line: http://www.epa.state.oh.us/derr/rules/riskgoal.pdf .

Recommendation: Please search this document for phrases containing "*management*", remove them (except those correctly explaining that values in BHHRA "*are derived to support risk management decisions*") and also remove all statements and other phrases suggesting that risk management decisions are being made at the baseline risk assessment phase of the RI.

Response: The use of the term "risk management range" is not used to indicate any risk management decision. Its use is consistent with EPA guidance such as *Role of the Baseline Risk Assessment,* which indicates that EPA seeks to "manage" risks within the range of 10^{-4} to 10^{-6} ELCR, also referred to as a "target risk range," and OEPA's Technical Decision Compendium *Human Health Cumulative Carcinogenic Risk and Non-carcinogenic Hazard Goals for DERR Remedial Response and Office of Federal Facility Oversight,* which states that "the NCP defines an acceptable upper excess lifetime cancer risk as generally between 10^{-6} and 10^{-4}". The text has been revised to eliminate references to "risk management" and any statements indicating that risk management decision are being made at the risk assessment phase.

3. Table 2-1

Comment: The column head states: "*Region 9 Residential PRG...*", while actually listing **1/10** of the residential PRG values for non-carcinogenic chemicals in soil. For chemicals in water: there are listed PRG values for **tap water** (100% or 1/10 for carcinogenic or non-carcinogenic chemicals, respectively), rather than "*Residential*" values.

Since values in this column are being used as screening levels, based on toxicity values derived from U.S. EPA Region 9 PRGs for residential soil and tap water, they should be labeled appropriately (there are no "*Residential PRGs*" for water).

Reference:

OEPA – DERR (2004) Use of U.S. EPA Region 9 PRGs as screening Values in Human Health Risk Assessments. Technical Decision Compendium, 28 April 2004. On-line: http://www.epa.state.oh.us/derr/rules/screening.pdf
(U.S. EPA Region 9 PRGs may be found at http://www.epa.gov/region09/waste/sfund/prg/index.htm)

Recommendation: Please change the column heading to "**Toxicity Screen Level**", mark it with an asterisk and explain in a footnote to the table the origin (PRGs for Residential soil and Tap

water) and the method of derivation (100% for carcinogenic chemicals and 1/10 for non-carcinogenic chemicals). Refer to OEPA – DERR (2004) guidelines.

Response: The term "tap water" in the Region 9 PRG Tables denotes a residential use of groundwater. The column heading has been changed to "Toxicity Screening Level" and a footnote has been added.

4. Table 4-1

Comment: Several toxicity values listed in this table are different from those, derived according to OEPA-DERR (2004) methodology and guidance. Also, the toxicity values for TCE are different from those, listed by OEPA at http://www.epa.state.oh.us/derr/rules/vapor.pdf.

However, in this case the differences between values in the table and OEPA guidelines do not affect the overall risk assessment, because they do concern chemicals not selected as COCs for this Site.

Reference:

OEPA–DERR (2004) "Assessing Compounds without Formal Toxicity Values Available for Use in Human Health Risk Assessment". Ohio EPA Division of Emergency and Remedial Response, Remedial Response Program. Date: 14 April 2004 (updated August 2005). On-line: http://www.epa.state.oh.us/derr/rules/notaxtdc.pdf

Recommendation: No change needed.

Response: Comment noted.

Comments of Jim Beaujon Concerning Jacob's *Draft Baseline Human Health Risk Assessment, Acid Area 3*, Former Plum Brook Ordnance Works, dated September 2007

1. Executive Summary: Please add an Executive Summary.

Response: An Executive Summary has been added to the document.

2. Page 1-1, Section 1.0, 2nd paragraph: Please change appropriate sentences to read- "This work is being conducted for … (DERP)-Formerly Used Defense Sites (FUDS). Investigations at PBOW under DERP-FUDS are being managed by"

Response: In response to this comment and a similar comment from another reviewer, the text has been revised as follows:

"This work is being conducted for the U.S. Army Corp of Engineers (USACE) under the Defense Environmental Restoration Program (DERP) – Formerly Used Defense Sites (FUDS). The Army is the executive agent for the FUDS program and the USACE manages and directs the program's administration. Investigations at PBOW under DERP-FUDS are being managed by the USACE Huntington District and technically overseen by the USACE Nashville District (CELRN)."

3. Page 1-2, Section 1.2, end of 2nd paragraph: The U.S. General Services Administration (GSA) is an independent federal agency and not a component of the Army.

Response: The text has been modified to remove mention of the Army in this context.

4. Page 2-1, second line: Given the EPA's current regional naming system wouldn't it be "Region 3" rather than "Region III"?

Response: The EPA regional naming convention has been changed throughout the document in response to this comment.

5. Page 2-4, Section 2.1.5, 1st paragraph: Please edit for clarity. The first reference to "derivation of BSCs" (4th line of paragraph) appears to be for groundwater but it isn't clearly stated (e.g. "derivation of groundwater BSCs"). Then in the last sentence "Background values for soil" are mentioned, are these also BSCs

Response: The text has been revised to clarify that there are two sets of BSCs: one for groundwater and one for soil.

6. Page 2-5: Definitions for Equation 2.2 variables: The "s_y" in the equation appears to use a lower case "s" rather than the upper case as used in the definition.

Response: The "S" in the definition has been changed to lower case.

7. Page 2-8, Shallow Groundwater, 2nd paragraph: When discussing possible lab artifacts showing up in sample analysis rather than saying "detected in monitoring well" it might be better to say something like "detected in the sample from monitoring well".

Response: The text has been modified to read "reported in the sample…"

8. Page 3-2, last two sentences of paragraph preceding Section 3.1.1 and page 3-3 last sentence of paragraph preceding Section 3.1.2: There seems to be a conflict between these two areas as the first indicates groundwater can plausibly be used as tap water and the second that it is unsuitable as a potable water source. Please reconcile this conflict.

Response: Although the presence of petroleum and hydrogen sulfide makes site groundwater unsuitable for use as a drinking water source at Acid Area 3, groundwater in the PBOW area is used for drinking water. Because future use of groundwater is plausible, it was retained as a potential exposure medium.

9. Page 3-7, Future On-Site Resident, last sentence of 1st paragraph: Rather than "Cancer risk were estimated" shouldn't it be "Cancer risk was estimated"?

Response: The text has been revised to read "Lifetime cancer risk was…"

10. General comment for Equations: Not a big deal but some of the "Eq. #" entries are given on the same line as the equation while others are on the line following the equation.

Response: The equations have been reformatted so that the Equation Number appears on the same line as the equation.

11. Page 5-3, Equation 5.6 and definitions: Shouldn't there be a space between "Total" and "HI_a"?

Response: A space has been added between "Total" and "HI_a."

12. Tables and Figures appendix: If the tables and figures are to be presented in the same appendix then they should not be segregated within the appendix but should be presented in the order in which they are first referenced in the text. For example, Figures 1-1 and 1-2 are referenced before any tables therefore they should be presented in the appendix ahead of the tables.

Response: The figures and tables are now provided under separate tabs.

13. Tables: Please add page numbers to each table that lacks them, in the form of "Page # of # pages". This would probably work best as a header or footer.

Response: The page numbers have been added as requested.

14. Figure 1-2: Although not critical to this document you might as well correct it now, the area marked as Acid Area #1 is incorrect. The correct area is just south of what is marked. Also, consider narrowing the area marked for Acid Area #3. Generally the #3 area is considered to be bounded by Ransom Road on the east and the service road on the west.

Response: The figure has been modified as requested.

15. Figures 2-1 and 5-2: Please add a North arrow.

Response: North arrows have been added to the figures as requested.

MCHB-TS-REH

MEMORANDUM FOR District Engineer, US Army Corps of Engineers, Nashville District (CELRN-EC-R-M/Ms. Kathy McClanahan), 110 Ninth Avenue South, Room 682, US Court House Annex, Nashville, TN 37203

SUBJECT: Draft Baseline Human Health Risk Assessment (BHHRA), Acid Area 3, Former Plum Brook Ordnance Works (PBOW), Sandusky, OH, September 2007

1. The US Army Center for Health Promotion and Preventive Medicine (USACHPPM) reviewed the subject document on behalf of the Office of The Surgeon General pursuant to AR 200-1 (Environmental Protection and Enhancement). We appreciate the opportunity to review this risk assessment. Our comments and recommendations are enclosed.

2. Our comments on this well-written assessment are seeking only a few technical clarifications. We look forward to providing further technical risk assessment support on this and other PBOW projects.

3. The scientist reviewing this document and our point of contact is Mr. Larry Tannenbaum, Environmental Health Risk Assessment Program, at DSN 584-5210 or commercial (410-436-5210).

FOR THE COMMANDER:

Encl

JEFFREY S. KIRKPATRICK
Director, Health Risk Management

CF:
HQDA (DASG-PPM-NC) (wo/encl)
USACE (CENWO-HX-H) (w/encl)

COMMENTS AND RECOMMENDATIONS

1. Page 1-1, Section 1.0, L. Tannenbaum
   Introduction
   Comment: The Army Corps of Engineers, in this Section's second paragraph, is said to be the lead agency for environmental response actions at PBOW. Might the text mean that the U.S. Army is the lead agency in this regard?
   Recommendation: Please reword the identified text, and consider clarifying the matter based on a distinction found on the Corps' website: "The Army is the executive agent for the (FUDS) program and the U.S. Army Corps of Engineers manages and directs the program's administration."

Response: In response to this comment and a similar comment from another reviewer, the text has been revised as follows:

"This work is being conducted for the U.S. Army Corp of Engineers (USACE) under the Defense Environmental Restoration Program (DERP) – Formerly Used Defense Sites (FUDS). The Army is the executive agent for the FUDS program and the USACE manages and directs the program's administration. Investigations at PBOW under DERP-FUDS are being managed by the ACE Huntington District and technically overseen by the USACE Nashville District (CELRN)."

2. Page 5-4, Section 5.2, L. Tannenbaum
   Noncancer Hazards
   Comment: The term "RBRL" does not appear to have been coined in its first usage in the page's first full paragraph. Note that the term appears to be fully spelled out in the title of Section 5.3 (on this same page) and also that the spelled-out term is found throughout Appendix C.
   Recommendation: Please coin the identified term in its first usage.

Response: "RBRL" has been called out in its first usage in Section 1.5 and the acronym used thereafter.

3. Pages 5-6 and 5-7, Section 5.4, L. Tannenbaum
   Risk Characterization Results and Discussion
   Comment: The last paragraph on page 5-6 (and carrying over to page 5-7) presents a few complications. First, after a definition is supplied for contaminant of concern (COC), the text goes on to provide two examples of COCs, but these do not satisfy the definition. An exposure route that has a summed incremental lifetime cancer risk (ILCR) that exceeds 1E-06 is not necessarily "unacceptable" (note that 1E-04 is a cancer risk "trigger" level), and not all of the computed ILCRs in the subject document exceeded 1E-04. Similarly, a summed Hazard Index (HI; across all exposure routes) exceeding 0.1 is not necessarily "unacceptable". There is surely no need to speak in terms of "risk drivers" (see this paragraph's last sentence) for HIs that are less than 1.0. Second, a reference is not supplied for the definitions that are provided here. The

definitions are questionable since, as a matter of course, sites are usually not remediated unless the ILCR is 1E-04 or greater, or there is a final HI in excess of 1.0 (unity).

Recommendation: Please address the issues raised in the Comment and modify the text as necessary.

Response: The definitions here and on page 5-5 have been revised to be consistent with the discussion on Page 15/16 of RAGS Part B, wherein COCs are selected for a given medium when the total ILCR or HI summed across chemicals and exposure routes is greater than 10^{-4} or 1, respectively. When either of these conditions is met, a COC is selected if it's ILCR or HI summed across exposure routes is greater than 10^{-6} or 0.1, respectively. The sentence referencing "risk drivers" has been deleted.

4. Page 6-1, Section 6.0, L. Tannenbaum
   Uncertainty and Analysis

Comment: The text provided, elaborating on the philosophy of calculating the central tendency (CT) exposure case, is challengeable. The intent of U.S. Environmental Protection Agency risk assessment guidance with regard to CT risk and hazard estimation, is not specifically stated (although it may be that CT estimates *are*, in fact, more descriptive of the actual receptor of interest). Risk assessors understand that the CT estimate is a management tool designed to realize how much greater the scope of cleanups can be under a relatively conservative exposure scenario (as compared with a more typical or more likely exposure scenario). Also, we disagree with the statement in the page's fourth paragraph to the effect that employing a concentration term that is the 95th UCL on the arithmetic mean "defeats the purpose of the CT." The 95th UCL on the arithmetic mean (of the reported concentrations of a chemical in a given medium) is a term developed so as not to underestimate the mean concentration.

Recommendation: Please consider modifying the text of the page's third and fourth paragraphs in order to address the points made in the Comment.

Response: The text in question does not add to the discussion of uncertainties and has been deleted from the document.

5. Appendix B, L. Tannenbaum
   Risk Calculations

Comment: All 40 tables of this appendix share a title that is not fully descriptive of the contents.

Recommendation: In the revised risk assessment, please have all 40 titles begin "Risk and Hazards from . . ."

Response: The table titles have been revised as requested.

MEMORANDUM

TO: LISA Humphreys, USACE PBOW Coordinator, and others

FROM: Julie Weatherington-Rice, Ph.D., RAB TAPP Coordinator

RE: Draft Baseline Human Health Risk Assessment Acid Area 2 & Acid Area 3; Draft Screening Level Ecological Risk Assessment Acid Area 2 & Acid Area 3, Jacobs Engineering Group, September, 2007 (four volumes)

DATE: November 29, 2007

Per our current contractual arrangement with US ACE which require both a technical memorandum for each report and an educational explanation to the RAB, this memorandum constitutes the technical review of the Jacobs September 2007 "Draft Baseline Human Health Risk Assessment Acid Area 2 & Acid Area 3; Draft Screening Level Ecological Risk Assessment Acid Area 2 & Acid Area 3, (four volumes)" documents. Please forward to those who need to read this technical review.

Introduction

These four documents were reviewed together. The comments for the Human Health Risk Assessments and the Ecological Risk Assessments hold for both Acid Areas 2 & 3 unless so noted. In some cases, the explanations and/or supporting information needed for further clarity for some of my technical comments are contained in the educational memorandum. Rather than repeat that supporting information here, if the reviewer needs to understand the source(s) of documentation that support the request and/or comment and/or correction, the reviewer is directed to the educational memorandum which should also be available through Lisa Humphreys if the reviewer is interested.

Review Draft Baseline Human Health Risk Assessment Acid Area 2 and Acid Area 3 Specific Comments

1. 1.3.2 Groundwater Use

Thank you for referencing the new Ohio Department of Natural Resources Division of Water bedrock aquifer map for projected yields of the carbonate aquifer at the site. More text is found in this section in the educational memorandum.

2. 2.3 Results of the Data Evaluation

Did anyone ever determine the source(s) of the thallium that keeps showing up at the site in surface and subsurface soils and ground water?

Response: Thallium is likely present as a background constituent. The detections of thallium in recent soil and groundwater samples is likely due to either a lowering of the detection limits for thallium or a change in the analytical methods which have lower detection limits. For example, the background data set for thallium was reported as 100 percent nondetect for thallium and the

reported concentrations were <1.1 to <6.1 mg/kg, which is a common practice for reporting nondetects. For Acid Area 2, the detection limits were reported as 1.1 to 12 mg/kg and the range of detected concentrations was reported as 2.07 to 5.24 mg/kg. Therefore, the detected concentrations are within the range of detection limits for the background data.

3. Shallow Groundwater and Bedrock Groundwater sections

Change the bedrock identification from Delaware Limestone to Columbus Limestone when referencing naturally occurring petroleum products in the carbonate formations under the PBOW site. See the October 22, 2007 Response to Comments documents from Shaw Engineering for clarification.

Response: The text has been revised as requested.

4. 3.1.1 Physical Setting Groundwater

Note: There is no local information that the Delaware Limestone has petroleum or hydrogen sulfide gas in the formation. These comments are attached to other formations in the area. The Columbus Limestone is noted to have petroleum products in the formation. The presence of hydrogen sulfide gas in the formation is more typically noted in the Raisin River underlying the Columbus Limestone and/or in the overlying Ohio Shale. Please correct the text. This information was documented in the May 31, 2007 presentation to the RAB on the Wagner Quarry by Dr. Julie Weatherington-Rice.

Response: The text has been revised as requested.

5. 3.1.3.2 Bedrock Groundwater Resident

We should be adding a risk assessment for intensive site gardening for vegetable and fruit production for the projected family who will be moving to the site and using ground water resources. While there is no "official" risk assessment for intensive cropping of the site as an annual food source of vegetables and fruit for an average family that I know of, it should be possible to create such a risk assessment from existing risk assessment components and information in the literature. The soil and subsoil exposure risk assessment to skin and breathing can be coupled with chemicals of concern uptake from the soil, subsoil, and ground water of typical vegetable plants and fruit trees and brambles. As a conservative surrogate, I would recommend using the phyto-remediation literature for heavy metals up take of the Brassicaceae family of plants (broccoli/mustard family). I would assume ingestion of at least 80 percent of all fruits and vegetables year round for the family would be a reasonable expectation.

Response: The assessment of potential risks from consumption of home grown produce is seldom performed due to the uncertainties associated with the selection of exposure parameters for ingestion rates (such as the ratio of root or leaf vegetables and fruit) and contaminant uptake factors. EPA's *Risk Assessment Guidance for Superfund* has equations and default parameters for the consumption of produce and the *Exposure Factors Handbook* has information to develop such an exposure scenario. In addition, this scenario seldom results in unacceptable risks/hazards as suggested by the results of the assessment for ingestion of venison. Concerns over contact rates are also applicable to the tending of flower beds. The contact rates for the residential and the groundskeeper scenarios are adequate to account for the variability in contact

over the course of the year. The short term increase in dermal contact and ingestion of soil during planting and harvesting are off-set by the long duration of reduced or minimal contact with soil. Additionally, there are numerous variations in how gardens may be tended ranging from nearly complete manual tending to nearly complete mechanical tending. As gardens become larger as would be needed for production of sufficient crop yield to provide for a family, the less direct contact with the soil the receptor experiences. For small scale intensive cropping, such as in raised beds, the amount of amendments necessary to maintain proper nutrients, aeration, etc. effectively reduce contaminant concentrations in the soil. Therefore, with the exception of the potential increase in contaminant uptake from ingestion of home grown produce, the residential scenario adequately addresses the potential risk from exposure to contaminants in soil. The document has been revised to include a discussion relative to the exclusion of this potential exposure scenario.

For an explanation as to why this risk behavior should be added to the analyses, see the section "*Human Activities for Which There are no Developed Risk Assessments*" in the educational memorandum to the RAB. In addition, there is supporting text in the educational memorandum in this section that will help to clarify this request.

6. 3.1.3.3 Surface Soil Future on-Site Resident

See comment above about site intensive gardening.

Response: Please see the response to Comment #5.

7. 3.1.3.4 Subsurface Soil Future On-Site Resident

See comment above about site intensive gardening.

Response: Please see the response to Comment #5.

8. 3.2.2 Concentrations in Household Air from Groundwater Use

The number used in model assumption 3) "the daily groundwater use is 720 L/day" for a family of four is not a typical water use for that size of a family in Ohio. A more realistic figure would be approximately 400 gallons per day or approximately 1515 liters per day. For supporting documentation, see section "*Some of the Pitfalls of a Standardized Risk Assessment*" in the educational memorandum to the RAB.

Response: The number used in the baseline human health risk assessment is a default value from EPA.

9. 7.3 Conclusions

This comment number was used in the educational memorandum.