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OCT 20 2017

PPPO-02-4430042-18

Mr. Brian Begley
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Division of Waste Management
Kentucky Department for Environmental Protection
300 Sower Boulevard, 2nd Floor
Frankfort, Kentucky 40601

Ms. Julie Corkran
Federal Facility Agreement Manager
U.S. Environmental Protection Agency, Region 4
61 Forsyth Street
Atlanta, Georgia 30303

Dear Mr. Begley and Ms. Corkran:

TRANSMITTAL OF THE REVISED ADDENDUM TO THE SOILS OPERABLE UNIT REMEDIAL INVESTIGATION REPORT FOR SOLID WASTE MANAGEMENT UNIT 1 AT THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY, DOE/LX/07-0358&D2/R1/A2/R2

References:

1. Letter from J. Corkran to T. Duncan, "EPA Conditional Approval: Addendum to the Soils Operable Unit Remedial Investigation Report for Solid Waste Management Unit 1 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, DOE/LX/07-0358&D2/R1/A2/R1 (August 15, 2017) U.S. EPA ID KY8890008982," dated October 16, 2017
2. Letter from A. Webb to T. Duncan, "Conditional Concurrence with the Addendum to the Soils Operable Unit Remedial Investigation Report for SWMU 1 (DOE/LX/07-0358&D2/R1/A2/R1), Paducah Site, Paducah, McCracken County, Kentucky KY8-890-008-982," dated September 6, 2017

Please find enclosed the revised certified *Addendum to the Soils Operable Unit Remedial Investigation Report for Solid Waste Management Unit 1 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0358&D2/R1/A2/R2. The subject document has been revised in response to the conditions received from the Kentucky Department for Environmental Protection and the U.S. Environmental Protection Agency on September 6, 2017, and October 16, 2017, respectively. Replacement pages for the redlined version of the subject document and condition response summaries also are enclosed.

If you have any questions or require additional information, please contact April Ladd at (270) 441-6843.

Sincerely,

Tracey Duncan
Federal Facility Agreement Manager
Portsmouth/Paducah Project Office

Enclosures:

1. Revised Addendum to the Soils OU RI Report for SWMU 1, DOE/LX/07-0358&D2/R1/A2/R2—Clean
2. Replacement Pages for the Revised Addendum to the Soils OU RI Report for SWMU 1 DOE/LX/07 0358&D2/R1/A2/R1—Redline
3. Comment Response Summary to Conditions—EPA
4. Comment Response Summary to Conditions—KDEP

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CERTIFICATION

Document Identification: ***Addendum to the Soils Operable Unit Remedial Investigation Report for Solid Waste Management Unit 1 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,*** **DOE/LX/07-0358&D2/R1/A2/R2**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Fluor Federal Services, Inc.

Myrna E. Redfield, Director
Environmental Management

10/19/17
Date Signed

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

U.S. Department of Energy

Jennifer Woodard, Paducah Site Lead
Portsmouth/Paducah Project Office

10/20/17
Date Signed

DOE/LX/07-0358&D2/R1/A2/R2
Primary Document

Addendum to the Soils Operable Unit Remedial Investigation Report for Solid Waste Management Unit 1 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

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Primary Document

Addendum to the Soils Operable Unit Remedial Investigation Report for Solid Waste Management Unit 1 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—October 2017

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
FLUOR FEDERAL SERVICES, INC.,
Paducah Deactivation Project
managing the
Deactivation Project at the
Paducah Gaseous Diffusion Plant
under Task Order DE-DT0007774

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ACRONYMS

AL	action level
amsl	above mean sea level
AOC	area of concern
AT123D	Analytical Transient 1-,2-,3-Dimensional
BGOU	Burial Grounds Operable Unit
BHHRA	baseline human health risk assessment
BRA	baseline risk assessment
CAS	Chemical Abstracts Service
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
COC	contaminant of concern
COE	U.S. Army Corps of Engineers
COPC	chemical or radionuclide of potential concern
COPEC	chemical or radionuclide of potential ecological concern
CSOU	Comprehensive Site Operable Unit
DAF	dilution attenuation factor
DL	detection limit
DOE	U.S. Department of Energy
DQO	data quality objective
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ESV	ecological screening value
EU	exposure unit
FFA	Federal Facility Agreement
FOE	frequency of exposure
FS	feasibility study
FSP	field sampling plan
GDP	gaseous diffusion plant
GWOU	Groundwater Operable Unit
HI	hazard index
HQ	hazard quotient
HU	hydrogeologic unit
LUC	land use control
MCL	maximum contaminant level
NAL	no action level
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PAL	project action limit
PGDP	Paducah Gaseous Diffusion Plant
POE	point of exposure
QC	quality control
RAGS	Risk Assessment Guidance for Superfund
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RGA	Regional Gravel Aquifer
RGO	remedial goal option
RI	remedial investigation
RME	reasonable maximum exposure
ROD	Record of Decision

RPD	relative percent difference
SERA	screening-level ecological risk assessment
SESOIL	Seasonal Soil Compartment Model
SMP	Site Management Plan
SSL	soil screening level
SVOC	semivolatile organic compound
SWMU	solid waste management unit
SWOU	Surface Water Operable Unit
TED	total effective dose
TEF	toxicity equivalence factor
UCL	upper confidence limit
UCRS	Upper Continental Recharge System
USGS	U.S. Geological Survey
WAG	waste area group
VOC	volatile organic compound
WKWMA	West Kentucky Wildlife Management Area
XRF	X-ray fluorescence
ZVI	zero-valent iron

EXECUTIVE SUMMARY

This addendum to the Soils Operable Unit (OU) Remedial Investigation (RI) Report (DOE 2013a) documents the nature and extent of contamination, contaminant fate and transport, and risk characterization[1] of constituents present in Solid Waste Management Unit (SWMU) 1 of the Soils OU at the Paducah Gaseous Diffusion Plant (PGDP).

SWMU 1, the C-747-C Oil Landfarm, is a facility located inside the plant Limited Access Area, near the west fence of the industrial section of PGDP. Between 1973 and 1979, the area was used for landfarming (mixing waste oils with soil to aid biodegradation of the oil in an area that prevents runoff) waste oils contaminated with trichloroethene (TCE), uranium, polychlorinated biphenyls (PCBs), and 1,1,1-trichloroethane. These waste oils are believed to have been derived from a variety of PGDP processes. The landfarm consisted of two approximately 1,125-ft^2 plots that were plowed to a depth of 1 to 2 ft. Waste oils were spread on the surface every three to four months; then the area was limed and fertilized. The volatile organic compounds (VOCs) in the soils at C-747-C are assumed to be residuals from landfarming waste oils.

SWMU 1 was determined to be adequately characterized, and no additional samples were collected during the Soils OU RI (DOE 2013a). However after completion of a deep soil mixing remedy for groundwater contaminants, an area of existing soil at SWMU 1 was disturbed. This disturbed area required recharacterization, as outlined in the Soils OU RI/Feasibility Study (FS) Work Plan (Work Plan) (DOE 2010). This SWMU 1 addendum summarizes the information collected and evaluated about SWMU 1, including results of the additional investigation and evaluation conducted following the deep soil mixing remedial action and the work performed to recharacterize the soil disturbed during the deep soil mixing project.

The remedial action, *In Situ* Source Treatment Using Deep Soil Mixing, was chosen in accordance with a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) activity. Deep soil mixing of 258 soil columns (8 ft in diameter) at SWMU 1 occurred from ground surface to approximately 60 ft (± 5 ft) bgs reaching the top of the Regional Gravel Aquifer (RGA). An 8-ft diameter auger was operated by a crane and was supplemented by hot air/steam injection with vapor extraction and vapor-phase treatment, which were followed by zero-valent iron (ZVI) and guar gum injection. Contaminants treated as part of the remedial action included TCE, *cis*-1,2-dichloroethene (DCE), *trans*-1,2-DCE, 1,1-DCE, and vinyl chloride. The remedial action recovered an estimated 24 ± 12 gal of solvents total with a 95% confidence interval. In addition to that quantity recovered, the action left ZVI (estimated at 958,395 lb) in place to continue to provide passive treatment for any residual VOC contamination. Prior to soil mixing, the area to be mixed was excavated to approximately 4 ft bgs on average. This area was excavated to allow soil mixing to reach target mixing depth and to allow creating a level surface for mixing equipment to operate. During the excavation, alumina particles (trap mix) and other debris (e.g., drum rings, empty drums, broken concrete, etc.) that were present inside the soil mixing area were removed. In addition, SWMU 1 soil grids with surface soil contaminated above target levels for PCBs were removed and properly dispositioned. Excavation also included a roadway for equipment access and a retention basin. The total volume of soil excavated was approximately 4,850 yd^3. Then, approximately 2 ft of soil from the 4-ft deep excavation was replaced to make less than 1% slope to allow

[1] The baseline human health risk assessment (BHHRA) in this report considers residential land use consistent with EPA Region 4 Human Health Risk Assessment Supplemental Guidance. As discussed in the Paducah SMP (DOE 2015a), the Paducah Human Health Risk Methods Document (DOE 2016), and this Soils OU SWMU 1 Addendum, industrial use, not residential use, is the reasonably anticipated land use for SWMU 1. The risk characterization under a future residential scenario has been developed and will be used in subsequent documents to identify actions needed to support no further action determinations and including land use controls appropriate to establish and maintain reasonably anticipated land uses.

for the crane to operate on the soil mixing area. The remaining excavated soil was stockpiled on the west side of SWMU 1 to allow project team to distribute it over the area following the remedial action.

PGDP is an inactive uranium enrichment facility that is owned by the U.S. Department of Energy (DOE). DOE is conducting environmental restoration activities at PGDP in accordance with the requirements of the Paducah Federal Facility Agreement (FFA), which coordinates Resource Conservation and Recovery Act (RCRA) and the CERCLA cleanup requirements. PGDP was placed on the National Priorities List in 1994. DOE, the U.S. Environmental Protection Agency (EPA), and the Commonwealth of Kentucky (Kentucky) entered into an FFA in 1998 (EPA 1998).

This addendum generally follows the outline for an integrated RI report found in Appendix D of the FFA for PGDP (EPA 1998) and is consistent with the elements found in Appendix B of the Work Plan (DOE 2010) and RI Work Plan Addendum (DOE 2014a).

PROJECT OBJECTIVES AND GOALS

The goals for this addendum are consistent with those established in the Paducah FFA (EPA 1998) and the Site Management Plan (SMP) (DOE 2015a) negotiated among DOE, EPA, and Kentucky. The primary objectives for the Soils OU presented in the SMP are to protect human health and the environment by taking actions necessary to prevent both on-site and off-site human exposure to soil that presents an unacceptable risk or threat and to implement actions that provide the greatest opportunities to achieve significant risk reduction before site closure.

The goals of this addendum, consistent with Work Plan (DOE 2010), are as follows:

Goal 1: Characterize Nature and Extent of Source Zone(s);
Goal 2: Determine Surface and Subsurface Transport Mechanisms and Pathways;
Goal 3: Complete a Baseline Risk Assessment for the Soils OU; and
Goal 4: Support Evaluation of Remedial Alternatives.

The Work Plan (DOE 2010) and the RI Work Plan Addendum (DOE 2014a) utilized a compilation of sampling information collected on and around PGDP from 1988 to 2014. During development of the Work Plan, data existing at that time were evaluated relative to the data quality objectives (DQOs) defined in the Work Plan (DOE 2010). The result of the evaluation was the identification of data gaps for each SWMU/area of concern (AOC). Sampling results collected during both Soils OU RIs and historical data of sufficient quality to meet DQOs, per the evaluation in the Work Plan (DOE 2010), have been used (1) to determine nature and extent of contamination, (2) to model the effect contamination may have on groundwater, and (3) to assess potential risks and hazards posed by each SWMU.

This RI Report Addendum summarizes the results of the characterization of the SWMU 1 soils from historical data collected and evaluated as part of the Soils OU RI Report (DOE 2013a), as updated with recent soil analyses of the soil disturbed as a result of the deep soil mixing remedy implemented as part of the Southwest Plume remediation (DOE 2016a) as part of the Groundwater OU project. These data document soil impacts from constituents, identify potential for migration of these constituents from the soil at SWMU 1 to groundwater or runoff to adjacent drainage ways, and summarize potential risks/hazards associated with SWMU 1 (Goals 1–3). These form the basis for supporting an evaluation of potential actions in an FS (Goal 4).

As with the other Soils OU SWMUs/AOCs, SWMU 1 was evaluated based on the criteria in the FFA for a reasonable maximum exposure (RME) for both current and future land use for excess lifetime cancer risks (ELCRs) of 1E-06 or hazard index (HI) greater than 1 and for adverse environmental impacts (EPA 1998).

The BHHRA characterized cancer risks and noncancer hazards by exposure unit for all chemicals or radionuclides of potential concern (COPCs) for the following scenarios:

- Current Industrial Worker[2]
- Future Industrial Worker [see footnote (2)]
- Outdoor Worker
- Excavation Worker
- Recreational User
- Future Hypothetical Resident

Likely scenarios for the SWMU 1 are discussed in Chapter 5 and include that of the future industrial worker because SWMU 1 is located inside the Limited Area. Additionally, a hypothetical residential scenario and an excavation worker scenario were assessed.

CHARACTERIZE NATURE AND EXTENT OF SOURCE ZONE (GOAL 1)

The "source zone" is surface soil and subsurface soil down to 10 ft bgs or up to 16 ft bgs at infrastructure, such as pipelines, at SWMU 1. The conceptual site model for SWMU 1 represents no migration of contamination as the expected condition. The scenario that contaminants within the source zone currently may impact surface water and the groundwater underlying SWMU 1 through vertical infiltration is unlikely.

SWMU 1 is located in the extreme west-central portion of the plant and is approximately 2.3 acres (Figure ES.1). The southern border of this SWMU is the Kentucky Pollutant Discharge Elimination System Outfall 008 Ditch. This SWMU is part of the Soils OU and the Groundwater OU. SWMU 1 was used from 1973 to 1979 for the biodegradation of waste oils contaminated with TCE, PCBs, 1,1,1-trichloroethane, and uranium. It is estimated that approximately 5,000 gal of waste oil was applied to the landfarm during its period of operation (DOE 1999). These waste oils were believed to have been derived from a variety of plant processes. The landfarm consisted of two 1,125 ft^2 plots that were plowed to 1 ft to 2 ft depth. Waste oils were spread on the surface every three to four months, then limed and fertilized. No water lines or sewers were associated with the operation of this facility, but storm sewers, plant water lines, and raw water lines are located within the boundary of the SWMU. Average depths to these utilities are 3 ft and 13 ft below ground surface (bgs), respectively. The area has been mowed regularly as part of PGDP maintenance operations leading up to the Groundwater OU remedial action deep soil mixing, which disturbed the soils from surface to approximately 60 ft.

A Remedial Design Site Investigation (RDSI) was conducted in 2012 to gather supplemental data necessary for the design and implementation of the *in-situ* source treatment deep soil mixing remedial action selected for SWMU 1. Data collected from 22 soil borings during the RDSI allowed for a more refined delineation of the size and shape of the overall treatment area for this remedial action. The completion of this analysis was documented in the *Remedial Design Report In Situ Source Treatment Using Deep Soil Mixing for Southwest Groundwater Plume Volatile Organic Source at the C-747-C Oil*

[2] The "future industrial worker" reflects default assumptions (i.e., 250 days/year for 25 years). A "current industrial worker" scenario has been added to the default scenario to be more reflective of current site conditions and practices with a lower exposure frequency (i.e., 14 days/years for 25 years) (DOE 2015c).

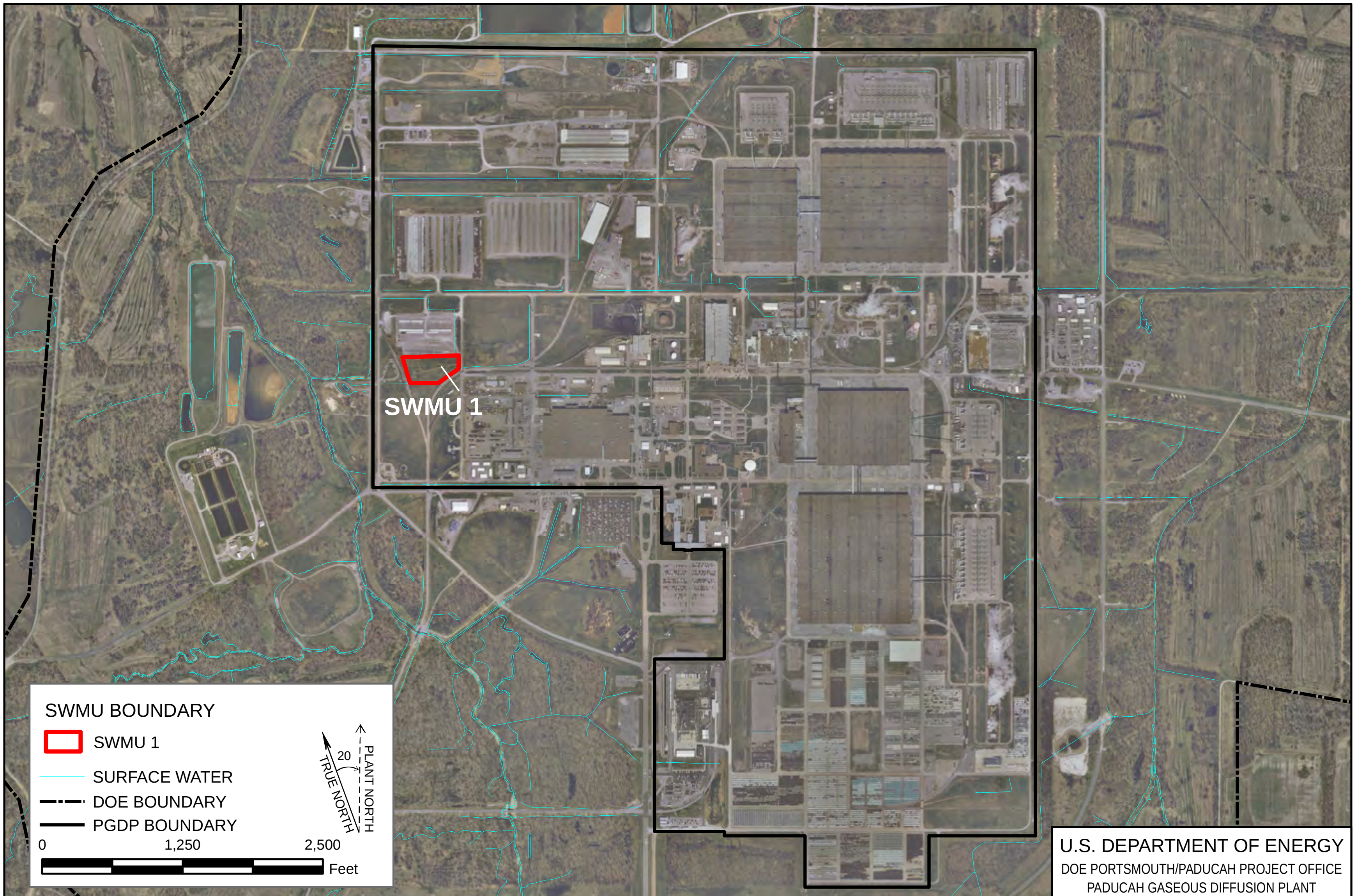

Figure ES.1. Location of SWMU 1

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Landfarm at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, DOE/LX/07-1276, (DOE 2013b) and further refined the area to undergo soil mixing treatment. These investigations and actions identified solvents, PCBs, dioxins, semivolatile organic compounds (SVOCs), heavy metals, and radionuclides (DOE 1999).

Historical investigations that have collected data on SWMU 1 include the Phase I and Phase II Site Investigation (SI) (CH2M HILL 1991; CH2M HILL 1992). Additional sampling was performed to support the Waste Area Group (WAG) 23 FS (DOE 1996), the WAG 23 Proposed Remedial Action Plan (DOE 1998), the WAG 27 RI (DOE 1999), and the Southwest Plume Site Investigation (DOE 2004). After completion of a deep soil mixing remedy for groundwater contaminants, 23 grids at SWMU 1 that were disturbed were sampled for recharacterization.

Analysis of SWMU 1 historical data and recharacterization data indicates the presence of inorganic compounds, organic compounds, and radionuclides above screening levels. Soil sampling results were compared to the appropriate no action levels (NALs) and background concentrations to identify the list of potential contaminants to be evaluated for the purposes of determining nature and extent of contamination. Consistent with the Work Plan (DOE 2010), which identified industrial or recreational use as the current and reasonably anticipated future land uses, the horizontal and vertical extent was based on NALs for future industrial workers (inside the Limited Area). For naturally occurring constituents, delineation also is based on comparison with background concentrations. Tables 5.1 and 5.2 present surface soils data (i.e., 0–1 ft bgs) and subsurface soils (i.e., 1–16 ft bgs) data summaries for SWMU 1, respectively. These tables include historical results from soil samples collected following the deep soil mixing remedy, as appropriate. Thus, this table is considered to represent the current constituent concentrations of subsurface soil at SWMU 1.

The constituents present above background or industrial worker NALs include metals (including uranium), PCBs, polycyclic aromatic hydrocarbons (PAHs), and radionuclides. In addition, VOCs have been addressed as part of the Southwest Plume Deep Soil Mixing remedy and the post-remedy VOC results are presented in the Deep Soil Mixing Report (DOE 2016a). In performing the deep soil mixing remedy, the top 4 ft of soil was removed and staged at the site (and ultimately replaced after the remediation).

Prior to implementing the deep soil mixing remedy, SWMU 1 soil grids with surface soil contaminated above target levels for PCBs were removed and properly dispositioned. With exception of removed PCB-contaminated soils, soil characterization data collected prior to the deep soil mixing remediation are considered representative of the nature of the SWMU 1 soil constituents before remediation, recognizing that in the remediation areas, the constituents have been smeared. To confirm this assumption, grid sampling was performed for this investigation in a manner consistent with the Work Plan (DOE 2010) by collecting samples on primarily 45-ft centers with compositing of five grab samples within each of the affected 23 grids for two horizons: surface (0–1 ft bgs) and subsurface (1–4 ft bgs) (for a total of 46 grid samples). Coordinates for these samples were recorded as the center of the grid because the composite sampling was designed to be representative of the grid. The grid sampling yielded approximately 10 samples per horizon per half acre, on average. [One-half acre is significant because it typically is used as the size of an exposure unit (EU) for risk assessment purposes (DOE 2016b).] The post-remedy results are summarized and evaluated and found to be consistent with the pre-remedy results, confirming the assumption.

DETERMINE SURFACE AND SUBSURFACE TRANSPORT MECHANISMS AND PATHWAYS (GOAL 2)

Chapter 5 documents the evaluation of fate and transport of SWMU 1 constituents. Previous work has shown that the primary pathway for groundwater flow is vertical migration through the Upper Continental Recharge System (UCRS), followed by lateral migration in the RGA. Contaminated groundwater could migrate to points of exposure (POEs). The POE evaluated was the RGA at the SWMU boundary.

Impacts on groundwater in the RGA were evaluated for those soil constituents that had the potential to cause an exceedance of a primary drinking water standard [maximum contaminant level (MCL)] or health based/risk based level (if no MCL was available) at the SWMU boundary.

As part of the Soils OU RI 1, the constituents found in SWMU 1 soils were screened (along with the constituents of the other SWMUs/AOCs) for the potential to pose above-target (MCL or health based/risk based level) soil-to-RGA-groundwater impacts at the SWMU/AOC boundary.[3] For those SWMU/AOC soil constituent combinations whose average concentration at that SWMU/AOC exceeded the screening levels, the next step was to review those combinations against the groundwater contaminants of concern list, the groundwater data, and the other site-specific considerations (e.g., location of the SWMU/AOC relative to the groundwater data) to support a determination of those constituents that then were subjected to modeling. The determination about which soil constituent SWMU/AOC combinations to subject to modeling considered the nature of the soil constituents (such as naturally occurring compounds) and whether there was an identified groundwater impact of that soil constituent in the vicinity of the SWMU/AOC in question.

The Soils OU RI 1 selected for modeling uranium at SWMU 81, Total PCBs at SWMU 81 and AOC 541, technetium-99 (Tc-99) at SWMU 14, arsenic at SWMU 165 and AOC 564, chromium at SWMU 14, and nickel at SWMU 14. These were the constituent/SWMU/AOC pairs with concentrations that exceeded screening levels by the largest amount and were distributed most extensively or were considered site constituents of concerns with the potential for RGA groundwater impacts. Groundwater modeling was performed to evaluate the potential for impacts to RGA groundwater. Seasonal Soil Compartment Model (SESOIL) and Analytical Transient 1-,2-,3-Dimensional Model (AT123D) simulation results are summarized in the Table ES.1 reproduced from the Soils OU RI Report (DOE 2013a).

Results of the modeling showed that none of the modeled constituents except for Tc-99 had the potential to reach the RGA in the 1,000 year modeling period. Thus, constituents in SWMU 1 are not expected to have soil-to-groundwater impacts (with possible exception of Tc-99) because other SWMUs with higher concentrations/greater extent of constituents did not migrate to the RGA in 1,000 years.

The Soils OU modeling efforts for Tc-99 demonstrated that the modeling tended to overstate the potential impact on RGA groundwater of soil Tc-99 concentrations. Several SWMUs/AOCs were modeled, with modeling SWMU 14 only indicating a potential for RGA impacts above the target 900 pCi/L. A review of actual groundwater data from the vicinity of SWMU 14 identified no measurable incremental Tc-99 contribution from SWMU 14, demonstrating that the modeling tended to overstate the potential Tc-99 impacts.

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[3] Soil screening for RGA impacts had been based on a dilution attenuation factor (DAF) of 58. This DAF was used to maintain consistency with previous Soils OU reports, which was in accordance with the approved Work Plan. Because technical uncertainties have arisen with use of a DAF of 58, use of DAF for future CERCLA remedy selection and response action implementation documents for SWMU 1 and future projects under the FFA will be discussed further by the FFA parties and decided on a project-specific basis.

Table ES.1. SESOIL and AT123D Maximum Predicted Groundwater Concentrations[a]

SWMU/ AOC	Soil Constituents	Target	RGA Groundwater Concentration at SWMU/AOC Boundary (Time to Reach Boundary)	RGA Groundwater Concentration at DOE Property Boundary (Time to Reach Boundary)	RGA Groundwater Concentration at Discharge Location[b] (Time to Reach Location)
14	Technetium-99	900 pCi/L[c]	1,700 pCi/L (38 years)	1,020 pCi/L (38 years)	339 pCi/L (45 years)
14	Chromium	Uranium, arsenic, Total PCBs, and chromium (+3 or +6), do not reach the RGA in the 1,000 year SESOIL modeling period.			
81	Total PCBs				
81	Uranium				
165	Arsenic				
541	Total PCBs				
564	Arsenic				

[a] This table, as appropriately modified, is reproduced from Table ES.3 of DOE 2013a.
[b] The discharge location is the location to which RGA groundwater discharges to surface water.
[c] 900 pCi/L is a value derived by EPA from the 4 mrem/yr MCL for technetium-99 in residential drinking water (EPA 2002).

SWMU 1 had much lower Tc-99 concentrations than other SWMUs that were modeled for Tc-99 and shown not to pose a soil-to-RGA-groundwater impact above the 900 pCi/L target. In addition, Tc-99 concentrations at SWMU 1 soil did not exceed the screening values. Thus, SWMU 1 was determined not to pose a soil-to-RGA-groundwater impact above the target level.

A comparison was performed between the average contaminant concentrations in soil samples taken from grids included in the deep soil mixing action area prior to and after the action. This comparison did not identify major differences between the averages for any constituent.

Given that the previous Soils OU screening and modeling did not indicate a soil-to-RGA-groundwater issue and the fact that SWMU 1 constituent concentrations were lower than those subjected to modeling, no additional screening was conducted of the post-deep soil mixing concentrations to identify the need for modeling.

Additional discussion is provided that evaluates the possible impacts of deep soil mixing on the potential for soil-to-groundwater migration. This evaluation indicates that the deep soil mixing is not likely to cause a SWMU (like SWMU 1) with low constituent concentrations/low mobility (lower concentrations than the SWMUs whose constituent concentrations did not reach the RGA in 1,000 years) to impact the RGA within 1,000 years.

COMPLETE A BASELINE RISK ASSESSMENT FOR THE SOILS OU (GOAL 3)

PGDP is an industrial facility surrounded by a state-maintained wildlife refuge and residential property. The current and reasonably anticipated future use of locations within the current Limited Area is industrial. The risk characterization for these current and reasonably anticipated future uses will be used when making risk management decisions in subsequent documents.

Consistent with the Paducah Human Health Risk Methods Document (DOE 2016b), which incorporates both EPA and Kentucky risk assessment guidance, the BHHRA for SWMU 1 characterized risk for a range of reasonably anticipated and hypothetical current and future use scenarios. In developing these scenarios, the concept of RME was used. Additionally, consistent with the results available, the exposure assessment considered primarily exposure to soil (surface and/or subsurface). Potential exposure to groundwater was evaluated using soil screening levels; groundwater sampling results were not taken, nor were they considered for this SWMU as part of this project because risks originating from contaminants present in the underlying groundwater are anticipated to be deferred to the Dissolved-Phase Plumes Remedial Action Project within the Groundwater OU.

To determine use scenarios of concern, risk characterization results for Total HI and Total ELCR were compared to benchmarks of 1.0 and 1E-06, respectively. Use scenarios with Total HI or Total ELCR exceeding either of these benchmarks were deemed use scenarios of concern. To determine contaminants of concern (COCs), potential risk characterization results for chemical-specific hazard quotient (HQ) and chemical-specific ELCR over all pathways within a use scenario of concern were compared to benchmarks of 0.1 and 1E-06, respectively. COPCs within a use scenario of concern exceeding either of these benchmarks were deemed COCs for the use scenario of concern. The COCs are identified in tables in Chapter 5. In addition, priority COCs have been identified in this report. Priority COCs are those COCs with either a chemical-specific HQ or chemical-specific ELCR over all pathways within a use scenario of concern greater than 1 and 1E-04, respectively. Priority COCs are identified to highlight those COCs contributing most to Total HI and Total ELCR.

The following summarizes the baseline risk assessment (BRA) results for SWMU 1.

- The BHHRA completed as part of this addendum indicates that the cumulative ELCR benchmark of 1E-06 and/or cumulative HI benchmark of 1.0 is exceeded at SWMU 1 (for one or more exposure scenarios evaluated); therefore, as stated in the Work Plan, Decision Rule D1a, an FS is appropriate to address impacted media (i.e., surface and subsurface soil) at SWMU 1 (DOE 2010).

- One priority COC, Total PCBs for the hypothetical residential scenario, is associated with the highest Total ELCRs at SWMU 1 (priority COCs are identified as those COCs with a chemical-specific ELCR > 1E-04 or a chemical-specific HQ > 1, to highlight to risk managers the COCs driving Total Cumulative ELCR or Total Cumulative HI).

SCREENING ECOLOGICAL RISK ASSESSMENT

Consistent with the Paducah Ecological Risk Methods Document (DOE 2015b), which incorporates both EPA and Kentucky risk assessment guidance, the screening ecological risk assessment (SERA) was limited to a comparison of maximum and exposure point concentrations in surface soils at the SWMU against ecological screening levels in order to identify the chemicals or radionuclides of potential ecological concern (COPECs). The SERA does not consider the limited habitat, SWMU size, or other factors that also need to be considered to characterize ecological risk. The results of the SERA will be used in the future sitewide ecological BRA that will be conducted as part of the SWOU. Twenty-three COPECs, including metals, PCBs, SVOCs, and VOCs, were identified in this report.

SUPPORT EVALUATION OF REMEDIAL ALTERNATIVES (GOAL 4)

The representative data set used for SWMU 1 is sufficient to support the evaluation of remedial alternatives in the FS. Other information was gathered in support of the evaluation of remedial alternatives to include infrastructure issues, extent of contamination, and verification of site descriptions. Discussion of possible remedial technologies applicable for SWMU 1 is located in Chapter 5 along with impacts on or by groundwater and surface water.

Remedial goal options (RGOs) were developed for each SWMU 1 EU for scenarios analyzed in the BHHRA. RGOs were calculated for each COC as determined by the conclusions of the BHHRA. These RGOs should not be interpreted as being cleanup goals, but as risk-based values that may be used by risk managers to revise preliminary remediation goals to be consistent with the remedial action objectives in the FS and to develop cleanup goals from these revised preliminary remediation goals in the Record of Decision (ROD). The COCs and RGOs consistent with the current and reasonably anticipated future use scenarios (i.e., industrial use, including both the industrial and excavation worker) are presented to evaluate direct contact exposure and can be found in Chapter 6, Table 6.5.

CONCLUSIONS

The risk levels associated with contamination at SWMU 1 meet the criteria to be evaluated further in an FS. Consistent with the FFA, an FS will be developed to evaluate remedial action alternatives to mitigate the potential risks and hazards to human health and the environment and address the potential migration of contaminants from source areas to surface water and groundwater for SWMU 1 that were evaluated in this addendum.

UNCERTAINTIES/ASSUMPTIONS

The Work Plan identified data gaps on a SWMU-by-SWMU basis that needed to be filled to proceed with the FS (DOE 2010). The Work Plan (DOE 2010) and RI Work Plan Addendum (DOE 2014a) were implemented to reduce any remaining uncertainties from previous investigations regarding the nature of the source zone, extent of the source zone and secondary sources, surface transport mechanisms, and to support evaluation of remedial technologies in the FS.

Nature of the Source Zone

For SWMU 1, the available documentation and soil characterization data are sufficient (relative to chemical and physical properties of soil) to screen technology types and to conduct detailed alternative analysis. The RI, however, identified several uncertainties that may affect the FS. The potential impact of these source zone uncertainties on alternatives analysis will be documented, as necessary, and evaluated further in the FS (see Section 4.1 for examples). Additional uncertainty exists because of the higher detection limits for the field data used in the risk assessment, which is discussed further in Appendix B.

SWMU 1 has been investigated previously. This addendum uses a combination of historical and recharacterization analytical results of soil and groundwater from the area of SWMU 1. The results of historical investigations and the recharacterization sampling documented and confirmed the presence of metals, PCBs, PAHs, VOCs, and radionuclides in SWMU 1. The VOCs were addressed by the deep soil mixing remedy.

The associated samples were collected and analyzed over previous investigations, as well as for this addendum, using several methods. Quality control/quality assurance practices at PGDP, now and previously, limit the uncertainty associated with the sampling and analysis process. Nevertheless, changes have occurred to analytical methods that limit the strict comparison of data (e.g., laboratory reporting limits have varied over time). In some cases, analytical method detection limits are above screening criteria, such as the future industrial worker NAL.

Extent of the Source Zone and Secondary Sources

This portion of the RI investigated extent of contamination from ground surface to 4 ft bgs in the areas disturbed by the deep soil mixing (DOE 2013b). Uncertainties associated with horizontal and vertical extent will be managed in the FS. SWMU 1 VOC results are reported as part of this effort, but a more complete evaluation of the VOCs remaining after remedy implementation and an evaluation of the effectiveness of the remedy can be found in the remedial action report.

Surface and Subsurface Transport Mechanisms

Whether contaminants found in soil could migrate to the POE (i.e., SWMU boundary) via a groundwater pathway was evaluated. Previous work has shown that the primary pathway for groundwater flow and the site-related contaminants is vertical migration through the UCRS, followed by lateral migration in the RGA. Modeling results, which came from analysis of this primary pathway for groundwater flow in Soils OU RI (DOE 2013a) and RI 2 (DOE 2015c), show that present levels of contaminants in soil are not expected to migrate to groundwater and reach concentrations in groundwater above targets (e.g., MCLs).

Internal plant ditches are grass-lined and the outfall ditches are grass-lined or otherwise stabilized; therefore, a quantitative analysis in DOE 2008a determined that the contaminants are not likely to be transported attached to suspended soil particles within the ditches and outfalls in the event transport or runoff to a drainageway did occur.

Vapor Intrusion

Soils at SWMU 1 contain detectable amounts of TCE. Though these TCE detections are lower than direct contact screening levels, they have the potential for vapor intrusion (using default screening values for site conditions).

The inhalation of vapors exposure route is not characterized because the VOC emission by subsurface soils is an incomplete exposure pathway (i.e., no buildings exist at SWMU 1 through which a receptor could be exposed to vapors). Inhalation of vapors migrating from the VOC-contaminated soils could, however, be a medium of concern under certain potential future exposure scenarios (e.g., the future industrial worker, excavation worker and future rural resident exposure scenarios where buildings may be constructed and then occupied). Potential risks for these scenarios should be addressed as an uncertainty in the FS. Similarly, inhalation of vapors migrating from the residual VOCs in subsurface soils at SWMU 1 and VOCs in groundwater under SWMU 1 could be medium of concern under the future industrial worker and future hypothetical resident scenarios. While deep soil mixing at SWMU 1 has remediated areas with high concentrations of VOCs, residual VOC contamination in soil remains, and the remedial action for SWMU 1 did not address VOC contamination known to be present in groundwater. The potential risks from vapors that might migrate from these sources also should be addressed as an uncertainty in the FS.

1. INTRODUCTION

The Paducah Gaseous Diffusion Plant (PGDP), located within the Jackson Purchase region of western Kentucky, was an active uranium enrichment complex from 1952 until 2013. The U.S. Department of Energy (DOE) owns the area on which the enrichment complex operated and is responsible for environmental restoration activities associated with legacy operation of PGDP (CERCLIS #KY8-890-008-982). DOE is the lead agency for response actions, and the U.S. Environmental Protection Agency (EPA) and the Kentucky Department for Environmental Protection have regulatory oversight responsibilities.

In 1988, off-site groundwater contamination was detected in groundwater wells north of PGDP. Consequently, DOE and EPA Region 4 entered into an Administrative Consent Order under Sections 104 and 106 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). In 1994, PGDP was placed on the National Priorities List (NPL), a list of sites designated by EPA as having the highest priority for site remediation. Additionally, Section 120 of CERCLA requires federally owned NPL sites to enter into a Federal Facility Agreement (FFA) (EPA 1998). An FFA was finalized among DOE, EPA, and the Commonwealth of Kentucky (Kentucky) in 1998.

Source units and areas of contamination at PGDP have been combined into operable units (OUs) for evaluation of remedial actions. These OUs include the Surface Water OU (SWOU), the Burial Grounds OU (BGOU), the Soils OU, the Groundwater OU (GWOU), and the Decontamination and Decommissioning OU. Each OU is designed to remediate contaminated media and/or facilities associated with PGDP. After completion of these activities, the Comprehensive Site OU (CSOU) evaluation will be conducted, with implementation of additional actions, as needed, to ensure long-term protectiveness.

The Soils OU is being implemented in a phased approach [i.e., pre-gaseous diffusion plant (GDP) shutdown and post-GDP shutdown] consisting of remedial and removal actions to accomplish the following goals (DOE 2015a):

- Prevent human exposure to contamination presenting an unacceptable risk;
- Prevent or minimize further off-site migration; and
- Reduce, control, or minimize contaminated soil hot spots contributing to off-site contamination.

Additionally, the phased approach allows the site to use information gained in earlier phases of the cleanup to refine and implement subsequent cleanup objectives and actions in support of final cleanup status. Slabs, subsurface structures, and underlying soils left after completing decontamination and decommissioning of the operating GDP, will be addressed in subsequent actions. Figure 1.1, adapted from the Site Management Plan (SMP) (DOE 2015a), illustrates the phases and accomplishments of the Soils OU. Figure 1.2 shows the location of Solid Waste Management Unit (SWMU) 1.

SWMU 1, the C-747-C Oil Landfarm, is a facility located inside the plant Limited Access Area, near the west fence of the industrial section of PGDP. Between 1973 and 1979, the area was used for landfarming (mixing waste oils with soil to aid biodegradation of the oil in an area that prevents runoff) waste oils contaminated with trichloroethene (TCE), uranium, polychlorinated biphenyls (PCBs), and 1,1,1-trichloroethane. These waste oils are believed to have been derived from a variety of PGDP processes. The landfarm consisted of two approximately 1,125-ft^2 plots that were plowed to a depth of 1 to 2 ft. Waste oils were spread on the surface every three to four months; then the area was limed and fertilized. The volatile organic compounds (VOCs) in the soils at C-747-C are assumed to be residuals from landfarming waste oils.

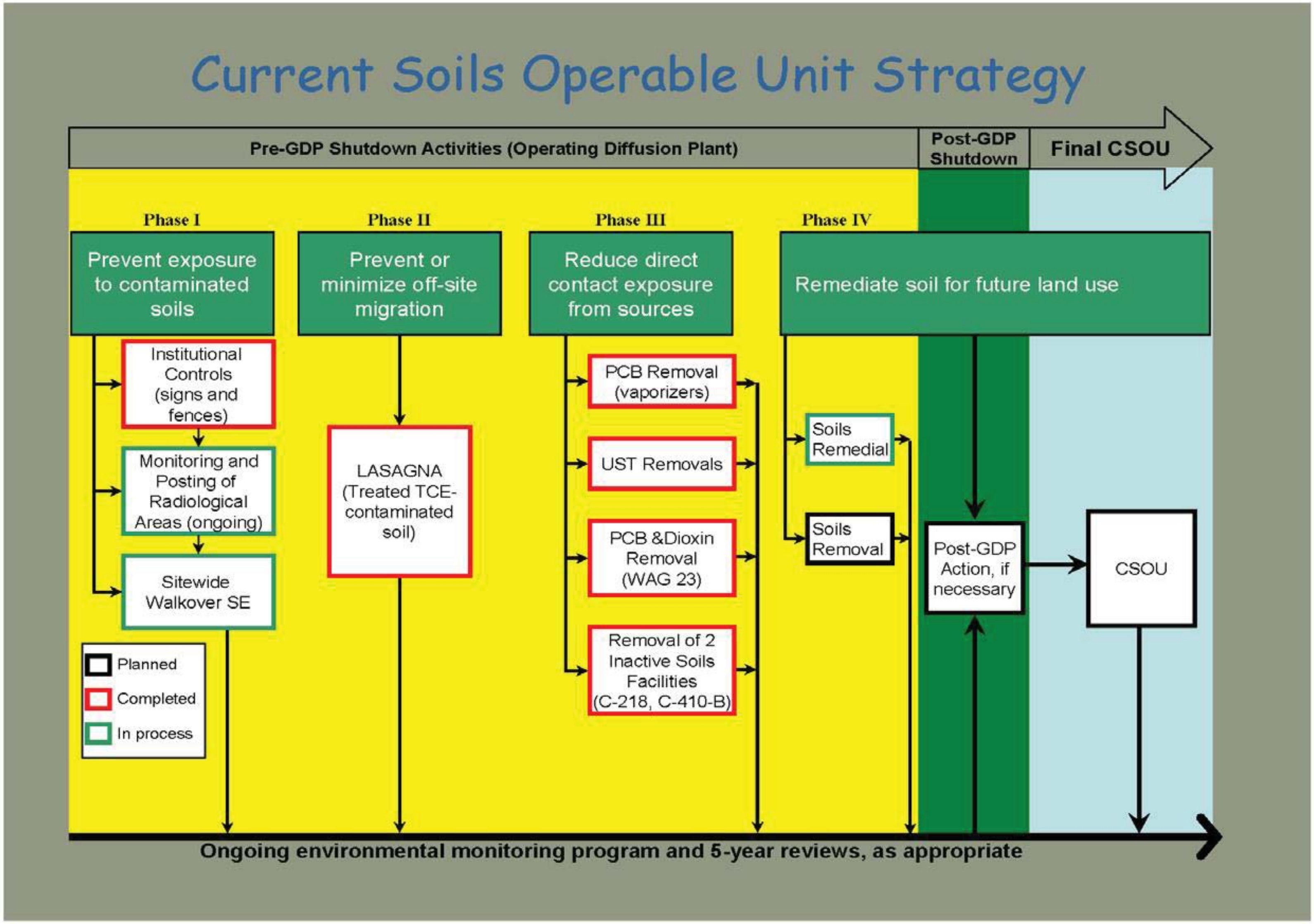

Figure 1.1. Soils OU Paducah Soils Strategy

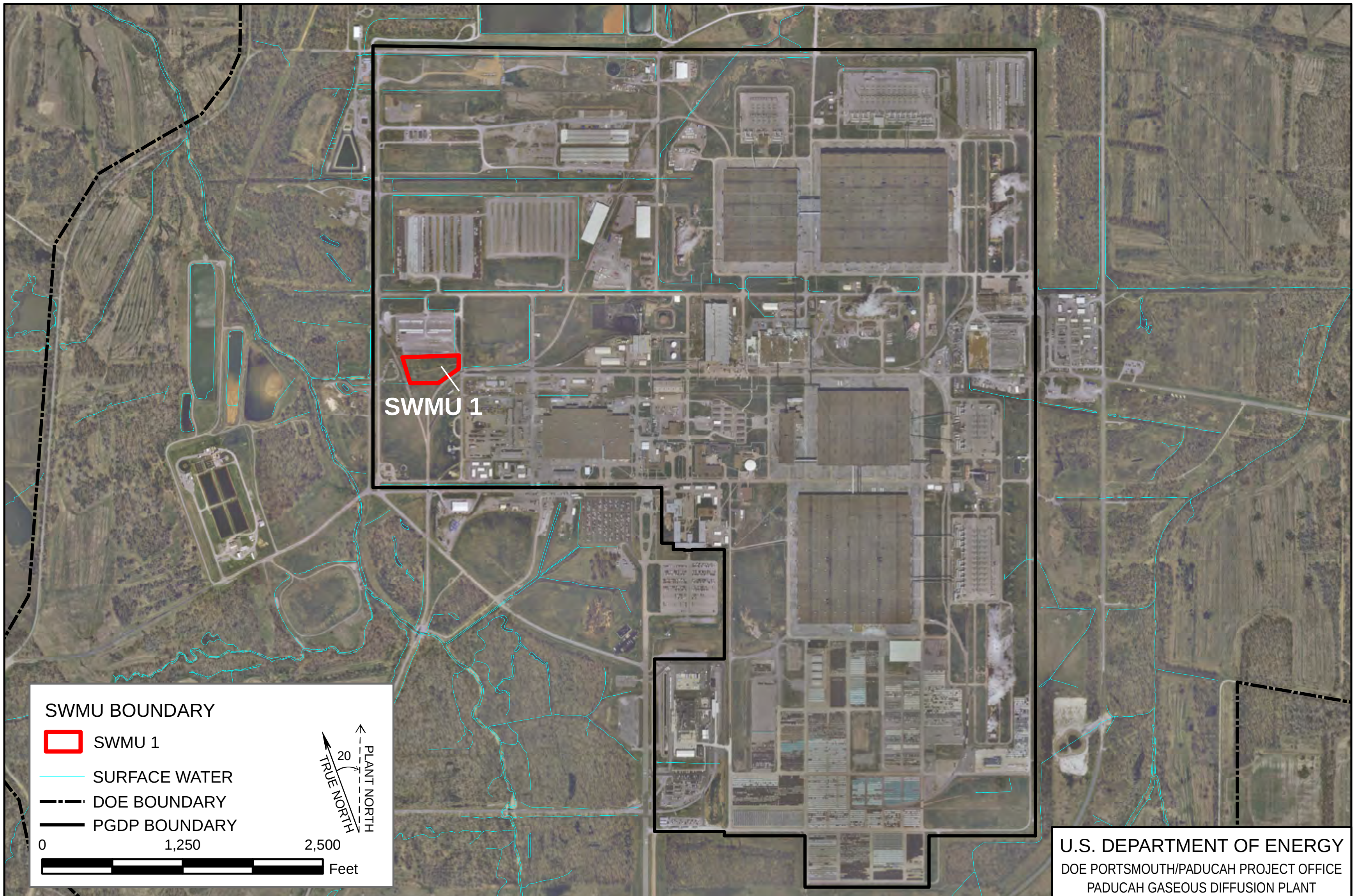

Figure 1.2. Location of SWMU 1

6/23/2016 G:\GIS\ARCVIEWS\PROJECTS\SoilsOU\RI Report\Addendum1_E1 SWMU location.mxd

1.1 PURPOSE OF REPORT

The SWMU 1 field investigation followed the investigation outlined in the Soils OU Remedial Investigation (RI) Work Plan (DOE 2010) and RI Work Plan Addendum (DOE 2014a). This report documents the results of the RI, Baseline Human Health Risk Assessment (BHHRA), and Screening Ecological Risk Assessment (SERA) for SWMU 1.

Historical data in addition to data collected during the 2016 investigation were combined to form the data set used to evaluate SWMU 1. This data set will be used in the feasibility study (FS).

The work plan utilized the data quality objective (DQO) process as a planning tool to assist in the identification of environmental problems and to define the data collection process needed to support decisions (DOE 2010).

The problem statement developed through the DQO process and documented in the Work Plan follows (DOE 2010):

> Past releases from the PGDP may have resulted in the contamination of soil found at the SWMUs and AOCs. The nature and extent of contamination has not been adequately defined, nor is it known whether these potential contaminants pose unacceptable risks to current and reasonably anticipated future receptors under some exposure scenarios.

The goals of the RI are (1) characterize nature and extent of source zone; (2) determine surface and subsurface transport mechanisms and pathways; (3) complete a baseline risk assessment (BRA) for the Soils OU; and (4) support evaluation of remedial alternatives. These goals are listed in Table 1.1.

Recommended remedial action objectives (RAOs) will be presented in the forthcoming FS.

Table 1.1. Goals, Decisions, and Questions Identified for the Soils OU

GOAL 1: CHARACTERIZE NATURE AND EXTENT OF SOURCE ZONE
Decisions and questions 1-1: What are the suspected contaminants? 1-2: What are the plant processes that could have contributed to the contamination? When and over what duration did releases occur? 1-3: What are the concentrations and activities at the source? 1-4: What is the area and volume of the source zone? What is the vertical and lateral extent of contamination? 1-5: What are the chemical and physical properties of associated material at the source areas? 1-6: What are the past, current, and potential future migratory paths?
GOAL 2: DETERMINE SURFACE AND SUBSURFACE TRANSPORT MECHANISMS AND PATHWAYS
Decisions and questions 2-1: What are the contaminant migration trends? 2-2: What are the effects of underground pipelines and plant operations on migration pathways including ditches? 2-3: What are the physical and chemical properties of the formations and subsurface matrices?
GOAL 3: COMPLETE A BASELINE RISK ASSESSMENT FOR THE SOILS OU
Decisions and questions 3-1: Where do the contaminant concentrations exceed no action levels (NALs)? 3-2: Are isolated areas of contamination present or is contamination general? 3-3: What are the contaminants of concern (COCs) that define the contamination? 3-4: What are the NALs? 3-5: Are SWMUs/AOCs within the Soils OU similar enough to be addressed in the same manner?

Table 1.1. Goals, Decisions, and Questions Identified for the Soils OU (Continued)

GOAL 4: SUPPORT EVALUATION OF REMEDIAL ALTERNATIVES
Decisions and questions
4-1: What are the possible remedial technologies applicable for this unit?
4-2: What are the physical and chemical properties of media to be remediated?
4-3: Are cultural impediments present?
4-4: What is the extent of contamination (geologic limitations presented by the source zone)?
4-5: What would be the impact of action on and by other sources?
4-6: What would the impact of an action at the source be on the integrator units?
4-7: What are stakeholders' perceptions of contamination at or migrating from source zone?

Table is from Work Plan (DOE 2010).

1.2 PROJECT SCOPE

This addendum is focused on SWMU 1 soils and the soil areas immediately surrounding SWMU 1 to determine if SWMU 1 poses an unacceptable risk to human health or the environment under a range of exposure scenarios. As stated in the SMP, a primary objective for this project is to contribute to the protection of on-site workers and off-site residents by addressing sources of soil contamination (DOE 2015a).

The scope of the Soils OU includes potential contaminant migration pathways from the soil to surface water and groundwater, but does not include sampling either the surface water or groundwater. Also, the scope of the Soils OU does not include any drainage ditches bounding the Soils OU SWMUs/AOCs. These ditches are components of the SWOU. The GWOU will address dissolved-phase groundwater contamination in the Regional Gravel Aquifer (RGA) beneath the Soils OU SWMUs/AOCs. The secondary sources of groundwater contamination that are derived from deep subsurface soil are within the scope of the BGOU or the CSOU. DOE integrates the Natural Resource Damage Assessment values into the CERCLA process. As such, it is expected that the sampling data generated by this RI, in addition to the historical data available, will be sufficient to support the Natural Resource Damage Assessment process.

The DQO process was used to focus the sampling strategy on SWMU/AOC-specific media, contamination, and migration pathways, and identify data needs. Data collected during this Soils OU RI field effort, together with historical data presented in the Work Plan (DOE 2010), met project DQOs and were used to determine nature and extent of contamination.

The following list summarizes the activities that were conducted for SWMU 1:

- Grid sampling of 23 grids with 5 point composite samples taken from each grid at different horizons, 0–1 ft bgs and 1–4 ft bgs;
- Evaluation of nature and extent of contamination based on collected RI soil samples and historical soil samples;
- Evaluation of modeling of contaminant fate and transport and estimation of future contaminant concentrations at selected points of exposure; and
- Determination of potential ecological and human health risks associated with SWMU 1, including the following:

— On-site future industrial worker (inside the PGDP security fence); and
— Residential scenarios were assessed consistent with the Risk Methods Document (DOE 2016b).

Consistent with the Work Plan (DOE 2010), the nature and extent of constituents present in surface soils (0–1 ft bgs) within the Soils OU are included in this addendum.

To address uncertainties identified in the Soils OU, the observational approach was used in the design of the sampling strategy for the Soils OU RI/FS Work Plan (DOE 2010). The following are the key concepts.

- The RI strategy is based on a specified "most probable site condition," which, for the Soils OU RI/FS, assumes that contamination is limited to surface and near surface soil (0–4 ft bgs) and potentially adversely impacting human health and welfare or the environment.

- Reasonable deviations from the most probable site condition are identified. One reasonable deviation for the Soils OU RI/FS is that no contamination is impacting human health and welfare or the environment adversely. Other reasonable deviations would be that contamination has migrated to depths greater than 4 ft bgs, but still within the Soils OU bound of 10 ft bgs (16 ft bgs at pipelines) and to either the SWOU or GWOU. Site conditions should not differ significantly from the postulated conditions shown in the conceptual models, described in Chapter 3.

- Site assessment factors were identified for observation to detect contamination. These factors included sensory observation of contamination (site walkdowns), field screening, field analyses with portable instruments, geophysical surveys, historical data evaluation, and laboratory analysis of soil samples.

- The Field Sampling Plan (FSP) included a contingency plan to address deviations from the most probable site conditions.

This field effort provided information to fill data gaps identified for SWMU 1. Data were screened against significant chemicals or radionuclides of potential concern (COPCs) listed in Table 2.1 of the *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Volume 1: Human Health* (DOE 2016b).

1.3 SOILS OU SWMU EVALUATION

The scope of the Soils OU includes an RI, BHHRA, SERA, evaluation of remedial alternatives, remedy selection, and implementation of actions [e.g., excavation, land use controls (LUCs)], as necessary, for protection of human health and the environment.

Project uncertainties that could affect the scope and schedule include the amount and scope of RI characterization needed (e.g., field samples, borings) to achieve the RI goals and the remedial action necessary to achieve a final decision.

One objective of this investigation is to determine the nature and extent of contamination in the soils to a depth of 10 ft bgs or up to 16 ft bgs at infrastructure (e.g., pipelines). For all source units, the initial focus of the investigation was surface and subsurface soil contamination to a depth of 4 ft bgs. If contamination at 4 ft bgs was found, then the subsurface soil to a depth of 10 ft bgs was investigated. Any contamination that was found to extend past the depths specified in this investigation will be addressed by another OU.

Remedial alternatives will be screened at the time the RAOs for the Soils OU are developed.

1.4 PROJECT SCHEDULE

Table 1.2 provides a planning schedule for the Soils OU. This schedule is an estimate for planning and is included here for informational purposes only and is not intended to establish enforceable schedules or milestones. Enforceable milestones are contained in Appendix C of the FFA or Appendix 5 of the SMP (DOE 2015a).

Table 1.2. Project Schedule for Soils OU RI and FS[1]

Activity	Milestone
Issue D1 FS	3rd quarter 2025
Issue D1 Proposed Plan	1st quarter 2026
Issue D1 Record of Decision (ROD)	3rd quarter 2026
Issue D1 Remedial Design Work Plan	4th quarter 2026
Issue D1 Remedial Design Report	4th quarter 2027
Issue D1 Remedial Action Work Plan	4th quarter 2027
Issue D1 Remedial Action Completion Report	September 30, 2030

[1] These are general planning dates for submittal of the CERCLA decision documents. Any extensions will impact the schedule. This schedule is included in this document for information purposes only and is not intended to establish enforceable schedules or milestones. Enforceable milestones, if any, will be established in the FFA or SMP and will be updated in accordance with Sections XXIX and/or XXXIX of the FFA.

1.5 REPORT ORGANIZATION

This addendum to the Soils OU RI report was prepared following guidance found in Appendix D of the FFA for PGDP (EPA 1998) and is consistent with the elements found in Appendix B of the Work Plan (DOE 2010), but was modified to meet specific project requirements.

Chapter 1—Introduction
Chapter 2—Study Area Investigation
Chapter 3—Physical Characteristics of the Study Area
Chapter 4—Evaluation Approach
Chapter 5—SWMU 1, C-747-C Oil Landfarm

Following the outline of the preceding Soils OU RI Report (DOE 2013a), Chapter 5 contains the following information on SWMU 1:

- Background
- Fieldwork Summary
- Nature and Extent of Contamination—Surface Soils
- Nature and Extent of Contamination—Subsurface Soils
- Comparison of Soil Results Before and After Deep Soil Mixing
- Fate and Transport
- Baseline Human Health Risk Assessment
- Screening Ecological Risk Assessment
- Summary
- Conclusions

Chapter 6—Conclusions for the Soils OU RI
Chapter 7—References

Additionally, the following appendices are included to support the information presented in the text.

Appendix A—Technical Memorandum for Field Activities
Appendix B—Data Quality Analysis
Appendix C—Fate and Transport Modeling
Appendix D—Baseline Human Health Risk Assessment
Appendix E—Screening Ecological Risk Assessment
Appendix F—Analytical Data (CD)

2. STUDY AREA INVESTIGATION

This section includes descriptions of field activities associated with site characterization of SWMU 1, which was conducted in accordance with the approved Work Plan (DOE 2010) and the RI Work Plan Addendum (DOE 2014a). A technical memorandum documenting details of field activities is included in Appendix A.

2.1 SOIL INVESTIGATIONS

When the Work Plan was being developed, existing/historical sampling information collected at and around PGDP over the course of the last several years was compiled, and a searchable database of soil analytical results was included in Appendix B of the Soils OU RI Work Plan (DOE 2010) on a compact disk. Historical data were compiled from the resources listed in Table 2.1.

Table 2.1. Summary of Historical Information[1]

Year	Reference	Title
1991	CH2M HILL 1991	Results of the Site Investigation, Phase I
1992	CH2M HILL 1992	Results of the Site Investigation, Phase II
1996	DOE 1996a	Feasibility Study for Waste Area Group 23 and Solid Waste Management Unit 1 of Waste Area Group 27 at the Paducah Gaseous Diffusion Plant
1997	DOE 1997a	Action Memorandum for Waste Area Group 23 and Solid Waste Management Unit 1 of Waste Area Group 27, PCB Sites, Paducah Gaseous Diffusion Plant, Paducah, Kentucky
1997	DOE 1997c	Proposed Remedial Action Plan for Waste Area Group 23 and Solid Waste Management Unit 1 of Waste Area Group 27, PCB Sites
1998	DOE 1998b	Integrated Remedial Investigation/Feasibility Study Work Plan for Waste Area Group 27 at Paducah Gaseous Diffusion Plant
1998	DOE 1998c	Proposed Remedial Action Plan for Waste Area Group 23 and Solid Waste Management Unit 1 of Waste Area Group 27, PCB Sites
1999	DOE 1999a	Remedial Investigation Report for Waste Area Group 27 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky
1999	DOE 1999f	Proposed Remedial Action Plan for Waste Area Group 23 and Solid Waste Management Unit 1 of Waste Area Group 27, PCB Sites
1999	DOE 1999g	Remedial Investigation/Feasibility Study Work Plan for the Surface Water Operable Unit at PGDP
1999	DOE 1999h	Residual Risk Evaluation Report for Waste Area Group 23 and Solid Waste Management Unit 1 of Waste Area Group 27, PCB Sites

[1] Table adapted from DOE 2010.

A review of historical data for SWMU 1 was used to determine the following:

- SWMU COPCs,
- Extent and quality of existing data, and
- Sufficiency of data to support an FS for remedial options.

Where data were absent or insufficient to characterize the nature and extent of contamination and to support remedy selection, specific data gaps were identified. These data gaps were the basis for additional sampling. Contamination has been defined as concentrations exceeding background or any detected concentration if instrument reporting limits are higher than background values (DOE 2010). Sampling for SWMU 1 included grid-based composite sampling.

Historical data, in addition to data collected during the 2016 investigation (Soils OU RI), were combined to form the data set used to evaluate SWMU 1. This data set will be used in the FS.

At SWMU 1, for which additional sampling was performed, one five-point composite over each 45-ft grid was collected for surface soils (0–1 ft bgs) and shallow subsurface soils (1–4 ft bgs). One grab sample was collected from the center of each grid with four additional grab samples collected 15 ft from the center point in each cardinal direction (north, south, east, and west) to make up the five-point composite. On alternating grids, grab samples were collected from the center of the grid, and four additional grab samples were collected 15 ft from the center point in each secondary direction (northeast, northwest, southeast, southwest) to make up the five-point composite. Twenty-three grids were sampled at SWMU 1 for surface and shallow subsurface soils.

Soil samples were collected from 0–1 ft and 1–4 ft in order to identify potential contaminant migration and exposure pathways, as directed by the Work Plan (DOE 2010). Soil samples then were analyzed by the field laboratory to determine if contingency samples were needed by comparing the field laboratory results to the project action levels (PALs) listed in Table 2.2. The PALs were agreed to as a benchmark for determining step-outs/stepdowns in December 2014 by the Soils OU project team (DOE 2015d). Additional depth (4–7 ft and 7–10 ft bgs) and/or horizontal extent (step-out grid) sampling was required if the field laboratory results exceeded these levels. There were no locations for SWMU 1 that required additional sampling. Summary tables of data are included in Chapter 5 of this addendum.

Split samples and replicates were obtained from the composite as necessary. Analyses for each composite sample consisted of field analysis of Resource Conservation and Recovery Act (RCRA) metals, plus uranium, by X-ray fluorescence (XRF) and Total PCB by PCB test kits. Ten percent of the samples had fixed-base laboratory confirmation splits. The 10% included at least one surface and one shallow subsurface that was sampled. As directed by the Work Plan (DOE 2010), these fixed-base laboratory samples were selected randomly from all sample locations within the SWMU.

2.2 MODIFICATION FROM ORIGINALLY PLANNED SAMPLE LOCATIONS

Site conditions did not necessitate modifications of the sampling strategy for SWMU 1.

2.3 QUALITY ASSURANCE/QUALITY CONTROL

Quality control (QC) was monitored throughout the RI process. QC included field sampling, laboratory analysis, and data management. QC for this addendum was evaluated in Chapter 2 of the Soils OU RI Report (DOE 2013a). A review of data collected during the summer of 2016 as part of the Soils OU RI is included in Appendix B.

Table 2.2. Field Analysis and Limits for Grid Sampling

Analyte	Project Quantitation Limit (mg/kg)	Industrial Worker ELCR = 1E-5 (mg/kg)[a]	Industrial Worker HI = 1 (mg/kg)[a]	PGDP Background (mg/kg)[a]	Project Action Limit (mg/kg)[a]
Arsenic	11	9.99	160	7.9	11
Chromium (total)	85	1,980	32,300	16	1,980
Copper	35	N/A	14,300	19	14,300
Iron	100	N/A	100,000	28,000	100,000
Lead	13	N/A	800	23	800
Manganese	85	N/A	515	820	820
Mercury (inorganic)	10	N/A	9	0.13	10
Molybdenum	15	N/A	1,790	N/A	1,790
Nickel	65	100,000	430	21	430
Selenium	20	N/A	1,790	0.7	1,790
Silver	10	N/A	108	2.3	108
Uranium	20	224	1,070	4.6	224
Vanadium	70	N/A	108	37	108
Zinc	25	N/A	100,000	60	100,000
Total PCBs	5	28.6	N/A	N/A	28.6

N/A = not applicable.
[a] Excess lifetime cancer risk (ELCR), hazard index (HI), and background values and project action limits are documented in DOE 2015d.

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3. PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This chapter presents the physical and ecological characteristics of PGDP and the region surrounding it. The discussion focuses on region- and PGDP-wide characteristics to support subsequent evaluations of the nature and extent and the fate and transport of contaminants exiting at SWMU 1.

This RI field effort focused on collection and analysis of soil samples to address deficiencies in the existing characterization of the nature and extent of contamination. These sampling and analytical activities yielded additional data for the soils in SWMU 1. The results of those activities have been incorporated into the SWMU-specific discussion.

3.1 SURFACE FEATURES

PGDP is located on a 3,556-acre DOE site approximately 10 miles west of Paducah, Kentucky, and 3.5 miles south of the Ohio River in the western part of McCracken County (Figure 3.1). The PGDP industrial area occupies approximately 650 acres of the DOE site, surrounded by an additional 689-acre buffer zone. DOE licenses most of the remaining acreage to the Commonwealth of Kentucky as part of the West Kentucky Wildlife Management Area (WKWMA). Tennessee Valley Authority Shawnee Fossil Plant borders the DOE site to the northeast, between PGDP and the Ohio River.

Three small communities are situated within three miles of the DOE property boundary: Heath and Grahamville to the east and Kevil to the southwest. The next closest municipality is Metropolis, IL, five miles to the northeast of PGDP on the north side of the Ohio River.

The dominant topographic features in the area of PGDP are nearly level to gently sloping dissected plains and the flood plain of the Ohio River. Local elevations range from 290 ft above mean sea level (amsl) along the Ohio River to 450 ft amsl southwest of PGDP. Ground surface elevations vary from 360 ft to 390 ft amsl within the PGDP boundary, where SWMU 1 is located. Generally, the topography in the PGDP area slopes toward the Ohio River at an approximate gradient of 27 ft per mile (CH2M HILL 1992).

3.2 METEOROLOGY

The National Weather Service office at Barkley Regional Airport (located four miles to the southeast of PGDP) documents hourly meteorological measurements. Current and historical meteorological information regarding temperature, precipitation, and wind speed/direction are available from the National Oceanic and Atmospheric Administration's (NOAA's) National Climatic Data Center.

The climate of the PGDP region is humid-continental. Summers are warm (July averages 79°F) and winters are moderately cold (January averages 35°F). PGDP experiences a yearly surplus of precipitation versus evapotranspiration. The 30-year average monthly precipitation for the period 1961 through 1990 is 4.11 inches, varying from an average of 3.00 inches in October (the monthly average low) to an average of 5.01 inches in April (the monthly average high). Monthly estimates of evapotranspiration using the Thornthwaite method (Thornthwaite and Mather 1957) equal or exceed average rainfall for the period May through September (season of no net infiltration).

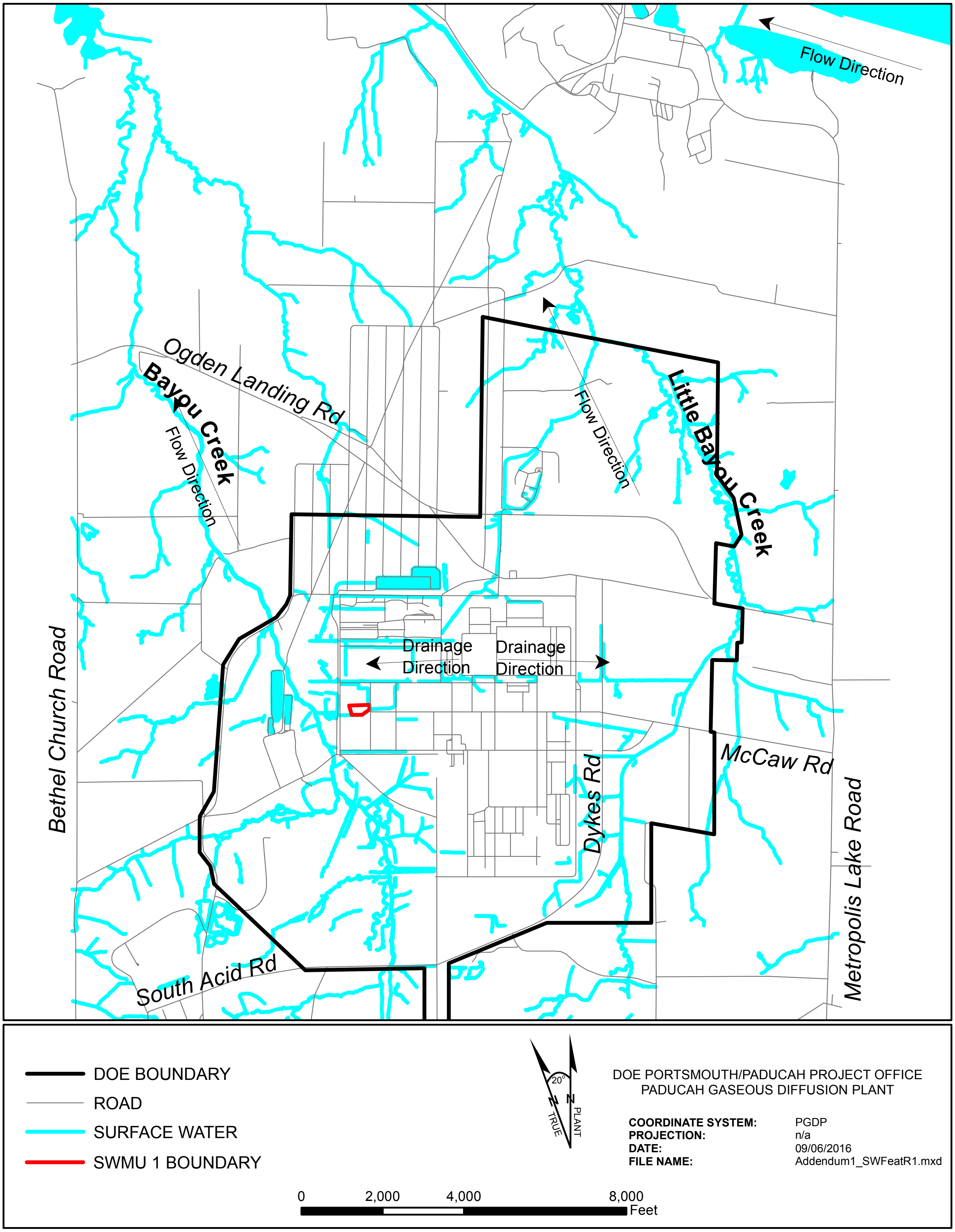


Figure 3.1. Surface Water Features in the Vicinity of the DOE Site

Heavy rainfall associated with thunderstorms or low-pressure systems occurs occasionally at PGDP. Table 3.1 presents the predicted storm recurrence intervals for PGDP (Dupont and Allen 2000).

Table 3.1. Rainfall Intensity as a Function of Recurrence Interval and Storm Duration for Western Kentucky

	Recurrence Interval (years)					
Storm Duration (minutes)	2	5	10	25	50	100
	Precipitation (inches per hour)					
5	11.80	16.69	19.98	24.19	27.33	30.46
10	7.02	9.44	11.05	13.09	14.61	16.11
15	5.20	6.82	7.90	9.25	10.26	11.26
20	4.20	5.43	6.25	7.27	8.04	8.79
30	3.12	3.96	4.52	5.22	5.74	6.25
60	1.89	2.34	2.64	3.02	3.31	3.59
80	1.54	1.89	2.13	2.43	2.65	2.87
100	1.30	1.61	1.81	2.05	2.24	2.43
120	1.15	1.41	1.58	1.80	1.96	2.12
1,440	0.20	0.26	0.30	0.34	0.38	0.41

The prevailing wind is from the south-southwest at approximately 10 miles per hour. Historically, stronger winds are recorded when the winds are from the southwest.

3.3 SURFACE WATER HYDROLOGY

PGDP is located in the western portion of the Ohio River basin, 15 miles downstream of the confluence of the Ohio River with the Tennessee River and 35 miles upstream of the confluence of the Ohio River with the Mississippi River. The Ohio River is located approximately 3.5 miles north of PGDP. It is the most significant surface water feature in the region, carrying over 25 billion gal/day of water through its channel. A U.S. Geological Survey (USGS) gaging station at Metropolis, IL (USGS 03611500), monitors the Ohio River stage near PGDP. River stage typically varies between 290 ft and 328 ft amsl over the course of a year. Water levels on the lower Ohio River generally are highest in winter and early spring and lowest in late summer and early fall. The entire PGDP is above the historical high water floodplain of the Ohio River (CH2M HILL 1991) and above the local 100-year flood elevation of the Ohio River (333 ft). [The highest Ohio River stage recorded at Metropolis, IL (February 2, 1937) was 343 ft.]

The plant overlies the divide between Bayou and Little Bayou Creeks (Figure 3.1). Bayou Creek is a perennial stream on the western boundary of the plant that flows generally northward, from approximately 2.5 miles south of the plant site to the Ohio River along a 9-mile course. Little Bayou Creek is an intermittent stream located on the eastern boundary of the plant; its drainage originates within WKWMA and extends northward along a 6.5-mile course, which joins Bayou Creek near the Ohio River. Most of the flow within Bayou and Little Bayou Creeks is from surface water runoff from PGDP. Networks of ditches discharge effluent and surface water runoff from PGDP to the creeks. Any surface water migrating from SWMU 1 would discharge to Bayou Creek because SWMU 1 is located in the west central area of PGDP. Contributions from PGDP comprise approximately 85% of the base flow within Bayou Creek and 100% of the base flow within Little Bayou Creek.

Multiple groundwater aquifers underlie PGDP (see Section 3.6 for a discussion of PGDP hydrogeology). The shallowest aquifers occur in the Continental Deposits and the McNairy Formation, both of which discharge into the Ohio River north of PGDP. (The shallow groundwater system beneath SWMU 1 occurs in the Continental Deposits.) A large, downward, vertical hydraulic gradient within the Upper Continental

Deposits, which represents an aquitard, typically limits the amount of groundwater discharge to the ditches of PGDP and adjacent creeks. Gaining reaches in the creeks are found on Bayou Creek south of PGDP and on Little Bayou Creek to the north of PGDP where it meets the Ohio River flood plain. Both creeks have gaining reaches adjacent to the Ohio River.

Other surface water bodies in the vicinity of PGDP include several small ponds, inactive clay and gravel pits, and settling basins scattered throughout the PGDP plant area; a marshy area just south of the confluence of Bayou Creek and Little Bayou Creek; ash settling ponds of the Shawnee Fossil Plant; and Metropolis Lake, located east of the Shawnee Fossil Plant.

3.4 GEOLOGY

PGDP lies within the Jackson Purchase region of western Kentucky, which represents the northern tip of the Mississippi Embayment portion of the Coastal Plain Province. The stratigraphic sequence in the region consists of Cretaceous, Tertiary, and Quaternary sediments unconformably overlying Paleozoic bedrock (Figure 3.2). The following sections describe the primary geologic units of the PGDP region.

3.4.1 Bedrock

Mississippian carbonates, composed of dark gray limestone with some interbedded chert and shale, underlie the entire PGDP area at an approximate depth of 300 ft to 340 ft.

3.4.2 Rubble Zone

Deep soil borings at PGDP commonly encounter a rubble zone of chert gravel at the top of the bedrock. The age and continuity of the rubble zone remain undetermined.

3.4.3 McNairy Formation

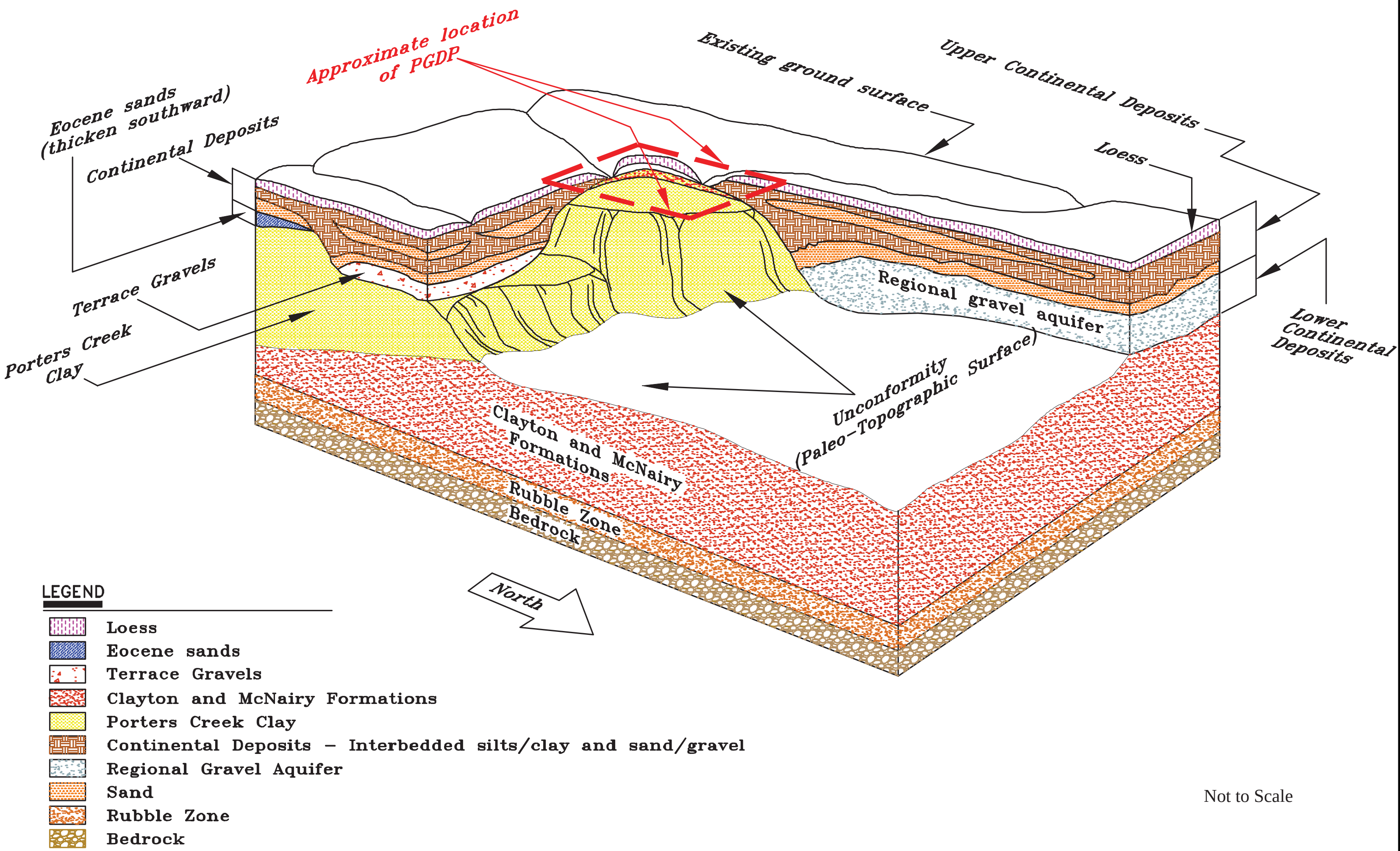
The McNairy Formation consists of Upper Cretaceous, fine clastic sediments. At PGDP, the upper and middle members of the McNairy Formation are typically grayish-white to dark-gray, micaceous silt and clay interbedded with gray to yellow, very fine- to fine-grained sand. The middle (Levings) member tends to contain fewer sand interbeds. The basal McNairy member at PGDP is primarily a light gray, very fine to fine sand.

3.4.4 Porters Creek Clay/Porters Creek Terrace Slope

Paleocene age Porters Creek Clay underlies the southern portions of the DOE site and consists of dark gray to black silt with varying amounts of clay and fine-grained, micaceous, commonly glauconitic, sand. The Porters Creek Clay subcrops along a buried terrace slope that extends east–west under the south end of the PGDP industrial area. This subcrop is the northern limit of Porters Creek Clay and the southern limit of the Pleistocene Lower Continental Deposits under PGDP. SWMU 1 lies north of the subcrop of the Porters Creek Clay.

3.4.5 Eocene Sands

Eocene sands occur south of PGDP (and south of SWMU 1) above the Porters Creek Clay. This unit includes undifferentiated quartz sands and interbedded and interlensing silts and clays of the Claiborne Group and Wilcox Formation (Olive 1980). The Eocene sands thicken to the south of PGDP.



Source: Clausen et al. 1992a

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Figure 3.2. PGDP Stratigraphic Sections

3.4.6 Continental Deposits

Continental sediments [Pliocene(?)[4] to Pleistocene age] unconformably overlie the Cretaceous through Eocene strata throughout the area. These continental sediments were deposited on an irregular erosional surface consisting of several terraces. The thicker Continental Deposits sections represent Pleistocene valley fill sediments that comprise a fining-upward cycle. The continental sediments have been divided into the two distinct facies described below.

(1) Lower Continental Deposits. The Lower Continental Deposits is a gravel facies consisting of chert, ranging from pebbles to cobbles, in a matrix of poorly sorted sand and silt. Gravels of the Lower Continental Deposits overlie three distinct terraces in the PGDP area.

- The upper terrace Lower Continental Deposits consists of Pliocene(?) gravel units, ranging in thickness from near 0 ft to 30 ft, occurring in the southern portion of the DOE site and south of SWMU 1 at elevations greater than 350 ft amsl. This gravel unit overlies the Eocene sands and Porters Creek Clay (where the Eocene sands are missing).

- Pliocene(?) gravels of the Lower Continental Deposits also occur on an intermediate terrace eroded into the Porters Creek Clay at an elevation of approximately 320 ft to 345 ft amsl in the southeastern and eastern portions of the DOE site and southeast of SWMU 1. The thickness of this unit typically ranges from 15 ft to 20 ft.

- The Lower Continental Deposits of the upper and intermediate terraces are collectively referred to as the Terrace Gravel.

- The third and most prominent of the three Lower Continental Deposits members consists of a Pleistocene gravel deposit resting on an erosional surface at an elevation of approximately 280 ft amsl. This gravel underlies SWMU 1 and most of the plant area and the region to the north, but pinches out under the south side of PGDP along the subcrop of the Porters Creek Clay. The Pleistocene member of the Lower Continental Deposits averages approximately 30 ft in thickness. Trends of greater thickness, as much as 50 ft, fill deeper scour channels that trend east-west beneath the site.

(2) Upper Continental Deposits. The Upper Continental Deposits are a Pleistocene age, fine-grained clastics facies that commonly overlies the Lower Continental Deposits. This unit commonly ranges in thickness from 15 ft to 55 ft and is approximately 60 ft-thick beneath SWMU 1. The Upper Continental Deposits includes three general horizons beneath PGDP: (1) an upper silt and clay interval, (2) an intermediate interval of common sand and gravel lenses (sand and gravel content generally diminishes northward), and (3) a lower silt and clay interval. The upper silt and clay interval consists of the Peoria Loess and Roxana Silt (DOE 2003b; WLA 2006). The Peoria Loess and Roxana Silt blanket the entire PGDP area.

3.5 SOILS

The surficial deposits found in the vicinity of PGDP are Pleistocene loess and Holocene alluvium. Both units commonly consist of clayey silt or silty clay and range in color from yellowish-brown to brownish-gray or tan, making field differentiation difficult. The general soil map for Ballard and McCracken Counties delineates three soil associations within the vicinity of PGDP: the

[4] A question mark indicates uncertain age.

Rosebloom-Wheeling-Dubbs association, the Grenada-Calloway association, and the Calloway-Henry association (USDA 1976).

In the immediate PGDP area, the predominant soil is the Henry soil series of the Calloway-Henry association, which consists of nearly level, somewhat poorly to poorly drained, medium-textured soils on upland positions. The Henry soil series contains poorly drained, acidic soils that have a fragipan. Henry soils typically have moderate permeability above the fragipan and low permeability within the fragipan. Permeability in the fragipan is less than 0.4 ft/day (DOE 1998). It should be noted that soils within the industrial area of PGDP, including SWMU 1, could be classified as "urban" since they have been impacted by human influence and many of the original characteristics have been lost.

Several other soil groups also occur in limited areas of the region, including the Grenada, Falaya-Collins, Waverly, Vicksburg, and Loring.

3.6 HYDROGEOLOGY

The significant geologic units relative to shallow groundwater flow at PGDP include the Terrace Gravel and Porters Creek Clay (south part of the DOE site) and the Pleistocene Continental Deposits and McNairy Formation (underlying PGDP and adjacent areas to the north). Groundwater flow in the Pleistocene Continental Deposits is a primary pathway for transport of dissolved contamination from PGDP and the SWMU 1 area. The following paragraphs provide the framework of the shallow groundwater flow system at PGDP.

(1) Terrace Gravel Flow System. The Porters Creek Clay is a confining unit to downward groundwater flow south of the PGDP industrial area. A shallow water table flow system is developed in the Terrace Gravel, where it overlies the Porters Creek Clay south of SWMU 1 and the PGDP industrial area. Discharge from this water table flow system provides baseflow to Bayou Creek and underflow to the Pleistocene Continental Deposits to the east of PGDP.

The elevation of the top of the Porters Creek Clay is an important control to the area's groundwater flow trends. A distinct groundwater divide is centered in hills located approximately 9,000 ft southwest of the PGDP industrial area, where the Terrace Gravel and Eocene sands overlie a "high" on the top of the Porters Creek Clay. In adjacent areas where the top of the Porters Creek Clay approaches land surface, as it does south of PGDP and near the subcrop of the Porters Creek Clay to the west of the industrial complex, the majority of groundwater flow is forced to discharge into surface streams (gaining reaches) and little underflow occurs into the Pleistocene Continental Deposits. To the east of PGDP, the Terrace Gravel overlies a lower terrace eroded into the top of the Porters Creek Clay. In this area, a thick sequence of Terrace Gravel occurs adjacent to the Pleistocene Continental Deposits, allowing significant underflow from the Terrace Gravel. Surface drainages in this area are typically losing reaches. Figure 3.3 presents hydraulic potential trends for the Terrace Gravel flow system.

(2) Upper Continental Recharge System (UCRS). The upper strata, where infiltration of water from the surface occurs and where the uppermost zone of saturation exists, in the Upper Continental Deposits (beneath SWMU 1 and PGDP and the contiguous land to the north) is called the UCRS. Groundwater flow is primarily downward in the Upper Continental Deposits. A plot of elevation of water level versus midpoint of well screen for UCRS wells at PGDP (Figure 3.4) demonstrates that steep vertical hydraulic gradients are characteristic of the UCRS. Vertical hydraulic gradients generally range from 0.5 to 1 ft/ft where measured by wells completed at different depths in the UCRS. Vertical gradients are 1 to 2 orders of magnitude greater than lateral hydraulic gradients. While groundwater flow is predominantly downward, there will be some lateral flow due to heterogeneities in the shallow soils.

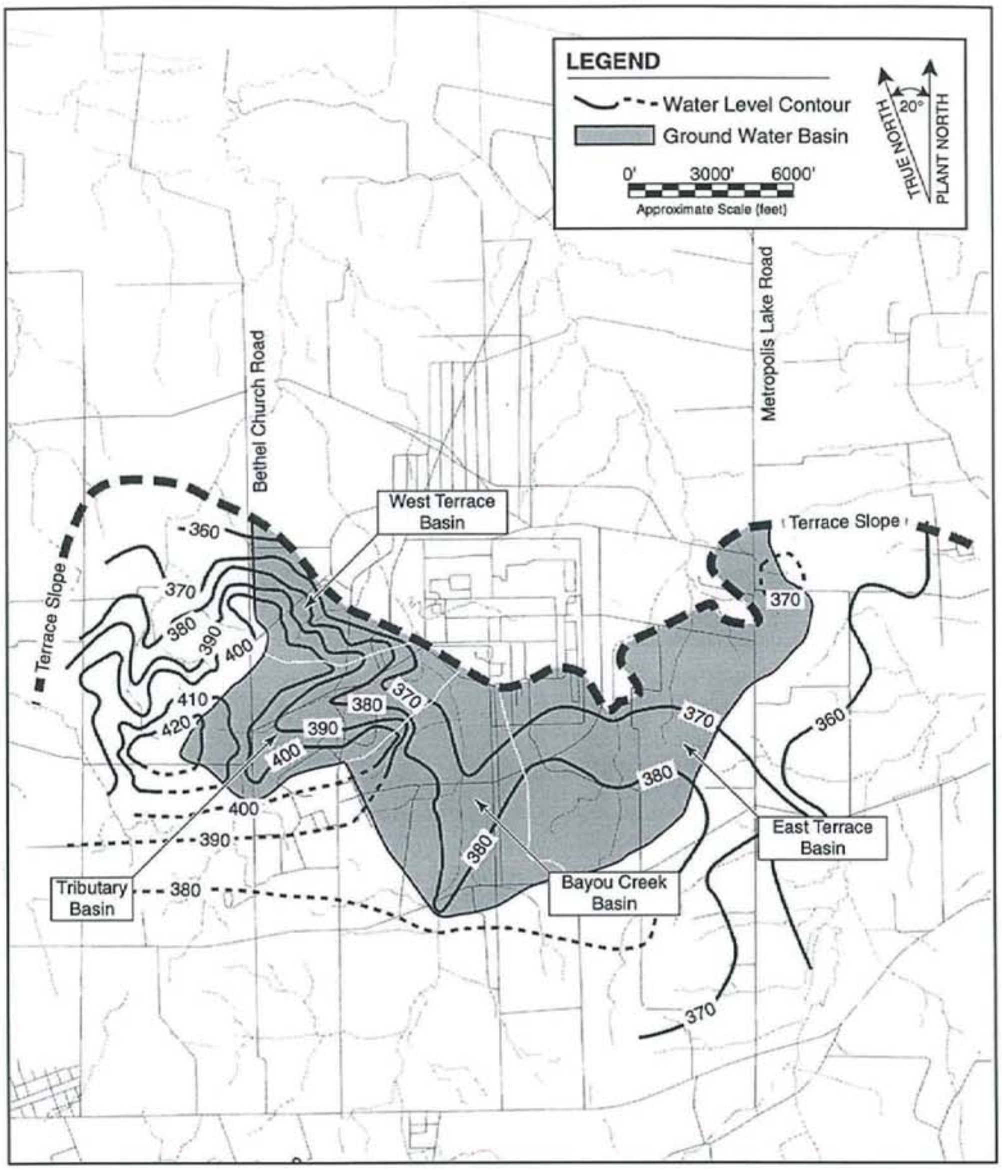

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Figure 3.3. Water Table Trends in the Terrace Deposits South of the PGDP

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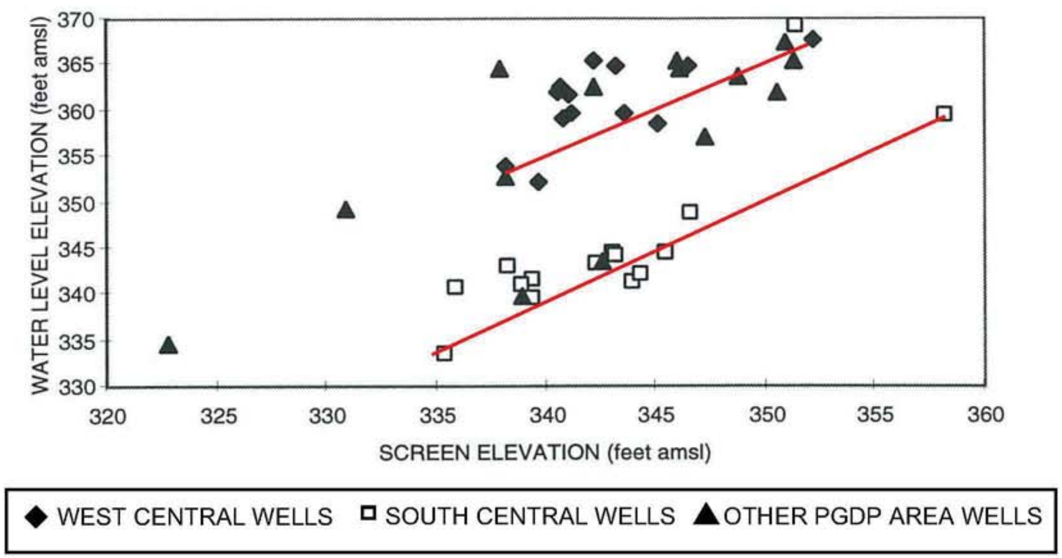

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Figure 3.4. Plot of Water Level versus Well Screen for Upper Continental Recharge System Wells

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The infiltration rate for the PGDP area is approximately 6.6 inches/yr based on site-specific groundwater modeling. This 6.6 inches/yr applied over the area of the industrial area of the plant yields approximately 0.4 mgd of recharge to the shallow groundwater system. Leakage from plant water utilities, ditches, lagoons, and cooling tower basins is suspected to be another important source of infiltration at PGDP. Water use for PGDP for calendar year 2006 averaged 13 mgd. Municipal water systems lose as much as 24% of the daily conveyance (Jowitt and Xu 1990). A similar loss of the PGDP system would equal 3.1 mgd. Since the UCRS groundwater flow is predominantly downward, areas with higher anthropogenic recharge create mounding of hydraulic head in the RGA that can affect contaminant transport. Because the hydraulic conductivity in the RGA on-site is relatively large, the mounding is only slight (often less than 1 ft) and difficult to attribute.

(3) RGA. Vertically infiltrating water from the UCRS moves downward into a basal sand member of the Upper Continental Deposits and the Pleistocene gravel member of the Lower Continental Deposits and then laterally north toward the Ohio River. This lateral flow system is called the RGA. The RGA is the shallow aquifer beneath SWMU 1 and PGDP and contiguous lands to the north. Groundwater of the RGA meets requirements of a Class II groundwater as delineated in *Guidelines for Ground-Water Classification under the EPA Ground-Water Protection Strategy* (EPA 1988).

Hydraulic potential in the RGA declines toward the Ohio River, which is the control of base level of the region's surface water and groundwater systems. The RGA potentiometric surface gradient beneath PGDP is commonly 10^{-4} ft/ft, but increases by an order of magnitude near the Ohio River. (Vertical gradients are not well documented, but small.)

The hydraulic conductivity of the RGA varies spatially. Pumping tests have documented the hydraulic conductivity of the RGA ranges from 53 ft/day to 5,700 ft/day. East-to-west flow of the ancestral Tennessee River, which laid down the Pleistocene Continental Deposits gravel member, tended to orient permeable gravel and sand lenses east-west. Thus, with the hydraulic head in the RGA generally decreasing northward toward the Ohio River, groundwater flow trends to the northeast and northwest from PGDP in response to the anisotropy of the hydraulic conductivity as well as the anthropogenic recharge, which is greatest in the industrial portion of the plant. Anthropogenic recharge from waterline leaks, lagoons, cooling tower basins, and other sources provides the primary driving force in moving groundwater in northeastern and northwestern flow directions from the industrial plant area. Ambient groundwater flow rates in the more permeable pathways of the RGA commonly range from 1 to 3 ft/day.

Previous work has shown that the primary pathway for groundwater flow and the site-related contaminants is vertical migration through the UCRS, followed by lateral migration in the RGA. The two primary groundwater plume contaminants at PGDP are TCE and Tc-99. Interpretation of the location of these plumes is updated on a regular basis with the addition of groundwater analytical data from various projects at the site. Figures 3.5 and 3.6 illustrate the plume maps presented in the calendar year 2012 plume map update (LATA Kentucky 2015). Monitoring wells used to generate the plume maps are plotted on the figures.

(4) McNairy Flow System. Groundwater flow in the fine sands and silts of the McNairy Formation is called the McNairy Flow System. The overall McNairy groundwater flow direction in the area of PGDP is northward to the Ohio River, similar to that of the RGA. Hydraulic potential is greater in the RGA than in the McNairy Flow System beneath PGDP. Area monitoring well clusters document an average downward vertical gradient of 0.03 ft/ft. Because the RGA has a steeper hydraulic potential slope toward the Ohio River than does the McNairy Flow System, the vertical gradient reverses nearer the Ohio River. [The "hinge line," which is where the vertical hydraulic gradient between the RGA and McNairy Flow System changes from a downward vertical gradient to an upward vertical gradient, parallels the Ohio River near the northern DOE property boundary (LMES 1996).]

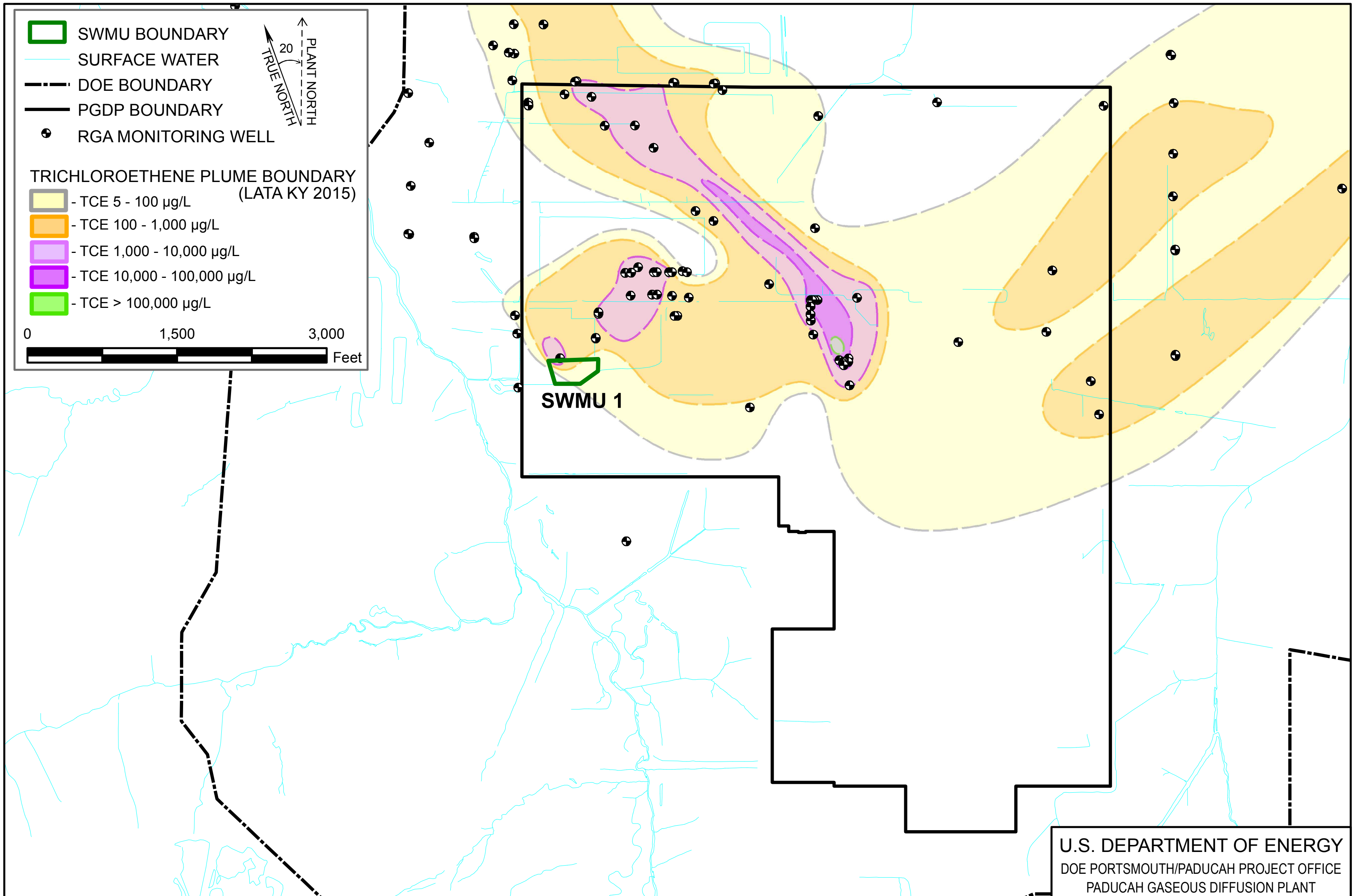

Figure 3.5. Location of Trichloroethene Plume in Relation to SWMU 1

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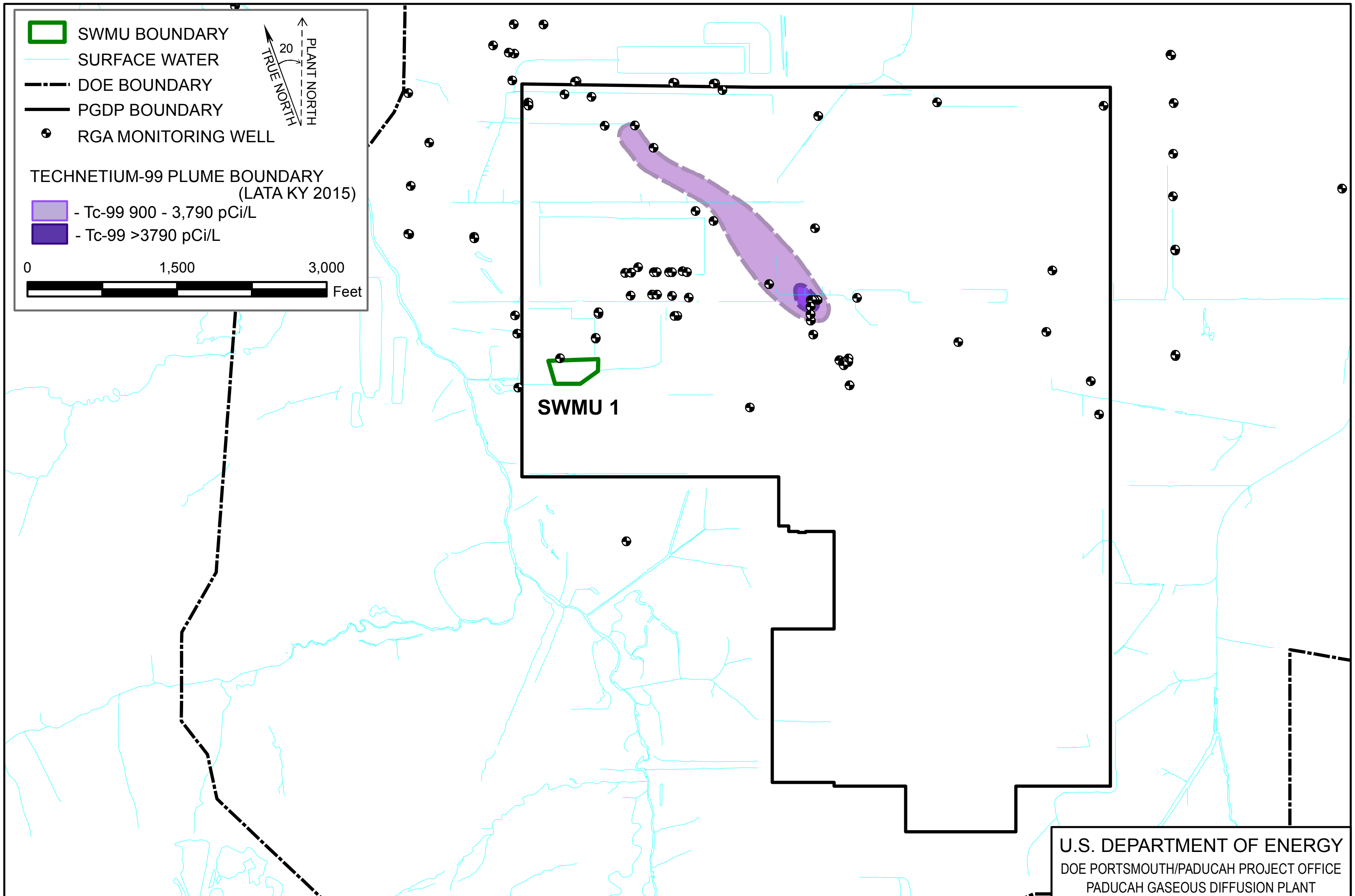

Figure 3.6. Location of Technetium-99 Plume in Relation to SWMU 1

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The contact between the Lower Continental Deposits and the McNairy Formation is a marked hydraulic properties boundary. Representative lateral and vertical hydraulic conductivities of the upper McNairy Formation in the area of PGDP are approximately 0.02 ft/day and 0.0005 ft/day, respectively. Vertical infiltration of groundwater into the McNairy Formation beneath PGDP is on the order of 0.1 inch per year. (Lateral flow in the McNairy Formation beneath PGDP is on the order of 0.03 inch per year.) As a result, little interchange occurs between the RGA and McNairy Flow System.

Hydrogeologic Units

Five hydrogeologic units (HUs) commonly are used to discuss the shallow groundwater flow system beneath the DOE site and the contiguous lands to the north (Figure 3.7). HUs 1 through 5 underlie SWMU 1. In descending order, the HUs are described as follows:

- Upper Continental Deposits
  - HU 1 (UCRS): Loess that covers the entire site.
  - HU 2 (UCRS): Discontinuous sand and gravel lenses in a clayey silt matrix. In some areas of the plant, the HU2 interval consists of an upper sand and gravel member (HU2A) and a lower sand and gravel member (HU2B) separated by a thin silt unit.
  - HU 3 (UCRS): Relatively impermeable unit that acts as the upper semiconfining-to-confining layer for the RGA. The lithologic composition of HU3 varies from clay to fine sand, but is predominantly silt and clay.
  - HU 4 (RGA): Near-continuous sand unit with a clayey silt matrix that forms the top of the RGA.
- Lower Continental Deposits
  - HU 5 (RGA): Gravel, sand, and silt.

3.7 DEMOGRAPHY AND LAND USE

The WKWMA and some sparsely populated agricultural lands surround PGDP. Historically, the economy of western Kentucky had been based on agriculture, although there has been increased industrial development in recent years. The population of McCracken County, Kentucky is approximately 66,000 (DOC 2013). The major city in McCracken County is Paducah, Kentucky, whose population is approximately 25,000 (DOC 2013). Three small communities are located within 3 miles of the DOE property boundary at PGDP: Heath and Grahamville to the east and Kevil to the southwest.

The population within a 50-mile radius of PGDP is about 534,000 according to the 2010 census. Within a 10-mile radius of PGDP, the population is about 89,000 (ESRI 2012).

In addition to the residential population surrounding the plant, WKWMA draws thousands of visitors each year for recreational purposes. Visitors use the area primarily for hunting and fishing, but other activities include horseback riding, hiking, and bird watching. An estimated 7,500 fishermen visit the area each year (DOE 2016b).

For the PGDP area, current and reasonably anticipated future land use is depicted in the SMP, as shown in Figures 3.8 and 3.9 (DOE 2015a).

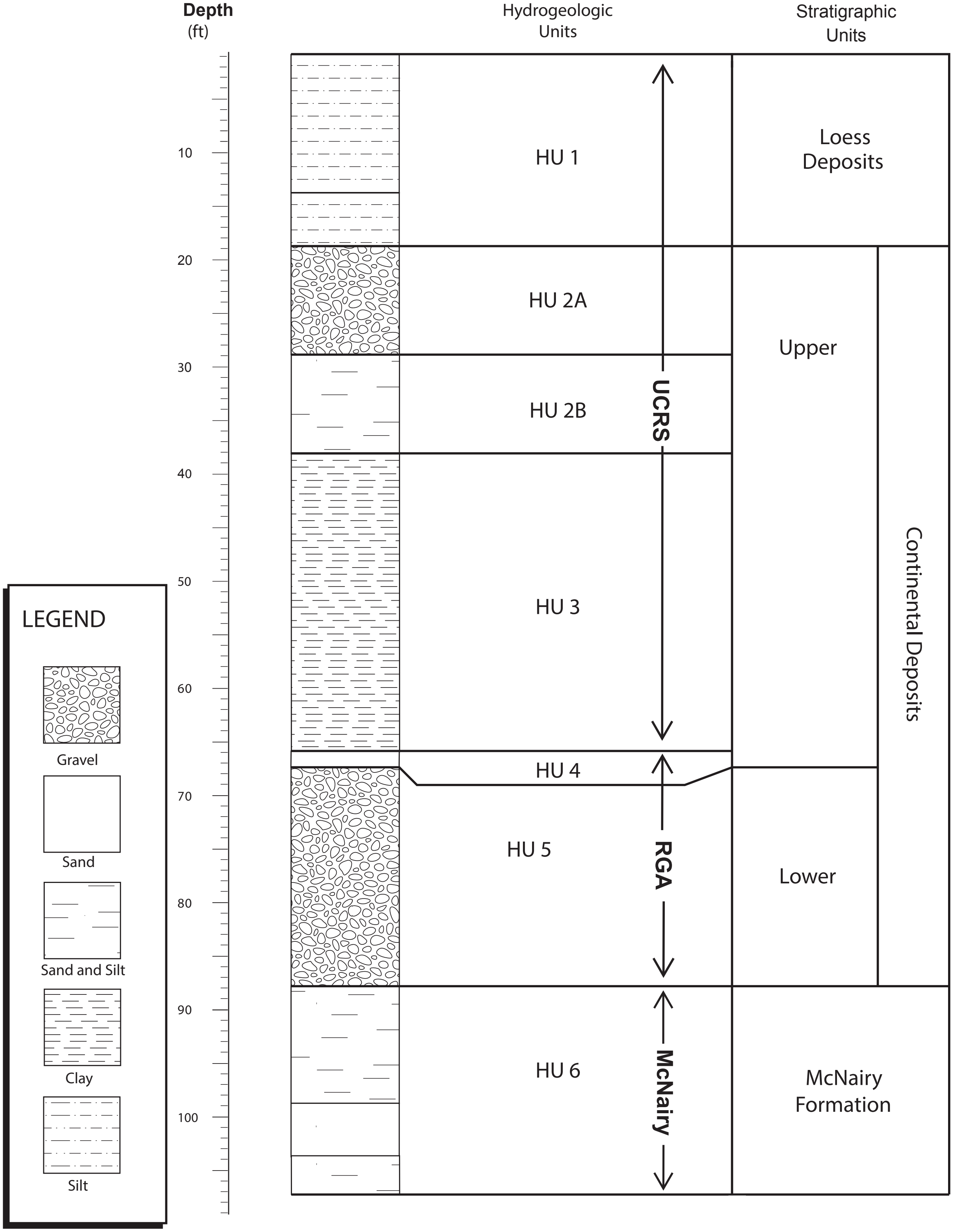

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Figure 3.7. Example Stratigraphic and Hydrogeologic Units

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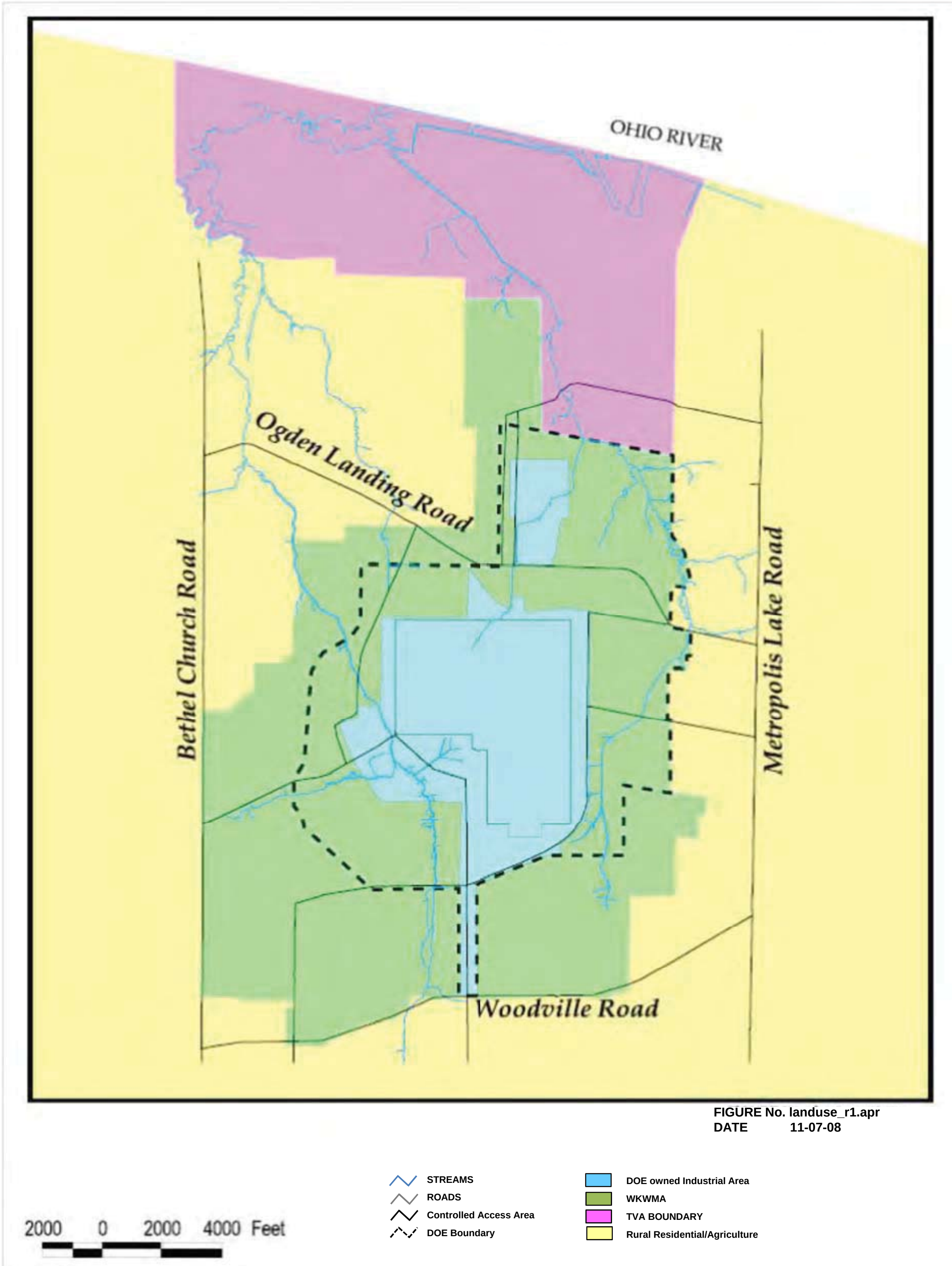

Figure 3.8. Current Land Use at PGDP

Figure taken from DOE 2015a.

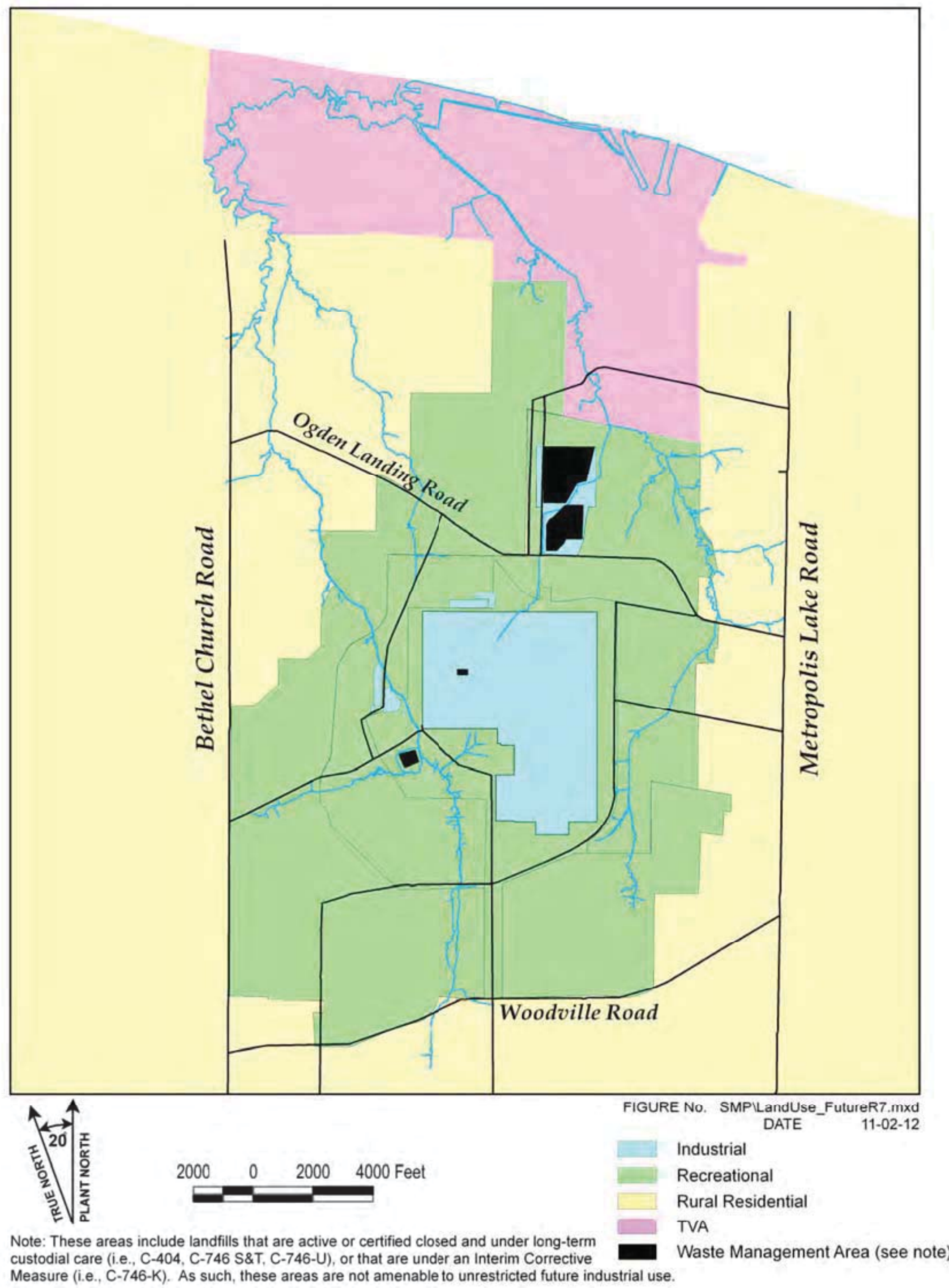

Figure 3.9. Reasonably Anticipated Future Land Use at PGDP

Figure taken from DOE 2015a.

3.8 ECOLOGY

The following sections give a brief overview of the terrestrial and aquatic systems at PGDP. A more detailed description, including identification and discussion of sensitive habitats and threatened/endangered species, is contained in the *Investigation of Sensitive Ecological Resources Inside the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (CDM Federal 1994) and *Environmental Investigations at the Paducah Gaseous Diffusion Plant and Surrounding Area, McCracken County, Kentucky, Volume V: Floodplain Investigation, Part A: Results of Field Survey* (COE 1994).

3.8.1 Terrestrial Systems

The terrestrial component of the PGDP ecosystem includes the plants and animals that use the upland habitats for food, reproduction, and protection. Upland vegetative communities in the vicinity of PGDP consist primarily of grassland, forest, and thicket habitats with agricultural areas. The main crops grown in the PGDP area include soybeans, corn, tobacco, and sorghum.

Most of the area in the vicinity of PGDP has been cleared of vegetation at some time. PGDP mows much of the grassland habitat adjacent to the plant. The Kentucky Department of Fish and Wildlife Resources manages a large percentage of the adjacent WKWMA to promote native prairie vegetation by burning, mowing, and various other techniques.

Dominant overstory species of the forested areas include oaks, hickories, maples, elms, and sweetgum. Understory species include snowberry, poison ivy, trumpet creeper, Virginia creeper, and Solomon’s seal. Thicket areas consist predominantly of maples, black locust, sumac, persimmon, and forest species in the sapling stage with herbaceous ground cover similar to that of the forest understory.

Wildlife commonly found in the PGDP area consists of species indigenous to open grassland, thicket, and forest habitats. Small mammal surveys conducted on WKWMA documented the presence of southern short-tailed shrew, prairie vole, house mouse, rice rat, and deer mouse (KSNPC 1991). Large mammals commonly present in the area include coyote, eastern cottontail, opossum, groundhog, whitetail deer, raccoon, and gray squirrel. Mist netting activities in the area have captured red bat, little brown bat, Indiana bat, northern long-eared bat, evening bat, and eastern pipistrelle (KSNPC 1991).

The typical birds of the area are European starling, cardinal, red-winged blackbird, mourning dove, bobwhite quail, turkey, killdeer, American robin, eastern meadowlark, eastern bluebird, blue jay, red-tail hawk, and great horned owl.

Amphibians and reptiles present in the PGDP area include cricket frog, Fowler’s toad, common snapping turtle, green tree frog, chorus frog, southern leopard frog, eastern fence lizard, and red-eared slider (KSNPC 1991). Additionally, snakes, skinks, and salamanders have been observed in the PGDP area according to the Kentucky Department of Fish and Wildlife Resources (KDFWR 2015).

3.8.2 Aquatic Systems

The aquatic communities, which include vertebrates and invertebrates, in and around the PGDP area that could be impacted by PGDP discharges are found in two perennial streams (Bayou Creek and Little Bayou Creek), the North-South Diversion Ditch (a former ditch for the discharge of plant effluents to Little Bayou Creek), a marsh located at the confluence of Bayou Creek and Little Bayou Creek, and other drainage areas. The dominant fish species found are several species of sunfish, especially bluegill and green sunfish, bass, and catfish. Shallow streams, characteristic of the two main area creeks, are commonly dominated by bluegill, green and longear sunfish, and stonerollers.

3.8.3 Wetlands and Floodplains

The wetlands of the PGDP vicinity include a swamp covering 165 acres immediately south of the confluence of Bayou and Little Bayou Creeks. A 1994 study of the PGDP area by the U.S. Corps of Engineers (COE) (1994) groups the area wetlands into 16 vegetative cover types encompassing forested, scrub/shrub, and emergent wetlands. Wetland vegetation consists of species such as sedges, rushes, spikerushes, and various other grasses and forbs in the emergent portions; red maple, sweet gum, oaks, and hickories in the forested portions; and black willow and various other saplings of forested species in the thicket portions. Wetlands inside the plant security fence are confined to portions of drainage ditches traversing the site (CDM Federal 1994).

At PGDP, three bodies of water cause most area flooding: the Ohio River, Bayou Creek, and Little Bayou Creek. The floodplain analysis performed by the COE found that much of the built-up portions of the plant lie outside the 100- and 500-year floodplains of these streams (COE 1994). In addition, this analysis determined that ditches within the plant area can contain the expected 100- and 500-year discharges. It should be noted that precipitation frequency estimates for the 100- and 500-year events were updated in 2004 in the NOAA Atlas 14 (NOAA 2004). In the updated report, the mean precipitation estimate for the 100-year, 24-hour event in Atlas 14 for the Paducah area is 10.1% to 15% greater than the mean estimate in previous publications. As stated in Atlas 14, in many cases, the mean precipitation estimate used previously still is within the confidence limits provided in Atlas 14; therefore, it is likely the plant ditches still will contain the 100- and 500-year discharges.

4. EVALUATION APPROACH

This project was scoped prior to GDP shutdown (see Chapter 1). As discussed in the SMP, prior to GDP shutdown, the Soils OU will focus on accessible plant surface soils (ground surface to 10 ft bgs and 16 ft bgs in the vicinity of pipelines) not associated with PGDP operations (DOE 2015a). This Soils OU Report addendum has been prepared to present findings from the investigation conducted to assess adequately the nature and extent of the release or threat of release of hazardous substances, pollutants, or contaminants or hazardous wastes and hazardous constituents. The addendum investigation gathered necessary data to support the corresponding BRA and FS at, and it is consistent with 40 *CFR* § 300.5 (EPA 1989), as detailed by the Work Plan (DOE 2010) and the RI Work Plan Addendum (DOE 2014a). This report is a foundation to determine what actions, if any, are needed to address any impacts in soils associated with the Soils OU SWMU 1 remedial action.

This report does the following:

- Provides a summary of the soil samples collected and analytical results by COPC, including a summary of the sampling methodology;
- Screens the results against background and risk-based levels taken from the Risk Methods Document (DOE 2016b) and developed in the BHHRA (Appendix D) to identify COPCs and COCs that are present at the SWMU;
- Presents the results of a BHHRA, including selection of COCs and priority COCs, based upon consideration of uncertainties in risk characterization and observations on the risk evaluation;
- Presents the results of a SERA;
- Develops remedial goal options (RGOs) for scenarios evaluated in the BHHRA; and
- Compares the analytical results to the RGOs and presents a summary of those comparisons.

The information/data and analyses that form the basis of the decision process for SWMU 1 are documented in Chapter 5 of this RI Addendum. This chapter highlights the information to be presented generally for the SWMU 1 evaluation to address the goals of the RI.

4.1 DATA SETS

The data set for SWMU 1 consists of historical data collected at depths up to 16 ft bgs and 2016 recharacterization of soils following the deep soil mixing remedial action. Use of historical and RI data is addressed in Appendix B. The historical data set includes the Soils OU analytical suite as defined in the RI Work Plan Addendum (DOE 2014a); it was evaluated as described in the Work Plan (DOE 2010). Any exceptions to the rules identified in the Work Plan have been noted in Appendix B (DOE 2010).

Collectively, historical and RI data meeting data quality objectives are considered the representative data set and are sufficient for decision making associated with SWMU 1. In order to evaluate the data for SWMU 1 more comprehensively, plutonium-239 data were assessed as plutonium-239/240 and uranium-235/236 were assessed as uranium-235. Data summaries use Total PCBs and Total PAHs; individual contributors are not included in the summaries (DOE 2016b). Total PAHs are derived following the guidance in the Risk Methods Document using toxicity equivalence factors (TEFs). TEFs for the following carcinogenic PAHs are available: benzo(a)pyrene; benzo(a)anthracene; benzo(b)fluoranthene; benzo(k)fluoranthene; chrysene; dibenzo(a,h)anthracene; and indeno(1,2,3-c,d)pyrene. All other PAHs have a TEF of zero; therefore, they are not included in the total. These TEFs are applied to the concentrations of detected PAHs in each sample, and the Total PAH concentration in each sample will be the sum of the products of each PAH and its TEF. For samples in which PAHs are not detected, the value for the minimum detection limit of the PAHs with TEFs will be used in the calculation of the EPC (DOE 2016b).

XRF data are discussed in the Soils OU RI Report (DOE 2013a). See Appendix B for additional information.

Uncertainty Analysis. In developing alternatives in the FS, additional evaluation of data collected and compiled for this addendum may be performed to address any uncertainties identified. Additional evaluation may include these steps or processes; some of these are discussed further in the Data Quality Analysis (Appendix B) and the BHHRA (Appendix D).

1. Incorporate future changes to site conditions.

2. Evaluate the data from SWMU 1 against the full range of background (rather than the initial screening against site-specific background already conducted). This additional evaluation would seek to identify whether the presence of certain metals and radionuclides in SWMU 1 is at levels consistent with or above background.

3. Reconsider the default assumptions used in the data treatment for SWMU 1 to ensure that the FS considers the data and determines them to be representative of the SWMU conditions.

4. Evaluate individual constituent results to ensure that they should properly be considered as representative of the data set. These evaluations may include these steps or processes.

    - Review data associated with common laboratory contaminants [e.g., methylene chloride (EPA 1996)]. The concentrations in the Soils OU data set may be associated with laboratory contamination; therefore, before an action is taken to address the methylene chloride at a given SWMU, its presence in the SWMU may be reevaluated to determine whether these data are representative of the actual site conditions.

    - Reevaluate data to develop a set more representative of actual conditions. As noted, the RI typically conducted an initial screening using the maximum value. The FS may perform additional data evaluation to subdivide the SWMU to allow the remedial approach to treat sub-areas differently, should this evaluation warrant. For example, the FS could contemplate removal of hot spots that then would allow a reestimation of the data set to be representative of the residual conditions.

5. Adjust the default parameters to more accurately reflect the specific SWMU conditions. For example, the soil/water distribution coefficient (i.e., K_d) for Tc-99 is a very sensitive parameter used in groundwater modeling (DOE 2016b). The K_d (0.2 L/kg) for Tc-99 that was used in the modeling assumes the Tc-99 is in a form that will readily dissolve in water; however, the form of this constituent at a particular SWMU may not conform to this assumption. Should additional evaluation identify that the K_d for a given constituent for a SWMU is not appropriate, the value may be adjusted and the modeling reperformed, with agreement among the FFA parties during scoping that additional modeling is warranted to support the FS remedy evaluation.

4.2 GRID SAMPLING

Grid sampling was completed as part of the investigation covered by this addendum to characterize the soils by the collection of 5-point composite samples from each of the 23 grids at two different horizons, 0–1 ft bgs and 1–4 ft bgs (for a total of 46 grid samples), for fixed-base laboratory analysis to be used to better understand the nature and extent of contamination (DOE 2010) remaining after deep soil mixing remediation. Results of the grid sampling indicated no need for step-down and step-outs to be performed.

4.3 NATURE AND EXTENT

The Soils OU evaluations focus first on summarizing the representative analytical results for surface and subsurface soils. The process for highlighting chemicals of greatest potential interest was done consistent with the Work Plan (DOE 2010) considering the following:

- Background concentrations;
- Action levels (ALs) and NALs (future industrial worker[5] for inside the Limited Area); and
- Groundwater protection site-specific soil screening levels (SSLs) for the UCRS and RGA [dilution attenuation factors (DAFs) of 1 and 58 for the UCRS and RGA, respectively, based on maximum contaminant levels (MCLs), where available] (see Appendix C).[6]

The values used for highlighting the contaminants of greatest potential interest (denoted as COPCs in Nature and Extent sections) are consistent with the Risk Methods Document (DOE 2016b) and are included in Appendix D for the chemicals evaluated for this RI. The SSLs protective of groundwater for the RGA screening are discussed further in Section 4.4. In addition to these comparisons, the range of detection limits (DLs) also is summarized.

4.4 FATE AND TRANSPORT

Potential migration of surface and subsurface contamination via leaching to groundwater and subsequent transport or runoff of surface contamination to adjacent drainageways is unlikely (as previously evaluated) though SWMU 1 is near a drainageway (KPDES Outfall 008). In addition, internal plant ditches are grass-lined, and the outfall ditches are grass-lined or otherwise stabilized; therefore, the contaminants are not likely to be transported attached to suspended soil particles within the ditches and outfalls in an event where transport or runoff to a drainageway has occurred (DOE 2008a).

A primary migration pathway of concern for contaminants in soil is the potential for these contaminants to pose an ongoing source of contamination to RGA groundwater and subsequent migration to off-site areas. In Chapter 5 of this RI, the nature and extent evaluation highlights detected contaminants exceeding the SSL for one or more of the samples. The SSL for the RGA screening is derived using the

[5] The "future industrial worker" reflects default assumptions (i.e., 250 days/year for 25 years) (DOE 2016b).

[6] Soil screening for RGA impacts had been based on a dilution attenuation factor (DAF) of 58. This DAF was used to maintain consistency with previous Soils OU reports, which was in accordance with the approved Work Plan. Because technical uncertainties have arisen with use of a DAF of 58, use of DAF for future CERCLA remedy selection and response action implementation documents for SWMU 1 and future projects under the FFA will be discussed further by the FFA parties and decided on a project-specific basis.

project-specific DAF of 58 and the SSL for the UCRS screening was derived using the project-specific DAF of 1, as presented in Appendix C, Attachment C2 of the Soils OU RI Report[7] (DOE 2013a).

This screening process conservatively identifies chemicals that should be considered further for potential impacts to the RGA and downgradient receptors. The screening process is supplemented with a review of related information to ensure that concentrations that may be below background levels of constituents that do not pose a threat to the RGA at PGDP and/or are infrequently detected/exceeded are not evaluated further. A process to refine this list and identify chemicals for more detailed modeling was established in Appendix C, Attachment C1, of the Soils OU RI Report (DOE 2013a).

4.4.1 Process for Developing Target Soil Constituents for Modeling

The overall modeling process for the entire Soils OU RI process includes the following:

- Screen historical and RI analytical results against the SSLs protective of groundwater to identify soil constituents that might impact groundwater;

- Review the site-related soil constituents that are not screened from further modeling to identify which SWMU soil constituent combinations to subject to more detailed modeling;

- Identify certain process-related soil constituents for detailed modeling though they were not detected above SSLs for groundwater protection to ensure the appropriate DAF was used;

- Identify hotspots by evaluating the distribution of soil contaminants across the SWMU using three-dimensional modeling software;

- Evaluate transport to the RGA using Seasonal Soil Compartment Model (SESOIL) for soil constituents selected for detail modeling; and

- Estimate the concentrations of soil constituents in RGA groundwater at the SWMU boundary using Analytical Transient 1-,2-,3-Dimensional (AT123D).

It was clear when reviewing these screening results that many of these chemicals present no potential threats to groundwater based on the data patterns, background, and results of groundwater monitoring. Many of the SSLs are at concentrations consistent with background for many naturally occurring chemicals, a factor that was considered further in the modeling process. Because of these issues, the list of chemicals was refined to include only those with potential concern for impacts to the RGA. This evaluation was presented Appendix C of the Soils OU RI 1.

Several constituent/SWMU pairs were subjected to modeling as part of the Soils OU RI 1 and the modeling determined that, except for Tc-99, none of the constituents was found to migrate to the RGA within 1,000 years. Modeling of Tc-99 for SWMU 14 indicated a potential for an RGA concentration downgradient of SWMU 14 of 1,700 pCi/L; however, actual RGA concentrations immediately downgradient of SWMU 14 have not exceeded 900 pCi/L since 1998, and even the residual concentrations exhibit no incremental contribution from SWMU 14. This information is presented in Appendix C of the Soils OU RI 1.

[7] The derivation of the project-specific DAF for the RGA of 58 is described in Appendix C of the Soils OU RI 1 Report and has been determined to be appropriate for screening to identify worst-case constituent/SWMU pairs subjected to modeling.

As part of the Soils OU RI 2, the modeling conducted in the Soils OU RI 1 was determined to be sufficient to demonstrate that, except for Tc-99, none of the Soils OU RI constituents were present at levels that would migrate to the RGA within 1,000 years. However, three more Tc-99/SWMU pairs were subjected to modeling and determined not to cause an exceedance of 900 pCi/L in the RGA immediately downgradient of the SWMU. This information is presented in Appendix C of the Soils OU RI 2.

As part of this addendum, the SWMU 1 constituent concentrations/extents were evaluated and determined to be lower than concentrations modeled in the Soils OU RI 1 and Soils OU RI 2, thus, no additional constituents were subjected to modeling for this Addendum.

This RI Addendum developed information to support the FS evaluation of a range of remedial alternatives that addresses potentially complete exposure pathways and manages the risks/uncertainties identified in this RI.

Initial screening of the maximum detected value of constituents included determining how many of the results from the SWMU had a detected value greater than the SSL or the greater of the surface and subsurface background value.

Additional evaluation was conducted to identify which groundwater SWMU soil constituent combinations actually were subjected to groundwater modeling. The additional evaluation included a comparison of the overall average value of the constituent (calculated using both detected values and nondetected values at one-half the detection limit) with the screening values described above. If the overall average value of the constituent for the SWMU was below the background value or the SSL, then the constituent was not considered further for modeling for fate and transport. If the average value was above both the background value and the SSL, then the constituent was reviewed further to identify whether modeling would be performed.

Additionally, to determine if hot spots existed within the SWMU, the detected results of those constituents exceeding either the SSL or background value were examined visually and evaluated, [e.g., consideration of GWOU FS (DOE 2001a) and AT123D software].

Based on the screening, no modeling was completed for the soil constituents in SWMU 1 because concentrations of these constituents either were below screening levels or below concentrations detected at other Soils OU SWMUs/AOCs that were subjected to modeling and shown not to reach the RGA within 1,000 years. Similarly, Tc-99 concentrations at SWMU 1 were below screening levels and also below concentrations from other SWMUs that were subjected to screening and shown to not result in an above-900 pCi/L impact in RGA groundwater.

4.5 RISK ASSESSMENT

Grid sampling for the Soils OU was set up primarily on 45-ft centers with compositing of five grab samples within each of the affected 23 grids for two horizons: surface soils and subsurface soils (for a total of 46 grid samples). Coordinates for these samples were recorded as the center of the grid because the composite sampling was designed to be representative of the grid. The grid sampling yielded approximately 10 samples per horizon per half acre, on average. [One-half acre is significant because it typically is used as the size of an exposure unit (EU) for risk assessment purposes (DOE 2016b).]

Acceptable historical data, as determined by the data quality analysis, were assigned to an appropriate grid before beginning the data analysis described here. Historical data located outside the SWMU boundary were not considered representative of the SWMU.

For each grid, a detect or nondetect flag was assigned for each analyte using field laboratory data, fixed-base laboratory data, and/or historical data. For purposes of assigning flags, historical data should be included with fixed-base laboratory results or field laboratory results, whichever is applicable. A nondetect flag was set only if both field laboratory results and fixed-base results are nondetect or not available. Flags were assigned according to the following rules as specified in the work plan (DOE 2010):

(1) If field laboratory result is a nondetect and a fixed-base laboratory sample was not collected and an acceptable historical result is not available for the grid, then the grid is assigned a nondetect flag.

(2) If the field laboratory result is a nondetect and a fixed-base laboratory sample was collected or an acceptable historical result is available, then the fixed-base laboratory or historical result is used in assigning flag.

  (a) If the fixed-base laboratory result is a nondetect, then the grid is assigned a nondetect flag.
  (b) If the fixed-base laboratory result is a detect, then the grid is assigned a detect flag.

(3) If the field laboratory result is a detect and a fixed-base laboratory sample was not collected and no acceptable historical result is available for the grid, then the grid is assigned a detect flag.

(4) If the field laboratory result is a detect and a fixed-base laboratory sample was collected or an acceptable historical result is available, then

  (a) If the fixed-base laboratory result is a nondetect, then the grid is assigned a detect flag.
  (b) If the fixed-base laboratory result is a detect, then the grid is assigned a detect flag.

For each grid, a concentration for each analyte was assigned.

(1) If the analyte has a nondetect flag for the grid, then the concentration was set as the lower of field laboratory and fixed-base laboratory detection limit.

(2) If the analyte has a detect flag, then the concentration was set as the maximum detected value across field laboratory and fixed-base laboratory results.

These rules are in the flowchart depicted in Figure 4.1.

Background values (see Appendix D) were compared on an EU basis by examining the results across all the grids within the EU. Nondetect results were not considered present above background even if the detection limit for the chemical was greater than the background value; a discussion of the uncertainty associated with this approach is presented in Appendix D, Attachment D5. The magnitude of this uncertainty was determined to be small. If an analyte was detected in one or more grids within the EU, then the maximum detected value across all grids within the EU was used for background comparison. (If the maximum detected value was greater than background, then the analyte is considered to be present above background. If the maximum detected value was less than background, then the analyte is not considered to be present above background.) The maximum radiological value across all the grids within the EU was used for background comparison.

COPCs were selected for each EU for those analytes that were detected above background and where the maximum detected value is greater than the NAL [as defined in the Risk Methods Document

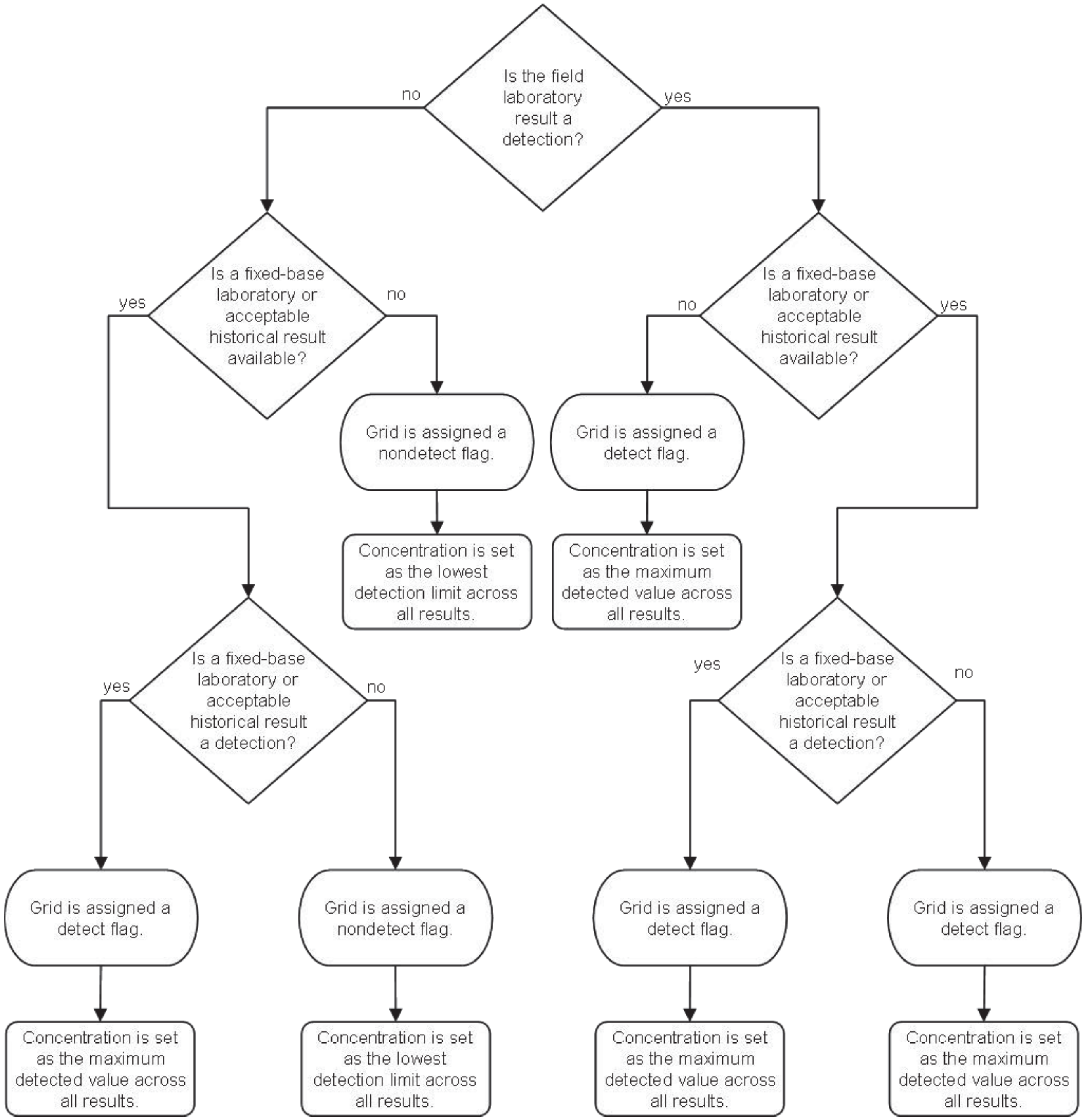

Figure taken from DOE 2010.

Figure 4.1. Flowchart Depicting Application of Detect and Nondetect Flags

(DOE 2016b) for the hypothetical child residential scenario,[8] see Appendix D]. As described in the Work Plan, for those analytes that were never detected within an EU, even if the detection limit is greater than the NAL, the analyte was not considered a COPC (DOE 2010). With the large number of samples required for the gridded sampling approach, the majority of the samples were analyzed using field analytical instruments. Though the quantitation limits are higher for these instruments, the increased coverage of each unit decreases the uncertainty of the analytical precision. Trace analytes may not be determined throughout the unit, but major constituents are less likely to be missed. Fixed-base laboratory detection limits that are higher than NALs were addressed as an uncertainty in the BHHRA.

Exposure point calculations were performed for each EU for those analytes that were retained as COPCs. For each COPC, data were summarized within each sampling location (i.e., within each grid) before calculating the exposure point concentration (EPC) for the EU. This was necessary to ensure that each location was equally represented in the EU EPC calculation. The scenarios shown in Figure 4.2 illustrate each possible case that may have resulted from implementation of the field sampling strategy for this RI and its response.

Further, in Case 1, shown in Figure 4.2, the COPC consists of all detected results, so the EPC was calculated using, as the grid result, the maximum detected value within the grid.

In Case 2, only detect and nondetect field results are available for grids. In this case, the EPC for the EU is calculated using the maximum detected field result for grids with detected results and the field detection limit for grids without a detected result.

In Case 3, data are a combination of historical and field results. In this case, maximum field detect result is used for the grid value if all historical results are nondetects; the maximum historical detect result is used for the grid value if all field results are nondetects; the largest detected value is used as the grid result if all field and historical results are detects; and the smallest detection limit is used for the grid result if all field and historical results are nondetects. [It should be noted, discarding nondetect results that are greater than the maximum detected result in this manner, if they do not significantly influence the outcome, is consistent with EPA Risk Assessment Guidance for Superfund (RAGS) (EPA 1989).]

In Case 4, data are a combination of historical, fixed-base laboratory, and field results. In this case, maximum field detect result is used for the grid value if all historical results and fixed-base results are nondetects; the maximum fixed-base detect result is used for the grid value if all field results and historical results are nondetects; the maximum historical detect result is used for the grid value if all field results and fixed-base results are nondetects; the largest detected value is used as the grid result if a combination of field, fixed-base and historical results are detects; and the smallest detection limit is used for the grid result if all field, fixed-base, and historical results are nondetects. [This methodology is consistent with RAGS (EPA 1989).] A calculation was completed to determine the importance of the anomalous situation where the nondetect result exceeds the maximum detected value within a data set being analyzed. If the nondetect value that exceeds the maximum detected result would cause the EPC to exceed the maximum detected result, then it would be discarded from the data set.

[8] In the Risk Methods Document, the child resident scenario NAL is the lesser of the hazard-based value for a child age 1 to 6 and the ELCR-based value for the resident. The hazard target used in the calculation is 0.1, and the excess cancer risk target used in the calculation is 1×10^{-6}. Consistent with the Work Plan (DOE 2010), the PALs in the Quality Assurance Project Plan were set to the child resident scenario NAL for the Risk Methods Document (DOE 2001b).

	RESULTS	TO REPRESENT GRID ANALYTE CONCENTRATION
Case 1: *Field laboratory results,* *Fixed-base laboratory results,* *No historical results*	Field laboratory: detect Fixed-base laboratory: nondetect	Use the field laboratory result
	Field laboratory: nondetect Fixed-base laboratory: detect	Use the fixed-base laboratory result
	Field laboratory: detect Fixed-base laboratory: detect	Use the maximum detected result
	Field laboratory: nondetect Fixed-base laboratory: nondetect	Use the smaller detection limit
Case 2: *Field laboratory results,* *No fixed-base laboratory results,* *No historical results*	Field laboratory: detect	Use the field laboratory result
	Field laboratory: nondetect	Use the field laboratory detection limit
Case 3: *Field laboratory results,* *No fixed-base laboratory results,* *Historical results*	Field laboratory: detect Historical: nondetect	Use the field laboratory result
	Field laboratory: nondetect Historical: detect	Use the historical result
	Field laboratory: detect Historical: detect	Use the maximum detected result
	Field laboratory: nondetect Historical: nondetect	Use the smaller detection limit
Case 4: *Field laboratory results,* *Fixed-base laboratory results,* *Historical results*	Field laboratory: detect Fixed-base laboratory: nondetect Historical: nondetect	Use the field laboratory result
	Field laboratory: nondetect Fixed-base laboratory: detect Historical: nondetect	Use the fixed-base laboratory result
	Field laboratory: nondetect Fixed-base laboratory: nondetect Historical: detect	Use the historical result and consider any uncertainties regarding historical data during project nature and extent scoping
	Field laboratory: detect Fixed-base laboratory: detect Historical: nondetect	Use the maximum detected result
	Field laboratory: detect Fixed-base laboratory: nondetect Historical: detect	Use the maximum detected result
	Field laboratory: nondetect Fixed-base laboratory: detect Historical: detect	Use the maximum detected result
	Field laboratory: detect Fixed-base laboratory: detect Historical: detect	Use the maximum detected result
	Field laboratory: nondetect Fixed-base laboratory: nondetect Historical: nondetect	Use the smallest detection limit

Figure taken from DOE 2010.

Figure 4.2. Exposure Point Concentration Calculation Scenarios

Analytical results from historical sampling were included with other fixed-base laboratory results when assigning grid values with the grid sampling previously described.

After the data set was built for each analyte within the EU, the rules for EPC calculation were as follows:

(1) If results from fewer than 10 grids are available, then the EU EPC was the maximum detected concentration across all grids within the EU.

(2) If results from 10 or more grids are available, then a distribution check was performed, and the EU EPC was the lesser of the maximum detected concentration and the 95% upper confidence limit (UCL) on the mean of the appropriate distribution. EPA's ProUCL software incorporates a number of different distributional tests that may be used to perform the distributional tests and calculate the most appropriate UCL (EPA 2015). An exception to this is if not all the grids contained a value for an analyte. In this instance, the average of the grid values present was assigned to the grids with no value before the EU EPC was calculated.

The BHHRA characterized cancer risks and noncancer hazards by EU for all COPCs for the following scenarios:

- Current Industrial Worker[9]
- Future Industrial Worker (see footnote 6)
- Outdoor Worker
- Excavation Worker
- Recreational User
- Future Hypothetical Resident

Likely scenarios for SWMU 1 are discussed in Chapter 5 and include that of the future industrial worker since SWMU 1 is located inside the Limited Area. Additionally, a hypothetical residential scenario and an excavation worker scenario were assessed.

4.5.1 Human Health

A detailed approach to the risk assessment and the supporting information and tables are provided in Appendix D. For the SWMU 1 summary, tables are provided with the risk estimates for the various receptors, the COCs, and the primary routes of exposure that are driving these results.

The receptors evaluated and the exposure parameters used to develop risk estimates are in Table 4.1. The following highlighted components of the risk assessment are included in the SWMU 1 summary, as appropriate.

Direct Contact Exposures. This includes incidental ingestion, inhalation, dermal absorption, and external exposure to ionizing radiation routes of exposure. This may include contact with contamination currently at the surface or to contaminants in the entire soil column in the future during earthwork.

- **Surface soil (0–1 ft) impacts are evaluated with a range of exposure scenarios.** Because of the sizes of the EUs and limited activities in these areas, current worker exposures are estimated based on a more representative frequency (14 days/year); however, the future worker scenario includes default

[9] The "future industrial worker" reflects default assumptions (i.e., 250 days/year for 25 years) (DOE 2016b). A "current industrial worker" scenario has been added to the default scenario to be more reflective of current site conditions and practices with a lower exposure frequency (i.e., 14 days/years for 25 years) (DOE 2008a).

Table 4.1. Exposure Factors Used for Intake Calculations in BHHRA[a]

Pathway Variable	Units	Current Industrial Worker[b]	Future Industrial Worker	Outdoor Worker	Excavation Worker	Adult Resident	Child Resident	Adult Recreational User	Teen Recreational User	Child Recreational User
Exposure frequency	days/year	14	250	185	185	350	350	104	140	140
Exposure duration	years	25	25	25	5	20	6	10	10	6
Body weight	kg	80	80	80	80	80	15	80	44	15
Averaging time—cancer	days	70 × 365	70 × 365	70 × 365	70 × 365	70 × 365	70 × 365	70 × 365	70 × 365	70 × 365
Averaging time—noncancer	days	365 × 25	365 × 25	365 × 25	365 × 5	365 × 20	365 × 6	365 × 10	365 × 10	365 × 6
Incidental Ingestion of Soil/Sediment										
Incidental ingestion rate	mg/day	50	50	480	480	100	200	100	100	200
Fraction ingested		1	1	1	1	1	1	1	1	1
Dermal Contact with Soil/Sediment										
Body surface area exposed	m^2/day	0.3527	0.3527	0.3527	0.3527	0.6032	0.2373	0.6032	0.75	0.2373
Soil-to-skin adherence factor	mg/cm^2 – day	1	1	1	1	1	1	1	1	1
Inhalation of Vapors and Particulates Emitted from Soil/Sediment										
Total inhalation rate	m^3/hour	2.5	2.5	2.5	2.5	0.833	0.833	2.5	2.5	2.5
Exposure time	hours/day	8	8	8	8	24	24	5	5	5
Particulate emission factor	m^3/kg	6.20E+08	6.20E+08	6.20E+08	6.20E+08	9.30E+08	9.30E+08	9.30E+08	9.30E+08	9.30E+08
External Exposure to Ionizing Radiation from Soil/Sediment										
Exposure frequency	day/day	14/365	250/365	185/365	185/365	350/365	350/365	104/365	140/365	140/365
Gamma shielding factor	Unitless	0.2	0.2	0.2	0.2	0.2	0.2	0	0	0
Gamma exposure time factor	hr/hr	8/24	8/24	8/24	8/24	18/24	18/24	5/24	5/24	5/24

Notes:
[a] Information compiled September 2015, See DOE 2016b, Methods for Conducting Risk Assessment and Risk Evaluation at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Volume 1. Human Health, DOE/LX/07-0107&D2/R6/V1, June.
[b] Best professional judgment; similar to value used for DOE 2008a.
N/A = not available or not applicable.

assumptions (250 days/year). A future hypothetical resident, a recreational user, and outdoor worker scenarios also were evaluated.

- **Surface/subsurface soils.** Bounding the potential contact issues with contaminants that may be present in soils from 0–16 ft requires scenarios either for temporary exposures during excavation or longer term exposures if the soil column was mixed during future activities and a receptor, subsequently, may be in contact with this average concentration for a longer duration. The surface/subsurface soils were evaluated using the outdoor worker assumptions [185 days/year for 25 years as per the Risk Methods Document (DOE 2016b)]. The intake parameters for the excavation worker are the same as the outdoor worker with the exception of exposure duration. Exposure duration was shortened to 5 years for the excavation worker.

- **Surface Water.** Although SWMU 1 is located near drainageways, significant surface water contamination is not expected as a result of the SWMU (UK 2007). Internal plant ditches are grass-lined and the outfalls are grass-lined or otherwise stabilized; therefore, the contaminants are not likely to be transported attached to suspended soil particles within the ditches and outfalls in the event transport or runoff to a drainageway did occur (DOE 2008a). Further, due to the physical cover at the SWMU limiting the potential for particulate transport through sheet flow and based upon the modeling performed as part of the SI report for the outfalls and the associated internal ditches, no contaminants are migrating in surface water (dissolved or through sediment) from ditches to surrounding creeks at concentrations that may adversely impact human health (DOE 2008b). The uncertainty in surface water transport of contaminants will be managed in the FS**.** As a result, human health risks associated with exposure to surface water will not be assessed in the BHHRA (Appendix D).

Groundwater. Ingestion of groundwater is evaluated only for hypothetical future residential scenarios at SWMU 1 identified in the fate and transport section and modeled to show transport potentially reaching the RGA. The modeled RGA groundwater concentration at the SWMU boundary was used for risk estimates. No UCRS groundwater samples were collected as part of this addendum to the RI 2 report, and evaluation refers to modeling results only. The UCRS groundwater is not evaluated specifically; however, the tables shown in the nature and extent section highlight those constituents that exceeded SSL values for the UCRS. Though not quantified in this evaluation, UCRS groundwater could pose as a medium of concern under certain exposure scenarios; however, these risks were not quantified due to the high improbability of the UCRS being used as a drinking water aquifer [see Section 3.3.4.3 of the Risk Methods Document (DOE 2016b)].

Dose Assessment. This RI does not integrate potential dose across multiple routes of exposure, particularly since radionuclides were not identified during the evaluation of impacts to groundwater and dose from ingestion of game was not evaluated for the current on-site areas. Dose assessments are conducted to provide information for risk managers and are separate from the risk assessment conducted for decision making. The Risk Methods Document (Table A.8) provides dose-based SSLs. These were used to derive an estimate of the total dose (mrem/yr) for each of the primary scenarios evaluated (DOE 2016b). In presenting these results, the following comparisons are considered:

- Per the Risk Methods Document (DOE 2016b), a dose less than 1 mrem/yr is *de minimis,* and the benchmark for dose-based action is 25 mrem/year [DOE Order 458.1 states that if the estimated total effective dose (TED) for members of the public exceeds 25 mrem in a year, then additional evaluation is conducted] (DOE 2016b).

- DOE Order 458.1, *Radiation Protection of the Public and Environment*, requires that all exposure pathways not result in radiation exposures to members of the general public greater than a TED of 100 mrem/year (not applicable for current on-site areas, but consideration for future use).

- These do not reflect exposures to the public, which would be estimated at the site boundary. Radionuclide releases to air are not expected from SWMU 1 soil-related COPCs because these COPCs are nonvolatile. Thus, there is no potential for soil vapor generation, vapor migration, or building vapor intrusion related to these COPCs. For an evaluation of the potential for releases to air from the VOCs treated by the Southwest Plume remedial action, refer to the Southwest Plume remedial action report.

Pathways not Quantitatively Evaluated. The following discusses pathways not quantitatively evaluated.

- SWMU 1 is adjacent to a drainageway and that is noted as such in Section 4.4, under Fate and Transport. Surface water pathways were not quantitatively evaluated in this OU because the potential for surface water migration of contaminants was addressed during the SWOU (On-Site) SI. The Engineering Evaluation/Cost Analysis for that project stated the following: "Based upon the modeling performed as part of the SI report for the outfalls and the associated internal ditches, no contaminants are migrating in surface water (dissolved or through sediment) from ditches to surrounding creeks at concentrations that may adversely impact human health" (DOE 2008b).

  A removal action for the contaminated sediment associated with SWOU (On-Site) (DOE 2011) was conducted for Outfalls 001, 008, 010, 011, and 015 and associated internal ditches. A final response action for internal ditches, outfalls, and creeks will be addressed by the SWOU, as described in the SMP (DOE 2015a).

- The inhalation of vapors exposure route is not quantified as part of the risk characterization because VOC emission by subsurface soils is an incomplete pathway (i.e., no buildings exist at SWMU 1 through which a receptor could be exposed). Inhalation of vapors migrating from the VOC-contaminated soils and/or TCE-contaminated groundwater underlying SWMU 1 could be a medium of concern under certain exposure scenarios (for example, the future industrial worker and future rural resident exposure scenarios). However, these exposure pathways were outside the scope of this investigation and were not quantified in this risk characterization.

- Existing contamination in groundwater underlying SWMU 1 could be a medium of concern under certain exposure scenarios (such as ingestion of groundwater); however, these risks were not quantified as part of this risk characterization. Those risks are addressed under the GWOU.

- A rural resident with a garden or raising beef was not evaluated. Residential use on-site is not reasonably anticipated. Criteria more protective than the typical residential scenarios may be derived during the FS. (SWMU 1 exceeds the 1E-06 cumulative risk criteria requiring development of an FS for the hypothetical resident without including the garden/beef scenarios.)

- Ingestion of game. Recreational use of the area has been evaluated; however, ingestion of game was not included in the SWMU 1 evaluation. Considering the range of the game, the range of the hunter, and the small size of the SWMU (and the location of SWMU 1 is in the Limited Area), the analysis of this has great uncertainty for any SWMU-specific risk management decision.

Lead. Lead is evaluated separately from the cancer risks and noncancer hazards assessment methodology, as proposed by EPA. Exposures to lead were evaluated based on the approach recommended in the

Memorandum: Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities (EPA 1994). The site media lead levels are compared directly against the health protective lead concentrations for the risk-based site management decisions. Lead was not identified as a COPC because the maximum concentration is less than 400 mg/kg (residential screening value) consistent with the Risk Methods Document (DOE 2016b).

Contaminants of Concern. For SWMU 1, the total ELCR and total HI for all pathways within a use scenario of concern are compared to the benchmarks of ELCR > 1E-06 or an HI > 0.1, respectively. COPCs within a use scenario of concern exceeding either of these benchmarks are deemed COCs for the use scenario of concern. The COCs are identified in the tables in Chapter 5. Priority COCs are identified as those COCs with either ELCR > 1E-04 or HI > 1 or both to highlight to risk managers the COCs driving total ELCR or total HI at SWMU 1 (DOE 2016b).

Uncertainty Analysis. The uncertainty discussion for the BHHRA (Appendix D) documents a range of issues that may be considered by risk managers in making decisions for these sites.

4.5.2 Ecological Risk Screening

The surface soil concentrations were screened against the ecological screening values (ESVs) for soil as included in Appendix E. This approach does not include consideration of background or other factors; however, given the industrial nature of SWMU 1, the background screening values are included. Consistent with the Soils OU RI Report, for the SWMU 1 summary, the primary chemicals that exceeded the respective screening values are shown [hazard quotient (HQ) ≥ 10] with the total HQ for the constituents detected, allowing comparison of the HQs, SWMU size, and other factors like proximity to a drainageway (DOE 2013a). These primary chemicals exceeding screening values with an HQ ≥ 10 are termed priority chemicals or radionuclides of potential ecological concern (COPECs) within this report.

4.6 REMEDIAL GOAL OPTIONS

RGOs were developed individually for each SWMU 1 EU for scenarios analyzed in the BHHRA. RGOs were calculated for each COC as determined in the conclusions of the BHHRA. COCs and RGOs are presented to evaluate direct contact exposure for the future industrial worker, excavation worker, and future hypothetical resident for SWMU 1 located inside the Limited Area in Chapter 6.

4.7 SWMU AREA DETERMINATIONS

The human health and ecological risk assessments used acreage for the SWMU based on global positioning system coordinates and mapping tools. This acreage is reflected in the figures within this document. Of note, the acreage presented in the background sections of this document may be inconsistent with acreage used in risk assessments due to its being based on historical SWMU assessment report administrative boundaries, which typically were estimated using a map/figure.

5. SWMU 1, C-747-C OIL LANDFARM

5.1 BACKGROUND

SWMU 1, The C-747-C Oil Landfarm, is a facility located inside the plant limited access area, near the west fence of the industrial section of PGDP. The facility is bound on the north by the C 745-A Cylinder Yard and by railroad tracks on the east, west, and south. The nearest plant streets are the intersection of Tennessee Avenue and 4th Street, which lies southeast of SWMU 1.

Between 1973 and 1979 the area was used for landfarming (mixing waste oils with soil to aid biodegradation of the oil in an area that prevents runoff) waste oils contaminated with TCE, uranium, PCBs, and 1,1,1-trichloroethane. These waste oils are believed to have been derived from a variety of PGDP processes. The landfarm consisted of two approximately 1,125-ft^2 plots that were plowed to a depth of 1 to 2 ft. Waste oils were spread on the surface every three to four months; then the area was limed and fertilized. The VOC contaminants in the soils at C-747-C are assumed to be residuals from landfarming waste oils.

5.2 FIELDWORK SUMMARY

Post-deep soil mixing remedial action grid sampling was performed for this investigation for the Soils OU and was set up primarily on 45-ft centers with compositing of five grab samples within each of the affected grids for two horizons: surface (0–1 ft bgs) and subsurface (1–4 ft bgs) (for a total of 46 grid samples). Coordinates for these samples were recorded as the center of the grid, as the composite sampling was designed to be representative of the grid. The grid sampling yielded approximately 10 samples per horizon per half acre, on average. [One-half acre is significant because it typically is used as the size of an EU for risk assessment purposes (DOE 2016b).]. The location of the remedial action, the grids, and EUs for SWMU 1 are shown in Figure 5.1.

5.3 NATURE AND EXTENT OF CONTAMINATION—SURFACE SOILS

The representative data set presented in Table 5.1 provides the nature of the contamination in SWMU 1 surface soils with the post-deep soil mixing remedy values replacing the pre-deep soil mixing values for those locations that were disturbed by the remedy. Figures 5.2–5.4 illustrate the horizontal extent. A complete list of sampling results is provided in Appendix F.

The lateral extent of SWMU 1 surface soil contamination is considered defined adequately for supporting the BRA and FS. SWMU 1 consists of five EUs.

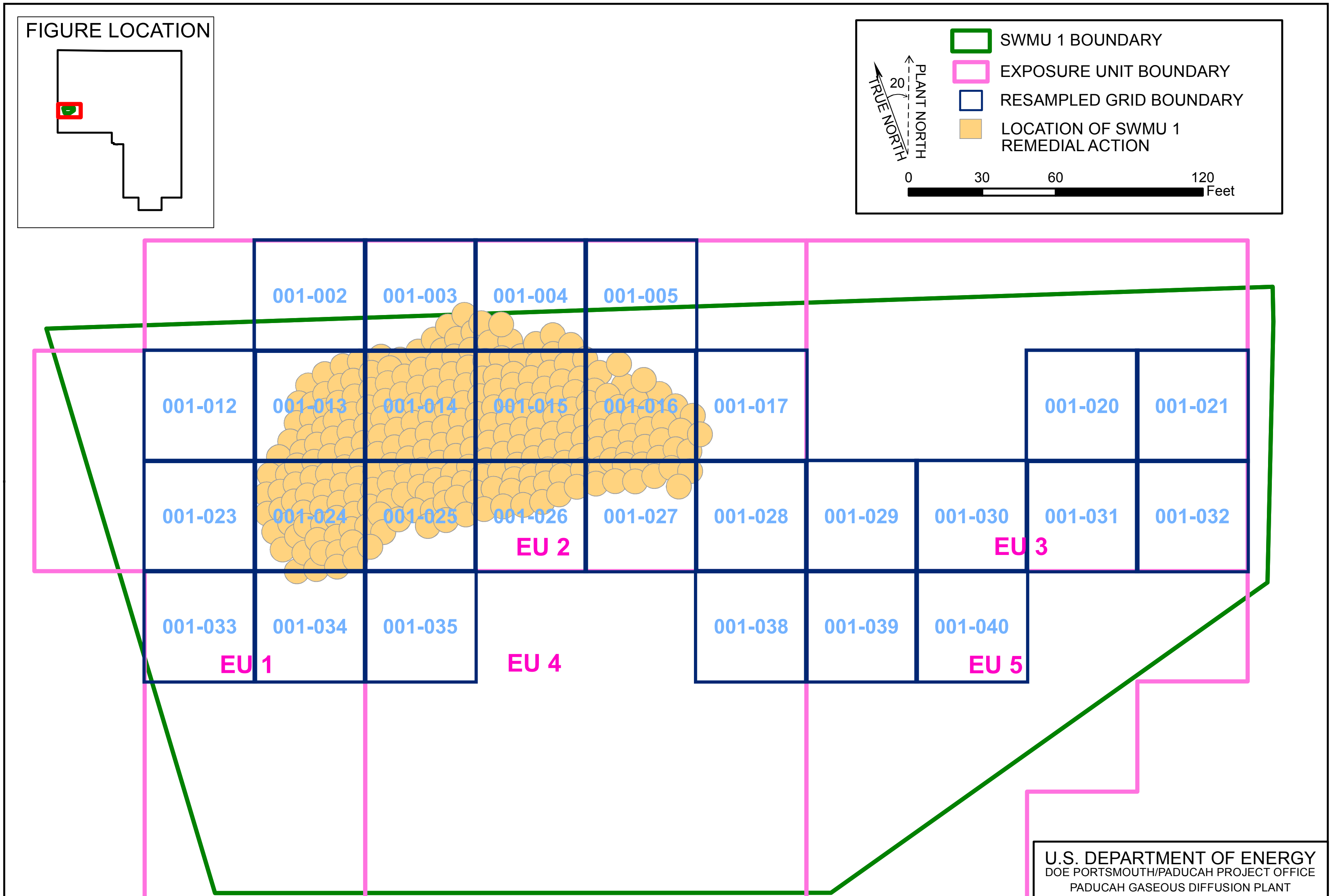

Figure 5.1. SWMU 1 Grid Sampling for SWMU 1 Report Addendum

Table 5.1. Surface Soil Data Summary: SWMU 1

			Detected Results			J-qualified		Provisional Background		Industrial Worker		Industrial Worker		GW Protection Screen		
Type	Analysis	Unit	Min	Max	Avg	FOD	FOD	FOE	Bkgd	FOE	NAL	FOE	AL	RGA	UCRS	DL Range
METAL	Aluminum	mg/kg	4.29E+03	1.11E+04	7.61E+03	0/21	21/21	0/21	1.30E+04	0/21	1.00E+05	0/21	1.00E+05	0/21	21/21	1.3135 - 19.5
METAL	Antimony	mg/kg	1.60E-01	2.40E-01	1.85E-01	0/20	4/20	1/20	2.10E-01	0/20	9.34E+01	0/20	2.80E+03	0/20	0/20	0.032 - 12.2
METAL	Arsenic	mg/kg	3.00E+00	8.90E+00	5.53E+00	0/52	37/52	0/52	1.20E+01	37/52	1.60E+00	0/52	1.60E+02	0/52	37/52	0.0827 - 4.83
METAL	Barium	mg/kg	3.74E+01	1.24E+02	8.62E+01	0/24	24/24	0/24	2.00E+02	0/24	4.04E+04	0/24	1.00E+05	0/24	14/24	0.0242 - 2.44
METAL	Beryllium	mg/kg	4.10E-01	8.30E+00	1.44E+00	0/21	17/21	3/21	6.70E-01	0/21	4.50E+02	0/21	1.35E+04	0/21	2/21	0.0188 - 0.48
METAL	Cadmium	mg/kg	7.10E-02	1.20E+00	4.97E-01	0/24	7/24	3/24	2.10E-01	0/24	6.05E+01	0/24	1.82E+03	0/24	3/24	0.032 - 1.95
METAL	Calcium	mg/kg	2.29E+01	3.10E+04	6.15E+03	0/21	21/21	0/21	2.00E+05	0/21	N/A	0/21	N/A	N/A	N/A	0.005 - 120
METAL	Chromium	mg/kg	4.50E+00	1.37E+02	2.19E+01	0/52	26/52	7/52	1.60E+01	0/52	1.98E+02	0/52	1.98E+04	0/52	0/52	0.1325 - 19
METAL	Cobalt	mg/kg	3.40E+00	1.20E+01	6.12E+00	0/21	21/21	0/21	1.40E+01	0/21	6.87E+01	0/21	2.06E+03	21/21	21/21	0.0847 - 3
METAL	Copper	mg/kg	6.00E+00	4.66E+01	1.38E+01	0/49	49/49	3/49	1.90E+01	0/49	9.34E+03	0/49	1.00E+05	0/49	1/49	0.1067 - 5
METAL	Iron	mg/kg	4.46E+03	2.40E+04	1.53E+04	0/49	49/49	0/49	2.80E+04	0/49	1.00E+05	0/49	1.00E+05	49/49	49/49	0.6677 - 19.5
METAL	Lead	mg/kg	1.02E-01	2.30E+01	1.53E+01	0/52	20/52	0/52	3.60E+01	0/52	8.00E+02	0/52	8.00E+02	0/52	13/52	0.0024 - 19.5
METAL	Magnesium	mg/kg	8.34E+02	1.12E+04	1.81E+03	0/21	21/21	1/21	7.70E+03	0/21	N/A	0/21	N/A	N/A	N/A	3.7451 - 48.8
METAL	Manganese	mg/kg	4.39E+00	1.20E+03	4.61E+02	0/49	49/49	0/49	1.50E+03	0/49	4.72E+03	0/49	1.00E+05	46/49	49/49	0.0003 - 18
METAL	Mercury	mg/kg	1.90E-02	1.80E-01	5.27E-02	3/52	10/52	0/52	2.00E-01	0/52	7.01E+01	0/52	2.10E+03	0/52	6/52	0.0078 - 6
METAL	Molybdenum	mg/kg	6.90E-01	1.42E+01	7.35E+00	0/38	17/38	0/38	N/A	0/38	1.17E+03	0/38	3.51E+04	1/38	17/38	0.11 - 6
METAL	Nickel	mg/kg	4.95E+00	6.38E+01	1.68E+01	0/52	28/52	6/52	2.10E+01	0/52	4.30E+03	0/52	1.00E+05	0/52	28/52	0.1277 - 6.8
METAL	Selenium	mg/kg	1.71E-01	9.90E-01	5.94E-01	0/52	10/52	3/52	8.00E-01	0/52	1.17E+03	0/52	3.51E+04	0/52	6/52	0.0891 - 19.5
METAL	Silver	mg/kg	2.20E-02	1.20E-01	5.29E-02	0/52	4/52	0/52	2.30E+00	0/52	1.17E+03	0/52	3.51E+04	0/52	1/52	0.011 - 10
METAL	Sodium	mg/kg	4.96E+01	1.81E+02	8.88E+01	3/21	13/21	0/21	3.20E+02	0/21	N/A	0/21	N/A	N/A	N/A	2.7264 - 120
METAL	Thallium	mg/kg	1.30E-01	1.80E-01	1.55E-01	0/24	4/24	0/24	2.10E-01	0/24	2.34E+00	0/24	7.02E+01	0/24	3/24	0.021 - 19.5
METAL	Uranium	mg/kg	2.86E+00	9.86E+00	6.83E+00	0/38	10/38	7/38	4.90E+00	0/38	6.81E+02	0/38	2.04E+04	0/38	0/38	0.011 - 53
METAL	Vanadium	mg/kg	2.53E-01	3.30E+01	2.15E+01	0/49	23/49	0/49	3.80E+01	0/49	1.15E+03	0/49	3.45E+04	0/49	22/49	0.0014 - 8
METAL	Zinc	mg/kg	2.31E+01	8.72E+01	3.78E+01	0/49	49/49	1/49	6.50E+01	0/49	7.01E+04	0/49	1.00E+05	0/49	16/49	0.0806 - 19.5
PPCB	PCB, Total	mg/kg	1.30E-02	9.50E+00	1.49E+00	1/112	12/112	0/112	N/A	2/112	2.95E-01	0/112	2.95E+01	1/112	11/112	0.017 - 5
SVOA	1,2,4-Trichlorobenzene	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	1,2-Dichlorobenzene	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	1,3-Dichlorobenzene	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	1,4-Dichlorobenzene	mg/kg	N/A	N/A	N/A	0/18	0/18	0/18	N/A	0/18	N/A	0/18	N/A	N/A	N/A	0.33 - 0.43
SVOA	2,4,5-Trichlorophenol	mg/kg	N/A	N/A	N/A	0/18	0/18	0/18	N/A	0/18	N/A	0/18	N/A	N/A	N/A	0.33 - 2.2
SVOA	2,4,6-Trichlorophenol	mg/kg	N/A	N/A	N/A	0/18	0/18	0/18	N/A	0/18	N/A	0/18	N/A	N/A	N/A	0.33 - 0.43
SVOA	2,4-Dichlorophenol	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	2,4-Dimethylphenol	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	2,4-Dinitrophenol	mg/kg	N/A	N/A	N/A	0/18	0/18	0/18	N/A	0/18	N/A	0/18	N/A	N/A	N/A	0.75 - 2.2
SVOA	2,4-Dinitrotoluene	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.23 - 0.43
SVOA	2,6-Dinitrotoluene	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.23 - 0.43
SVOA	2-Chloronaphthalene	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	2-Chlorophenol	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	2-Methyl-4,6-dinitrophenol	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.75 - 2.2
SVOA	2-Methylnaphthalene	mg/kg	9.00E-02	9.00E-02	9.00E-02	1/15	1/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	2-Methylphenol	mg/kg	N/A	N/A	N/A	0/18	0/18	0/18	N/A	0/18	N/A	0/18	N/A	N/A	N/A	0.33 - 0.43
SVOA	2-Nitrobenzenamine	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	2.87E+02	0/15	8.61E+03	0/15	0/15	0.75 - 2.2
SVOA	2-Nitrophenol	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	3,3'-Dichlorobenzidine	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.23 - 0.86
SVOA	3-Nitrobenzenamine	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.75 - 2.2
SVOA	4-Bromophenyl phenyl ether	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	4-Chloro-3-methylphenol	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	4-Chlorobenzenamine	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	4-Chlorophenyl phenyl ether	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	4-Nitrophenol	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.75 - 2.2
SVOA	Acenaphthene	mg/kg	N/A	N/A	N/A	0/21	0/21	0/21	N/A	0/21	1.38E+03	0/21	4.14E+04	0/21	0/21	0.33 - 0.5
SVOA	Acenaphthylene	mg/kg	N/A	N/A	N/A	0/21	0/21	0/21	N/A	0/21	1.38E+03	0/21	4.14E+04	0/21	0/21	0.33 - 0.5
SVOA	Anthracene	mg/kg	N/A	N/A	N/A	0/21	0/21	0/21	N/A	0/21	6.89E+03	0/21	1.00E+05	0/21	0/21	0.33 - 0.5

FOD = frequency of detection
FOE = frequency of exceedance
N/A = not applicable

Table 5.1. Surface Soil Data Summary: SWMU 1 (Continued)

			Detected Results			J-qualified		Provisional Background		Industrial Worker		Industrial Worker		GW Protection Screen		
Type	Analysis	Unit	Min	Max	Avg	FOD	FOD	FOE	Bkgd	FOE	NAL	FOE	AL	RGA	UCRS	DL Range
SVOA	Benzenemethanol	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	Benzo(ghi)perylene	mg/kg	N/A	N/A	N/A	0/21	0/21	0/21	N/A	0/21	N/A	0/21	N/A	N/A	N/A	0.33 - 0.5
SVOA	Benzoic acid	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	1.65 - 2.2
SVOA	Bis(2-chloroethoxy)methane	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	Bis(2-chloroethyl) ether	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	Bis(2-chloroisopropyl) ether	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	Bis(2-ethylhexyl)phthalate	mg/kg	8.90E-02	1.60E-01	1.13E-01	3/15	3/15	0/15	N/A	0/15	5.80E+01	0/15	5.80E+03	0/15	0/15	0.33 - 0.41
SVOA	Butyl benzyl phthalate	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	Dibenzofuran	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	Diethyl phthalate	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	Dimethyl phthalate	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	Di-n-butyl phthalate	mg/kg	6.70E-02	6.70E-02	6.70E-02	1/15	1/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	Di-n-octylphthalate	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	Fluoranthene	mg/kg	8.30E-02	6.20E-01	3.54E-01	2/21	4/21	0/21	N/A	0/21	9.19E+02	0/21	2.76E+04	0/21	0/21	0.33 - 0.5
SVOA	Fluorene	mg/kg	N/A	N/A	N/A	0/21	0/21	0/21	N/A	0/21	9.19E+02	0/21	2.76E+04	0/21	0/21	0.33 - 0.5
SVOA	Hexachlorobenzene	mg/kg	N/A	N/A	N/A	0/18	0/18	0/18	N/A	0/18	1.26E+00	0/18	1.26E+02	0/18	0/18	0.0038 - 0.43
SVOA	Hexachlorobutadiene	mg/kg	N/A	N/A	N/A	0/18	0/18	0/18	N/A	0/18	N/A	0/18	N/A	N/A	N/A	0.23 - 0.43
SVOA	Hexachlorocyclopentadiene	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	Hexachloroethane	mg/kg	N/A	N/A	N/A	0/18	0/18	0/18	N/A	0/18	N/A	0/18	N/A	N/A	N/A	0.33 - 0.43
SVOA	Isophorone	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	m,p-Cresol	mg/kg	N/A	N/A	N/A	0/7	0/7	0/7	N/A	0/7	N/A	0/7	N/A	N/A	N/A	0.38 - 0.4
SVOA	Naphthalene	mg/kg	6.30E-02	6.30E-02	6.30E-02	1/21	1/21	0/21	N/A	0/21	1.67E+01	0/21	1.61E+03	1/21	1/21	0.33 - 0.5
SVOA	Nitrobenzene	mg/kg	N/A	N/A	N/A	0/18	0/18	0/18	N/A	0/18	N/A	0/18	N/A	N/A	N/A	0.33 - 0.43
SVOA	N-Nitroso-di-n-propylamine	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	1.16E-01	0/15	1.16E+01	0/15	0/15	0.33 - 0.43
SVOA	N-Nitrosodiphenylamine	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	Pentachlorophenol	mg/kg	N/A	N/A	N/A	0/18	0/18	0/18	N/A	0/18	8.77E-01	0/18	8.77E+01	0/18	0/18	0.68 - 2.2
SVOA	Phenanthrene	mg/kg	4.50E-02	6.00E-01	2.33E-01	2/21	3/21	0/21	N/A	0/21	1.38E+03	0/21	4.14E+04	0/21	1/21	0.33 - 0.5
SVOA	Phenol	mg/kg	1.80E+00	1.80E+00	1.80E+00	0/15	1/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.33 - 0.43
SVOA	p-Nitroaniline	mg/kg	N/A	N/A	N/A	0/15	0/15	0/15	N/A	0/15	N/A	0/15	N/A	N/A	N/A	0.75 - 2.2
SVOA	Pyrene	mg/kg	9.50E-02	6.80E-01	3.46E-01	2/21	4/21	0/21	N/A	0/21	6.89E+02	0/21	2.07E+04	0/21	0/21	0.33 - 0.5
SVOA	Pyridine	mg/kg	N/A	N/A	N/A	0/7	0/7	0/7	N/A	0/7	N/A	0/7	N/A	N/A	N/A	0.38 - 0.4
SVOA	Total PAH	mg/kg	5.19E-03	9.83E-02	4.40E-02	0/21	7/21	0/21	N/A	1/21	8.81E-02	0/21	8.81E+00	0/21	0/21	-
VOA	1,1,1-Trichloroethane	mg/kg	N/A	N/A	N/A	0/12	0/12	0/12	N/A	0/12	3.58E+03	0/12	1.00E+05	0/12	0/12	0.005 - 0.006
VOA	1,1,2,2-Tetrachloroethane	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	N/A	0/6	N/A	N/A	N/A	0.006 - 0.006
VOA	1,1,2-Trichloroethane	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	6.32E-01	0/6	1.90E+01	0/6	0/6	0.006 - 0.006
VOA	1,1-Dichloroethane	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	1.58E+01	0/6	1.58E+03	0/6	0/6	0.006 - 0.006
VOA	1,1-Dichloroethene	mg/kg	N/A	N/A	N/A	0/9	0/9	0/9	N/A	0/9	1.00E+02	0/9	3.00E+03	0/9	0/9	0.006 - 0.006
VOA	1,2-Dichloroethane	mg/kg	N/A	N/A	N/A	0/8	0/8	0/8	N/A	0/8	2.09E+00	0/8	2.09E+02	0/8	0/8	0.006 - 0.006
VOA	1,2-Dichloroethene	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	2.10E+03	0/6	6.30E+04	0/6	0/6	0.006 - 0.006
VOA	1,2-Dichloropropane	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	N/A	0/6	N/A	N/A	N/A	0.006 - 0.006
VOA	2-Butanone	mg/kg	N/A	N/A	N/A	0/9	0/9	0/9	N/A	0/9	N/A	0/9	N/A	N/A	N/A	0.011 - 0.013
VOA	2-Hexanone	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	N/A	0/6	N/A	N/A	N/A	0.011 - 0.013
VOA	4-Methyl-2-pentanone	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	N/A	0/6	N/A	N/A	N/A	0.011 - 0.013
VOA	Acetone	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	N/A	0/6	N/A	N/A	N/A	0.012 - 0.025
VOA	Benzene	mg/kg	N/A	N/A	N/A	0/9	0/9	0/9	N/A	0/9	5.31E+00	0/9	5.31E+02	0/9	0/9	0.006 - 0.006
VOA	Bromodichloromethane	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	1.30E+00	0/6	1.30E+02	0/6	0/6	0.006 - 0.006
VOA	Bromoform	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	N/A	0/6	N/A	N/A	N/A	0.006 - 0.006
VOA	Bromomethane	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	N/A	0/6	N/A	N/A	N/A	0.011 - 0.013
VOA	Carbon disulfide	mg/kg	1.00E-03	1.00E-03	1.00E-03	1/6	1/6	0/6	N/A	0/6	N/A	0/6	N/A	N/A	N/A	0.006 - 0.006
VOA	Carbon tetrachloride	mg/kg	N/A	N/A	N/A	0/9	0/9	0/9	N/A	0/9	2.96E+00	0/9	2.96E+02	0/9	0/9	0.006 - 0.006
VOA	Chlorobenzene	mg/kg	N/A	N/A	N/A	0/9	0/9	0/9	N/A	0/9	N/A	0/9	N/A	N/A	N/A	0.006 - 0.006
VOA	Chloroethane	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	N/A	0/6	N/A	N/A	N/A	0.011 - 0.013
VOA	Chloroform	mg/kg	4.00E-03	4.00E-03	4.00E-03	1/9	1/9	0/9	N/A	0/9	1.39E+00	0/9	1.39E+02	0/9	0/9	0.006 - 0.006

FOD = frequency of detection
FOE = frequency of exceedance
N/A = not applicable

Table 5.1. Surface Soil Data Summary: SWMU 1 (Continued)

			Detected Results			J-qualified		Provisional Background		Industrial Worker		Industrial Worker		GW Protection Screen		
Type	Analysis	Unit	Min	Max	Avg	FOD	FOD	FOE	Bkgd	FOE	NAL	FOE	AL	RGA	UCRS	DL Range
VOA	Chloromethane	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	N/A	0/6	N/A	N/A	N/A	0.011 - 0.013
VOA	cis-1,3-Dichloropropene	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	N/A	0/6	N/A	N/A	N/A	0.006 - 0.006
VOA	Dibromochloromethane	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	N/A	0/6	N/A	N/A	N/A	0.006 - 0.006
VOA	Ethylbenzene	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	2.66E+01	0/6	2.66E+03	0/6	0/6	0.006 - 0.006
VOA	Methylene chloride	mg/kg	6.00E-03	6.00E-03	6.00E-03	0/6	1/6	0/6	N/A	0/6	N/A	0/6	N/A	N/A	N/A	0.006 - 0.031
VOA	Styrene	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	N/A	0/6	N/A	N/A	N/A	0.006 - 0.006
VOA	Tetrachloroethene	mg/kg	N/A	N/A	N/A	0/9	0/9	0/9	N/A	0/9	4.00E+01	0/9	1.20E+03	0/9	0/9	0.006 - 0.006
VOA	Toluene	mg/kg	4.00E-03	4.00E-03	4.00E-03	1/6	1/6	0/6	N/A	0/6	6.25E+03	0/6	1.00E+05	0/6	0/6	0.006 - 0.006
VOA	Total Xylene	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	2.82E+02	0/6	8.46E+03	0/6	0/6	0.006 - 0.006
VOA	trans-1,3-Dichloropropene	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	N/A	0/6	N/A	N/A	N/A	0.006 - 0.006
VOA	Trichloroethene	mg/kg	1.00E-03	1.50E-02	9.00E-03	1/15	3/15	0/15	N/A	0/15	1.90E+00	0/15	5.70E+01	0/15	2/15	0.001 - 0.006
VOA	Vinyl acetate	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	N/A	0/6	N/A	N/A	N/A	0.011 - 0.013
VOA	Vinyl chloride	mg/kg	N/A	N/A	N/A	0/9	0/9	0/9	N/A	0/9	2.06E+00	0/9	2.06E+02	0/9	0/9	0.001 - 0.013
RADS	Alpha activity	pCi/g	3.44E+00	1.92E+01	1.07E+01	0/4	4/4	0/4	N/A	0/4	N/A	0/4	N/A	N/A	N/A	0.726 - 2.77
RADS	Americium-241	pCi/g	-1.94E-02	9.98E-01	2.32E-01	0/10	6/10	0/10	N/A	0/10	5.99E+00	0/10	5.99E+02	0/10	1/10	0.0183 - 0.05
RADS	Beta activity	pCi/g	5.38E+00	1.47E+01	9.40E+00	0/4	4/4	0/4	N/A	0/4	N/A	0/4	N/A	N/A	N/A	1.16 - 2.7
RADS	Cesium-137	pCi/g	8.78E-02	7.53E-01	3.17E-01	0/10	9/10	2/10	4.90E-01	8/10	1.02E-01	0/10	1.02E+01	0/10	2/10	0.0252 - 0.08
RADS	Cobalt-60	pCi/g	-2.26E-02	2.20E-02	-3.10E-03	0/6	6/6	0/6	N/A	0/6	N/A	0/6	N/A	N/A	N/A	0.03 - 0.08
RADS	Neptunium-237	pCi/g	-3.33E-03	6.63E-01	8.36E-02	0/10	9/10	1/10	1.00E-01	1/10	2.29E-01	0/10	2.29E+01	0/10	1/10	0.00812 - 0.04
RADS	Plutonium-238	pCi/g	-8.63E-03	1.11E-01	2.63E-02	0/10	6/10	1/10	7.30E-02	0/10	2.87E+01	0/10	2.87E+03	0/10	0/10	0.00955 - 0.04
RADS	Plutonium-239/240	pCi/g	2.21E-03	9.05E+00	1.34E+00	0/10	10/10	7/10	2.50E-02	0/10	2.47E+01	0/10	2.47E+03	0/10	4/10	0.0036 - 0.02
RADS	Technetium-99	pCi/g	3.43E-01	8.29E+00	3.07E+00	0/10	10/10	6/10	2.50E+00	0/10	1.20E+03	0/10	1.00E+05	9/10	10/10	0.582 - 3.27
RADS	Thorium-228	pCi/g	2.52E-01	1.06E+00	6.51E-01	0/10	10/10	0/10	1.60E+00	0/10	N/A	0/10	N/A	N/A	N/A	0.0329 - 0.0851
RADS	Thorium-230	pCi/g	3.37E-01	6.50E+01	9.84E+00	0/10	10/10	4/10	1.50E+00	1/10	3.39E+01	0/10	3.39E+03	0/10	3/10	0.0468 - 0.21
RADS	Thorium-232	pCi/g	1.59E-01	9.86E-01	6.53E-01	0/10	10/10	0/10	1.50E+00	0/10	N/A	0/10	N/A	N/A	N/A	0.00996 - 0.05
RADS	Uranium-234	pCi/g	4.70E-01	9.01E+00	2.54E+00	0/10	10/10	6/10	1.20E+00	0/10	5.53E+01	0/10	5.53E+03	4/10	10/10	0.0198 - 0.15
RADS	Uranium-235	pCi/g	2.26E-02	5.11E-01	1.44E-01	0/10	10/10	7/10	6.00E-02	1/10	3.40E-01	0/10	3.40E+01	0/10	8/10	0.00836 - 0.03
RADS	Uranium-238	pCi/g	5.97E-01	9.86E+00	3.05E+00	0/10	10/10	10/10	1.20E+00	6/10	1.60E+00	0/10	1.60E+02	4/10	10/10	0.0198 - 0.16

One or more samples exceed AL value. AL value is taken from Table A.1 of DOE 2016b.
One or more samples exceed NAL value. NAL value is taken from Table A.4 of DOE 2016b.
One or more samples exceed background value. Background value is taken from Table A.12 of DOE 2016b.
One or more samples exceed SSLs of RGA and UCRS groundwater protection. SSLs are taken from Tables A.7a and A.7b of DOE 2016b. SSLs use DAFs of 1 and 58 for the UCRS and RGA, respectively, based on MCLs, where available. Radionuclides use SSLs for 10-6 and 10-4 for the UCRS and RGA, respectively.

Summaries of analyses are based on the maximum detected result from a sample (i.e., if a sample has analytical results from two different labs, only the maximum value is summarized).
Field replicates, or separate samples are counted independently.

The uranium (metal)/uranium (isotopic) may not be from the same sample thus a correlation between uranium (metal)/uranium (isotopic) data may not be possible.

Uranium-238 that was analyzed using method RL-7128NITRIC is compared to a background value of 0.4 pCi/g.

FOD = frequency of detection
FOE = frequency of exceedance
N/A = not applicable

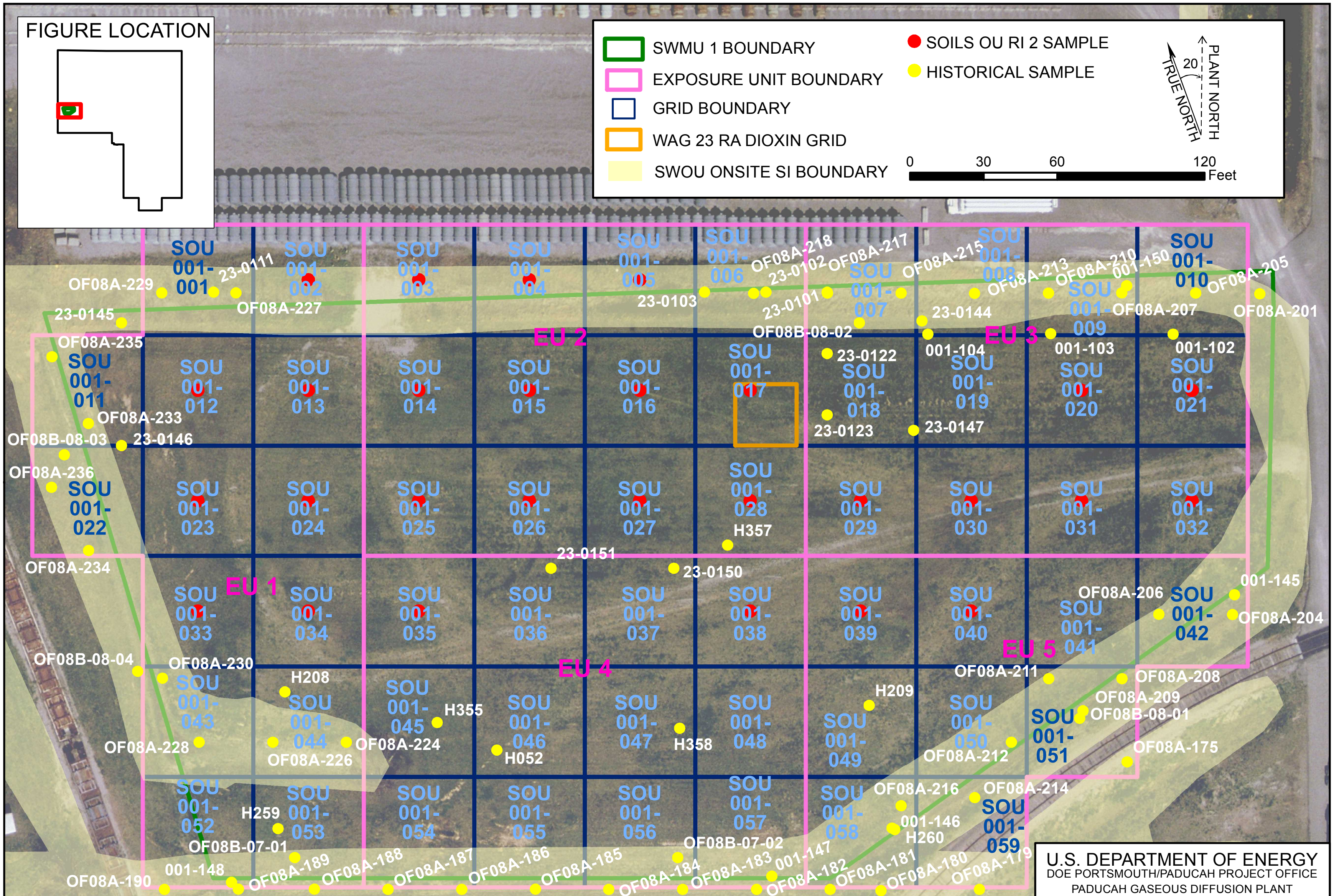

Figure 5.2. SWMU 1 Sample Locations—Surface Soil

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10/31/2016

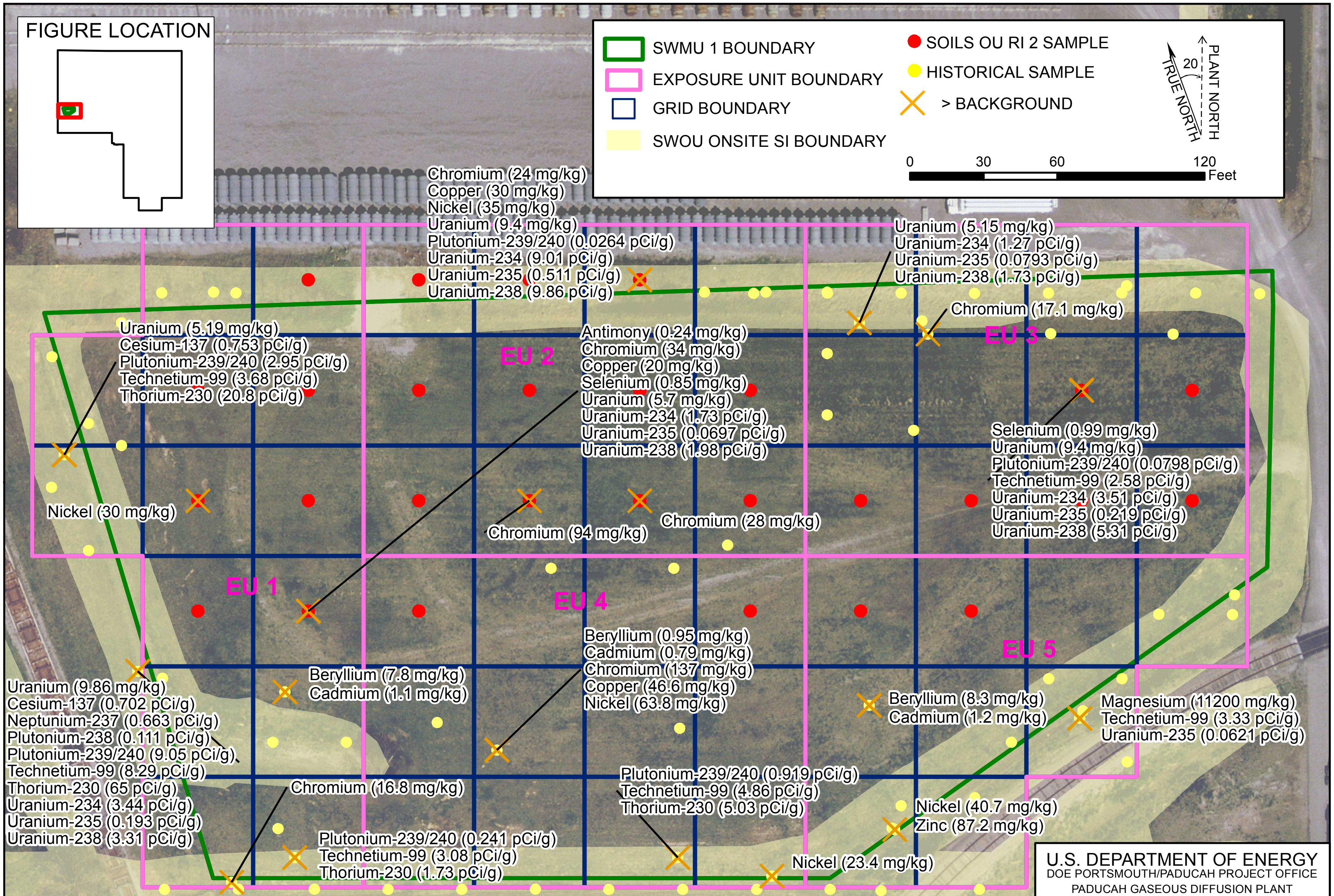

Figure 5.3. SWMU 1 Background Exceedances—Surface Soil

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10/31/2016

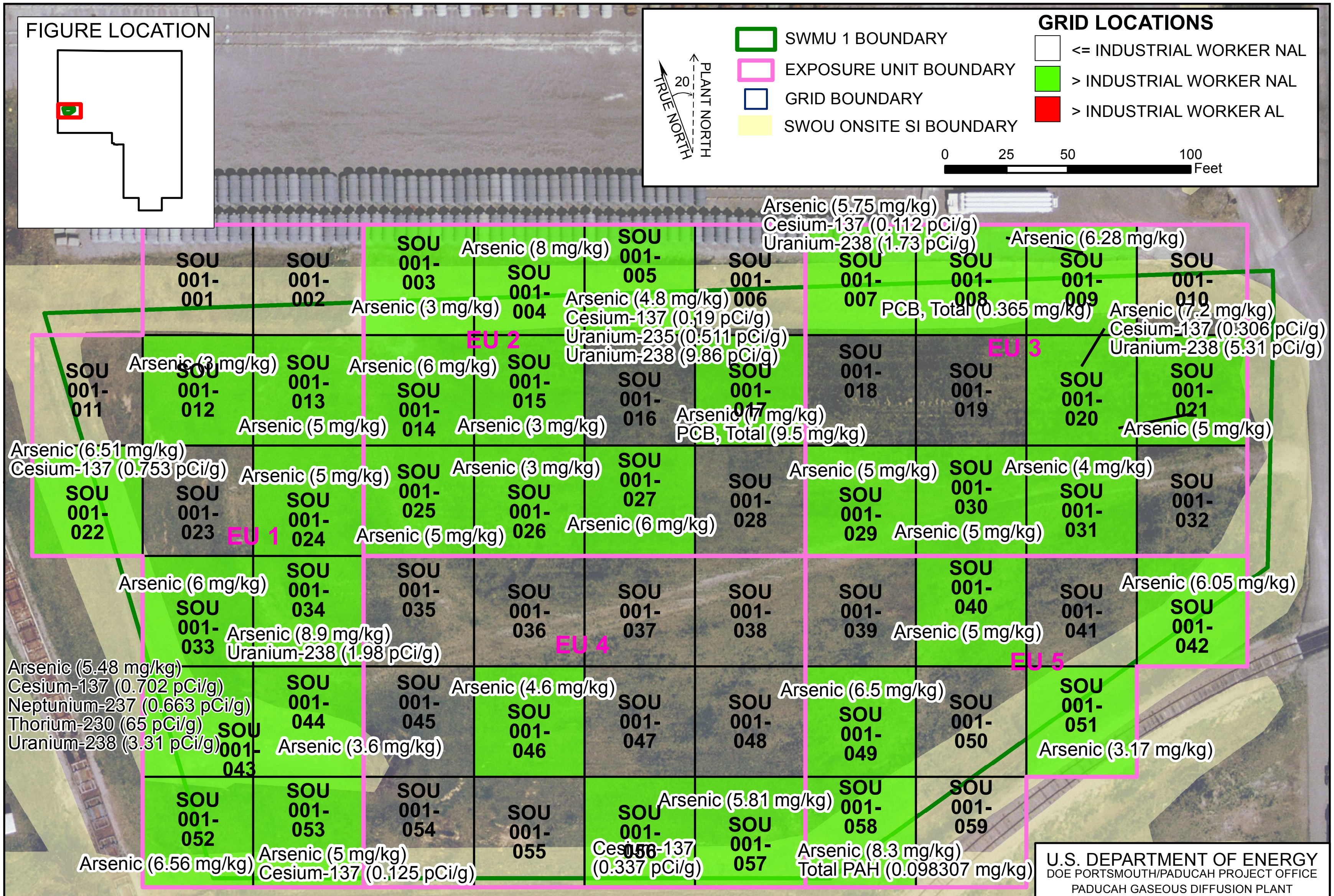

Figure 5.4. SWMU 1 NAL Exceedances—Surface Soil

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10/31/2016

Metals

No metals were detected in the surface soil above both the background screening level and the industrial worker NAL.

The following metals were detected in the SWMU 1 surface soil above both the SSLs for the protection of UCRS groundwater and the background screening levels (if available): beryllium (EU1, EU5), cadmium (EU1, EU4, EU5), copper (EU4), molybdenum (EU1, EU2, EU3, EU5), nickel (EU1, EU2, EU4, EU5), selenium (EU1, EU3), and zinc (EU5). Additionally, molybdenum (EU5) was detected above the SSL for the protection of RGA groundwater and the background screening level.

PCBs

PCBs were detected in EUs 2 and 3 above the industrial worker NAL for this unit. Total PCBs were detected in the SWMU 1 surface soil above the SSLs for the protection of UCRS groundwater in EUs 2, 3, 4, and 5 and above the SSL for the protection of RGA groundwater in EU2.

Semivolatile Organic Compounds (SVOCs)

Total PAHs (EU5) was detected above industrial worker NALs in the surface soil in SWMU 1.

Two SVOCs were detected in the SWMU 1 surface soil above the SSLs for the protection of UCRS groundwater: naphthalene (EU5) and phenanthrane (EU4). Additionally, naphthalene (EU5) was detected above the SSL for the protection of RGA groundwater.

VOCs

No volatile organic compounds (VOCs) were detected above the industrial worker NAL in surface soil for this unit. TCE was detected above the SSL for the protection of UCRS groundwater in EU3.

RADs

Cesium-137, neptunium-237, thorium-230, and uranium-238 were detected in the surface soil exceeding both the background screening level and industrial worker NAL values in EU1. Additionally, uranium-235 in EU2 and uranium-238 in EUs 2 and 3 were detected in the surface soil above both background and industrial worker NAL screening levels. No values exceeded the industrial worker AL value in the surface soil at SWMU 1.

Americium-241 (EU1), cesium-137 (EU1), neptunium-237 (EU1), plutonium-239/240 (EU1, EU4), Tc-99 (EU1, EU3, EU4, EU5), thorium-230 (EU1, EU4), uranium-234 (EU1, EU2, EU3), uranium-235 (EU1, EU2, EU3, EU5) and uranium-238 (EU1, EU2, EU3) were detected in the SWMU 1 surface soil above the SSLs for the protection of UCRS groundwater and the background screening levels. Additionally, the following were detected above the SSLs for the protection of RGA groundwater and the background screening level: Tc-99 (EU1, EU3, EU4, EU5), uranium-234 (EU1, EU2, EU3), and uranium-238 (EU1, EU2, EU3).

5.4 NATURE AND EXTENT OF CONTAMINATION—SUBSURFACE SOILS

The data summary presented in Table 5.2 provides the nature of the contamination in SWMU 1 subsurface soils with the post-deep soil mixing remedy values replacing the pre-deep soil mixing values

Table 5.2. Subsurface Soil Data Summary: SWMU 1

			Detected Results			J-qualified		Provisional Background		Industrial Worker		Industrial Worker		GW Protection Screen		
Type	Analysis	Unit	Min	Max	Avg	FOD	FOD	FOE	Bkgd	FOE	NAL	FOE	AL	RGA	UCRS	DL Range
METAL	Aluminum	mg/kg	1.04E+03	1.43E+04	7.72E+03	0/83	82/83	1/83	1.20E+04	0/83	1.00E+05	0/83	1.00E+05	0/83	81/83	1.3135 - 13.135
METAL	Antimony	mg/kg	1.30E-02	5.00E+00	1.08E+00	0/79	15/79	12/79	2.10E-01	0/79	9.34E+01	0/79	2.80E+03	0/79	11/79	0.0052 - 5.1
METAL	Arsenic	mg/kg	1.00E+00	1.67E+01	4.77E+00	0/111	105/111	8/111	7.90E+00	102/111	1.60E+00	0/111	1.60E+02	0/111	105/111	0.0827 - 4.6
METAL	Barium	mg/kg	1.27E+00	2.47E+02	1.11E+02	0/83	83/83	6/83	1.70E+02	0/83	4.04E+04	0/83	1.00E+05	0/83	66/83	0.0002 - 0.1709
METAL	Beryllium	mg/kg	5.94E-03	1.07E+00	4.98E-01	0/83	81/83	12/83	6.90E-01	0/83	4.50E+02	0/83	1.35E+04	0/83	0/83	0.0001 - 0.4
METAL	Cadmium	mg/kg	4.33E-03	3.35E+00	1.55E+00	0/83	47/83	34/83	2.10E-01	0/83	6.05E+01	0/83	1.82E+03	0/83	30/83	0.0004 - 0.971
METAL	Calcium	mg/kg	4.57E+02	1.00E+04	1.38E+03	0/83	83/83	2/83	6.10E+03	0/83	N/A	0/83	N/A	N/A	N/A	0.1 - 120
METAL	Chromium	mg/kg	1.29E-01	8.30E+01	1.49E+01	0/111	84/111	2/111	4.30E+01	0/111	1.98E+02	0/111	1.98E+04	0/111	0/111	0.0013 - 19
METAL	Cobalt	mg/kg	5.76E-02	1.54E+01	5.64E+00	0/83	82/83	3/83	1.30E+01	0/83	6.87E+01	0/83	2.06E+03	80/83	82/83	0.0008 - 3
METAL	Copper	mg/kg	2.09E-01	2.10E+01	1.07E+01	0/111	111/111	0/111	2.50E+01	0/111	9.34E+03	0/111	1.00E+05	0/111	0/111	0.0021 - 5
METAL	Iron	mg/kg	1.41E+02	2.54E+04	1.50E+04	0/111	111/111	0/111	2.80E+04	0/111	1.00E+05	0/111	1.00E+05	110/111	111/111	0.007 - 23.597
METAL	Lead	mg/kg	2.92E+00	2.60E+01	9.28E+00	0/111	85/111	1/111	2.30E+01	0/111	8.00E+02	0/111	8.00E+02	0/111	15/111	0.057 - 11
METAL	Magnesium	mg/kg	1.17E+02	2.63E+03	1.54E+03	0/83	83/83	9/83	2.10E+03	0/83	N/A	0/83	N/A	N/A	N/A	3.7451 - 12
METAL	Manganese	mg/kg	3.04E+00	2.16E+03	4.19E+02	0/111	111/111	10/111	8.20E+02	0/111	4.72E+03	0/111	1.00E+05	100/111	111/111	0.0003 - 18
METAL	Mercury	mg/kg	2.71E-04	1.52E-01	3.57E-02	3/111	62/111	1/111	1.30E-01	0/111	7.01E+01	0/111	2.10E+03	0/111	23/111	0 - 6
METAL	Molybdenum	mg/kg	2.40E+00	1.30E+01	7.33E+00	0/31	15/31	0/31	N/A	0/31	1.17E+03	0/31	3.51E+04	1/31	15/31	0.11 - 6
METAL	Nickel	mg/kg	2.98E-01	2.97E+01	1.33E+01	0/111	92/111	6/111	2.20E+01	0/111	4.30E+03	0/111	1.00E+05	0/111	91/111	0.0012 - 6.8
METAL	Selenium	mg/kg	8.91E-02	1.10E+00	3.80E-01	0/111	25/111	2/111	7.00E-01	0/111	1.17E+03	0/111	3.51E+04	0/111	12/111	0.0008 - 3
METAL	Silver	mg/kg	1.85E-03	7.39E+01	7.66E+00	0/111	9/111	3/111	2.70E+00	0/111	1.17E+03	0/111	3.51E+04	2/111	5/111	0.0017 - 10
METAL	Sodium	mg/kg	5.22E+00	5.70E+02	2.97E+02	3/83	79/83	28/83	3.40E+02	0/83	N/A	0/83	N/A	N/A	N/A	0.0272 - 121
METAL	Thallium	mg/kg	1.17E-01	1.56E+00	2.06E-01	0/83	31/83	1/83	3.40E-01	0/83	2.34E+00	0/83	7.02E+01	0/83	20/83	0.0053 - 9.3
METAL	Uranium	mg/kg	1.30E+00	7.80E+00	4.60E+00	0/31	3/31	2/31	4.60E+00	0/31	6.81E+02	0/31	2.04E+04	0/31	0/31	0.011 - 53
METAL	Vanadium	mg/kg	2.31E-01	5.33E+01	2.32E+01	0/111	82/111	3/111	3.70E+01	0/111	1.15E+03	0/111	3.45E+04	0/111	81/111	0.0014 - 8
METAL	Zinc	mg/kg	7.40E+00	1.65E+02	3.95E+01	0/111	111/111	14/111	6.00E+01	0/111	7.01E+04	0/111	1.00E+05	0/111	44/111	0.0806 - 3
PPCB	PCB, Total	mg/kg	6.30E-02	3.00E-01	1.93E-01	0/145	4/145	0/145	N/A	1/145	2.95E-01	0/145	2.95E+01	0/145	3/145	0.017 - 5
SVOA	1,2,4-Trichlorobenzene	mg/kg	N/A	N/A	N/A	0/89	0/89	0/89	N/A	0/89	N/A	0/89	N/A	N/A	N/A	0.006 - 2.5
SVOA	1,2-Dichlorobenzene	mg/kg	8.50E-02	1.20E-01	1.03E-01	2/91	2/91	0/91	N/A	0/91	N/A	0/91	N/A	N/A	N/A	0.006 - 2.5
SVOA	1,3-Dichlorobenzene	mg/kg	N/A	N/A	N/A	0/89	0/89	0/89	N/A	0/89	N/A	0/89	N/A	N/A	N/A	0.006 - 2.5
SVOA	1,4-Dichlorobenzene	mg/kg	N/A	N/A	N/A	0/89	0/89	0/89	N/A	0/89	N/A	0/89	N/A	N/A	N/A	0.006 - 2.5
SVOA	2,4,5-Trichlorophenol	mg/kg	N/A	N/A	N/A	0/90	0/90	0/90	N/A	0/90	N/A	0/90	N/A	N/A	N/A	0.33 - 2.5
SVOA	2,4,6-Trichlorophenol	mg/kg	N/A	N/A	N/A	0/90	0/90	0/90	N/A	0/90	N/A	0/90	N/A	N/A	N/A	0.33 - 2.5
SVOA	2,4-Dichlorophenol	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	2,4-Dimethylphenol	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	2,4-Dinitrophenol	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.8 - 5
SVOA	2,4-Dinitrotoluene	mg/kg	N/A	N/A	N/A	0/90	0/90	0/90	N/A	0/90	N/A	0/90	N/A	N/A	N/A	0.24 - 2.5
SVOA	2,6-Dinitrotoluene	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.24 - 2.5
SVOA	2-Chloronaphthalene	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	2-Chlorophenol	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	2-Methyl-4,6-dinitrophenol	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.8 - 2.5
SVOA	2-Methylnaphthalene	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	2-Methylphenol	mg/kg	N/A	N/A	N/A	0/90	0/90	0/90	N/A	0/90	N/A	0/90	N/A	N/A	N/A	0.33 - 2.5
SVOA	2-Nitrobenzenamine	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	2.87E+02	0/88	8.61E+03	0/88	0/88	0.8 - 2.5
SVOA	2-Nitrophenol	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	3,3'-Dichlorobenzidine	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.24 - 2.5
SVOA	3-Nitrobenzenamine	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.8 - 2.5
SVOA	4-Bromophenyl phenyl ether	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	4-Chloro-3-methylphenol	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	4-Chlorobenzenamine	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	4-Chlorophenyl phenyl ether	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	4-Nitrophenol	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.8 - 2.5
SVOA	Acenaphthene	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	1.38E+03	0/88	4.14E+04	0/88	0/88	0.33 - 2.5
SVOA	Acenaphthylene	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	1.38E+03	0/88	4.14E+04	0/88	0/88	0.33 - 2.5
SVOA	Anthracene	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	6.89E+03	0/88	1.00E+05	0/88	0/88	0.33 - 2.5

FOD = frequency of detection
FOE = frequency of exceedance
N/A = not applicable

Table 5.2. Subsurface Soil Data Summary: SWMU 1 (Continued)

			Detected Results			J-qualified		Provisional Background		Industrial Worker		Industrial Worker		GW Protection Screen		
Type	Analysis	Unit	Min	Max	Avg	FOD	FOD	FOE	Bkgd	FOE	NAL	FOE	AL	RGA	UCRS	DL Range
SVOA	Benzenemethanol	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	Benzo(ghi)perylene	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	Benzoic acid	mg/kg	6.60E-02	3.80E+00	1.93E+00	1/89	2/89	0/89	N/A	0/89	N/A	0/89	N/A	N/A	N/A	1.65 - 2.5
SVOA	Bis(2-chloroethoxy)methane	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	Bis(2-chloroethyl) ether	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	Bis(2-chloroisopropyl) ether	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	Bis(2-ethylhexyl)phthalate	mg/kg	6.20E-02	1.50E+00	3.13E-01	15/88	19/88	0/88	N/A	0/88	5.80E+01	0/88	5.80E+03	0/88	2/88	0.02 - 2.5
SVOA	Butyl benzyl phthalate	mg/kg	2.00E-01	2.00E-01	2.00E-01	1/88	1/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.02 - 2.5
SVOA	Dibenzofuran	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	Diethyl phthalate	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	Dimethyl phthalate	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	Di-n-butyl phthalate	mg/kg	5.00E-02	2.20E+01	3.60E+00	7/90	9/90	0/90	N/A	0/90	N/A	0/90	N/A	N/A	N/A	0.01 - 2.5
SVOA	Di-n-octylphthalate	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	Fluoranthene	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	9.19E+02	0/88	2.76E+04	0/88	0/88	0.33 - 2.5
SVOA	Fluorene	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	9.19E+02	0/88	2.76E+04	0/88	0/88	0.33 - 2.5
SVOA	Hexachlorobenzene	mg/kg	N/A	N/A	N/A	0/90	0/90	0/90	N/A	0/90	1.26E+00	0/90	1.26E+02	0/90	0/90	0.004 - 2.5
SVOA	Hexachlorobutadiene	mg/kg	N/A	N/A	N/A	0/91	0/91	0/91	N/A	0/91	N/A	0/91	N/A	N/A	N/A	0.006 - 2.5
SVOA	Hexachlorocyclopentadiene	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	Hexachloroethane	mg/kg	N/A	N/A	N/A	0/90	0/90	0/90	N/A	0/90	N/A	0/90	N/A	N/A	N/A	0.33 - 2.5
SVOA	Isophorone	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	m,p-Cresol	mg/kg	2.80E-01	2.30E+00	1.29E+00	1/9	2/9	0/9	N/A	0/9	N/A	0/9	N/A	N/A	N/A	0.4 - 2.4
SVOA	Naphthalene	mg/kg	N/A	N/A	N/A	0/89	0/89	0/89	N/A	0/89	1.67E+01	0/89	1.61E+03	0/89	0/89	0.006 - 2.5
SVOA	Nitrobenzene	mg/kg	N/A	N/A	N/A	0/90	0/90	0/90	N/A	0/90	N/A	0/90	N/A	N/A	N/A	0.33 - 2.5
SVOA	N-Nitroso-di-n-propylamine	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	1.16E-01	0/88	1.16E+01	0/88	0/88	0.33 - 2.5
SVOA	N-Nitrosodiphenylamine	mg/kg	6.40E-02	6.40E-02	6.40E-02	2/88	2/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.33 - 2.5
SVOA	Pentachlorophenol	mg/kg	1.10E-01	1.10E-01	1.10E-01	1/90	1/90	0/90	N/A	0/90	8.77E-01	0/90	8.77E+01	0/90	1/90	0.4 - 2.5
SVOA	Phenanthrene	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	1.38E+03	0/88	4.14E+04	0/88	0/88	0.33 - 2.5
SVOA	Phenol	mg/kg	5.40E-01	1.70E+01	5.16E+00	0/89	4/89	0/89	N/A	0/89	N/A	0/89	N/A	N/A	N/A	0.33 - 2.5
SVOA	p-Nitroaniline	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	N/A	0/88	N/A	N/A	N/A	0.8 - 5
SVOA	Pyrene	mg/kg	N/A	N/A	N/A	0/88	0/88	0/88	N/A	0/88	6.89E+02	0/88	2.07E+04	0/88	0/88	0.33 - 2.5
SVOA	Pyridine	mg/kg	N/A	N/A	N/A	0/6	0/6	0/6	N/A	0/6	N/A	0/6	N/A	N/A	N/A	0.4 - 2.4
SVOA	Total PAH	mg/kg	2.60E-04	2.96E-02	1.28E-02	0/88	3/88	0/88	N/A	0/88	8.81E-02	0/88	8.81E+00	0/88	0/88	-
VOA	1,1,1,2-Tetrachloroethane	mg/kg	N/A	N/A	N/A	0/1	0/1	0/1	N/A	0/1	N/A	0/1	N/A	N/A	N/A	-
VOA	1,1,1-Trichloroethane	mg/kg	1.30E-02	1.30E-02	1.30E-02	0/20	1/20	0/20	N/A	0/20	3.58E+03	0/20	1.00E+05	0/20	0/20	0.006 - 0.006
VOA	1,1,2,2-Tetrachloroethane	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	N/A	0/20	N/A	N/A	N/A	0.006 - 0.006
VOA	1,1,2-Trichloroethane	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	6.32E-01	0/20	1.90E+01	0/20	0/20	0.006 - 0.006
VOA	1,1-Dichloroethane	mg/kg	N/A	N/A	N/A	0/24	0/24	0/24	N/A	0/24	1.58E+01	0/24	1.58E+03	0/24	0/24	0.006 - 0.006
VOA	1,1-Dichloroethene	mg/kg	N/A	N/A	N/A	0/102	0/102	0/102	N/A	0/102	1.00E+02	0/102	3.00E+03	0/102	0/102	0.006 - 1
VOA	1,2-Dibromoethane	mg/kg	N/A	N/A	N/A	0/1	0/1	0/1	N/A	0/1	N/A	0/1	N/A	N/A	N/A	-
VOA	1,2-Dichloroethane	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	2.09E+00	0/20	2.09E+02	0/20	0/20	0.006 - 0.006
VOA	1,2-Dichloroethene	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	2.10E+03	0/20	6.30E+04	0/20	0/20	0.006 - 0.006
VOA	1,2-Dichloropropane	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	N/A	0/20	N/A	N/A	N/A	0.006 - 0.006
VOA	1,2-Dimethylbenzene	mg/kg	N/A	N/A	N/A	0/1	0/1	0/1	N/A	0/1	2.81E+02	0/1	8.43E+03	0/1	0/1	-
VOA	2-Butanone	mg/kg	N/A	N/A	N/A	0/18	0/18	0/18	N/A	0/18	N/A	0/18	N/A	N/A	N/A	0.011 - 0.013
VOA	2-Chloroethyl vinyl ether	mg/kg	N/A	N/A	N/A	0/1	0/1	0/1	N/A	0/1	N/A	0/1	N/A	N/A	N/A	-
VOA	2-Hexanone	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	N/A	0/20	N/A	N/A	N/A	0.011 - 0.013
VOA	4-Methyl-2-pentanone	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	N/A	0/20	N/A	N/A	N/A	0.011 - 0.013
VOA	Acetone	mg/kg	3.00E-03	1.20E-01	6.69E-02	1/20	8/20	0/20	N/A	0/20	N/A	0/20	N/A	N/A	N/A	0.006 - 0.069
VOA	Acrolein	mg/kg	N/A	N/A	N/A	0/1	0/1	0/1	N/A	0/1	N/A	0/1	N/A	N/A	N/A	-
VOA	Acrylonitrile	mg/kg	N/A	N/A	N/A	0/1	0/1	0/1	N/A	0/1	1.24E+00	0/1	1.24E+02	0/1	0/1	-
VOA	Benzene	mg/kg	9.00E-03	9.00E-03	9.00E-03	0/20	1/20	0/20	N/A	0/20	5.31E+00	0/20	5.31E+02	0/20	1/20	0.006 - 0.006
VOA	Bromodichloromethane	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	1.30E+00	0/20	1.30E+02	0/20	0/20	0.006 - 0.006
VOA	Bromoform	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	N/A	0/20	N/A	N/A	N/A	0.006 - 0.006

FOD = frequency of detection
FOE = frequency of exceedance
N/A = not applicable

Table 5.2. Subsurface Soil Data Summary: SWMU 1 (Continued)

Type	Analysis	Unit	Detected Results			J-qualified		Provisional Background		Industrial Worker		Industrial Worker		GW Protection Screen		
			Min	Max	Avg	FOD	FOD	FOE	Bkgd	FOE	NAL	FOE	AL	RGA	UCRS	DL Range
VOA	Bromomethane	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	N/A	0/20	N/A	N/A	N/A	0.011 - 0.013
VOA	Carbon disulfide	mg/kg	2.00E-03	2.00E-03	2.00E-03	4/20	4/20	0/20	N/A	0/20	N/A	0/20	N/A	N/A	N/A	0.006 - 0.006
VOA	Carbon tetrachloride	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	2.96E+00	0/20	2.96E+02	0/20	0/20	0.006 - 0.006
VOA	Chlorobenzene	mg/kg	1.00E-03	1.00E-03	1.00E-03	1/20	1/20	0/20	N/A	0/20	N/A	0/20	N/A	N/A	N/A	0.006 - 0.006
VOA	Chloroethane	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	N/A	0/20	N/A	N/A	N/A	0.011 - 0.013
VOA	Chloroform	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	1.39E+00	0/20	1.39E+02	0/20	0/20	0.006 - 0.006
VOA	Chloromethane	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	N/A	0/20	N/A	N/A	N/A	0.011 - 0.013
VOA	cis-1,2-Dichloroethene	mg/kg	N/A	N/A	N/A	0/83	0/83	0/83	N/A	0/83	4.67E+02	0/83	1.40E+04	0/83	0/83	0.4 - 1
VOA	cis-1,3-Dichloropropene	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	N/A	0/20	N/A	N/A	N/A	0.006 - 0.006
VOA	Dibromochloromethane	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	N/A	0/20	N/A	N/A	N/A	0.006 - 0.006
VOA	Dibromomethane	mg/kg	N/A	N/A	N/A	0/1	0/1	0/1	N/A	0/1	N/A	0/1	N/A	N/A	N/A	-
VOA	Dichlorodifluoromethane	mg/kg	N/A	N/A	N/A	0/1	0/1	0/1	N/A	0/1	3.68E+01	0/1	1.10E+03	0/1	0/1	-
VOA	Ethyl methacrylate	mg/kg	N/A	N/A	N/A	0/1	0/1	0/1	N/A	0/1	N/A	0/1	N/A	N/A	N/A	-
VOA	Ethylbenzene	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	2.66E+01	0/20	2.66E+03	0/20	0/20	0.006 - 0.006
VOA	Iodomethane	mg/kg	N/A	N/A	N/A	0/1	0/1	0/1	N/A	0/1	N/A	0/1	N/A	N/A	N/A	-
VOA	m,p-Xylene	mg/kg	N/A	N/A	N/A	0/1	0/1	0/1	N/A	0/1	2.82E+02	0/1	8.46E+03	0/1	0/1	-
VOA	Methylene chloride	mg/kg	4.40E-02	1.40E-01	7.34E-02	0/20	7/20	0/20	N/A	0/20	N/A	0/20	N/A	N/A	N/A	0.005 - 0.12
VOA	Styrene	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	N/A	0/20	N/A	N/A	N/A	0.006 - 0.006
VOA	Tetrachloroethene	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	4.00E+01	0/20	1.20E+03	0/20	0/20	0.006 - 0.006
VOA	Toluene	mg/kg	2.00E-03	3.00E-03	2.33E-03	3/20	3/20	0/20	N/A	0/20	6.25E+03	0/20	1.00E+05	0/20	0/20	0.006 - 0.006
VOA	Total Xylene	mg/kg	N/A	N/A	N/A	0/19	0/19	0/19	N/A	0/19	2.82E+02	0/19	8.46E+03	0/19	0/19	0.006 - 0.006
VOA	trans-1,2-Dichloroethene	mg/kg	1.00E-01	1.00E-01	1.00E-01	1/83	1/83	0/83	N/A	0/83	4.54E+01	0/83	1.36E+03	0/83	1/83	0.4 - 1
VOA	trans-1,3-Dichloropropene	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	N/A	0/20	N/A	N/A	N/A	0.006 - 0.006
VOA	trans-1,4-Dichloro-2-butene	mg/kg	N/A	N/A	N/A	0/1	0/1	0/1	N/A	0/1	N/A	0/1	N/A	N/A	N/A	-
VOA	Trichloroethene	mg/kg	6.00E-04	2.00E-01	7.19E-02	5/102	6/102	0/102	N/A	0/102	1.90E+00	0/102	5.70E+01	2/102	4/102	0.001 - 1
VOA	Trichlorofluoromethane	mg/kg	N/A	N/A	N/A	0/1	0/1	0/1	N/A	0/1	N/A	0/1	N/A	N/A	N/A	-
VOA	Vinyl acetate	mg/kg	N/A	N/A	N/A	0/20	0/20	0/20	N/A	0/20	N/A	0/20	N/A	N/A	N/A	0.011 - 0.013
VOA	Vinyl chloride	mg/kg	N/A	N/A	N/A	0/102	0/102	0/102	N/A	0/102	2.06E+00	0/102	2.06E+02	0/102	0/102	0.001 - 1
RADS	Alpha activity	pCi/g	4.01E+00	9.38E+00	6.13E+00	0/3	3/3	0/3	N/A	0/3	N/A	0/3	N/A	N/A	N/A	0.727 - 1.09
RADS	Americium-241	pCi/g	N/A	N/A	N/A	0/3	0/3	0/3	N/A	0/3	5.99E+00	0/3	5.99E+02	0/3	0/3	0.0209 - 0.0271
RADS	Beta activity	pCi/g	2.73E+00	6.55E+00	4.34E+00	0/3	3/3	0/3	N/A	0/3	N/A	0/3	N/A	N/A	N/A	1 - 1.1
RADS	Cesium-137	pCi/g	N/A	N/A	N/A	0/3	0/3	0/3	2.80E-01	0/3	1.02E-01	0/3	1.02E+01	0/3	0/3	0.0197 - 0.0234
RADS	Neptunium-237	pCi/g	1.30E-02	1.30E-02	1.30E-02	0/3	1/3	0/3	N/A	0/3	2.29E-01	0/3	2.29E+01	0/3	0/3	0.0088 - 0.0257
RADS	Plutonium-238	pCi/g	1.30E-02	1.30E-02	1.30E-02	0/3	1/3	0/3	N/A	0/3	2.87E+01	0/3	2.87E+03	0/3	0/3	0.0093 - 0.0152
RADS	Plutonium-239/240	pCi/g	1.08E-02	1.79E-02	1.44E-02	0/3	2/3	0/3	N/A	0/3	2.47E+01	0/3	2.47E+03	0/3	0/3	0.00365 - 0.0116
RADS	Technetium-99	pCi/g	8.53E-01	2.25E+00	1.55E+00	0/3	2/3	0/3	2.80E+00	0/3	1.20E+03	0/3	1.00E+05	2/3	2/3	0.554 - 1.42
RADS	Thorium-228	pCi/g	9.50E-01	1.00E+00	9.69E-01	0/3	3/3	0/3	1.60E+00	0/3	N/A	0/3	N/A	N/A	N/A	0.0288 - 0.0673
RADS	Thorium-230	pCi/g	9.06E-01	1.11E+00	1.03E+00	0/3	3/3	0/3	1.40E+00	0/3	3.39E+01	0/3	3.39E+03	0/3	0/3	0.0445 - 0.0617
RADS	Thorium-232	pCi/g	8.91E-01	9.87E-01	9.29E-01	0/3	3/3	0/3	1.50E+00	0/3	N/A	0/3	N/A	N/A	N/A	0.0118 - 0.0211
RADS	Uranium-234	pCi/g	9.30E-01	3.47E+00	2.03E+00	0/3	3/3	2/3	1.20E+00	0/3	5.53E+01	0/3	5.53E+03	1/3	3/3	0.007 - 0.0193
RADS	Uranium-235	pCi/g	3.04E-02	1.77E-01	9.27E-02	0/3	3/3	2/3	6.00E-02	0/3	3.40E-01	0/3	3.40E+01	0/3	2/3	0.00824 - 0.0249
RADS	Uranium-238	pCi/g	9.47E-01	3.91E+00	2.22E+00	0/3	3/3	2/3	1.20E+00	2/3	1.60E+00	0/3	1.60E+02	1/3	3/3	0.00694 - 0.0193

One or more samples exceed AL value. AL value is taken from Table A.1 of DOE 2016b.

One or more samples exceed NAL value. NAL value is taken from Table A.4 of DOE 2016b.

One or more samples exceed background value. Background value is taken from Table A.12 of DOE 2016b.

One or more samples exceed SSLs of RGA and UCRS groundwater protection. SSLs are taken from Tables A.7a and A.7b of DOE 2016b. SSLs use DAFs of 1 and 58 for the UCRS and RGA, respectively, based on MCLs, where available. Radionuclides use SSLs for 10-6 and 10-4 for the UCRS and RGA, respectively.

Summaries of analyses are based on the maximum detected result from a sample (i.e., if a sample has analytical results from two different labs, only the maximum value is summarized).
Field replicates, or separate samples are counted independently.

The uranium (metal)/uranium (isotopic) may not be from the same sample thus a correlation between uranium (metal)/uranium (isotopic) data may not be possible.

FOD = frequency of detection
FOE = frequency of exceedance
N/A = not applicable

for those locations that were disturbed by the remedy. Figures 5.5–5.7 illustrate the horizontal extent. A complete list of sampling results is provided in Appendix F. Grid numbers shown below are truncated from the figures. Figures contain the SWMU#–grid#, with zeros filling the appropriate spaces to make three digits.

The lateral extent of SWMU 1 subsurface soil contamination is considered defined adequately for supporting the BRA and FS. SWMU 1 consists of 5 EUs.

Metals

Arsenic (EU1, EU2, EU3, EU5) was detected in the subsurface soil above both the background screening level and the industrial worker NAL. No metals were detected above the industrial worker ALs in the subsurface soils.

The following metals were detected in the SWMU 1 subsurface soil above both the SSLs for the protection of UCRS groundwater and the background screening levels (if available): aluminum (EU1), antimony (EU1, EU3), arsenic (EU1, EU2, EU3, EU5), barium (EU1, EU2, EU3, EU5), cadmium (EU1, EU2, EU3, EU4, EU5), cobalt (EU1, EU5), lead (EU4), manganese (EU1, EU2, EU3, EU4, EU5), mercury (EU4), molybdenum (EU1, EU2, EU3, EU5), nickel (EU1, EU2, EU3, EU5), selenium (EU2, EU5), silver (EU2), thallium (EU1), vanadium (EU1, EU2, EU4), and zinc (EU1, EU2, EU4). Additionally, cobalt (EU1, EU5), manganese (EU1, EU2, EU3, EU4, EU5), molybdenum (EU1), and silver (EU2) were detected above the SSL for the protection of RGA groundwater and the background screening level.

PCBs

Total PCBs were detected above the industrial worker NAL in subsurface soils in EU2 of SWMU 1. Total PCBs (EU2, EU3, EU5) were detected above the SSL for the protection of UCRS groundwater, but not above the SSL for the protection of RGA groundwater.

SVOCs

No SVOCs were detected above NALs in the subsurface soils at SWMU 1. Two SVOCs, bis(2-ethylhexyl)phthalate (EU1, EU2) and pentachlorophenol (EU1) were detected above the SSLs for the protection of UCRS groundwater, but not above the SSLs for the protection of RGA groundwater.

VOCs

No VOCs were detected above NALs in the subsurface soils at SWMU 1. Benzene (EU4); *trans*-1,2-dichloroethene (EU2); and TCE (EU1, EU3, EU4) were detected in SWMU 1 subsurface soils above the SSLs for the protection of UCRS groundwater. TCE (EU2) also was detected above the SSLs for the protection of RGA groundwater.

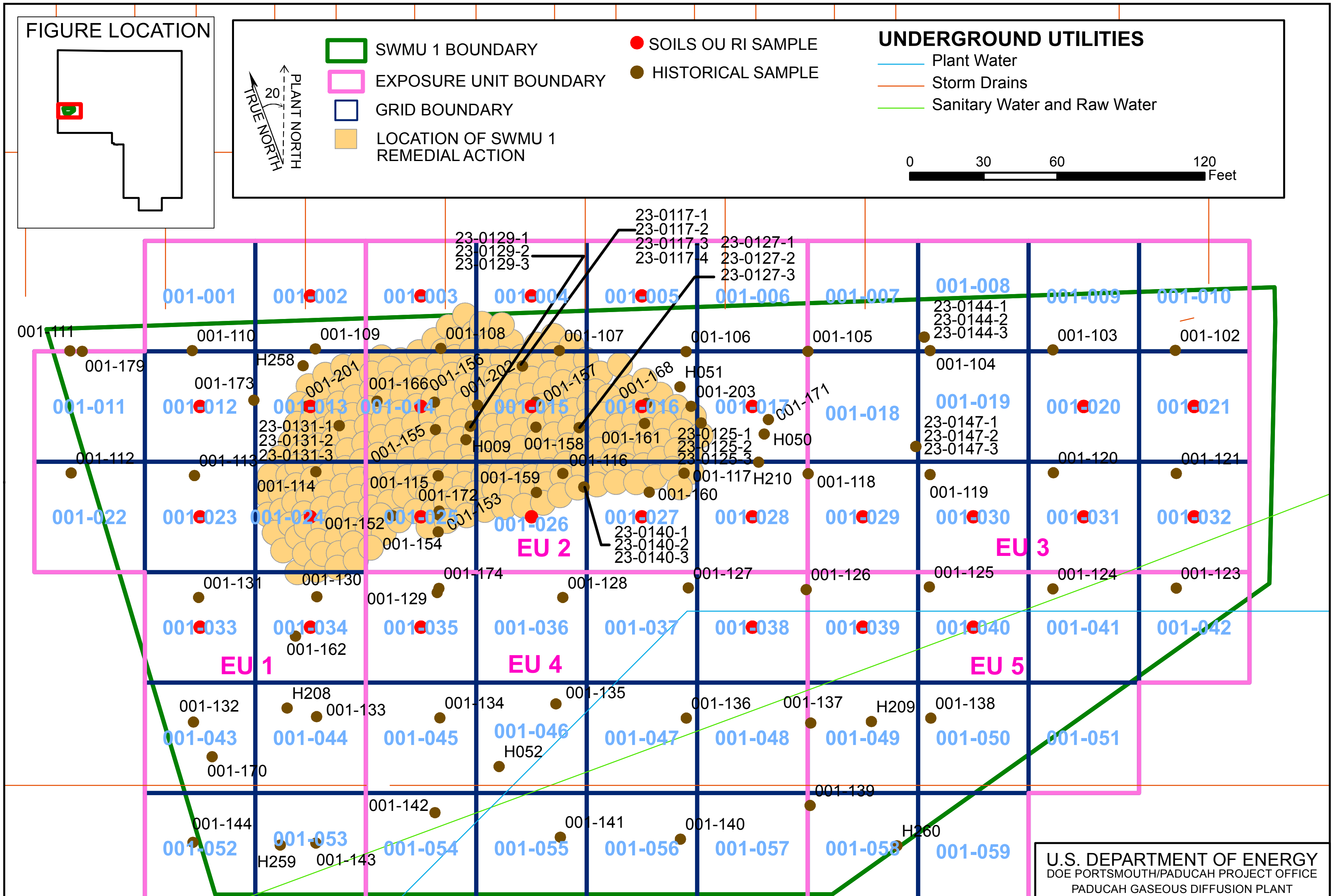

Figure 5.5. SWMU 1 Sample Locations—Subsurface Soil

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

FLUOR

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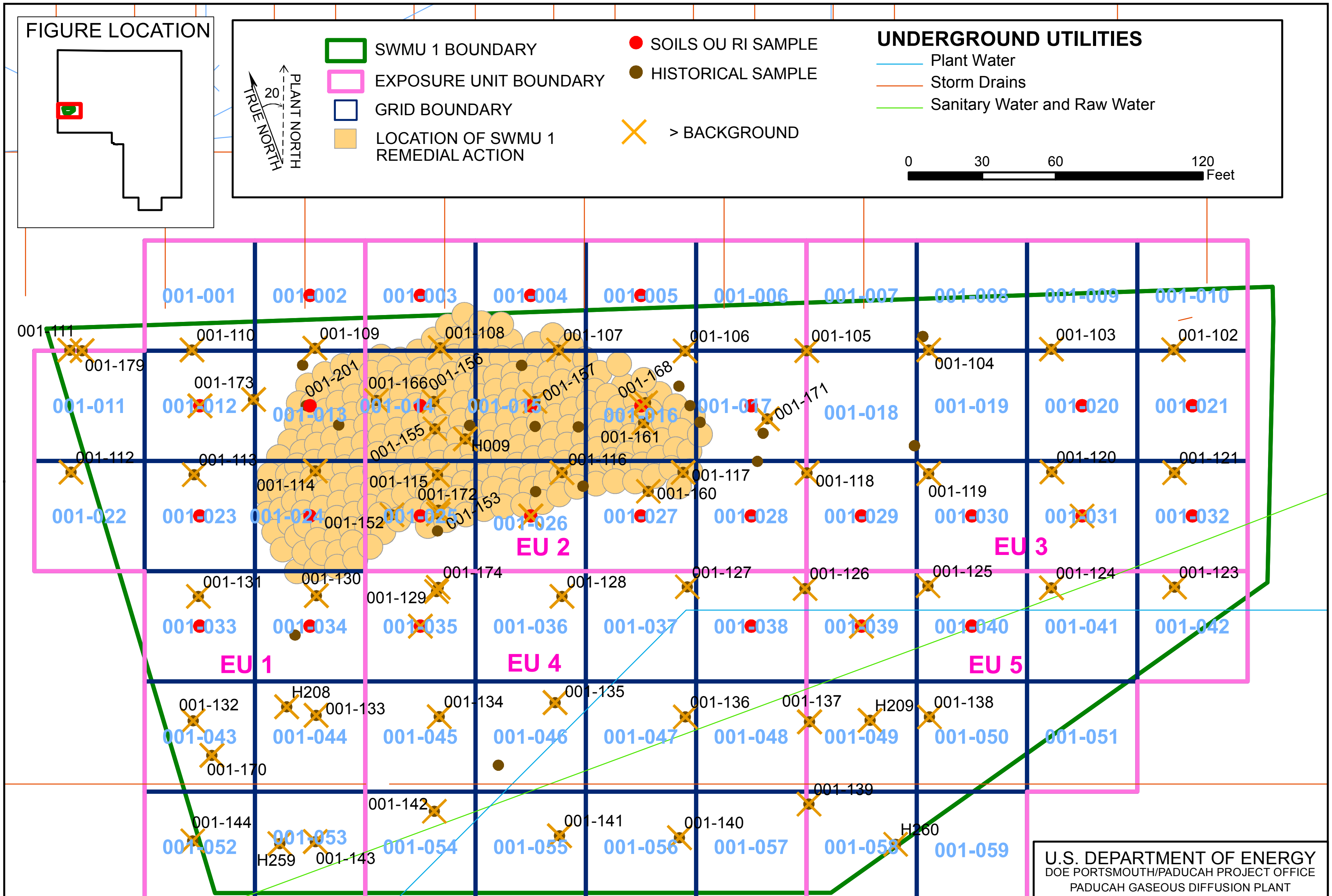

Figure 5.6. SWMU 1 Background Exceedances—Subsurface Soil

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001-102	Antimony (0.784 mg/kg)
	Sodium (492 mg/kg)
001-103	Cadmium (1.65 mg/kg)
	Sodium (480 mg/kg)
001-104	Cadmium (2.19 mg/kg)
	Sodium (556 mg/kg)
001-105	Sodium (476 mg/kg)
	Cadmium (2.32 mg/kg)
001-106	Sodium (434 mg/kg)
	Cadmium (2.48 mg/kg)
001-107	Cadmium (2.82 mg/kg)
001-108	Barium (181 mg/kg)
	Cadmium (2.83 mg/kg)
	Nickel (26.2 mg/kg)
	Sodium (405 mg/kg)
001-109	Antimony (1.32 mg/kg)
	Magnesium (2190 mg/kg)
	Sodium (418 mg/kg)
001-110	Antimony (1.4 mg/kg)
	Magnesium (2160 mg/kg)
	Nickel (26.8 mg/kg)
	Sodium (431 mg/kg)
001-111	Antimony (1.11 mg/kg)
	Sodium (393 mg/kg)
001-112	Cadmium (2.81 mg/kg)
	Sodium (419 mg/kg)
001-113	Antimony (0.638 mg/kg)
001-114	Arsenic (10.7 mg/kg)
	Cadmium (3.08 mg/kg)
	Magnesium (2110 mg/kg)
001-115	Arsenic (9.41 mg/kg)
	Barium (174 mg/kg)
	Cadmium (3.13 mg/kg)
001-116	Barium (175 mg/kg)
	Cadmium (0.997 mg/kg)
	Sodium (350 mg/kg)
001-117	Cadmium (3.2 mg/kg)
	Sodium (410 mg/kg)
001-118	Cadmium (3.32 mg/kg)
	Magnesium (2310 mg/kg)
	Sodium (570 mg/kg)
001-119	Arsenic (10.5 mg/kg)
	Barium (197 mg/kg)
	Cadmium (2.9 mg/kg)
	Manganese (881 mg/kg)
	Nickel (29.7 mg/kg)
	Sodium (534 mg/kg)
001-120	Cadmium (2.68 mg/kg)
	Sodium (487 mg/kg)
001-121	Cadmium (2.17 mg/kg)
	Sodium (446 mg/kg)
001-123	Cadmium (2.35 mg/kg)
	Sodium (471 mg/kg)
001-124	Cadmium (1.5 mg/kg)
	Sodium (417 mg/kg)
001-125	Cadmium (2.23 mg/kg)
001-126	Cadmium (1.52 mg/kg)
001-127	Cadmium (2.66 mg/kg)
001-128	Cadmium (2.46 mg/kg)
	Magnesium (2520 mg/kg)
001-129	Cadmium (0.513 mg/kg)
	Zinc (60.8 mg/kg)
001-130	Antimony (0.934 mg/kg)
	Beryllium (0.745 mg/kg)
001-131	Antimony (1.72 mg/kg)
001-132	Antimony (0.633 mg/kg)
001-133	Antimony (1.51 mg/kg)
	Sodium (388 mg/kg)
001-134	Beryllium (1.07 mg/kg)
	Cadmium (3.35 mg/kg)
	Magnesium (2450 mg/kg)
001-135	Cadmium (2.21 mg/kg)
	Sodium (372 mg/kg)
001-136	Cadmium (2.74 mg/kg)
	Mercury (0.152 mg/kg)
001-137	Arsenic (16.7 mg/kg)
	Barium (215 mg/kg)
	Beryllium (0.936 mg/kg)
	Cadmium (2.97 mg/kg)
	Cobalt (13.3 mg/kg)
	Manganese (2160 mg/kg)
	Nickel (24 mg/kg)
	Sodium (350 mg/kg)
001-138	Cadmium (1.99 mg/kg)
001-139	Cadmium (1.48 mg/kg)
001-140	Beryllium (0.776 mg/kg)
	Cadmium (0.22 mg/kg)
	Magnesium (2630 mg/kg)
	Sodium (421 mg/kg)
	Zinc (108 mg/kg)
001-141	Cadmium (0.212 mg/kg)
	Magnesium (2140 mg/kg)
	Zinc (75.8 mg/kg)
001-142	Zinc (118 mg/kg)
001-143	Aluminum (14300 mg/kg)
	Arsenic (10.6 mg/kg)
	Beryllium (0.767 mg/kg)
	Manganese (1080 mg/kg)
001-144	Zinc (60.2 mg/kg)
001-152	Cadmium (0.284 mg/kg)
	Zinc (70.1 mg/kg)
001-153	Zinc (64.7 mg/kg)
001-155	Zinc (73.3 mg/kg)
001-156	Zinc (63.6 mg/kg)
001-157	Zinc (165 mg/kg)
001-160	Sodium (409 mg/kg)
001-161	Zinc (80.7 mg/kg)
001-166	Sodium (354 mg/kg)
001-168	Zinc (78.9 mg/kg)
001-170	Barium (247 mg/kg)
	Beryllium (0.802 mg/kg)
	Cobalt (15.4 mg/kg)
	Manganese (1990 mg/kg)
	Thallium (1.56 mg/kg)

Figure 5.6. SWMU 1 Background Exceedances—Subsurface Soil (Continued)

001-171	Arsenic (11.5 mg/kg) Beryllium (0.757 mg/kg) Manganese (902 mg/kg) Nickel (27 mg/kg) Silver (73.9 mg/kg) Zinc (85.3 mg/kg)
001-172	Cadmium (1.67 mg/kg)
001-173	Beryllium (0.715 mg/kg) Sodium (489 mg/kg)
001-174	Sodium (401 mg/kg) Vanadium (40.2 mg/kg)
001-179	Antimony (0.552 mg/kg) Beryllium (0.699 mg/kg) Cadmium (0.287 mg/kg) Chromium (56.2 mg/kg) Vanadium (53.3 mg/kg)

H009	Beryllium (0.95 mg/kg) Manganese (847.6 mg/kg) Silver (2.9 mg/kg) Vanadium (37.5 mg/kg)
H208	Antimony (5 mg/kg) Manganese (1290 mg/kg)
H209	Cobalt (14.3 mg/kg) Manganese (1500 mg/kg) Sodium (427 mg/kg)
H259	Magnesium (2120 mg/kg)
H260	Beryllium (0.72 mg/kg)
SOU001-012	Calcium (10000 mg/kg) Uranium (7.8 mg/kg) Uranium-234 (3.47 pCi/g) Uranium-235 (0.177 pCi/g) Uranium-238 (3.91 pCi/g)

SOU001-016	Nickel (23 mg/kg)
SOU001-026	Antimony (0.23 mg/kg) Arsenic (8.7 mg/kg) Calcium (9700 mg/kg) Selenium (0.87 mg/kg) Silver (12 mg/kg) Uranium (4.7 mg/kg) Uranium-234 (1.69 pCi/g) Uranium-235 (0.0707 pCi/g) Uranium-238 (1.8 pCi/g)
SOU001-031	Chromium (83 mg/kg)
SOU001-035	Lead (26 mg/kg) Manganese (1077 mg/kg)
SOU001-039	Arsenic (10 mg/kg) Manganese (850 mg/kg) Selenium (1.1 mg/kg)

Figure 5.6. SWMU 1 Background Exceedances—Subsurface Soil (Continued)

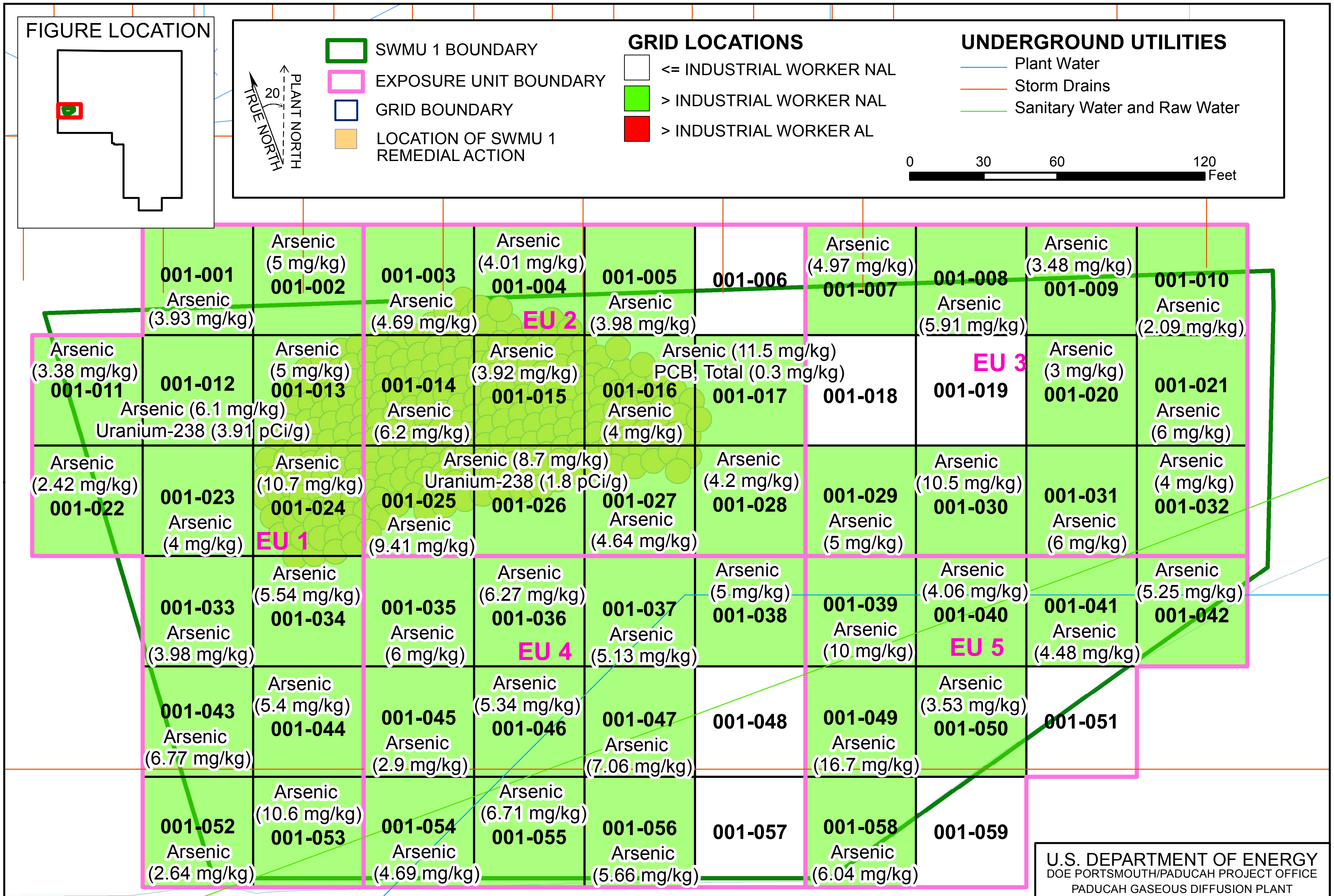

Figure 5.7. SWMU 1 NAL Exceedances—Subsurface Soil

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RADs

Uranium-238 (EU1, EU2) was detected in the subsurface soil exceeding both the background screening level and industrial worker NAL values. No RADs exceeded the industrial worker AL value in the subsurface soil at SWMU 1.

Uranium-234 (EU1, EU2), uranium-235 (EU1, EU2) and uranium-238 (EU1, EU2) were detected in the SWMU 1 surface soil above the SSLs for the protection of UCRS groundwater and the background screening levels. Additionally, uranium-234 and uranium-238 (both in EU1) were detected above the SSLs for the protection of RGA groundwater and the background screening level.

5.5 COMPARISON OF RI AND HISTORICAL SURFACE AND SUBSURFACE SOIL DATA SETS

The detected concentrations in the RI and historical datasets for SWMU 1 surface and subsurface soil are compared in Tables 5.3 and 5.4, respectively. The historical data set is that in the Soils OU RI Report (DOE 2013a). The RI dataset included the results found in the historical dataset, except that newly collected results replace historical results from the area disturbed by the deep soil mixing action. The expectation was that the average concentrations for analytes in the two datasets would be similar, allowing the use of historical data for the RI to characterize the nature and extent of contamination and complete the baseline risk assessment. Although some difference are seen in the average concentrations, the general conclusion is that the two datasets are similar and that the replacement of historical results from the area disturbed by the deep soil mixing with newly collected sampling results from that area yielded a dataset that meets project DQOs.

The constituent concentrations in surface soil summarized by Table 5.1 were compared to the surface soil constituent concentrations summarized by Table 5.1.1 of the Soils OU RI Report (DOE 2013a). A comparison is presented in Table 5.3. The concentrations of each constituent in the data set representing current conditions were compared to the concentrations in the historical data set to determine if the data were comparable. The data were found to be comparable, as demonstrated in part by the small RPD between the current data average (Table 5.1) and the historical data average. The deep soil mixing was not expected to change the mean concentration significantly, but may have reduced the range of concentrations due to the homogenization of the soils.

Selenium results are not considered different from one another because the historical data had only 1 of 23 samples exceed the background (with a maximum value of 0.980 mg/kg), while the current data had 3 of 52 samples exceed the background (with a maximum value of 0.990 mg/kg). In addition, the average selenium values did not exceed the industrial worker NAL of 1,170 mg/kg (DOE 2016b).

Although the average uranium concentrations were two orders of magnitude below the industrial worker NAL, the isotopic uranium concentrations of recent samples had more above-background detections; thus, isotopic uranium concentrations had a higher average soil concentration (that exceeded background).The average isotopic uranium concentrations in detected results (2.54 and 0.144 pCi/g for uranium-234 and -235, respectively) did not exceed the respective industrial worker NALs of 55.3 and 0.34 pCi/g. The average uranium-238 concentration in detected results (3.05 pCi/g) exceeded the industrial worker NAL of 1.60, but was within the same order of magnitude (DOE 2016b).

Table 5.3. Comparison of Detected Results in RI and Historical Surface Soil Data Sets

Analysis	Unit	RI Data Set Detected Results (See Table 5.1)			Historically Detected Results (See Table 5.1.1 of DOE 2013a)		
		Min	Max	Avg	Min	Max	Avg
Metals							
Aluminum	mg/kg	4.29E+03	1.11E+04	7.61E+03	4.29E+03	1.24E+04	7.91E+03
Antimony	mg/kg	1.60E-01	2.40E-01	1.85E-01	N/A	N/A	N/A
Arsenic	mg/kg	3.00E+00	8.90E+00	5.53E+00	3.17E+00	9.00E+00	5.84E+00
Barium	mg/kg	3.74E+01	1.24E+02	8.62E+01	3.74E+01	1.59E+02	9.12E+01
Beryllium	mg/kg	4.10E-01	8.30E+00	1.44E+00	4.67E-01	1.05E+01	2.14E+00
Cadmium	mg/kg	7.10E-02	1.20E+00	4.97E-01	7.90E-01	6.50E+00	3.20E+00
Calcium	mg/kg	2.29E+01	3.10E+04	6.15E+03	2.29E+01	3.10E+04	4.72E+03
Chromium	mg/kg	4.50E+00	1.37E+02	2.19E+01	4.50E+00	2.58E+02	2.79E+01
Cobalt	mg/kg	3.40E+00	1.20E+01	6.12E+00	3.40E+00	1.37E+01	6.58E+00
Copper	mg/kg	6.00E+00	4.66E+01	1.38E+01	6.70E+00	2.31E+02	2.31E+01
Iron	mg/kg	4.46E+03	2.40E+04	1.53E+04	9.13E+03	1.83E+04	1.36E+04
Lead	mg/kg	1.02E-01	2.30E+01	1.53E+01	1.02E-01	3.23E+02	3.34E+01
Magnesium	mg/kg	8.34E+02	1.12E+04	1.81E+03	8.34E+02	1.12E+04	1.78E+03
Manganese	mg/kg	4.39E+00	1.20E+03	4.61E+02	4.39E+00	1.06E+03	5.17E+02
Mercury	mg/kg	1.90E-02	1.80E-01	5.27E-02	1.99E-02	7.70E+00	1.17E+00
Molybdenum	mg/kg	6.90E-01	1.42E+01	7.35E+00	1.42E+01	1.42E+01	1.42E+01
Nickel	mg/kg	4.95E+00	6.38E+01	1.68E+01	4.95E+00	8.54E+01	2.04E+01
Selenium	mg/kg	1.71E-01	9.90E-01	5.94E-01	1.71E-01	9.80E-01	3.84E-01
Silver	mg/kg	2.20E-02	1.20E-01	5.29E-02	4.25E+01	4.25E+01	4.25E+01
Sodium	mg/kg	4.96E+01	1.81E+02	8.88E+01	4.46E+01	1.81E+02	8.58E+01
Thallium	mg/kg	1.30E-01	1.80E-01	1.55E-01	3.70E-01	3.70E-01	3.70E-01
Uranium	mg/kg	2.86E+00	9.86E+00	6.83E+00	2.86E+00	9.86E+00	5.07E+00
Vanadium	mg/kg	2.53E-01	3.30E+01	2.15E+01	2.53E-01	4.21E+01	2.08E+01
Zinc	mg/kg	2.31E+01	8.72E+01	3.78E+01	2.31E+01	3.90E+02	6.01E+01
PCBs							
PCB, Total	mg/kg	1.30E-02	9.50E+00	1.49E+00	2.00E-02	3.50E+01	1.57E+00
SVOCs							
2-Methylnaphthalene	mg/kg	9.00E-02	9.00E-02	9.00E-02	9.00E-02	9.00E-02	9.00E-02
Bis(2-ethylhexyl)phthalate	mg/kg	8.90E-02	1.60E-01	1.13E-01	8.90E-02	4.00E-01	1.67E-01
Di-n-butyl phthalate	mg/kg	6.70E-02	6.70E-02	6.70E-02	5.70E-02	6.70E-02	6.20E-02
Fluoranthene	mg/kg	8.30E-02	6.20E-01	3.54E-01	8.30E-02	6.20E-01	3.54E-01
Naphthalene	mg/kg	6.30E-02	6.30E-02	6.30E-02	6.30E-02	6.30E-02	6.30E-02
Phenanthrene	mg/kg	4.50E-02	6.00E-01	2.33E-01	4.50E-02	6.00E-01	2.33E-01
Phenol	mg/kg	1.80E+00	1.80E+00	1.80E+00	1.80E+00	1.80E+00	1.80E+00
Pyrene	mg/kg	9.50E-02	6.80E-01	3.46E-01	9.50E-02	6.80E-01	3.46E-01
Total PAH	mg/kg	5.19E-03	9.83E-02	4.40E-02	7.93E-02	9.83E-02	8.84E-02
VOCs							
Carbon disulfide	mg/kg	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
Chloroform	mg/kg	4.00E-03	4.00E-03	4.00E-03	4.00E-03	4.00E-03	4.00E-03
Methylene chloride	mg/kg	6.00E-03	6.00E-03	6.00E-03	6.00E-03	6.00E-03	6.00E-03
Toluene	mg/kg	4.00E-03	4.00E-03	4.00E-03	4.00E-03	4.00E-03	4.00E-03
Trichloroethene	mg/kg	1.00E-03	1.50E-02	9.00E-03	1.00E-03	1.50E-02	9.00E-03
RADs							
Americium-241	pCi/g	-1.94E-02	9.98E-01	2.32E-01	-1.94E-02	9.98E-01	2.32E-01
Cesium-137	pCi/g	8.78E-02	7.53E-01	3.17E-01	8.78E-02	7.53E-01	3.53E-01
Cobalt-60	pCi/g	-2.26E-02	2.20E-02	-3.10E-03	-2.26E-02	2.20E-02	-3.10E-03
Neptunium-237	pCi/g	-3.33E-03	6.63E-01	8.36E-02	-3.33E-03	6.63E-01	1.14E-01
Plutonium-238	pCi/g	-8.63E-03	1.11E-01	2.63E-02	-8.63E-03	1.11E-01	2.63E-02
Plutonium-239/240	pCi/g	2.21E-03	9.05E+00	1.34E+00	2.21E-03	9.05E+00	2.20E+00
Technetium-99	pCi/g	3.43E-01	8.29E+00	3.07E+00	3.43E-01	8.29E+00	3.93E+00
Thorium-228	pCi/g	2.52E-01	1.06E+00	6.51E-01	2.52E-01	7.64E-01	4.46E-01
Thorium-230	pCi/g	3.37E-01	6.50E+01	9.84E+00	3.37E-01	6.50E+01	1.56E+01
Thorium-232	pCi/g	1.59E-01	9.86E-01	6.53E-01	1.59E-01	7.94E-01	4.79E-01

Table 5.3. Comparison of Detected Results in RI and Historical Surface Soil Summary Data Sets (Continued)

Analysis	Unit	RI Data Set Detected Results (See Table 5.1)			Historically Detected Results (See Table 5.1.1 of DOE 2013a)		
		Min	Max	Avg	Min	Max	Avg
Uranium-234	pCi/g	4.70E-01	9.01E+00	2.54E+00	4.70E-01	3.44E+00	1.27E+00
Uranium-235	pCi/g	2.26E-02	5.11E-01	1.44E-01	2.26E-02	1.93E-01	7.21E-02
Uranium-238	pCi/g	5.97E-01	9.86E+00	3.05E+00	5.97E-01	3.31E+00	1.36E+00

The constituent concentrations in subsurface soil summarized by Table 5.2 were compared to the subsurface soil constituent concentrations summarized by Table 5.1.2 of the Soils OU RI Report (DOE 2013a). During the deep soil mixing project, 139 tons of quick lime were added to the area to stabilize soils. The majority of the impact expected on soil concentrations would be to soils deeper than four ft bgs. Although the soils physical properties may have been affected by raising pH, the mean concentrations of constituents are not expected to vary significantly. A comparison is presented in Table 5.4. The average concentration of each constituent typically was lower after deep soil mixing, as demonstrated by the negative RPD between the current data average (Table 5.1) and the historical data average.

Table 5.4 indicates only selenium has a positive RPD over 50%. The average selenium concentration is less than the background values. Molybdenum and uranium results were not reported in Table 5.1.2, thus, the current concentrations (that have averages below the background values) were not able to be compared to historical results; however, the found average values also are below background levels.

In a manner similar to that for surface soils, the average uranium concentrations were two orders of magnitude below the industrial worker NAL; however, the isotopic uranium concentrations for two of the three samples exceeded background, and two of the three U-238 samples exceeded the industrial worker NAL.

In addition, the average selenium, molybdenum, and uranium values did not exceed the industrial worker NALs (1,170 mg/kg; 1,170 mg/kg; and 681 mg/kg, respectively) (DOE 2016b).

Table 5.4. Comparison of Detected Results in RI and Historical Subsurface Soil Data Sets

Analysis	Unit	Detected Results (See Table 5.2)			Historically Detected Results (See Table 5.1.2 of DOE 2013a)		
		Min	Max	Avg	Min	Max	Avg
			Metals				
Aluminum	mg/kg	1.04E+03	1.43E+04	7.72E+03	1.04E+03	1.43E+04	7.68E+03
Antimony	mg/kg	1.30E-02	5.00E+00	1.08E+00	1.30E-02	5.00E+00	1.30E+00
Arsenic	mg/kg	1.00E+00	1.67E+01	4.77E+00	1.00E+00	1.67E+01	4.70E+00
Barium	mg/kg	1.27E+00	2.47E+02	1.11E+02	1.27E+00	2.47E+02	1.12E+02
Beryllium	mg/kg	5.94E-03	1.07E+00	4.98E-01	5.94E-03	1.07E+00	4.95E-01
Cadmium	mg/kg	4.33E-03	3.35E+00	1.55E+00	4.33E-03	3.35E+00	1.65E+00
Calcium	mg/kg	4.57E+02	1.00E+04	1.38E+03	4.57E+02	3.24E+03	1.17E+03
Chromium	mg/kg	1.29E-01	8.30E+01	1.49E+01	1.29E-01	6.35E+01	1.39E+01
Cobalt	mg/kg	5.76E-02	1.54E+01	5.64E+00	5.76E-02	1.54E+01	5.62E+00
Copper	mg/kg	2.09E-01	2.10E+01	1.07E+01	2.09E-01	6.01E+01	1.08E+01
Iron	mg/kg	1.41E+02	2.54E+04	1.50E+04	1.41E+02	2.48E+04	1.39E+04
Lead	mg/kg	2.92E+00	2.60E+01	9.28E+00	2.92E+00	7.04E+01	9.29E+00
Magnesium	mg/kg	1.17E+02	2.63E+03	1.54E+03	1.17E+02	2.63E+03	1.54E+03
Manganese	mg/kg	3.04E+00	2.16E+03	4.19E+02	3.04E+00	2.16E+03	4.30E+02
Mercury	mg/kg	2.71E-04	1.52E-01	3.57E-02	2.71E-04	2.80E-01	4.13E-02
Molybdenum	mg/kg	2.40E+00	1.30E+01	7.33E+00	N/A	N/A	N/A
Nickel	mg/kg	2.98E-01	2.97E+01	1.33E+01	2.98E-01	2.97E+01	1.31E+01

Table 5.4. Comparison of Detected Results in RI and Historical Subsurface Soil Data Sets (Continued)

Analysis	Unit	Detected Results (See Table 5.2)			Historically Detected Results (See Table 5.1.2 of DOE 2013a)		
		Min	Max	Avg	Min	Max	Avg
Metals							
Selenium	mg/kg	8.91E-02	1.10E+00	3.80E-01	8.91E-02	5.90E-01	2.45E-01
Silver	mg/kg	1.85E-03	7.39E+01	7.66E+00	1.85E-03	7.39E+01	1.56E+01
Sodium	mg/kg	5.22E+00	5.70E+02	2.97E+02	5.22E+00	5.70E+02	3.01E+02
Thallium	mg/kg	1.17E-01	1.56E+00	2.06E-01	1.17E-01	1.56E+00	2.11E-01
Uranium	mg/kg	1.30E+00	7.80E+00	4.60E+00	N/A	N/A	N/A
Vanadium	mg/kg	2.31E-01	5.33E+01	2.32E+01	2.31E-01	5.33E+01	2.23E+01
Zinc	mg/kg	7.40E+00	1.65E+02	3.95E+01	7.40E+00	1.65E+02	4.47E+01
PCBs							
PCB, Total	mg/kg	6.30E-02	3.00E-01	1.93E-01	1.69E-01	1.10E+01	2.93E+00
VOCs							
1,2-Dichlorobenzene	mg/kg	8.50E-02	1.20E-01	1.03E-01	8.50E-02	1.20E-01	1.03E-01

5.6 FATE AND TRANSPORT

No constituents were identified for further evaluation under fate and transport (Chapter 4) because concentrations in SWMU 1 either were below screening levels[10] or below constituent concentrations in other SWMUs/AOCs that were modeled using SESOIL and AT123D simulation modeling and were determined not to reach the RGA within 1,000 years.

5.7 BASELINE RISK ASSESSMENT

Human Health. Potential risks and hazards for current/future human health for SWMU 1 were evaluated for each of the five EUs (~ 0.5 acres each) for direct contact. The methods and presentations used in the BHHRA are consistent with those presented in *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant* (DOE 2016b). The Risk Methods Document integrates the human health risk assessment guidance from EPA and KDEP and incorporates instructions contained in regulatory agency comments on earlier risk assessments performed for PGDP. Screening levels for this RI Report Addendum are presented in Table A.4 of the Risk Methods Document (DOE 2016b). These results are presented in Appendix D and summarized in the subsections that follow, including the COCs and relative contributions to the overall cumulative ELCRs and HIs.

The cumulative ELCR and/or the cumulative HI for all EUs at SWMU 1 exceed the benchmarks of cumulative ELCR of 1E-06 and cumulative HI greater than 1, respectively, for one or more scenarios; therefore, as stated in the Work Plan, Decision Rule D1a, (DOE 2010) this SWMU will be evaluated in the FS. As described in the BHHRA (Appendix D), COCs were identified after considering the results of the risk characterization and the uncertainties affecting the results, based on the risk methodologies in the Risk Methods Document (DOE 2016b).

[10] Soil screening for RGA impacts had been based on a dilution attenuation factor (DAF) of 58. This DAF was used to maintain consistency with previous Soils OU reports, which was in accordance with the approved Work Plan. Because technical uncertainties have arisen with use of a DAF of 58, use of DAF for future CERCLA remedy selection and response action implementation documents for SWMU 1 and future projects under the FFA will be discussed further by the FFA parties and decided on a project-specific basis.

COCs were identified as those COPCs considered contributing at least 1E-06 ELCR or 0.1 HI to a scenario of concern. The basis for COC identification is presented in Appendix D.

The identified COCs considered to contribute to the ELCR/HI, the EPC, and the RGOs calculated for a range of ELCR/HI benchmarks are presented in Chapter 6 for the future industrial worker, excavation worker, and the hypothetical resident. Chapter 6 also compares the EPC to the RGO for each COC under each exposure scenario. Chapter 6 summarizes the ELCR/HI posed by the COCs for this SWMU under each exposure scenario by depicting the maximum ELCR/HI contribution per COC.

Ecological Screening. COPECs for SWMU 1 include metals, PCBs, SVOCs, and VOCs. Potential hazards for ecological receptors and the associated priority COPECs (maximum HQ ≥ 10) are discussed further in Chapter 6, based on the risk methodologies Ecological Risk Methods Document (DOE 2015b).

5.8 SWMU 1 SUMMARY

Goal 1. Characterize Nature and Extent of Source Zone

Plant processes that could have contributed to contamination at SWMU 1 are spill and/or discharges from the waste and equipment stored there and nonbiodegradable materials associated with waste oils brought to the site.

COPCs for surface and subsurface soils from SWMU 1 are shown on Tables 5.1 and 5.2 as those analytes with green boxes under the "Industrial Worker/Frequency of Exposure (FOE)" columns for surface and shallow subsurface soil, and those with blue boxes under the "GW Protection Screen, RGA, and UCRS" columns for protection of groundwater. For metals and radioisotopes, an orange box under the "Provisional Background" also must accompany the green and blue boxes in order to be identified as a COPC. Contaminants were detected greater than background and greater than industrial worker NALs to a maximum depth of 16 ft bgs. Screening levels are described in Section 4.3. The COPCs identified for each EU in SWMU 1 are as follows:

- EU1
  - Surface—metals, radionuclides
  - Subsurface—metals, SVOCs, VOCs, radionuclides
- EU2
  - Surface—metals, PCBs, radionuclides
  - Subsurface—metals, PCBs, SVOCs, VOCs, radionuclides
- EU3
  - Surface—metals, PCBs, radionuclides
  - Subsurface—metals
- EU4
  - Surface—metals, PCBs, SVOCs, radionuclides
  - Subsurface—metals, VOCs

- EU5
  - Surface—metals, PCBs, PAHs, SVOCs, radionuclides
  - Subsurface—metals

Goal 2. Determine Surface and Subsurface Transport Mechanisms and Pathways

The contaminants at SWMU 1 are readily adsorbed to soil particles, so they do not migrate without a direct connection to surface water. The conceptual site model can be found in Appendix D.

Goal 3. Complete a Baseline Risk Assessment for the Soils OU

Cumulative ELCRs exceeded benchmarks of 1E-06 for the future industrial worker, excavation worker, and hypothetical residential scenarios. COCs for these scenarios for SWMU 1 listed in Tables D.43–D.47 and are summarized as follows:

- Current Industrial Worker
  - None
- Future Industrial Worker
  - Total PCBs
  - Total PAHs
  - Cesium-137
  - Neptunium-237
  - Thorium-230
  - Uranium-235
  - Uranium-238
- Excavation Worker
  - Arsenic
  - Total PCBs
  - Total PAHs
  - Cesium-137
  - Thorium-230
- Hypothetical Resident
  - Chromium
  - Total PCBs
  - Total PAHs
  - Cesium-137
  - Neptunium-237
  - Plutonium-239/240
  - Thorium-230
  - Uranium-234
  - Uranium-235
  - Uranium-238

COCs for additional scenarios are discussed in Appendix D.

Figure 5.8 shows the COCs exceeding RGOs for the future industrial worker.

Only Total PCBs in EU2 is a priority COC (i.e., chemical-specific ELCR > 1E-04) for SWMU 1. The priority COC is for the hypothetical resident scenario.

For SWMU 1, COPECs exceed ESVs. Priority COPECs (i.e., maximum HQ ≥ 10) are the following:

- Aluminum
- Antimony
- Iron
- Mercury
- Total PCBs
- Phenol

Goal 4. Support Evaluation of Remedial Alternatives

The representative data set used for SWMU 1 is sufficient to support decision making and indicates that an FS is appropriate. An uncertainty concerning depth of contamination should be considered in the FS. Possible remedial technologies applicable for this unit, as discussed in the Work Plan (DOE 2010), are posting, fencing (or other means of limiting access), excavation, and/or other remedial technologies that will be described in the FS.

5.9 SWMU 1 CONCLUSION

This RI Addendum defines adequately the nature and extent of contamination in soils at SWMU 1; consistent with the guidelines in the FFA, an FS is appropriate for the SWMU due to cancer risks and/or noncancer hazards exceeding the decision rule benchmarks for scenarios, including the future industrial worker, excavation worker, and hypothetical resident (DOE 2010). The reasonably anticipated future land use of this SWMU is industrial, as shown in the SMP (DOE 2015a). Benchmarks for cancer risk and noncancer hazards were not exceeded for the current industrial worker scenario.

Similarly, inhalation of vapors migrating from the residual VOCs in subsurface soils at SWMU 1 and VOCs in groundwater under SWMU 1 could be media of concern under the future industrial worker, excavation worker, and future hypothetical resident scenarios. While deep soil mixing at SWMU 1 has remediated areas with high concentrations of VOCs, residual VOC contamination in soil remains, and the remedial action for SWMU 1 did not address VOC contamination known to be present in groundwater. The potential risks from vapors that might migrate from these sources also should be addressed as an uncertainty in the FS.

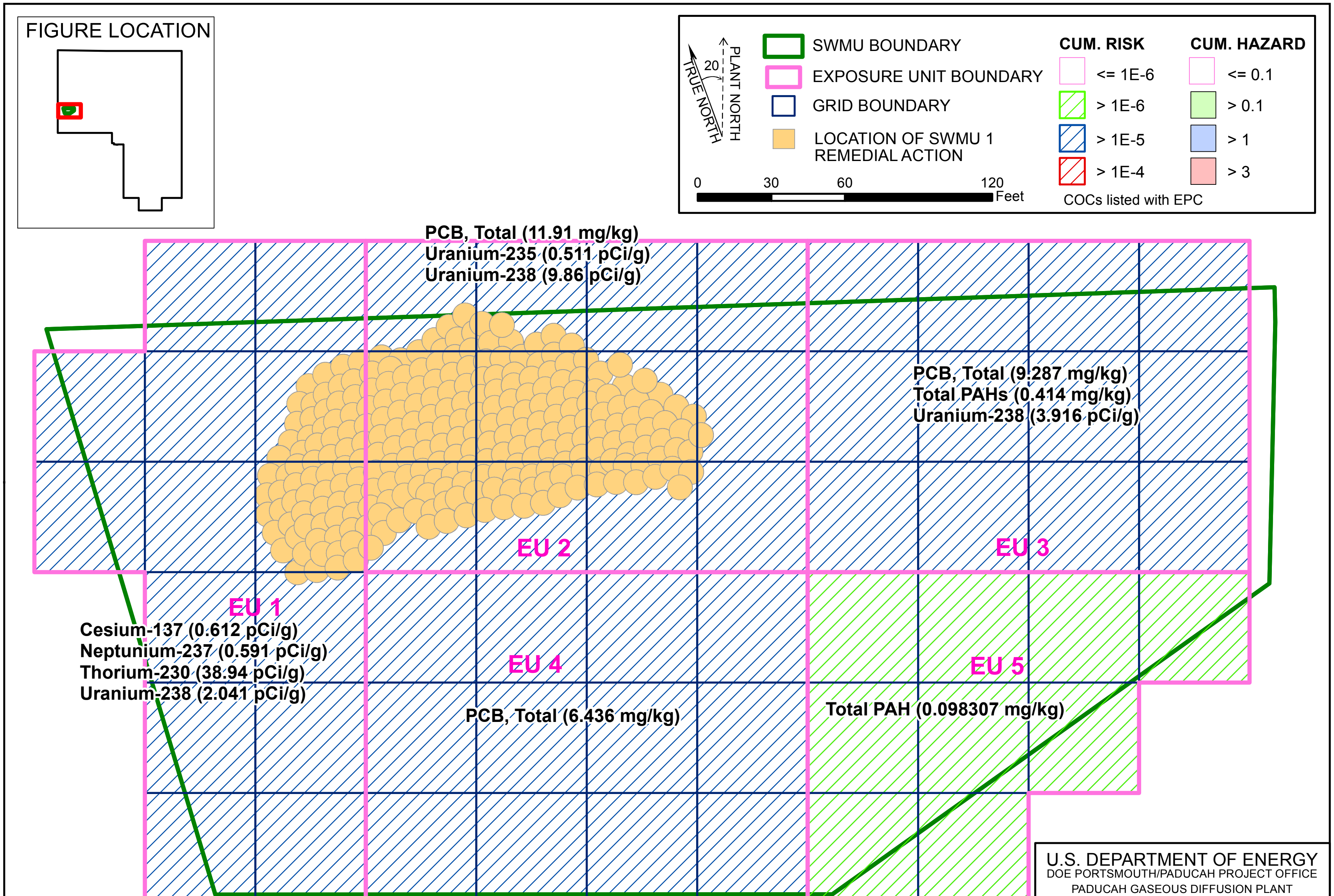

Figure 5.8. Summary of COCs Contributing to Risk to the Future Industrial Worker at SWMU 1

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6. CONCLUSIONS FOR THE SOILS OU REMEDIAL INVESTIGATION

This RI was designed to investigate nature and extent of contamination and contaminant fate and transport and to characterize potential risks/hazards from potential current and future exposures[11] as a basis for evaluating remedial alternatives in an FS for SWMU 1 using historical data along with data collected during the post-remedy investigation to supplement the existing data. The final representative data set includes soil samples analyzed by laboratory and field methods combined with the historical data. Among the objectives for the sampling and analysis strategy were to provide sufficient delineation of COCs and to provide grid-based sampling that allows better estimates of average concentrations to be used for risk estimates.

The goals of this RI, consistent with Work Plan (DOE 2010), are as follows:

(1) Goal 1: Characterize Nature and Extent of Source Zone(s);
(2) Goal 2: Determine Surface and Subsurface Transport Mechanisms and Pathways;
(3) Goal 3: Complete a Baseline Risk Assessment for the Soils OU; and
(4) Goal 4: Support Evaluation of Remedial Alternatives.

6.1 GOAL 1: CHARACTERIZE NATURE AND EXTENT OF SOURCE ZONE(S)

The "source zone" is surface soil and subsurface soil down to 10 ft bgs or 16 ft bgs at infrastructure, such as pipelines, at SWMU 1. The nature and extent of contamination at SWMU 1 is considered defined adequately.

To determine nature of contamination in surface soils, results of analyses in SWMU 1 were compared to surface background values, where available. Consistent with the Work Plan (DOE 2010), which identifies industrial use as the current and reasonably anticipated future land use, results of analyses were compared further to future industrial worker NALs for SWMU 1 since it is located inside the Limited Area. Table 6.1 indicates the constituent that exceeded this screening in at least one location (shown with a green, italic *X*). No constituents exceeded ALs.

Table 6.1. Exceedances of NAL Screening

	Surface Soils	**Subsurface Soils**
	Future Industrial Worker*	**Future Industrial Worker***
Metals		
Arsenic	*X*	*X*
SVOCs		
Total PAHs	*X*	
PCBs		
Total PCBs	*X*	*X*
Radionuclides		
Cesium-137	*X*	
Neptunium-237	*X*	

[11] The BHHRA in this report considers residential land use consistent with EPA Region 4 Human Health Risk Assessment Supplemental Guidance. As discussed in the Paducah SMP (DOE 2015a), the Paducah Human Health Risk Methods Document (DOE 2016b), and the Soils OU RI 2 Report (DOE 2015b), industrial, and not residential use, is the reasonably anticipated land use for SWMU 1. The risk characterization for the residential scenario will be used in subsequent documents to identify unlimited use/unlimited exposure for no further action determinations and any LUCs appropriate for reasonably anticipated land uses.

Table 6.1. Exceedances of NAL Screening (Continued)

	Surface Soils	Subsurface Soils
	Future Industrial Worker*	**Future Industrial Worker***
Thorium-230	*X*	
Uranium-235	*X*	
Uranium-238	*X*	*X*

* Future Industrial Worker reflects default assumptions (i.e., 250 days/year for 25 years).
X constituent that exceeds the NAL in at least one location (DOE 2016b).

6.2 GOAL 2: DETERMINE SURFACE AND SUBSURFACE TRANSPORT MECHANISMS AND PATHWAYS

6.2.1 Migration to Groundwater

Screening evaluation, as described in Chapter 4, identified that there were no constituents in SWMU 1 having soil contamination high enough to leach to groundwater and impact the RGA above drinking water standards using the conditions existing at SWMU 1 prior to the deep soil mixing remedial action. No constituents were identified for further evaluation under fate and transport (Chapter 4) because concentrations in SWMU 1 either were below screening levels or below concentrations in other SWMUs/AOCs that were modeled using SESOIL and AT123D simulation modeling and determined not to reach the RGA within 1,000 years. The results of the modeling on the other SWMU/AOC/COC combinations showed that none of the modeled constituents except Tc-99 had the potential to reach the RGA in the 1,000 year modeling period.

Thus, constituents in SWMU 1 are not expected to have soil-to-groundwater impacts (with the possible exception of Tc-99) because SWMUs with higher concentrations/greater extent of constituents did not migrate to the RGA in 1,000 years. In addition, SWMU 1 did not have Tc-99 concentrations exceeding the screening values and the Tc-99 concentrations were below those from other SWMUs that were modeled for Tc-99 and demonstrated to not cause above-900 pCi/L impacts. Results of the modeling showed that none of the modeled constituents except Tc-99 had the potential to reach the RGA in the 1,000 year modeling period.

A comparison was performed between the average contaminant concentrations in soil samples taken from grids included in the deep soil mixing action area prior to and after the action. This comparison is summarized in Tables 5.3 and 5.4 using average constituent concentrations from historical data compared to the post-remedy data set. The results of the comparison showed that there were no major differences between the mean concentrations for any constituent.

The deep soil mixing remedy did modify the matrix at SWMU 1. This modification would tend to decrease the potential soil-to-groundwater migration because of the following reasons:

- The presence of heterogeneities (worm holes, open fractures, etc.) largely have been eliminated by the deep soil mixing; thus, preferential paths they may have provided have been destroyed, reducing the potential for constituent migration. The increase in pH (due to the addition of lime) would tend to increase the attenuation (and limit mobility) for most constituents; NOTE: some amphoteric constituents[12] can be mobilized (e.g., lead, arsenic) but the concentrations and extents of these constituents are not high enough to pose a likely issue at SWMU 1 under current conditions; over

[12] Amphoteric constituents are those that are able to react both as a base and as an acid (especially metal oxides and hydroxides).

time, this elevated pH will be buffered by the environment, restoring the matrix to closer to pre-remediation conditions.

- The pozzolanic nature[13] of some of the additives would also decrease the mobility through the matrix.

- Other parameters that can affect constituent mobility (e.g., intrinsic permeability, density, porosity, etc.) that have been modified by the deep soil mixing may further reduce the potential for soil-to-groundwater migration relative to the pre-remediation SWMU 1 conditions.

In summary, post-remediation SWMU 1 does not have constituent concentrations or matrix conditions that were conducive to soil-to-RGA-groundwater migration. Deep soil mixing did not increase concentrations of parameters of concern and did not modify the matrix to make it more conducive to migration. Thus, the soil-to-groundwater pathway evaluation that included modeling of the constituent/SWMU/AOC pair most likely to migrate has demonstrated that none of the Soils OU SWMUs, including SWMU 1, has a soil-to-groundwater issue that would require additional remedial actions above those needed to address impacts of the soil contamination itself.

6.2.2 Runoff

Section 5 and Table 6.4, included in the summary of the potential ecological risks, identifies the ground cover and whether the SWMU is located near a drainageway or outfall. Impacts in these receiving areas have been evaluated separately in the SWOU and are not quantified in this assessment (DOE 2008a). A removal action for the contaminated sediment associated with SWOU (On-Site) (DOE 2011) was conducted for Outfalls 001, 008, 010, 011, 015, and associated internal ditches. A final response action for internal ditches, outfalls, and creeks will be addressed by the SWOU, as described in the SMP (DOE 2015a).

6.3 GOAL 3: COMPLETE A BASELINE RISK ASSESSMENT FOR THE SOILS OU

PGDP is an industrial facility surrounded by a state-maintained wildlife refuge and residential property. The current and reasonably anticipated future use of locations within the Limited Area is industrial, and the reasonably anticipated future use of locations outside the Limited Area is recreational. The risk characterization for these current and reasonably anticipated future uses will be used when making risk management decisions in subsequent documents.

Consistent with the Paducah Human Health Risk Methods Document (DOE 2016b), which incorporates both EPA and Kentucky risk assessment guidance, the BHHRA for SWMU 1 characterized risk for a range of reasonably anticipated and hypothetical current and future use scenarios. In developing these scenarios, the concept of reasonable maximum exposure (RME) was used. Additionally, consistent with the results available, the exposure assessment primarily considered exposure to soil (surface and/or subsurface).

This section summarizes the following:

(1) <u>Priority contaminants</u>. Identification of the contaminants that are present most frequently and contribute most substantially to the ELCR/HI estimates at SWMU 1.

[13] Pozzolanic materials in soils can form compounds with cement-like properties, resulting in limiting mobility of contaminants through the soil matrix.

(2) Relative risks and hazards. Relative risks (ELCRs) and hazards (HIs) at SWMU 1 based on contact with contaminants in soil and interpretation of these as priorities for management action.

(3) Ecological risk/hazard considerations of potential ecological receptors.

(4) Other COPECs/uncertainties.

6.3.1 Priority Contaminants

For SWMU 1, there are seven COCs with a chemical-specific ELCR > 1E-6 for the future industrial worker scenario based on analytical results. The seven COCs are Total PCBs, Total PAHs, cesium-137, neptunium-237, thorium-230, uranium-235, and uranium-238. There were no priority COCs for the future industrial worker [priority COCs are identified as those COCs with a chemical-specific ELCR > 1E-04 or a chemical-specific HQ > 1, to highlight to risk managers the COCs driving Total ELCR or Total HQ at SWMU 1] at SWMU 1. Potential cancer risk and noncancer hazard for SWMU 1 are illustrated in Chapter 5, as appropriate.

6.3.2 Dose Assessment

The dose assessment performed for the surface soil estimated dose for SWMU 1 inside the Limited Area at a maximum of 1.2 mrem/yr for the future industrial worker. Although the risk assessment estimates ELCR for radionuclides included in the total risk, a dose assessment for these constituents allows comparison of the detected levels (pCi/g), with an estimate of mrem/yr to consider DOE guidelines for radiation exposure. The results of this analysis indicate in a parallel analysis that radionuclides are not significant contributors to radiation dose.

6.3.3 Relative Risks (ELCRs) and Hazards (HIs)

The BHHRA process allows a range of scenarios to be considered to help understand the contaminants that pose the greatest hazards. For SWMU 1, the scenarios consistent with reasonably anticipated future use include default assumptions used for future industrial worker since the SWMU is inside the Limited Area (DOE 2016b). Similarly, evaluation of ELCRs and HIs provides an upper bounding estimate, if the site were to become residential. Incidental ingestion of contaminated soil, dermal contact with contaminated soil, inhalation of particulates emitted from contaminated soil, and external exposure to ionizing radiation emitted from contaminated soil were the exposure routes evaluated in the BHHRA. Each of these exposure routes presented a pathway of concern (i.e., HI ≥ 0.1 and/or ELCR ≥ 1E-06) at SWMU 1.

Scenarios that assume some future contact with contaminants in the subsurface soil (e.g., the excavation worker) are used to consider contact with the entire soil column (0–16 ft bgs) either during construction or over the longer term as the site soils are mixed and disturbed for alternate uses.

Table 6.2 shows a summary of direct contact risks for SWMU 1, along with the highlighted scenario. The scenarios highlighted are those for the reasonably anticipated future use of the area of SWMU 1, as presented in the discussions in Chapter 5. Additionally, for SWMU 1, since it has more than one EU, the highest Total HI, Total ELCR, and Total Dose across each of the five EUs is presented.

Following are the uncertainties affecting the estimation of ELCR and HI in the human health risk assessment for SWMU 1.

Table 6.2. Summary of Maximum Direct Contact Total HI, Total ELCR, and Total Dose for SWMU 1

EU	Scenario	Direct Contact*		
		Total HI	Total ELCR	Total Dose (mrem/yr)
Former Facilities				
1	Future Industrial Worker	< 1	**1.1E-05**	1.2
2	Future Industrial Worker	< 1	**4.8E-05**	0.3
3	Future Industrial Worker	< 1	**3.8E-05**	0.1
4	Future Industrial Worker	< 1	**2.3E-05**	< 0.1
5	Future Industrial Worker	< 1	**2.0E-06**	< 0.1

Bold indicates total HI > 1 or total ELCR > 1E-06; ***bold italics*** indicates total HI > 3 or total ELCR > 1E-04.
*For direct contact, future industrial worker for SWMU 1 inside the Limited Area. Total HI and Total ELCR represent the cumulative value across all exposure routes assessed within this BHHRA (i.e., incidental ingestion, dermal contact, inhalation, and external exposure to ionizing radiation).
See Risk Methods Document for additional information (DOE 2016b).

- The range of background was not considered beyond the initial screening against site-specific background.

- Concentration of total cancerous PAHs was used to estimate risk, and the minimum detection limit of the PAHs with TEFs was used when PAHs were not detected.

- Some detection limits for XRF data are above background concentrations and NALs; the COPCs identified using these data are expected to overstate the presence of these metals.

- For those constituents that never were detected within an EU, even if the detection limit is greater than the NAL, the constituent was not considered a COPC.

- Using RME assumptions and exposure factors per the Risk Methods Document (DOE 2016b) may result in an overestimation of potential ELCRs and HIs.

- The risk assessment does not consider that concentrations of some COCs may be lower or higher in the future because of processes such as degradation and attenuation.

- Additivity of multiple chemicals is assumed. Whether assuming additivity can lead to an underestimation or overestimation of risk is unknown.

- Most of the assumptions about exposure and toxicity used in the BHHRA are representative of the maximums for each parameter. The result of combining several such upper-bound assumptions is that the final estimate of potential exposure or potential risk is over-estimated.

6.3.4 Ecological Risk Considerations

Consistent with the Paducah Ecological Risk Methods Document, which incorporates both EPA and Kentucky risk assessment guidance (DOE 2015b), the SERA was limited to a comparison of maximum concentrations in surface soils at the SWMU against ecological screening levels in order to identify COPECs. EPCs also were determined and used for comparison of the COPECs. The SERA does not consider the limited habitat, SWMU size, or other factors that also need to be considered to characterize ecological risk. The following observations were made for the SERA as summarized on Tables 6.3 and 6.4.

Table 6.3. Summary of Suite of COPECs Retained in Surface Soil

SWMU	Media	Number of Metals	Number of Rads	Number of PCBs	Number of SVOCs	Number of VOCs
1	Soil	18	---	1	3	1

---: no COPECs

Table 6.4. SWMU 1 Ecological Risk Summary

Description	Area (Acres)	Ground Cover	Near a Surface Water Body?	Total HQ[a]	Priority COPECs	Background (mg/kg)[b]	Maximum Detection or ½ Maximum Detection Limit (mg/kg)	Soil ESV (mg/kg)	EPC (mg/kg)	HQ[a]
Oil Landfarm (disposal of waste oil)	2.29	Grass	Yes	468	Aluminum	13000	11100	50	8574	171.5
					Antimony	0.21	7.5	0.27	9.763	36.2
					Iron	28,000	24000	200	16398	82.0
					Mercury	0.2	3	0.1	2.74	27.4
					PCB, Total	N/A	9.5	0.02	1.439	72.0
					Phenol	N/A	1.8	0.05	0.851	17.0

[a] Total HQ and HQ calculated from the EPC (Section E.3).
[b] Background values are for surface soil taken from DOE 2016b; ESVs are taken from DOE 2015b and Appendix E of this document.

The primary risk drivers when comparing maximum detection to ecological risk are metals, PCBs, and phenol. Metals, especially aluminum and iron, contribute the majority of the total estimated HQ for ecological risk.

6.3.5 Other COPECs/Uncertainties

As indicated in Appendix B, there may be uncertainties when using XRF data to estimate risks. Four metals (aluminum, antimony, iron, and mercury) show significant exceedances of the ESVs.

6.4 GOAL 4: SUPPORT EVALUATION OF REMEDIAL ALTERNATIVES

The representative data set used for SWMU 1 is sufficient to support decision making and indicates that an FS is appropriate. Other information was gathered in support of the evaluation of remedial alternatives to include infrastructure issues, extent of contamination, and verification of site descriptions. Possible remedial technologies applicable for this unit are, as discussed in the Work Plan (DOE 2010), posting, fencing (or other means of limiting access), excavation, and/or other remedial technologies that will be described in the FS. Chapter 5 contains SWMU 1-specific details.

6.4.1 Remedial Goal Options

SWMU 1 requires further review in the FS to evaluate the appropriate options to address current or potential future risks/hazards. The BHHRA in this RI characterized the cancer risks and noncancer hazards (i.e., Total ELCRs and Total HIs, respectively) potentially resulting from exposure to contaminants in soil.

RGOs were calculated for each COC, as determined by the conclusions of the BHHRA. These RGOs should not be interpreted as being cleanup goals, but as risk-based values that may be used by risk managers to revise preliminary remediation goals to be consistent with the RAOs in the FS and to develop cleanup goals from these revised preliminary remediation goals in the ROD. The COCs and RGOs consistent with the current and reasonably anticipated future use scenarios (i.e., industrial use, including both the industrial and excavation worker) are shown in Table 6.5.

Table 6.5. RGOs for SWMU 1

EU	COC	EPC	Units	ELCR	RGO at ELCR=1E-6	RGO at ELCR=1E-5	RGO at ELCR=1E-4	HI	RGO at HI=0.1	RGO at HI=1	RGO at HI=3
Industrial Worker Soil Exposure											
1	Cesium-137	0.612	pCi/g	5.4E-06	0.114	1.14	11.4	N/A	N/A	N/A	N/A
1	Neptunium-237	0.591	pCi/g	2.3E-06	0.255	2.55	25.5	N/A	N/A	N/A	N/A
1	Thorium-230	38.9	pCi/g	1.2E-06	32.5	325	3250	N/A	N/A	N/A	N/A
1	Uranium-238	2.04	pCi/g	1.1E-06	1.78	17.8	178	N/A	N/A	N/A	N/A
2	PCB, Total	11.9	mg/kg	4.0E-05	0.295	2.95	29.5	N/A	N/A	N/A	N/A
2	Uranium-235	0.511	pCi/g	1.4E-06	0.378	3.78	37.8	N/A	N/A	N/A	N/A
2	Uranium-238	9.86	pCi/g	5.5E-06	1.78	17.8	178	N/A	N/A	N/A	N/A
3	PCB, Total	9.29	mg/kg	3.1E-05	0.295	2.95	29.5	N/A	N/A	N/A	N/A
3	Total PAH	0.414	mg/kg	4.7E-06	0.0881	0.881	8.81	N/A	N/A	N/A	N/A
3	Uranium-238	3.92	pCi/g	2.2E-06	1.78	17.8	178	N/A	N/A	N/A	N/A
4	PCB, Total	6.44	mg/kg	2.2E-05	0.295	2.95	29.5	N/A	N/A	N/A	N/A
5	Total PAH	0.0983	mg/kg	1.1E-06	0.0881	0.881	8.81	N/A	N/A	N/A	N/A
Excavation Worker Surface and Subsurface Soil Exposure											
1	Arsenic	7.43	mg/kg	3.0E-06	2.51	25.1	251	< 1	N/A	N/A	N/A
1	Total PAH	0.453	mg/kg	1.4E-06	0.323	3.23	32.3	N/A	N/A	N/A	N/A
1	Cesium-137	0.874	pCi/g	1.4E-06	0.614	6.14	61.4	N/A	N/A	N/A	N/A
1	Thorium-230	35.8	pCi/g	1.3E-06	28.3	283	2830	N/A	N/A	N/A	N/A
2	Arsenic	7.76	mg/kg	3.1E-06	2.51	25.1	251	< 1	N/A	N/A	N/A
2	PCB, Total	8.68	mg/kg	7.7E-06	1.12	11.2	112	N/A	N/A	N/A	N/A
2	Total PAH	1.22	mg/kg	3.8E-06	0.323	3.23	32.3	N/A	N/A	N/A	N/A
3	Arsenic	6.89	mg/kg	2.7E-06	2.51	25.1	251	N/A	N/A	N/A	N/A
3	PCB, Total	4.60	mg/kg	4.1E-06	1.12	11.2	112	N/A	N/A	N/A	N/A
3	Total PAH	0.407	mg/kg	1.3E-06	0.323	3.23	32.3	N/A	N/A	N/A	N/A
5	Arsenic	16.7	mg/kg	6.6E-06	2.51	25.1	251	< 1	N/A	N/A	N/A

Table 6.5. RGOs for SWMU 1 (Continued)

EU	COC	EPC	Units	ELCR	RGO at ELCR=1E-6	RGO at ELCR=1E-5	RGO at ELCR=1E-4	HI	RGO at HI=0.1	RGO at HI=1	RGO at HI=3
Hypothetical Child Residential User Soil Exposure											
1	Cesium-137	0.612	pCi/g	1.7E-05	0.0351	0.351	3.51	N/A	N/A	N/A	N/A
1	Neptunium-237	0.591	pCi/g	7.7E-06	0.0772	0.772	7.72	N/A	N/A	N/A	N/A
1	Plutonium-239/240	8.44	pCi/g	2.3E-06	3.73	37.3	373	N/A	N/A	N/A	N/A
1	Thorium-230	38.9	pCi/g	8.0E-06	4.89	48.9	489	N/A	N/A	N/A	N/A
1	Uranium-238	2.04	pCi/g	4.1E-06	0.499	4.99	49.9	N/A	N/A	N/A	N/A
2	PCB, Total	11.9	mg/kg	1.5E-04	0.08	0.80	8.00	N/A	N/A	N/A	N/A
2	Uranium-234	9.01	pCi/g	1.6E-06	5.73	57.3	573	N/A	N/A	N/A	N/A
2	Uranium-235	0.511	pCi/g	4.5E-06	0.114	1.14	11.4	N/A	N/A	N/A	N/A
2	Uranium-238	9.86	pCi/g	2.0E-05	0.499	4.99	49.9	N/A	N/A	N/A	N/A
3	PCB, Total	9.29	mg/kg	1.2E-04	0.08	0.80	8.00	N/A	N/A	N/A	N/A
3	Total PAH	0.414	mg/kg	1.8E-05	0.0236	0.236	2.36	N/A	N/A	N/A	N/A
3	Uranium-238	3.92	pCi/g	7.9E-06	0.499	4.99	49.9	N/A	N/A	N/A	N/A
4	Chromium	81.5	mg/kg	2.0E-06	41.4	414	4140	< 1	N/A	N/A	N/A
4	PCB, Total	6.44	mg/kg	8.0E-05	0.08	0.800	8.00	N/A	N/A	N/A	N/A
5	PCB, Total	0.270	mg/kg	3.4E-06	0.08	0.800	8.00	N/A	N/A	N/A	N/A
5	Total PAH	0.0983	mg/kg	4.2E-06	0.0236	0.236	2.36	N/A	N/A	N/A	N/A

Grayed cells indicate EPC value is lower than RGO value or an RGO value is not applicable.
N/A = Not applicable because the COC was of concern for HI, but not ELCR or it was of concern for ELCR, but not HI.

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APPENDIX A

TECHNICAL MEMORANDUM FOR FIELD ACTIVITIES

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CONTENTS

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TABLES

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ACRONYMS

AOC	area of concern
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ES&H	environment, safety, and health
FS	feasibility study
KPDES	Kentucky Pollutant Discharge Elimination System
OU	operable unit
PGDP	Paducah Gaseous Diffusion Plant
PPE	personal protective equipment
QC	quality control
RCRA	Resource Conservation and Recovery Act
RCT	radiological control technician
RI	remedial investigation
SWMU	solid waste management unit

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A.1. INTRODUCTION

The purpose of this memorandum is to provide certain technical details regarding field activities pertaining to the Soils Operable Unit (OU) Remedial Investigation (RI) for Solid Waste Management Unit (SWMU) 1. A brief summary of project objectives is provided below; a more thorough discussion is contained in the main text of the report.

The Soils OU is one of the OUs located within the Paducah Gaseous Diffusion Plant (PGDP). This OU consists of contamination associated with PGDP's soils.

The primary focus of this RI was to collect field and fixed-base analytical data necessary to determine the nature and extent of any soil contamination. The data will be used to support the completion of a baseline human health risk assessment and a screening-level ecological risk assessment. The data also will be used in conjunction with other data that may be necessary to evaluate appropriate remedial alternatives, as necessary, at SWMU 1.

Table A.1 presents procedures and work instructions that were used to complete the fieldwork conducted as part of the RI.

Table A.1. Examples of Procedures Used in the RI

Work Instructions or Procedures Required for Fieldwork and Sampling Activities
Archival of Environmental Data Within the Environmental Restoration Program
Chain-of-Custody
Cleaning and Decontaminating Sample Containers and Sampling Equipment
Data Entry
Data Management Coordination
Data Validation
Environmental Radiological Screening
Equipment Decontamination
Field Quality Control
Identification and Management of Waste not from a Radioactive Material Management Area
Labeling, Packaging, and Shipping of Environmental Field Samples
On-Site Handling and Disposal of Waste Materials
Opening Containerized Waste
Paducah Contractor Records Management Program
Quality Assured Data
Sampling of Soil
Composite Sampling
Use of Field Logbooks

The original scope of the soils OU consisted of 86 SWMUs/areas of concern (AOCs). During the Soils OU RI conducted in 2010, sampling at SWMU 1 was determined to be adequate to define nature and extent of contamination and was documented in the RI Report (DOE 2013). Following the Soils OU RI Report, a deep soil mixing remedial action was performed at SWMU 1, which necessitated recharacterizing 23 grids previously included in the Soils OU RI. A work plan addendum was developed and approved to describe how additional sampling would be performed (DOE 2014). This work plan addendum supplemented the approved Soils OU RI/Feasibility Study (FS) Work Plan (Work Plan) (DOE 2010), which was completed in June 2010.

A.2. SOIL SAMPLING STRATEGY

The field sampling strategy used for the RI consisted of intrusive media sampling (surface and subsurface soil). The investigation activities used standard industry practices that were consistent with U.S. Environmental Protection Agency (EPA) procedures and protocols. Sampling activities for the Soils OU focused on the soils from 0–10 ft below ground surface (bgs).

Soil samples generally were taken by hand using a hand-auger for the 0–1 ft bgs; the 1–4 ft bgs were collected with a track-mounted rig capable of direct push technology drilling. This track-mounted drill rig utilized push rods to advance a soil sample tube with an acetate liner to collect undisturbed soil samples. If refusal was met using the push rods, the sample was offset 10 ft and attempted again up to 2 times. Samples consisted of a 5-point composite in each 45 ft by 45 ft grid and for each depth interval, as described in the Work Plan (DOE 2010).

The field crew sampled the soil borings in accordance with U.S. Department of Energy (DOE) Prime Contractor-approved procedures, consistent with *Environmental Investigation Standard Operating Procedures and Quality Assurance Manual* (EPA 2001). As soon as the drill crew recovered the acetate liner containing the soil sample, the soil core was placed in the sample preparation area. A health and safety specialist and radiological control technician (RCT) scanned the acetate sleeve and the ends of the soil core for volatile organic compounds and radiation before releasing the core to the sample crew. Once the soil core in acetate sleeve was cleared, the sample crew opened the acetate sleeve with a utility knife and, once again, a health and safety specialist and RCT scanned the sample for contamination. When contamination was found, the health and safety specialist and RCT directed the field crew in any additional personal protective equipment (PPE) requirements and appropriate handling precautions.

Immediately upon approval from the health and safety specialist and RCT, the field crew collected the samples by placing the soil in a clean bowl and mixed thoroughly. Samplers placed the resulting soil mixture in the appropriate sample jars for analysis.

A.3. SURVEYING

As the field crew performed the Soils OU sampling, they marked the boring locations using flagging and/or paint. Global Positioning System units with submeter accuracy documented the sample locations. The RI included surveying of sampling center grid locations prior to sampling activities. This survey work was performed by or under responsible charge of a Professional Land Surveyor registered in the Commonwealth of Kentucky, locating each sample point with its horizontal and vertical position using the PGDP coordinate system for horizontal control. Additionally, the survey identified the State Plane Coordinates for each sample location using the U.S. Coast and Geodetic Survey North American Datum of 1983. The datum for vertical control was the U.S. Coast and Geodetic Survey North American Vertical Datum of 1988. Accuracy for this work was that of a Class 1 First Order survey.

Project personnel entered the coordinates into the Paducah Project Environmental Measurements System and the coordinate locations were transferred with the station’s ready-to-load file to the Paducah Oak Ridge Environmental Information System.

A.4. SAMPLING PROCEDURES

During the sampling event, two types of samples—soil and field quality control (QC)—were collected and submitted for analysis. Prior to initiation of field sampling, all sample team members completed all required training.

The sampling team collected, stored, and shipped the samples according to preestablished QC protocols and approved project procedures, which were consistent with EPA Region 4 sampling methodologies. Sample container, preservation, and holding time requirements were in accordance with the EPA Engineering Support Branch Standard Operating Procedures.

Samples collected for this project were assigned unique sample identifiers that were recorded on the sample labels and chain-of-custody forms. Soil samples (surface and subsurface) were selected randomly for fixed-base laboratory analysis, as directed by the Work Plan (DOE 2010).

An example of the sample numbering scheme used for SWMU 1, as discussed in the Work Plan (DOE 2010), is provided below.

SOUssseeeMA000

Where:

SOU	Identifies the project (i.e., Soils OU)
sss	Identifies the SWMU being investigated
eee	Identifies the grid
M	Identifies the media type (W identifies the sample as water, S identifies the sample as soil)
A	Identifies the sequential sample (usually "A" for a primary sample and "B" for a secondary sample) If additional rounds of sampling are required, the sequential letter designations will continue
000	Identifies the planned depth of the sample in ft bgs

Sample team crew members directly affixed labels to the sample containers that included the following information:

- Station name
- Sample identification number
- Sample matrix
- Sample type
- Type or types of analysis required
- Date and time of collection
- Sampler name
- Sample preservation (if required)
- Destination laboratory

The sampling team wore proper PPE during sampling. PPE consisted of, in part, company-issued clothing, safety glasses, and latex gloves. Sampling in radiological contamination areas sometimes necessitated modifications of the PPE requirements (as prescribed in work permits and directed by the project's health physics technician).

A.4.1 SOIL SAMPLES

Samples were collected in accordance with the Work Plan (DOE 2010) and addendum (DOE 2014). The field crew sampled the soil borings in accordance with DOE Prime Contractor-approved procedures, consistent with EPA guidance (EPA 2001). Soil was placed in a clean, stainless steel bowl and mixed thoroughly using a stainless steel spoon to homogenize the soil taken from the sample interval before sampling for other analyses.

Sample team members filled the sample containers and ensured that each lid was tightened securely. The sample containers then were placed in a cooler with an ice pack to maintain a preservation temperature of 4°C. Crew members recorded all required information in the sampling logbook.

A.4.2 FIELD QC SAMPLES

To ensure reliability of the analytical data and to meet the data quality objectives for the project, the following QC sample types were obtained during sample collection.

- Field Blanks—Field blanks served as a check for potential airborne environmental contamination at the sample site. For the field blanks, the sample crew typically filled sample bottles with deionized water for samples required for fixed-base laboratory analysis and with clean soil for samples required for field laboratory analysis in the project's sample staging area and transported the bottles to the field sample station where they were opened during the sampling process. Field blanks also were used as a reagent blank, as needed. Field blanks were collected at a frequency of 1 in 20 samples (5%) for each sample matrix.

- Field Duplicate Samples—Field duplicate samples determined the sampling variance. The sampling crew collected 1 duplicate for every 20 samples (5%), per matrix. The field duplicate was analyzed for the same set of analytical parameters as the sample it duplicated.

A.5. FIELD DECONTAMINATION

The field decontamination procedure, *Decontamination of Sampling Equipment and Devices*, CP4-ES-2702, determined the decontamination activities for the stainless steel spoons and bowls used in soil sampling. This procedure, as applied during the RI, is summarized as follows:

- Equipment first was cleaned with tap water and nonphosphate detergent, using a brush if necessary, to remove particulate matter and surface films.

- The equipment then was rinsed thoroughly with tap water, followed by an analyte-free water rinse, and then wiped with an isopropyl alcohol towelette.

- Cleaned sample equipment was allowed to air dry.

- Cleaned equipment was handled only by personnel wearing clean latex gloves to prevent recontamination.

- If cleaned sampling equipment was not reused immediately, it was wrapped in aluminum foil.

Large Equipment Decontamination, CP4-ER-2701, governed the cleaning of other sampling equipment such as the drill rigs and associated tooling. This procedure provides for the use of high-pressure steam as the primary cleaning agent. The on-site decontamination facility, C-752, supported cleaning activities for the drill rig and associated tooling during sampling.

A.6. WASTE MANAGEMENT

The Work Plan (DOE 2010) included a project-specific waste management plan to provide instruction regarding waste storage and disposition. A variety of wastes were generated during the field investigation, including sample residuals and associated waste derived from sample collection. The waste generated was stored in Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) waste storage areas within the CERCLA AOC during the characterization period and prior to disposal. Consistent with EPA policy, the storage of waste within the CERCLA AOC does not trigger Resource Conservation and Recovery Act (RCRA) storage requirements (similarly, movement of waste within a CERCLA AOC does not trigger RCRA disposal requirements). As a best management practice, waste storage areas within the CERCLA AOC were managed in accordance with the substantive requirements of RCRA. Because this is a CERCLA project, the administrative requirements do not apply.

PPE was considered to fall into the same waste classification as the environmental media with which it came into contact. PPE, plastic, and paper were segregated by classification, collected in plastic bags, and labeled appropriately. These items then were handled as solid waste and dispositioned based on the waste classification of the residual soil samples.

Decontamination water that included small quantities of soil/mud was generated from cleaning the equipment. The water was collected and stored in a polyethylene tank and discharged to the Kentucky Pollutant Discharge Elimination System (KPDES) Outfall 001 after final characterization documented that the stored water met release criteria in the KPDES permit for Outfall 001.

Solid waste was containerized in 55-gal drums, or approved equivalent, that were lined with a thick plastic liner and placed in CERCLA waste storage areas. The amount of free liquid was minimized. Any substantial amount of free liquid was decanted and placed in an approved container. Characterized soils and other solid wastes were being disposed of in the C-746-U Landfill.

All clean trash (i.e., trash that was not chemically or radiologically contaminated) was segregated according to established guidelines and then collected and disposed of. Examples of clean trash are office paper, aluminum cans, packaging materials, and glass bottles not used to store potentially hazardous chemicals, aluminum foil, and food items.

Based on sample analyses, existing data, or process knowledge, the waste was classified into one of the following categories:

- RCRA-listed hazardous waste
- RCRA-characteristic hazardous waste
- Polychlorinated biphenyl waste

- Low-level waste
- Mixed waste
- Nonhazardous waste

Waste minimization was implemented in accordance with Hazardous and Solid Waste Amendments of RCRA of 1984 as well as other requirements. Requirements specified in the waste management plan regarding waste generation, waste tracking, waste reduction techniques, and the waste reduction program, in general, also were implemented.

To support DOE's commitment to waste reduction, an effort was made during field activities to minimize waste generation as much as possible, largely through ensuring that potentially contaminated wastes were localized and did not come into contact with any clean media (which could create more contaminated waste). Waste minimization also was accomplished through waste segregation, selection of PPE, waste handling (spill control), and the use of alternative treatment standards.

A.7. ENVIRONMENT, SAFETY, AND HEALTH

A project-specific environment, safety, and health (ES&H) plan was included as Chapter 10 in the approved Work Plan and was used to provide instruction regarding safety and health of workers, the public, and the environment (DOE 2010). The ES&H plan established the specific applicable standards and practices to be used during execution of the RI to protect the safety and health of workers, the public, and the environment. The document contained information about the sites, potential contaminants and hazards that may be encountered on-site, and hazards inherent in routine procedures. The list of contaminants was site-specific and based on previous investigations. The plan also outlined directly, or by reference, federal and state standards, pertinent consensus standards, and applicable contract requirements. The ES&H plan was implemented in accordance with 29 *CFR* § 1910.120, "Hazardous Waste Operations and Emergency Response." Additional health and safety requirements were incorporated into the ES&H plan for the various field activities through preparation of project-specific activity hazard analyses.

The project team held daily safety and plan of the day meetings at the beginning of each shift. This approach ensured that the planned daily activities were reviewed prior to execution and the potential hazards were identified and discussed with the entire field team. These meetings are documented in the project work package and in the field logbooks.

A.8. FIELDWORK DOCUMENTATION

Field documentation was maintained throughout the RI in various types of documents and formats, including the field logbooks, sample labels, sample tags, chain-of-custody forms, and field data sheets. The following general guidelines for maintaining field documentation were implemented. Documentation requirements are listed below. Entries were written clearly and legibly using indelible ink.

- Corrections were made by striking through the error with a single line that did not obliterate the original entry. Corrections were dated and initialed.

- Dates and times were recorded using the format "mm/dd/yy" for the date and the military clock (i.e., 24-hour) for the time.

- Zeroes were recorded with a slash (/) to distinguish them from the letter O.
- Blank lines were prohibited. Information was recorded on each line or a blank line was lined out, initialed, and dated.
- No documents were altered, destroyed, or discarded, even if they were illegible or contained inaccuracies that required correction.
- Information blocks on field data forms were completed or a line was drawn through the unused section, and the area was dated and initialed.
- Unused logbook pages were marked with a diagonal line drawn from corner to corner and a signature and date was placed on the line.
- Photocopies of logbooks, field data sheets, and chain-of-custody forms were made and stored in the project file.
- The following information was recorded on the outside of the front cover of each logbook using indelible ink:

  — Project name
  — Unique logbook name and number
  — Client and contract number
  — Task and document control number
  — Activity or site name
  — Start and completion date of the logbook

Quality assurance personnel conducted periodic reviews of the data forms and logbooks (including data forms placed in the logbooks) prepared by field personnel to verify the following:

- Accuracy of entries;
- Legibility and clarity of entries;
- Completeness, to ensure that at least the minimum required information was recorded;
- Consistency of information recorded; and
- Signature and date of entries by the designated team member.

A.9. RECTIFICATION OF PLANNED SAMPLE LOCATIONS

A.9.1 INTRODUCTION

A Geographic Information System provided sample coordinates from maps of the intended sample locations in the Soils OU RI/FS Work Plan addendum (DOE 2014). Conventional survey methods were used to locate the center point sample coordinates at each grid within the SWMU.

A.9.2 DISCUSSION OF PLANNED SAMPLE LOCATIONS

Table A.2 is a summary of the number of samples planned and the number of samples collected during the 2016 field investigation for SWMU 1. Site conditions did not necessitate modifications of the sampling strategy for SWMU 1.

Table A.2. Samples Collected

SWMU/ AOC	Planned Grid Samples	Collected Grid Samples	Contingency/ Step-out Samples Anticipated	Contingency/ Step-out Samples Collected
1	46	46	0	0

A.10. REFERENCES

DOE (U.S. Department of Energy) 2010. *Work Plan for the Soils Operable Unit Remedial Investigation/Feasibility Study at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0120&D2/R2, U.S. Department of Energy, Paducah, KY, June.

DOE 2013. *Soils Operable Unit Remedial Investigation Report at the Paducah Gaseous Diffusion Plant Paducah, Kentucky*, DOE/LX/07-0358&D2/R1, U.S. Department of Energy, Paducah, KY, February.

DOE 2014. *Addendum to the Work Plan for the Soils Operable Unit Remedial Investigation/Feasibility Study at the* Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Remedial Investigation 2, Sampling and Analysis Plan, DOE/LX/07-0120&D2/R2/A1/R1, U.S. Department of Energy, Paducah, KY, August.

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APPENDIX B

DATA QUALITY ANALYSIS

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TABLES

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ACRONYMS

DQO	data quality objective
DQA	data quality analysis
EU	exposure unit
FOD	frequency of detection
FS	feasibility study
GWS	gamma walkover survey
MDC	minimum detectable concentrations
NAL	no action level
OREIS	Paducah Oak Ridge Environmental Informational System
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
RI	remedial investigation
SQL	sample quantitation limit
SWMU	solid waste management unit
SVOC	semivolatile organic compound
VOC	volatile organic compound
XRF	X-ray fluorescence

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Historical sampling for Solid Waste Management Unit (SWMU) 1 occurred from 1989 through 2005. Because soils in the area remediated as part of the Southwest Plume source action were disturbed, the surface soils in that area were recharacterized for use in the Soils Operable Unit (OU). Surface soil and shallow subsurface sampling followed the completion of the source action once the soil had been respread. The goals for this Remedial Investigation (RI), as stated in the work plan (DOE 2010) and addendum (DOE 2014), include providing data for characterization of source zones, defining extent of contamination in soil, risk characterization, and evaluation of remedial alternatives. Sampling for the Soils OU RI included collection of laboratory analytical data with field data that included results from X-ray fluorescence (XRF) and polychlorinated biphenyl (PCB) field test kits. This section provides a review of the overall data set to determine potential data quality issues that limit the uses of some of these data to support decisions at these sites. Table B.1 provides a general overview of the data set.

Table B.1. Summary of Sampling

Total Surface Fixed-base Laboratory Samples	Total Surface Field Laboratory Samples	Total Subsurface/ Shallow Fixed-base Laboratory Samples	Total Subsurface/ Shallow Field Laboratory Samples
3	28	3	28

Depth	Analytical Group	Number of RI 2 Addendum Samples
Surface*	VOCs	0
	SVOCs	3
	PCBs	3
	Metals	3
	Radionuclides	3
	Metals by XRF	28
	PCBs by test kit	28
Subsurface*	VOCs	0
	SVOCs	3
	PCBs	3
	Metals	3
	Radionuclides	3
	Metals by XRF	28
	PCBs by test kit	28

*Surface is defined as 0–1 ft bgs, and subsurface is defined as 1–16 ft bgs.

The field sampling strategy for the original RI included elements of stratified sampling, grid sampling, adaptive cluster sampling, composite sampling, and random sampling. These data, as described in detail for each exposure unit (EU), were collected consistent with the protocols documented in the work plan.

B.1. HISTORICAL DATA

The historical data set that the data quality analysis (DQA) evaluates is defined in the Soils OU RI/Feasibility Study (FS) Work Plan (DOE 2010) and in the Soils OU RI Report (DOE 2013). This evaluation will look only at whether the location from which the data were collected is representative of the SWMU area (i.e., was the sample collected within the area of the influence of the SWMU) and whether the data itself were analyzed to a quality adequate for decision making for this Soils OU RI 2 Addendum.

Some of the decision rules that will be used in the DQA when determining the usability of historical data were established in the RI/FS Work Plan. Those rules are the following:

- Historical data that have been qualified as rejected by data validation or by data assessment will not be included in the historical data set.
- Historical data that contain units inconsistent with the sampled media or with the analysis will not be included in the historical data set (e.g., a soil sample with analytical units reported in mg/L or a radiological result with units reported in mg/kg).
- Historical data for radionuclide results with no minimum detectable concentration recorded will not be included in the historical data set.
- Historical data for nonradionuclide results with no reported result and no detection limit recorded will not be included in the historical data set.
- Historical data for radionuclide results with a null or zero recorded as a counting error will not be included in the historical data set.
- Data assessment qualifiers previously placed on the data will be noted and applied as appropriate.
- A result will be considered a nondetect if it is qualified by the reporting laboratory with the following:
  - A “U” qualifier or a “<” qualifier or
  - An “A” qualifier if the result is a radiological result analyzed by a laboratory with codes “PGDP” or “PARGN.”
- A result will be considered a nondetect if it has a “U” validation code or a “U” data assessment code.
- A radiological result may be considered a nondetect if the reported total propagated uncertainty is greater than the reported result.

Any exceptions to these rules will be documented in this DQA.

The historical data review for SWMU 1 follows a similar format as that for the Soils OU RI and Soils OU RI 2 Reports.

Comparisons are made to the child resident no action levels (NALs) and to background values reported in the Risk Methods Document (DOE 2016). Calculated values were added for total polycyclic aromatic hydrocarbons (PAHs), total PCBs, and total dioxins/furans, if necessary, according to the methodology described in the Risk Methods Document.

B.1.1 DATA EVALUATION AND SCREENING

Historical data for this SWMU from the surface soils include dioxins/furans, metals, pesticides/PCBs, radionuclides, semivolatile organic compounds (SVOCs), and volatile organic compounds (VOCs). The data from the shallow subsurface include dioxins/furans, metals, pesticides/PCBs, SVOCs, and VOCs. These data were collected from the following projects:

- Agreement in Principle (AIP) Soil Remediation PR June 2004 Split w/DOE AIPSORUPRSP06-04
- Remedial Action Site Investigation (SI)—Phase 1
- Remedial Action SI—Phase 2
- Southwest Plume SI SWMU001 ERI04SW-SWMU001
- Southwest Plume SI SWMU001—Head Space 2 Day Turn ERI04SW-001HS-2
- Southwest Plume SI SWMU001—Head Space 7 Day Turn ERI04SW-001HS-7
- Surface Water OU—Activity 1 *In Situ* Object Counting System (ISOCS) data SWOU05-ISOCS
- Surface Water OU—Kentucky Pollutant Discharge Elimination System (KPDES) Outfall 008 Activity 1 Exposure Unit (EU)07 SWOU05-K008A107
- Surface Water OU—KPDES outfall 008 Activity 1 EU08 SWOU05-K008A108
- Surface Water OU—KPDES outfall 008 Activity 2 EU07 AND EU08 SWOU05-K008A20708
- Waste Area Group (WAG) 23 Excavation Sampling
- WAG 23 Phase 1
- WAG 23 Phase 2
- WAG 27 Excavation Sampling
- WAG 27 Remedial Investigation (RI) Sampling

B.1.2 SAMPLING REPRESENTATIVE OF THE SWMU AREA

Figures in Chapter 5 illustrate the location of the historical data points associated with this SWMU. For project scoping, all data within a 50-ft boundary of the SWMU administrative boundary were selected and assigned to SWMU 001. For use in the Remedial Action, data within the grid of the SWMU boundary were assigned to the SWMU. Samples assigned a “Remediated Flag” in the Paducah Oak Ridge Environmental Information System (OREIS) were removed from the data set. Section B.1.8 contains additional information about historical sampling locations for which data was removed because it is considered no longer representative of the SWMU area.

B.1.3 USABILITY OF HISTORICAL DATA

Validation. Validation was performed for 10% of the AIP Soil Remediation project, Phase 1 and 2 SIs, WAG 23, and WAG 27 projects. The validation qualifiers that have been applied to this data are "?," "=," E, J, N, U, and V.

Data Assessment. The assessment qualifiers that have been applied to the data set for SWMU 001 are as presented in Table B.2.

Table B.2. Assessment Qualifiers Applied to SWMU 1 Historic Data Assessment Qualifier Definition

Assessment Qualifier	Definition
BL-T	Result may be biased low; sample holding time exceeded.
J	Result estimated
U	Not detected.
USECNITRIC-CF	During the period from May 2004 to September 2009, the United States Enrichment Corporation (USEC)-Paducah Gaseous Diffusion Plant (PGDP) laboratory used method RL-7128-NITRIC for isotopic uranium analysis by alpha spec. Method RL-7128-NITRIC utilizes only nitric acid for dissolution rather than hydrofluoric/nitric acid. The use of nitric acid only is a less aggressive dissolution for isotopic uranium analysis by alpha spec. It has been demonstrated that Method RL-7128-NITRIC can be utilized only for isotopic uranium analysis of soil with activity greater than 10 pCi/g due to low recoveries below that level. If the data from Method RL-7128-NITRIC will be screened against the background values reported in *Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media at the PGDP* (1997), the following adjusted background values must be used: U-234: 1.73 pCi/g surface and 1.63 pCi/g subsurface; U-235: 0.10 pCi/g; and U-238: 0.40 pCi/g [*Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant*, Appendix E (2009)]. Risk assessors may use data from this time period for comparison against other thresholds below 10 pCi/g without adjusting the values as long as the level of uncertainty and its impact on the risk assessment/evaluation are adequately discussed. No additional action is required for comparisons to thresholds above 10 pCi/g.

It was noted in the Surface Water OU SI/Baseline Risk Assessment that data for cesium-137 and uranium-238 were produced using an ISOCS unit, as opposed to a fixed-base laboratory. The data are considered screening level only (its intended purpose) and did not meet data evaluation methods; therefore, they could not be used in the risk assessment (DOE 2008). These data subsequently were removed from the Soils OU data set.

B.1.4 UNITS OF RESULTS

Reported units within the data set are appropriate for the analytical types.

B.1.5 DETECTION LIMITS/MINIMUM DETECTABLE CONCENTRATION

All of the nonradionuclide historical data that had no reported result and no detection limit have been removed from the data set.

There are 43 chemicals that are nondetects and have their sample quantitation limit (SQL)/minimum detectable concentrations (MDCs) greater than background or the child resident NAL.

Those chemicals and referenced values are shown in Table B.3.

Table B.3. Analytes with SQL or MDC Greater than Background or Child Resident NAL for SWMU 1

Chemical	Unit	Maximum SQL/MDC for Nondetects	NAL*	Background*	
				Surface	Subsurface
Inorganics					
Antimony	mg/kg	1.22E+01	3.13E+00	2.10E-01	2.10E-01
Arsenic	mg/kg	4.83E+00	3.56E-01	1.20E+01	7.90E+00
Cadmium	mg/kg	1.95E+00	5.28E+00	2.10E-01	2.10E-01
Selenium	mg/kg	1.95E+01	3.91E+01	8.00E-01	7.00E-01
Silver	mg/kg	3.50E+00	3.91E+01	2.30E+00	2.70E+00
Thallium	mg/kg	1.95E+01	7.82E-02	2.10E-01	3.40E-01
Organics					
Benz(a)anthracene	mg/kg	2.50E+00	6.54E-02	N/A	N/A
Benzo(a)pyrene	mg/kg	2.50E+00	6.55E-03	N/A	N/A
Benzo(b)fluoranthene	mg/kg	2.50E+00	6.55E-02	N/A	N/A
Benzo(k)fluoranthene	mg/kg	2.50E+00	6.55E-01	N/A	N/A
Dibenz(a,h)anthracene	mg/kg	2.50E+00	6.55E-03	N/A	N/A
Hexachlorobenzene	mg/kg	2.50E+00	2.12E-01	N/A	N/A
Indeno(1,2,3-cd)pyrene	mg/kg	2.50E+00	6.55E-02	N/A	N/A
N-Nitroso-di-n-propylamine	mg/kg	2.50E+00	2.97E-02	N/A	N/A
PCB-1016	mg/kg	9.40E-01	2.06E-01	N/A	N/A
PCB-1221	mg/kg	9.40E-01	7.10E-02	N/A	N/A
PCB-1232	mg/kg	9.40E-01	7.08E-02	N/A	N/A
PCB-1242	mg/kg	9.40E-01	7.96E-02	N/A	N/A
PCB-1248	mg/kg	9.40E-01	7.88E-02	N/A	N/A
PCB-1254	mg/kg	1.90E+00	5.88E-02	N/A	N/A
PCB-1260	mg/kg	1.90E+00	8.03E-02	N/A	N/A
Pentachlorophenol	mg/kg	2.50E+00	2.54E-01	N/A	N/A
Trichloroethene	mg/kg	1.00E+00	4.12E-01	N/A	N/A
Vinyl chloride	mg/kg	3.50E+00	5.92E-02	N/A	N/A

*NAL is for the Child Resident NAL at the lesser of ELCR of 1E-06 and HI of 0.1. NAL and background values are reported in the Risk Methods Document (DOE 2016).

B.1.6 RADIONUCLIDE COUNTING ERRORS

Radionuclide historical data records that have no MDCs and no counting errors reported have been removed from the data set.

B.1.7 NONDETECT RESULT QUALIFIERS

All usable data records that were considered nondetect were considered so due to laboratory qualification.

B.1.8 ASSIGNMENT OF HISTORICAL DATA TO RI SAMPLING GRIDS

The historic data have been assigned to grids as discussed. The assignments are listed in Table B.4.

Because soils in the area remediated as part of the Southwest Plume source action were disturbed, samples of soils 0–4 ft bgs in the affected grids should be considered no longer representative. Approximately 28 grids were sampled to provide recharacterization. The grids include SOU001-002, SOU001-003, SOU001-004, SOU001-005, SOU001-012, SOU001-013, SOU001-014, SOU001-015, SOU001-016, SOU001-017, SOU001-020, SOU001-021, SOU001-023, SOU001-024, SOU001-025, SOU001-026, SOU001-027, SOU001-028, SOU001-029, SOU001-030, SOU001-031, SOU001-032, SOU001-033, SOU001-034, SOU001-035, SOU001-038, SOU001-039, and SOU001-040.

Stations with historical samples collected soils 0–4 ft bgs in the affected grids are denoted with an asterisk in Table B.4. These samples also have been flagged in OREIS as no longer representative of current conditions. Stations with historical samples collected below 4 ft bgs in the area of the SWMU 1 deep soil mixing have been flagged in OREIS as VOCs remediated and no longer representative of current conditions (Figure B.1). These stations are denoted with a # in Table B.4.

Table B.4. Stations and Grids for Historical Data from SWMU 1

Grid No.	Station Name	Grid No.	Station Name	Grid No.	Station Name
SOU001-001	001-110	SOU001-008	23-0144-1	SOU001-014	*23-0116
SOU001-001	23-0111	SOU001-008	23-0144-2	SOU001-014	*23-0129
SOU001-001	23-0145	SOU001-008	23-0144-3	SOU001-014	23-0129-1
SOU001-001	OF08A-227	SOU001-008	OF08A-213	SOU001-014	23-0129-2
SOU001-001	OF08A-229	SOU001-009	001-103	SOU001-014	23-0129-3
SOU001-002	001-109	SOU001-009	001-150	SOU001-014	*23-0130
SOU001-002	*23-0109	SOU001-009	OF08A-207	SOU001-014	#H009
SOU001-002	*23-0110	SOU001-009	OF08A-210	SOU001-015	#001-157
SOU001-002	*OF08A-225	SOU001-010	001-102	SOU001-015	#001-158
SOU001-003	#001-108	SOU001-010	OF08A-201	SOU001-015	#001-202
SOU001-003	*23-0107	SOU001-010	OF08A-205	SOU001-015	*23-0117
SOU001-003	*23-0108	SOU001-011	001-111	SOU001-015	23-0117-1
SOU001-003	*OF08A-222	SOU001-011	001-179	SOU001-015	#23-0117-2
SOU001-003	*OF08A-223	SOU001-011	23-0146	SOU001-015	#23-0117-3
SOU001-004	#001-107	SOU001-011	OF08A-233	SOU001-015	23-0117-4
SOU001-004	*23-0105	SOU001-011	OF08A-235	SOU001-015	*23-0118
SOU001-004	*23-0106	SOU001-012	001-173	SOU001-015	*23-0127
SOU001-004	*OF08A-221	SOU001-012	*23-0112	SOU001-015	23-0127-1
SOU001-005	001-106	SOU001-012	*23-0132	SOU001-015	23-0127-2
SOU001-005	*23-0104	SOU001-012	*23-0133	SOU001-015	23-0127-3
SOU001-005	*OF08A-219	SOU001-013	#001-201	SOU001-015	*23-0128
SOU001-005	*OF08A-220	SOU001-013	*23-0113	SOU001-016	#001-161
SOU001-006	23-0102	SOU001-013	*23-0114	SOU001-016	#001-168
SOU001-006	23-0103	SOU001-013	*23-0131	SOU001-016	#001-203
SOU001-006	OF08A-218	SOU001-013	23-0131-1	SOU001-016	*23-0119
SOU001-007	001-105	SOU001-013	23-0131-2	SOU001-016	*23-0126
SOU001-007	23-0101	SOU001-013	23-0131-3	SOU001-016	*H051
SOU001-007	OF08A-215	SOU001-013	*H258	SOU001-017	001-001
SOU001-007	OF08A-217	SOU001-014	#001-155	SOU001-017	001-002
SOU001-007	OF08B-08-02	SOU001-014	#001-156	SOU001-017	001-003
SOU001-008	001-104	SOU001-014	#001-166	SOU001-017	001-005
SOU001-008	23-0144	SOU001-014	*23-0115	SOU001-017	001-171

Table B.4. Stations and Grids for Historical Data from SWMU 1 (Continued)

Grid No.	Station Name	Grid No.	Station Name	Grid No.	Station Name
SOU001-017	*23-0120	SOU001-028	001-004	SOU001-045	H355
SOU001-017	*23-0121	SOU001-028	*23-0142	SOU001-046	001-135
SOU001-017	23-0124	SOU001-028	*23-0143	SOU001-046	H052
SOU001-017	*23-0125	SOU001-028	*H210	SOU001-047	001-136
SOU001-017	23-0125-1	SOU001-028	H357	SOU001-047	H358
SOU001-017	23-0125-2	SOU001-029	001-118	SOU001-049	001-137
SOU001-017	23-0125-3	SOU001-029	*23-0155	SOU001-049	H209
SOU001-017	H050	SOU001-030	001-119	SOU001-050	001-138
SOU001-018	23-0122	SOU001-031	001-120	SOU001-050	OF08A-212
SOU001-018	23-0123	SOU001-032	*001-121	SOU001-051	OF08A-175
SOU001-018	23-0147	SOU001-033	001-131	SOU001-051	OF08A-208
SOU001-018	23-0147-1	SOU001-033	*23-0154	SOU001-051	OF08A-209
SOU001-018	23-0147-2	SOU001-034	001-130	SOU001-051	OF08A-211
SOU001-018	23-0147-3	SOU001-034	001-162	SOU001-051	OF08B-08-01
SOU001-022	001-112	SOU001-034	*23-0153	SOU001-052	001-144
SOU001-022	OF08A-234	SOU001-035	001-129	SOU001-052	001-148
SOU001-022	OF08A-236	SOU001-035	001-174	SOU001-052	OF08A-189
SOU001-022	OF08B-08-03	SOU001-035	*23-0152	SOU001-052	OF08A-190
SOU001-023	001-113	SOU001-036	001-128	SOU001-053	001-143
SOU001-023	*23-0134	SOU001-036	23-0151	SOU001-053	H259
SOU001-024	#001-114	SOU001-037	001-127	SOU001-053	OF08A-188
SOU001-024	*23-0135	SOU001-037	23-0150	SOU001-053	OF08B-07-01
SOU001-024	*23-0136	SOU001-038	001-126	SOU001-054	001-142
SOU001-025	#001-115	SOU001-038	*23-0149	SOU001-054	OF08A-186
SOU001-025	#001-152	SOU001-040	001-125	SOU001-054	OF08A-187
SOU001-025	#001-153	SOU001-040	*23-0148	SOU001-055	001-141
SOU001-025	#001-154	SOU001-041	001-124	SOU001-055	OF08A-185
SOU001-025	#001-172	SOU001-042	001-123	SOU001-056	001-140
SOU001-025	*23-0137	SOU001-042	001-145	SOU001-056	OF08A-183
SOU001-025	*23-0138	SOU001-042	OF08A-204	SOU001-056	OF08A-184
SOU001-026	#001-116	SOU001-042	OF08A-206	SOU001-056	OF08B-07-02
SOU001-026	#001-159	SOU001-043	001-132	SOU001-057	001-147
SOU001-026	*23-0139	SOU001-043	001-170	SOU001-057	OF08A-182
SOU001-026	*23-0140	SOU001-043	OF08A-228	SOU001-058	001-139
SOU001-026	23-0140-1	SOU001-043	OF08A-230	SOU001-058	001-146
SOU001-026	23-0140-2	SOU001-043	OF08B-08-04	SOU001-058	H260
SOU001-026	23-0140-3	SOU001-044	001-133	SOU001-058	OF08A-180
SOU001-026	*H356	SOU001-044	H208	SOU001-058	OF08A-181
SOU001-027	#001-117	SOU001-044	OF08A-224	SOU001-058	OF08A-216
SOU001-027	001-160	SOU001-044	OF08A-226	SOU001-059	OF08A-179
SOU001-027	*23-0141	SOU001-045	001-134	SOU001-059	OF08A-214

*Station with historical samples collected 0–4 ft bgs that have been removed from the dataset because the samples no longer are representative of the SWMU.

#Station with historical samples collected below 4 ft bgs in the area of SWMU 1 deep soil mixing that have VOC results removed from the dataset because the samples no longer are representative of the SWMU.

Similarly, pretreatment sampling for SWMU 1 VOCs, conducted in 2012, has not been included with historical samples because the VOCs have been remediated and no longer representative of current conditions.

B.1.9 SUMMARY OF DETECTED CHEMICALS

A summary of detected chemicals is provided in Section 5.

B.2. RI LABORATORY ANALYTICAL DATA

Consistent with the work plan, the following analytical data are not considered usable for the RI:

- Data qualified as rejected by data validation.
- Data qualified as rejected by data assessment.

Samples collected for this addendum was not validated by a third party. Data validation was adequately performed for the historical data collected during the 2010 Soils OU RI. The data was, however, assessed following DOE Prime Contractor procedure PAD-ENM-5003, *Quality Assured Data*, as specified in the work plan addendum (DOE 2014).

B.3. FIELD RESULTS

Field laboratory data such as XRF data and results from PCB field test kits are available in addition to the laboratory analytical data. The primary use of such data is for site characterization, but these survey-type data also can play a role in risk-based decision making. Survey-type data assist in determining distribution of chemicals or radionuclides of potential concern and can be used to identify which sets of laboratory data should be combined to develop site average contaminant concentrations. Consistent with previous projects at the site, survey-type data also could be combined with laboratory data in a risk assessment to determine the average concentrations for contaminants, but this would require demonstrating that the laboratory and survey-type data possess similar detection limits and analytical uncertainty, and data sets are comparable and representative of the site conditions. This is the one focus of the considerations in determining the usability of these results.

Per U.S. Environmental Protection Agency data usability guidance (EPA 1992), the analytical data objective for baseline risk assessment is that uncertainty is known and acceptable, not that uncertainty should be reduced to a particular level. In addition, because sampling variability typically contributes much more to total error than analytical variability, the use of a larger number of field method results to characterize the site may provide a better estimate of the average concentration, provided these data are defensible.

The following discussions consider whether the detection limits are sufficiently low to distinguish from background or risk-based concentrations, detected concentration ranges and ability to use to identify “hot spots” (values above action levels), potential for false negatives that could result in underestimating risks, and comparison of field results with confirmatory samples.

B.3.1 XRF

XRF data were evaluated in multiple stages. The initial comparison of XRF and fixed-base laboratory data includes correlation and graphical comparison between paired data (i.e., composite split samples with both XRF and fixed-base results). The second stage of comparison includes false negative/false positive comparison (assuming fixed-base laboratory data represent the soil sample concentration).

A summary of the XRF data collected for this RI Addendum is presented in Table B.5.

Table B.5. Ranges of XRF Results

		ALL XRF DATA		PAIRED XRF DATA	
Analysis	**Units**	**Min**	**Max**	**Min**	**Max**
Arsenic	mg/kg	2	8	4	6
Chromium	mg/kg	19	94	19	34
Copper	mg/kg	5	19	10	13
Iron	mg/kg	4,457	25,371	13,158	17,500
Lead	mg/kg	11	26	11	18
Manganese	mg/kg	108	1,077	258	711
Mercury	mg/kg	6	6	6	6
Molybdenum	mg/kg	6	13	6	7
Nickel	mg/kg	5	30	5	17
Selenium	mg/kg	3	3	3	3
Silver	mg/kg	10	12	10	10
Uranium	mg/kg	53	53	53	53
Vanadium	mg/kg	8	33	8	8
Zinc	mg/kg	22	60	26	34

B.3.1.1 Initial Comparison

Data collected from the SWMU 1 RI Addendum sampling to evaluate the nature and extent of metals in surface soils yielded 6 laboratory analyses that were supplemented with approximately 56 (plus 6 field duplicate) field analyses using XRF. As expected, the XRF data correlated better with the laboratory data for many constituents, but not all constituents (Johnson 2008). This discrepancy provides an uncertainty that is documented in this data quality analysis (DQA) and will be addressed in Section 6 of this RI Addendum to support remedial decision making. The attachment to this DQA provides additional statistics for the XRF data.

B.3.1.2 Graphical Comparison of Paired Samples Based Upon Analytical Method

The results for six soil samples analyzed by cup XRF and laboratory methods were assessed graphically. These pairs were sorted graphically by increasing XRF and laboratory result and by sample number. In general, it appears that XRF results have higher detection limits, but not always higher reported values than the laboratory results. There are exceptions to this generalization and other factors such as laboratory dissolution methods may contribute to the higher reported values for the XRF. Thus, using the higher value in a risk assessment typically will overstate the risk/hazard (hereafter referred to as risk).

The graphs for comparison are presented in the attachment to this appendix along with the additional statistics. The graphs illustrate the differences in results for the samples in which both an XRF and a fixed-base laboratory result were obtained. The graphs illustrate the results obtained by the two different methods (on the same sample), sorted by increasing XRF result. Each graph also shows the XRF reporting limits and the subsurface background values (DOE 2016). Table B.6 lists observations from the initial review of the data.

Table B.6. Summary of Initial Observations by Analyte

Analyte	Correlation*	Notes
Arsenic	0.425	Fairly good correlation; lab data reported higher than XRF data.
Chromium	0.069	Only one detection in XRF data; reported higher than lab data.
Copper	0.380	Fairly good correlation; lab data reported higher than XRF data.
Iron	0.312	Fairly good correlation; lab data reported higher than XRF data.
Lead	-0.217	Only two detections in XRF data; reported higher than lab data.
Manganese	0.004	Poor correlation; most lab data reported higher than XRF data.
Mercury	N/A	No detections in XRF data; lab data reported below XRF detection limit.
Molybdenum	-0.969	Detected in 3 of 6 paired samples, reported close to detection limit; lab data reported below XRF detection limit.
Nickel	-0.121	Only two detections in XRF data; reported lower than lab data.
Selenium	N/A	No detections in XRF data; lab data reported below XRF detection limit.
Silver	N/A	No detections in XRF data; lab data reported below XRF detection limit.
Uranium	N/A	No detections in XRF data; lab data reported below XRF detection limit.
Vanadium	N/A	No detections in XRF data; lab data reported above XRF detection limit.
Zinc	0.259	Fair correlation; lab data reported both higher and lower than XRF data. No XRF detections reported above background value.

*Pearson correlation coefficient for sample pairs.
Note: Additional information regarding XRF performance by analyte at PGDP can be found in Johnson 2008.

B.3.1.2.1 Differences between XRF results and fixed-base laboratory results

Some differences between XRF results and fixed-base laboratory results are expected due to the differences in how the constituents were measured [i.e., the XRF measures the secondary (fluorescent) X-rays emitted by elements after they have been stimulated by (primary) X-rays]. Thus, this technique tends to measure the concentrations of elements located near the surface of the sample, while the fixed-base laboratory method theoretically measures the concentration of an element located throughout the entire sample volume (assuming homogeneity and complete dissolution).

The XRF and the fixed-base laboratory results are expected to correlate generally (because they are expected to correlate generally, higher XRF results would be expected to be found when the laboratory result is higher). Many of the data collected with the XRF are consistent with the laboratory results; however, the degree to which these data correlate varies by analyte.

B.3.1.3 Summary of Frequencies of Detection of Analytes and False Positive/Negative Results

A summary of frequencies of false positive and false negative results in field data are compiled in Table B.7. A result was designated as a false positive if the XRF result was detected greater than the fixed-base laboratory result and as a false negative if the XRF was not detected or was detected less than a fixed-base laboratory result that was greater than the XRF detection limit.

The graphs (in the Attachment) and Table B.7 indicate that many of the metals show false negative XRF results. This indication is an uncertainty that should be addressed in the risk assessment.

Table B.7. Summary of Frequencies of False Positive and False Negative Results in Field Data

Analyte	Frequency of Detection for Field Data	Frequency of False Positive Results	Frequency of False Negative Results
Arsenic	46/62	0/6	6/6
Chromium	5/62	1/6	3/6
Copper	62/62	1/6	4/6
Iron	62/62	1/6	5/6
Lead	9/62	2/6	2/6
Manganese	62/62	1/6	5/6
Mercury	0/62	0/6	0/6
Molybdenum	27/62	3/6	0/6
Nickel	19/62	1/6	5/6
Selenium	0/62	0/6	0/6
Silver	1/62	0/6	0/6
Uranium	0/62	0/6	0/6
Vanadium	2/62	0/6	6/6
Zinc	62/62	1/6	5/6

B.3.1.4 Summary

Evaluation of the XRF data with laboratory data indicates the use of results from XRF is acceptable.

B.3.2 PCBS

Consistent with the SAP addendum, 56 samples and 6 field duplicates samples were analyzed for PCBs using field test kits, and approximately 10% of these were split with the analytical laboratory to evaluate potential uncertainties or biases in the results.

Initial sampling of the SWMU 1 grids for PCBs utilized PCB test kits that had not been properly refrigerated. Results from these test kits were rejected by data assessment and the locations were resampled and reanalyzed. Only the second set of sampling data for PCB test kits is included in the project data set. Analytical laboratory results from the first set of sampling is included in the project data set, but are not used for comparison to test kit data.

Table B.8 is an overview of the results from the field tests.

Table B.8. Ranges of PCB Test Kit Results

		ALL PCB DATA			PAIRED PCB DATA		
Analysis	**Units**	**Frequency of Detection**	**Min**	**Max**	**Frequency of Detection**	**Min**	**Max**
Total PCBs	mg/kg	0/62	5	5	0/6	5	5

The detection limit for the field test kits was 5 mg/kg, compared to approximately 0.02 mg/kg for the laboratory results. Results of field test kits were not detected at a reporting limit of 5 mg/kg.

The six confirmatory samples were collected to evaluate the results of the field data. Five laboratory results were reported as less than 5 mg/kg or not detected. One result was report as 9.5 mg/kg. This comparison suggests field results for PCBs are an uncertainty that should be addressed in the risk assessment.

B.4. REFERENCES

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Johnson, R. I. 2008. *Real Time Demonstration Project XRF Performance Evaluation Report for Paducah Gaseous Diffusion Plant AOC 492*, Kentucky Consortium for Energy and Environment, Lexington, KY, April 3.

ATTACHMENT B1

XRF STATISTICS

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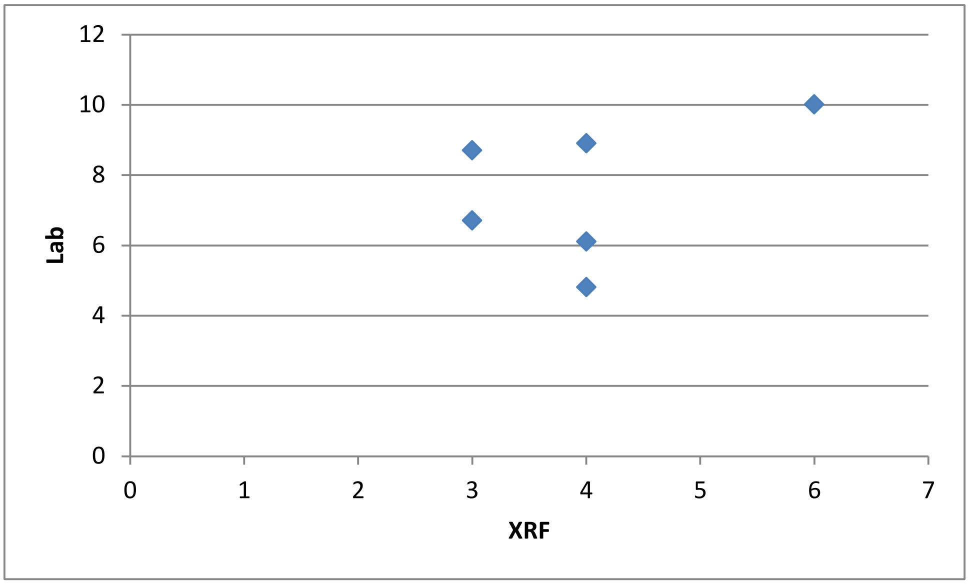
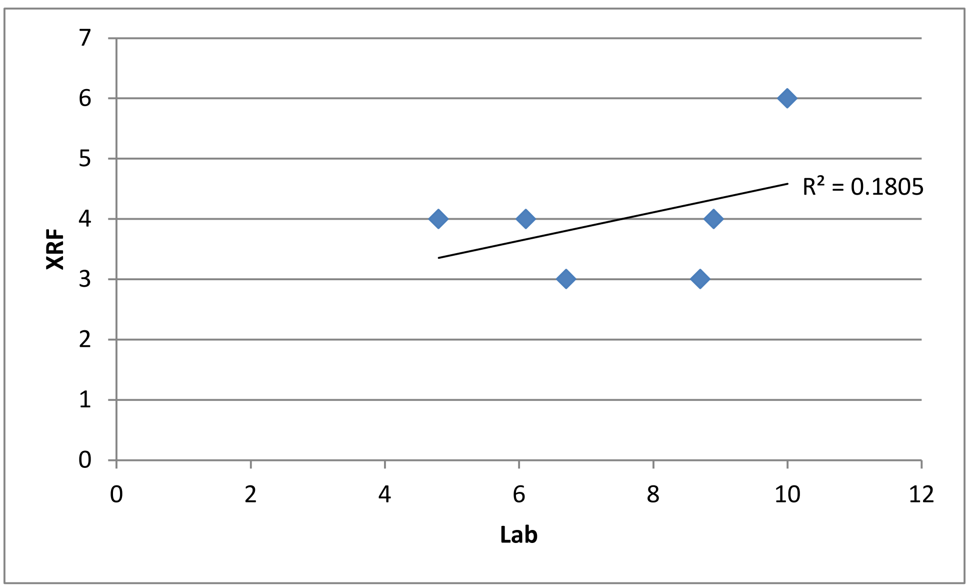
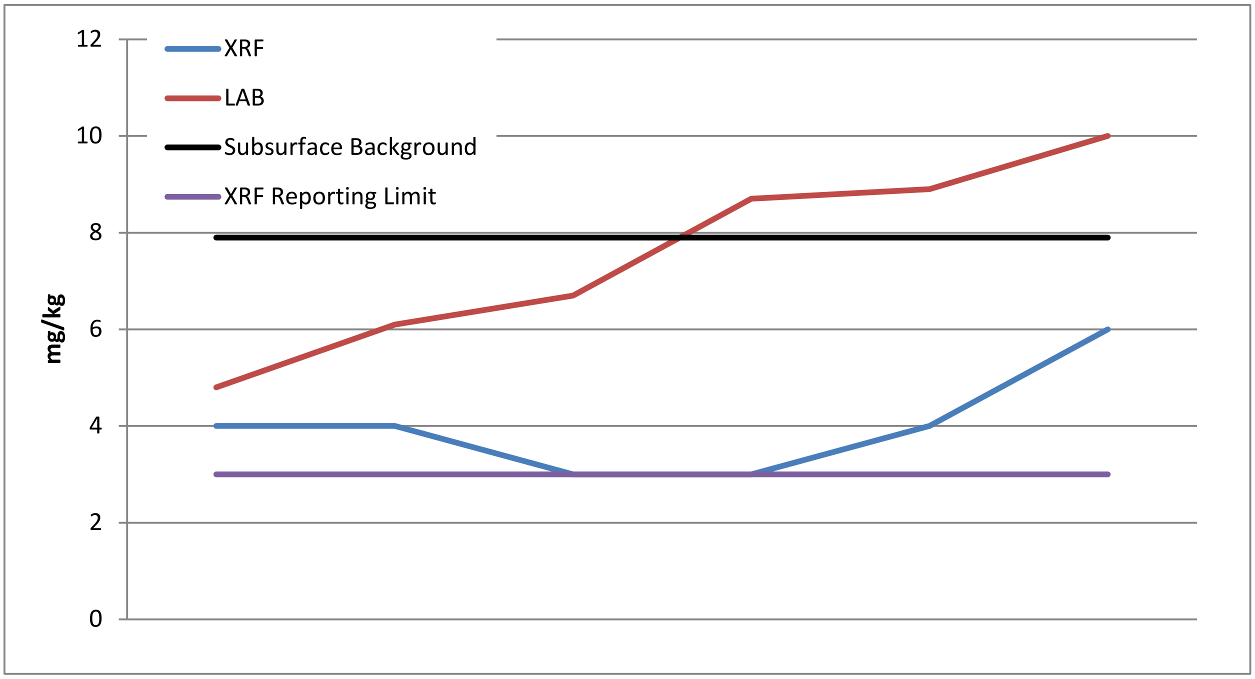
The XRF data correlated better with the laboratory data for many constituents, but not all constituents (Johnson 2008). This discrepancy provides an uncertainty that is documented in this DQA and will be addressed in Section 6 of this RI Addendum to support remedial decision making. This attachment provides additional statistics for the XRF data to support Section B.3.1.1, Initial Comparison.

Arsenic

Pearson's Correlation Coefficient	0.425	Bkg (Surface/Subsurface)	12/7.9
		IW NAL	1.6



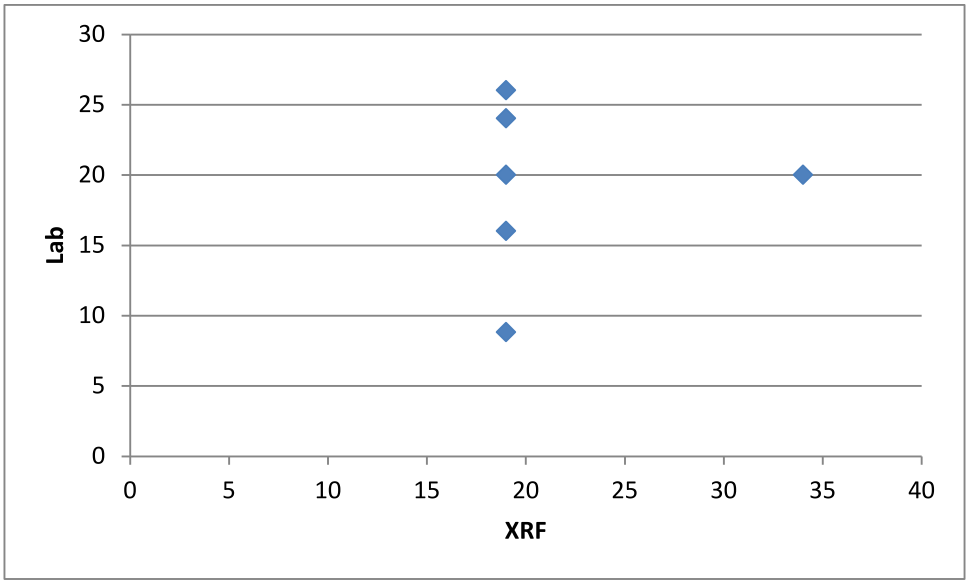


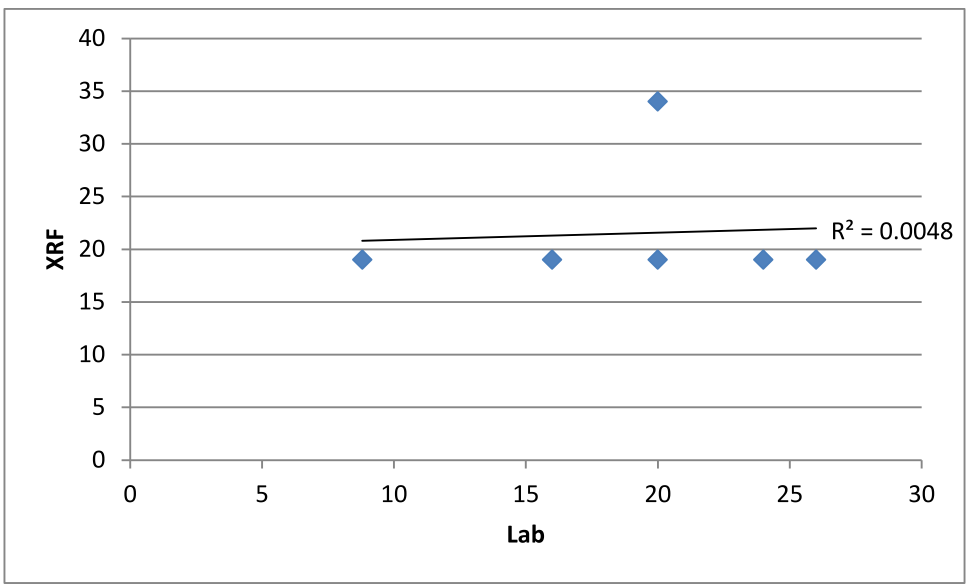


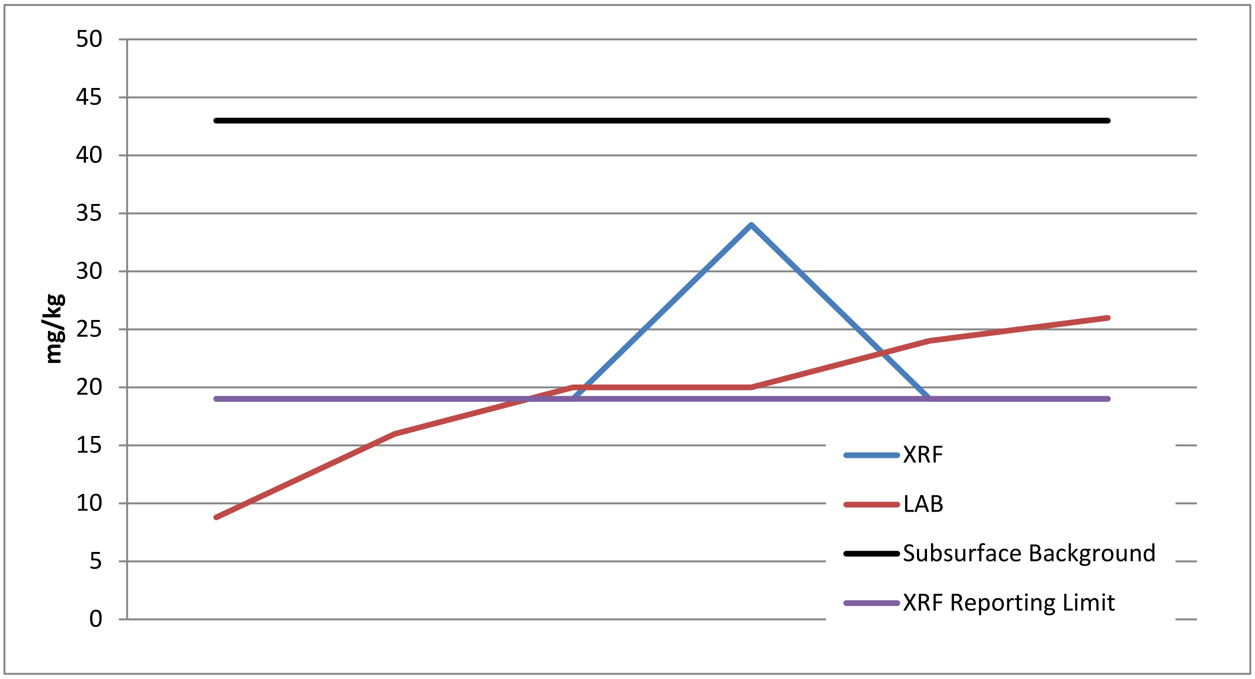
XRF
LAB
Subsurface Background
XRF Reporting Limit
mg/kg
12
10
8
6
4
2
0

Chromium

Pearson's Correlation Coefficient	0.069	Bkg (Surface/Subsurface)	16/43
		IW NAL	198



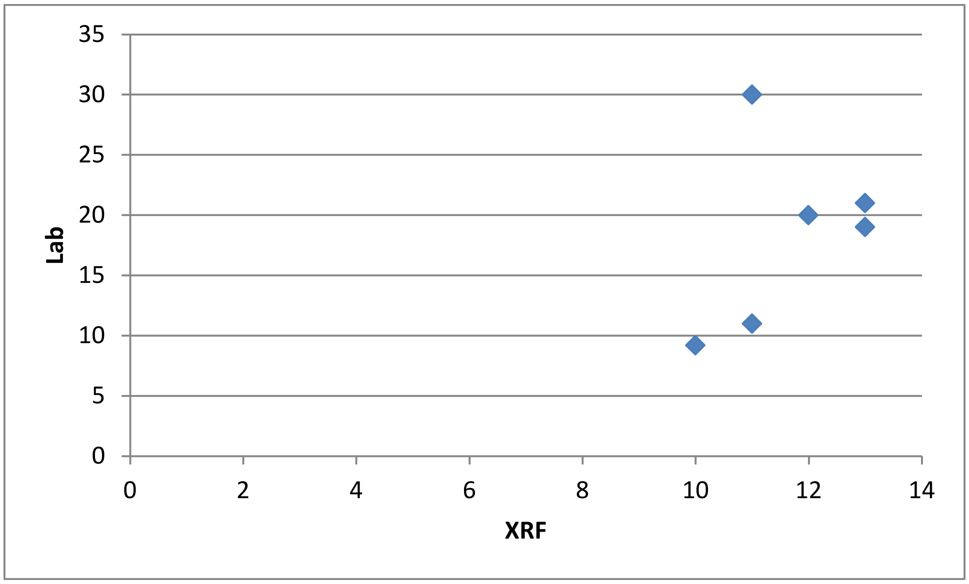


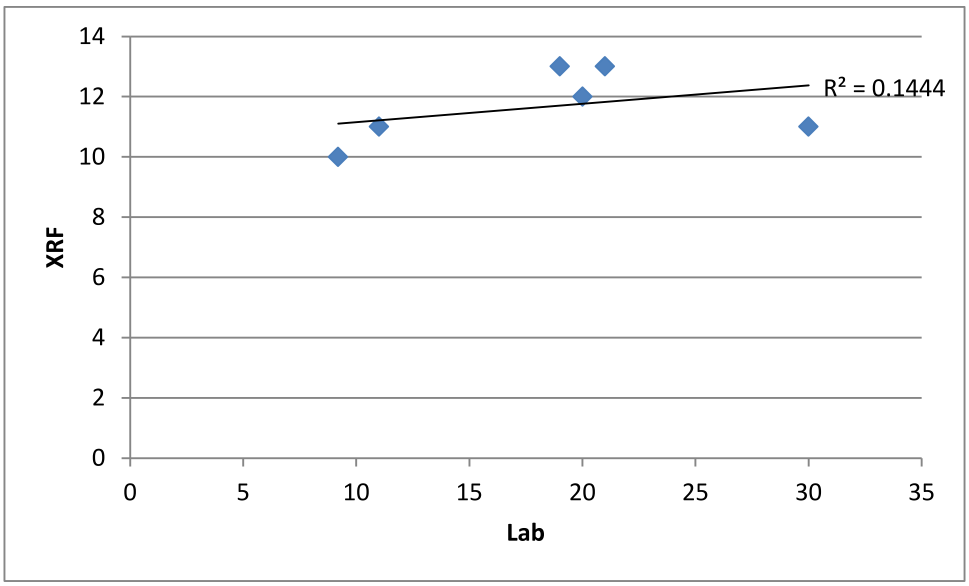


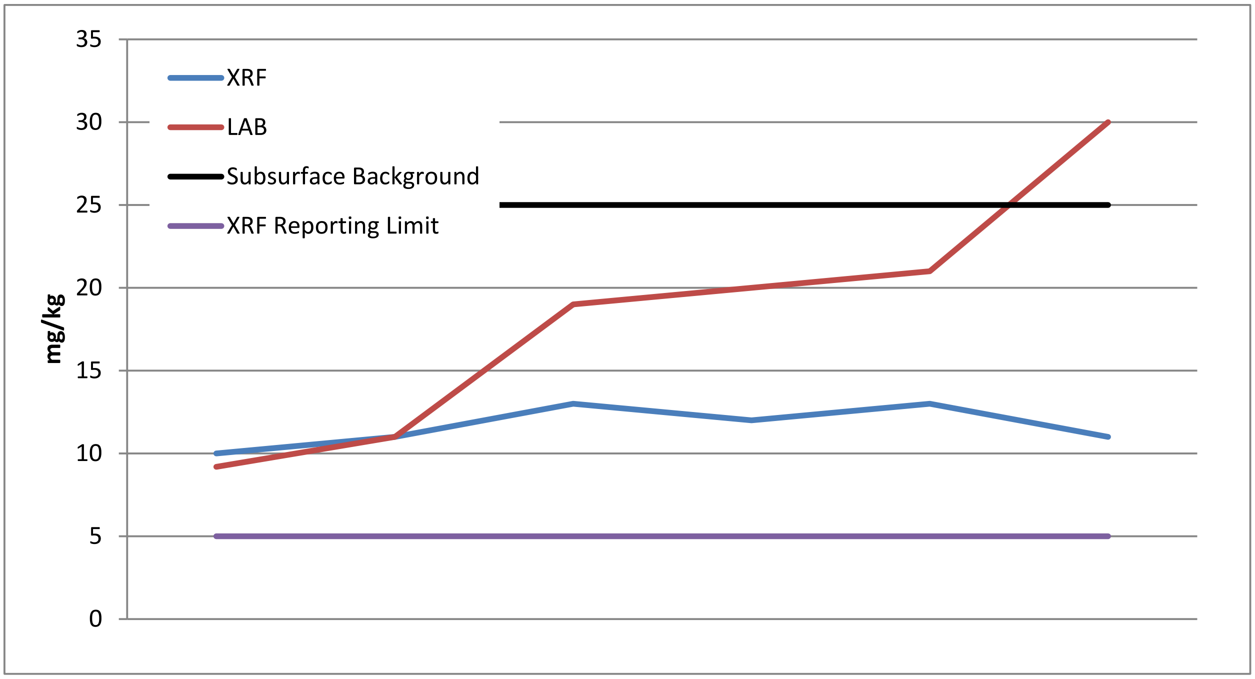
50
45
40
35
30
25
20
15
10
5
0
mg/kg
XRF
LAB
Subsurface Background
XRF Reporting Limit

Copper

Pearson's Correlation Coefficient	0.380	Bkg (Surface/Subsurface)	19/25
		IW NAL	9,340

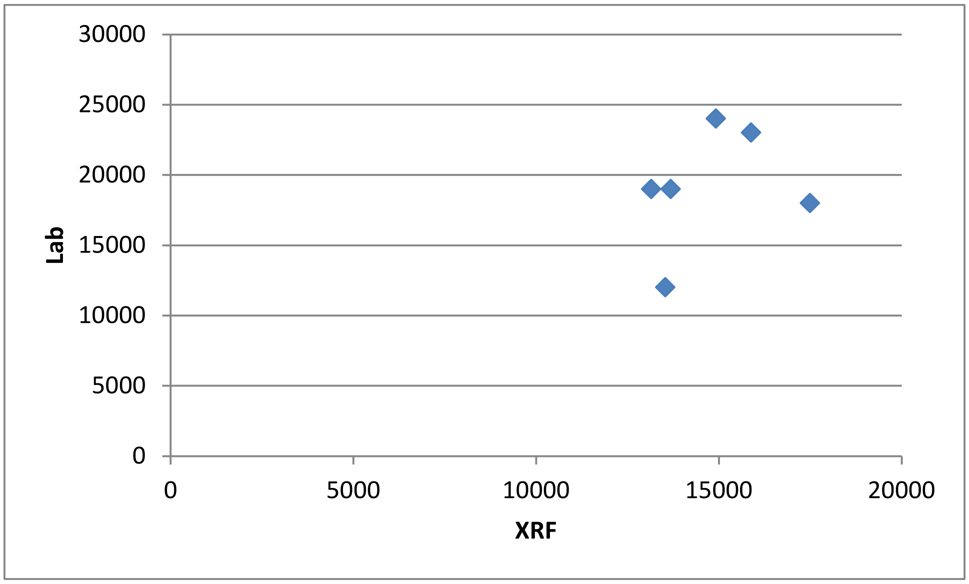


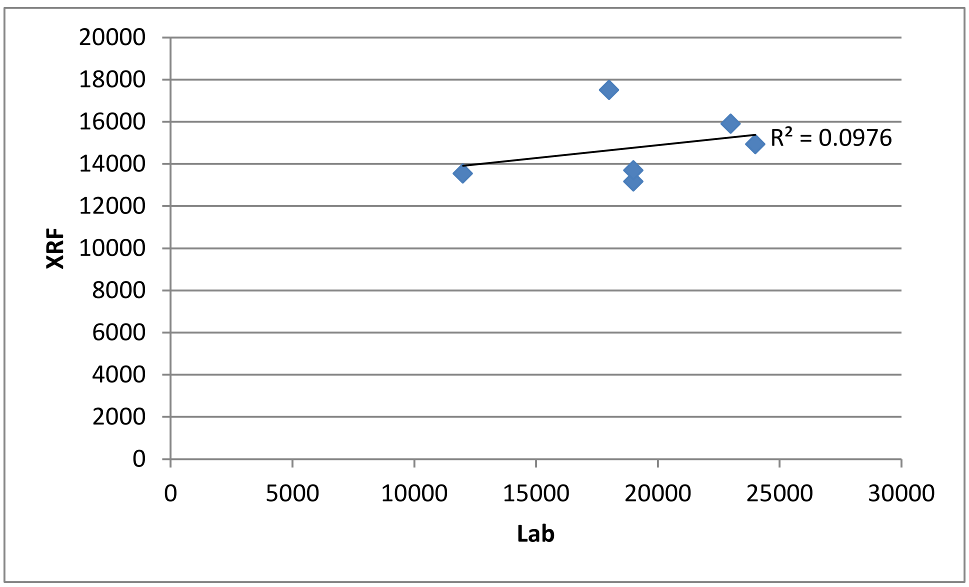


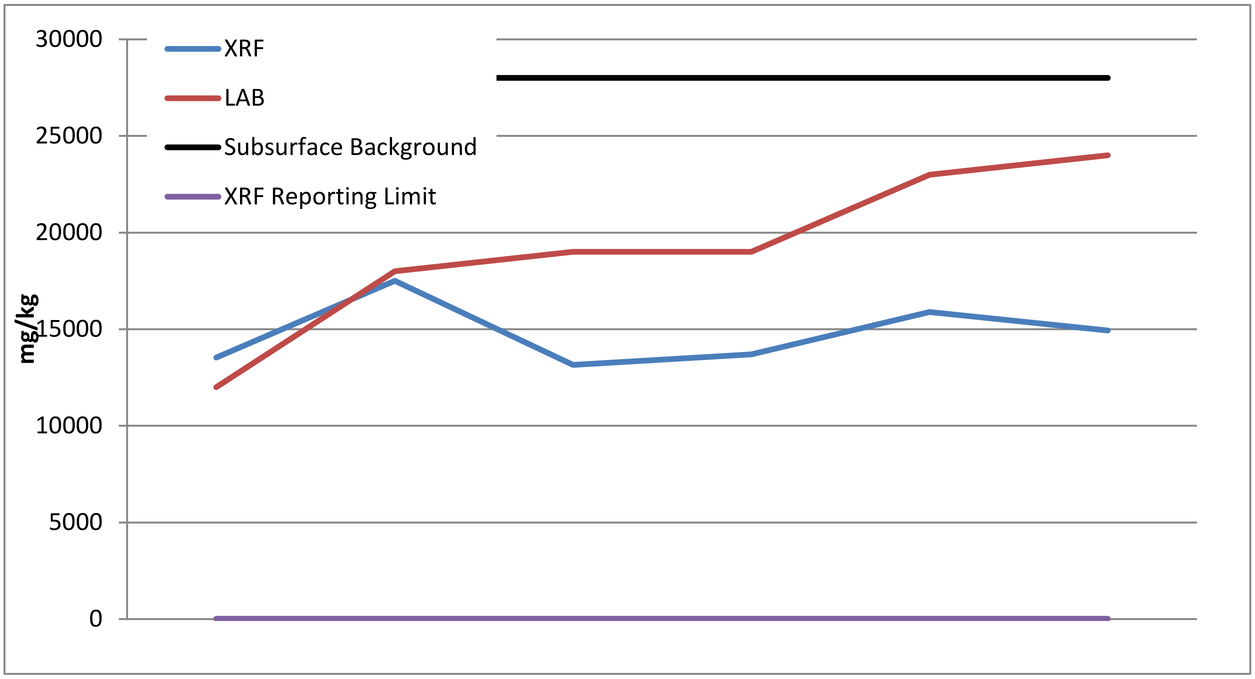

35
30
25
20
15
10
5
0
mg/kg
XRF
LAB
Subsurface Background
XRF Reporting Limit

Iron

Pearson's Correlation Coefficient	0.312	Bkg (Surface/Subsurface)	28,000/28,000
		IW NAL	100,000

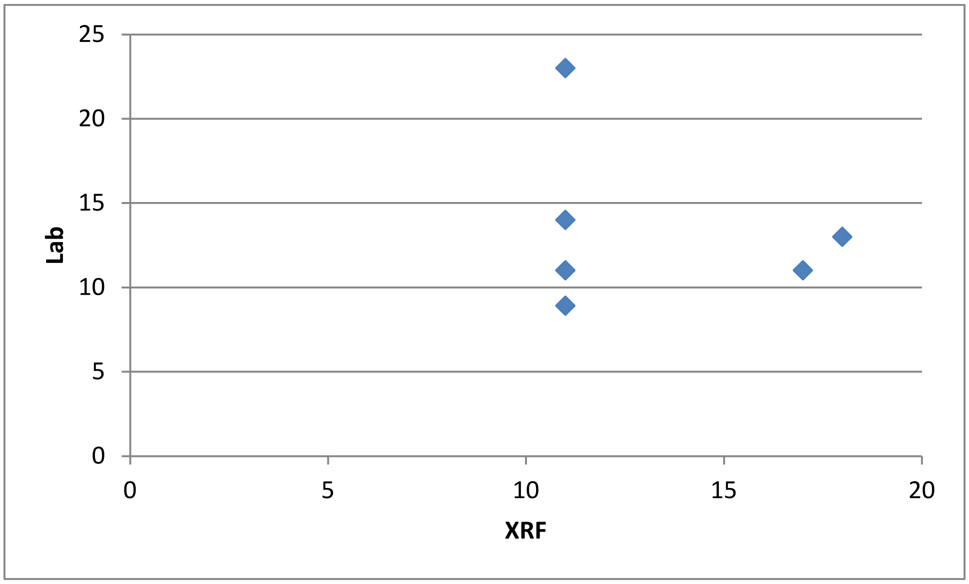


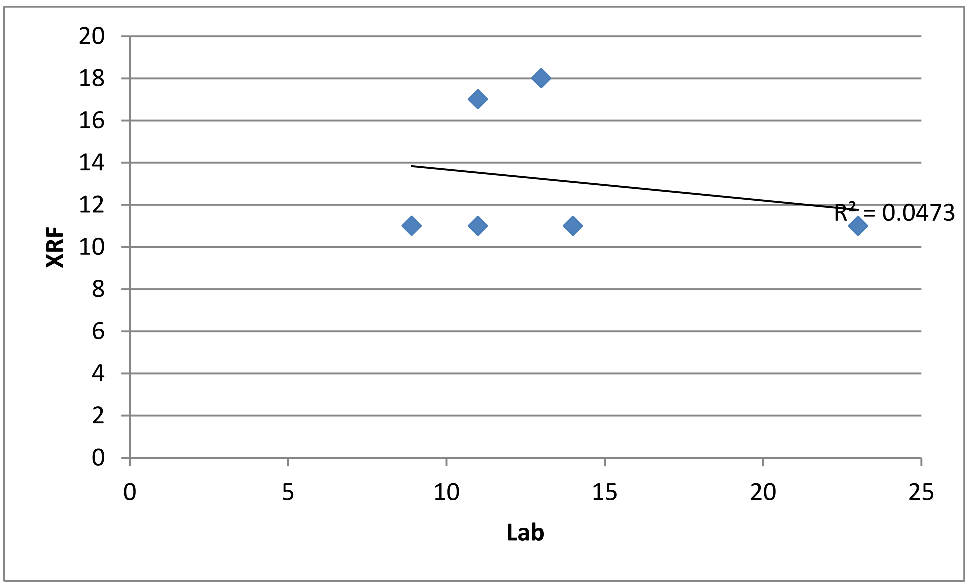


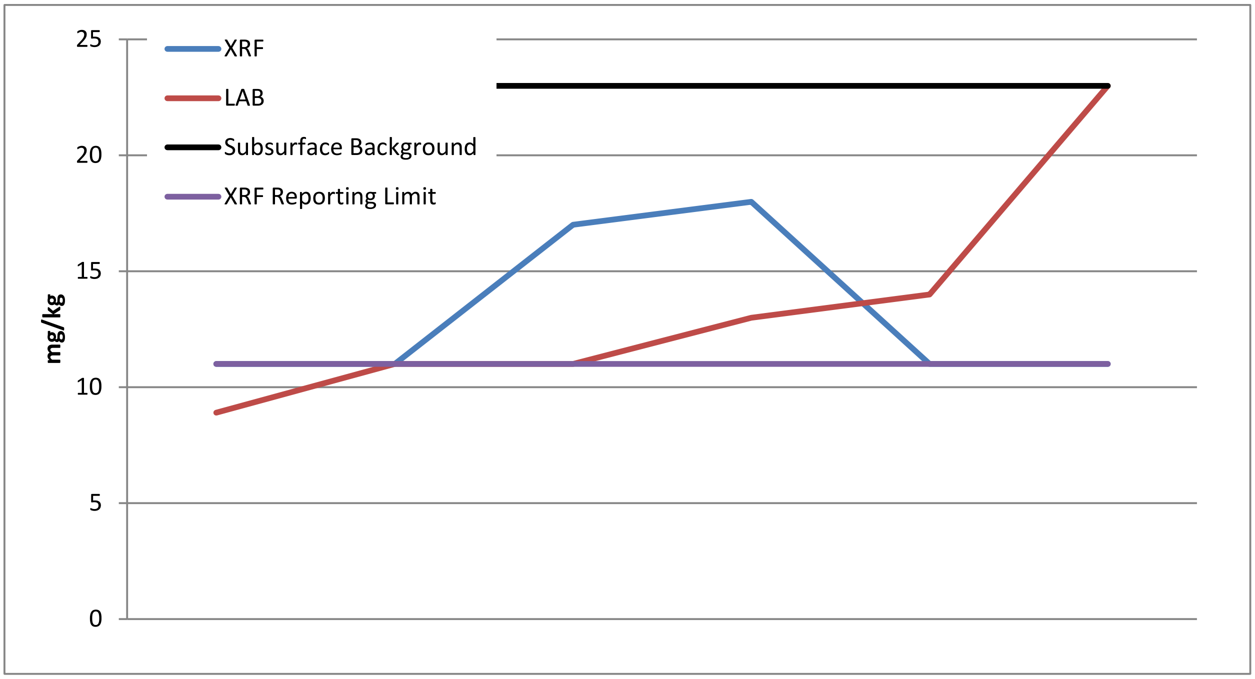

30000
25000
20000
15000
10000
5000
0
mg/kg
XRF
LAB
Subsurface Background
XRF Reporting Limit

Lead

Pearson's Correlation Coefficient	-0.217	Bkg (Surface/Subsurface)	36/23
		IW NAL	800

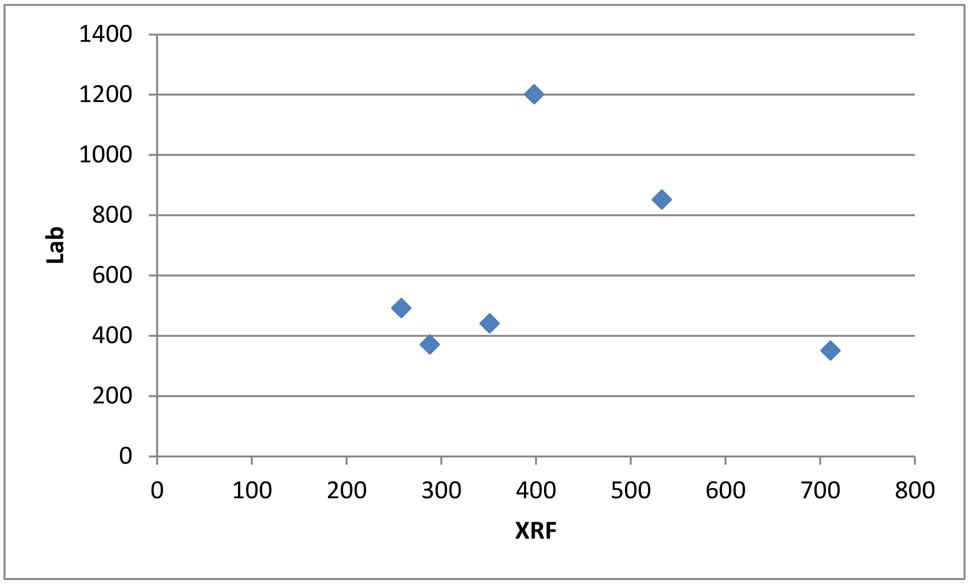


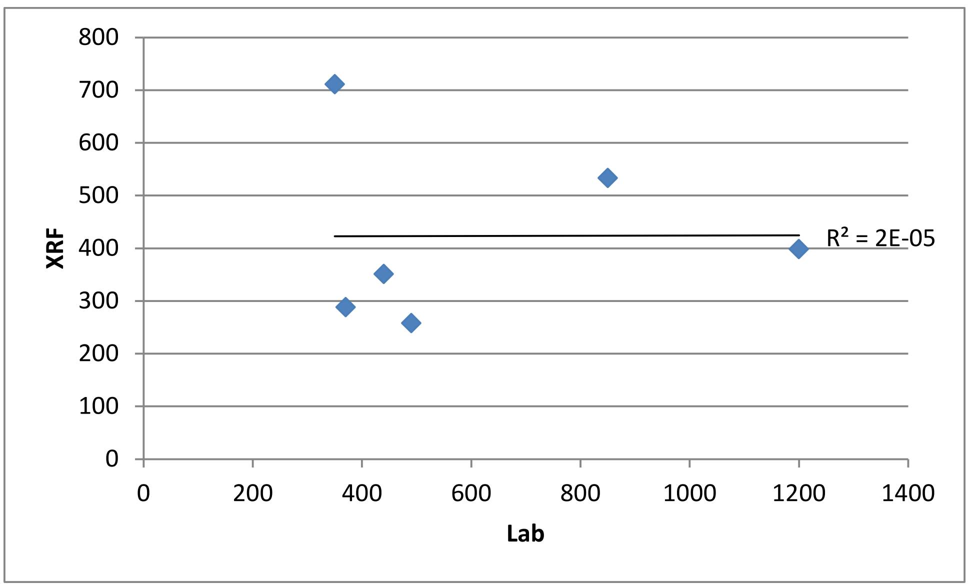


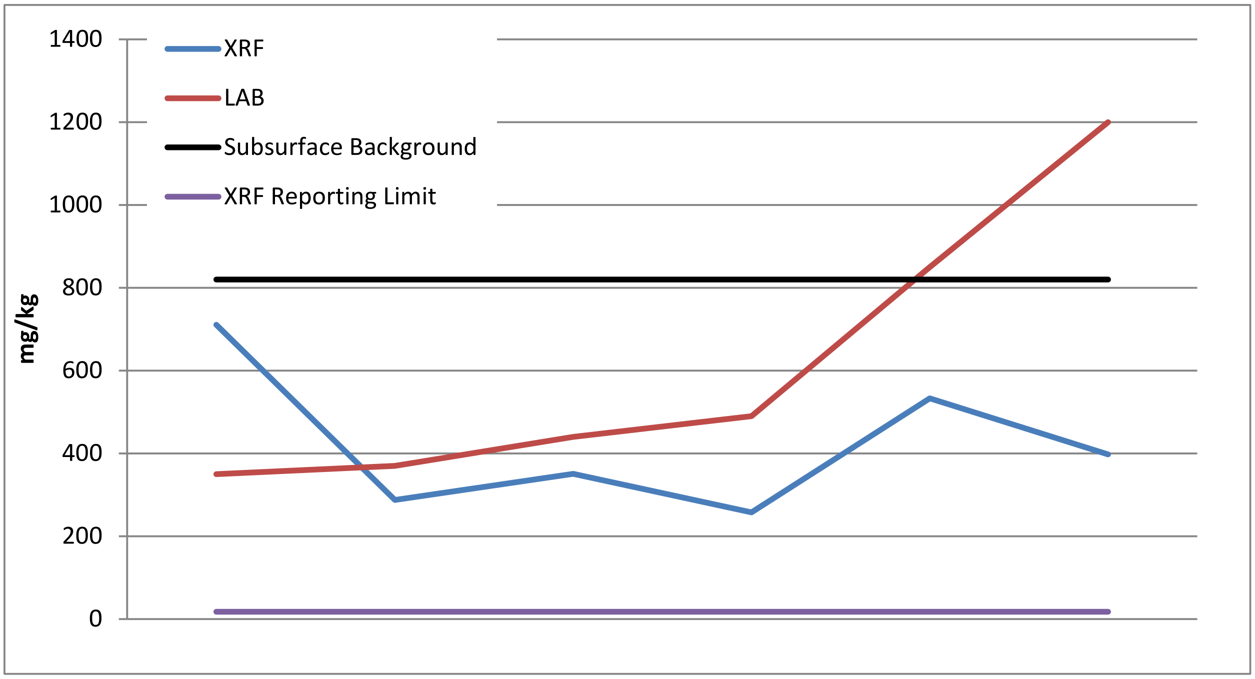

25
20
15
10
5
0
mg/kg
XRF
LAB
Subsurface Background
XRF Reporting Limit

Manganese

Pearson's Correlation Coefficient	0.004	Bkg (Surface/Subsurface)	1,500/820
		IW NAL	4,720

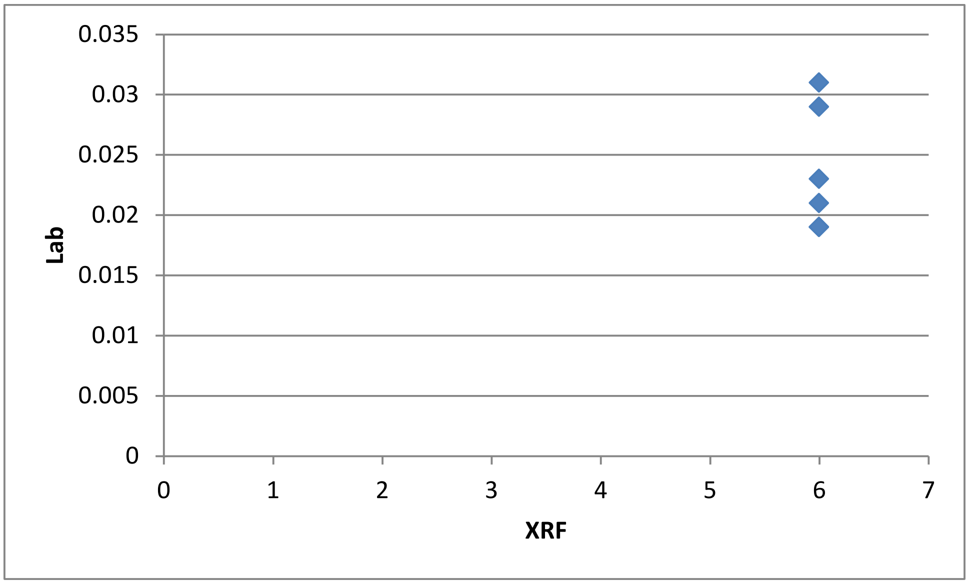


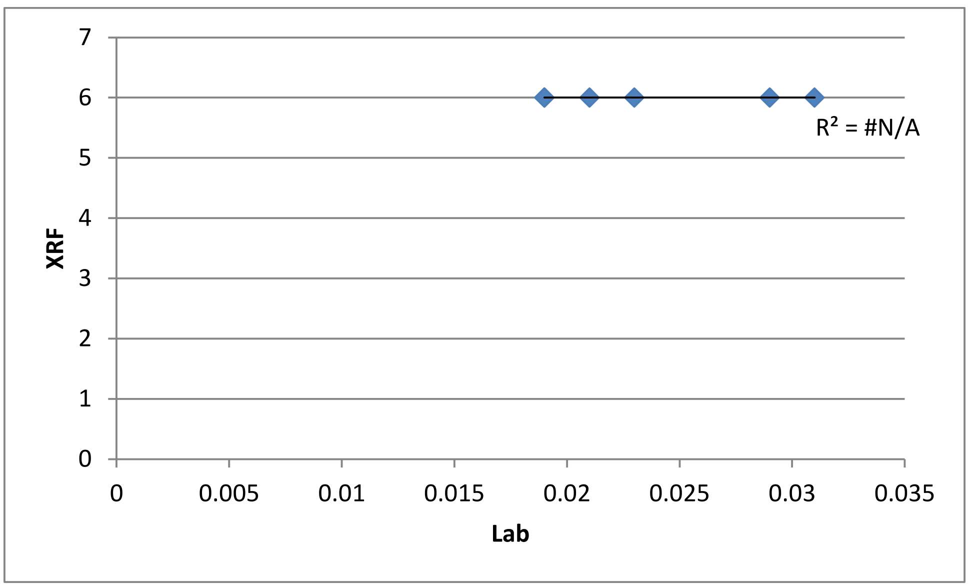


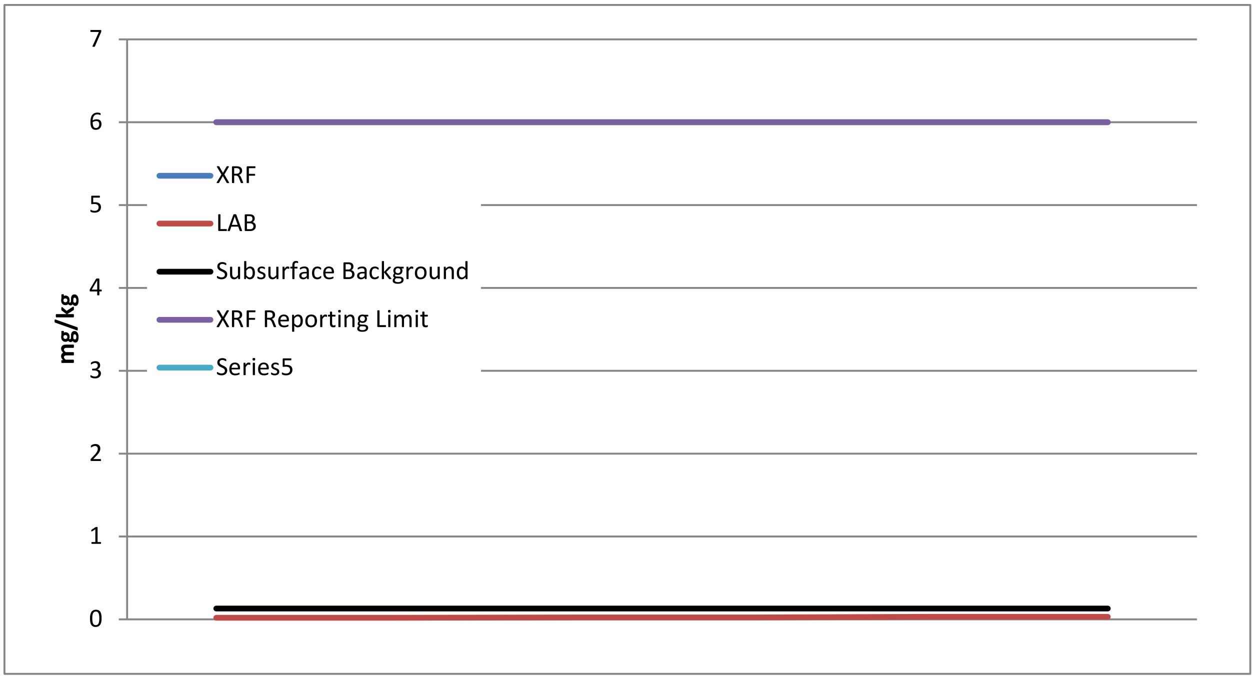

1400
1200
1000
800
600
400
200
0
mg/kg
XRF
LAB
Subsurface Background
XRF Reporting Limit

Mercury

Pearson's Correlation Coefficient	N/A	Bkg (Surface/Subsurface)	0.2/0.13
		IW NAL	70.1

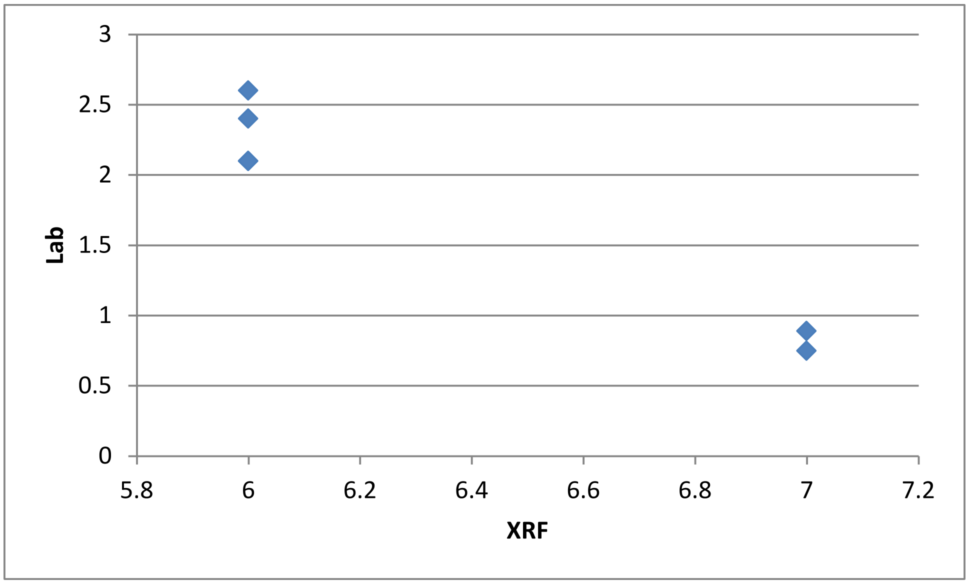


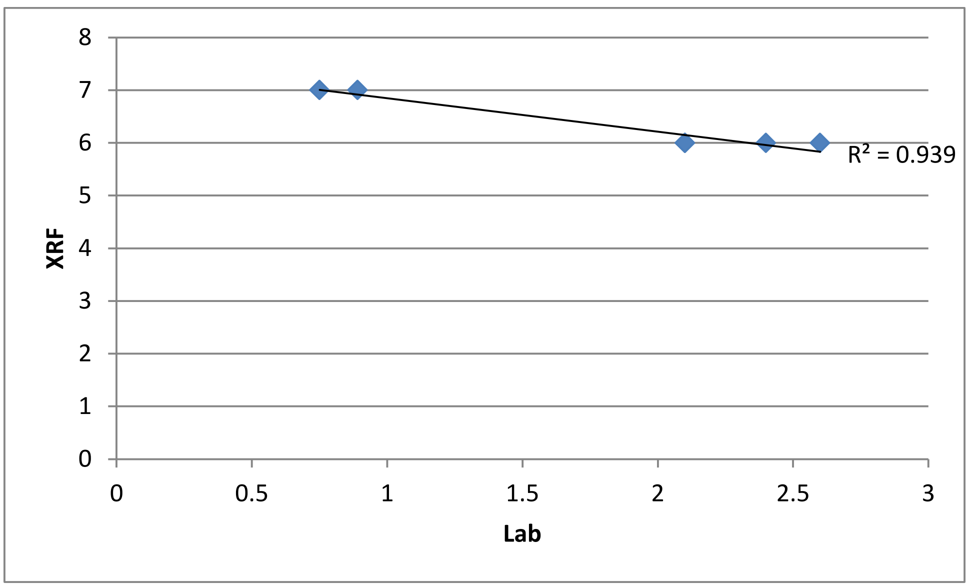


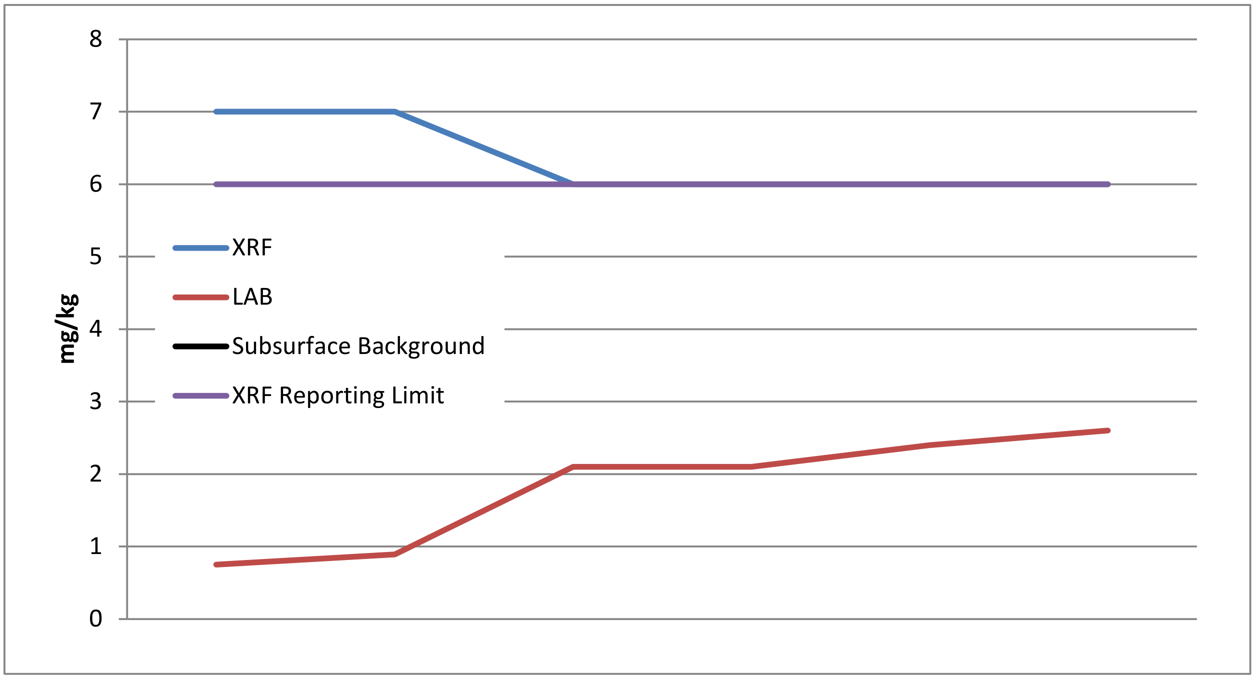

7
6
5
4
3
2
1
0
mg/kg
XRF
LAB
Subsurface Background
XRF Reporting Limit
Series5

Molybdenum

Pearson's Correlation Coefficient	-0.969	Bkg (Surface/Subsurface)	N/A
		IW NAL	1,170



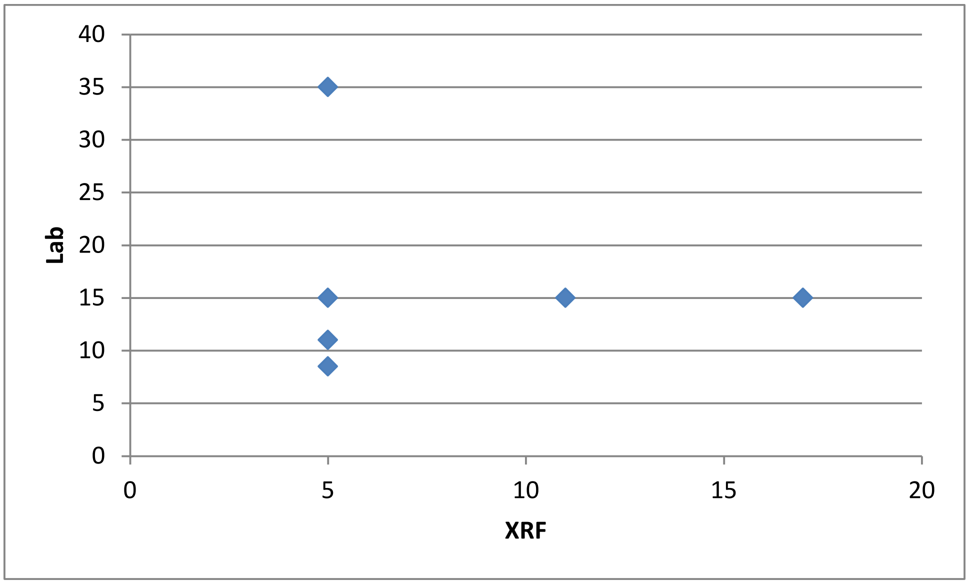


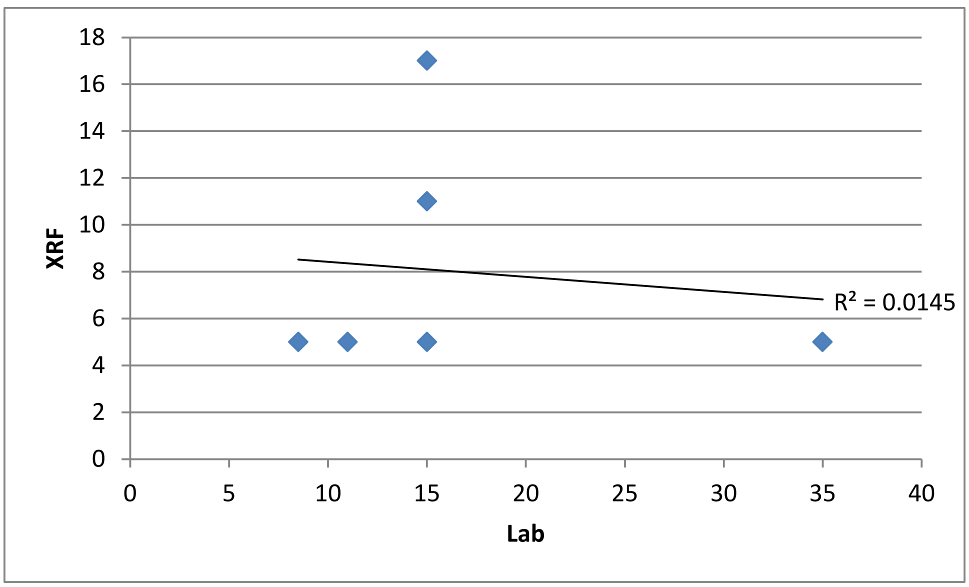


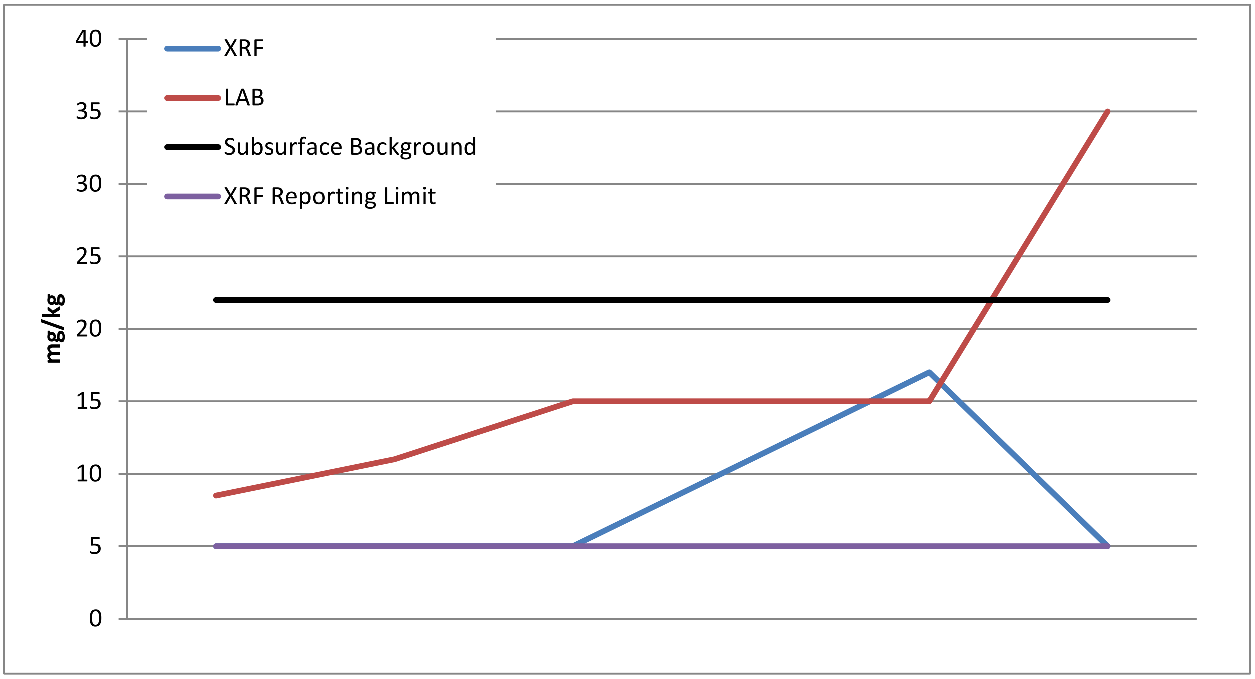
8
7
6
5
4
3
2
1
0
mg/kg
XRF
LAB
Subsurface Background
XRF Reporting Limit

Nickel

Pearson's Correlation Coefficient	-0.121	Bkg (Surface/Subsurface)	21/22
		IW NAL	4,300



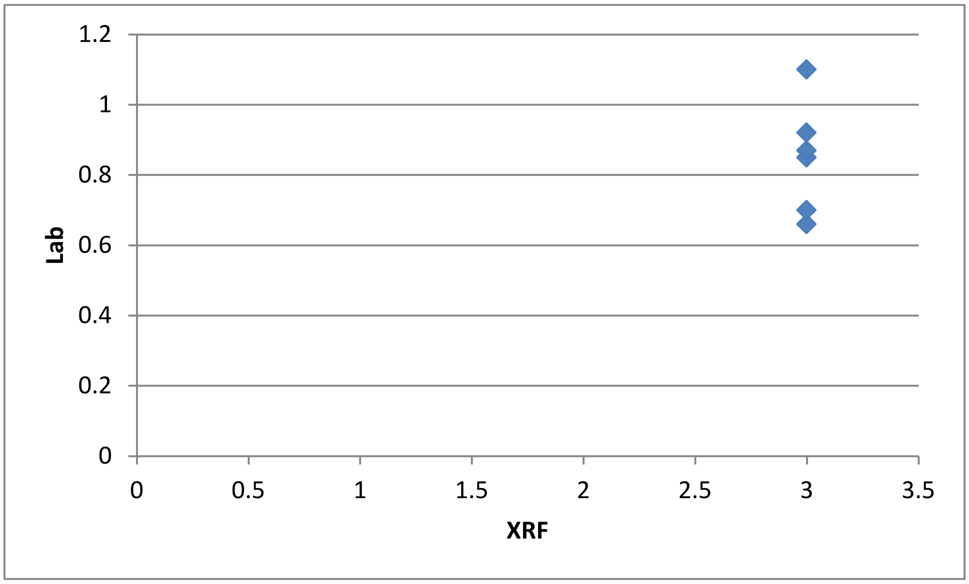


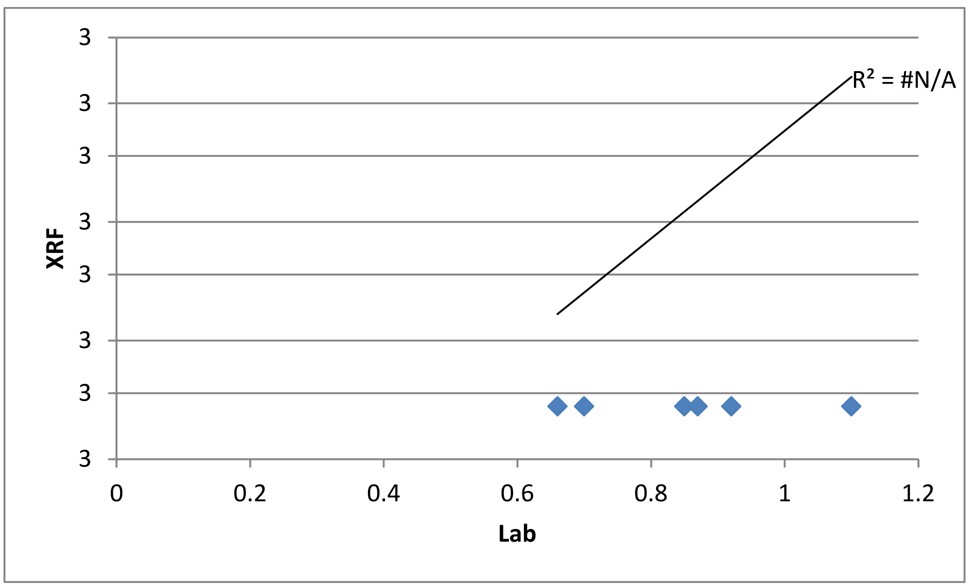


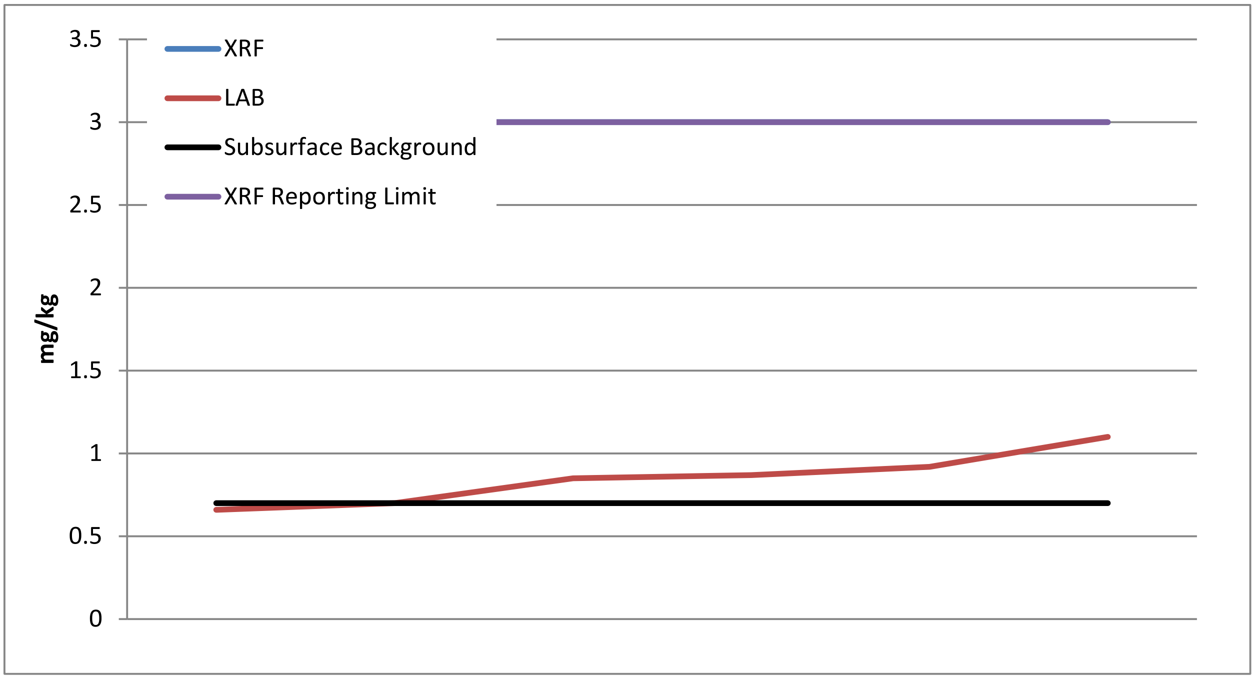
40
35
30
25
20
15
10
5
0
mg/kg
XRF
LAB
Subsurface Background
XRF Reporting Limit

Selenium

Pearson's Correlation Coefficient	N/A	Bkg (Surface/Subsurface)	0.8/0.7
		IW NAL	1,170

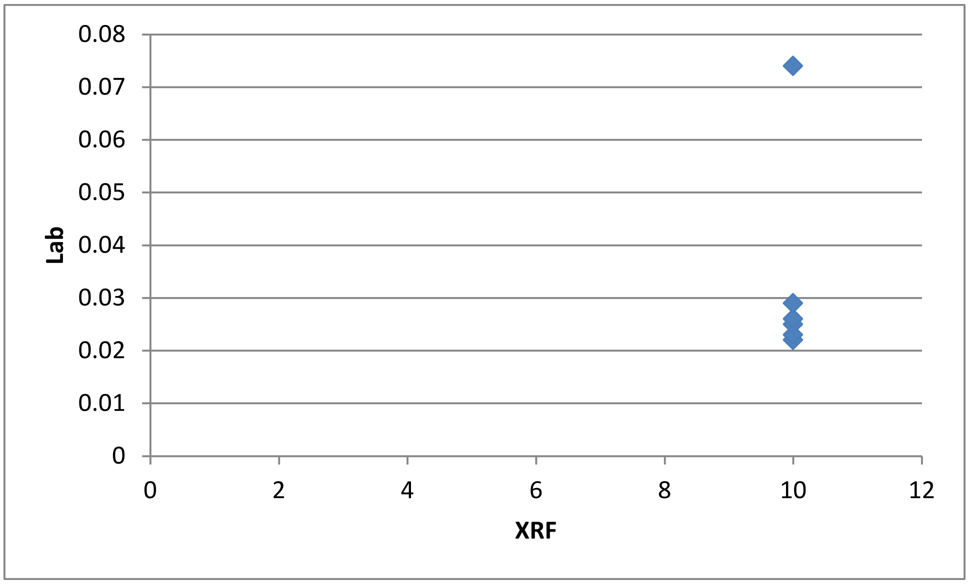


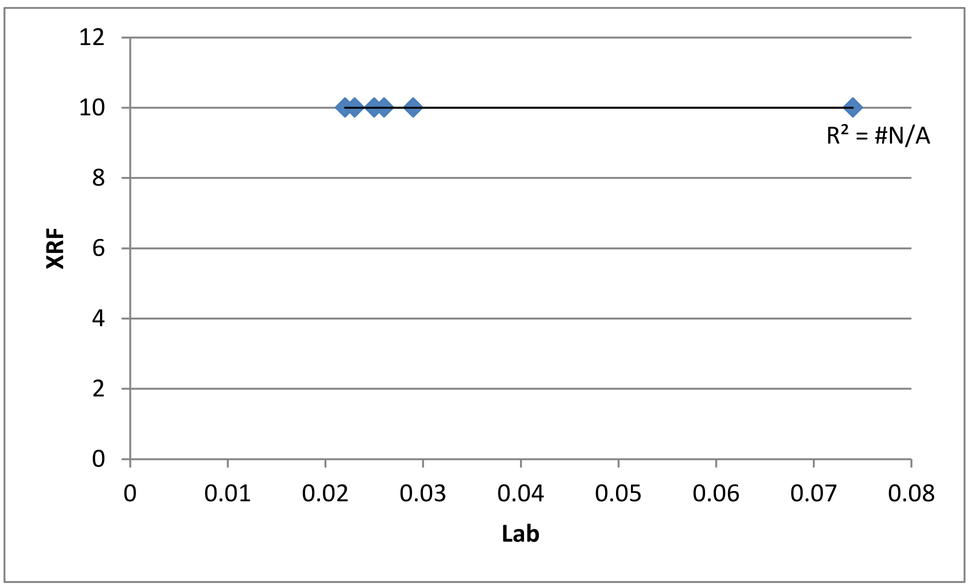


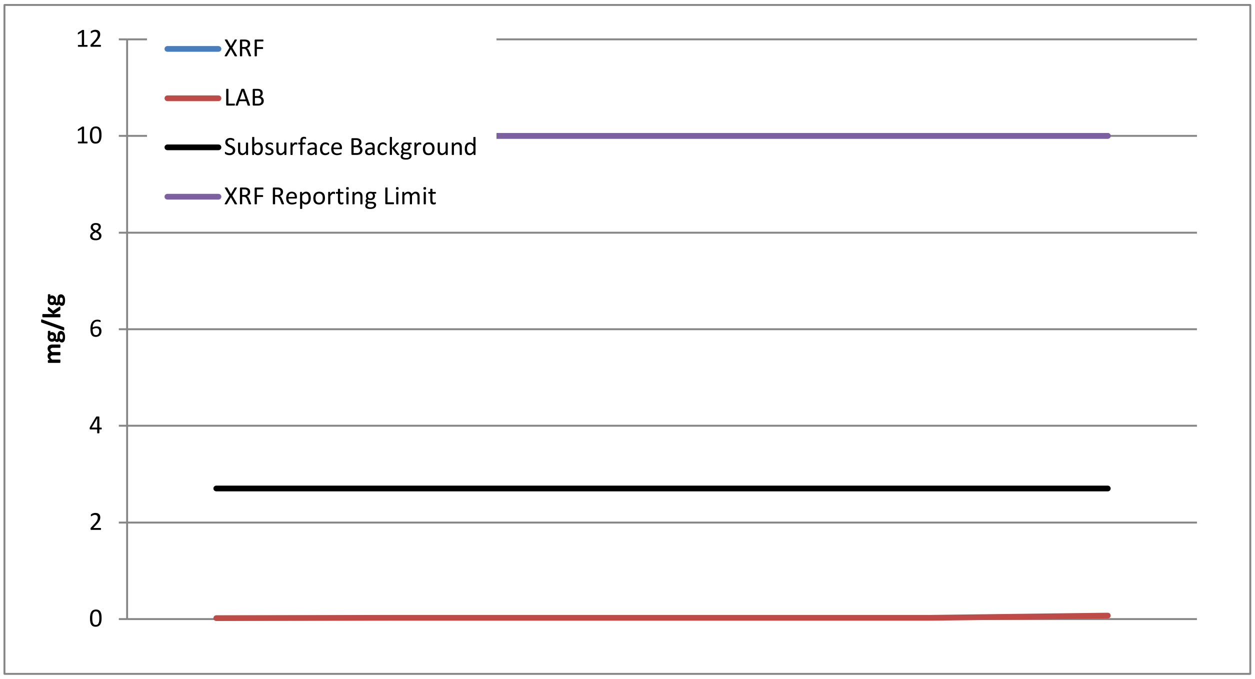

3.5
3
2.5
2
1.5
1
0.5
0
mg/kg
XRF
LAB
Subsurface Background
XRF Reporting Limit

Silver

Pearson’s Correlation Coefficient	N/A	Bkg (Surface/Subsurface)	2.3/2.7
		IW NAL	1,170



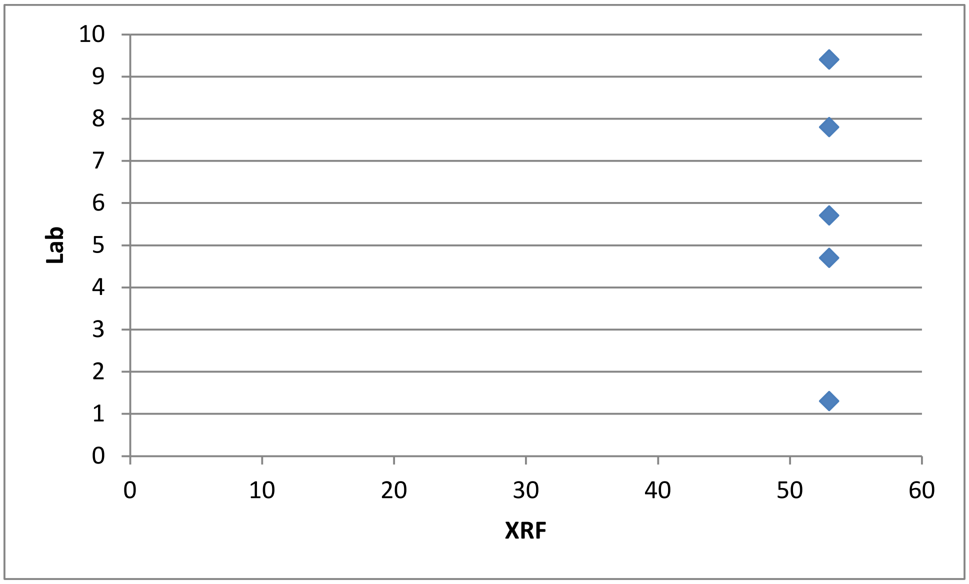


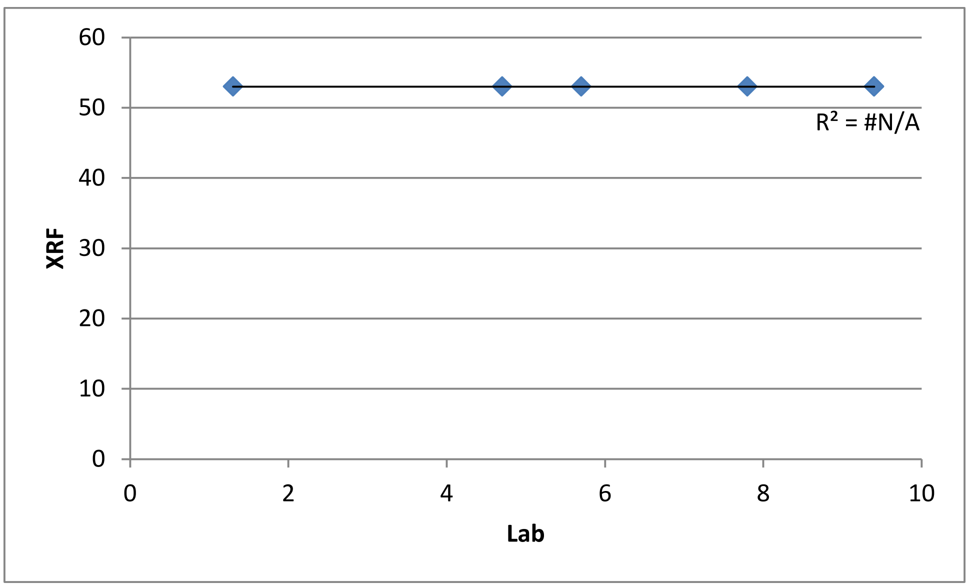


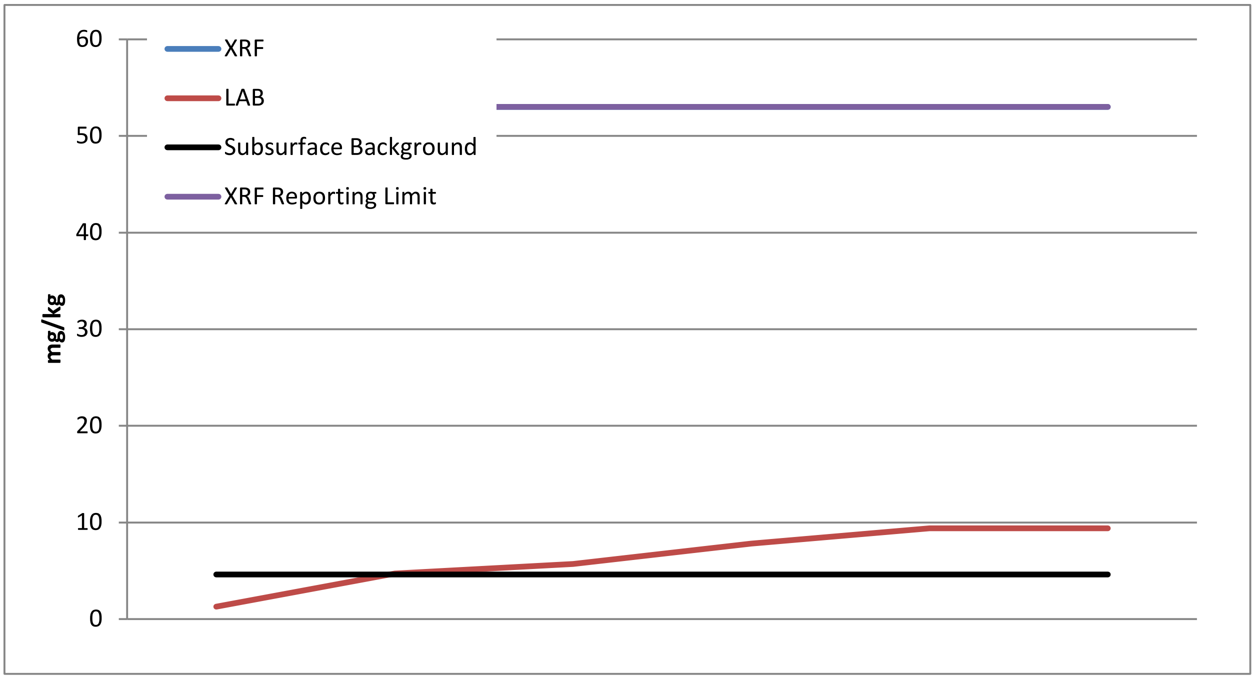
12
10
8
6
4
2
0
mg/kg
XRF
LAB
Subsurface Background
XRF Reporting Limit

Uranium

Pearson's Correlation Coefficient	N/A	Bkg (Surface/Subsurface)	4.9/4.6
		IW NAL	681

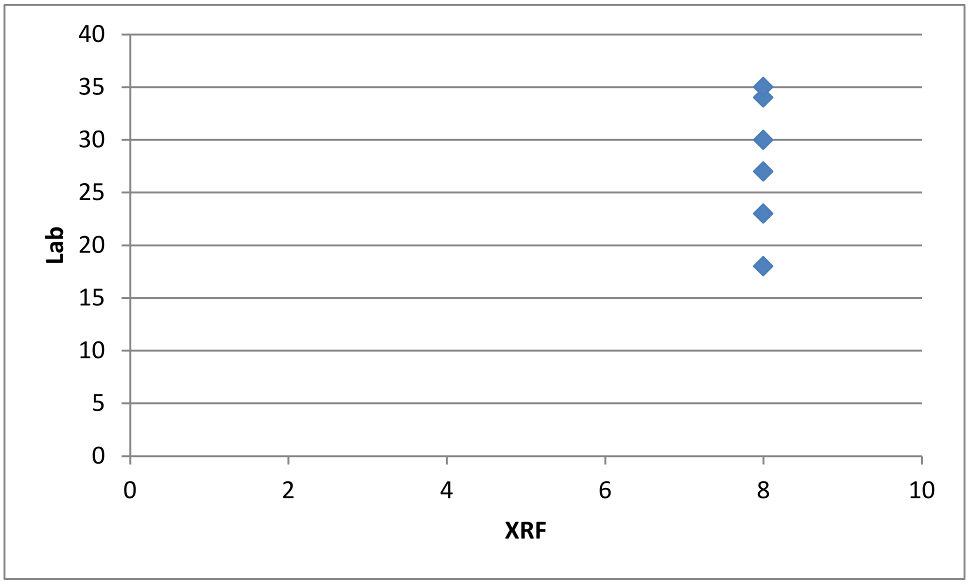


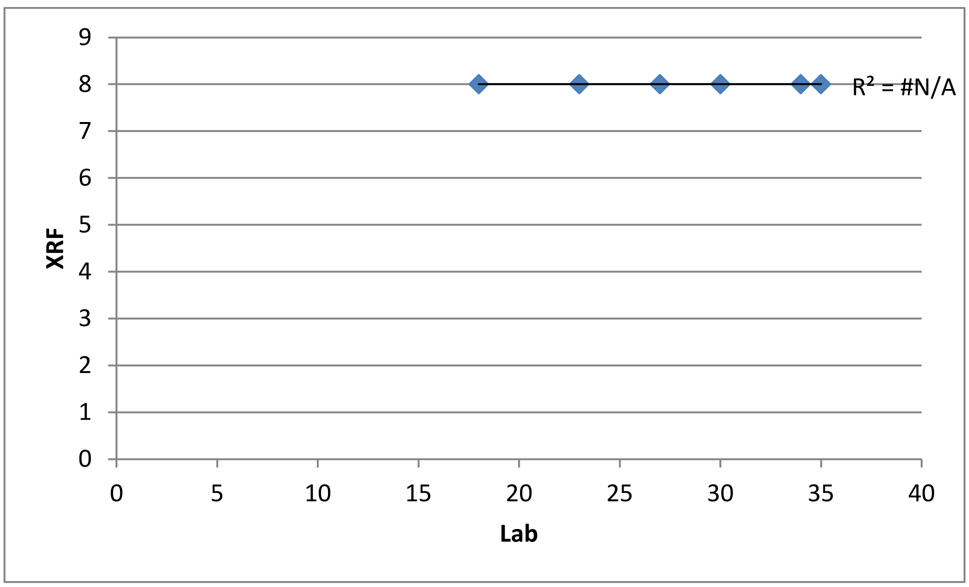


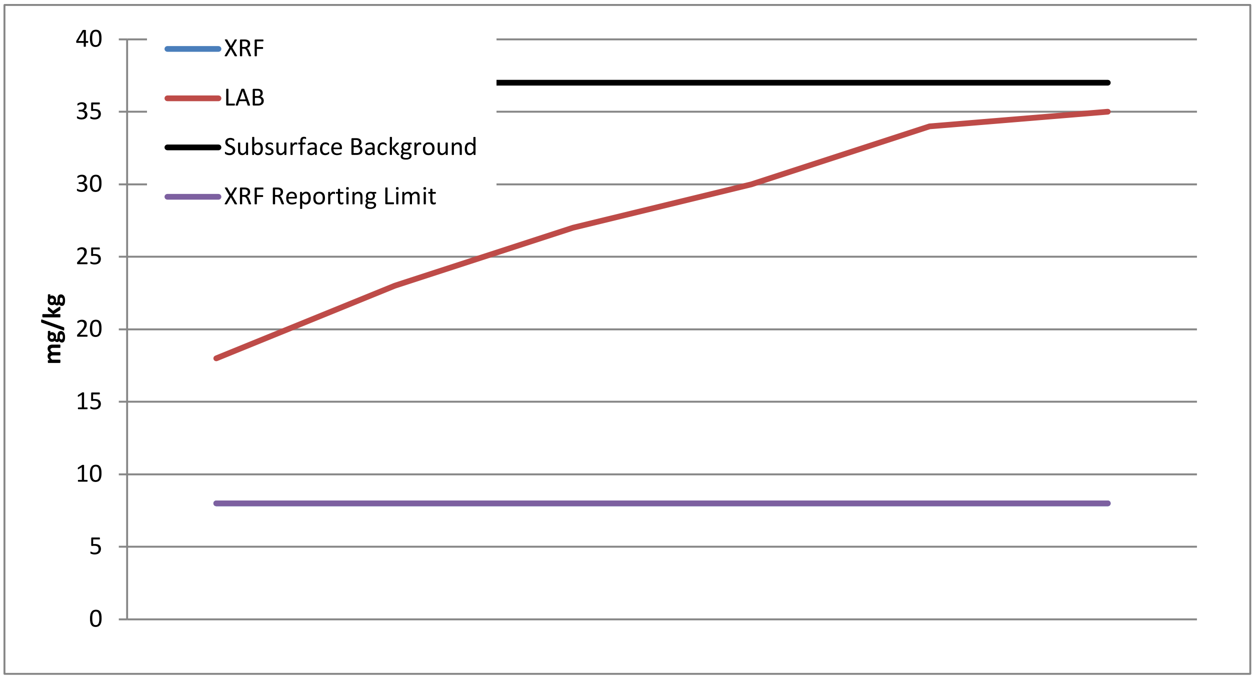

60
50
40
30
20
10
0
mg/kg
XRF
LAB
Subsurface Background
XRF Reporting Limit

Vanadium

Pearson's Correlation Coefficient	N/A	Bkg (Surface/Subsurface)	38/37
		IW NAL	1,150



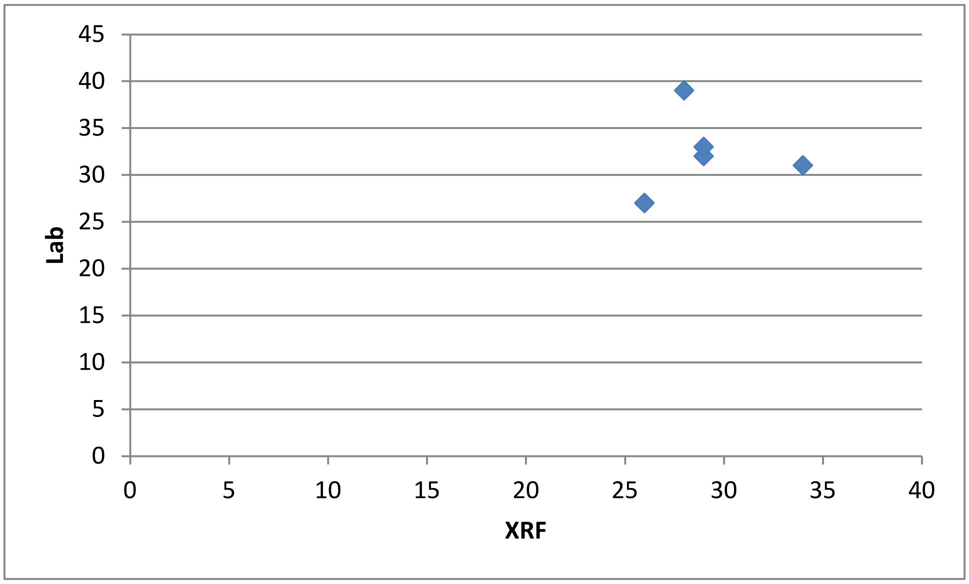


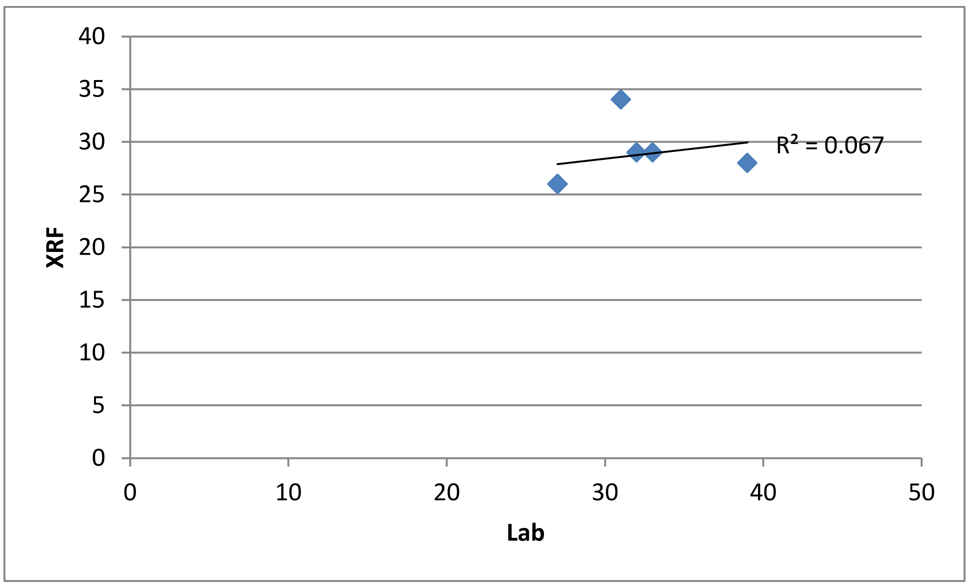


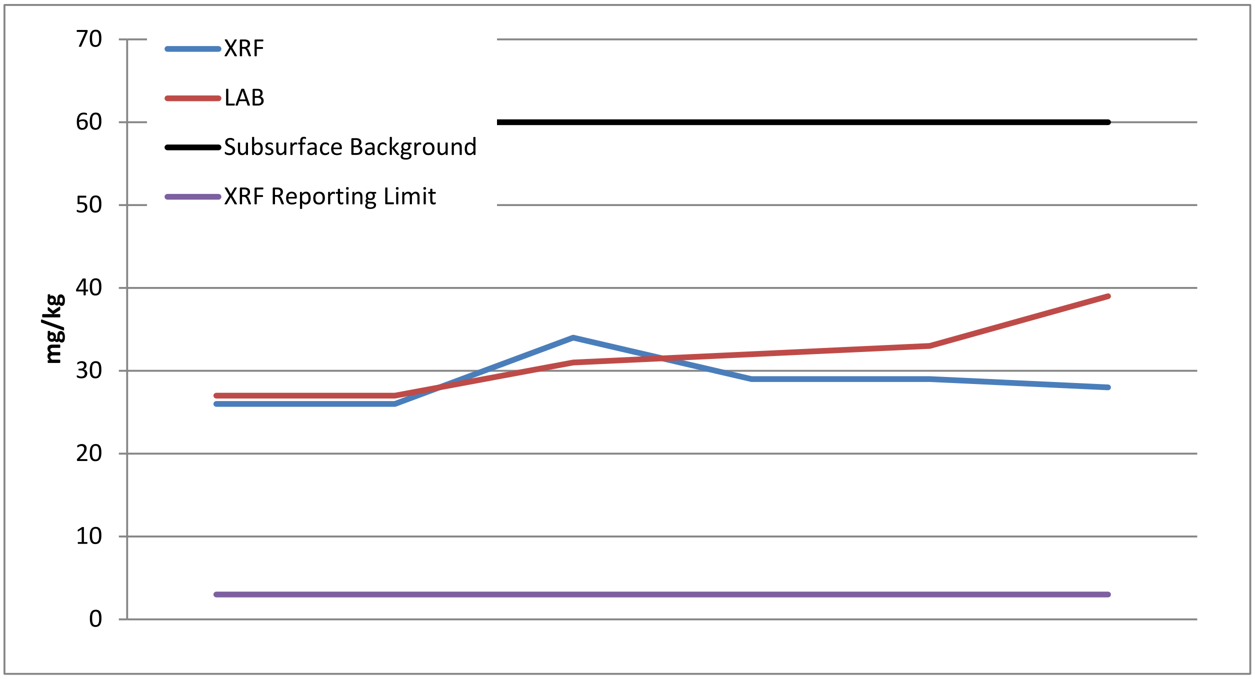
40
35
30
25
20
15
10
5
0
mg/kg
XRF
LAB
Subsurface Background
XRF Reporting Limit

Zinc

Pearson's Correlation Coefficient	0.259	Bkg (Surface/Subsurface)	65/60
		IW NAL	70,100







70
60
50
40
30
20
10
0
mg/kg
XRF
LAB
Subsurface Background
XRF Reporting Limit

APPENDIX C

FATE AND TRANSPORT MODELING

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Based on the screening, no modeling was completed for the soil constituents in Solid Waste Management Unit (SWMU) 1 because concentrations of these constituents either were below screening levels or below concentrations detected at other Soils Operable Unit SWMUs/Areas of Concern that were subjected to modeling and shown not to reach the Regional Gravel Aquifer (RGA) within 1,000 years. Similarly, technetium-99 concentrations at SWMU 1 were below screening levels and also below concentrations from other SWMUs that were subjected to screening and shown not to result in an above-900 pCi/L impact in RGA groundwater.

For more information, see this reference: DOE 2013. *Soils Operable Unit Remedial Investigation Report at the Paducah Gaseous Diffusion Plant Paducah, Kentucky,* DOE/LX/07-0358&D2/R1, LATA Environmental Services of Kentucky, LLC, Kevil, KY, February.

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APPENDIX D

BASELINE HUMAN HEALTH RISK ASSESSMENT

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CONTENTS

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FIGURES

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TABLES

ACRONYMS

ABS	dermal absorption factor
AT	averaging time
bgs	below ground surface
BHHRA	Baseline Human Health Risk Assessment
BW	body weight
CAS	Chemical Abstract Service
CDI	chronic daily intake
COC	contaminant of concern
COPC	chemical or radionuclide of potential concern
CSM	conceptual site model
DQA	data quality analysis
EC	exposure concentration
ED	exposure duration
EF	exposure frequency
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
EU	exposure unit
GI	gastrointestinal tract
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HQ	hazard quotient
IRIS	Integrated Risk Information System
IUR	inhalation unit risk
KDEP	Kentucky Department for Environmental Protection
NAL	no action level
NCEA	National Center for Environmental Assessment
OREIS	Oak Ridge Environmental Information System
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PbB	blood lead
PGDP	Paducah Gaseous Diffusion Plant
POC	pathway of concern
POE	point of exposure
RAGS	Risk Assessment Guidance for Superfund
RAIS	Risk Assessment Information System
RfC	reference concentration
RfD	reference dose
RGA	Regional Gravel Aquifer
RGO	remedial goal option
RI	remedial investigation
RME	reasonable maximum exposure
SAP	Sampling and Analysis Plan
SF	slope factor

SI	site investigation
SQL	sample quantitation limit
SSL	soil screening level
SWMU	solid waste management unit
TEF	toxicity equivalence factor
TPU	total propagated uncertainty
UCRS	Upper Continental Recharge System
VOC	volatile organic compound
WAG	waste area group
WKWMA	West Kentucky Wildlife Management Area
XRF	X-ray fluorescence

BASELINE HUMAN HEALTH RISK ASSESSMENT

This baseline human health risk assessment (BHHRA) addresses one solid waste management unit (SWMU) that initially was included in the Soils Operable Unit (OU) remedial investigation (RI) (DOE 2010). SWMU 1 was determined to have sufficient historical data available that additional sampling was not required. Because soils in the area remediated as part of the Southwest Plume source action were disturbed, however, the surface soils in that area were recharacterized for use in the Soils OU. Surface soil and shallow subsurface sampling followed the completion of the source action once the soil had been respread. Sampling activities generally followed the initial work plan (DOE 2010), with exceptions noted in the Soils OU RI 2 Sampling and Analysis Plan (SAP) Addendum (DOE 2014). This BHHRA uses information collected during historical sampling (collected 1989–2005) and recent sampling (collected 2016) to characterize the baseline risks posed to human health from contact with contaminants in soil at SWMU 1 and at locations to which contaminants may migrate. A summary of the data is presented Section 5 of the main text.

Part of Goal 3 for the Soils OU RI, as presented in the Soils OU Work Plan (DOE 2010), was to determine if contaminants at the Soils OU units are present at levels sufficiently high to pose a risk to human health or the environment. Risk assessments for potential residential, industrial, excavation, and recreational scenarios are presented here. The sampling information collected during the RI and in earlier investigations, the analyses of these data presented in Chapter 5 of the RI Report, and the results of this BHHRA will be used to determine if response actions are appropriate for SWMU 1 and to screen among response action alternatives. This risk assessment also considered modeled concentrations of contaminants in the Regional Gravel Aquifer (RGA) to support refinement of an assessment of potential risks to human health and the environment through groundwater for contaminant concentrations exceeding the respective soil screening levels (SSLs) for the RGA (see Appendix C). The groundwater investigation was limited to contaminants that might leach from the soil at SWMU 1. The risk assessment does not consider actual trichloroethene (TCE) and technetium-99 contaminant concentrations in the groundwater underlying the SWMU.

The methods and presentations used in this BHHRA are consistent with those presented in *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant* (DOE 2016). The Risk Methods Document integrates the human health risk assessment guidance from the U.S. Environmental Protection Agency (EPA) and the Kentucky Department for Environmental Protection (KDEP) and incorporates instructions contained in regulatory agency comments on earlier risk assessments performed for Paducah Gaseous Diffusion Plant (PGDP). Screening levels for this RI Report Addendum are presented in Table A.4 of the Risk Methods Document (DOE 2016).

Consistent with the 2016 revision to the Risk Methods Document, the SWMU 1 BHHRA is presented in nine sections, as described below.

- The first section (D.1) reviews the results of previous risk assessments that are useful in understanding the potential risks posed to human health by contaminants at or migrating from the source areas.

- The second section (D.2) includes identification of chemicals or radionuclides of potential concern (COPCs).

- The third section (D.3) documents the exposure assessment for the sources, including the following:

  — The characterization of the exposure setting,

  — Identification of exposure pathways,

- Consideration of land use,
- Determination of potential receptors,
- Delineation of exposure points and routes [including development of the conceptual site model (CSM)], and
- Calculation of chronic daily intakes (CDIs) and exposure concentrations (ECs).

- The fourth section (D.4) presents the following:
  - The toxicity assessment, including information on the noncarcinogenic (i.e., systemic toxicity or hazard) and carcinogenic effects of the COPCs, and
  - The uncertainties in the toxicity information.
- The fifth section (D.5) reports the following:
  - The results of the risk characterization for current and future land uses; and
  - Identifies contaminants, pathways, and land use scenarios of concern.
- The sixth section (D.6) contains qualitative and quantitative analyses of the uncertainties affecting the results of the BHHRA.
- The seventh section (D.7) summarizes the methods used in the BHHRA and presents the BHHRA's conclusions and observations.
- The eighth section (D.8) uses the results of the BHHRA to develop site-specific risk-based remedial goal options (RGOs).
- The ninth section (D.9) contains references.

The overall risk assessment process is presented in Figure D.1, which graphically displays the steps identified in the preceding section.

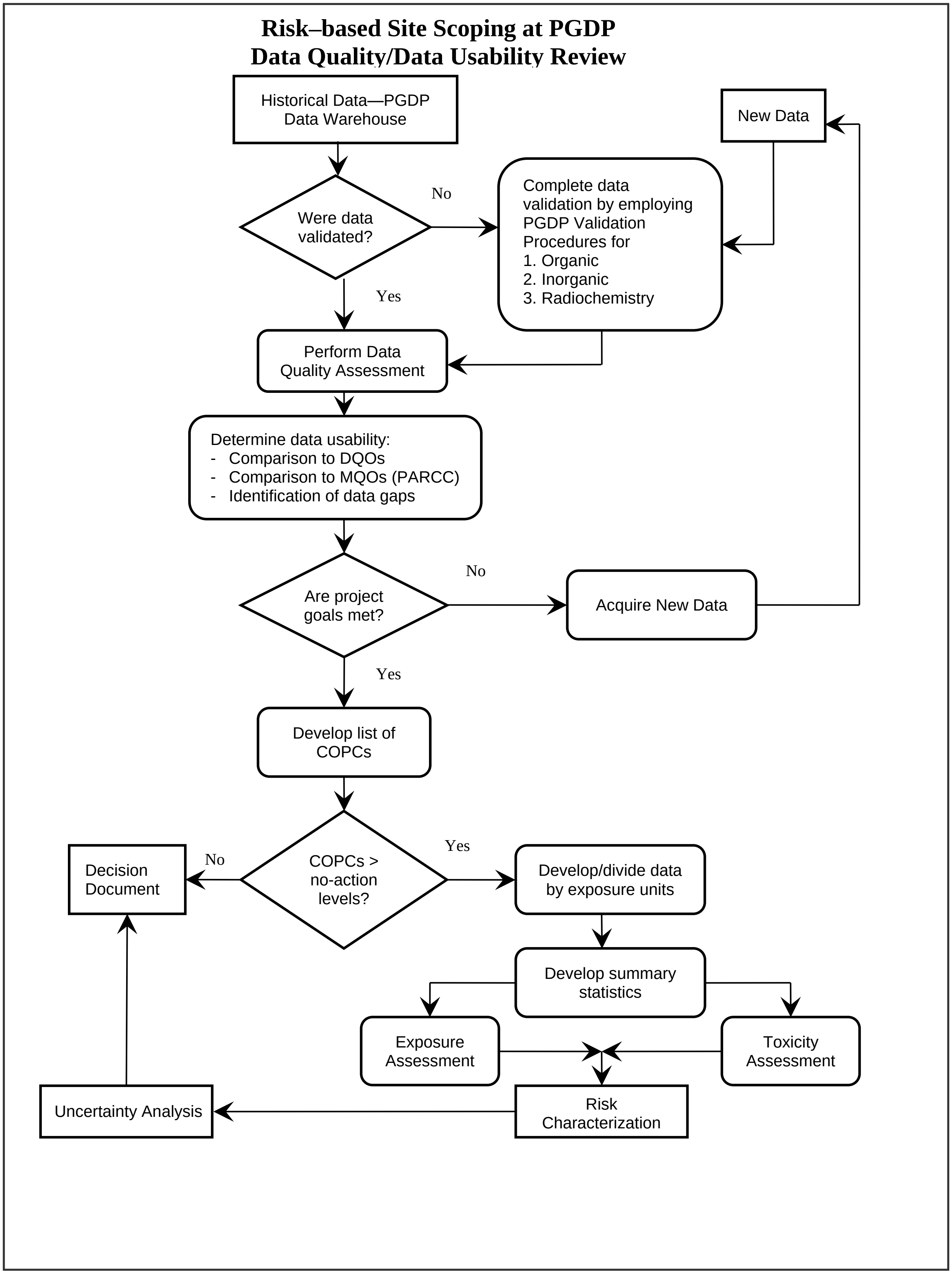

Figure D.1. BHHRA Flow Chart

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D.1. RESULTS OF PREVIOUS STUDIES

Investigations that have collected data on SWMU 1 include the Phase I and Phase II Site Investigation (SI) (CH2M HILL 1991, 1992). Additional sampling was performed to support the Waste Area Group (WAG) 23 FS (DOE 1996), the WAG 23 Proposed Remedial Action Plan (DOE 1998a), the WAG 27 RI (DOE 1999), and the Southwest Plume SI (DOE 2004a). These investigations and actions identified solvents, polychlorinated biphenyls (PCBs), dioxins, semivolatile organic compounds (SVOCs), heavy metals, and radionuclides as potential contaminants of concern (COCs) (DOE 1999).

A summary of conclusions from the WAG 23 effort is as follows (DOE 1998b):

> Following the removal action at WAG 23 sites, the residual polychlorinated biphenyl (PCB) ELCR based on a 250 day/year exposure scenario is…below de minimis [i.e., a cumulative human health excess lifetime cancer risk (ELCR) of 1×10^{-6} or a cumulative hazard index (HI) of 1]. These risk levels are well within the EPA's acceptable risk range of 1×10^{-4} to 1×10^{-6}, as required by the NCP [National Oil and Hazardous Substances Pollution Contingency Plan].

The WAG 27 RI found TCE in SWMU 1 soils. The areal extent of TCE contamination in the vadose zone (vadose zone is defined as extending from the top of the ground surface to the water table) soils on the north side of the site is approximately 175 ft x 115 ft. The TCE-impacted soil was found to extend from 5 ft bgs to the top of the water table at 50 ft bgs. Metals also were detected in the subsurface soils at concentrations that were 27 times (silver) background levels. The metals are widely dispersed throughout the SWMU, but the highest metal concentrations generally are restricted to the upper 20 ft of vadose soil.

The primary COCs identified in WAG 27 RI were beryllium and lead for surface and subsurface soils. Scenarios that were assessed in the WAG 27 baseline risk assessment are the following:

- Current on-site industrial worker,
- Future on-site industrial worker,
- Future on-site excavation worker,
- Future on-site recreational user,
- Future off-site recreational user,
- Future on-site rural resident, and
- Future off-site rural resident.

The following is an excerpt on land use scenarios from WAG 27 RI (where scenarios of concern were considered for an ELCR $\geq 1 \times 10^{-6}$ and/or an HI $\geq$ 1) (DOE 1999a):

"At SWMU 1 and SWMU 91, all scenarios assessed are a land use scenario of concern for both systemic toxicity and ELCR."

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D.2. IDENTIFICATION OF COPCS

The process used to determine the list of COPCs used in the BHHRA is described in the following subsections. Specifically, these subsections describe the sources of data, the procedures used to screen the data, and the methods used to derive exposure point concentrations (EPCs) under both potential current and future conditions. Additionally, this section describes the site characterization data used in the exposure assessment performed in Section D.3.

The SWMU 1 evaluation in the Nature and Extent section of the main text focused on summarizing the representative analytical results for surface and subsurface soils. The process for highlighting chemicals of greatest potential interest, consistent with the work plan, considered background concentrations, action levels and no action levels (NALs) (for the industrial worker), and groundwater protection SSLs for the Upper Continental Recharge System (UCRS)[1] and RGA. This screening was independent of COPC identification for this BHHRA.

D.2.1 SOURCES OF DATA

Data used in the BHHRA describing current contaminant concentrations in surface and subsurface soil at SWMU 1 that were sampled historically and during the summer of 2016 were acquired from the Paducah Oak Ridge Environmental Information System (OREIS) database. The nature and extent of contamination in surface and subsurface soils are described in Section 5 of this report.

D.2.2 GENERAL DATA EVALUATION CONSIDERATIONS

This section describes the data evaluation steps that were used to ensure that the soil data were appropriate for use in BHHRAs. A general description of the eight steps used and their outcome in relation to the SWMU 1 BHHRA data set are provided in this section. A graphical presentation of this process is shown in Figure D.2.

D.2.2.1 Evaluation of Sampling

Data were examined to ensure that sampling methods were adequate for determining the nature and extent of contamination and were representative of site conditions. It was determined that samples from the Soils OU RI were collected using appropriate methods that were consistent with the project's work plan.

D.2.2.2 Evaluation of Analytical Methods

Methods used to collect and analyze the selected surface soil and subsurface soil samples were evaluated to determine if they were those approved by EPA. As described in work plans and project reports (see Section 5 of the main text and Appendix B), the analytical methods used for surface and subsurface soil samples meet these requirements.

The data evaluation and COPC identification steps include a comprehensive evaluation of the analytical data collected during the nature and extent definition for a site. The data collection and evaluation by media were included as part of the nature and extent discussion section. The data quality analysis (DQA)

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[1] Screening of groundwater protection SSLs for the UCRS serves as a qualitative evaluation of the UCRS groundwater.

section (Appendix B) identifies the quality assurance/quality control-related issues to determine which data are useable for evaluations performed in the RI. The data used for the COPC selection were validated in accordance with the DQA.

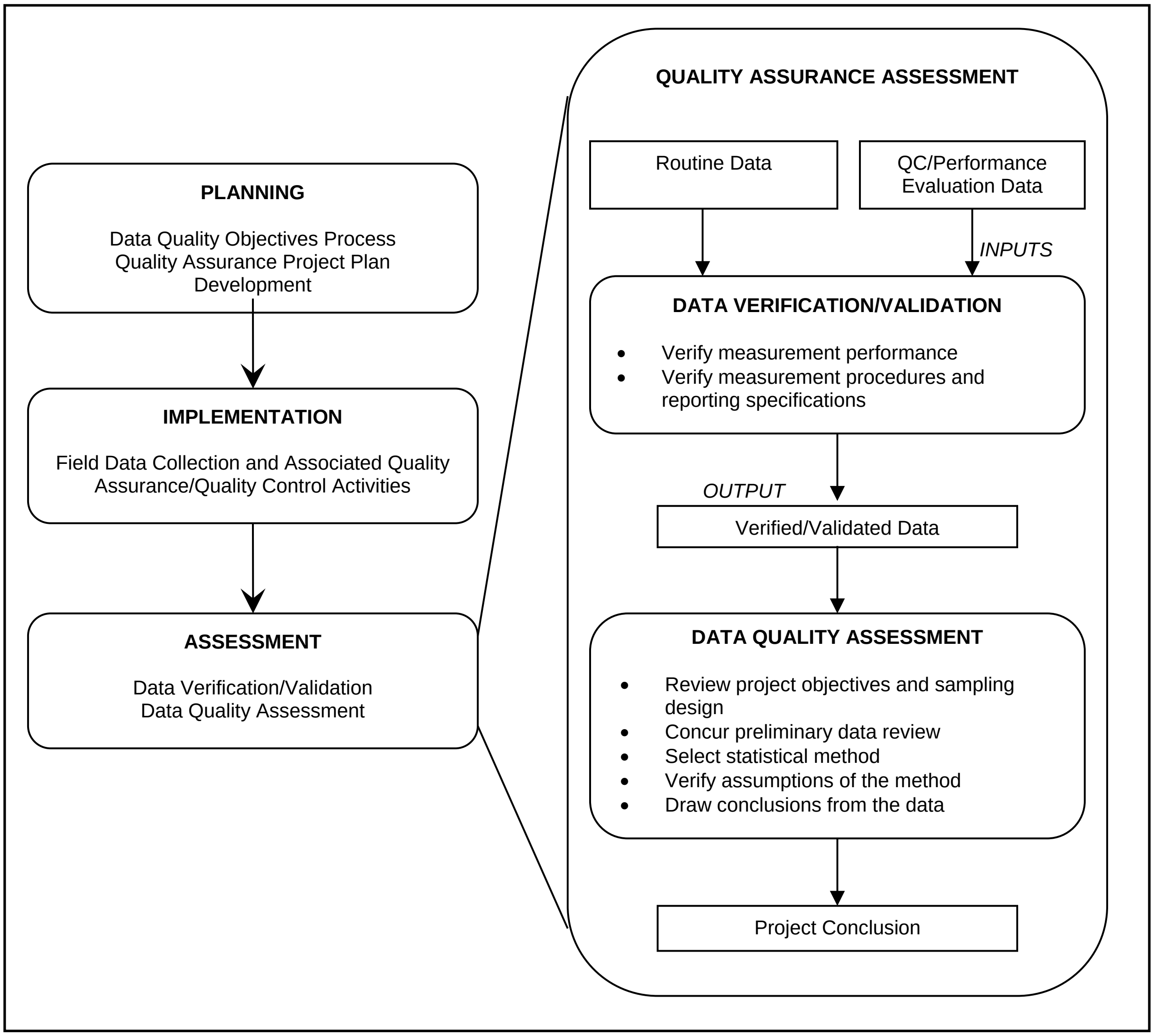

Figure D.2. Data Evaluation Steps

To address the data set for the SWMU more comprehensively, plutonium-239 data were evaluated as plutonium-239/240 and uranium-235/236 were evaluated as uranium-235.

The Soils OU RI and Soils OU RI 2 data include field screening such as X-ray fluorescence (XRF) data. The primary use of such data is for site characterization, but this survey-type data [called field data in the RI Work Plan (DOE 2010)] also can play a role in risk-based decision making. Survey-type data assist in determining the distribution of COPCs and can be used to identify which sets of laboratory data should be combined to develop site average contaminant concentrations. The XRF data were evaluated to determine if some or all could be combined with laboratory data for use in the risk assessment to determine the average concentrations for contaminants by evaluating whether the laboratory and XRF data possess similar detection limits and analytical uncertainty. This analysis was conducted (included in Appendix B) and indicated that a subset of XRF data qualified for use in the risk assessment in conjunction with the laboratory data. Similarly, use of XRF data was applied to historical data. The Risk Methods Document (DOE 2016) allows for use of this type of data after the DQA is performed. Any uncertainties associated with the results that impact potential decisions are highlighted in the Uncertainties section.

D.2.2.3 Evaluation of Sample Quantitation Limits

The sample quantitation limits (SQLs) used in the analyses of the selected soil samples were examined to determine if these limits were below the concentration at which the contaminant may pose a risk to human health. Generally, the SQLs for each analyte met this goal. Table D.1 presents a comparison between each undetected analyte's maximum SQLs for soil for the SWMU 1 data set and the analyte's residential use no action screening value. The implications of this finding upon risk characterization (presented in this BHHRA) are discussed in Section D.6, Uncertainty in the Risk Assessment.

Table D.1. Comparison between Undetected Analyte's Maximum SQLs and Site-Specific Soil Screening Levels[a]

Analyte	Frequency of Detection[b]	Maximum SQL	No Action Screening Value[c]	Units	Screening Value Exceeded?
Inorganic Compounds					
Aluminum	103/104	13.135	7740	mg/kg	No
Antimony	19/99	12.2	3.13	mg/kg	Yes
Arsenic	147/169	4.83	0.356	mg/kg	Yes
Beryllium	98/104	0.48	15.6	mg/kg	No
Cadmium	54/107	1.95	5.28	mg/kg	No
Chromium	111/169	19	16.4	mg/kg	Yes
Cobalt	103/104		2.34	mg/kg	No
Lead	107/169	19.5	400	mg/kg	No
Mercury	72/169	6	2.35	mg/kg	Yes
Molybdenum	35/75	6	39.1	mg/kg	No
Nickel	122/169	5	155	mg/kg	No
Selenium	35/169	19.5	39.1	mg/kg	No
Silver	13/169	10	39.1	mg/kg	No
Thallium	35/107	19.5	0.0782	mg/kg	Yes
Uranium	13/75	53	23.4	mg/kg	Yes
Vanadium	105/166	8	39.3	mg/kg	No
PCBs					
PCB, Total	16/308	5	0.0796	mg/kg	Yes
Semivolatile Organic Compounds					
2-Nitrobenzenamine	0/103	2.5	35.6	mg/kg	No
Acenaphthene	0/109	2.5	185	mg/kg	No
Acenaphthylene	0/109	2.5	185	mg/kg	No
Anthracene	0/109	2.5	923	mg/kg	No
Bis(2-ethylhexyl)phthalate	22/103	2.5	14.9	mg/kg	No
Fluoranthene	4/109	2.5	123	mg/kg	No
Fluorene	0/109	2.5	123	mg/kg	No
Hexachlorobenzene	0/108	2.5	0.212	mg/kg	Yes
Naphthalene	1/110	2.5	3.83	mg/kg	No
N-Nitroso-di-n-propylamine	0/103	2.5	0.0297	mg/kg	Yes
Pentachlorophenol	1/108	2.5	0.254	mg/kg	Yes
Phenanthrene	3/109	2.5	185	mg/kg	No
Pyrene	4/109	2.5	92.3	mg/kg	No
Total PAH	10/109		0.00655	mg/kg	No

Table D.1. Comparison between Undetected Analyte's Maximum SQLs and Site-Specific Soil Screening Levels[a] (Continued)

Analyte	Frequency of Detection[b]	Maximum SQL	No Action Screening Value[c]	Units	Screening Value Exceeded?
Volatile Organic Compounds					
1,1,1-Trichloroethane	1/32	0.006	815	mg/kg	No
1,1,2-Trichloroethane	0/26	0.006	0.15	mg/kg	No
1,1-Dichloroethane	0/30	0.006	3.55	mg/kg	No
1,1-Dichloroethene	0/112	1	22.7	mg/kg	No
1,2-Dichloroethane	0/28	0.006	0.464	mg/kg	No
1,2-Dichloroethene	0/26	0.006	70.4	mg/kg	No
1,2-Dimethylbenzene	0/1	0.01	64.5	mg/kg	No
Acrylonitrile	0/1	0.01	0.255	mg/kg	No
Benzene	1/29	0.006	1.16	mg/kg	No
Bromodichloromethane	0/26	0.006	0.293	mg/kg	No
Carbon tetrachloride	0/29	0.006	0.653	mg/kg	No
Chloroform	1/29	0.006	0.316	mg/kg	No
cis-1,2-Dichloroethene	0/88	1	15.6	mg/kg	No
Dichlorodifluoromethane	0/1	0.01	8.72	mg/kg	No
Ethylbenzene	0/26	0.006	5.78	mg/kg	No
m,p-Xylene	0/1	0.01	64.7	mg/kg	No
Tetrachloroethene	0/29	0.006	8.1	mg/kg	No
Toluene	4/26	0.006	489	mg/kg	No
Total Xylene	0/25	0.006	64.7	mg/kg	No
trans-1,2-Dichloroethene	1/88	1	10.2	mg/kg	No
Trichloroethene	9/122	1	0.412	mg/kg	Yes
Vinyl chloride	0/116	1	0.0592	mg/kg	Yes
Radionuclides					
Americium-241	6/13	0.0271	3.03	pCi/g	No
Cesium-137	9/13	0.0252	0.116	pCi/g	No
Neptunium-237	10/13	0.0257	0.239	pCi/g	No
Plutonium-238	7/13	0.0152	4.42	pCi/g	No
Plutonium-239/240	12/13	0.0116	3.87	pCi/g	No
Technetium-99	12/13	0.554	117	pCi/g	No

[a] Results shown are over all soil samples collected within the SWMU.
[b] Number of detected results over total number of samples collected within the SWMU.
[c] Risk-based screening values are from DOE 2016. The screening values are the lesser of the HI and ELCR NALs used for the child resident of 0.1 and 1E-06, respectively.

Consistent with the Risk Methods Document (DOE 2016), if the maximum SQL for an analyte over all samples within a medium exceeded the no action screening value, then the data for that analyte was deemed of uncertain quality, and a qualitative assessment for that analyte was performed; this information can be found in Section D.6. In developing the qualitative assessment for such chemicals, the maximum SQL for the chemical is used in the qualitative assessment if historical or process knowledge indicates that the chemical potentially could be present. If historical or process knowledge indicates that the chemical is not expected to be present, one-half of the SQL is used in the qualitative assessment (EPA 1991). The qualitative analysis is presented in Section D.6, Uncertainty in the Risk Assessment.

D.2.2.4 Evaluation of Data Qualifiers and Codes

The soil data used in the BHHRA were tagged with various qualifiers and codes. Tagged data were evaluated following rules in Exhibits 5-4 and 5-5 of the Risk Assessment Guidance for Superfund (RAGS)

(EPA 1989). Generally, this resulted in the retention of all results for which the identity of the analyte was certain even if there was substantial uncertainty in the analyte concentration within an individual sample. The qualifiers and codes attached to the soil data used in the BHHRA are defined in Table D.2. Data rejected by validation were not used in the human health and screening ecological risk assessments.

Table D.2. Definitions of Qualifiers and Codes Present in the OREIS Data Set Used for the SWMU 1 BHHRA

Qualifier	Definition	Data Used?
Field = VALIDATION (Validation Qualifier)		
=	Validated result that is detected and unqualified.	Yes
E		Yes
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.	Yes
N		Yes
R	Result rejected due to quality deficiency.	No
U	The analyte was analyzed for, but was not detected above the reported sample quantitation limit.	Yes
X	Not validated; refer to RSLTQUAL field for more information.	Yes
Field = RSLTQUAL (Result Qualifier)		
Blank	Result not qualified.	Yes
*	Duplicate analysis is not within control limits.	Yes
<	Numerical value reported was less than the requested reporting limit.	Yes
B	Inorganic: The result is less than the project contract required detection limit, but greater than the instrument detection limit.	Yes
D	Identified in an analysis at a secondary dilution.	Yes
E	Inorganic: Estimated value; matrix interference.	Yes
	Organic: Concentration exceeds calibration range of gas chromatograph/mass spectrometer.	Yes
J	Estimated value, tentatively identified compound, or less than specified detection limit.	Yes
N	Inorganic: Spike recovery not within control limits.	Yes
	Organic: Applied to TIC results, except generic characteristics.	Yes
S	Inorganic: Determined by Method of Standard Additions.	Yes
T	RADS: Tracer recovery is < 20% or > 105%.	Yes
U	ALL ANALYSIS TYPES EXCEPT RADS: Not detected; RADS: Value reported is < minimum detectable activity and/or total propagated uncertainty (TPU).	Yes
W	Inorganic: Post-digestion spike for Atomic Absorption out of control limit.	Yes
X	Used when more than five qualifiers are required for a result.	Yes
Y	Chemical yield exceeds acceptance limits.	Yes

D.2.2.5 Elimination of Chemicals Not Detected

Consistent with the Risk Methods Document (DOE 2016), any analyte passing the earlier screens and not detected in at least one sample using an appropriate SQL was eliminated from the data set. These data are not considered further in this BHHRA.

D.2.2.6 Examination of Toxicity of Detected Analytes

Each analyte's maximum detected concentration in the data set was compared to that analyte's residential use no action human health risk-based screening value for soil. These screening values are provided in the Risk Methods Document (DOE 2016). Analytes not provided in the Risk Methods Document are listed in Attachment D1.

D.2.2.7 Examination of Analyte Maximum Concentrations for Essential Human Nutrients Detected in Site Samples to Recommended Dietary Allowances for Children

Seven analytes known to be essential nutrients and known to be toxic only at extremely high concentrations were removed from the data set. These analytes were calcium, chloride, iodine, magnesium, phosphorus, potassium, and sodium. Consistent with the Risk Methods Document (DOE 2016), no other analytes were removed from the data set based upon the essential nutrient screen.

D.2.2.8 Comparison of Analyte Maximum Concentrations and Activities Detected in Site Samples to Analyte Concentrations and Activities Detected in Background Samples

Consistent with the 2016 revision to the Risk Methods Document, a background screen was used to develop the BHHRA data set. Table D.3 shows the current PGDP background concentration for surface and subsurface soils used in the screening process.

Table D.3. Provisional Background Concentrations for Surface and Subsurface Soil at PGDP

Analyte	Background Value	
Inorganic Chemicals (mg/kg)	**Surface**	**Subsurface**
Aluminum	13,000	12,000
Antimony	0.21	0.21
Arsenic	12	7.9
Barium	200	170
Beryllium	0.67	0.69
Cadmium	0.21	0.21
Calcium	200,000	6,100
Chromium (III)	16	43
Cobalt	14	13
Copper	19	25
Iron	28,000	28,000
Lead	36	23
Magnesium	7,700	2,100
Manganese	1,500	820
Mercury	0.2	0.13
Nickel	21	22
Potassium	1,300	950
Selenium	0.8	0.7
Silver	2.3	2.7
Sodium	320	340
Thallium	0.21	0.34
Uranium	4.9	4.6
Vanadium	38	37
Zinc	65	60
Radionuclide (pCi/g)	**Surface**	**Subsurface**
Cesium-137	0.49	0.28
Neptunium-237[a]	0.1	---
Plutonium-238[a]	0.073	---
Plutonium-239[a]	0.025	---
Potassium-40	16	16
Radium-226	1.5	1.5
Strontium-90[a]	4.7	---
Technetium-99	2.5	2.8
Thorium-228	1.6	1.6
Thorium-230	1.5	1.4
Thorium-232	1.5	1.5

Table D.3. Provisional Background Concentrations for Surface and Subsurface Soil at PGDP (Continued)

Analyte	Background Value	
Radionuclide (pCi/g)	**Surface**	**Subsurface**
Uranium-234	1.2[b]	1.2[b]
Uranium-235	0.06[b]	0.06[b]
Uranium-238	1.2	1.2

Notes: Cells with "---" indicated data are not available or not applicable.
Values contained in this table are taken from the Risk Methods Document (DOE 2016), but have not been approved for all uses by the PGDP Risk Assessment Working Group; therefore, the values presented here are provisional values and subject to change.
[a] Concentrations for these radionuclides in subsurface soil were not derived.
[b] The values listed for uranium-234 and uranium-235 are not from the 1996 background study, but are derived from the natural isotopic abundance ratio and the uranium-238 values. The values for these radionuclides that appeared in the 2001 version of the Risk Methods Document (DOE 2001) were the upper tolerance limits of measured values for the individual isotopes as reported in the PGDP background study (DOE 1997).

D.2.2.9 RI Analytes

For this project, both historical and Soils OU RI data were combined into one data set; however, only those analytes listed in the approved Soils OU RI Work Plan (DOE 2010) were evaluated for this BHHRA. Historical data were downloaded from the Paducah OREIS database in February 2011 in preparation for the Soils OU RI Report. Data from within the grids and exposure units (EUs) for SWMU 1 that were in the approved work plan were downloaded. Appendix B addresses data quality and applicability of the historical data. Additional data for samples collected for the recharacterization were downloaded in July 2016. The potential for undetermined risk from historical data not evaluated during this BHHRA is addressed in the Uncertainties Section, D.6.

D.2.3 RISK ASSESSMENT SPECIFIC DATA EVALUATION

This section discusses details associated with the surface soil data set, the subsurface soil data set, and groundwater modeling data set used to examine potential current and future ELCRs and HIs to human health presented in this BHHRA.

D.2.3.1 Current Conditions

The specific processes used to evaluate data and calculate EPCs under current conditions are described in this section. The analyte's names were checked to ensure that names and Chemical Abstract Service (CAS) numbers were uniform. This activity was performed so that the analyte names and CAS numbers in the data set matched those used in the PGDP toxicity database presented in the Risk Methods Document (DOE 2016).

D.2.3.2 Evaluation of Concentrations for Soil

The following describes the processes that were used in the surface and subsurface COPC selection. For this screening and the subsequent BHHRA, surface soil was defined as 0–1 ft below ground surface (bgs) and subsurface soil was defined as 0–16 ft bgs. All surface soil samples at the sites were evaluated together as soil whether the sample came from the SWMU surface area or the surrounding ditches.

SWMU 1 was divided into five EUs consistent with the Risk Methods Document (DOE 2016) and the Soils OU Work Plan (DOE 2010). EUs are areas within a site that, because of similar levels of contamination or because of expected human activity patterns, can be assessed reasonably using one EPC for each COPC. EUs typically are 0.5 acre in size.

- *Convert units of measure to a consistent basis.* The units of measure used for analyte classes (i.e., inorganic chemicals, organic compounds, and radionuclides) were assigned consistent units of measure. The units of measure used were mg/kg for inorganic chemicals and organic compounds and pCi/g for radionuclides. This activity was performed so that the units of measure in the data set matched those found in the equations that are used to calculate CDIs and ECs as part of the BHHRA.

- *Categorize all sample results as detects or nondetects.* Each result was coded either detected or nondetected based upon the data qualifier codes present in the data set. Any data assigned a "U" or "UJ" qualifier was considered to be nondetected. All radiological data were considered detects for this project and used at the reported value. This coding subsequently was used to calculate the frequency of detection statistics and to assign surrogate values to results listed as nondetects.

- *Analyze duplicate samples.* Duplicate samples were available for some sample analyses. In cases where the value from the original sample and its duplicate both were detected values, the greater of the results from the original sample and its duplicate was retained in the data set. In cases where one value was a detected value and the other was a nondetect, the detected value was retained in the data set. Finally, when both values were listed as nondetects, the lesser of the two detection limits was retained in the data set.

- *Compare maximum detected concentrations to human health screening values.* The maximum detected result for each analyte within the SWMU 1 EUs was compared to NAL screening values for soil use as part of the toxicity screen. Analytes with a maximum detected value less than the analyte's NAL were not retained as COPCs. The values used to screen surface and subsurface soil were the direct contact residential child NAL values are provided in the 2016 Risk Methods Document (DOE 2016). The EPA residential screening levels for lead in soil (400 mg/kg) were used to screen lead to determine if it is a COPC. For all scenarios, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbon (PAHs) were screened and evaluated in the BHHRA using the Total PCB values and Total PAH values calculated following the Risk Methods Document (DOE 2016). The term "Total PAH" indicates Total Carcinogenic PAHs within this document.

- *Compare maximum detected concentrations to PGDP background soil levels for metals and radionuclides.* The maximum detected result for each analyte within each of the SWMU 1 EUs was compared to the background levels of metals and radionuclides (Table D.3) that have been negotiated with EPA and KDEP. [Surface soil background levels were used for all but the outdoor worker (exposed to surface and subsurface soil) and the excavation worker where subsurface soil background levels were used for screening.] Analytes with a maximum detected value less than the analyte's associated background value are not retained as COPCs.

- *Remove essential nutrients from the data sets.* Results for the seven essential nutrients listed earlier were removed from the data sets.

- *Remove protactinium-234m, potassium-40, and thorium-234 from the data sets.* All results for protactinium-234m were removed to prevent double-counting its contribution to cancer risk through use of a toxicity value for uranium-238 that includes its short-lived progeny. All potassium-40 and thorium-234 results were removed to be consistent with the Risk Methods Document and earlier BHHRAs prepared for PGDP (DOE 2016).

Analytes retained as surface soil COPCs under current conditions are presented for each SWMU 1 EU in Table D.4. Analytes retained as subsurface soil COPCs under current conditions are presented for each SWMU 1 EU in Table D.5. Tables D.4 and D.5 include a listing of all detected analytes in soil samples. In addition to the analyte's name, human health risk-based screening value, and background value, each table also contains the analyte's frequency of detection, whether it was chosen as a COPC, and the COPC's maximum detected concentration.

Table D.4. Surface Soil COPCs for SWMU 1

Chemical	Maximum Concentration	Units	# of Analyses	# of Detects	Surface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
			EU 1				
Aluminum	9380	mg/kg	7	7	13000	7740	No (B)
Antimony	0.24	mg/kg	6	1	0.21	3.13	No (A)
Arsenic	8.9	mg/kg	14	11	12	0.356	No (B)
Barium	110	mg/kg	7	7	200	1530	No (AB)
Beryllium	7.8	mg/kg	7	6	0.67	15.6	No (A)
Bis(2-ethylhexyl)phthalate	0.16	mg/kg	4	1		14.9	No (A)
Cadmium	1.1	mg/kg	7	2	0.21	5.28	No (A)
Calcium	17000	mg/kg	7	7	200000		No (BE)
Carbon disulfide	0.001	mg/kg	2	1		76.8 [d]	No (A)
Chloroform	0.004	mg/kg	2	1		0.316	No (A)
Chromium	34	mg/kg	14	7	16	16.4	Yes
Cobalt	12	mg/kg	7	7	14	2.34	No (B)
Copper	20	mg/kg	14	14	19	313	No (A)
Di-n-butyl phthalate	0.067	mg/kg	4	1		358 [d]	No (A)
Iron	24000	mg/kg	14	14	28000	5480	No (B)
Lead	23	mg/kg	14	6	36	400	No (AB)
Magnesium	3400	mg/kg	7	7	7700		No (BE)
Manganese	1200	mg/kg	14	14	1500	183	No (B)
Mercury	0.029	mg/kg	14	2	0.2	2.35	No (AB)
Molybdenum	8	mg/kg	11	5		39.1	No (A)
Nickel	30	mg/kg	14	10	21	155	No (A)
PCB, Total	0.013	mg/kg	32	1		0.0796	No (A)
Selenium	0.85	mg/kg	14	2	0.8	39.1	No (A)
Silver	0.022	mg/kg	14	1	2.3	39.1	No (AB)
Sodium	110	mg/kg	7	4	320		No (BE)
Thallium	0.18	mg/kg	7	1	0.21	0.0782	No (B)
Toluene	0.004	mg/kg	2	1		489	No (A)
Total PAH	0.00519	mg/kg	7	1		0.00655	No (A)
Trichloroethene	0.001	mg/kg	5	1		0.412	No (A)
Uranium	9.86	mg/kg	11	4	4.9	23.4	No (A)
Vanadium	33	mg/kg	14	8	38	39.3	No (AB)
Zinc	39	mg/kg	14	14	65	2350	No (AB)
Americium-241	0.998	pCi/g	4	3		3.03	No (A)
Cesium-137	0.753	pCi/g	4	3	0.49	0.116	Yes
Cobalt-60	0.00537	pCi/g	3	3		0.0721 [d]	No (A)
Neptunium-237	0.663	pCi/g	4	4	0.1	0.239	Yes
Plutonium-238	0.111	pCi/g	4	3	0.073	4.42	No (A)
Plutonium-239/240	9.05	pCi/g	4	4	0.025	3.87	Yes
Technetium-99	8.29	pCi/g	4	4	2.5	117	No (A)
Thorium-228	0.819	pCi/g	4	4	1.6		No (B)
Thorium-230	65	pCi/g	4	4	1.5	5.22	Yes
Thorium-232	0.794	pCi/g	4	4	1.5		No (B)
Uranium-234	3.44	pCi/g	4	4	1.2	5.93	No (A)
Uranium-235	0.193	pCi/g	4	4	0.06	0.347	No (A)
Uranium-238	3.31	pCi/g	4	4	1.2	1.28	Yes

Table D.4. Surface Soil COPCs for SWMU 1 (Continued)

Chemical	Maximum Concentration	Units	# of Analyses	# of Detects	Surface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
EU 2							
Aluminum	7000	mg/kg	1	1	13000	7740	No (AB)
Antimony	0.16	mg/kg	1	1	0.21	3.13	No (AB)
Arsenic	8	mg/kg	12	9	12	0.356	No (B)
Barium	66	mg/kg	1	1	200	1530	No (AB)
Beryllium	0.48	mg/kg	1	1	0.67	15.6	No (AB)
Cadmium	0.071	mg/kg	1	1	0.21	5.28	No (AB)
Calcium	19000	mg/kg	1	1	200000		No (BE)
Chromium	94	mg/kg	12	3	16	16.4	Yes
Cobalt	5.3	mg/kg	1	1	14	2.34	No (B)
Copper	30	mg/kg	12	12	19	313	No (A)
Iron	22506	mg/kg	12	12	28000	5480	No (B)
Lead	19	mg/kg	12	3	36	400	No (AB)
Magnesium	1100	mg/kg	1	1	7700		No (BE)
Manganese	834	mg/kg	12	12	1500	183	No (B)
Mercury	0.019	mg/kg	12	1	0.2	2.35	No (AB)
Molybdenum	11	mg/kg	12	6		39.1	No (A)
Nickel	35	mg/kg	12	5	21	155	No (A)
PCB, Total	9.5	mg/kg	19	1		0.0796	Yes
Selenium	0.7	mg/kg	12	1	0.8	39.1	No (AB)
Silver	0.029	mg/kg	12	1	2.3	39.1	No (AB)
Sodium	55	mg/kg	1	1	320		No (BE)
Thallium	0.13	mg/kg	1	1	0.21	0.0782	No (B)
Total PAH	0.00634	mg/kg	1	1		0.00655	No (A)
Uranium	9.4	mg/kg	12	1	4.9	23.4	No (A)
Vanadium	23	mg/kg	12	1	38	39.3	No (AB)
Zinc	39	mg/kg	12	12	65	2350	No (AB)
Cesium-137	0.19	pCi/g	1	1	0.49	0.116	No (B)
Plutonium-239/240	0.0264	pCi/g	1	1	0.025	3.87	No (A)
Technetium-99	0.851	pCi/g	1	1	2.5	117	No (AB)
Thorium-228	0.908	pCi/g	1	1	1.6		No (B)
Thorium-230	1.45	pCi/g	1	1	1.5	5.22	No (AB)
Thorium-232	0.928	pCi/g	1	1	1.5		No (B)
Uranium-234	9.01	pCi/g	1	1	1.2	5.93	Yes
Uranium-235	0.511	pCi/g	1	1	0.06	0.347	Yes
Uranium-238	9.86	pCi/g	1	1	1.2	1.28	Yes

Table D.4. Surface Soil COPCs for SWMU 1 (Continued)

Chemical	Maximum Concentration	Units	# of Analyses	# of Detects	Surface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
EU 3							
Aluminum	10500	mg/kg	4	4	13000	7740	No (B)
Antimony	0.18	mg/kg	7	2	0.21	3.13	No (AB)
Arsenic	7.2	mg/kg	12	8	12	0.356	No (B)
Barium	120	mg/kg	7	7	200	1530	No (AB)
Beryllium	0.484	mg/kg	4	3	0.67	15.6	No (AB)
Cadmium	0.15	mg/kg	7	2	0.21	5.28	No (AB)
Calcium	11000	mg/kg	4	4	200000		No (BE)
Chromium	17.1	mg/kg	12	7	16	16.4	Yes
Cobalt	5.8	mg/kg	4	4	14	2.34	No (B)
Copper	18	mg/kg	9	9	19	313	No (AB)
Iron	18161	mg/kg	9	9	28000	5480	No (B)
Lead	19.7	mg/kg	12	4	36	400	No (AB)
Magnesium	1200	mg/kg	4	4	7700		No (BE)
Manganese	711	mg/kg	9	9	1500	183	No (B)
Mercury	0.176	mg/kg	12	3	0.2	2.35	No (AB)
Molybdenum	10	mg/kg	8	5		39.1	No (A)
Nickel	13.1	mg/kg	12	4	21	155	No (AB)
PCB, Total	0.365	mg/kg	26	7		0.0796	Yes
Selenium	0.99	mg/kg	12	3	0.8	39.1	No (A)
Silver	0.12	mg/kg	12	2	2.3	39.1	No (AB)
Sodium	181	mg/kg	4	2	320		No (BE)
Thallium	0.16	mg/kg	7	2	0.21	0.0782	No (B)
Total PAH	0.0189	mg/kg	4	2		0.00655	Yes
Trichloroethene	0.015	mg/kg	4	2	`	0.412	No (A)
Uranium	9.4	mg/kg	8	3	4.9	23.4	No (A)
Vanadium	29	mg/kg	9	5	38	39.3	No (AB)
Zinc	59.2	mg/kg	9	9	65	2350	No (AB)
Americium-241	-0.0194	pCi/g	3	1		3.03	No (A)
Cesium-137	0.306	pCi/g	3	3	0.49	0.116	No (B)
Cobalt-60	-0.0226	pCi/g	1	1		0.0721 [d]	No (A)
Neptunium-237	0.0308	pCi/g	3	3	0.1	0.239	No (AB)
Plutonium-238	-0.00159	pCi/g	3	1	0.073	4.42	No (AB)
Plutonium-239/240	0.0798	pCi/g	3	3	0.025	3.87	No (A)
Technetium-99	2.58	pCi/g	3	3	2.5	117	No (A)
Thorium-228	1.06	pCi/g	3	3	1.6		No (B)
Thorium-230	1.31	pCi/g	3	3	1.5	5.22	No (AB)
Thorium-232	0.986	pCi/g	3	3	1.5		No (B)
Uranium-234	3.51	pCi/g	3	3	1.2	5.93	No (A)
Uranium-235	0.219	pCi/g	3	3	0.06	0.347	No (A)
Uranium-238	5.31	pCi/g	3	3	1.2	1.28	Yes

Table D.4. Surface Soil COPCs for SWMU 1 (Continued)

Chemical	Maximum Concentration	Units	# of Analyses	# of Detects	Surface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
EU 4							
Aluminum	11100	mg/kg	3	3	13000	7740	No (B)
Arsenic	5.81	mg/kg	6	2	12	0.356	No (B)
Barium	124	mg/kg	3	3	200	1530	No (AB)
Beryllium	0.95	mg/kg	3	2	0.67	15.6	No (A)
Cadmium	0.79	mg/kg	3	1	0.21	5.28	No (A)
Calcium	8840	mg/kg	3	3	200000		No (BE)
Chromium	137	mg/kg	6	3	16	16.4	Yes
Cobalt	6.29	mg/kg	3	3	14	2.34	No (B)
Copper	46.6	mg/kg	6	6	19	313	No (A)
Fluoranthene	0.62	mg/kg	3	1		123	No (A)
Iron	17300	mg/kg	6	6	28000	5480	No (B)
Lead	18	mg/kg	6	2	36	400	No (AB)
Magnesium	1720	mg/kg	3	3	7700		No (BE)
Manganese	359	mg/kg	6	6	1500	183	No (B)
Mercury	0.18	mg/kg	6	2	0.2	2.35	No (AB)
Nickel	63.8	mg/kg	6	3	21	155	No (A)
PCB, Total	0.13	mg/kg	15	1		0.0796	Yes
Phenanthrene	0.6	mg/kg	3	1		185	No (A)
Phenol	1.8	mg/kg	2	1		1070 [d]	No (A)
Pyrene	0.68	mg/kg	3	1		92.3	No (A)
Selenium	0.171	mg/kg	6	1	0.8	39.1	No (AB)
Sodium	122	mg/kg	3	2	320		No (BE)
Uranium	3.04	mg/kg	4	1	4.9	23.4	No (AB)
Vanadium	23.9	mg/kg	6	3	38	39.3	No (AB)
Zinc	60	mg/kg	6	6	65	2350	No (AB)
Americium-241	0.0992	pCi/g	1	1		3.03	No (A)
Cesium-137	0.337	pCi/g	1	1	0.49	0.116	No (B)
Cobalt-60	0.022	pCi/g	1	1		0.0721 [d]	No (A)
Neptunium-237	0.000571	pCi/g	1	1	0.1	0.239	No (AB)
Plutonium-238	-0.00225	pCi/g	1	1	0.073	4.42	No (AB)
Plutonium-239/240	0.919	pCi/g	1	1	0.025	3.87	No (A)
Technetium-99	4.86	pCi/g	1	1	2.5	117	No (A)
Thorium-228	0.435	pCi/g	1	1	1.6		No (B)
Thorium-230	5.03	pCi/g	1	1	1.5	5.22	No (A)
Thorium-232	0.504	pCi/g	1	1	1.5		No (B)
Uranium-234	0.47	pCi/g	1	1	1.2	5.93	No (AB)
Uranium-235	0.0226	pCi/g	1	1	0.06	0.347	No (AB)
Uranium-238	0.597	pCi/g	1	1	1.2	1.28	No (AB)

Table D.4. Surface Soil COPCs for SWMU 1 (Continued)

Chemical	Maximum Concentration	Units	# of Analyses	# of Detects	Surface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
EU 5							
2-Methylnaphthalene	0.09	mg/kg	5	1		12.3 [d]	No (A)
Aluminum	9150	mg/kg	6	6	13000	7740	No (B)
Arsenic	8.3	mg/kg	8	7	12	0.356	No (B)
Barium	117	mg/kg	6	6	200	1530	No (AB)
Beryllium	8.3	mg/kg	6	5	0.67	15.6	No (A)
Bis(2-ethylhexyl)phthalate	0.09	mg/kg	5	2		14.9	No (A)
Cadmium	1.2	mg/kg	6	1	0.21	5.28	No (A)
Calcium	31000	mg/kg	6	6	200000		No (BE)
Chromium	13.8	mg/kg	8	6	16	16.4	No (AB)
Cobalt	10.1	mg/kg	6	6	14	2.34	No (B)
Copper	15.2	mg/kg	8	8	19	313	No (AB)
Fluoranthene	0.62	mg/kg	6	3		123	No (A)
Iron	16300	mg/kg	8	8	28000	5480	No (B)
Lead	18.9	mg/kg	8	5	36	400	No (AB)
Magnesium	11200	mg/kg	6	6	7700		No (E)
Manganese	763	mg/kg	8	8	1500	183	No (B)
Mercury	0.0461	mg/kg	8	2	0.2	2.35	No (AB)
Methylene chloride	0.006	mg/kg	3	1		35 [d]	No (A)
Molybdenum	14.2	mg/kg	3	1		39.1	No (A)
Naphthalene	0.063	mg/kg	6	1		3.83	No (A)
Nickel	40.7	mg/kg	8	6	21	155	No (A)
PCB, Total	0.27	mg/kg	20	2		0.0796	Yes
Phenanthrene	0.055	mg/kg	6	2		185	No (A)
Pyrene	0.49	mg/kg	6	3		92.3	No (A)
Selenium	0.5	mg/kg	8	3	0.8	39.1	No (AB)
Sodium	142	mg/kg	6	4	320		No (BE)
Total PAH	0.098307	mg/kg	6	3		0.00655	Yes
Uranium	2.86	mg/kg	3	1	4.9	23.4	No (AB)
Vanadium	25.5	mg/kg	8	6	38	39.3	No (AB)
Zinc	87.2	mg/kg	8	8	65	2350	No (A)
Americium-241	0.000857	pCi/g	1	1		3.03	No (A)
Cesium-137	0.0878	pCi/g	1	1	0.49	0.116	No (AB)
Cobalt-60	-0.00558	pCi/g	1	1		0.0721 [d]	No (A)
Neptunium-237	-0.00169	pCi/g	1	1	0.1	0.239	No (AB)
Plutonium-238	-0.00863	pCi/g	1	1	0.073	4.42	No (AB)
Plutonium-239/240	0.00221	pCi/g	1	1	0.025	3.87	No (AB)
Technetium-99	3.33	pCi/g	1	1	2.5	117	No (A)
Thorium-228	0.252	pCi/g	1	1	1.6		No (B)
Thorium-230	0.337	pCi/g	1	1	1.5	5.22	No (AB)
Thorium-232	0.159	pCi/g	1	1	1.5		No (B)
Uranium-234	0.947	pCi/g	1	1	1.2	5.93	No (AB)
Uranium-235	0.0621	pCi/g	1	1	0.06	0.347	No (A)
Uranium-238	0.65	pCi/g	1	1	1.2	1.28	No (AB)

Data summaries may not match those presented in Section 5 because the summary methods are different (e.g., data in this table are divided into EUs and Section 5 is not).

[a] See Table D.3.

[b] Risk-based screening values are from DOE 2016. The screening values are the lesser of the HI and ELCR NALs used for the child resident of 0.1 and 1E-06, respectively.

[c] Explanations for chemicals not being COPCs are listed below.

A – Maximum result is less than child resident NAL.
B – Maximum result is less than background value.
E – Chemical is an essential nutrient.

[d] See Attachment D1 for screening value.

Table D.5. Subsurface Soil (0–16 ft bgs) COPCs for SWMU 1

Chemical	Maximum Concentration	Units	# of Analyses	# of Detects	Subsurface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
EU 1							
Aluminum	14300	mg/kg	31	30	12000	7740	Yes
Antimony	5	mg/kg	30	12	0.21	3.13	Yes
Arsenic	10.7	mg/kg	45	41	7.9	0.356	Yes
Barium	247	mg/kg	31	31	170	1530	No (A)
Beryllium	7.8	mg/kg	31	30	0.69	15.6	No (A)
Cadmium	3.08	mg/kg	31	13	0.21	5.28	No (A)
Calcium	17000	mg/kg	31	31	6100		No (E)
Chromium	56.2	mg/kg	45	31	43	16.4	Yes
Cobalt	15.4	mg/kg	31	31	13	2.34	Yes
Copper	20	mg/kg	45	45	25	313	No (AB)
Iron	24000	mg/kg	45	45	28000	5480	No (B)
Lead	23	mg/kg	45	31	23	400	No (A)
Magnesium	3400	mg/kg	31	31	2100		No (E)
Manganese	1990	mg/kg	45	45	820	183	Yes
Mercury	0.0487	mg/kg	45	18	0.13	2.35	No (AB)
Molybdenum	13	mg/kg	19	10		39.1	No (A)
Nickel	30	mg/kg	45	37	22	155	No (A)
Selenium	0.85	mg/kg	45	13	0.7	39.1	No (A)
Silver	0.026	mg/kg	45	2	2.7	39.1	No (AB)
Sodium	489	mg/kg	31	27	340		No (E)
Thallium	1.56	mg/kg	31	8	0.34	0.0782	Yes
Uranium	9.86	mg/kg	19	5	4.6	23.4	No (A)
Vanadium	53.3	mg/kg	45	32	37	39.3	Yes
Zinc	60.2	mg/kg	45	45	60	2350	No (A)
PCB, Total	0.063	mg/kg	65	2		0.0796	No (A)
Benzoic acid	0.066	mg/kg	24	1		14300 [d]	No (A)
Bis(2-ethylhexyl)phthalate	0.3	mg/kg	28	7		14.9	No (A)
Di-n-butyl phthalate	0.067	mg/kg	28	5		358 [d]	No (A)
Pentachlorophenol	0.11	mg/kg	24	1		0.254	No (A)
Phenol	0.54	mg/kg	24	1		1070 [d]	No (A)
Total PAH	0.00852	mg/kg	31	2		0.00655	Yes
Acetone	0.097	mg/kg	7	3		6070 [d]	No (A)
Carbon disulfide	0.001	mg/kg	2	1		76.8 [d]	No (A)
Chlorobenzene	0.001	mg/kg	7	1		27.7 [d]	No (A)
Chloroform	0.004	mg/kg	2	1		0.316	No (A)
Methylene chloride	0.05	mg/kg	7	2		35 [d]	No (A)
Toluene	0.004	mg/kg	9	4		489	No (A)
Trichloroethene	0.006	mg/kg	39	4		0.412	No (A)
Americium-241	0.998	pCi/g	4	3		3.03	No (A)
Cesium-137	0.753	pCi/g	4	3	0.28	0.116	Yes
Cobalt-60	0.00537	pCi/g	3	3		0.0721 [d]	No (A)
Neptunium-237	0.663	pCi/g	4	4		0.239	Yes
Plutonium-238	0.111	pCi/g	5	4		4.42	No (A)
Plutonium-239/240	9.05	pCi/g	4	4		3.87	Yes
Technetium-99	8.29	pCi/g	5	5	2.8	117	No (A)
Thorium-228	0.95	pCi/g	5	5	1.6		No (B)
Thorium-230	65	pCi/g	5	5	1.4	5.22	Yes
Thorium-232	0.891	pCi/g	5	5	1.5		No (B)
Uranium-234	3.47	pCi/g	5	5	1.2	5.93	No (A)
Uranium-235	0.193	pCi/g	5	5	0.06	0.347	No (A)
Uranium-238	3.91	pCi/g	5	5	1.2	1.28	Yes

Table D.5. Subsurface Soil (0–16 ft bgs) COPCs for SWMU 1 (Continued)

Chemical	Maximum Concentration	Units	# of Analyses	# of Detects	Subsurface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
EU 2							
Aluminum	8733.5	mg/kg	27	27	12000	7740	No (B)
Antimony	0.23	mg/kg	25	2	0.21	3.13	No (A)
Arsenic	11.5	mg/kg	49	42	7.9	0.356	Yes
Barium	181	mg/kg	27	27	170	1530	No (A)
Beryllium	0.95	mg/kg	27	26	0.69	15.6	No (A)
Cadmium	3.2	mg/kg	27	10	0.21	5.28	No (A)
Calcium	19000	mg/kg	27	27	6100		No (E)
Chromium	94	mg/kg	49	30	43	16.4	Yes
Cobalt	11.3	mg/kg	27	27	13	2.34	No (B)
Copper	30	mg/kg	49	49	25	313	No (A)
Iron	25371	mg/kg	49	49	28000	5480	No (B)
Lead	19	mg/kg	49	31	23	400	No (AB)
Magnesium	2080	mg/kg	27	27	2100		No (E)
Manganese	902	mg/kg	49	49	820	183	Yes
Mercury	0.0362	mg/kg	49	21	0.13	2.35	No (AB)
Molybdenum	11	mg/kg	24	13		39.1	No (A)
Nickel	35	mg/kg	49	34	22	155	No (A)
Selenium	0.87	mg/kg	49	8	0.7	39.1	No (A)
Silver	73.9	mg/kg	49	6	2.7	39.1	Yes
Sodium	434	mg/kg	27	27	340		No (E)
Thallium	0.161	mg/kg	27	7	0.34	0.0782	No (B)
Uranium	9.4	mg/kg	24	2	4.6	23.4	No (A)
Vanadium	37.5	mg/kg	49	27	37	39.3	No (A)
Zinc	165	mg/kg	49	49	60	2350	No (A)
PCB, Total	9.5	mg/kg	78	4		0.0796	Yes
1,2-Dichlorobenzene	0.12	mg/kg	32	2		181 [d]	No (A)
Benzoic acid	3.8	mg/kg	30	1		14300 [d]	No (A)
Bis(2-ethylhexyl)phthalate	1.5	mg/kg	29	4		14.9	No (A)
Di-n-butyl phthalate	22	mg/kg	31	4		358 [d]	No (A)
m,p-cresol	2.3	mg/kg	6	2		358 [d]	No (A)
N-Nitrosodiphenylamine	0.064	mg/kg	29	2		42.5 [d]	No (A)
Phenol	17	mg/kg	30	2		1070 [d]	No (A)
Total PAH	0.0296	mg/kg	30	2		0.00655	Yes
1,1,1-Trichloroethane	0.0005	mg/kg	9	1		815	No (A)
Acetone	0.066	mg/kg	5	2		6070 [d]	No (A)
Carbon disulfide	0.002	mg/kg	5	1		76.8 [d]	No (A)
Methylene chloride	0.065	mg/kg	5	2		35 [d]	No (A)
trans-1,2-Dichloroethene	0.1	mg/kg	6	1		10.2	No (A)
Trichloroethene	0.2	mg/kg	11	2		0.412	No (A)
Cesium-137	0.19	pCi/g	1	1	0.28	0.116	No (B)
Neptunium-237	0.013	pCi/g	1	1		0.239	No (A)
Plutonium-239/240	0.0264	pCi/g	2	2		3.87	No (A)
Technetium-99	0.853	pCi/g	2	2	2.8	117	No (AB)
Thorium-228	0.958	pCi/g	2	2	1.6		No (B)
Thorium-230	1.45	pCi/g	2	2	1.4	5.22	No (A)
Thorium-232	0.928	pCi/g	2	2	1.5		No (B)
Uranium-234	9.01	pCi/g	2	2	1.2	5.93	Yes
Uranium-235	0.511	pCi/g	2	2	0.06	0.347	Yes
Uranium-238	9.86	pCi/g	2	2	1.2	1.28	Yes

Table D.5. Subsurface Soil (0–16 ft bgs) COPCs for SWMU 1 (Continued)

Chemical	Maximum Concentration	Units	# of Analyses	# of Detects	Subsurface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
EU 3							
Aluminum	10500	mg/kg	12	12	12000	7740	No (B)
Antimony	0.784	mg/kg	15	3	0.21	3.13	No (A)
Arsenic	10.5	mg/kg	26	22	7.9	0.356	Yes
Barium	197	mg/kg	15	15	170	1530	No (A)
Beryllium	0.484	mg/kg	12	11	0.69	15.6	No (AB)
Cadmium	3.32	mg/kg	15	10	0.21	5.28	No (A)
Calcium	11000	mg/kg	12	12	6100		No (E)
Chromium	83	mg/kg	26	16	43	16.4	Yes
Cobalt	5.8	mg/kg	12	12	13	2.34	No (B)
Copper	18	mg/kg	23	23	25	313	No (AB)
Iron	22971	mg/kg	23	23	28000	5480	No (B)
Lead	19.7	mg/kg	26	12	23	400	No (AB)
Magnesium	2310	mg/kg	12	12	2100		No (E)
Manganese	881	mg/kg	23	23	820	183	Yes
Mercury	0.176	mg/kg	26	11	0.13	2.35	No (A)
Molybdenum	10	mg/kg	14	6		39.1	No (A)
Nickel	29.7	mg/kg	26	15	22	155	No (A)
Selenium	0.99	mg/kg	26	5	0.7	39.1	No (A)
Silver	0.12	mg/kg	26	3	2.7	39.1	No (AB)
Sodium	570	mg/kg	12	10	340		No (E)
Thallium	0.16	mg/kg	15	5	0.34	0.0782	No (B)
Uranium	9.4	mg/kg	8	3	4.6	23.4	No (A)
Vanadium	29	mg/kg	23	13	37	39.3	No (AB)
Zinc	59.2	mg/kg	23	23	60	2350	No (AB)
PCB, Total	0.365	mg/kg	26	7		0.0796	Yes
Bis(2-ethylhexyl)phthalate	0.1	mg/kg	8	2		14.9	No (A)
Butyl benzyl phthalate	0.2	mg/kg	8	1		110 [d]	No (A)
Di-n-butyl phthalate	0.05	mg/kg	8	1		358 [d]	No (A)
Total PAH	0.0189	mg/kg	4	2		0.00655	Yes
Trichloroethene	0.015	mg/kg	4	2		0.412	No (A)
Americium-241	-0.0194	pCi/g	3	1		3.03	No (A)
Cesium-137	0.306	pCi/g	3	3	0.28	0.116	Yes
Cobalt-60	-0.0226	pCi/g	1	1		0.0721 [d]	No (A)
Neptunium-237	0.0308	pCi/g	3	3		0.239	No (A)
Plutonium-238	-0.00159	pCi/g	3	1		4.42	No (A)
Plutonium-239/240	0.0798	pCi/g	3	3		3.87	No (A)
Technetium-99	2.58	pCi/g	3	3	2.8	117	No (AB)
Thorium-228	1.06	pCi/g	3	3	1.6		No (B)
Thorium-230	1.31	pCi/g	3	3	1.4	5.22	No (AB)
Thorium-232	0.986	pCi/g	3	3	1.5		No (B)
Uranium-234	3.51	pCi/g	3	3	1.2	5.93	No (A)
Uranium-235	0.219	pCi/g	3	3	0.06	0.347	No (A)
Uranium-238	5.31	pCi/g	3	3	1.2	1.28	Yes

Table D.5. Subsurface Soil (0–16 ft bgs) COPCs for SWMU 1 (Continued)

Chemical	Maximum Concentration	Units	# of Analyses	# of Detects	Subsurface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
EU 4							
Aluminum	11900	mg/kg	14	14	12000	7740	No (B)
Antimony	0.013	mg/kg	11	1	0.21	3.13	No (AB)
Arsenic	7.06	mg/kg	20	16	7.9	0.356	No (B)
Barium	141	mg/kg	14	14	170	1530	No (AB)
Beryllium	1.07	mg/kg	14	13	0.69	15.6	No (A)
Cadmium	3.35	mg/kg	14	12	0.21	5.28	No (A)
Calcium	8840	mg/kg	14	14	6100		No (E)
Chromium	137	mg/kg	20	14	43	16.4	Yes
Cobalt	7.37	mg/kg	14	14	13	2.34	No (B)
Copper	46.6	mg/kg	20	20	25	313	No (A)
Iron	24800	mg/kg	20	20	28000	5480	No (B)
Lead	26	mg/kg	20	13	23	400	No (A)
Magnesium	2630	mg/kg	14	14	2100		No (E)
Manganese	1077	mg/kg	20	20	820	183	Yes
Mercury	0.18	mg/kg	20	12	0.13	2.35	No (A)
Nickel	63.8	mg/kg	20	14	22	155	No (A)
Selenium	0.171	mg/kg	20	2	0.7	39.1	No (AB)
Silver	0.576	mg/kg	14	1	2.7	39.1	No (AB)
Sodium	421	mg/kg	14	13	340		No (E)
Thallium	0.258	mg/kg	11	7	0.34	0.0782	No (B)
Uranium	3.04	mg/kg	4	1	4.6	23.4	No (AB)
Vanadium	40.2	mg/kg	20	14	37	39.3	Yes
Zinc	118	mg/kg	20	20	60	2350	No (A)
PCB, Total	0.13	mg/kg	15	1		0.0796	Yes
Bis(2-ethylhexyl)phthalate	0.7	mg/kg	13	2		14.9	No (A)
Fluoranthene	0.62	mg/kg	3	1		123	No (A)
Phenanthrene	0.6	mg/kg	3	1		185	No (A)
Phenol	1.8	mg/kg	15	2		1070 [d]	No (A)
Pyrene	0.68	mg/kg	3	1		92.3	No (A)
1,1,1-Trichloroethane	0.013	mg/kg	2	1		815	No (A)
Benzene	0.009	mg/kg	2	1		1.16	No (A)
Trichloroethene	0.19	mg/kg	23	1		0.412	No (A)
Americium-241	0.0992	pCi/g	1	1		3.03	No (A)
Cesium-137	0.337	pCi/g	1	1	0.28	0.116	Yes
Cobalt-60	0.022	pCi/g	1	1		0.0721 [d]	No (A)
Neptunium-237	0.000571	pCi/g	1	1		0.239	No (A)
Plutonium-238	-0.00225	pCi/g	1	1		4.42	No (A)
Plutonium-239/240	0.919	pCi/g	1	1		3.87	No (A)
Technetium-99	4.86	pCi/g	1	1	2.8	117	No (A)
Thorium-228	0.435	pCi/g	1	1	1.6		No (B)
Thorium-230	5.03	pCi/g	1	1	1.4	5.22	No (A)
Thorium-232	0.504	pCi/g	1	1	1.5		No (B)
Uranium-234	0.47	pCi/g	1	1	1.2	5.93	No (AB)
Uranium-235	0.0226	pCi/g	1	1	0.06	0.347	No (AB)
Uranium-238	0.597	pCi/g	1	1	1.2	1.28	No (AB)

Table D.5. Subsurface Soil (0–16 ft bgs) COPCs for SWMU 1 (Continued)

Chemical	Maximum Concentration	Units	# of Analyses	# of Detects	Subsurface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
EU 5							
Aluminum	12000	mg/kg	20	20	12000	7740	Yes
Antimony	0.17	mg/kg	12	1	0.21	3.13	No (AB)
Arsenic	16.7	mg/kg	23	21	7.9	0.356	Yes
Barium	215	mg/kg	20	20	170	1530	No (A)
Beryllium	8.3	mg/kg	20	18	0.69	15.6	No (A)
Cadmium	2.97	mg/kg	20	9	0.21	5.28	No (A)
Calcium	31000	mg/kg	20	20	6100		No (E)
Chromium	16	mg/kg	23	19	43	16.4	No (AB)
Cobalt	14.3	mg/kg	20	19	13	2.34	Yes
Copper	15.2	mg/kg	23	23	25	313	No (AB)
Iron	19100	mg/kg	23	23	28000	5480	No (B)
Lead	18.9	mg/kg	23	18	23	400	No (AB)
Magnesium	11200	mg/kg	20	20	2100		No (E)
Manganese	2160	mg/kg	23	23	820	183	Yes
Mercury	0.104	mg/kg	23	10	0.13	2.35	No (AB)
Molybdenum	14.2	mg/kg	5	3		39.1	No (A)
Nickel	40.7	mg/kg	23	20	22	155	No (A)
Selenium	1.1	mg/kg	23	7	0.7	39.1	No (A)
Silver	0.025	mg/kg	15	1	2.7	39.1	No (AB)
Sodium	471	mg/kg	20	15	340		No (E)
Thallium	0.198	mg/kg	14	8	0.34	0.0782	No (B)
Uranium	2.86	mg/kg	5	2	4.6	23.4	No (AB)
Vanadium	35	mg/kg	23	19	37	39.3	No (AB)
Zinc	87.2	mg/kg	23	23	60	2350	No (A)
PCB, Total	0.27	mg/kg	20	2		0.0796	Yes
2-Methylnaphthalene	0.09	mg/kg	5	1		35 [d]	No (A)
Bis(2-ethylhexyl)phthalate	0.13	mg/kg	19	7		14.9	No (A)
Fluoranthene	0.62	mg/kg	6	3		123	No (A)
Naphthalene	0.063	mg/kg	6	1		3.83	No (A)
Phenanthrene	0.055	mg/kg	6	2		185	No (A)
Pyrene	0.49	mg/kg	6	3		92.3	No (A)
Total PAH	0.098307	mg/kg	20	4		0.00655	Yes
Acetone	0.12	mg/kg	6	3		6070 [d]	No (A)
Carbon disulfide	0.002	mg/kg	6	3		76.8 [d]	No (A)
Methylene chloride	0.14	mg/kg	9	4		35 [d]	No (A)
Americium-241	0.000857	pCi/g	1	1		3.03	No (A)
Cesium-137	0.0878	pCi/g	1	1	0.28	0.116	No (AB)
Cobalt-60	-0.00558	pCi/g	1	1		0.0721 [d]	No (A)
Neptunium-237	-0.00169	pCi/g	1	1		0.239	No (A)
Plutonium-238	-0.00863	pCi/g	1	1		4.42	No (A)
Plutonium-239/240	0.0108	pCi/g	2	2		3.87	No (A)
Technetium-99	3.33	pCi/g	1	1	2.8	117	No (A)
Thorium-228	1	pCi/g	2	2	1.6		No (B)
Thorium-230	1.11	pCi/g	2	2	1.4	5.22	No (AB)
Thorium-232	0.987	pCi/g	2	2	1.5		No (B)
Uranium-234	0.947	pCi/g	2	2	1.2	5.93	No (AB)
Uranium-235	0.0621	pCi/g	2	2	0.06	0.347	No (A)
Uranium-238	0.947	pCi/g	2	2	1.2	1.28	No (AB)

Table D.5. Subsurface Soil (0–16 ft bgs) COPCs for SWMU 1 (Continued)

Data summaries may not match those presented in Section 5 because the summary methods are different (e.g., data in this table are divided into EUs and Section 5 is not).
[a] See Table D.3.
[b] Risk-based screening values are from DOE 2016. The screening values are the lesser of the HI and ELCR NALs used for the child resident of 0.1 and 1E-06, respectively.
[c] Explanations for chemicals not being COPCs are listed below.
A – Maximum result is less than child resident NAL.
B – Maximum result is less than background value.
E – Chemical is an essential nutrient.
[d] See Attachment D1 for screening value.

EPCs were calculated for each EU for those constituents that are retained as COPCs. For each COPC, data were summarized within each sampling grid before calculating the EPC for the EU. This was necessary to ensure that each sampling grid was represented equally (i.e., received equal weight) in the EU EPC calculation. Section 4 of the main text further illustrates this implementation.

The representative sampling design for SWMU 1 was gridding. In some instances, when a grid is applied to SWMU 1, a grid lacking a sample result results. In order to fill a grid lacking a sample result, the average of the grids within the EU with sampling results was used. The Soils OU RI Report presented an uncertainty evaluation in determining EPC values using these averages against EPC values calculated without using the averages or the maximum value, as applicable. An example for determining the EPC through averaging is illustrated in Exhibit D.1.

For EU 5, which has less than 10 grids, the maximum grid result was used as the EPC. For the remaining EUs, where there are 10 or more grids, the grid values were used to determine the 95% upper confidence level of the mean (UCL95). Grid values were determined following guidance in the work plan. Basically, the maximum detected result from within the grid applies to the grid. If not detected, the minimum detection limit applies to the grid.

If a grid had no result (detect or nondetect) for the COPC, an average of the results for the grids with results was used. See Exhibit D.1 for example illustrating this average.

The EPC is determined consistent with the Risk Methods Document (DOE 2016). Where results from ten or more samples are available, then the most recent version of EPA's ProUCL software (i.e., version 5.1) has been used to determine the EPC. The value selected as the EPC is the value recommended by ProUCL, noted as the "Potential UCL to Use." EPA's ProUCL software incorporates a number of different distributional tests that may be used to calculate the most appropriate EPC (EPA 2015a). In the current version of ProUCL, the software has computation methods for handling data sets with nondetect values. Consistent with previous Soils OU RI Reports, all results were evaluated as detections in ProUCL. Attachment D2 presents the output from the ProUCL software. Tables D.6 and D.7 present the SWMU 1 data set for surface and subsurface soils, respectively, with the assigned grid values and the EPC.

Exhibit D.1. Example for Calculating UCL95

NO RESULT	RESULT = 9	NO RESULT	RESULT = 2
RESULT = 7	NO RESULT	RESULT = 3	NO RESULT
RESULT = 3	NO RESULT	RESULT = 5	RESULT = 5

For grids with "NO RESULT," the average of the grids with results was used [i.e., (9+2+7+3+3+5+5)/7= 4.86]. The UCL95 would be calculated from the following:

4.86
9
4.86
2
7
4.86
3
4.86
3
4.86
5
5

EPC = 5.81

Table D.6. Surface Grid Values

Chemical	Grid	Grid Value	Units	Grid Value Derived from	EPC	Calculate EPC from
EU 1						
Chromium	SOU001-001	1.78E+01	mg/kg	Avg	2.04E+01	UCL95
	SOU001-002	1.90E+01	mg/kg	Grid Value		
	SOU001-011	1.78E+01	mg/kg	Avg		
	SOU001-012	1.90E+01	mg/kg	Grid Value		
	SOU001-013	1.90E+01	mg/kg	Grid Value		
	SOU001-022	1.16E+01	mg/kg	Grid Value		
	SOU001-023	1.90E+01	mg/kg	Grid Value		
	SOU001-024	1.90E+01	mg/kg	Grid Value		
	SOU001-033	1.90E+01	mg/kg	Grid Value		
	SOU001-034	3.40E+01	mg/kg	Grid Value		
	SOU001-043	1.23E+01	mg/kg	Grid Value		
	SOU001-044	1.40E+01	mg/kg	Grid Value		
	SOU001-052	1.68E+01	mg/kg	Grid Value		
	SOU001-053	1.03E+01	mg/kg	Grid Value		

Table D.6. Surface Grid Values (Continued)

Chemical	Grid	Grid Value	Units	Grid Value Derived from	EPC	Calculate EPC from
Cesium-137	SOU001-001	3.96E-01	pCi/g	Avg	6.12E-01	UCL95
	SOU001-002	3.96E-01	pCi/g	Avg		
	SOU001-011	3.96E-01	pCi/g	Avg		
	SOU001-012	3.96E-01	pCi/g	Avg		
	SOU001-013	3.96E-01	pCi/g	Avg		
	SOU001-022	7.53E-01	pCi/g	Grid Value		
	SOU001-023	3.96E-01	pCi/g	Avg		
	SOU001-024	3.96E-01	pCi/g	Avg		
	SOU001-033	3.96E-01	pCi/g	Avg		
	SOU001-034	2.71E-03	pCi/g	Grid Value		
	SOU001-043	7.02E-01	pCi/g	Grid Value		
	SOU001-044	3.96E-01	pCi/g	Avg		
	SOU001-052	3.96E-01	pCi/g	Avg		
	SOU001-053	1.25E-01	pCi/g	Grid Value		
Neptunium-237	SOU001-001	1.76E-01	pCi/g	Avg	5.91E-01	UCL95
	SOU001-002	1.76E-01	pCi/g	Avg		
	SOU001-011	1.76E-01	pCi/g	Avg		
	SOU001-012	1.76E-01	pCi/g	Avg		
	SOU001-013	1.76E-01	pCi/g	Avg		
	SOU001-022	2.66E-02	pCi/g	Grid Value		
	SOU001-023	1.76E-01	pCi/g	Avg		
	SOU001-024	1.76E-01	pCi/g	Avg		
	SOU001-033	1.76E-01	pCi/g	Avg		
	SOU001-034	1.20E-02	pCi/g	Grid Value		
	SOU001-043	6.63E-01	pCi/g	Grid Value		
	SOU001-044	1.76E-01	pCi/g	Avg		
	SOU001-052	1.76E-01	pCi/g	Avg		
	SOU001-053	1.48E-03	pCi/g	Grid Value		
Plutonium-239/240	SOU001-001	3.06E+00	pCi/g	Avg	8.44E+00	UCL95
	SOU001-002	3.06E+00	pCi/g	Avg		
	SOU001-011	3.06E+00	pCi/g	Avg		
	SOU001-012	3.06E+00	pCi/g	Avg		
	SOU001-013	3.06E+00	pCi/g	Avg		
	SOU001-022	2.95E+00	pCi/g	Grid Value		
	SOU001-023	3.06E+00	pCi/g	Avg		
	SOU001-024	3.06E+00	pCi/g	Avg		
	SOU001-033	3.06E+00	pCi/g	Avg		
	SOU001-034	1.86E-02	pCi/g	Grid Value		
	SOU001-043	9.05E+00	pCi/g	Grid Value		
	SOU001-044	3.06E+00	pCi/g	Avg		
	SOU001-052	3.06E+00	pCi/g	Avg		
	SOU001-053	2.41E-01	pCi/g	Grid Value		

Table D.6. Surface Grid Values (Continued)

Chemical	Grid	Grid Value	Units	Grid Value Derived from	EPC	Calculate EPC from
Thorium-230	SOU001-001	2.21E+01	pCi/g	Avg	3.89E+01	UCL95
	SOU001-002	2.21E+01	pCi/g	Avg		
	SOU001-011	2.21E+01	pCi/g	Avg		
	SOU001-012	2.21E+01	pCi/g	Avg		
	SOU001-013	2.21E+01	pCi/g	Avg		
	SOU001-022	2.08E+01	pCi/g	Grid Value		
	SOU001-023	2.21E+01	pCi/g	Avg		
	SOU001-024	2.21E+01	pCi/g	Avg		
	SOU001-033	2.21E+01	pCi/g	Avg		
	SOU001-034	1.06E+00	pCi/g	Grid Value		
	SOU001-043	6.50E+01	pCi/g	Grid Value		
	SOU001-044	2.21E+01	pCi/g	Avg		
	SOU001-052	2.21E+01	pCi/g	Avg		
	SOU001-053	1.73E+00	pCi/g	Grid Value		
Uranium-238	SOU001-001	1.78E+00	pCi/g	Avg	2.04E+00	UCL95
	SOU001-002	1.78E+00	pCi/g	Avg		
	SOU001-011	1.78E+00	pCi/g	Avg		
	SOU001-012	1.78E+00	pCi/g	Avg		
	SOU001-013	1.78E+00	pCi/g	Avg		
	SOU001-022	9.49E-01	pCi/g	Grid Value		
	SOU001-023	1.78E+00	pCi/g	Avg		
	SOU001-024	1.78E+00	pCi/g	Avg		
	SOU001-033	1.78E+00	pCi/g	Avg		
	SOU001-034	1.98E+00	pCi/g	Grid Value		
	SOU001-043	3.31E+00	pCi/g	Grid Value		
	SOU001-044	1.78E+00	pCi/g	Avg		
	SOU001-052	1.78E+00	pCi/g	Avg		
	SOU001-053	8.94E-01	pCi/g	Grid Value		
EU 2						
Chromium	SOU001-003	1.90E+01	mg/kg	Grid Value	3.82E+01	UCL95
	SOU001-004	1.90E+01	mg/kg	Grid Value		
	SOU001-005	2.40E+01	mg/kg	Grid Value		
	SOU001-006	2.71E+01	mg/kg	Avg		
	SOU001-014	1.90E+01	mg/kg	Grid Value		
	SOU001-015	1.90E+01	mg/kg	Grid Value		
	SOU001-016	1.90E+01	mg/kg	Grid Value		
	SOU001-017	1.90E+01	mg/kg	Grid Value		
	SOU001-025	1.90E+01	mg/kg	Grid Value		
	SOU001-026	9.40E+01	mg/kg	Grid Value		
	SOU001-027	2.80E+01	mg/kg	Grid Value		
	SOU001-028	1.90E+01	mg/kg	Grid Value		

Table D.6. Surface Grid Values (Continued)

Chemical	Grid	Grid Value	Units	Grid Value Derived from	EPC	Calculate EPC from
PCB, Total	SOU001-003	5.00E+00	mg/kg	Grid Value	1.19E+01	UCL95
	SOU001-004	5.00E+00	mg/kg	Grid Value		
	SOU001-005	1.70E-02	mg/kg	Grid Value		
	SOU001-006	5.00E-02	mg/kg	Grid Value		
	SOU001-014	5.00E+00	mg/kg	Grid Value		
	SOU001-015	5.00E+00	mg/kg	Grid Value		
	SOU001-016	5.00E+00	mg/kg	Grid Value		
	SOU001-017	9.50E+00	mg/kg	Grid Value		
	SOU001-025	5.00E+00	mg/kg	Grid Value		
	SOU001-026	5.00E+00	mg/kg	Grid Value		
	SOU001-027	5.00E+00	mg/kg	Grid Value		
	SOU001-028	8.50E-01	mg/kg	Grid Value		
Uranium-234	SOU001-003	9.01E+00	pCi/g	Avg	9.01E+00	UCL95
	SOU001-004	9.01E+00	pCi/g	Avg		
	SOU001-005	9.01E+00	pCi/g	Grid Value		
	SOU001-006	9.01E+00	pCi/g	Avg		
	SOU001-014	9.01E+00	pCi/g	Avg		
	SOU001-015	9.01E+00	pCi/g	Avg		
	SOU001-016	9.01E+00	pCi/g	Avg		
	SOU001-017	9.01E+00	pCi/g	Avg		
	SOU001-025	9.01E+00	pCi/g	Avg		
	SOU001-026	9.01E+00	pCi/g	Avg		
	SOU001-027	9.01E+00	pCi/g	Avg		
	SOU001-028	9.01E+00	pCi/g	Avg		
Uranium-235	SOU001-003	5.11E-01	pCi/g	Avg	5.11E-01	UCL95
	SOU001-004	5.11E-01	pCi/g	Avg		
	SOU001-005	5.11E-01	pCi/g	Grid Value		
	SOU001-006	5.11E-01	pCi/g	Avg		
	SOU001-014	5.11E-01	pCi/g	Avg		
	SOU001-015	5.11E-01	pCi/g	Avg		
	SOU001-016	5.11E-01	pCi/g	Avg		
	SOU001-017	5.11E-01	pCi/g	Avg		
	SOU001-025	5.11E-01	pCi/g	Avg		
	SOU001-026	5.11E-01	pCi/g	Avg		
	SOU001-027	5.11E-01	pCi/g	Avg		
	SOU001-028	5.11E-01	pCi/g	Avg		
Uranium-238	SOU001-003	9.86E+00	pCi/g	Avg	9.86E+00	UCL95
	SOU001-004	9.86E+00	pCi/g	Avg		
	SOU001-005	9.86E+00	pCi/g	Grid Value		
	SOU001-006	9.86E+00	pCi/g	Avg		
	SOU001-014	9.86E+00	pCi/g	Avg		
	SOU001-015	9.86E+00	pCi/g	Avg		
	SOU001-016	9.86E+00	pCi/g	Avg		
	SOU001-017	9.86E+00	pCi/g	Avg		
	SOU001-025	9.86E+00	pCi/g	Avg		
	SOU001-026	9.86E+00	pCi/g	Avg		
	SOU001-027	9.86E+00	pCi/g	Avg		
	SOU001-028	9.86E+00	pCi/g	Avg		

Table D.6. Surface Grid Values (Continued)

Chemical	Grid	Grid Value	Units	Grid Value Derived from	EPC	Calculate EPC from
EU 3						
Chromium	SOU001-007	1.41E+01	mg/kg	Grid Value	1.78E+01	UCL95
	SOU001-008	1.71E+01	mg/kg	Grid Value		
	SOU001-009	1.18E+01	mg/kg	Grid Value		
	SOU001-010	1.23E+01	mg/kg	Grid Value		
	SOU001-018	1.62E+01	mg/kg	Avg		
	SOU001-019	1.62E+01	mg/kg	Avg		
	SOU001-020	1.20E+01	mg/kg	Grid Value		
	SOU001-021	1.90E+01	mg/kg	Grid Value		
	SOU001-029	1.90E+01	mg/kg	Grid Value		
	SOU001-030	1.90E+01	mg/kg	Grid Value		
	SOU001-031	1.90E+01	mg/kg	Grid Value		
	SOU001-032	1.90E+01	mg/kg	Grid Value		
PCB, Total	SOU001-007	5.00E-02	mg/kg	Grid Value	9.29E+00	UCL95
	SOU001-008	3.65E-01	mg/kg	Grid Value		
	SOU001-009	1.00E-01	mg/kg	Grid Value		
	SOU001-010	1.00E-01	mg/kg	Grid Value		
	SOU001-018	1.97E-01	mg/kg	Grid Value		
	SOU001-019	2.36E+00	mg/kg	Avg		
	SOU001-020	1.40E-01	mg/kg	Grid Value		
	SOU001-021	5.00E+00	mg/kg	Grid Value		
	SOU001-029	5.00E+00	mg/kg	Grid Value		
	SOU001-030	5.00E+00	mg/kg	Grid Value		
	SOU001-031	5.00E+00	mg/kg	Grid Value		
	SOU001-032	5.00E+00	mg/kg	Grid Value		
Total PAH	SOU001-007	5.00E-01	mg/kg	Grid Value	4.14E-01	UCL95
	SOU001-008	2.83E-01	mg/kg	Avg		
	SOU001-009	3.30E-01	mg/kg	Grid Value		
	SOU001-010	2.83E-01	mg/kg	Avg		
	SOU001-018	2.83E-01	mg/kg	Avg		
	SOU001-019	2.83E-01	mg/kg	Avg		
	SOU001-020	1.89E-02	mg/kg	Grid Value		
	SOU001-021	2.83E-01	mg/kg	Avg		
	SOU001-029	2.83E-01	mg/kg	Avg		
	SOU001-030	2.83E-01	mg/kg	Avg		
	SOU001-031	2.83E-01	mg/kg	Avg		
	SOU001-032	2.83E-01	mg/kg	Avg		
Uranium-238	SOU001-007	1.73E+00	pCi/g	Grid Value	3.92E+00	UCL95
	SOU001-008	3.52E+00	pCi/g	Avg		
	SOU001-009	3.52E+00	pCi/g	Avg		
	SOU001-010	3.52E+00	pCi/g	Avg		
	SOU001-018	3.52E+00	pCi/g	Avg		
	SOU001-019	3.52E+00	pCi/g	Avg		
	SOU001-020	5.31E+00	pCi/g	Grid Value		
	SOU001-021	3.52E+00	pCi/g	Avg		
	SOU001-029	3.52E+00	pCi/g	Avg		
	SOU001-030	3.52E+00	pCi/g	Avg		
	SOU001-031	3.52E+00	pCi/g	Avg		
	SOU001-032	3.52E+00	pCi/g	Avg		

Table D.6. Surface Grid Values (Continued)

Chemical	Grid	Grid Value	Units	Grid Value Derived from	EPC	Calculate EPC from
EU 4						
Chromium	SOU001-035	1.90E+01	mg/kg	Grid Value	8.15E+01	UCL95
	SOU001-036	4.05E+01	mg/kg	Avg		
	SOU001-037	4.05E+01	mg/kg	Avg		
	SOU001-038	1.90E+01	mg/kg	Grid Value		
	SOU001-045	4.05E+01	mg/kg	Avg		
	SOU001-046	1.37E+02	mg/kg	Grid Value		
	SOU001-047	4.05E+01	mg/kg	Avg		
	SOU001-048	4.05E+01	mg/kg	Avg		
	SOU001-054	4.05E+01	mg/kg	Avg		
	SOU001-055	4.05E+01	mg/kg	Avg		
	SOU001-056	1.24E+01	mg/kg	Grid Value		
	SOU001-057	1.51E+01	mg/kg	Grid Value		
PCB, Total	SOU001-035	5.00E+00	mg/kg	Grid Value	6.44E+00	UCL95
	SOU001-036	5.00E-02	mg/kg	Grid Value		
	SOU001-037	5.00E-02	mg/kg	Grid Value		
	SOU001-038	5.00E+00	mg/kg	Grid Value		
	SOU001-045	9.90E-02	mg/kg	Grid Value		
	SOU001-046	9.40E-01	mg/kg	Grid Value		
	SOU001-047	9.90E-02	mg/kg	Grid Value		
	SOU001-048	1.07E+00	mg/kg	Avg		
	SOU001-054	1.30E-01	mg/kg	Grid Value		
	SOU001-055	1.30E-01	mg/kg	Grid Value		
	SOU001-056	1.30E-01	mg/kg	Grid Value		
	SOU001-057	1.30E-01	mg/kg	Grid Value		
EU 5						
PCB, Total	SOU001-039	5.00E+00	mg/kg	Grid Value	2.70E-01	Maximum
	SOU001-040	2.00E-02	mg/kg	Grid Value		
	SOU001-041	7.34E-01	mg/kg	Avg		
	SOU001-042	1.20E-01	mg/kg	Grid Value		
	SOU001-049	9.50E-02	mg/kg	Grid Value		
	SOU001-050	1.30E-01	mg/kg	Grid Value		
	SOU001-051	1.20E-01	mg/kg	Grid Value		
	SOU001-058	2.70E-01	mg/kg	Grid Value		
	SOU001-059	1.20E-01	mg/kg	Grid Value		
Total PAH	SOU001-039	2.26E-01	mg/kg	Avg	9.83E-02	Maximum
	SOU001-040	2.26E-01	mg/kg	Avg		
	SOU001-041	2.26E-01	mg/kg	Avg		
	SOU001-042	3.30E-01	mg/kg	Grid Value		
	SOU001-049	3.90E-01	mg/kg	Grid Value		
	SOU001-050	2.26E-01	mg/kg	Avg		
	SOU001-051	8.75E-02	mg/kg	Grid Value		
	SOU001-058	9.83E-02	mg/kg	Grid Value		
	SOU001-059	2.26E-01	mg/kg	Avg		

Table D.7. Subsurface Grid Values

Chemical	Grid	Grid Value	Units	Grid Value Derived from	EPC	Calculate EPC from
EU 1						
Aluminum	SOU001-034	9.28E+03	mg/kg	Grid Value	1.05E+04	UCL95
	SOU001-053	1.43E+04	mg/kg	Grid Value		
	SOU001-052	1.06E+04	mg/kg	Grid Value		
	SOU001-043	9.25E+03	mg/kg	Grid Value		
	SOU001-033	9.75E+03	mg/kg	Grid Value		
	SOU001-024	9.31E+03	mg/kg	Grid Value		
	SOU001-023	7.49E+03	mg/kg	Grid Value		
	SOU001-022	9.22E+03	mg/kg	Grid Value		
	SOU001-013	8.22E+03	mg/kg	Grid Value		
	SOU001-012	1.17E+04	mg/kg	Grid Value		
	SOU001-011	9.47E+03	mg/kg	Grid Value		
	SOU001-002	9.24E+03	mg/kg	Grid Value		
	SOU001-001	8.05E+03	mg/kg	Grid Value		
	SOU001-044	9.38E+03	mg/kg	Grid Value		
Antimony	SOU001-013	3.82E+00	mg/kg	Grid Value	2.31E+00	UCL95
	SOU001-024	2.30E-01	mg/kg	Grid Value		
	SOU001-053	5.22E-01	mg/kg	Grid Value		
	SOU001-052	5.22E-01	mg/kg	Grid Value		
	SOU001-044	5.00E+00	mg/kg	Grid Value		
	SOU001-043	6.33E-01	mg/kg	Grid Value		
	SOU001-034	9.34E-01	mg/kg	Grid Value		
	SOU001-033	1.72E+00	mg/kg	Grid Value		
	SOU001-022	2.30E-01	mg/kg	Grid Value		
	SOU001-012	1.60E-01	mg/kg	Grid Value		
	SOU001-011	1.11E+00	mg/kg	Grid Value		
	SOU001-002	1.32E+00	mg/kg	Grid Value		
	SOU001-001	1.40E+00	mg/kg	Grid Value		
	SOU001-023	6.38E-01	mg/kg	Grid Value		
Arsenic	SOU001-002	5.00E+00	mg/kg	Grid Value	7.43E+00	UCL95
	SOU001-052	6.56E+00	mg/kg	Grid Value		
	SOU001-044	5.40E+00	mg/kg	Grid Value		
	SOU001-043	6.77E+00	mg/kg	Grid Value		
	SOU001-034	8.90E+00	mg/kg	Grid Value		
	SOU001-024	1.07E+01	mg/kg	Grid Value		
	SOU001-022	6.51E+00	mg/kg	Grid Value		
	SOU001-013	5.00E+00	mg/kg	Grid Value		
	SOU001-011	3.38E+00	mg/kg	Grid Value		
	SOU001-053	1.06E+01	mg/kg	Grid Value		
	SOU001-001	3.93E+00	mg/kg	Grid Value		
	SOU001-033	6.00E+00	mg/kg	Grid Value		
	SOU001-012	6.10E+00	mg/kg	Grid Value		
	SOU001-023	4.00E+00	mg/kg	Grid Value		

Table D.7. Subsurface Grid Values (Continued)

Chemical	Grid	Grid Value	Units	Grid Value Derived from	EPC	Calculate EPC from
Chromium	SOU001-002	1.46E+01	mg/kg	Grid Value	2.64E+01	UCL95
	SOU001-044	1.46E+01	mg/kg	Grid Value		
	SOU001-043	1.31E+01	mg/kg	Grid Value		
	SOU001-034	3.40E+01	mg/kg	Grid Value		
	SOU001-033	1.54E+01	mg/kg	Grid Value		
	SOU001-024	1.50E+01	mg/kg	Grid Value		
	SOU001-023	1.16E+01	mg/kg	Grid Value		
	SOU001-022	1.46E+01	mg/kg	Grid Value		
	SOU001-013	4.50E+00	mg/kg	Grid Value		
	SOU001-011	5.62E+01	mg/kg	Grid Value		
	SOU001-052	1.68E+01	mg/kg	Grid Value		
	SOU001-053	2.06E+01	mg/kg	Grid Value		
	SOU001-012	2.00E+01	mg/kg	Grid Value		
	SOU001-001	1.46E+01	mg/kg	Grid Value		
Cobalt	SOU001-034	1.20E+01	mg/kg	Grid Value	1.04E+01	UCL95
	SOU001-001	5.36E+00	mg/kg	Grid Value		
	SOU001-052	9.60E+00	mg/kg	Grid Value		
	SOU001-043	1.54E+01	mg/kg	Grid Value		
	SOU001-053	1.14E+01	mg/kg	Grid Value		
	SOU001-033	1.27E+01	mg/kg	Grid Value		
	SOU001-024	4.03E+00	mg/kg	Grid Value		
	SOU001-023	7.21E+00	mg/kg	Grid Value		
	SOU001-022	6.74E+00	mg/kg	Grid Value		
	SOU001-013	8.00E+00	mg/kg	Grid Value		
	SOU001-012	6.40E+00	mg/kg	Grid Value		
	SOU001-011	9.87E+00	mg/kg	Grid Value		
	SOU001-002	3.79E+00	mg/kg	Grid Value		
	SOU001-044	1.01E+01	mg/kg	Grid Value		
Manganese	SOU001-024	3.76E+02	mg/kg	Grid Value	1.01E+03	UCL95
	SOU001-053	1.08E+03	mg/kg	Grid Value		
	SOU001-052	1.06E+03	mg/kg	Grid Value		
	SOU001-044	1.29E+03	mg/kg	Grid Value		
	SOU001-043	1.99E+03	mg/kg	Grid Value		
	SOU001-034	1.20E+03	mg/kg	Grid Value		
	SOU001-033	4.11E+02	mg/kg	Grid Value		
	SOU001-023	7.09E+02	mg/kg	Grid Value		
	SOU001-022	6.96E+02	mg/kg	Grid Value		
	SOU001-013	4.02E+02	mg/kg	Grid Value		
	SOU001-012	4.61E+02	mg/kg	Grid Value		
	SOU001-011	3.59E+02	mg/kg	Grid Value		
	SOU001-001	5.25E+02	mg/kg	Grid Value		
	SOU001-002	4.24E+02	mg/kg	Grid Value		

Table D.7. Subsurface Grid Values (Continued)

Chemical	Grid	Grid Value	Units	Grid Value Derived from	EPC	Calculate EPC from
Thallium	SOU001-044	1.26E-01	mg/kg	Grid Value	8.68E-01	UCL95
	SOU001-052	5.34E-01	mg/kg	Grid Value		
	SOU001-002	1.16E-01	mg/kg	Grid Value		
	SOU001-011	1.16E-01	mg/kg	Grid Value		
	SOU001-012	1.40E-01	mg/kg	Grid Value		
	SOU001-013	1.05E+00	mg/kg	Grid Value		
	SOU001-022	1.40E-01	mg/kg	Grid Value		
	SOU001-023	1.31E-01	mg/kg	Grid Value		
	SOU001-024	1.45E-01	mg/kg	Grid Value		
	SOU001-033	1.16E-01	mg/kg	Grid Value		
	SOU001-034	1.80E-01	mg/kg	Grid Value		
	SOU001-053	5.34E-01	mg/kg	Grid Value		
	SOU001-043	1.56E+00	mg/kg	Grid Value		
	SOU001-001	1.16E-01	mg/kg	Grid Value		
Total PAH	SOU001-001	3.30E-01	mg/kg	Grid Value	4.53E-01	UCL95
	SOU001-053	3.30E-01	mg/kg	Grid Value		
	SOU001-052	3.30E-01	mg/kg	Grid Value		
	SOU001-002	3.30E-01	mg/kg	Grid Value		
	SOU001-011	3.30E-01	mg/kg	Grid Value		
	SOU001-012	8.52E-03	mg/kg	Grid Value		
	SOU001-013	4.40E-01	mg/kg	Grid Value		
	SOU001-023	3.30E-01	mg/kg	Grid Value		
	SOU001-024	3.30E-01	mg/kg	Grid Value		
	SOU001-033	4.10E-01	mg/kg	Grid Value		
	SOU001-034	5.19E-03	mg/kg	Grid Value		
	SOU001-043	3.30E-01	mg/kg	Grid Value		
	SOU001-044	3.90E-01	mg/kg	Grid Value		
	SOU001-022	3.30E-01	mg/kg	Grid Value		
Vanadium	SOU001-024	2.63E+01	mg/kg	Grid Value	3.33E+01	UCL95
	SOU001-053	3.40E+01	mg/kg	Grid Value		
	SOU001-052	2.71E+01	mg/kg	Grid Value		
	SOU001-044	2.24E+01	mg/kg	Grid Value		
	SOU001-043	3.22E+01	mg/kg	Grid Value		
	SOU001-033	2.31E+01	mg/kg	Grid Value		
	SOU001-023	3.30E+01	mg/kg	Grid Value		
	SOU001-001	2.27E+01	mg/kg	Grid Value		
	SOU001-022	2.30E+01	mg/kg	Grid Value		
	SOU001-013	1.46E+01	mg/kg	Grid Value		
	SOU001-012	3.54E+01	mg/kg	Grid Value		
	SOU001-011	5.33E+01	mg/kg	Grid Value		
	SOU001-002	1.86E+01	mg/kg	Grid Value		
	SOU001-034	3.64E+01	mg/kg	Grid Value		

Table D.7. Subsurface Grid Values (Continued)

Chemical	Grid	Grid Value	Units	Grid Value Derived from	EPC	Calculate EPC from
Cesium-137	SOU001-002	3.20E-01	pCi/g	Avg	8.74E-01	UCL95
	SOU001-012	1.76E-02	pCi/g	Grid Value		
	SOU001-013	3.20E-01	pCi/g	Avg		
	SOU001-022	7.53E-01	pCi/g	Grid Value		
	SOU001-023	3.20E-01	pCi/g	Avg		
	SOU001-024	3.20E-01	pCi/g	Avg		
	SOU001-034	2.71E-03	pCi/g	Grid Value		
	SOU001-043	7.02E-01	pCi/g	Grid Value		
	SOU001-044	3.20E-01	pCi/g	Avg		
	SOU001-052	3.20E-01	pCi/g	Avg		
	SOU001-001	3.20E-01	pCi/g	Avg		
	SOU001-053	1.25E-01	pCi/g	Grid Value		
	SOU001-033	3.20E-01	pCi/g	Avg		
	SOU001-011	3.20E-01	pCi/g	Avg		
Neptunium-237	SOU001-001	1.42E-01	pCi/g	Avg	5.72E-01	UCL95
	SOU001-034	1.20E-02	pCi/g	Grid Value		
	SOU001-052	1.42E-01	pCi/g	Avg		
	SOU001-053	1.48E-03	pCi/g	Grid Value		
	SOU001-043	6.63E-01	pCi/g	Grid Value		
	SOU001-033	1.42E-01	pCi/g	Avg		
	SOU001-024	1.42E-01	pCi/g	Avg		
	SOU001-023	1.42E-01	pCi/g	Avg		
	SOU001-022	2.66E-02	pCi/g	Grid Value		
	SOU001-013	1.42E-01	pCi/g	Avg		
	SOU001-012	6.31E-03	pCi/g	Grid Value		
	SOU001-011	1.42E-01	pCi/g	Avg		
	SOU001-002	1.42E-01	pCi/g	Avg		
	SOU001-044	1.42E-01	pCi/g	Avg		
Plutonium-239/240	SOU001-053	2.41E-01	pCi/g	Grid Value	8.19E+00	UCL95
	SOU001-023	2.45E+00	pCi/g	Avg		
	SOU001-002	2.45E+00	pCi/g	Avg		
	SOU001-011	2.45E+00	pCi/g	Avg		
	SOU001-012	9.16E-03	pCi/g	Grid Value		
	SOU001-013	2.45E+00	pCi/g	Avg		
	SOU001-022	2.95E+00	pCi/g	Grid Value		
	SOU001-024	2.45E+00	pCi/g	Avg		
	SOU001-033	2.45E+00	pCi/g	Avg		
	SOU001-034	1.86E-02	pCi/g	Grid Value		
	SOU001-043	9.05E+00	pCi/g	Grid Value		
	SOU001-044	2.45E+00	pCi/g	Avg		
	SOU001-052	2.45E+00	pCi/g	Avg		
	SOU001-001	2.45E+00	pCi/g	Avg		

Table D.7. Subsurface Grid Values (Continued)

Chemical	Grid	Grid Value	Units	Grid Value Derived from	EPC	Calculate EPC from
Thorium-230	SOU001-001	1.79E+01	pCi/g	Avg	3.58E+01	UCL95
	SOU001-043	6.50E+01	pCi/g	Grid Value		
	SOU001-034	1.06E+00	pCi/g	Grid Value		
	SOU001-033	1.79E+01	pCi/g	Avg		
	SOU001-024	1.79E+01	pCi/g	Avg		
	SOU001-023	1.79E+01	pCi/g	Avg		
	SOU001-053	1.73E+00	pCi/g	Grid Value		
	SOU001-022	2.08E+01	pCi/g	Grid Value		
	SOU001-052	1.79E+01	pCi/g	Avg		
	SOU001-013	1.79E+01	pCi/g	Avg		
	SOU001-012	1.08E+00	pCi/g	Grid Value		
	SOU001-011	1.79E+01	pCi/g	Avg		
	SOU001-002	1.79E+01	pCi/g	Avg		
	SOU001-044	1.79E+01	pCi/g	Avg		
Uranium-238	SOU001-043	3.31E+00	pCi/g	Grid Value	2.57E+00	UCL95
	SOU001-023	2.21E+00	pCi/g	Avg		
	SOU001-001	2.21E+00	pCi/g	Avg		
	SOU001-002	2.21E+00	pCi/g	Avg		
	SOU001-011	2.21E+00	pCi/g	Avg		
	SOU001-012	3.91E+00	pCi/g	Grid Value		
	SOU001-013	2.21E+00	pCi/g	Avg		
	SOU001-022	9.49E-01	pCi/g	Grid Value		
	SOU001-052	2.21E+00	pCi/g	Avg		
	SOU001-034	1.98E+00	pCi/g	Grid Value		
	SOU001-044	2.21E+00	pCi/g	Avg		
	SOU001-053	8.94E-01	pCi/g	Grid Value		
	SOU001-024	2.21E+00	pCi/g	Avg		
	SOU001-033	2.21E+00	pCi/g	Avg		
EU 2						
Arsenic	SOU001-017	1.15E+01	mg/kg	Grid Value	7.76E+00	UCL95
	SOU001-016	4.00E+00	mg/kg	Grid Value		
	SOU001-028	4.20E+00	mg/kg	Grid Value		
	SOU001-027	6.00E+00	mg/kg	Grid Value		
	SOU001-025	9.41E+00	mg/kg	Grid Value		
	SOU001-003	4.69E+00	mg/kg	Grid Value		
	SOU001-014	6.20E+00	mg/kg	Grid Value		
	SOU001-004	8.00E+00	mg/kg	Grid Value		
	SOU001-006	6.49E+00	mg/kg	Avg		
	SOU001-005	4.80E+00	mg/kg	Grid Value		
	SOU001-026	8.70E+00	mg/kg	Grid Value		
	SOU001-015	3.92E+00	mg/kg	Grid Value		

Table D.7. Subsurface Grid Values (Continued)

Chemical	Grid	Grid Value	Units	Grid Value Derived from	EPC	Calculate EPC from
Chromium	SOU001-015	1.54E+01	mg/kg	Grid Value	3.87E+01	UCL95
	SOU001-028	5.60E+00	mg/kg	Grid Value		
	SOU001-027	2.80E+01	mg/kg	Grid Value		
	SOU001-026	9.40E+01	mg/kg	Grid Value		
	SOU001-025	2.79E+01	mg/kg	Grid Value		
	SOU001-016	1.54E+01	mg/kg	Grid Value		
	SOU001-014	1.69E+01	mg/kg	Grid Value		
	SOU001-006	2.47E+01	mg/kg	Avg		
	SOU001-005	2.40E+01	mg/kg	Grid Value		
	SOU001-004	1.36E+01	mg/kg	Grid Value		
	SOU001-003	1.44E+01	mg/kg	Grid Value		
	SOU001-017	1.61E+01	mg/kg	Grid Value		
Manganese	SOU001-017	9.02E+02	mg/kg	Grid Value	6.98E+02	UCL95
	SOU001-014	8.48E+02	mg/kg	Grid Value		
	SOU001-028	2.93E+02	mg/kg	Grid Value		
	SOU001-027	4.37E+02	mg/kg	Grid Value		
	SOU001-026	8.34E+02	mg/kg	Grid Value		
	SOU001-025	7.12E+02	mg/kg	Grid Value		
	SOU001-003	6.63E+02	mg/kg	Grid Value		
	SOU001-016	4.80E+02	mg/kg	Grid Value		
	SOU001-004	5.31E+02	mg/kg	Grid Value		
	SOU001-005	3.70E+02	mg/kg	Grid Value		
	SOU001-006	5.95E+02	mg/kg	Avg		
	SOU001-015	4.73E+02	mg/kg	Grid Value		
PCB, Total	SOU001-026	1.70E-02	mg/kg	Grid Value	8.68E+00	UCL95
	SOU001-025	1.70E-02	mg/kg	Grid Value		
	SOU001-005	1.70E-02	mg/kg	Grid Value		
	SOU001-027	1.70E-02	mg/kg	Grid Value		
	SOU001-003	1.70E-02	mg/kg	Grid Value		
	SOU001-016	9.80E-02	mg/kg	Grid Value		
	SOU001-015	5.00E-02	mg/kg	Grid Value		
	SOU001-006	5.00E-02	mg/kg	Grid Value		
	SOU001-004	1.70E-02	mg/kg	Grid Value		
	SOU001-017	9.50E+00	mg/kg	Grid Value		
	SOU001-014	5.00E-02	mg/kg	Grid Value		
	SOU001-028	2.40E-01	mg/kg	Grid Value		
Silver	SOU001-014	2.90E+00	mg/kg	Grid Value	6.87E+01	UCL95
	SOU001-003	2.91E-01	mg/kg	Grid Value		
	SOU001-028	1.12E+00	mg/kg	Grid Value		
	SOU001-006	8.31E+00	mg/kg	Avg		
	SOU001-004	2.91E-01	mg/kg	Grid Value		
	SOU001-015	2.91E-01	mg/kg	Grid Value		
	SOU001-016	8.00E-02	mg/kg	Grid Value		
	SOU001-017	7.39E+01	mg/kg	Grid Value		
	SOU001-025	1.80E-01	mg/kg	Grid Value		
	SOU001-026	1.20E+01	mg/kg	Grid Value		
	SOU001-027	2.91E-01	mg/kg	Grid Value		
	SOU001-005	2.90E-02	mg/kg	Grid Value		

Table D.7. Subsurface Grid Values (Continued)

Chemical	Grid	Grid Value	Units	Grid Value Derived from	EPC	Calculate EPC from
Total PAH	SOU001-015	2.30E+00	mg/kg	Grid Value	1.22E+00	UCL95
	SOU001-005	6.34E-03	mg/kg	Grid Value		
	SOU001-006	4.79E-01	mg/kg	Avg		
	SOU001-014	3.90E-01	mg/kg	Grid Value		
	SOU001-016	3.90E-01	mg/kg	Grid Value		
	SOU001-017	3.90E-01	mg/kg	Grid Value		
	SOU001-025	3.30E-01	mg/kg	Grid Value		
	SOU001-026	2.96E-02	mg/kg	Grid Value		
	SOU001-027	3.30E-01	mg/kg	Grid Value		
	SOU001-003	3.30E-01	mg/kg	Grid Value		
	SOU001-028	4.40E-01	mg/kg	Grid Value		
	SOU001-004	3.30E-01	mg/kg	Grid Value		
Uranium-234	SOU001-028	5.35E+00	pCi/g	Avg	6.16E+00	UCL95
	SOU001-017	5.35E+00	pCi/g	Avg		
	SOU001-026	1.69E+00	pCi/g	Grid Value		
	SOU001-025	5.35E+00	pCi/g	Avg		
	SOU001-016	5.35E+00	pCi/g	Avg		
	SOU001-015	5.35E+00	pCi/g	Avg		
	SOU001-014	5.35E+00	pCi/g	Avg		
	SOU001-006	5.35E+00	pCi/g	Avg		
	SOU001-005	9.01E+00	pCi/g	Grid Value		
	SOU001-004	5.35E+00	pCi/g	Avg		
	SOU001-003	5.35E+00	pCi/g	Avg		
	SOU001-027	5.35E+00	pCi/g	Avg		
Uranium-235	SOU001-004	2.91E-01	pCi/g	Avg	3.40E-01	UCL95
	SOU001-015	2.91E-01	pCi/g	Avg		
	SOU001-005	5.11E-01	pCi/g	Grid Value		
	SOU001-006	2.91E-01	pCi/g	Avg		
	SOU001-014	2.91E-01	pCi/g	Avg		
	SOU001-016	2.91E-01	pCi/g	Avg		
	SOU001-025	2.91E-01	pCi/g	Avg		
	SOU001-026	7.07E-02	pCi/g	Grid Value		
	SOU001-027	2.91E-01	pCi/g	Avg		
	SOU001-028	2.91E-01	pCi/g	Avg		
	SOU001-003	2.91E-01	pCi/g	Avg		
	SOU001-017	2.91E-01	pCi/g	Avg		
Uranium-238	SOU001-015	5.83E+00	pCi/g	Avg	6.72E+00	UCL95
	SOU001-025	5.83E+00	pCi/g	Avg		
	SOU001-026	1.80E+00	pCi/g	Grid Value		
	SOU001-027	5.83E+00	pCi/g	Avg		
	SOU001-028	5.83E+00	pCi/g	Avg		
	SOU001-016	5.83E+00	pCi/g	Avg		
	SOU001-014	5.83E+00	pCi/g	Avg		
	SOU001-006	5.83E+00	pCi/g	Avg		
	SOU001-005	9.86E+00	pCi/g	Grid Value		
	SOU001-004	5.83E+00	pCi/g	Avg		
	SOU001-003	5.83E+00	pCi/g	Avg		
	SOU001-017	5.83E+00	pCi/g	Avg		

Table D.7. Subsurface Grid Values (Continued)

Chemical	Grid	Grid Value	Units	Grid Value Derived from	EPC	Calculate EPC from
EU 3						
Arsenic	SOU001-029	5.00E+00	mg/kg	Grid Value	6.89E+00	UCL95
	SOU001-007	5.75E+00	mg/kg	Grid Value		
	SOU001-008	5.91E+00	mg/kg	Grid Value		
	SOU001-009	6.28E+00	mg/kg	Grid Value		
	SOU001-010	2.09E+00	mg/kg	Grid Value		
	SOU001-018	5.87E+00	mg/kg	Avg		
	SOU001-019	5.87E+00	mg/kg	Avg		
	SOU001-021	6.00E+00	mg/kg	Grid Value		
	SOU001-030	1.05E+01	mg/kg	Grid Value		
	SOU001-032	4.00E+00	mg/kg	Grid Value		
	SOU001-031	6.00E+00	mg/kg	Grid Value		
	SOU001-020	7.20E+00	mg/kg	Grid Value		
Chromium	SOU001-009	1.18E+01	mg/kg	Grid Value	4.58E+01	UCL95
	SOU001-029	1.29E+01	mg/kg	Grid Value		
	SOU001-007	1.43E+01	mg/kg	Grid Value		
	SOU001-008	1.71E+01	mg/kg	Grid Value		
	SOU001-032	1.19E+01	mg/kg	Grid Value		
	SOU001-030	1.37E+01	mg/kg	Grid Value		
	SOU001-021	1.90E+01	mg/kg	Grid Value		
	SOU001-020	1.20E+01	mg/kg	Grid Value		
	SOU001-019	2.08E+01	mg/kg	Avg		
	SOU001-018	2.08E+01	mg/kg	Avg		
	SOU001-010	1.23E+01	mg/kg	Grid Value		
	SOU001-031	8.30E+01	mg/kg	Grid Value		
Manganese	SOU001-007	4.27E+02	mg/kg	Grid Value	6.01E+02	UCL95
	SOU001-021	3.95E+02	mg/kg	Grid Value		
	SOU001-031	4.83E+02	mg/kg	Grid Value		
	SOU001-032	3.01E+02	mg/kg	Grid Value		
	SOU001-030	8.81E+02	mg/kg	Grid Value		
	SOU001-029	5.11E+02	mg/kg	Grid Value		
	SOU001-020	7.11E+02	mg/kg	Grid Value		
	SOU001-019	5.10E+02	mg/kg	Avg		
	SOU001-018	5.10E+02	mg/kg	Avg		
	SOU001-010	4.68E+02	mg/kg	Grid Value		
	SOU001-008	2.50E+02	mg/kg	Grid Value		
	SOU001-009	6.70E+02	mg/kg	Grid Value		
PCB, Total	SOU001-031	1.70E-02	mg/kg	Grid Value	4.60E+00	UCL95
	SOU001-021	5.00E+00	mg/kg	Grid Value		
	SOU001-029	1.70E-02	mg/kg	Grid Value		
	SOU001-007	1.70E-02	mg/kg	Grid Value		
	SOU001-030	1.70E-02	mg/kg	Grid Value		
	SOU001-020	1.40E-01	mg/kg	Grid Value		
	SOU001-019	5.29E-01	mg/kg	Avg		
	SOU001-018	1.97E-01	mg/kg	Grid Value		
	SOU001-010	1.70E-02	mg/kg	Grid Value		
	SOU001-009	1.70E-02	mg/kg	Grid Value		
	SOU001-008	3.65E-01	mg/kg	Grid Value		
	SOU001-032	1.70E-02	mg/kg	Grid Value		

Table D.7. Subsurface Grid Values (Continued)

Chemical	Grid	Grid Value	Units	Grid Value Derived from	EPC	Calculate EPC from
Total PAH	SOU001-007	3.30E-01	mg/kg	Grid Value	4.07E-01	UCL95
	SOU001-021	2.95E-01	mg/kg	Avg		
	SOU001-032	3.30E-01	mg/kg	Grid Value		
	SOU001-031	3.30E-01	mg/kg	Grid Value		
	SOU001-030	3.30E-01	mg/kg	Grid Value		
	SOU001-029	3.30E-01	mg/kg	Grid Value		
	SOU001-020	1.89E-02	mg/kg	Grid Value		
	SOU001-019	2.95E-01	mg/kg	Avg		
	SOU001-018	2.95E-01	mg/kg	Avg		
	SOU001-010	3.30E-01	mg/kg	Grid Value		
	SOU001-008	3.30E-01	mg/kg	Grid Value		
	SOU001-009	3.30E-01	mg/kg	Grid Value		
Cesium-137	SOU001-019	2.09E-01	pCi/g	Avg	2.30E-01	UCL95
	SOU001-031	2.09E-01	pCi/g	Avg		
	SOU001-030	2.09E-01	pCi/g	Avg		
	SOU001-029	2.09E-01	pCi/g	Avg		
	SOU001-021	2.09E-01	pCi/g	Avg		
	SOU001-009	2.09E-01	pCi/g	Avg		
	SOU001-018	2.09E-01	pCi/g	Avg		
	SOU001-032	2.09E-01	pCi/g	Avg		
	SOU001-007	1.12E-01	pCi/g	Grid Value		
	SOU001-020	3.06E-01	pCi/g	Grid Value		
	SOU001-008	2.09E-01	pCi/g	Avg		
	SOU001-010	2.09E-01	pCi/g	Avg		
Uranium-238	SOU001-029	3.52E+00	pCi/g	Avg	3.92E+00	UCL95
	SOU001-007	1.73E+00	pCi/g	Grid Value		
	SOU001-008	3.52E+00	pCi/g	Avg		
	SOU001-030	3.52E+00	pCi/g	Avg		
	SOU001-032	3.52E+00	pCi/g	Avg		
	SOU001-021	3.52E+00	pCi/g	Avg		
	SOU001-020	5.31E+00	pCi/g	Grid Value		
	SOU001-019	3.52E+00	pCi/g	Avg		
	SOU001-018	3.52E+00	pCi/g	Avg		
	SOU001-010	3.52E+00	pCi/g	Avg		
	SOU001-009	3.52E+00	pCi/g	Avg		
	SOU001-031	3.52E+00	pCi/g	Avg		
EU 4						
Chromium	SOU001-036	1.61E+01	mg/kg	Grid Value	7.09E+01	UCL95
	SOU001-057	1.51E+01	mg/kg	Grid Value		
	SOU001-056	1.78E+01	mg/kg	Grid Value		
	SOU001-055	1.59E+01	mg/kg	Grid Value		
	SOU001-054	1.36E+01	mg/kg	Grid Value		
	SOU001-048	2.70E+01	mg/kg	Avg		
	SOU001-047	1.29E+01	mg/kg	Grid Value		
	SOU001-046	1.37E+02	mg/kg	Grid Value		
	SOU001-045	1.89E+01	mg/kg	Grid Value		
	SOU001-037	1.30E+01	mg/kg	Grid Value		
	SOU001-035	2.37E+01	mg/kg	Grid Value		
	SOU001-038	1.27E+01	mg/kg	Grid Value		

Table D.7. Subsurface Grid Values (Continued)

Chemical	Grid	Grid Value	Units	Grid Value Derived from	EPC	Calculate EPC from
Manganese	SOU001-047	3.26E+02	mg/kg	Grid Value	7.41E+02	UCL95
	SOU001-036	2.41E+02	mg/kg	Grid Value		
	SOU001-037	3.30E+02	mg/kg	Grid Value		
	SOU001-038	6.07E+02	mg/kg	Grid Value		
	SOU001-046	3.31E+02	mg/kg	Grid Value		
	SOU001-035	1.08E+03	mg/kg	Grid Value		
	SOU001-048	3.28E+02	mg/kg	Avg		
	SOU001-054	1.30E+02	mg/kg	Grid Value		
	SOU001-055	3.04E+00	mg/kg	Grid Value		
	SOU001-056	3.59E+02	mg/kg	Grid Value		
	SOU001-057	4.39E+00	mg/kg	Grid Value		
	SOU001-045	2.00E+02	mg/kg	Grid Value		
PCB, Total	SOU001-048	3.75E-02	mg/kg	Avg	9.24E-02	UCL95
	SOU001-036	1.70E-02	mg/kg	Grid Value		
	SOU001-057	1.30E-01	mg/kg	Grid Value		
	SOU001-056	1.70E-02	mg/kg	Grid Value		
	SOU001-055	1.30E-01	mg/kg	Grid Value		
	SOU001-054	1.70E-02	mg/kg	Grid Value		
	SOU001-046	1.70E-02	mg/kg	Grid Value		
	SOU001-045	1.70E-02	mg/kg	Grid Value		
	SOU001-037	1.70E-02	mg/kg	Grid Value		
	SOU001-035	1.70E-02	mg/kg	Grid Value		
	SOU001-047	1.70E-02	mg/kg	Grid Value		
	SOU001-038	1.70E-02	mg/kg	Grid Value		
Vanadium	SOU001-048	2.37E+01	mg/kg	Avg	2.87E+01	UCL95
	SOU001-035	4.02E+01	mg/kg	Grid Value		
	SOU001-036	2.56E+01	mg/kg	Grid Value		
	SOU001-037	1.99E+01	mg/kg	Grid Value		
	SOU001-038	1.87E+01	mg/kg	Grid Value		
	SOU001-045	2.51E+01	mg/kg	Grid Value		
	SOU001-047	2.09E+01	mg/kg	Grid Value		
	SOU001-054	2.04E+01	mg/kg	Grid Value		
	SOU001-055	3.36E+01	mg/kg	Grid Value		
	SOU001-056	3.16E+01	mg/kg	Grid Value		
	SOU001-057	2.53E-01	mg/kg	Grid Value		
	SOU001-046	2.39E+01	mg/kg	Grid Value		
Cesium-137	SOU001-047	3.37E-01	pCi/g	Avg	3.37E-01	UCL95
	SOU001-036	3.37E-01	pCi/g	Avg		
	SOU001-037	3.37E-01	pCi/g	Avg		
	SOU001-045	3.37E-01	pCi/g	Avg		
	SOU001-048	3.37E-01	pCi/g	Avg		
	SOU001-054	3.37E-01	pCi/g	Avg		
	SOU001-055	3.37E-01	pCi/g	Avg		
	SOU001-035	3.37E-01	pCi/g	Avg		
	SOU001-057	3.37E-01	pCi/g	Avg		
	SOU001-038	3.37E-01	pCi/g	Avg		
	SOU001-056	3.37E-01	pCi/g	Grid Value		
	SOU001-046	3.37E-01	pCi/g	Avg		

Table D.7. Subsurface Grid Values (Continued)

Chemical	Grid	Grid Value	Units	Grid Value Derived from	EPC	Calculate EPC from
EU 5						
Aluminum	SOU001-059	8.11E+03	mg/kg	Avg	1.20E+04	Maximum
	SOU001-058	1.20E+04	mg/kg	Grid Value		
	SOU001-041	8.58E+03	mg/kg	Grid Value		
	SOU001-051	4.29E+03	mg/kg	Grid Value		
	SOU001-042	8.38E+03	mg/kg	Grid Value		
	SOU001-040	6.15E+03	mg/kg	Grid Value		
	SOU001-039	9.40E+03	mg/kg	Grid Value		
	SOU001-049	8.69E+03	mg/kg	Grid Value		
	SOU001-050	7.40E+03	mg/kg	Grid Value		
Arsenic	SOU001-049	1.67E+01	mg/kg	Grid Value	1.67E+01	Maximum
	SOU001-058	8.30E+00	mg/kg	Grid Value		
	SOU001-050	3.53E+00	mg/kg	Grid Value		
	SOU001-059	7.15E+00	mg/kg	Avg		
	SOU001-042	6.05E+00	mg/kg	Grid Value		
	SOU001-041	4.48E+00	mg/kg	Grid Value		
	SOU001-040	5.00E+00	mg/kg	Grid Value		
	SOU001-039	1.00E+01	mg/kg	Grid Value		
	SOU001-051	3.17E+00	mg/kg	Grid Value		
Cobalt	SOU001-050	4.39E+00	mg/kg	Grid Value	1.43E+01	Maximum
	SOU001-059	6.81E+00	mg/kg	Avg		
	SOU001-058	1.01E+01	mg/kg	Grid Value		
	SOU001-051	3.40E+00	mg/kg	Grid Value		
	SOU001-049	1.43E+01	mg/kg	Grid Value		
	SOU001-042	6.06E+00	mg/kg	Grid Value		
	SOU001-041	4.42E+00	mg/kg	Grid Value		
	SOU001-039	7.80E+00	mg/kg	Grid Value		
	SOU001-040	4.04E+00	mg/kg	Grid Value		
Manganese	SOU001-059	7.38E+02	mg/kg	Avg	2.16E+03	Maximum
	SOU001-058	7.63E+02	mg/kg	Grid Value		
	SOU001-041	3.31E+02	mg/kg	Grid Value		
	SOU001-051	3.84E+02	mg/kg	Grid Value		
	SOU001-042	3.49E+02	mg/kg	Grid Value		
	SOU001-040	7.42E+02	mg/kg	Grid Value		
	SOU001-039	8.50E+02	mg/kg	Grid Value		
	SOU001-049	2.16E+03	mg/kg	Grid Value		
	SOU001-050	3.21E+02	mg/kg	Grid Value		
PCB, Total	SOU001-051	1.20E-01	mg/kg	Grid Value	2.70E-01	Maximum
	SOU001-058	2.70E-01	mg/kg	Grid Value		
	SOU001-050	1.70E-02	mg/kg	Grid Value		
	SOU001-049	1.70E-02	mg/kg	Grid Value		
	SOU001-042	1.70E-02	mg/kg	Grid Value		
	SOU001-041	1.70E-02	mg/kg	Grid Value		
	SOU001-040	1.70E-02	mg/kg	Grid Value		
	SOU001-039	1.70E-02	mg/kg	Grid Value		
	SOU001-059	1.20E-01	mg/kg	Grid Value		

Table D.7. Subsurface Grid Values (Continued)

Chemical	Grid	Grid Value	Units	Grid Value Derived from	EPC	Calculate EPC from
Total PAH	SOU001-039	2.60E-04	mg/kg	Grid Value	9.83E-02	Maximum
	SOU001-040	3.30E-01	mg/kg	Grid Value		
	SOU001-041	3.30E-01	mg/kg	Grid Value		
	SOU001-042	3.30E-01	mg/kg	Grid Value		
	SOU001-049	3.30E-01	mg/kg	Grid Value		
	SOU001-050	3.30E-01	mg/kg	Grid Value		
	SOU001-051	8.75E-02	mg/kg	Grid Value		
	SOU001-058	9.83E-02	mg/kg	Grid Value		
	SOU001-059	2.30E-01	mg/kg	Avg		

D.2.3.3 Evaluation of Modeled Concentrations for Groundwater

Groundwater modeling was evaluated in a similar manner as the process described above for surface/subsurface soil. SSLs are risk-based soil concentrations considered to be protective of groundwater (DOE 2016). These SSLs were derived as described in Section 4.4 of the main text and Appendix C. No analytes were retained as COPCs for modeling.

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D.3. EXPOSURE ASSESSMENT

This section describes the exposure assessment used to determine the pathways of exposure that were considered for the surface and subsurface soil at SWMU 1. Specifically, the exposure assessment process is delineated, the exposure settings of the Soils OU are described, the routes of exposure are outlined, and the daily intakes and doses are derived. The ultimate products presented in this section are the CSM for the Soils OU and the CDIs and ECs used when calculating ELCR and HI in Section D.5.

D.3.1 DESCRIPTION OF THE EXPOSURE ASSESSMENT PROCESS

Exposure is the contact of an organism with a chemical or physical agent. The magnitude of exposure (i.e., dose) is determined by measuring or estimating the amount of an agent available at exchange boundaries (e.g., gut, skin, etc.) during a specified period. Exposure assessment is a process that uses information about the exposure setting and human activities to develop CSMs under current and potential future conditions.

The first step in the exposure assessment is to characterize the exposure setting. This includes describing the activities of the human population (on or near a site) that may affect the extent of exposure and the physical characteristics of the site. During this process, sensitive subpopulations that may be present at the site or that may be exposed to contamination migrating from the site also are considered. Generally, site characterization results in a qualitative evaluation of the site and the surrounding population.

The second step in the exposure assessment is to identify exposure pathways. Exposure pathways describe the path a contaminant travels from its source to an individual. A complete exposure pathway includes all links between the source and the exposed population; therefore, a complete pathway consists of a source of release, a mechanism of release, a transport medium, a point of potential human contact, and an exposure route.

The third step in the exposure assessment is to calculate dose by quantifying the magnitude, frequency, and duration of exposure for the populations for the exposure pathways selected for quantitative evaluation. This step involves using the EPCs developed for each COPC to quantify the pathway-specific CDIs and ECs for that COPC.

D.3.2 CHARACTERIZATION OF THE EXPOSURE SETTING

The first step in evaluating exposure is to characterize surface features, meteorology, geology, demography and land use, ecology, hydrology, and hydrogeology of the area inhabited by potential receptors. These aspects are discussed in Chapter 3 of this report. A physical description of SWMU 1 is summarized within this exposure assessment to support later discussions of the conceptual model and its uncertainties.

The C-747-C Oil Landfarm (SWMU 1) is located in the extreme west-central portion of the plant. SWMU 1 was used from 1975 to 1979 for the biodegradation of waste oils contaminated with TCE, PCBs, 1,1,1-trichloroethane, and uranium. It is estimated that approximately 5,000 gal of waste oil were applied to the landfarm during its period of operation (DOE 1999a). These waste oils were believed to have been derived from a variety of plant processes. The landfarm consisted of two 1,125 ft^2 plots that were plowed to 1 ft to 2 ft depth. Waste oils were spread on the surface every 3 to 4 months, then limed and fertilized.

The area now is mowed regularly as part of PGDP maintenance operations.

D.3.3 DEMOGRAPHY AND LAND USE

The land use for SWMU 1 is industrial. Under current use, because of access restrictions, only plant workers and authorized visitors are allowed access to the areas located inside the limited area. As discussed in the PGDP Site Management Plan (DOE 2015), foreseeable future land use of PGDP industrial area is expected to be industrial. The land use of the surrounding West Kentucky Wildlife Management Area (WKWMA) also is not expected to change; it will remain recreational and available to the outdoor worker.

At present, both recreational and residential land uses occur in areas surrounding PGDP. Recreational use occurs in WKWMA. WKWMA is used primarily for hunting and fishing, but other activities include horseback riding, field trials, hiking, and bird watching. An estimated 7,500 fishermen visit the area annually, according to the Kentucky Department of Fish and Wildlife Resources manager of the WKWMA (DOE 2016). Residential use near the plant and in areas to which the groundwater from the PGDP may migrate is rural residential and includes agricultural activities. Response actions have eliminated exposure of these rural residents to contaminated groundwater. More urban residential use occurs in the villages of Heath and Grahamville to the east and Kevil to the southwest, which are within 3 miles of DOE property boundaries, but outside of the area that may be impacted by the Soils OU. The population of McCracken County, Kentucky is approximately 65,000 (DOC 2016). The major city in McCracken County is Paducah, Kentucky, whose population is approximately 25,000 (DOC 2016). The closest commercial airport is Barkley Regional Airport, approximately 5 miles to the southeast. The population within a 50-mile radius of the Paducah Site is about 534,000 according to the 2010 census.

D.3.4 IDENTIFICATION OF EXPOSURE PATHWAYS

The general principles of the exposure assessment, as addressed in the Risk Methods Document (DOE 2016), provide the basis for the evaluations provided in this assessment. This subsection describes the potential exposure scenarios and receptors. Only the receptors potentially exposed to each media and location were evaluated. The exposure scenarios evaluated represent potential future scenarios, because most of the exposure assumptions are based on conservative input factors for the administered or absorbed dose estimations. Thus, most, if not all, exposure scenarios represent future hypothetical exposure assumptions, because current exposures are minimal or are not occurring at the site. As a result, the exposure assumptions either are the available default values or are conservatively selected based on assumed receptor behavior.

The current on-site land use is industrial, and this can be expected to continue in the foreseeable future; however, the expected exposure frequencies and durations may be higher in the future than duration and frequency of the current exposure. Additionally, use of groundwater drawn from the RGA at SWMU 1 is not expected; however, uses of areas surrounding PGDP indicate that it would be prudent to examine a range of land uses to provide decision makers with estimates of the risk that may be posed to humans under alternate uses. To provide consideration of a range of land uses, the BHHRA reports the hazards and risks for current and several hypothetical future uses, consistent with regulatory guidance.

The exposure scenarios and receptors evaluated in this BHHRA are pertinent to the activities conducted at the Soils OU. Default land use scenarios (e.g., current and future industrial and hypothetical future residential) and additional scenarios (e.g., recreational, excavation, and outdoor worker) were evaluated for each of the EUs.

A future on-site rural resident is not a likely land use scenario because land use controls are in place that prevent residential exposure at the site. More likely future on-site scenarios may include recreational uses (hunting), considering the WKWMA is adjacent to a buffer area that surrounds the industrial areas of the site. Further, although unauthorized access to the area (trespassing) is unlikely under current conditions, evaluation of this scenario could be represented under the assessment of the recreational user. Current and future industrial worker, outdoor worker, and excavation worker all are considered in this assessment.

As discussed in the Risk Methods Document (DOE 2016), risks from water drawn from the UCRS will not be presented in the main body of the risk assessment.

The exposure factors primarily are based on a reasonable maximum exposure (RME) assumption. The intent of the RME assumption is to estimate the highest exposure level that reasonably could be expected to occur (EPA 1989; EPA 1991). The RME assumptions were developed by EPA to represent an upper-bound estimate for the plausible exposures. In keeping with the EPA guidance (EPA 1991), the variables chosen for a baseline RME scenario for the intake rate, exposure frequency (EF), and exposure duration (ED) are generally upper-bounds. Other variables, such as body weight (BW) and exposed skin surface area are generally central tendency or average values. The conservatism built into the individual variables ensures that the entire estimate for the contact rate is more than sufficiently conservative.

The scenarios described in the following subsections assume that 100% of a receptor’s time is spent in contact with the contaminated medium at the site. For all sites, a worker is assumed to spend all of a workday in the area, which is a conservative estimate for the intake from a given site.

The averaging time (AT) for noncancer evaluation is computed as the product of ED (years) multiplied by 365 days per year, to estimate an average daily dose over the entire exposure period (EPA 1989). For the cancer evaluation, AT is computed as the product of 70 years, the assumed human lifetime, multiplied by 365 days per 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 a short-term exposure to a high dose of a given carcinogen is equivalent to a long-term exposure to a correspondingly lower dose, provided that the total lifetime doses are equivalent. For example, the current and future exposure scenarios represent exposures mostly under future hypothetical scenarios, because exposed soils are limited at most of these sites and a maintenance worker or a recreational visitor would not spend the amount of time assumed in the exposure assumptions. The more conservative exposure assumptions used are for conservatism in the potential exposure evaluations during site management. Thus, the estimated intake or exposure doses apply mostly to the future hypothetical exposure scenarios. The scenarios are discussed in the following text.

D.3.4.1 Potential Receptor Populations

The receptors and exposure factors are summarized in Table D.8, with an overview presented following. Exposure factors were taken from the most recent Risk Methods Document (DOE 2016).

Chemical-specific values are listed in Attachment D3. The dermal absorption (ABS) factors used are from the EPA values presented in the 2016 Risk Methods Document. Because these factors apply only to COPCs evaluated for dermal toxicity, these ABS factors are presented in Attachment D4 along with the dermal toxicity values.

Current On-site and Off-site Industrial Workers. The current on-site industrial worker exposure scenario was evaluated for direct contact to surface soils (0–1 ft). The current worker differs from the future industrial worker only by a lower EF equivalent to the current maintenance schedule for these areas [14 days for current on-site industrial worker (such as maintenance worker) versus 250 days for future industrial

Table D.8. Exposure Factors Used for Intake Calculations in BHHRA[a]

Pathway Variable	Units	Current Industrial Worker[b]	Future Industrial Worker	Outdoor Worker	Excavation Worker	Adult Resident	Child Resident	Adult Recreational User	Teen Recreational User	Child Recreational User
EF	days/year	14	250	185	185	350	350	104	140	140
ED	years	25	25	25	5	20	6	10	10	6
BW	kg	80	80	80	80	80	15	80	44	15
AT—cancer	days	70 × 365	70 × 365	70 × 365	70 × 365	70 × 365	70 × 365	70 × 365	70 × 365	70 × 365
AT—noncancer	days	365 × 25	365 × 25	365 × 25	365 × 5	365 × 20	365 × 6	365 × 10	365 × 10	365 × 6
Incidental Ingestion of Soil/Sediment										
Incidental ingestion rate	mg/day	50	50	480	480	100	200	100	100	200
Fraction ingested		1	1	1	1	1	1	1	1	1
Dermal Contact with Soil/Sediment										
Body surface area exposed	m^2/day	0.3527	0.3527	0.3527	0.3527	0.6032	0.2373	0.6032	0.75	0.2373
Soil-to-skin adherence factor	mg/cm^2–day	1	1	1	1	1	1	1	1	1
Inhalation of Vapors and Particulates Emitted from Soil/Sediment										
Total inhalation rate	m^3/hour	2.5	2.5	2.5	2.5	0.833	0.833	2.5	2.5	2.5
Exposure time	hours/day	8	8	8	8	24	24	5	5	5
Particulate emission factor	m^3/kg	6.20E+08	6.20E+08	6.20E+08	6.20E+08	9.30E+08	9.30E+08	9.30E+08	9.30E+08	9.30E+08
External Exposure to Ionizing Radiation from Soil/Sediment										
EF	day/day	14/365	250/365	185/365	185/365	350/365	350/365	104/365	140/365	140/365
Gamma shielding factor	unitless	0.2	0.2	0.2	0.2	0.2	0.2	0	0	0
Gamma exposure time factor	hr/hr	8/24	8/24	8/24	8/24	18/24	18/24	5/24	5/24	5/24

Notes:
[a] Information taken from DOE 2016.
[b] Best professional judgements similar to value used for DOE 2008.
N/A = Not available or not applicable

worker default scenario]. For workers outside the limited area, the workers also are assumed to have direct contact with surface soils (0–1 ft) under current conditions. This limited frequency reflects the size (roughly 0.5 acre or less for each EU) and limited activities at SWMU 1.

Future Industrial Workers. The future industrial worker exposure scenario 0–1 ft was evaluated using standard default assumptions as outlined in the Risk Methods Document (DOE 2016) (e.g., 80-kg adult who works 8 hours per day, approximately 5 days per week, year-round on-site, for a total of 250 days per year for 25 years). No ingestion of or contact with groundwater was assumed for the future industrial worker (only for the resident). Because no building currently exists at the site, potential volatile organic compound (VOC) emission from subsurface soils was assumed to be an incomplete exposure pathway, and inhalation of vapors was not quantified. Inhalation of vapors migrating from the contaminated groundwater that underlies SWMU 1, however, could be a medium of concern under the future industrial worker scenario (new building construction): these risks for the future industrial worker receptor population were not quantified as part of risk characterization.

Future Recreational Users. Per the Risk Methods Document (DOE 2016), recreational uses (child, teen, adult) are focused primarily on sediments, where areas are more attractive for wading. Rates of contact for the recreational user were selected assuming that the individual would be a local resident. However, a plausible future use on-site and off-site is for recreational use, specifically hunting (deer, rabbits, quail). Hunters are assumed primarily to be teens and adults, and direct contact to soils for these receptors is assumed to be limited because repeated contact with contaminated media at sites less than 0.5 acre would be unlikely for hunting activities [e.g., the ranges of deer, rabbit, and quail (in Tables D.14, D.15, and D.16, respectively), of the 2016 Risk Methods Document are 494 acres, 3.6 acres, and 15.4 acres, respectively]. This pathway was evaluated as a basis for SWMU-specific decisions in this assessment and is consistent with planning and scoping for the OU. Consumption of wild game was not included in this evaluation.

Future Hypothetical Resident. The future residential scenario is evaluated using both an adult and a child potentially exposed to site surface soils for SWMU 1, which is within the limited area. Although this land use is unlikely, this evaluation provides information on potential for adverse impacts if no land use restrictions were in place. Future residents are assumed to be exposed to RGA groundwater for SWMU 1 where potential impacts to groundwater are identified from the soils. Appendix C describes the groundwater modeling. VOCs in soils are addressed in a previous record of decision and are not characterized in this BHHRA (DOE 2012). Because no building currently exists at the site, potential VOC emission from subsurface soils was assumed to be an incomplete exposure pathway, and inhalation of vapors was not quantified. Inhalation of vapors migrating from the contaminated groundwater that underlies SWMU 1, however, could be a medium of concern under the future hypothetical resident scenario (new building construction): these risks for the future hypothetical resident receptor population were not quantified as part of risk characterization.

Future Outdoor Worker and Excavation Worker. For evaluation of potential future direct contact issues with subsurface soil, two scenarios were considered: excavation worker and outdoor worker. Each assumes contact with both surface and subsurface soils, but differ in that the excavation addresses contact during the excavation/construction process, so for each SWMU 1 EU, ED was limited to 5 years. Additional detail is provided below. For the outdoor worker, it is assumed that surface and subsurface soils are mixed (brought to the surface) where EDs may be extended.

According to the Risk Methods Document (DOE 2016), 185 days per year and 25 years are recommended for the EF and the ED, respectively, for the outdoor worker. However, the Risk Methods Document provides flexibility in this assumption when applying to an excavation worker. According to the Risk Methods Document (DOE 2016), "…the exposure duration of 25 years for the outdoor worker may be replaced with a shorter duration of 1 to 5 years that is more likely to reflect the potential exposures at the site. The shorter exposure duration and possibly a revised exposure frequency combined with the other default parameters for the outdoor worker scenario also may be used to produce an excavation worker scenario." When used for the excavation worker scenario, the ED has been reduced to 5 years (DOE 2016). Further, from a practical standpoint, defaulting to outdoor worker exposure assumptions for an excavation scenario will exceed the reasonable assumptions for SWMU 1 because the excavation scenario typically represents a soil removal action associated with construction of a foundation or excavation of contaminated soil. For nearly all waste sites or foundation construction sites, this is a one-time event of short duration.

Inhalation of vapors migrating from the contaminated groundwater that underlies SWMU 1, could be a medium of concern under the excavation worker scenario should trenching be conducted at the SWMU. These risks for the excavation worker were not quantified as part of risk characterization.

D.3.4.2 Delineation of Exposure Point/Exposure Routes

As discussed, human health risks are assessed by determining points of exposure (POEs) and exposure routes. POEs are locations where human receptors can contact contaminated media. Exposure routes are the processes by which human receptors contact contaminated media. The exposure routes considered during the exposure assessment for all BHHRAs per the Risk Methods Document (DOE 2016) are listed in the following paragraphs. This material also presents reasons for selecting or not selecting each exposure route for each of the potentially exposed populations in this BHHRA. The exposure routes evaluated and those that were assessed quantitatively in this BHHRA are described below.

Surface Water. SWMU 1 is located near a drainageway; however, significant surface water contamination is not expected as a result of this SWMU (UK 2007). Further, due to the physical cover at SWMU 1 that limits the potential for particulate transport through sheet flow and based upon the modeling performed as part of the SI report for the outfalls and their associated internal ditches, no contaminants are migrating in surface water (dissolved or through sediment) from ditches to surrounding creeks at concentrations that may impact human health adversely (DOE 2008). As a result, human health risks associated with exposure to surface water were not assessed in this BHHRA.

Groundwater. Residential and industrial use of RGA groundwater is common in western Kentucky. There is no current complete pathway for domestic use of RGA groundwater downgradient of the facility; however, a conservative assumption for evaluating impacts to the RGA is based on hypothetical future use of RGA groundwater by a resident. This SWMU was not identified with soil concentrations that could yield potentially unacceptable concentrations in groundwater associated with migration from the areas, and therefore was not modelled. Evaluation of exposure to groundwater was limited to contaminants in soil (0–16 ft bgs) at SWMU 1 that might contribute to groundwater contamination. Actual groundwater sampling data from contaminant plume underlying the SWMU was not considered in this evaluation.

For domestic use of groundwater by a hypothetical future resident, the following routes of exposure are evaluated:

- Groundwater ingestion (potable use of RGA groundwater),
- Inhalation of volatile constituents emitted while using groundwater (all household uses), and
- Dermal contact with groundwater while showering.

Vapor Intrusion. Transport of vapors in subsurface soils and shallow groundwater into buildings is considered a potential future exposure pathway (EPA 2015b). The POE—location where this is complete—is focused at the source areas where volatile compounds were released. These are the primary locations where VOCs may be in the soils or upper groundwater layer where a building may be constructed in the future. Although future residential use is not considered likely, this exposure route was considered in the exposure assessment for this BHHRA for the residential scenario, but not quantified, given the scope of the project. No additional contribution via inhalation of vapors that may be transported into basements is expected. Inhalation of vapors that originated from underlying groundwater contaminants might be transported into basements. Vapor intrusion from underlying groundwater contamination is not quantified as part of the risk characterization in this BHHRA.

Soil. A primary consideration for risks associated with contamination in soils is direct contact with these at SWMU 1; therefore, these are the POEs either under current conditions where exposure may be to contaminants in the 0–1 ft depth or possible future contact with contaminants in the subsurface. To estimate risks for the receptors described in the previous section, the following routes of exposure are quantified:

- Incidental ingestion of contaminated soil,
- Dermal contact with contaminated soil,
- Inhalation of particulates emitted from contaminated soil,
- Inhalation of volatile constituents emitted from contaminated soil, and
- External exposure to ionizing radiation emitted from contaminated soil.

D.3.5 QUANTIFICATION OF EXPOSURE

D.3.5.1 Calculation of EPCs of COPCs

The EPCs were determined as described in Section D.2.3.2.

Soil—Direct Contact Exposure. In determining the EPC for soil, the data are segregated into depth intervals relevant to receptors. For all scenarios, except the excavation worker and the outdoor worker (exposed to surface and subsurface soil), data from samples collected from 0–1 ft bgs are used to estimate the EPC. For the excavation worker and the outdoor worker (exposed to surface and subsurface soil), data collected from 0–16 ft bgs are used to estimate the EPC.

Groundwater—Residential Use. No groundwater COPCs were identified.

D.3.5.2 Chronic Daily Intakes

The EPC for each COPC was used to calculate potential chemical intakes. The equations to be used to combine the EPCs and exposure factors to estimate chemical intake followed the general format presented in RAGS, Part A (EPA 1989) as follows:

$$\text{Chemical Intake}[\text{mg/(kg} \times \text{day}] = \frac{C_s \times CF \times EF \times FI \times ED \times IR}{BW \times AT}$$

Where:

Chemical Intake = the dose
C_s = average concentration contacted over the exposure period
CF = contact rate or amount of contaminated medium contacted per unit time or event
EF = exposure frequency
FI = frequency of ingestion
ED = exposure duration
IR = ingestion rate

BW = average body weight of the receptor over the term of exposure
AT = averaging time or period over which exposure is averaged

and

$$\text{Radionuclide Intake (pCi)} = A_s \times CF_{rad} \times EF \times FI \times ED \times IR$$

Where:

Radionuclide Intake = the dose
A_s = average activity contacted over the exposure period
CF_{rad} = conversion factor
EF = exposure frequency
FI = fraction ingested
ED = exposure duration
IR = ingestion rate
EC = exposure concentration

Calculation of intake, both noncancerous and cancerous, is presented in Tables D.9 through D.25.

Table D.9. Noncancerous CDIs for the Current Industrial Worker Exposed to Surface Soil[a]

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation
1	Chromium	mg/kg	2.04E+01	4.89E-07		4.21E-07
2	Chromium	mg/kg	3.82E+01	9.15E-07		7.87E-07
3	Chromium	mg/kg	1.78E+01	4.26E-07		3.66E-07
4	Chromium	mg/kg	8.15E+01	1.95E-06		1.68E-06
5	No COPCs					

[a]See the Risk Methods Document for additional information (DOE 2016).

Table D.10. Cancerous CDIs for the Current Industrial Worker Exposed to Surface Soil[a]

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation	External Exposure
1	Chromium	mg/kg	2.04E+01	1.75E-07		1.50E-07	
1	Cesium-137	pCi/g	6.12E-01	8.15E+00		2.10E-03	1.19E-01
1	Neptunium-237	pCi/g	5.91E-01	1.03E+01		2.67E-03	1.51E-01
1	Plutonium-239/240	pCi/g	8.44E+00	1.48E+02		3.81E-02	2.16E+00
1	Thorium-230	pCi/g	3.89E+01	6.81E+02		1.76E-01	9.96E+00
1	Uranium-238	pCi/g	2.04E+00	3.57E+01		9.22E-03	5.22E-01
2	Chromium	mg/kg	3.82E+01	3.27E-07		2.81E-07	
2	PCB, Total	mg/kg	1.19E+01	1.02E-07	1.01E-06	6.94E-05	
2	Uranium-234	pCi/g	9.01E+00	1.58E+02		4.07E-02	2.30E+00
2	Uranium-235	pCi/g	5.11E-01	8.94E+00		2.31E-03	1.31E-01
2	Uranium-238	pCi/g	9.86E+00	1.73E+02		4.45E-02	2.52E+00
3	Chromium	mg/kg	1.78E+01	1.52E-07		1.31E-07	
3	PCB, Total	mg/kg	9.29E+00	7.95E-08	7.85E-07	5.41E-05	
3	Total PAH	mg/kg	4.14E-01	3.54E-09	3.25E-08	3.05E-09	
3	Uranium-238	pCi/g	3.92E+00	6.85E+01		1.77E-02	1.00E+00
4	Chromium	mg/kg	8.15E+01	6.98E-07		6.00E-07	
4	PCB, Total	mg/kg	6.44E+00	5.51E-08	5.44E-07	3.75E-05	
5	PCB, Total	mg/kg	2.70E-01	2.31E-09	2.28E-08	1.57E-06	
5	Total PAH	mg/kg	9.83E-02	8.42E-10	7.72E-09	7.24E-10	

[a] See Risk Methods Document for additional information (DOE 2016).

Table D.11. Noncancerous CDIs for the Future Industrial Worker Exposed to Surface Soil[a]

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation
1	Chromium	mg/kg	2.04E+01	8.74E-06		7.52E-06
2	Chromium	mg/kg	3.82E+01	1.63E-05		1.41E-05
3	Chromium	mg/kg	1.78E+01	7.61E-06		6.54E-06
4	Chromium	mg/kg	8.15E+01	3.49E-05		3.00E-05
5	No COPCs					

[a] See Risk Methods Document for additional information (DOE 2016).

Table D.12. Cancerous CDIs for the Future Industrial Worker Exposed to Surface Soil[a]

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation	External Exposure
1	Chromium	mg/kg	2.04E+01	3.12E-06		2.68E-06	
1	Cesium-137	pCi/g	6.12E-01	1.45E+02		3.75E-02	2.13E+00
1	Neptunium-237	pCi/g	5.91E-01	1.85E+02		4.77E-02	2.70E+00
1	Plutonium-239/240	pCi/g	8.44E+00	2.64E+03		6.80E-01	3.85E+01
1	Thorium-230	pCi/g	3.89E+01	1.22E+04		3.14E+00	1.78E+02
1	Uranium-238	pCi/g	2.04E+00	6.38E+02		1.65E-01	9.32E+00
2	Chromium	mg/kg	3.82E+01	5.83E-06		5.02E-06	
2	PCB, Total	mg/kg	1.19E+01	1.82E-06	1.80E-05	1.24E-03	
2	Uranium-234	pCi/g	9.01E+00	2.82E+03		7.27E-01	4.11E+01
2	Uranium-235	pCi/g	5.11E-01	1.60E+02		4.12E-02	2.33E+00
2	Uranium-238	pCi/g	9.86E+00	3.08E+03		7.95E-01	4.50E+01
3	Chromium	mg/kg	1.78E+01	2.72E-06		2.34E-06	
3	PCB, Total	mg/kg	9.29E+00	1.42E-06	1.40E-05	9.66E-04	
3	Total PAH	mg/kg	4.14E-01	6.33E-08	5.80E-07	5.44E-08	
3	Uranium-238	pCi/g	3.92E+00	1.22E+03		3.16E-01	1.79E+01
4	Chromium	mg/kg	8.15E+01	1.25E-05		1.07E-05	
4	PCB, Total	mg/kg	6.44E+00	9.84E-07	9.72E-06	6.69E-04	
5	PCB, Total	mg/kg	2.70E-01	4.13E-08	4.08E-07	2.81E-05	
5	Total PAH	mg/kg	9.83E-02	1.50E-08	1.38E-07	1.29E-08	

[a] See Risk Methods Document for additional information (DOE 2016).

Table D.13. Noncancerous CDIs for the Outdoor Worker Exposed to Surface Soil[a]

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation
1	Chromium	mg/kg	2.04E+01	6.21E-05		5.56E-06
2	Chromium	mg/kg	3.82E+01	1.16E-04		1.04E-05
3	Chromium	mg/kg	1.78E+01	5.40E-05		4.84E-06
4	Chromium	mg/kg	8.15E+01	2.48E-04		2.22E-05
5	No COPCs					

[a] See Risk Methods Document for additional information (DOE 2016).

Table D.14. Cancerous CDIs for the Outdoor Worker Exposed to Surface Soil[a]

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation	External Exposure
1	Chromium	mg/kg	2.04E+01	2.22E-05		1.99E-06	
1	Cesium-137	pCi/g	6.12E-01	1.03E+03		2.78E-02	1.57E+00
1	Neptunium-237	pCi/g	5.91E-01	1.31E+03		3.53E-02	2.00E+00
1	Plutonium-239/240	pCi/g	8.44E+00	1.87E+04		5.03E-01	2.85E+01
1	Thorium-230	pCi/g	3.89E+01	8.64E+04		2.32E+00	1.32E+02
1	Uranium-238	pCi/g	2.04E+00	4.53E+03		1.22E-01	6.90E+00
2	Chromium	mg/kg	3.82E+01	4.14E-05		3.71E-06	
2	PCB, Total	mg/kg	1.19E+01	1.29E-05	1.33E-05	9.17E-04	
2	Uranium-234	pCi/g	9.01E+00	2.00E+04		5.38E-01	3.04E+01
2	Uranium-235	pCi/g	5.11E-01	1.13E+03		3.05E-02	1.73E+00
2	Uranium-238	pCi/g	9.86E+00	2.19E+04		5.88E-01	3.33E+01
3	Chromium	mg/kg	1.78E+01	1.93E-05		1.73E-06	
3	PCB, Total	mg/kg	9.29E+00	1.01E-05	1.04E-05	7.15E-04	
3	Total PAH	mg/kg	4.14E-01	4.50E-07	4.30E-07	4.03E-08	
3	Uranium-238	pCi/g	3.92E+00	8.69E+03		2.34E-01	1.32E+01
4	Chromium	mg/kg	8.15E+01	8.85E-05		7.93E-06	
4	PCB, Total	mg/kg	6.44E+00	6.99E-06	7.19E-06	4.95E-04	
5	PCB, Total	mg/kg	2.70E-01	2.93E-07	3.02E-07	2.08E-05	
5	Total PAH	mg/kg	9.83E-02	1.07E-07	1.02E-07	9.57E-09	

[a] See Risk Methods Document for additional information (DOE 2016).

Table D.15. Noncancerous CDIs for the Outdoor Worker Exposed to Surface and Subsurface Soil[a]

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation
1	Aluminum	mg/kg	1.05E+04	3.18E-02		2.85E-03
1	Antimony	mg/kg	2.31E+00	7.03E-06		6.30E-07
1	Arsenic	mg/kg	7.43E+00	2.26E-05	4.98E-06	2.03E-06
1	Chromium	mg/kg	2.64E+01	8.03E-05		7.19E-06
1	Cobalt	mg/kg	1.04E+01	3.16E-05		2.83E-06
1	Manganese	mg/kg	1.01E+03	3.08E-03		2.76E-04
1	Thallium	mg/kg	8.68E-01	2.64E-06		2.37E-07
1	Vanadium	mg/kg	3.33E+01	1.01E-04		9.07E-06
2	Arsenic	mg/kg	7.76E+00	2.36E-05	5.20E-06	2.11E-06
2	Chromium	mg/kg	3.87E+01	1.18E-04		1.06E-05
2	Manganese	mg/kg	6.98E+02	2.12E-03		1.90E-04
2	Silver	mg/kg	6.87E+01	2.09E-04		1.87E-05
3	Arsenic	mg/kg	6.89E+00	2.09E-05	4.62E-06	1.88E-06
3	Chromium	mg/kg	4.58E+01	1.39E-04		1.25E-05
3	Manganese	mg/kg	6.01E+02	1.83E-03		1.64E-04
4	Chromium	mg/kg	7.09E+01	2.16E-04		1.93E-05
4	Manganese	mg/kg	7.41E+02	2.25E-03		2.02E-04
4	Vanadium	mg/kg	2.87E+01	8.73E-05		7.82E-06
5	Aluminum	mg/kg	1.20E+04	3.65E-02		3.27E-03
5	Arsenic	mg/kg	1.67E+01	5.08E-05	1.12E-05	4.55E-06
5	Cobalt	mg/kg	1.43E+01	4.35E-05		3.90E-06
5	Manganese	mg/kg	2.16E+03	6.57E-03		5.89E-04

[a] See Risk Methods Document for additional information (DOE 2016).

Table D.16. Cancerous CDIs for the Outdoor Worker Exposed to Surface and Subsurface Soil[a]

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation	External Exposure
1	Arsenic	mg/kg	7.43E+00	8.07E-06	1.78E-06	7.23E-07	
1	Chromium	mg/kg	2.64E+01	2.87E-05		2.57E-06	
1	Cobalt	mg/kg	1.04E+01	1.13E-05		1.01E-06	
1	Total PAH	mg/kg	4.53E-01	4.92E-07	4.70E-07	4.41E-08	
1	Cesium-137	pCi/g	8.74E-01	1.48E+03		3.97E-02	2.25E+00
1	Neptunium-237	pCi/g	5.72E-01	1.27E+03		3.41E-02	1.93E+00
1	Plutonium-239/240	pCi/g	8.19E+00	1.82E+04		4.89E-01	2.77E+01
1	Thorium-230	pCi/g	3.58E+01	7.94E+04		2.14E+00	1.21E+02
1	Uranium-238	pCi/g	2.57E+00	5.70E+03		1.53E-01	8.67E+00
2	Arsenic	mg/kg	7.76E+00	8.42E-06	1.86E-06	7.55E-07	
2	Chromium	mg/kg	3.87E+01	4.21E-05		3.77E-06	
2	PCB, Total	mg/kg	8.68E+00	9.42E-06	9.69E-06	6.68E-04	
2	Total PAH	mg/kg	1.22E+00	1.33E-06	1.27E-06	1.19E-07	
2	Uranium-234	pCi/g	6.16E+00	1.37E+04		3.68E-01	2.08E+01
2	Uranium-235	pCi/g	3.40E-01	7.55E+02		2.03E-02	1.15E+00
2	Uranium-238	pCi/g	6.72E+00	1.49E+04		4.01E-01	2.27E+01
3	Arsenic	mg/kg	6.89E+00	7.48E-06	1.65E-06	6.70E-07	
3	Chromium	mg/kg	4.58E+01	4.98E-05		4.46E-06	
3	PCB, Total	mg/kg	4.60E+00	5.00E-06	5.14E-06	3.54E-04	
3	Total PAH	mg/kg	4.07E-01	4.42E-07	4.22E-07	3.96E-08	
3	Cesium-137	pCi/g	2.30E-01	3.88E+02		1.04E-02	5.91E-01
3	Uranium-238	pCi/g	3.92E+00	8.69E+03		2.34E-01	1.32E+01
4	Chromium	mg/kg	7.09E+01	7.70E-05		6.90E-06	
4	PCB, Total	mg/kg	9.24E-02	1.00E-07	1.03E-07	7.11E-06	
4	Cesium-137	pCi/g	3.37E-01	5.69E+02		1.53E-02	8.66E-01
5	Arsenic	mg/kg	1.67E+01	1.81E-05	4.00E-06	1.63E-06	
5	Cobalt	mg/kg	1.43E+01	1.55E-05		1.39E-06	
5	PCB, Total	mg/kg	2.70E-01	2.93E-07	3.02E-07	2.08E-05	
5	Total PAH	mg/kg	9.83E-02	1.07E-07	1.02E-07	9.57E-09	

[a] See Risk Methods Document for additional information (DOE 2016).

Table D.17. Noncancerous CDIs for the Excavation Worker Exposed to Surface and Subsurface Soil[a]

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation
1	Aluminum	mg/kg	1.05E+04	3.18E-02		2.85E-03
1	Antimony	mg/kg	2.31E+00	7.03E-06		6.30E-07
1	Arsenic	mg/kg	7.43E+00	2.26E-05	4.98E-06	2.03E-06
1	Chromium	mg/kg	2.64E+01	8.03E-05		7.19E-06
1	Cobalt	mg/kg	1.04E+01	3.16E-05		2.83E-06
1	Manganese	mg/kg	1.01E+03	3.08E-03		2.76E-04
1	Thallium	mg/kg	8.68E-01	2.64E-06		2.37E-07
1	Vanadium	mg/kg	3.33E+01	1.01E-04		9.07E-06
2	Arsenic	mg/kg	7.76E+00	2.36E-05	5.20E-06	2.11E-06
2	Chromium	mg/kg	3.87E+01	1.18E-04		1.06E-05
2	Manganese	mg/kg	6.98E+02	2.12E-03		1.90E-04
2	Silver	mg/kg	6.87E+01	2.09E-04		1.87E-05

Table D.17. Noncancerous CDIs for the Excavation Worker Exposed to Surface and Subsurface Soil (Continued)

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation
3	Arsenic	mg/kg	6.89E+00	2.09E-05	4.62E-06	1.88E-06
3	Chromium	mg/kg	4.58E+01	1.39E-04		1.25E-05
3	Manganese	mg/kg	6.01E+02	1.83E-03		1.64E-04
4	Chromium	mg/kg	7.09E+01	2.16E-04		1.93E-05
4	Manganese	mg/kg	7.41E+02	2.25E-03		2.02E-04
4	Vanadium	mg/kg	2.87E+01	8.73E-05		7.82E-06
5	Aluminum	mg/kg	1.20E+04	3.65E-02		3.27E-03
5	Arsenic	mg/kg	1.67E+01	5.08E-05	1.12E-05	4.55E-06
5	Cobalt	mg/kg	1.43E+01	4.35E-05		3.90E-06
5	Manganese	mg/kg	2.16E+03	6.57E-03		5.89E-04

[a] See Risk Methods Document for additional information (DOE 2016).

Table D.18. Cancerous CDIs for the Excavation Worker Exposed to Surface and Subsurface Soil[a]

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation	External Exposure
1	Arsenic	mg/kg	7.43E+00	1.61E-06	3.56E-07	1.45E-07	
1	Chromium	mg/kg	2.64E+01	5.73E-06		5.14E-07	
1	Cobalt	mg/kg	1.04E+01	2.25E-06		2.02E-07	
1	Total PAH	mg/kg	4.53E-01	9.84E-08	9.40E-08	8.82E-09	
1	Cesium-137	pCi/g	8.74E-01	3.67E+02		9.85E-03	5.58E-01
1	Neptunium-237	pCi/g	5.72E-01	2.54E+02		6.83E-03	3.87E-01
1	Plutonium-239/240	pCi/g	8.19E+00	3.64E+03		9.78E-02	5.54E+00
1	Thorium-230	pCi/g	3.58E+01	1.59E+04		4.27E-01	2.42E+01
1	Uranium-238	pCi/g	2.57E+00	1.14E+03		3.06E-02	1.73E+00
2	Arsenic	mg/kg	7.76E+00	1.68E-06	3.71E-07	1.51E-07	
2	Chromium	mg/kg	3.87E+01	8.42E-06		7.54E-07	
2	PCB, Total	mg/kg	8.68E+00	1.88E-06	1.94E-06	1.34E-04	
2	Total PAH	mg/kg	1.22E+00	2.66E-07	2.54E-07	2.38E-08	
2	Uranium-234	pCi/g	6.16E+00	2.73E+03		7.35E-02	4.16E+00
2	Uranium-235	pCi/g	3.40E-01	1.51E+02		4.06E-03	2.30E-01
2	Uranium-238	pCi/g	6.72E+00	2.98E+03		8.02E-02	4.54E+00
3	Arsenic	mg/kg	6.89E+00	1.50E-06	3.30E-07	1.34E-07	
3	Chromium	mg/kg	4.58E+01	9.95E-06		8.92E-07	
3	PCB, Total	mg/kg	4.60E+00	1.00E-06	1.03E-06	7.08E-05	
3	Total PAH	mg/kg	4.07E-01	8.84E-08	8.45E-08	7.92E-09	
3	Cesium-137	pCi/g	2.30E-01	9.65E+01		2.59E-03	1.47E-01
3	Uranium-238	pCi/g	3.92E+00	1.74E+03		4.67E-02	2.65E+00
4	Chromium	mg/kg	7.09E+01	1.54E-05		1.38E-06	
4	PCB, Total	mg/kg	9.24E-02	2.01E-08	2.06E-08	1.42E-06	
4	Cesium-137	pCi/g	3.37E-01	1.41E+02		3.80E-03	2.15E-01
5	Arsenic	mg/kg	1.67E+01	3.63E-06	8.00E-07	3.25E-07	
5	Cobalt	mg/kg	1.43E+01	3.11E-06		2.78E-07	
5	PCB, Total	mg/kg	2.70E-01	5.86E-08	6.03E-08	4.16E-06	
5	Total PAH	mg/kg	9.83E-02	2.14E-08	2.04E-08	1.91E-09	

[a] See Risk Methods Document for additional information (DOE 2016).

Table D.19. Noncancerous CDIs for the Adult Resident Exposed to Surface Soil[a]

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation
1	Chromium	mg/kg	2.04E+01	2.45E-05		1.58E-05
2	Chromium	mg/kg	3.82E+01	4.57E-05		2.95E-05
3	Chromium	mg/kg	1.78E+01	2.13E-05		1.37E-05
4	Chromium	mg/kg	8.15E+01	9.77E-05		6.30E-05
5	No COPCs					

[a] See Risk Methods Document for additional information (DOE 2016).

Table D.20. Noncancerous CDIs for the Child Resident Exposed to Surface Soil[a]

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation
1	Chromium	mg/kg	2.04E+01	2.61E-04		1.58E-05
2	Chromium	mg/kg	3.82E+01	4.88E-04		2.95E-05
3	Chromium	mg/kg	1.78E+01	2.27E-04		1.37E-05
4	Chromium	mg/kg	8.15E+01	1.04E-03		6.30E-05
5	No COPCs					

[a] See Risk Methods Document for additional information (DOE 2016).

Table D.21. Cancerous CDIs for the Resident Exposed to Surface Soil[a]

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation	External Exposure
1	Chromium	mg/kg	2.04E+01	2.94E-05		5.86E-06	
1	Cesium-137	pCi/g	6.12E-01	5.16E+02		8.11E-02	6.89E+00
1	Neptunium-237	pCi/g	5.91E-01	6.62E+02		1.04E-01	8.84E+00
1	Plutonium-239/240	pCi/g	8.44E+00	9.45E+03		1.49E+00	1.26E+02
1	Thorium-230	pCi/g	3.89E+01	4.36E+04		6.86E+00	5.82E+02
1	Uranium-238	pCi/g	2.04E+00	2.29E+03		3.59E-01	3.05E+01
2	Chromium	mg/kg	3.82E+01	5.49E-05		1.10E-05	
2	PCB, Total	mg/kg	1.19E+01	1.71E-05	5.61E-05	4.06E-03	
2	Uranium-234	pCi/g	9.01E+00	1.01E+04		1.59E+00	1.35E+02
2	Uranium-235	pCi/g	5.11E-01	5.72E+02		9.00E-02	7.64E+00
2	Uranium-238	pCi/g	9.86E+00	1.10E+04		1.74E+00	1.47E+02
3	Chromium	mg/kg	1.78E+01	2.56E-05		5.10E-06	
3	PCB, Total	mg/kg	9.29E+00	1.34E-05	4.38E-05	3.16E-03	
3	Total PAH	mg/kg	4.14E-01	5.95E-07	1.81E-06	1.19E-07	
3	Uranium-238	pCi/g	3.92E+00	4.39E+03		6.90E-01	5.86E+01
4	Chromium	mg/kg	8.15E+01	1.17E-04		2.34E-05	
4	PCB, Total	mg/kg	6.44E+00	9.26E-06	3.03E-05	2.19E-03	
5	PCB, Total	mg/kg	2.70E-01	3.88E-07	1.27E-06	9.20E-05	
5	Total PAH	mg/kg	9.83E-02	1.41E-07	4.30E-07	2.82E-08	

[a] See Risk Methods Document for additional information (DOE 2016).

Table D.22. Noncancerous CDIs for the Adult Recreational User Exposed to Surface Soil[a]

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation
1	Chromium	mg/kg	2.04E+01	7.27E-06		1.30E-06
2	Chromium	mg/kg	3.82E+01	1.36E-05		2.44E-06
3	Chromium	mg/kg	1.78E+01	6.33E-06		1.13E-06
4	Chromium	mg/kg	8.15E+01	2.90E-05		5.20E-06
5	No COPCs					

[a] See Risk Methods Document for additional information (DOE 2016).

Table D.23. Noncancerous CDIs for the Teen Recreational User Exposed to Surface Soil[a]

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation
1	Chromium	mg/kg	2.04E+01	1.78E-05		1.75E-06
2	Chromium	mg/kg	3.82E+01	3.33E-05		3.28E-06
3	Chromium	mg/kg	1.78E+01	1.55E-05		1.53E-06
4	Chromium	mg/kg	8.15E+01	7.10E-05		7.00E-06
5	No COPCs					

[a] See Risk Methods Document for additional information (DOE 2016).

Table D.24. Noncancerous CDIs for the Child Recreational User Exposed to Surface Soil[a]

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation
1	Chromium	mg/kg	2.04E+01	1.04E-04		1.75E-06
2	Chromium	mg/kg	3.82E+01	1.95E-04		3.28E-06
3	Chromium	mg/kg	1.78E+01	9.09E-05		1.53E-06
4	Chromium	mg/kg	8.15E+01	4.17E-04		7.00E-06
5	No COPCs					

[a] See Risk Methods Document for additional information (DOE 2016).

Table D.25. Cancerous CDIs for the Recreational User Exposed to Surface Soil[a]

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation	External Exposure
1	Chromium	mg/kg	2.04E+01	1.21E-05		5.87E-07	
1	Cesium-137	pCi/g	6.12E-01	2.15E+02		8.12E-03	8.62E-01
1	Neptunium-237	pCi/g	5.91E-01	2.43E+02		1.04E-02	1.11E+00
1	Plutonium-239/240	pCi/g	8.44E+00	3.48E+03		1.49E-01	1.58E+01
1	Thorium-230	pCi/g	3.89E+01	1.60E+04		6.87E-01	7.29E+01
1	Uranium-238	pCi/g	2.04E+00	8.41E+02		3.60E-02	3.82E+00
2	Chromium	mg/kg	3.82E+01	2.26E-05		1.10E-06	
2	PCB, Total	mg/kg	1.19E+01	7.06E-06	2.60E-05	4.06E-04	
2	Uranium-234	pCi/g	9.01E+00	3.71E+03		1.59E-01	1.69E+01
2	Uranium-235	pCi/g	5.11E-01	2.11E+02		9.01E-03	9.57E-01
2	Uranium-238	pCi/g	9.86E+00	4.06E+03		1.74E-01	1.85E+01
3	Chromium	mg/kg	1.78E+01	1.05E-05		5.11E-07	
3	PCB, Total	mg/kg	9.29E+00	5.50E-06	2.03E-05	3.17E-04	
3	Total PAH	mg/kg	4.14E-01	2.45E-07	8.41E-07	1.19E-08	
3	Uranium-238	pCi/g	3.92E+00	1.61E+03		6.91E-02	7.33E+00
4	Chromium	mg/kg	8.15E+01	4.83E-05		2.34E-06	
4	PCB, Total	mg/kg	6.44E+00	3.81E-06	1.41E-05	2.19E-04	
5	PCB, Total	mg/kg	2.70E-01	1.60E-07	5.91E-07	9.21E-06	
5	Total PAH	mg/kg	9.83E-02	5.82E-08	2.00E-07	2.83E-09	

[a] See Risk Methods Document for additional information (DOE 2016).

D.3.6 SUMMARY OF EXPOSURE ASSESSMENT

Consistent with the data collected during the RI, the receptors selected for summary in the main text are the outdoor/excavation worker, future industrial worker, and resident. In addition, current industrial worker and recreational scenarios are assessed in the BHHRA.

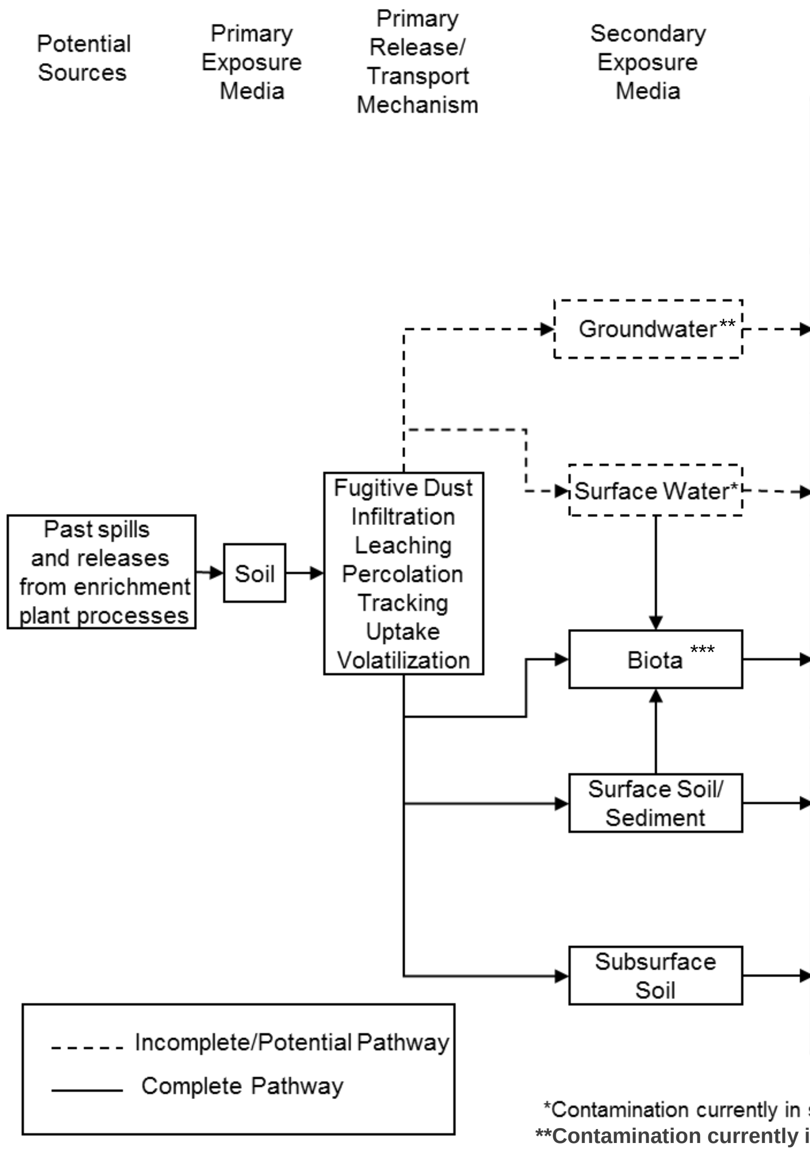
D.3.6.1 Development of Conceptual Site Models

The scope of the sampling in support of the RI discussed in Section 1 of the RI/Feasibility Study Work Plan is as follows:

> The objective of this investigation is to determine the nature and extent of contamination in the soils to a depth of 10 ft below ground surface (bgs) or up to 16 ft bgs at infrastructure (e.g., pipelines). For all source units, the initial focus of the investigation will be surface and subsurface soil contamination to a depth of 4 ft bgs. If contamination at the 4 ft bgs is found, then secondary sources from the unit located in the subsurface soil, which extend to a depth of 10 ft bgs, will be investigated. Any contamination that is found to extend past the depths specified in this investigation will be addressed under another OU.

This scope and the uncertainties in site conditions subsequently were used in the baseline risk assessment to develop a CSM that identified the sources of contamination (from both process releases and unspecified releases), release mechanisms, primary and secondary contaminated environmental media, transport mechanisms, potential receptors, and routes of exposure consistent with the RI. This CSM is presented in Figure D.3.

SWMU 1, as gridded, includes 2.29 acres and 5 EUs. The inhalation of vapors exposure route is not quantified as part of the risk characterization because VOC emission by subsurface soils is an incomplete pathway (i.e., no buildings are present).



Potential Receptor and Exposure Routes/Pathways

Current Industrial Worker	Future Industrial Worker[1]	Future Excavation Worker[2]	Future Recreational User	Future Rural Resident	Ecological
	· Ingestion · Dermal · Inhalation	· Ingestion · Dermal · Inhalation		· Ingestion · Dermal · Inhalation	· Ingestion · Dermal · Inhalation · External Exposure
· Ingestion · Dermal · Inhalation · External Exposure	· Ingestion · Dermal · Inhalation · External Exposure	· Ingestion · Dermal · Inhalation · External Exposure	· Ingestion · Dermal · Inhalation · External Exposure	· Ingestion · Dermal · Inhalation · External Exposure	· Ingestion · Dermal · Inhalation · External Exposure
			· Ingestion	· Ingestion	· Ingestion
· Ingestion · Dermal · Inhalation · External Exposure	· Ingestion · Dermal · Inhalation · External Exposure	· Ingestion · Dermal · Inhalation · External Exposure	· Ingestion · Dermal · Inhalation · External Exposure	· Ingestion · Dermal · Inhalation · External Exposure	· Ingestion · Dermal · Inhalation · External Exposure
		· Ingestion · Dermal · Inhalation · External Exposure		· Inhalation	

[1] Future industrial worker exposure routes/pathways are consistent with the outdoor worker exposed to surface soils.
[2] Future excavation worker exposure routes/pathways are consistent with the outdoor worker exposed to subsurface soils.

*Contamination currently in sediments in ditches or surface water will be evaluated as part of the SWOU.

Contamination currently in groundwater underlying SWMU 1 will be evaluated as part of the GWOU.

*****See Section D.3.4.1 for additional information regarding biota.**

Revised from DOE 2013 (Figure D.3)

Figure D.3. CSM for SWMU 1

D.4. TOXICITY ASSESSMENT

This section summarizes the potential toxicological effects of the COPCs on exposed populations. Many of the toxicological summaries were obtained from the *Risk Assessment Information System* (RAIS) Web site, available at https://rais.ornl.gov/ (UT 2016). This site also lists toxicity values taken from EPA's Integrated Risk Information System (IRIS) database (EPA 2015c), National Center for Environmental Assessment (NCEA), and Health Effects Assessment Summary Tables (HEAST) database (EPA 1998). This list formed the basis of the toxicity values reported in this section. For those chemicals not profiled in RAIS, a brief summary of information drawn from Agency for Toxic Substances and Disease Registry or other library research sources is included in this section. The last paragraph of each profile contains the toxicity values used in this BHHRA.

The toxicity information considered in the assessment of potential carcinogenic risks includes (1) a weight-of-evidence classification and (2) a slope factor (SF) or inhalation unit risk (IUR). The weight-of-evidence classification qualitatively describes the likelihood that an agent is a human carcinogen, based on the available data from animal and human studies. A chemical may be placed in one of three groups to indicate its potential for carcinogenic effects: Group A, a known human carcinogen; Group B, a probable human carcinogen; and Group C, a possible human carcinogen. Group B is divided into Subgroups B1 and B2. Assignment of a chemical to Subgroup B1 indicates that the judgment that the chemical is a probable human carcinogen is based on limited human data, and assignment of a chemical to Subgroup B2 indicates that the judgment that the chemical is a probable human carcinogen is based on animal data because human data are lacking or inadequate. Chemicals that cannot be classified as human carcinogens because of a lack of data are categorized in Group D, and those for which there is evidence of noncarcinogenicity in humans are categorized in Group E.

The SF for chemicals is defined as a plausible upper bound estimate of the probability of a response (i.e., development of cancer) per unit intake of a chemical over a lifetime (EPA 1989). SFs are specific for each chemical and route of exposure. Similarly, IURs may be called the inhalation slope factor. SFs and IURs currently are available for ingestion and inhalation pathways. The SFs and IURs used for oral and inhalation routes of exposure for the COPCs considered in this report are shown in Attachment D3.

Toxicity values used in risk calculations also include the chronic reference dose (RfD) and reference concentration (RfC), which is used to estimate the potential for systemic toxicity or noncarcinogenic risk. The chronic RfD is defined as an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime (EPA 1989). RfD values are specific to the route of exposure. The RfDs used for oral routes of exposure and the RfCs used for inhalation routes of exposure for the COPCs considered in this report are presented in Attachment D3.

For the dermal routes of exposure (i.e., dermal exposure to contaminated water while showering or bathing or dermal contact with contaminated soil), it is necessary to consider the absorbed dose received by a receptor. This is reflected by the addition of an absorption coefficient in the equations used to calculate the CDI for these pathways. Because the CDI is expressed as an absorbed dose, it is necessary to use RfDs and SFs that also are expressed in terms of absorbed dose. Currently, EPA has not produced lists of RfDs and SFs based on absorbed dose, but has produced guidance concerning the estimation of absorbed dose RfDs and SFs from administered dose RfDs and SFs. This guidance is found in *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (EPA 2004) and states, "that to convert an administered dose slope factor to an absorbed dose slope factor, the administered dose slope factor is divided by the gastrointestinal (GI) absorption efficiency of the contaminant." Alternatively, to convert an administered dose RfD to an absorbed dose RfD, the administered dose RfD is multiplied by the GI absorption efficiency of the contaminant. The absorbed dose slope factors and RfDs and the information used in their derivation are presented in Attachment D3.

Toxicity profiles for primary COCs identified in this assessment are included in Attachment D3.

D.4.1 CHEMICALS OR RADIONUCLIDES FOR WHICH NO TOXICITY VALUES ARE AVAILABLE

Toxicity values are available for all chemicals or radionuclides identified as COPCs for SWMU 1.

D.4.2 UNCERTAINTIES RELATED TO TOXICITY INFORMATION

Standard EPA RfDs/RfCs and SFs/IURs were used to estimate potential noncarcinogenic and carcinogenic health effects from exposure to detected chemical contaminants. Considerable uncertainty is associated with the methodology applied to derive SFs/IURs and RfDs/RfCs. EPA working groups review all relevant human and animal studies for each compound and select the studies pertinent to the derivation of the specific RfD/RfC and SF/IUR. These studies often involve data from experimental studies in animals, high exposure levels, and exposures under acute or occupational conditions. Extrapolation of these data to humans under low-dose, chronic conditions introduces uncertainties. The magnitude of these uncertainties is addressed by applying uncertainty factors to the dose response data for each applicable uncertainty. These factors are incorporated to provide a margin of safety for use in human health assessments.

D.4.2.1 Development of Dermal Toxicity Factors

Dermal RfDs and SFs are derived from the corresponding oral values, using a route-to-route extrapolation based on the absorption efficiency of the chemical though the exposure route (for example, through the gastrointestinal tract), provided that 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 (ABS_{GI}), 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 ABS_{GI}. The oral SF is divided, rather than multiplied, by the ABS_{GI} because SFs are expressed as a reciprocal dose.

Dermal contact with soil has been a driving exposure route in previous BHHRAs at PGDP, with most of this risk arising from contact with metals (e.g., beryllium, vanadium). This was a direct result of using dermal absorption factors that exceeded GI absorption values and may have overestimated potential risks. In such circumstances, risk estimates from the dermal exposure route may have been unrealistic and exceeded the real risk posed by this route of exposure. Although chemical-specific ABS values were used when available, default ABS values were used for most chemicals because chemical-specific values were lacking. It should be noted that risk management decisions based on the dermal contact with soil exposure route should be considered carefully because of the uncertainty associated with risk from this exposure route.

In the past, it has been assumed that 5% of the inorganic materials will be absorbed through the skin as from the gastrointestinal tract. This was considered conservative because the primary function of the GI tract is to allow absorption of minerals and nutrients, where the function of the skin is to act as a barrier to entry of foreign materials. Therefore, absorption of materials from the GI tract generally is considered to occur more readily than dermal absorption. In addition, once ingested, it will remain in contact with the GI tract for approximately 24 hours or more, while materials on skin most likely will be washed off more frequently. The current Risk Methods Document (DOE 2016) recommends using GI absorption values less than 5% for inorganics whose dermal absorption factor otherwise would be set to the default of 5%. These absorption values are more in line with GI absorption values, minimizing the effect of this uncertainty.

D.4.2.2 Lead Toxicity

Although it is known that exposure to lead can result in systemic toxic effects and possibly cancer, the approved toxicity values required to estimate potential for systemic toxicity and carcinogenesis are not available. Thus, the approach to evaluating health risks associated with exposure to lead is different from other chemicals detected at the site. To determine if exposure to lead has occurred, the amount of lead present in the blood can be measured; the level of lead in the blood is measured in micrograms per deciliter (μg/dL). Ten μg/dL is considered the national health criteria that no more than 5% of the population should exceed this level before health effects may be exhibited (EPA 2003a). Based on the target blood lead (PbB) level of 10 μg/dL, EPA has derived a residential screening level of 400 mg/kg lead in soil, which is considered protective for young children exposed routinely under a residential scenario. This residential screening value of 400 mg/kg also is adopted as the NAL for lead in soils at PGDP for identifying lead as a COPC. EPA also has derived an industrial screening level of 800 mg/kg lead in soil.

Lead is unique in that a continuous level of exposure is needed to detect an increase in PbB. According to EPA guidance on intermittent exposures to lead (EPA 2003b), the magnitude and duration of the increase in PbB will vary depending on the temporal pattern of exposure at a site. According to EPA guidance (EPA 2003a; 2003b), an increase in PbB will be greatest if exposure occurs every day in succession over an extended period of time (e.g., summer); in comparison to intermittent exposures (e.g., once every 7 days) would give rise to smaller PbB increases. Infrequent exposures (i.e., less than 1 day per week) over a minimum duration of 90 days would be expected to produce oscillations in blood lead concentrations associated with the absorption and subsequent clearance of lead from the blood between each exposure event. As a result, EPA's Technical Review Workgroup recommends that PbB models for evaluating child and adult exposure to lead be applied to exposure that exceed a minimum frequency of one day per week and a duration of 3 consecutive months (EPA 2003b).

For PGDP, the preliminary risk characterization of lead is conducted for SWMU 1 by comparing the maximum detected result to the residential screening value of 400 mg/kg. Lead is not considered a COPC at SWMU 1 because it does not exceed the screening value.

D.4.2.3 Carcinogenic PAHs

During the development of the list of COPCs, concentrations of total carcinogenic PAHs were derived based on the methodology in the Risk Methods Document (DOE 2016). When deriving Total PAHs, the toxicity equivalence factors (TEFs) presented in Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (EPA 2005) were used. These TEFs were applied to the concentrations of detected PAHs in each sample and then the Total PAH concentration in a sample was the sum of the products of each carcinogenic PAH and its TEF. When calculating the EPC for carcinogenic PAHs, for samples in which PAHs are not detected, the value for the minimum detection limit of the PAHs with TEFs were used.

D.4.2.4 Total Dioxins/Furans

In 1998, an area where dioxins and furans were found was remediated. As such, dioxin and furan historical data are no longer applicable.

D.4.2.5 Chromium Toxicity

Based on the nature of the soils present at SWMU 1, the presence of chromium(VI) is not expected. In order to ensure risk to human health is not underestimated and consistent with the Risk Methods Document, the IUR for chromium(VI) and the RfD for chromium(III) were used.

D.5. RISK CHARACTERIZATION

Risk characterization is the final step in the risk assessment process. In this step, the information from the exposure and toxicity assessments is integrated to quantitatively estimate both carcinogenic health risks and noncarcinogenic hazard potential. For this assessment, risk is defined as both the lifetime probability of excess cancer incidence for carcinogens and the estimate of daily intake exceeding intake that may lead to toxic effects for noncarcinogens.

D.5.1 DETERMINATION OF POTENTIAL FOR NONCANCER EFFECTS

In this BHHRA, the numeric estimate of the potential for noncancer effects posed by a single chemical within one pathway of exposure is derived as the ratio of the CDI or EC of a chemical, from a single pathway to the appropriate RfD or RfC. This ratio also is referred to as a hazard quotient (HQ). This value is calculated as shown in the following equations, as appropriate:

$$HQ_i = \frac{CDI_i[\text{mg/(kg} \times \text{day)}]}{RfD_i[\text{mg/(kg} \times \text{day)}]}$$

where:

HQ_i is the hazard quotient, an estimate of the systemic toxicity posed by a single chemical, dimensionless

CDI_i is the estimate of chronic daily intake (or absorbed dose for some exposure routes) from the exposure assessment

RfD_i is the chronic reference dose for administered or absorbed dose, as appropriate

or

$$HQ_i = \frac{EC_i\ (\mu\text{g/m}^3)}{[RfC_i\ (\text{mg/m}^3) \times 1000\ (\mu\text{g/mg})]}$$

where:

HQ_i is the hazard quotient, an estimate of the systemic toxicity posed by a single chemical for inhalation

EC_i is the exposure concentration for chronic exposure

RfC_i is the reference concentration for chronic inhalation exposure

When performing this calculation, the proper RfD/RfC was used for each CDI/EC. For CDIs that reflect ingestion, the RfD used was that for administered dose. For CDIs that reflect absorption, as in dermal contact, the RfD used was that for absorbed dose. Finally, for ECs that reflect inhalation exposure, the RfC used was that for inhalation. For all exposures, regardless of duration, the chronic RfD was used (DOE 2016).

If several chemicals may reach a receptor through a common pathway, guidance (DOE 2016) recommends adding the HQs of all chemicals reaching the receptor through the common pathway to calculate a pathway HI. This can be represented by the following equation:

$$HI_p = \sum_{i=1}^{n} HQ_i$$

where:

HI_p or the pathway HI is the sum of the individual chemical HQs, dimensionless
HQ_1 to HQ_n are the individual chemical hazard quotients relevant to the pathway, dimensionless

Similarly, guidance (DOE 2016) recommends summing the pathway HIs for all pathways relevant to an individual receptor to develop a total HI. The total HI is not an estimate of the systemic toxicity posed by all contaminants that may reach the receptor, but can be used to estimate if a toxic effect may result if all contaminants reaching the receptor have additive effects over all pathways. This can be represented as in the following equation:

$$HI_{total} = \sum_{p=1}^{n} HI_p$$

where:

HI_{total} or total HI is the sum of all pathways relevant to a single receptor, dimensionless
HI_1 to HI_n are the individual pathway HIs

Note that the HQ, the pathway HI, and the total HI do not define a dose-response relationship. That is, the magnitude of the HQ or HI does not represent a statistical probability of incurring an adverse effect. If the HQ is less than 1, the estimated exposure to a substance may be judged to be below a level that could present a toxic effect. If the HQ is greater than 1, a toxic effect may or may not result depending on the assumptions used to develop the CDI/EC and assumptions used in deriving the RfD/RfC. Similarly, if the pathway HI is less than 1, then the estimated exposure to multiple chemicals contributing to the pathway HI should not be expected to present a toxic effect. If the pathway HI is greater than 1, then exposure may or may not result in a toxic effect depending on what assumptions were used to develop the pathway and how the chemicals included in the pathway interact. Finally, if the total HI is less than 1, then the estimated exposure to multiple chemicals over multiple pathways should not be expected to result in a toxic effect. If the total HI is greater than 1, then a toxic effect may or may not result depending on the rigor used to develop the CSM for all pathways and the interaction between pathways and individual chemicals.

D.5.2 DETERMINATION OF EXCESS LIFETIME CANCER RISK

Estimates of the potential for cancer induction are measured by calculating estimates of ELCR. Generally, ELCR can be defined as the incremental increase in the probability that a receptor may develop cancer if the receptor is exposed to chemicals or radionuclides or both. ELCRs are specific to the CSM used to define the routes and magnitude of exposure. The magnitude of the ELCRs could vary markedly if the exposure assumptions used to develop the CSM are varied.

D.5.2.1 Chemical Excess Cancer Risk

The numeric estimate of the ELCR resulting from exposure to a single chemical carcinogen is derived by multiplying the CDI or EC through a particular pathway by the SF or IUR appropriate to that pathway.

The resulting value is referred to as a chemical-specific ELCR. These values are calculated as shown in the following equations:

$$\text{ELCR}_i = \text{CDI}_i[\text{mg/(kg} \times \text{day)}] \times \text{SF}_i[\text{mg/(kg} \times \text{day)}]^{1}$$

where:

ELCR_i or chemical-specific ELCR is an estimate of the excess lifetime probability of developing cancer that results because of exposure to the specific chemical, dimensionless

CDI_i is the chronic daily intake of the chemical

SF_i is the slope factor for the specific chemical

or

$$\text{ELCR}_i = \text{EC}_i\ (\mu\text{g/m}^3) \times \text{IUR}_i\ (\mu\text{g/m}^3)^{-1}$$

where:

ELCR_i or chemical-specific ELCR is an estimate of the excess lifetime probability of developing cancer that results because of exposure to the specific chemical, dimensionless

EC_i is the exposure concentration for chronic exposure to the chemical

IUR_i is the unit risk for chronic inhalation exposure for the specific chemical

As with the calculation used to derive HQs, the proper SF/IUR was used for each CDI/EC when performing this calculation. For CDIs that reflect ingestion, the SF was that for an administered dose. For CDIs that reflect absorption, the SF was that for absorbed dose. Finally, for ECs that reflect inhalation exposure, the IUR was that for inhalation.

If several chemicals may reach a receptor through a common pathway, the chemical specific ELCRs of all chemicals reaching the receptor through the common pathway are summed to calculate a pathway ELCR. This can be represented by the following equation:

$$\text{ELCR}_p = \sum_{i=1}^{n} \text{ELCR}_i$$

where:

ELCR_p or the pathway ELCR is the sum of the individual chemical-specific ELCRs, dimensionless
ELCR_1 to ELCR_n are the chemical-specific ELCRs relevant to the pathway; dimensionless

Similarly, the pathway ELCRs for all pathways relevant to an individual receptor are summed to develop a total ELCR. The total ELCR is not an actuarial estimate of an individual developing cancer, but can be used to estimate the total ELCR that may result if all contaminants reaching the receptor have additive effects over all pathways. This can be represented as in the following equation:

$$\text{ELCR}_{total} = \sum_{p=1}^{n} \text{ELCR}_p$$

where:

$ELCR_{total}$ or total ELCR is the sum of all pathways relevant to a single receptor, dimensionless

$ELCR_1$ to $ELCR_n$ is the individual pathway ELCRs

Unlike the HQ, the pathway HI and the total HI, the chemical-specific ELCR, the pathway ELCR, and total ELCR define a dose-response relationship. That is, the ELCRs represent a statistical probability of the increased risk of developing cancer that exists in receptors exposed under the assumptions used in the calculation of the CDI/EC.

D.5.2.2 Radionuclide Excess Cancer Risk

Calculation of cancer risk due to exposure to radionuclides through ingestion or inhalation is conceptually similar to calculation of risks for chemical carcinogens. In performing this calculation, ELCR due to exposure to a particular radionuclide within a specific pathway is calculated by multiplying the intake of the radionuclide by the route-specific cancer slope factor. This can be represented by the following equations:

For ingestion:

$$\text{ELCR}_i = \text{CDI}_i(\text{pCi}) \times \text{SF}_i(\text{risk/pCi})$$

where:

$ELCR_i$ or radionuclide-specific ELCR is an estimate of the excess lifetime probability of developing cancer that results because of exposure to the specific radionuclide, dimensionless

CDI_i is the ingestion chronic daily intake of the radionuclide

SF_i is the ingestion slope factor for the specific radionuclide

For external exposure to ionizing radiation, the equation above is used, except units for CDI and SF are pCi-year/g and risk-g/pCi-year, respectively.

For inhalation:

$$\text{ELCR}_i = \text{EC}_i(\text{pCi}) \times \text{IUR}_i(\text{risk/pCi})$$

where:

$ELCR_i$ or radionuclide-specific ELCR is an estimate of the excess lifetime probability of developing cancer that results because of exposure to the specific radionuclide, dimensionless

EC_i is the exposure concentration for chronic exposure to the radionuclide

IUR_i is the unit risk for chronic inhalation exposure for the specific chemical

As with the calculation used to derive chemical-specific ELCRs, the proper SF or IUR was used for each CDI when performing this calculation. For CDIs that reflect ingestion, the SF was that for ingestion. Similarly, for ECs that reflect inhalation exposure, the IUR was that for inhalation.

Both the pathway ELCR for radionuclides and the total ELCR from exposure to multiple radionuclides within a pathway and over multiple pathways, respectively, are calculated as illustrated for chemical carcinogens in the Risk Methods Document (DOE 2016). These equations will not be presented in this risk assessment. The uncertainties related to this method of determining ELCR from exposure to radionuclides is discussed in detail in Section D.6.

In this risk assessment, ELCRs from exposure to chemicals and radionuclides were summed within pathways and over all pathways to indicate the potential health risk to a receptor that may be exposed to radionuclides and chemicals over all pathways. The uncertainties associated with combining radionuclide and chemical ELCRs are discussed in detail in Section D.6.

D.5.3 RISK CHARACTERIZATION FOR SOIL

This subsection presents the systemic toxicity [hazard index (HI)] and ELCR for soil exposure at each source area calculated from the COPCs at each unit. Both HI and ELCR are presented. The results of the quantitative risk assessment are presented in Tables D.24 through D.40 and include (1) risks by contaminant for each pathway, (2) risks by contaminant across all pathways (shown in “Total” column), (3) total pathway risks for all contaminants (shown across “Totals” row), and d) total risk for all contaminants across all pathways (bold value in “Totals” row).

Table D.24. HIs for the Current Industrial Worker Exposed to Surface Soil[a,b]

EU	COPC	EPC (mg/kg)	Ingestion	Dermal	Inhalation	Total HI	% Contribution across All Pathways
1	Chromium	2.04E+01	0.00		0.00	0.00	100%
1	Totals		0.00		0.00	**0.00**	
1	% Contribution within a Pathway		7%		93%		
2	Chromium	3.82E+01	0.00		0.00	0.00	100%
2	Totals		0.00		0.00	**0.00**	
2	% Contribution within a Pathway		7%		93%		
3	Chromium	1.78E+01	0.00		0.00	0.00	100%
3	Totals		0.00		0.00	**0.00**	
3	% Contribution within a Pathway		7%		93%		
4	Chromium	8.15E+01	0.00		0.00	0.00	100%
4	Totals		0.00		0.00	**0.00**	
4	% Contribution within a Pathway		7%		93%		

[a] Only noncarcinogenic COPCs are shown for HI tables (for the current industrial worker exposed to SWMU 1 surface soils, only chromium is noncarcinogenic).
[b] See Risk Methods Document for additional information (DOE 2016).

Table D.25. HIs for the Future Industrial Worker Exposed to Surface Soil[a,b]

EU	COPC	EPC (mg/kg)	Ingestion	Dermal	Inhalation	Total HI	% Contribution across All Pathways
1	Chromium	2.04E+01	0.00		0.00	0.00	100%
1	Totals		0.00		0.00	**0.00**	
1	% Contribution within a Pathway		7%		93%		

Table D.25. HIs for the Future Industrial Worker Exposed to Surface Soil (Continued)

EU	COPC	EPC (mg/kg)	Ingestion	Dermal	Inhalation	Total HI	% Contribution across All Pathways
2	Chromium	3.82E+01	0.00		0.00	0.00	100%
2	Totals		0.00		0.00	**0.00**	
2	% Contribution within a Pathway		7%		93%		
3	Chromium	1.78E+01	0.00		0.00	0.00	100%
3	Totals		0.00		0.00	**0.00**	
3	% Contribution within a Pathway		7%		93%		
4	Chromium	8.15E+01	0.00		0.00	0.00	100%
4	Totals		0.00		0.00	**0.00**	
4	% Contribution within a Pathway		7%		93%		

[a] Only noncarcinogenic COPCs are shown for HI tables (for the future industrial worker exposed to SWMU 1 surface soils, only chromium is noncarcinogenic).
[b] See Risk Methods Document for additional information (DOE 2016).

Table D.26. HIs for the Outdoor Worker Exposed to Surface Soil[a,b]

EU	COPC	EPC (mg/kg)	Ingestion	Dermal	Inhalation	Total HI	% Contribution across All Pathways
1	Chromium	2.04E+01	0.00		0.00	0.00	100%
1	Totals		0.00		0.00	**0.00**	
1	% Contribution within a Pathway		43%		57%		
2	Chromium	3.82E+01	0.00		0.00	0.00	100%
2	Totals		0.00		0.00	**0.00**	
2	% Contribution within a Pathway		43%		57%		
3	Chromium	1.78E+01	0.00		0.00	0.00	100%
3	Totals		0.00		0.00	**0.00**	
3	% Contribution within a Pathway		43%		57%		
4	Chromium	8.15E+01	0.00		0.00	0.00	100%
4	Totals		0.00		0.00	**0.00**	
4	% Contribution within a Pathway		43%		57%		

[a] Only noncarcinogenic COPCs are shown for HI tables (for the outdoor worker exposed to SWMU 1 surface soils, only chromium is noncarcinogenic).
[b] See Risk Methods Document for additional information (DOE 2016).

Table D.27. HIs for the Outdoor Worker Exposed to Surface and Subsurface Soil[a]

EU	COPC	EPC (mg/kg)	Ingestion	Dermal	Inhalation	Total HI	% Contribution across All Pathways[b]
1	Aluminum	1.05E+04	0.03		0.00	0.03	5%
1	Antimony	2.31E+00	0.02			0.02	3%
1	Arsenic	7.43E+00	0.08	0.02	0.00	0.09	14%
1	Chromium	2.64E+01	0.00		0.00	0.00	0%
1	Cobalt	1.04E+01	0.11		0.00	0.11	16%
1	Manganese	1.01E+03	0.13		0.01	0.13	20%
1	Thallium	8.68E-01	0.26			0.26	40%
1	Vanadium	3.33E+01	0.02		0.00	0.02	3%
1	Totals		0.64	0.02	0.01	**0.66**	
1	% Contribution within a Pathway[b]		96%	2%	1%		
2	Arsenic	7.76E+00	0.08	0.02	0.00	0.10	42%
2	Chromium	3.87E+01	0.00		0.00	0.00	0%
2	Manganese	6.98E+02	0.09		0.00	0.09	40%
2	Silver	6.87E+01	0.04			0.04	18%
2	Totals		0.21	0.02	0.00	**0.23**	
2	% Contribution within a Pathway[b]		91%	8%	2%		
3	Arsenic	6.89E+00	0.07	0.02	0.00	0.09	52%
3	Chromium	4.58E+01	0.00		0.00	0.00	0%
3	Manganese	6.01E+02	0.08		0.00	0.08	48%
3	Totals		0.15	0.02	0.00	**0.17**	
3	% Contribution within a Pathway[b]		89%	9%	0%		
4	Chromium	7.09E+01	0.00		0.00	0.00	0%
4	Manganese	7.41E+02	0.09		0.00	0.10	85%
4	Vanadium	2.87E+01	0.02		0.00	0.02	15%
4	Totals		0.11		0.00	**0.12**	
4	% Contribution within a Pathway		96%		4%		
5	Aluminum	1.20E+04	0.04		0.00	0.04	6%
5	Arsenic	1.67E+01	0.17	0.04	0.00	0.21	31%
5	Cobalt	1.43E+01	0.14		0.00	0.15	22%
5	Manganese	2.16E+03	0.27		0.01	0.29	42%
5	Totals		0.62	0.04	0.01	**0.69**	
5	% Contribution within a Pathway		**92%**	**6%**	**2%**		

[a] See Risk Methods Document for additional information (DOE 2016).
[b] Not all percent contribution totals in the table add up to 100%, due to rounding.

Table D.28. HIs for the Excavation Worker Exposed to Surface and Subsurface Soil[a]

EU	COPC	EPC (mg/kg)	Ingestion	Dermal	Inhalation	Total HI	% Contribution across All Pathways[b]
1	Aluminum	1.05E+04	0.03		0.00	0.03	5%
1	Antimony	2.31E+00	0.02			0.02	3%
1	Arsenic	7.43E+00	0.08	0.02	0.00	0.09	14%
1	Chromium	2.64E+01	0.00		0.00	0.00	0%
1	Cobalt	1.04E+01	0.11		0.00	0.11	16%
1	Manganese	1.01E+03	0.13		0.01	0.13	20%
1	Thallium	8.68E-01	0.26			0.26	40%
1	Vanadium	3.33E+01	0.02		0.00	0.02	3%
1	Totals		0.64	0.02	0.01	**0.66**	
1	% Contribution within a Pathway[b]		96%	2%	1%		
2	Arsenic	7.76E+00	0.08	0.02	0.00	0.10	42%
2	Chromium	3.87E+01	0.00		0.00	0.00	0%
2	Manganese	6.98E+02	0.09		0.00	0.09	40%
2	Silver	6.87E+01	0.04			0.04	18%
2	Totals		0.21	0.02	0.00	**0.23**	
2	% Contribution within a Pathway[b]		91%	8%	2%		
3	Arsenic	6.89E+00	0.07	0.02	0.00	0.09	52%
3	Chromium	4.58E+01	0.00		0.00	0.00	0%
3	Manganese	6.01E+02	0.08		0.00	0.08	48%
3	Totals		0.15	0.02	0.00	**0.17**	
3	% Contribution within a Pathway		89%	9%	2%		
4	Chromium	7.09E+01	0.00		0.00	0.00	0%
4	Manganese	7.41E+02	0.09		0.00	0.10	85%
4	Vanadium	2.87E+01	0.02		0.00	0.02	15%
4	Totals		0.11		0.00	**0.12**	
4	% Contribution within a Pathway		96%		4%		
5	Aluminum	1.20E+04	0.04		0.00	0.04	6%
5	Arsenic	1.67E+01	0.17	0.04	0.00	0.21	31%
5	Cobalt	1.43E+01	0.14		0.00	0.15	22%
5	Manganese	2.16E+03	0.27		0.01	0.29	42%
5	Totals		0.62	0.04	0.01	**0.69**	
5	% Contribution within a Pathway		**92%**	**6%**	**2%**		

[a] See Risk Methods Document for additional information (DOE 2016).
[b] Not all percent contribution totals in the table add up to 100%, due to rounding.

Table D.29. HIs for the Future Hypothetical Adult Resident Exposed to Surface Soil[a,b]

EU	COPC	EPC (mg/kg)	Ingestion	Dermal	Inhalation	Total HI	% Contribution across All Pathways
1	Chromium	2.04E+01	0.00		0.00	0.00	100%
1	Totals		0.00		0.00	**0.00**	
1	% Contribution within a Pathway		**9%**		**91%**		

Table D.29. HIs for the Future Hypothetical Adult Resident Exposed to Surface Soil (Continued)

EU	COPC	EPC (mg/kg)	Ingestion	Dermal	Inhalation	Total HI	% Contribution across All Pathways
2	Chromium	3.82E+01	0.00		0.00	0.00	100%
2	Totals		0.00		0.00	**0.00**	
2	% Contribution within a Pathway		**9%**		**91%**		
3	Chromium	1.78E+01	0.00		0.00	0.00	100%
3	Totals		0.00		0.00	**0.00**	
3	% Contribution within a Pathway		**9%**		**91%**		
4	Chromium	8.15E+01	0.00		0.00	0.00	100%
4	Totals		0.00		0.00	**0.00**	
4	% Contribution within a Pathway		**9%**		**91%**		

[a] Only noncarcinogenic COPCs are shown for HI tables (for the hypothetical adult resident exposed to SWMU 1 surface soils, only chromium is noncarcinogenic).
[b] See Risk Methods Document for additional information (DOE 2016).

Table D.30. HIs for the Future Hypothetical Child Resident Exposed to Surface Soil[a,b]

EU	COPC	EPC (mg/kg)	Ingestion	Dermal	Inhalation	Total HI	% Contribution across All Pathways
1	Chromium	2.04E+01	0.00		0.00	0.00	100%
1	Totals		0.00		0.00	**0.00**	
1	% Contribution within a Pathway		**52%**		**48%**		
2	Chromium	3.82E+01	0.00		0.00	0.00	100%
2	Totals		0.00		0.00	**0.00**	
2	% Contribution within a Pathway		**52%**		**48%**		
3	Chromium	1.78E+01	0.00		0.00	0.00	100%
3	Totals		0.00		0.00	**0.00**	
3	% Contribution within a Pathway		**52%**		**48%**		
4	Chromium	8.15E+01	0.00		0.00	0.00	100%
4	Totals		0.00		0.00	**0.00**	
4	% Contribution within a Pathway		**52%**		**48%**		

[a] Only noncarcinogenic COPCs are shown for HI tables (for the hypothetical child resident exposed to SWMU 1 surface soils, only chromium is noncarcinogenic).
[b] See Risk Methods Document for additional information (DOE 2016).

Table D.31. HIs for the Adult Recreational User Exposed to Surface Soil[a,b]

EU	COPC	EPC (mg/kg)	Ingestion	Dermal	Inhalation	Total HI	% Contribution across All Pathways
1	Chromium	2.04E+01	0.00		0.00	0.00	100%
1	Totals		0.00		0.00	**0.00**	
1	% Contribution within a Pathway		**27%**		**73%**		

Table D.31. HIs for the Adult Recreational User Exposed to Surface Soil (Continued)

EU	COPC	EPC (mg/kg)	Ingestion	Dermal	Inhalation	Total HI	% Contribution across All Pathways
2	Chromium	3.82E+01	0.00		0.00	0.00	100%
2	Totals		0.00		0.00	**0.00**	
2	% Contribution within a Pathway		**27%**		**73%**		
3	Chromium	1.78E+01	0.00		0.00	0.00	100%
3	Totals		0.00		0.00	**0.00**	
3	% Contribution within a Pathway		**27%**		**73%**		
4	Chromium	8.15E+01	0.00		0.00	0.00	100%
4	Totals		0.00		0.00	**0.00**	
4	% Contribution within a Pathway		**27%**		**73%**		

[a] Only noncarcinogenic COPCs are shown for HI tables (for the adult recreational user exposed to SWMU 1 surface soils, only chromium is noncarcinogenic).
[b] See Risk Methods Document for additional information (DOE 2016).

Table D.32. HIs for the Teen Recreational User Exposed to Surface Soil[a,b]

EU	COPC	EPC (mg/kg)	Ingestion	Dermal	Inhalation	Total HI	% Contribution across All Pathways
1	Chromium	2.04E+01	0.00		0.00	0.00	100%
1	Totals		0.00		0.00	**0.00**	
1	% Contribution within a Pathway		**40%**		**60%**		
2	Chromium	3.82E+01	0.00		0.00	0.00	100%
2	Totals		0.00		0.00	**0.00**	
2	% Contribution within a Pathway		**40%**		**60%**		
3	Chromium	1.78E+01	0.00		0.00	0.00	100%
3	Totals		0.00		0.00	**0.00**	
3	% Contribution within a Pathway		**40%**		**60%**		
4	Chromium	8.15E+01	0.00		0.00	0.00	100%
4	Totals		0.00		0.00	**0.00**	
4	% Contribution within a Pathway		**40%**		**60%**		

[a] Only noncarcinogenic COPCs are shown for HI tables (for the teen recreational user exposed to SWMU 1 surface soils, only chromium is noncarcinogenic).
[b] See Risk Methods Document for additional information (DOE 2016).

Table D.33. HIs for the Child Recreational User Exposed to Surface Soil[a,b]

EU	COPC	EPC (mg/kg)	Ingestion	Dermal	Inhalation	Total HI	% Contribution across All Pathways
1	Chromium	2.04E+01	0.00		0.00	0.00	100%
1	Totals		0.00		0.00	**0.00**	
1	% Contribution within a Pathway		**80%**		**20%**		
2	Chromium	3.82E+01	0.00		0.00	0.00	100%
2	Totals		0.00		0.00	**0.00**	
2	% Contribution within a Pathway		**80%**		**20%**		
3	Chromium	1.78E+01	0.00		0.00	0.00	100%
3	Totals		0.00		0.00	**0.00**	
3	% Contribution within a Pathway		**80%**		**20%**		
4	Chromium	8.15E+01	0.00		0.00	0.00	100%
4	Totals		0.00		0.00	**0.00**	
4	% Contribution within a Pathway		**80%**		**20%**		

[a] Only noncarcinogenic COPCs are shown for HI tables (for the child recreational user exposed to SWMU 1 surface soils, only chromium is noncarcinogenic).
[b] See Risk Methods Document for additional information (DOE 2016).

Table D.34. ELCRs for the Current Industrial Worker Exposed to Surface Soil[a]

EU	COPC	EPC (mg/kg or pCi/g)	Ingestion	Dermal	Inhalation	External Exposure	Total ELCR	% Contribution across All Pathways[b]
1	Chromium	2.04E+01			1.26E-08		1.26E-08	2%
1	Cesium-137	6.12E-01	2.59E-10		2.35E-13	3.01E-07	3.01E-07	51%
1	Neptunium-237	5.91E-01	5.13E-10		7.66E-11	1.29E-07	1.30E-07	22%
1	Plutonium-239/240	8.44E+00	1.79E-08		2.11E-09	4.51E-10	2.04E-08	3%
1	Thorium-230	3.89E+01	5.27E-08		6.00E-09	8.41E-09	6.71E-08	11%
1	Uranium-238	2.04E+00	2.01E-09		2.18E-10	6.21E-08	6.43E-08	11%
1	Totals		7.33E-08		2.10E-08	5.01E-07	**5.95E-07**	
1	% Contribution within a Pathway		12%		4%	84%		
2	Chromium	3.82E+01			2.36E-08		2.36E-08	1%
2	PCB, Total	1.19E+01	2.04E-07	2.01E-06	3.96E-08		2.26E-06	84%
2	Uranium-234	9.01E+00	8.06E-09		1.13E-09	5.83E-10	9.77E-09	0%
2	Uranium-235	5.11E-01	4.47E-10		5.77E-11	7.53E-08	7.58E-08	3%
2	Uranium-238	9.86E+00	9.70E-09		1.06E-09	3.00E-07	3.11E-07	12%
2	Totals		2.22E-07	2.01E-06	6.55E-08	3.76E-07	**2.68E-06**	
2	% Contribution within a Pathway[b]		8%	75%	2%	14%		
3	Chromium	1.78E+01			1.10E-08		1.10E-08	1%
3	PCB, Total	9.29E+00	1.59E-07	1.57E-06	3.09E-08		1.76E-06	82%
3	Total PAH	4.14E-01	2.59E-08	2.37E-07	3.35E-12		2.63E-07	12%
3	Uranium-238	3.92E+00	3.85E-09		4.19E-10	1.19E-07	1.23E-07	6%
3	Totals		1.89E-07	1.81E-06	4.23E-08	1.19E-07	**2.16E-06**	
3	% Contribution within a Pathway[b]		9%	84%	2%	6%		
4	Chromium	8.15E+01			5.04E-08		5.04E-08	4%
4	PCB, Total	6.44E+00	1.10E-07	1.09E-06	2.14E-08		1.22E-06	96%
4	Totals		1.10E-07	1.09E-06	7.18E-08		**1.27E-06**	
4	% Contribution within a Pathway[b]		9%	86%	6%			
5	PCB, Total	2.70E-01	4.62E-09	4.57E-08	8.98E-10		5.12E-08	45%
5	Total PAH	9.83E-02	6.14E-09	5.63E-08	7.96E-13		6.25E-08	55%
5	Totals		1.08E-08	1.02E-07	8.99E-10		**1.14E-07**	
5	% Contribution within a Pathway		9%	90%	1%			

[a] See Risk Methods Document for additional information (DOE 2016).
[b] Not all percent contribution totals in the table add up to 100%, due to rounding.

Table D.35. ELCRs for the Future Industrial Worker Exposed to Surface Soil[a]

EU	COPC	EPC (mg/kg or pCi/g)	Ingestion	Dermal	Inhalation	External Exposure	Total ELCR	% Contribution across All Pathways[b]
1	Chromium	2.04E+01			2.25E-07		2.25E-07	2%
1	Cesium-137	6.12E-01	4.63E-09		4.20E-12	5.38E-06	5.38E-06	51%
1	Neptunium-237	5.91E-01	9.16E-09		1.37E-09	2.31E-06	2.32E-06	22%
1	Plutonium-239/240	8.44E+00	3.19E-07		3.78E-08	8.05E-09	3.65E-07	3%
1	Thorium-230	3.89E+01	9.41E-07		1.07E-07	1.50E-07	1.20E-06	11%
1	Uranium-238	2.04E+00	3.58E-08		3.90E-09	1.11E-06	1.15E-06	11%
1	Totals		1.31E-06		3.76E-07	8.95E-06	**1.06E-05**	
1	% Contribution within a Pathway		12%		4%	84%		
2	Chromium	3.82E+01			4.22E-07		4.22E-07	1%
2	PCB, Total	1.19E+01	3.64E-06	3.60E-05	7.07E-07		4.03E-05	84%
2	Uranium-234	9.01E+00	1.44E-07		2.02E-08	1.04E-08	1.74E-07	0%
2	Uranium-235	5.11E-01	7.98E-09		1.03E-09	1.34E-06	1.35E-06	3%
2	Uranium-238	9.86E+00	1.73E-07		1.88E-08	5.36E-06	5.55E-06	12%
2	Totals		3.97E-06	3.60E-05	1.17E-06	6.71E-06	**4.78E-05**	
2	% Contribution within a Pathway[b]		8%	75%	2%	14%		
3	Chromium	1.78E+01			1.96E-07		1.96E-07	1%
3	PCB, Total	9.29E+00	2.84E-06	2.80E-05	5.52E-07		3.14E-05	82%
3	Total PAH	4.14E-01	4.62E-07	4.24E-06	5.99E-11		4.70E-06	12%
3	Uranium-238	3.92E+00	6.88E-08		7.48E-09	2.13E-06	2.20E-06	6%
3	Totals		3.37E-06	3.23E-05	7.55E-07	2.13E-06	**3.85E-05**	
3	% Contribution within a Pathway[b]		9%	84%	2%	6%		
4	Chromium	8.15E+01			9.00E-07		9.00E-07	4%
4	PCB, Total	6.44E+00	1.97E-06	1.94E-05	3.82E-07		2.18E-05	96%
4	Totals		1.97E-06	1.94E-05	1.28E-06		**2.27E-05**	
4	% Contribution within a Pathway[b]		9%	86%	6%			
5	PCB, Total	2.70E-01	8.26E-08	8.15E-07	1.60E-08		9.14E-07	45%
5	Total PAH	9.83E-02	1.10E-07	1.01E-06	1.42E-11		1.12E-06	55%
5	Totals		1.92E-07	1.82E-06	1.60E-08		**2.03E-06**	
5	% Contribution within a Pathway		9%	90%	1%			

[a] See Risk Methods Document for additional information (DOE 2016).
[b] Not all percent contribution totals in the table add up to 100%, due to rounding.

Table D.36. ELCRs for the Outdoor Worker Exposed to Surface Soil[a]

EU	COPC	EPC (mg/kg or pCi/g)	Ingestion	Dermal	Inhalation	External Exposure	Total ELCR	% Contribution across All Pathways[b]
1	Chromium	2.04E+01			1.67E-07		1.67E-07	1%
1	Cesium-137	6.12E-01	3.29E-08		3.11E-12	3.98E-06	4.01E-06	25%
1	Neptunium-237	5.91E-01	6.51E-08		1.01E-09	1.71E-06	1.77E-06	11%
1	Plutonium-239/240	8.44E+00	2.27E-06		2.79E-08	5.96E-09	2.30E-06	14%
1	Thorium-230	3.89E+01	6.68E-06		7.92E-08	1.11E-07	6.87E-06	42%
1	Uranium-238	2.04E+00	2.55E-07		2.89E-09	8.21E-07	1.08E-06	7%
1	Totals		9.30E-06		2.78E-07	6.62E-06	**1.62E-05**	
1	% Contribution within a Pathway		57%		2%	41%		
2	Chromium	3.82E+01			3.12E-07		3.12E-07	1%
2	PCB, Total	1.19E+01	2.59E-05	2.66E-05	5.23E-07		5.30E-05	87%
2	Uranium-234	9.01E+00	1.02E-06		1.49E-08	7.70E-09	1.04E-06	2%
2	Uranium-235	5.11E-01	5.67E-08		7.62E-10	9.95E-07	1.05E-06	2%
2	Uranium-238	9.86E+00	1.23E-06		1.39E-08	3.96E-06	5.21E-06	9%
2	Totals		2.82E-05	2.66E-05	8.65E-07	4.97E-06	**6.06E-05**	
2	% Contribution within a Pathway[b]		46%	44%	1%	8%		
3	Chromium	1.78E+01			1.45E-07		1.45E-07	0%
3	PCB, Total	9.29E+00	2.02E-05	2.08E-05	4.08E-07		4.13E-05	83%
3	Total PAH	4.14E-01	3.28E-06	3.14E-06	4.43E-11		6.42E-06	13%
3	Uranium-238	3.92E+00	4.89E-07		5.54E-09	1.57E-06	2.07E-06	4%
3	Totals		2.39E-05	2.39E-05	5.59E-07	1.57E-06	**4.99E-05**	
3	% Contribution within a Pathway		48%	48%	1%	3%		
4	Chromium	8.15E+01			6.66E-07		6.66E-07	2%
4	PCB, Total	6.44E+00	1.40E-05	1.44E-05	2.83E-07		2.86E-05	98%
4	Totals		1.40E-05	1.44E-05	9.49E-07		**2.93E-05**	
4	% Contribution within a Pathway		48%	49%	3%			
5	PCB, Total	2.70E-01	5.86E-07	6.03E-07	1.19E-08		1.20E-06	44%
5	Total PAH	9.83E-02	7.79E-07	7.45E-07	1.05E-11		1.52E-06	56%
5	Totals		1.37E-06	1.35E-06	1.19E-08		**2.72E-06**	
5	% Contribution within a Pathway[b]		50%	49%	0%			

[a] See Risk Methods Document for additional information (DOE 2016).
[b] Not all percent contribution totals in the table add up to 100%, due to rounding.

Table D.37. ELCRs for the Outdoor Worker Exposed to Surface and Subsurface Soil[a]

EU	COPC	EPC (mg/kg or pCi/g)	Ingestion	Dermal	Inhalation	External Exposure	Total ELCR	% Contribution across All Pathways[b]
1	Arsenic	7.43E+00	1.21E-05	2.67E-06	3.11E-09		1.48E-05	38%
1	Chromium	2.64E+01			2.16E-07		2.16E-07	1%
1	Cobalt	1.04E+01			9.09E-09		9.09E-09	0%
1	Total PAH	4.53E-01	3.59E-06	3.43E-06	4.85E-11		7.02E-06	18%
1	Cesium-137	8.74E-01	4.69E-08		4.44E-12	5.68E-06	5.73E-06	15%
1	Neptunium-237	5.72E-01	6.30E-08		9.80E-10	1.65E-06	1.72E-06	4%
1	Plutonium-239/240	8.19E+00	2.20E-06		2.71E-08	5.78E-09	2.23E-06	6%
1	Thorium-230	3.58E+01	6.14E-06		7.28E-08	1.02E-07	6.32E-06	16%
1	Uranium-238	2.57E+00	3.20E-07		3.63E-09	1.03E-06	1.36E-06	3%
1	Totals		2.45E-05	6.10E-06	3.33E-07	8.48E-06	**3.94E-05**	
1	% Contribution within a Pathway		62%	15%	1%	22%		
2	Arsenic	7.76E+00	1.26E-05	2.79E-06	3.25E-09		1.54E-05	20%
2	Chromium	3.87E+01			3.17E-07		3.17E-07	0%
2	PCB, Total	8.68E+00	1.88E-05	1.94E-05	3.81E-07		3.86E-05	49%
2	Total PAH	1.22E+00	9.70E-06	9.27E-06	1.31E-10		1.90E-05	24%
2	Uranium-234	6.16E+00	6.99E-07		1.02E-08	5.27E-09	7.14E-07	1%
2	Uranium-235	3.40E-01	3.77E-08		5.07E-10	6.62E-07	7.00E-07	1%
2	Uranium-238	6.72E+00	8.39E-07		9.51E-09	2.70E-06	3.55E-06	5%
2	Totals		4.28E-05	3.14E-05	7.22E-07	3.37E-06	**7.83E-05**	
2	% Contribution within a Pathway		55%	40%	1%	4%		
3	Arsenic	6.89E+00	1.12E-05	2.47E-06	2.88E-09		1.37E-05	31%
3	Chromium	4.58E+01			3.75E-07		3.75E-07	1%
3	PCB, Total	4.60E+00	1.00E-05	1.03E-05	2.02E-07		2.05E-05	46%
3	Total PAH	4.07E-01	3.23E-06	3.08E-06	4.36E-11		6.31E-06	14%
3	Cesium-137	2.30E-01	1.23E-08		1.17E-12	1.50E-06	1.51E-06	3%
3	Uranium-238	3.92E+00	4.89E-07		5.54E-09	1.57E-06	2.07E-06	5%
3	Totals		2.49E-05	1.58E-05	5.85E-07	3.07E-06	**4.45E-05**	
3	% Contribution within a Pathway		56%	36%	1%	7%		
4	Chromium	7.09E+01			5.80E-07		5.80E-07	18%
4	PCB, Total	9.24E-02	2.01E-07	2.06E-07	4.06E-09		4.11E-07	13%
4	Cesium-137	3.37E-01	1.81E-08		1.71E-12	2.19E-06	2.21E-06	69%
4	Totals		2.19E-07	2.06E-07	5.84E-07	2.19E-06	**3.20E-06**	
4	% Contribution within a Pathway[b]		7%	6%	18%	68%		
5	Arsenic	1.67E+01	2.72E-05	6.00E-06	6.99E-09		3.32E-05	92%
5	Cobalt	1.43E+01			1.25E-08		1.25E-08	0%
5	PCB, Total	2.70E-01	5.86E-07	6.03E-07	1.19E-08		1.20E-06	3%
5	Total PAH	9.83E-02	7.79E-07	7.45E-07	1.05E-11		1.52E-06	4%
5	Totals		2.86E-05	7.35E-06	3.14E-08		**3.59E-05**	
5	% Contribution within a Pathway[b]		79%	20%	0%			

[a] See Risk Methods Document for additional information (DOE 2016).

[b] Not all percent contribution totals in the table add up to 100%, due to rounding.

Table D.38. ELCRs for the Excavation Worker Exposed to Surface and Subsurface Soil[a]

EU	COPC	EPC (mg/kg or pCi/g)	Ingestion	Dermal	Inhalation	External Exposure	Total ELCR	% Contribution across All Pathways[b]
1	Arsenic	7.43E+00	2.42E-06	5.34E-07	6.22E-10		2.96E-06	36%
1	Chromium	2.64E+01			4.32E-08		4.32E-08	1%
1	Cobalt	1.04E+01			1.82E-09		1.82E-09	0%
1	Total PAH	4.53E-01	7.18E-07	6.86E-07	9.70E-12		1.40E-06	17%
1	Cesium-137	8.74E-01	1.17E-08		1.10E-12	1.41E-06	1.42E-06	17%
1	Neptunium-237	5.72E-01	1.26E-08		1.96E-10	3.31E-07	3.43E-07	4%
1	Plutonium-239/240	8.19E+00	4.40E-07		5.43E-09	1.16E-09	4.47E-07	5%
1	Thorium-230	3.58E+01	1.23E-06		1.46E-08	2.04E-08	1.26E-06	15%
1	Uranium-238	2.57E+00	6.41E-08		7.26E-10	2.06E-07	2.71E-07	3%
1	Totals		4.90E-06	1.22E-06	6.65E-08	1.97E-06	**8.15E-06**	
1	% Contribution within a Pathway		60%	15%	1%	24%		
2	Arsenic	7.76E+00	2.53E-06	5.57E-07	6.49E-10		3.08E-06	20%
2	Chromium	3.87E+01			6.33E-08		6.33E-08	0%
2	PCB, Total	8.68E+00	3.77E-06	3.88E-06	7.62E-08		7.72E-06	49%
2	Total PAH	1.22E+00	1.94E-06	1.85E-06	2.62E-11		3.79E-06	24%
2	Uranium-234	6.16E+00	1.40E-07		2.04E-09	1.05E-09	1.43E-07	1%
2	Uranium-235	3.40E-01	7.55E-09		1.01E-10	1.32E-07	1.40E-07	1%
2	Uranium-238	6.72E+00	1.68E-07		1.90E-09	5.41E-07	7.10E-07	5%
2	Totals		8.55E-06	6.29E-06	1.44E-07	6.74E-07	**1.56E-05**	
2	% Contribution within a Pathway		55%	40%	1%	4%		
3	Arsenic	6.89E+00	2.24E-06	4.95E-07	5.76E-10		2.74E-06	31%
3	Chromium	4.58E+01			7.49E-08		7.49E-08	1%
3	PCB, Total	4.60E+00	2.00E-06	2.06E-06	4.04E-08		4.10E-06	46%
3	Total PAH	4.07E-01	6.45E-07	6.16E-07	8.71E-12		1.26E-06	14%
3	Cesium-137	2.30E-01	3.07E-09		2.90E-13	3.71E-07	3.75E-07	4%
3	Uranium-238	3.92E+00	9.77E-08		1.11E-09	3.15E-07	4.14E-07	5%
3	Totals		4.99E-06	3.17E-06	1.17E-07	6.86E-07	**8.96E-06**	
3	% Contribution within a Pathway		56%	35%	1%	8%		
4	Chromium	7.09E+01			1.16E-07		1.16E-07	16%
4	PCB, Total	9.24E-02	4.01E-08	4.13E-08	8.12E-10		8.22E-08	11%
4	Cesium-137	3.37E-01	4.49E-09		4.26E-13	5.44E-07	5.49E-07	73%
4	Totals		4.46E-08	4.13E-08	1.17E-07	5.44E-07	**7.47E-07**	
4	% Contribution within a Pathway[b]		6%	6%	16%	73%		
5	Arsenic	1.67E+01	5.44E-06	1.20E-06	1.40E-09		6.64E-06	92%
5	Cobalt	1.43E+01			2.51E-09		2.51E-09	0%
5	PCB, Total	2.70E-01	1.17E-07	1.21E-07	2.37E-09		2.40E-07	3%
5	Total PAH	9.83E-02	1.56E-07	1.49E-07	2.10E-12		3.05E-07	4%
5	Totals		5.71E-06	1.47E-06	6.28E-09		**7.19E-06**	
5	% Contribution within a Pathway[b]		79%	20%	0%			

[a] See Risk Methods Document for additional information (DOE 2016).
[b] Not all percent contribution totals in the table add up to 100%, due to rounding.

Table D.39. ELCRs for the Resident Exposed to Surface Soil[a]

EU	COPC	EPC (mg/kg or pCi/g)	Ingestion	Dermal	Inhalation	External Exposure	Total ELCR	% Contribution across All Pathways[b]
1	Chromium	2.04E+01			4.92E-07		4.92E-07	1%
1	Cesium-137	6.12E-01	2.20E-08		9.09E-12	1.74E-05	1.75E-05	44%
1	Neptunium-237	5.91E-01	9.33E-08		2.99E-09	7.56E-06	7.66E-06	19%
1	Plutonium-239/240	8.44E+00	2.15E-06		8.25E-08	2.64E-08	2.26E-06	6%
1	Thorium-230	3.89E+01	7.24E-06		2.34E-07	4.92E-07	7.96E-06	20%
1	Uranium-238	2.04E+00	4.50E-07		8.52E-09	3.63E-06	4.09E-06	10%
1	Totals		9.96E-06		8.20E-07	2.91E-05	**3.99E-05**	
1	% Contribution within a Pathway		25%		2%	73%		
2	Chromium	3.82E+01			9.21E-07		9.21E-07	1%
2	PCB, Total	1.19E+01	3.43E-05	1.12E-04	2.32E-06		1.49E-04	85%
2	Uranium-234	9.01E+00	1.49E-06		4.41E-08	3.41E-08	1.57E-06	1%
2	Uranium-235	5.11E-01	8.81E-08		2.25E-09	4.40E-06	4.49E-06	3%
2	Uranium-238	9.86E+00	2.18E-06		4.12E-08	1.76E-05	1.98E-05	11%
2	Totals		3.80E-05	1.12E-04	3.32E-06	2.20E-05	**1.76E-04**	
2	% Contribution within a Pathway[b]		22%	64%	2%	13%		
3	Chromium	1.78E+01			4.29E-07		4.29E-07	0%
3	PCB, Total	9.29E+00	2.67E-05	8.75E-05	1.81E-06		1.16E-04	82%
3	Total PAH	4.14E-01	4.35E-06	1.32E-05	1.31E-10		1.76E-05	12%
3	Uranium-238	3.92E+00	8.64E-07		1.63E-08	6.97E-06	7.85E-06	6%
3	Totals		3.19E-05	1.01E-04	2.25E-06	6.97E-06	**1.42E-04**	
3	% Contribution within a Pathway		22%	71%	2%	5%		
4	Chromium	8.15E+01			1.97E-06		1.97E-06	2%
4	PCB, Total	6.44E+00	1.85E-05	6.07E-05	1.25E-06		8.04E-05	98%
4	Totals		1.85E-05	6.07E-05	3.22E-06		**8.24E-05**	
4	% Contribution within a Pathway		22%	74%	4%			
5	PCB, Total	2.70E-01	7.77E-07	2.54E-06	5.25E-08		3.37E-06	45%
5	Total PAH	9.83E-02	1.03E-06	3.14E-06	3.11E-11		4.17E-06	55%
5	Totals		1.81E-06	5.68E-06	5.25E-08		**7.55E-06**	
5	% Contribution within a Pathway		24%	75%	1%			

[a] See Risk Methods Document for additional information (DOE 2016).
[b] Not all percent contribution totals in the table add up to 100%, due to rounding.

Table D.40. ELCRs for the Recreational User Exposed to Surface Soil[a]

EU	COPC	EPC (mg/kg or pCi/g)	Ingestion	Dermal	Inhalation	External Exposure	Total ELCR	% Contribution across All Pathways
1	Chromium	2.04E+01			4.93E-08		4.93E-08	1%
1	Cesium-137	6.12E-01	9.17E-09		9.10E-13	2.18E-06	2.19E-06	30%
1	Neptunium-237	5.91E-01	3.43E-08		2.99E-10	9.46E-07	9.81E-07	13%
1	Plutonium-239/240	8.44E+00	7.93E-07		8.26E-09	3.30E-09	8.04E-07	11%
1	Thorium-230	3.89E+01	2.66E-06		2.34E-08	6.16E-08	2.75E-06	37%
1	Uranium-238	2.04E+00	1.66E-07		8.53E-10	4.55E-07	6.21E-07	8%
1	Totals		3.66E-06		8.21E-08	3.65E-06	**7.39E-06**	
1	% Contribution within a Pathway		50%		1%	49%		
2	Chromium	3.82E+01			9.22E-08		9.22E-08	0%
2	PCB, Total	1.19E+01	1.41E-05	5.21E-05	2.32E-07		6.64E-05	94%
2	Uranium-234	9.01E+00	5.49E-07		4.42E-09	4.27E-09	5.58E-07	1%
2	Uranium-235	5.11E-01	3.24E-08		2.25E-10	5.51E-07	5.84E-07	1%
2	Uranium-238	9.86E+00	8.00E-07		4.12E-09	2.20E-06	3.00E-06	4%
2	Totals		1.55E-05	5.21E-05	3.33E-07	2.75E-06	**7.07E-05**	
2	% Contribution within a Pathway		22%	74%	0%	4%		
3	Chromium	1.78E+01			4.29E-08		4.29E-08	0%
3	PCB, Total	9.29E+00	1.10E-05	4.06E-05	1.81E-07		5.18E-05	85%
3	Total PAH	4.14E-01	1.79E-06	6.14E-06	1.31E-11		7.93E-06	13%
3	Uranium-238	3.92E+00	3.18E-07		1.64E-09	8.72E-07	1.19E-06	2%
3	Totals		1.31E-05	4.68E-05	2.25E-07	8.72E-07	**6.10E-05**	
3	% Contribution within a Pathway		22%	77%	0%	1%		
4	Chromium	8.15E+01			1.97E-07		1.97E-07	1%
4	PCB, Total	6.44E+00	7.63E-06	2.82E-05	1.25E-07		3.59E-05	99%
4	Totals		7.63E-06	2.82E-05	3.22E-07		**3.61E-05**	
4	% Contribution within a Pathway		21%	78%	1%			
5	PCB, Total	2.70E-01	3.20E-07	1.18E-06	5.26E-09		1.51E-06	44%
5	Total PAH	9.83E-02	4.25E-07	1.46E-06	3.11E-12		1.88E-06	56%
5	Totals		7.45E-07	2.64E-06	5.26E-09		**3.39E-06**	
5	% Contribution within a Pathway		22%	78%	0%			

[a] See Risk Methods Document for additional information (DOE 2016).

D.5.3.1 Systemic Toxicity (Direct Exposure to Soil)

Tables D.24 through D.33 summarize the computed HIs for soil exposure for each receptor. No total HIs greater than 1 were estimated for any scenario at SWMU 1.

D.5.3.2 Excess Lifetime Cancer Risk (Direct Exposure to Soil)

Tables D.34 through D.40 summarize the computed lifetime cancer risks for soil exposure for all receptors from all COPCs (including radionuclides). ELCRs greater than 1E-06 were estimated for the receptors listed below. Total ELCRs greater than 1E-04 are shown in italicized font.

- Industrial Worker (current),
- Industrial Worker (future),
- Outdoor Worker (exposed to surface soil),
- Outdoor Worker (exposed to surface and subsurface soil),
- Excavation Worker,
- *Future Hypothetical Residential Receptor*, and
- Recreational User.

D.5.4 RISK CHARACTERIZATION FOR RESIDENTIAL USE OF GROUNDWATER DRAWN FROM THE RGA (MODELED FROM SOIL CONCENTRATIONS)

Characterization of risks from groundwater at off-site POEs was not required because modeling from soil to groundwater was not necessary. Based on the screening, no modeling was completed for the soil constituents in SWMU 1 because concentrations of these constituents either were below screening levels or below concentrations detected at other Soils Operable Unit SWMUs/areas of concern that were subjected to modeling and shown not to reach the RGA within 1,000 years. Notably, technetium-99 concentrations at SWMU 1 were below screening levels and also were below concentrations from other SWMUs that were subjected to screening and shown not to result in an above-900 pCi/L impact in RGA groundwater. See also Appendix C.

D.5.5 LEAD ASSESSMENT

SWMU 1 did not identify lead as a COPC because the maximum detected result for each grid was below the residential screening value of 400 mg/kg. Because lead was not identified as a COPC, lead is not considered a COC.

D.5.6 DOSE ASSESSMENT

A dose assessment was performed for radionuclides (separate from the ELCR evaluation) selected as COPCs within each EU (Section D.2). Calculation of dose was performed using the following equation and screening values provided in the Risk Methods Document (DOE 2016):

$$\mathbf{Dose} = \frac{\mathbf{EPC}}{\mathbf{SSL}} \times \mathbf{Target\,Dose}$$

where:

EPC = exposure point concentration
SSL = soil screening level provided in the Risk Methods Document (DOE 2016, Table A.8)
Target Dose = The target dose upon which the SSL was based (1 mrem)

Tables D.41 and D.42 provide the results of the dose assessment.

Dose greater than 1 mrem were estimated for the following pathways for SWMU 1:

- Industrial Worker (future),
- Outdoor Worker (exposed to surface soil),
- Outdoor Worker (exposed to surface and subsurface soil),
- Excavation Worker,
- Future Hypothetical Adult Residential Receptor, and
- Future Hypothetical Child Residential Receptor.

D.5.7 IDENTIFICATION OF LAND USE SCENARIOS, PATHWAYS, MEDIA, AND COCS

This subsection outlines those chemicals, land use scenarios, exposure pathways, and media for each source area. Section D.8 presents the RGOs for each location and land use scenario.

D.5.7.1 Land Use Scenarios of Concern

To make a determination whether land use scenarios are of concern, quantitative risk and hazard results were compared to risk and hazard benchmarks for each land use scenario. The benchmarks used for this comparison were HI $\geq$ 1 and/or ELCR $\geq$ 1E-06. Land use scenarios with total HIs exceeding the benchmark of 1 are deemed land use scenarios of concern for noncancer hazard. Land use scenarios with a total ELCR exceeding the benchmark of 1E-06 are deemed land use scenarios of concern for cancer risk. The following are land uses of concern for SWMU 1.

- Industrial Worker (current) (ELCR),

- Industrial Worker (future) (ELCR),

- Outdoor Worker (exposed to surface soil) (ELCR),

- Outdoor Worker (exposed to surface and subsurface soil) (ELCR),

- Excavation Worker (ELCR),

- Future Hypothetical Residential Receptor (ELCR, the dose method incorporates age-adjusted values for the 30-year exposure duration), and

- Child Recreational User (ELCR, the dose method incorporates age-adjusted values for the 30-year exposure duration).

Table D.41. Surface Soil Dose Assessment for SWMU 1[a]

EU	COPC	EPC (pCi/g)	Dose (mrem/yr) Future Industrial Worker	Outdoor Worker (Exposed to Surface Soil)	Adult Resident	Child Resident	Adult Recreator	Teen Recreator	Child Recreator
1	Cesium-137	6.12E-01	0.4	0.3	1.2	1.2	0.1	0.1	0.2
1	Neptunium-237	5.91E-01	0.1	0.1	0.4	0.4	0.0	0.0	0.0
1	Plutonium-239/240	8.44E+00	0.1	0.7	0.3	0.7	0.0	0.0	0.1
1	Thorium-230	3.89E+01	0.5	2.8	1.2	3.3	0.1	0.1	0.3
1	Uranium-238	2.04E+00	0.0	0.1	0.2	0.2	0.0	0.0	0.0
1	**Totals**		**1.2**	**3.9**	**3.2**	**5.8**	**0.3**	**0.4**	**0.6**
2	Uranium-234	9.01E+00	0.0	0.1	0.1	0.2	0.0	0.0	0.0
2	Uranium-235	5.11E-01	0.1	0.1	0.2	0.2	0.0	0.0	0.0
2	Uranium-238	9.86E+00	0.2	0.3	0.7	0.9	0.1	0.1	0.1
2	**Totals**		**0.3**	**0.5**	**1.0**	**1.3**	**0.1**	**0.1**	**0.2**
3	Uranium-238	3.92E+00	0.1	0.1	0.3	0.4	0.0	0.0	0.0
3	**Totals**		**0.1**	**0.1**	**0.3**	**0.4**	**0.0**	**0.0**	**0.0**

[a] See Risk Methods Document for additional information (DOE 2016).

Table D.42. Subsurface Soil Dose Assessment for SWMU 1[a]

			Dose (mrem/yr)	
EU	**COPC**	**EPC (pCi/g)**	**Outdoor Worker (Exposed to Surface and Subsurface Soil)**	**Excavation Worker**
1	Cesium-137	8.74E-01	0.4	0.4
1	Neptunium-237	5.72E-01	0.1	0.1
1	Plutonium-239/240	8.19E+00	0.7	0.7
1	Thorium-230	3.58E+01	2.6	2.6
1	Uranium-238	2.57E+00	0.1	0.1
1	**Totals**		**3.8**	**3.8**
2	Uranium-234	6.16E+00	0.1	0.1
2	Uranium-235	3.40E-01	0.0	0.0
2	Uranium-238	6.72E+00	0.2	0.2
2	**Totals**		**0.4**	**0.4**
3	Cesium-137	2.30E-01	0.1	0.1
3	Uranium-238	3.92E+00	0.1	0.1
3	**Totals**		**0.2**	**0.2**
4	Cesium-137	3.37E-01	0.2	0.2
4	**Totals**		**0.2**	**0.2**

[a] See Risk Methods Document for additional information (DOE 2016).

D.5.7.2 Contaminants of Concern

To make a determination about whether contaminants are of concern, quantitative risk and hazard results over all pathways were compared to risk and hazard benchmarks for land use scenarios of concern. The benchmarks used for this comparison were HI ≥ 0.1 and/or ELCR ≥ 1E-06. COCs based on the toxicity factors listed in Attachment D3 are shown in summary tables in Section D.5.7.6.

Contaminants with chemical-specific HIs or ELCRs exceeding these benchmarks were deemed COCs. Priority COCs are contaminants where chemical-specific HI is greater than 1 or where ELCR is greater than 1E-04 for one or more scenarios. These priority COCs can be found in the summary tables in Section D.5.7.6.

D.5.7.3 Contaminants of Concern (Groundwater—Modeled from Soil)

Similarly, no priority COCs were identified (i.e., contaminants whose chemical-specific HI is greater than 1 or whose ELCR is greater than 1E-04) for domestic use of groundwater (modeled from soil) for a hypothetical future residential use of the SWMU.

D.5.7.4 Pathways of Concern

To determine whether pathways are of concern, the quantitative risks and hazards for each exposure route are summed over all contaminants and compared to benchmarks for land use scenarios of concern. The benchmarks used for this comparison were HI ≥ 0.1 and/or ELCR ≥ 1E-06. Exposure routes with HIs and ELCRs exceeding these benchmarks are considered pathways of concern (POCs). Each of the pathways included in the BHHRA is a POC for SWMU 1.

D.5.7.5 Media of Concern

Media of concern are those media that appear in at least one POC. Because they contribute to at least one POC, soil is a medium of concern for SWMU 1.

Though not quantified in this evaluation, UCRS groundwater could pose as a medium of concern under certain exposure scenarios; however, these risks were not quantified due to the high improbability of the UCRS at SWMU 1 being used as a drinking water aquifer [see Section 3.3.4.3 of the Risk Methods Document (DOE 2016)].

D.5.7.6 Summary of Risk Characterization

Tables D.43 through D.47 present summaries of the risk characterization by location considered in the BHHRA. They present land use scenarios of concern, COCs, and POCs. In addition, each table lists the following:

- Receptor risks for each land use scenario of concern;
- Percent contribution by pathway to the total risk; and
- Percent contribution each COC contributes to the total risk.

Table D.43. Summary of Risk Characterization for SWMU 1, EU 1

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Current Industrial Worker (surface soil)	**< 1E-06**	*No COCs		Ingestion Dermal Inhalation External exposure		**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Industrial Worker (surface soil)	**1.1E-05**	Cesium-137 Neptunium-237 Thorium-230 Uranium-238	51% 22% 11% 11%	Ingestion Dermal Inhalation External exposure	12% 0% 4% 84%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface soil)	**1.6E-05**	Cesium-137 Neptunium-237 Plutonium-239/240 Thorium-230 Uranium-238	25% 11% 14% 42% 7%	Ingestion Dermal Inhalation External exposure	57% 0% 2% 41%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface and subsurface soil)	**3.9E-05**	Arsenic Total PAH Cesium-137 Neptunium-237 Plutonium-239/240 Thorium-230 Uranium-238	38% 18% 15% 4% 6% 16% 3%	Ingestion Dermal Inhalation External exposure	62% 15% 1% 22%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Excavation Worker (surface and subsurface soil)	**8.2E-06**	Arsenic Total PAH Cesium-137 Thorium-230	36% 17% 17% 15%	Ingestion Dermal Inhalation External exposure	60% 15% 1% 24%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Adult Resident (surface soil)	**4.0E-05**	Cesium-137 Neptunium-237 Plutonium-239/240 Thorium-230 Uranium-238	44% 19% 6% 20% 10%	Ingestion Dermal Inhalation External exposure		**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Resident (surface soil)	See Future Adult Resident					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Table D.43. Summary of Risk Characterization for SWMU 1, EU 1 (Continued)

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Future Adult Recreational User (surface soil)	**7.4E-06**	Cesium-137 Thorium-230	30% 37%	Ingestion Dermal Inhalation External exposure		**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Teen Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Total ELCR and total HI represent total risk or hazard summed across all routes of exposure for all COPCs.
*No COCs = There are no COCs.
ELCR for Future Adult Resident and Future Child Resident are the combined lifetime scenario.
ELCR for Future Adult Recreational User, Future Teen Recreational User, and Future Child Recreational User are the combined lifetime scenario.
See Risk Methods Document for additional information (DOE 2016).

Table D.44. Summary of Risk Characterization for SWMU 1, EU 2

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Current Industrial Worker (surface soil)	**2.7E-06**	PCB, Total	84%	Ingestion Dermal Inhalation External exposure	8% 75% 2% 14%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Industrial Worker (surface soil)	**4.8E-05**	PCB, Total Uranium-235 Uranium-238	84% 3% 12%	Ingestion Dermal Inhalation External exposure	8% 75% 2% 14%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface soil)	**6.1E-05**	PCB, Total Uranium-234 Uranium-235 Uranium-238	87% 2% 2% 9%	Ingestion Dermal Inhalation External exposure	46% 44% 1% 8%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface and subsurface soil)	**7.8E-05**	Arsenic PCB, Total Total PAH Uranium-238	20% 49% 24% 5%	Ingestion Dermal Inhalation External exposure	55% 40% 1% 4%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Excavation Worker (surface and subsurface soil)	**1.6E-05**	Arsenic PCB, Total Total PAH	20% 49% 24%	Ingestion Dermal Inhalation External exposure	55% 40% 1% 4%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Adult Resident (surface soil)	**1.8E-04**	PCB, Total Uranium-234 Uranium-235 Uranium-238	85% 1% 3% 11%	Ingestion Dermal Inhalation External exposure	22% 64% 2% 13%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Resident (surface soil)	See Future Adult Resident					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Table D.44. Summary of Risk Characterization for SWMU 1, EU 2 (Continued)

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Future Adult Recreational User (surface soil)	**7.1E-05**	PCB, Total Uranium-238	94% 4%	Ingestion Dermal Inhalation External exposure	22% 74% 0% 4%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Teen Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Total ELCR and total HI represent total risk or hazard summed across all routes of exposure for all COPCs.
*No COCs = There are no COCs.
ELCR for Future Adult Resident and Future Child Resident are the combined lifetime scenario.
ELCR for Future Adult Recreational User, Future Teen Recreational User, and Future Child Recreational User are the combined lifetime scenario.
See Risk Methods Document for additional information (DOE 2016).

Table D.45. Summary of Risk Characterization for SWMU 1, EU 3

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Current Industrial Worker (surface soil)	**2.2E-06**	PCB, Total	82%	Ingestion Dermal Inhalation External exposure	9% 84% 2% 6%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Industrial Worker (surface soil)	**3.8E-05**	PCB, Total Total PAH Uranium-238	82% 12% 6%	Ingestion Dermal Inhalation External exposure	9% 84% 2% 6%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface soil)	**5.0E-05**	PCB, Total Total PAH Uranium-238	83% 13% 4%	Ingestion Dermal Inhalation External exposure	48% 48% 1% 3%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface and subsurface soil)	**4.4E-05**	Arsenic PCB, Total Total PAH Cesium-137 Uranium-238	31% 46% 14% 3% 5%	Ingestion Dermal Inhalation External exposure	56% 36% 1% 7%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Excavation Worker (surface and subsurface soil)	**9.0E-06**	Arsenic PCB, Total Total PAH	31% 46% 14%	Ingestion Dermal Inhalation External exposure	56% 35% 1% 8%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Adult Resident (surface soil)	**1.4E-04**	PCB, Total Total PAH Uranium-238	82% 12% 6%	Ingestion Dermal Inhalation External exposure	22% 71% 2% 5%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Resident (surface soil)	See Future Adult Resident					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Table D.45. Summary of Risk Characterization for SWMU 1, EU 3 (Continued)

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Future Adult Recreational User (surface soil)	**6.1E-05**	PCB, Total Total PAH Uranium-238	85% 13% 2%	Ingestion Dermal Inhalation External exposure	22% 77% 0% 1%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Teen Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Total ELCR and total HI represent total risk or hazard summed across all routes of exposure for all COPCs.
*No COCs = There are no COCs.
ELCR for Future Adult Resident and Future Child Resident are the combined lifetime scenario.
ELCR for Future Adult Recreational User, Future Teen Recreational User, and Future Child Recreational User are the combined lifetime scenario.
See Risk Methods Document for additional information (DOE 2016).

Table D.46. Summary of Risk Characterization for SWMU 1, EU 4

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Current Industrial Worker (surface soil)	**1.3E-06**	PCB, Total	96%	Ingestion Dermal Inhalation External exposure	9% 86% 6% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Industrial Worker (surface soil)	**2.3E-05**	PCB, Total	96%	Ingestion Dermal Inhalation External exposure	9% 86% 6% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface soil)	**2.9E-05**	PCB, Total	98%	Ingestion Dermal Inhalation External exposure	48% 49% 3% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface and subsurface soil)	**3.2E-06**	Cesium-137	69%	Ingestion Dermal Inhalation External exposure	7% 6% 18% 68%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Excavation Worker (surface and subsurface soil)	**< 1E-06**	*No COCs		Ingestion Dermal Inhalation External exposure		**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Adult Resident (surface soil)	**8.2E-05**	Chromium PCB, Total	2% 98%	Ingestion Dermal Inhalation External exposure	22% 74% 4% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Resident (surface soil)	See Future Adult Resident					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Table D.46. Summary of Risk Characterization for SWMU 1, EU 4 (Continued)

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Future Adult Recreational User (surface soil)	**3.6E-05**	PCB, Total	99%	Ingestion Dermal Inhalation External exposure	21% 78% 1% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Teen Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Total ELCR and total HI represent total risk or hazard summed across all routes of exposure for all COPCs.
*No COCs = There are no COCs.
ELCR for Future Adult Resident and Future Child Resident are the combined lifetime scenario.
ELCR for Future Adult Recreational User, Future Teen Recreational User, and Future Child Recreational User are the combined lifetime scenario.
See Risk Methods Document for additional information (DOE 2016).

Table D.47. Summary of Risk Characterization for SWMU 1, EU 5

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Current Industrial Worker (surface soil)	**< 1E-06**	*No COCs		Ingestion Dermal Inhalation External exposure	9% 90% 1% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Industrial Worker (surface soil)	**2.0E-06**	Total PAH	55%	Ingestion Dermal Inhalation External exposure	9% 90% 1% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface soil)	**2.7E-06**	PCB, Total Total PAH	44% 56%	Ingestion Dermal Inhalation External exposure	50% 49% 0% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface and subsurface soil)	**3.6E-05**	Arsenic PCB, Total Total PAH	92% 3% 4%	Ingestion Dermal Inhalation External exposure	79% 20% 0% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Excavation Worker (surface and subsurface soil)	**7.2E-06**	Arsenic	92%	Ingestion Dermal Inhalation External exposure	79% 20% 0% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Adult Resident (surface soil)	**7.5E-06**	PCB, Total Total PAH	45% 55%	Ingestion Dermal Inhalation External exposure	24% 75% 1% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Resident (surface soil)	See Future Adult Resident					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Table D.47. Summary of Risk Characterization for SWMU 1, EU 5 (Continued)

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Future Adult Recreational User (surface soil)	**3.4E-06**	PCB, Total Total PAH	44% 56%	Ingestion Dermal Inhalation External exposure	22% 78% 0% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Teen Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Total ELCR and total HI represent total risk or hazard summed across all routes of exposure for all COPCs.
*No COCs = There are no COCs.
ELCR for Future Adult Resident and Future Child Resident are the combined lifetime scenario.
ELCR for Future Adult Recreational User, Future Teen Recreational User, and Future Child Recreational User are the combined lifetime scenario.
See Risk Methods Document for additional information (DOE 2016).

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D.6. UNCERTAINTY IN THE RISK ASSESSMENT

Uncertainties are associated with each step of the risk assessment process. The potential effect of the uncertainties on the final risk characterization must be considered when interpreting the results of the risk characterization because a number of assumptions are made during the risk assessment. Types of uncertainties to consider are divided into four broad categories: (1) those associated with data, (2) exposure assessment, (3) toxicity assessment, and (4) risk characterization.

Specific uncertainties in each of these categories are discussed in the following sections. Magnitude of the effect of the uncertainty on the risk characterization is categorized as small, moderate, or large. Uncertainties categorized as small are assumed to not affect the risk estimates by more than one order of magnitude; those categorized as moderate are assumed to affect the risk estimates by between one and two orders of magnitude, and uncertainties categorized as large are assumed to affect the risk estimate by more than two orders of magnitude.

In evaluating these uncertainties and their estimated effect on the risk estimates, it should be remembered that the following uncertainties are neither independent nor mutually exclusive; therefore, the total effect of all uncertainties on the risk estimates (i.e., total ELCRs and HIs) is not necessarily the sum of the estimated effects.

D.6.1 UNCERTAINTIES ASSOCIATED WITH DATA AND DATA EVALUATION

The purpose of data evaluation is to determine which constituents, if any, are present at concentrations requiring evaluation in the risk assessment. Uncertainty with respect to data evaluation can arise from many sources, such as the quality of data used to characterize the site and the process used to select data and COPCs used in the risk assessment.

Since many of the detection limits for XRF data are above background concentrations (see Appendix B) and possibly NALs, the COPCs identified using these data are expected to overstate the presence of these metals. The potential uncertainty associated with this issue is small.

COPCs were selected for each EU for those analytes that were detected above background and where maximum detected value is greater than the NAL [Risk Methods Document (DOE 2016) for the child residential scenario]. For those analytes that never were detected within an EU, even if the detection limit is greater than the NAL [including nondetected results from PCB test kits (see Appendix B for additional information)], the analyte was not considered a COPC. Uncertainties are associated with this assumption. To assist in evaluating this uncertainty, the maximum detection limit was used as an EPC and hazard and ELCR calculated for the nondetected analyses. Attachment D5 presents the results of these calculations. The potential uncertainty associated with this assumption is small.

The use of historical data in addition to data collected during the RI is an uncertainty. As noted earlier, these data were added to the data set to augment the information collected during the RI. Use of these data is consistent with current EPA guidelines (EPA 1989). No statistical determination was performed to see if historical data and data collected during the remedial investigation were comparable; however, the estimated effect of this uncertainty on this risk assessment is assumed to be small.

The full range of background was not considered beyond the initial screening against site-specific background. Further, surface soil background levels were used for all but the outdoor worker (exposed to surface and subsurface soil) and the excavation worker, where subsurface soil background levels were used for screening to determine COPCs. If sample data used in determining COPCs for the outdoor worker (exposed to surface and subsurface soil) and the excavation worker actually were collected from the surface, the inappropriate background value was used for comparison. The potential uncertainty associated with this assumption is small.

Some SQLs for the data are above screening levels. Since nondetect results were used at their SQL in determining EPCs, the potential uncertainty for the high SQL is small.

Finally, uncertainties exist whenever survey-type data (i.e., XRF and PCB test kits) are combined with fixed-base laboratory data. Results of the risk assessment potentially could be underestimated if actual detections were reported as nondetects. Conversely, results of the risk assessment potentially could be overestimated, if detections were reported higher by the XRF and/or PCB test kits than by the fixed-base laboratory. In either case, the potential uncertainty for the use of survey-type data combined with fixed-base laboratory is assumed to be small.

D.6.2 UNCERTAINTIES ASSOCIATED WITH EXPOSURE ASSESSMENT

Uncertainties associated with dermal absorption have been included in Section 6.5.

Significant uncertainty exists in the exposure assumptions used to calculate chemical intakes from exposure to various media (e.g., rate of soil ingestion, frequency and duration of exposure, absorption through the skin). Conservative (i.e., health protective) exposure factors are used when information available is limited in the form of using RME exposure assumptions as per the draft update of the Risk Methods Document (DOE 2016). This may result in an overestimation of potential ELCRs and HIs; this potential uncertainty is moderate.

D.6.3 UNCERTAINTIES ASSOCIATED WITH TOXICITY ASSESSMENT

Uncertainty is involved in characterizing EPCs for environmental media under future conditions in this BHHRA. In calculating the EPCs at SWMU 1, the concentrations of COPCs are kept constant throughout the exposure period. That is, the risk assessment does not consider that concentrations of some COCs may be lower or higher in the future because of processes such as degradation and attenuation. Because the COCs driving risk at SWMU 1 is not expected to degrade significantly throughout a lifetime, the effect of this uncertainty is estimated to be small.

A second uncertainty is the potential risk that may develop as COPCs in media at SWMU 1 migrate to groundwater below the SWMU and are transported off-site. To address this uncertainty, results from a fate and transport model were used to estimate potential contributions from SWMU 1 to a POE for groundwater exposure away at the source boundary (see Appendix C). Based on the screening, no modeling was completed for the soil constituents in SWMU 1 because concentrations of these constituents either were below screening levels or below concentrations detected at other Soils OU SWMUs/areas of concern that were subjected to modeling and shown not to reach the RGA within 1,000 years. Generally, the estimated effect for most of the modeling uncertainties is moderate to small, indicating that the ELCR and HI estimates generated using the modeled concentrations can be expected to vary by less than an order of magnitude.

Additional information regarding uncertainties associated with toxicity assessment can be found in Section D.4.2.

D.6.4 UNCERTAINTIES ASSOCIATED WITH RISK CHARACTERIZATION

The potential risk of adverse health effects is characterized based on potential exposures to COPCs and potential dose-response relationships for the COPCs. Two important additional sources of uncertainty are introduced in this phase of the BHHRA: (1) the evaluation of potential simultaneous exposure to multiple chemicals and (2) the combination of upper-bound exposure estimates with upper-bound toxicity estimates.

As prescribed by the Risk Methods Document (DOE 2016), after potential exposures and potential risks from each COPC are calculated, the total potential upper-bound risk and HI associated with each receptor scenario are calculated by combining the estimated potential health risk from each COPC for each scenario. For virtually all combinations of chemicals, little if any evidence of interaction is available, and synergistic/antagonistic effects and magnitude of effects cannot be addressed; therefore, additivity is assumed. For noncarcinogenic effects, this is equivalent to the assumption of simple similar action. Whether assuming additivity can lead to an underestimation or overestimation of risk is unknown. The general consensus is that the effect of this uncertainty is small to moderate.

Additionally, some uncertainty is associated with adding risks from chemical exposure to those from exposure to radionuclides. Because SWMU 1 has multiple chemicals and radionuclides driving risk and these COCs have differing endpoints, the effect of this uncertainty could be moderate.

Though not quantified in this evaluation, UCRS groundwater could pose as a medium of concern under certain exposure scenarios; however, these risks were not quantified due to the high improbability of the UCRS at SWMU 1 being used as a drinking water aquifer (DOE 2016).

D.6.5 UNCERTAINTIES ASSOCIATED WITH DERMAL ABSORPTION

Due to the circumstances presented in Section D.4.2.1, Development of Dermal Toxicity Factors, Attachment D4 has been developed. Attachment D4 presents summaries of the risk characterization by location considered for metals in the BHHRA, as an analysis using an alternative approach to that described in the Risk Methods Document to incorporate recent guidance. The alternative approach considers dermal absorption for all metals because RAGS Part E lists ABS values for all metals except arsenic and cadmium as zero. The summaries presented in Attachment D4 are similar to those presented in Tables D.43 through and D.47. They present land use scenarios of concern, COCs, and POCs. In addition, each table lists the following:

- Receptor risks for each land use scenario of concern;
- Percent contribution by pathway to the total risk; and
- Percent contribution each COC contributes to the total risk.

Because the effects of this uncertainty are large, they have been considered further in selection of COCs. This COCs selection is provided in Section D.7.4.2.

D.6.6 UNCERTAINTIES ASSOCIATED WITH MUTAGENIC EFFECTS

Evaluation of risk is performed using equations found in the Risk Methods Document. These equations do not take mutagenic effects into consideration. Although not quantified, these effects are expected to have a small effect, lowering the risk characterized for the child resident and child recreator for those COPCs considered mutagens. Screening for COPCs (i.e., COPCs determination) utilize child resident

NALs (see Attachment D1), which do include adjustments for mutagenic effects because they are derived using RAIS. Therefore, mutagenic effects were considered in COPC identification.

D.6.7 SUMMARY OF UNCERTAINTIES

The large number of assumptions used in the risk assessment could introduce a great deal of uncertainty. While it is theoretically possible that this leads to underestimates of potential risk, the use of numerous upper-bound assumptions most likely results in conservative estimates of potential risks. Any individual's potential exposure and subsequent potential risk are influenced by their individual exposure and toxicity parameters and will vary on a case-by-case basis. Despite inevitable uncertainties associated with the steps used to derive potential risks, the use of numerous health-protective assumptions most likely will result in a protective estimate of potential health risks for receptors that could be exposed to site contaminants at EUs evaluated in this Soils OU RI Addendum.

D.7. CONCLUSIONS

This section summarizes the results of the BHHRA and draws conclusions from the results. The primary purpose of this section is to provide a concise summary of each of the BHHRA steps without the use of tables, extensive explanations, or justifications. This section also includes a series of observations in which the results of the BHHRA are combined with the uncertainties in the risk assessment.

D.7.1 CHEMICALS OF POTENTIAL CONCERN

COPCs were selected from soil data collected in historical data and post-Southwest Plume remediation recharacterization sampling from the OREIS database. This data set was screened to produce final COPCs lists aggregated by location.

Through a series of screening steps, which follow the Risk Methods Document (DOE 2016) and regulatory agency approved procedures (e.g., *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Parts A and B* (EPA 1989; EPA 1991, respectively) and *Region 4 Human Health Risk Assessment Supplemental Guidance*, EPA Region 4, Web site version last updated January 2014 (Draft Final) (EPA 2014), the data sets were reduced to lists of COPCs for SWMU 1.

D.7.2 EXPOSURE ASSESSMENT

Historical information and newly collected data were used to develop a CSM. After consideration of the available data and scope of the SI, the potential receptor population under current conditions at the source units is industrial workers, and the potential receptor populations under future conditions are industrial workers, excavation workers, and residents.

Industrial Worker

Incidental ingestion of surface soil
Dermal contact with surface soil
Inhalation of vapors emitted by surface soil
External exposure to ionizing radiation in surface soil

Outdoor Worker Exposed to Surface Soil

Incidental ingestion of surface soil
Dermal contact with surface soil
Inhalation of vapors emitted by surface soil
External exposure to ionizing radiation in surface soil

Outdoor Worker and Excavation Worker Exposed to Surface and Subsurface Soil

Incidental ingestion of surface and subsurface soil
Dermal contact with surface and subsurface soil
Inhalation of vapors emitted by surface and subsurface soil
External exposure to ionizing radiation in surface and subsurface soil

Future Resident

Incidental ingestion of surface soil
Dermal contact with surface soil
Inhalation of vapors emitted by surface soil
External exposure to ionizing radiation in surface soil
Ingestion of groundwater[2]
Dermal contact with groundwater while showering[2]
Inhalation of vapors emitted by groundwater during household use/showering[2] and
Inhalation of vapors indoors from transport from subsurface VOCs[2]

Recreational User

Incidental ingestion of surface soil
Dermal contact with surface soil
Inhalation of vapors emitted by surface soil
External exposure to ionizing radiation in surface soil

After selection of the exposure routes, CDIs were calculated using standard exposure models. Most parameters used in models were default values.

D.7.3 TOXICITY ASSESSMENT

The toxicity values used in the risk assessment were taken from the latest update of the Risk Methods Document (DOE 2016). After compiling toxicity information, the all of the COPCs had a toxicity value available for one or more routes of exposure (see Section D.3.5.2).

D.7.4 RISK CHARACTERIZATION

Quantitative risks were computed by integrating the CDIs tabulated from the exposure assessment and toxicity values calculated from the toxicity assessment. The quantitative risks indicate elevated risks associated with exposure to subsurface soil and surface soil. Significant findings are summarized below.

D.7.4.1 Land Use Scenarios of Concern

A list of land uses of concern for SWMU 1 is shown in Section D.5.7.1. The list shows that each land use is a concern.

D.7.4.2 Contaminants of Concern for Soil

To determine use scenarios of concern, risk characterization results for cumulative systemic toxicity (HI) and cumulative risk (ELCR) are compared to benchmarks of 1.0 and 1E-06, respectively. Use scenarios with cumulative HI or cumulative ELCR exceeding either of these benchmarks is deemed use scenarios of concern. To make a determination about whether contaminants are of concern, quantitative risk and hazard results over all pathways were compared to risk and hazard benchmarks for land use scenarios of concern, with the alternative evaluation approach described in Section D.6.5 considered. The benchmarks

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[2] The groundwater investigation was limited to contaminants that might arise from the soil 0-16 ft bgs at SWMU 1. The risk assessment does not consider actual TCE and Tc-99 contaminant concentrations in the groundwater underlying the SWMU.

used for this comparison were (a) 0.1 for a chemical-specific HQ and (b) 1E-06 for a chemical-specific ELCR.

In the subsections that follow, all COPCs are listed that meet the benchmarks above in the HI and ELCR calculations (Tables D.24–D.33 and D.34–D.40, respectively). After considering this list, including an evaluation of additional potential COCs based on dermal absorption assumptions (see Section D.6.5 and Attachment D4), contaminants with chemical-specific HQs or ELCRs exceeding these benchmarks were deemed COCs.

Priority COCs are identified to highlight those COCs contributing most to cumulative HI and ELCR for each SWMU 1 EU. Priority COCs are contaminants deemed COCs where chemical-specific HQ is greater than 1 or where chemical-specific ELCR is greater than 1E-04 for one or more scenarios. The priority COCs found in soil at SWMU 1 are summarized in the subsections that follow.

The chemical-specific benchmark for ELCR is set at 1E-06; however, many of the COPCs listed in Appendix D, Tables D.34 through D.40, correspond to individual risks less than 1E-06 for the particular receptor evaluated. Nevertheless, these individual risk values are summed to get the cumulative risk values shown in these tables, as well as in Tables D.43 through D.47 and Attachment D4.

As calculated and shown in Tables D.43−D.47, COCs for all exposure scenarios for SWMU 1 include those listed below. Uncertainty calculations, shown in Attachment D4, list several additional metals as COCs for the excavation worker and outdoor worker exposed to surface and subsurface soil. However, because the primary route of exposure for these metals is dermal and not ingestion, the calculation does not support addition of any COCs to the SWMU.

In SWMU 1 surface soil, there were no COCs for systemic toxicity; COCs for ELCR include arsenic, chromium, Total PAHs, Total PCBs, cesium-137, neptunium-237, plutonium-239/240, thorium-230, uranium-234, uranium-235, and uranium-238. In subsurface soil, COCs are arsenic, uranium, Total PAHs, Total PCBs, cesium-137, neptunium-237, plutonium-239/240, thorium-230, and uranium-238. The entire list of COCs is provided with the RGOs in Section D.8.

Priority COCs are located in EUs 2 and 3. These are for Total PCBs, residential exposure to surface soil.

D.7.4.3 Contaminants of Concern for Soils Potentially Contributing to Groundwater Contamination

The investigation was limited to contaminants that might arise from the surface to subsurface soil to 10 ft bgs or 16 ft bgs at infrastructure, such as pipelines, at SWMU 1. It was not necessary to model soil; therefore, there were no COCs for soils potentially contributing to groundwater contamination. The risk assessment does not consider TCE and Tc-99 contamination currently in the groundwater underlying the SWMU.

D.7.4.4 Pathways of Concern

Each of the pathways included in the BHHRA is a POC.

D.7.4.5 Media of Concern

Media of concern are those media that appear in at least one POC. Because they contribute to at least one POC, soil is a media of concern at SWMU 1.

D.7.5 OBSERVATIONS

Consistent with regulatory guidance and the Risk Methods Document (DOE 2016), this BHHRA presents ELCRs and HIs for land use scenarios representing current use, as well as for several hypothetical future uses. Risk evaluation of surface soil was conducted for SWMU 1 as part of the evaluation of the scenarios specified in the work plan. The scenarios described in the BHHRA are as follows:

- Current industrial use (e.g., site maintenance)—direct contact with surface soil (soil 0–1 ft bgs).
- Future on-site industrial use—direct contact with surface soil (soil 0–1 ft bgs).
- On-site outdoor use—direct contact with surface soil (soil 0–1 ft bgs).
- On-site outdoor use—direct contact with surface and subsurface soil (soil 0–16 ft bgs).
- On-site excavation worker—direct contact with surface and subsurface soil (soil 0–16 ft bgs).
- Future hypothetical on-site resident—direct contact with surface soil (soil 0–1 ft bgs) and use of groundwater drawn from the RGA at source areas. (Note: Actual contaminant concentrations in groundwater underlying the SWMU were not considered in the BHHRA.)
- Recreational use—direct contact with surface soil (soil 0–1 ft bgs).

Specific observations for this BHHRA are presented in Table D.48.

Table D.48. Summary of Direct Contact Risks for SWMU 1

		Direct Contact*		
EU	**Scenario**	**Total HI**	**Total ELCR**	**Total Dose (mrem/yr)**
1	Future Industrial Worker	< 1	**1.1E-05**	1.2
2	Future Industrial Worker	< 1	**4.8E-05**	0.3
3	Future Industrial Worker	< 1	**3.9E-05**	0.1
4	Future Industrial Worker	< 1	**2.3E-05**	< 0.1
5	Future Industrial Worker	< 1	**2.1E-06**	< 0.1

Bold indicates total HI > 1 or total ELCR > 1E-06; ***bold italics*** indicates total HI > 3 or total ELCR > 1E-04.
*For direct contact, future industrial worker is presented because SWMU 1 is inside the limited area. Total HI and Total ELCR represent the cumulative value across all exposure routes assessed within this BHHRA (i.e., incidental ingestion, dermal contact, inhalation, and external exposure to ionizing radiation).
Only total dose above 0.1 mrem/year is summarized.
See Risk Methods Document for additional information (DOE 2016).

D.8. REMEDIAL GOAL OPTIONS

This section presents RGOs for the COCs identified in this BHHRA and the methods used to calculate the RGOs. These RGOs should not be interpreted as being clean-up goals, but as risk-based values that may be used to guide the development of clean-up goals by risk managers. Cleanup goals will be determined in later decision documents.

RGOs were calculated for each COC based on targets presented in the Risk Methods Document (DOE 2016) and consistent with EPA guidance (EPA 2014). Target risks for the RGOs were 1E-04, 1E-05, and 1E-06. Target hazards were 0.1, 1, and 3. Additionally for dose, RGOs were calculated for 1, 12, and 25 mrem/yr, based on benchmarks presented in the Risk Methods Document (DOE 2016).

D.8.1 CALCULATION OF RGOS

EPA guidance directs that RGOs are to be calculated for all COCs identified in a BHHRA (EPA 1991). The COCs identified in this risk assessment and their RGOs are presented in Tables D.49 and D.50.

Table D.49. RGOs for SWMU 1

EU	COC	EPC	Units	ELCR	RGO at ELCR=1E-6	RGO at ELCR=1E-5	RGO at ELCR=1E-4	HI	RGO at HI=0.1	RGO at HI=1	RGO at HI=3
Industrial Worker Soil Exposure											
1	Cesium-137	6.12E-01	pCi/g	5.4E-06	1.14E-01	1.14E+00	1.14E+01	N/A	N/A	N/A	N/A
1	Neptunium-237	5.91E-01	pCi/g	2.3E-06	2.55E-01	2.55E+00	2.55E+01	N/A	N/A	N/A	N/A
1	Thorium-230	3.89E+01	pCi/g	1.2E-06	3.25E+01	3.25E+02	3.25E+03	N/A	N/A	N/A	N/A
1	Uranium-238	2.04E+00	pCi/g	1.1E-06	1.78E+00	1.78E+01	1.78E+02	N/A	N/A	N/A	N/A
2	PCB, Total	1.19E+01	mg/kg	4.0E-05	2.95E-01	2.95E+00	2.95E+01	N/A	N/A	N/A	N/A
2	Uranium-235	5.11E-01	pCi/g	1.4E-06	3.78E-01	3.78E+00	3.78E+01	N/A	N/A	N/A	N/A
2	Uranium-238	9.86E+00	pCi/g	5.5E-06	1.78E+00	1.78E+01	1.78E+02	N/A	N/A	N/A	N/A
3	PCB, Total	9.29E+00	mg/kg	3.1E-05	2.95E-01	2.95E+00	2.95E+01	N/A	N/A	N/A	N/A
3	Total PAH	4.14E-01	mg/kg	4.7E-06	8.81E-02	8.81E-01	8.81E+00	N/A	N/A	N/A	N/A
3	Uranium-238	3.92E+00	pCi/g	2.2E-06	1.78E+00	1.78E+01	1.78E+02	N/A	N/A	N/A	N/A
4	PCB, Total	6.44E+00	mg/kg	2.2E-05	2.95E-01	2.95E+00	2.95E+01	N/A	N/A	N/A	N/A
5	Total PAH	9.83E-02	mg/kg	1.1E-06	8.81E-02	8.81E-01	8.81E+00	N/A	N/A	N/A	N/A
Outdoor Worker Surface Soil Exposure											
1	Cesium-137	6.12E-01	pCi/g	4.0E-06	1.53E-01	1.53E+00	1.53E+01	N/A	N/A	N/A	N/A
1	Neptunium-237	5.91E-01	pCi/g	1.8E-06	3.33E-01	3.33E+00	3.33E+01	N/A	N/A	N/A	N/A
1	Plutonium-239/240	8.44E+00	pCi/g	2.3E-06	3.67E+00	3.67E+01	3.67E+02	N/A	N/A	N/A	N/A
1	Thorium-230	3.89E+01	pCi/g	6.9E-06	5.67E+00	5.67E+01	5.67E+02	N/A	N/A	N/A	N/A
1	Uranium-238	2.04E+00	pCi/g	1.1E-06	1.89E+00	1.89E+01	1.89E+02	N/A	N/A	N/A	N/A
2	PCB, Total	1.19E+01	mg/kg	5.3E-05	2.25E-01	2.25E+00	2.25E+01	N/A	N/A	N/A	N/A
2	Uranium-234	9.01E+00	pCi/g	1.0E-06	8.62E+00	8.62E+01	8.62E+02	N/A	N/A	N/A	N/A
2	Uranium-235	5.11E-01	pCi/g	1.1E-06	4.86E-01	4.86E+00	4.86E+01	N/A	N/A	N/A	N/A
2	Uranium-238	9.86E+00	pCi/g	5.2E-06	1.89E+00	1.89E+01	1.89E+02	N/A	N/A	N/A	N/A
3	PCB, Total	9.29E+00	mg/kg	4.1E-05	2.25E-01	2.25E+00	2.25E+01	N/A	N/A	N/A	N/A
3	Total PAH	4.14E-01	mg/kg	6.4E-06	6.45E-02	6.45E-01	6.45E+00	N/A	N/A	N/A	N/A
3	Uranium-238	3.92E+00	pCi/g	2.1E-06	1.89E+00	1.89E+01	1.89E+02	N/A	N/A	N/A	N/A
4	PCB, Total	6.44E+00	mg/kg	2.9E-05	2.25E-01	2.25E+00	2.25E+01	N/A	N/A	N/A	N/A
5	PCB, Total	2.70E-01	mg/kg	1.2E-06	2.25E-01	2.25E+00	2.25E+01	N/A	N/A	N/A	N/A
5	Total PAH	9.83E-02	mg/kg	1.5E-06	6.45E-02	6.45E-01	6.45E+00	N/A	N/A	N/A	N/A

Table D.49. RGOs for SWMU 1 (Continued)

EU	COC	EPC	Units	ELCR	RGO at ELCR=1E-6	RGO at ELCR=1E-5	RGO at ELCR=1E-4	HI	RGO at HI=0.1	RGO at HI=1	RGO at HI=3
Excavation Worker Surface and Subsurface Soil Exposure											
1	Arsenic	7.43E+00	mg/kg	3.0E-06	2.51E+00	2.51E+01	2.51E+02	< 1	N/A	N/A	N/A
1	Total PAH	4.53E-01	mg/kg	1.4E-06	3.23E-01	3.23E+00	3.23E+01	N/A	N/A	N/A	N/A
1	Cesium-137	8.74E-01	pCi/g	1.4E-06	6.14E-01	6.14E+00	6.14E+01	N/A	N/A	N/A	N/A
1	Thorium-230	3.58E+01	pCi/g	1.3E-06	2.83E+01	2.83E+02	2.83E+03	N/A	N/A	N/A	N/A
2	Arsenic	7.76E+00	mg/kg	3.1E-06	2.51E+00	2.51E+01	2.51E+02	< 1	N/A	N/A	N/A
2	PCB, Total	8.68E+00	mg/kg	7.7E-06	1.12E+00	1.12E+01	1.12E+02	N/A	N/A	N/A	N/A
2	Total PAH	1.22E+00	mg/kg	3.8E-06	3.23E-01	3.23E+00	3.23E+01	N/A	N/A	N/A	N/A
3	Arsenic	6.89E+00	mg/kg	2.7E-06	2.51E+00	2.51E+01	2.51E+02	N/A	N/A	N/A	N/A
3	PCB, Total	4.60E+00	mg/kg	4.1E-06	1.12E+00	1.12E+01	1.12E+02	N/A	N/A	N/A	N/A
3	Total PAH	4.07E-01	mg/kg	1.3E-06	3.23E-01	3.23E+00	3.23E+01	N/A	N/A	N/A	N/A
5	Arsenic	1.67E+01	mg/kg	6.6E-06	2.51E+00	2.51E+01	2.51E+02	< 1	N/A	N/A	N/A
Outdoor Worker Surface and Subsurface Soil Exposure											
1	Arsenic	7.43E+00	mg/kg	1.5E-05	5.03E-01	5.03E+00	5.03E+01	< 1	N/A	N/A	N/A
1	Total PAH	4.53E-01	mg/kg	7.0E-06	6.45E-02	6.45E-01	6.45E+00	N/A	N/A	N/A	N/A
1	Cesium-137	8.74E-01	pCi/g	5.7E-06	1.53E-01	1.53E+00	1.53E+01	N/A	N/A	N/A	N/A
1	Neptunium-237	5.72E-01	pCi/g	1.7E-06	3.33E-01	3.33E+00	3.33E+01	N/A	N/A	N/A	N/A
1	Plutonium-239/240	8.19E+00	pCi/g	2.2E-06	3.67E+00	3.67E+01	3.67E+02	N/A	N/A	N/A	N/A
1	Thorium-230	3.58E+01	pCi/g	6.3E-06	5.67E+00	5.67E+01	5.67E+02	N/A	N/A	N/A	N/A
1	Uranium-238	2.57E+00	pCi/g	1.4E-06	1.89E+00	1.89E+01	1.89E+02	N/A	N/A	N/A	N/A
2	Arsenic	7.76E+00	mg/kg	1.5E-05	5.03E-01	5.03E+00	5.03E+01	< 1	N/A	N/A	N/A
2	PCB, Total	8.68E+00	mg/kg	3.9E-05	2.25E-01	2.25E+00	2.25E+01	N/A	N/A	N/A	N/A
2	Total PAH	1.22E+00	mg/kg	1.9E-05	6.45E-02	6.45E-01	6.45E+00	N/A	N/A	N/A	N/A
2	Uranium-238	6.72E+00	pCi/g	3.6E-06	1.89E+00	1.89E+01	1.89E+02	N/A	N/A	N/A	N/A
3	Arsenic	6.89E+00	mg/kg	1.4E-05	5.03E-01	5.03E+00	5.03E+01	< 1	N/A	N/A	N/A
3	PCB, Total	4.60E+00	mg/kg	2.0E-05	2.25E-01	2.25E+00	2.25E+01	N/A	N/A	N/A	N/A
3	Total PAH	4.07E-01	mg/kg	6.3E-06	6.45E-02	6.45E-01	6.45E+00	N/A	N/A	N/A	N/A
3	Cesium-137	2.30E-01	pCi/g	1.5E-06	1.53E-01	1.53E+00	1.53E+01	N/A	N/A	N/A	N/A
3	Uranium-238	3.92E+00	pCi/g	2.1E-06	1.89E+00	1.89E+01	1.89E+02	N/A	N/A	N/A	N/A
4	Cesium-137	3.37E-01	pCi/g	2.2E-06	1.53E-01	1.53E+00	1.53E+01	N/A	N/A	N/A	N/A
5	Arsenic	1.67E+01	mg/kg	3.3E-05	5.03E-01	5.03E+00	5.03E+01	< 1	N/A	N/A	N/A
5	PCB, Total	2.70E-01	mg/kg	1.2E-06	2.25E-01	2.25E+00	2.25E+01	N/A	N/A	N/A	N/A
5	Total PAH	9.83E-02	mg/kg	1.5E-06	6.45E-02	6.45E-01	6.45E+00	N/A	N/A	N/A	N/A

Table D.49. RGOs for SWMU 1 (Continued)

EU	COC	EPC	Units	ELCR	RGO at ELCR=1E-6	RGO at ELCR=1E-5	RGO at ELCR=1E-4	HI	RGO at HI=0.1	RGO at HI=1	RGO at HI=3
Recreational User Soil Exposure											
1	Cesium-137	6.12E-01	pCi/g	2.2E-06	2.79E-01	2.79E+00	2.79E+01	N/A	N/A	N/A	N/A
1	Thorium-230	3.89E+01	pCi/g	2.7E-06	1.42E+01	1.42E+02	1.42E+03	N/A	N/A	N/A	N/A
2	PCB, Total	1.19E+01	mg/kg	6.6E-05	1.79E-01	1.79E+00	1.79E+01	N/A	N/A	N/A	N/A
2	Uranium-238	9.86E+00	pCi/g	3.0E-06	3.29E+00	3.29E+01	3.29E+02	N/A	N/A	N/A	N/A
3	PCB, Total	9.29E+00	mg/kg	5.2E-05	1.79E-01	1.79E+00	1.79E+01	N/A	N/A	N/A	N/A
3	Total PAH	4.14E-01	mg/kg	7.9E-06	5.22E-02	5.22E-01	5.22E+00	N/A	N/A	N/A	N/A
3	Uranium-238	3.92E+00	pCi/g	1.2E-06	3.29E+00	3.29E+01	3.29E+02	N/A	N/A	N/A	N/A
4	PCB, Total	6.44E+00	mg/kg	3.6E-05	1.79E-01	1.79E+00	1.79E+01	N/A	N/A	N/A	N/A
5	PCB, Total	2.70E-01	mg/kg	1.5E-06	1.79E-01	1.79E+00	1.79E+01	N/A	N/A	N/A	N/A
5	Total PAH	9.83E-02	mg/kg	1.9E-06	5.22E-02	5.22E-01	5.22E+00	N/A	N/A	N/A	N/A
Hypothetical Residential User Soil Exposure											
1	Cesium-137	6.12E-01	pCi/g	1.7E-05	3.51E-02	3.51E-01	3.51E+00	N/A	N/A	N/A	N/A
1	Neptunium-237	5.91E-01	pCi/g	7.7E-06	7.72E-02	7.72E-01	7.72E+00	N/A	N/A	N/A	N/A
1	Plutonium-239/240	8.44E+00	pCi/g	2.3E-06	3.73E+00	3.73E+01	3.73E+02	N/A	N/A	N/A	N/A
1	Thorium-230	3.89E+01	pCi/g	8.0E-06	4.89E+00	4.89E+01	4.89E+02	N/A	N/A	N/A	N/A
1	Uranium-238	2.04E+00	pCi/g	4.1E-06	4.99E-01	4.99E+00	4.99E+01	N/A	N/A	N/A	N/A
2	PCB, Total	1.19E+01	mg/kg	1.5E-04	8.00E-02	8.00E-01	8.00E+00	N/A	N/A	N/A	N/A
2	Uranium-234	9.01E+00	pCi/g	1.6E-06	5.73E+00	5.73E+01	5.73E+02	N/A	N/A	N/A	N/A
2	Uranium-235	5.11E-01	pCi/g	4.5E-06	1.14E-01	1.14E+00	1.14E+01	N/A	N/A	N/A	N/A
2	Uranium-238	9.86E+00	pCi/g	2.0E-05	4.99E-01	4.99E+00	4.99E+01	N/A	N/A	N/A	N/A
3	PCB, Total	9.29E+00	mg/kg	1.2E-04	8.00E-02	8.00E-01	8.00E+00	N/A	N/A	N/A	N/A
3	Total PAH	4.14E-01	mg/kg	1.8E-05	2.36E-02	2.36E-01	2.36E+00	N/A	N/A	N/A	N/A
3	Uranium-238	3.92E+00	pCi/g	7.9E-06	4.99E-01	4.99E+00	4.99E+01	N/A	N/A	N/A	N/A
4	Chromium	8.15E+01	mg/kg	2.0E-06	4.14E+01	4.14E+02	4.14E+03	< 1	N/A	N/A	N/A
4	PCB, Total	6.44E+00	mg/kg	8.0E-05	8.00E-02	8.00E-01	8.00E+00	N/A	N/A	N/A	N/A
5	PCB, Total	2.70E-01	mg/kg	3.4E-06	8.00E-02	8.00E-01	8.00E+00	N/A	N/A	N/A	N/A
5	Total PAH	9.83E-02	mg/kg	4.2E-06	2.36E-02	2.36E-01	2.36E+00	N/A	N/A	N/A	N/A

Grayed cells indicate EPC value is lower than RGO value or an RGO value is not applicable.
N/A = Not applicable because the COC was not applicable (i.e., the COC was of concern for HI but not ELCR or it was of concern for ELCR but not HI).
See Risk Methods Document for additional information (DOE 2016).

Table D.50. Dose RGOs for SWMU 1

EU	COC	EPC	RGO at 1 mrem/yr	RGO at 12 mrem/yr	RGO at 25 mrem/yr	Units
Industrial Worker Exposure to Surface Soil						
	No COCs with Dose > 1 mrem/yr					
Outdoor Worker Exposure to Surface Soil						
1	Thorium-230	3.89E+01	1.40E+01	N/A	N/A	pCi/g
Outdoor Worker Exposure to Surface and Subsurface Soil						
1	Thorium-230	3.58E+01	1.40E+01	N/A	N/A	pCi/g
Excavation Worker Exposure to Surface and Subsurface Soil						
1	Thorium-230	3.58E+01	1.40E+01	N/A	N/A	pCi/g
Adult Recreational User Exposure to Surface Soil						
	No COCs with Dose > 1 mrem/yr					
Teen Recreational User Exposure to Surface Soil						
	No COCs with Dose > 1 mrem/yr					
Child Recreational User Exposure to Surface Soil						
	No COCs with Dose > 1 mrem/yr					
Adult Resident Exposure to Surface Soil						
1	Cesium-137	6.12E-01	5.14E-01	N/A	N/A	pCi/g
1	Thorium-230	3.89E+01	3.34E+01	N/A	N/A	pCi/g
Child Resident Exposure to Surface Soil						
1	Cesium-137	6.12E-01	5.14E-01	N/A	N/A	pCi/g
1	Thorium-230	3.89E+01	1.19E+01	N/A	N/A	pCi/g

N/A = not applicable because the EPC value is lower than the RGO value.
See Risk Methods Document for additional information (DOE 2016).

These COCs were calculated using the following equation:

$$\frac{\textbf{Concentration}}{\textbf{Risk}} = \frac{\textbf{RGO}}{\textbf{Target Risk}}$$

where:

Concentration is the exposure concentration for the medium.
Risk is the risk posed by exposure to the contaminated medium.
RGO is the RGO.
Target Risk is one of the values listed in Tables D.49 and D.50.

D.8.2 PRESENTATION OF RGOS

The equation developed in the previous subsection was applied for each soil COC. The RGOs developed for all COCs using this equation are presented in Table D.49. Grayed cells in Table D.49 indicate the EPC value is lower than the RGO value, or an RGO value is not applicable. RGOs for dose are presented in Table D.50.

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ATTACHMENT D1

NO ACTION LEVEL SCREENING VALUES

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D1. NO ACTION LEVEL SCREENING VALUES

The Risk Methods Document (RMD) identifies those constituents considered potential chemicals and radionuclides of potential concern (COPCs) at the Paducah Gaseous Diffusion Plant (PGDP) and tabulates their no action levels (NALs) (see Table A.4 of the RMD) (DOE 2016). Additionally, 13 constituents [acetone, benzoic acid, butyl benzyl phthalate, carbon disulfide, chlorobenzene, m,p-cresol (also known as cresols), 1,2-dichlorobenzene, di-n-butyl phthalate (also known as dibutyl phthalate), phenol, 2-methylnaphthalene, methylene chloride, n-nitrosodiphenylamine, and cobalt-60] were detected in samples evaluated for Solid Waste Management Unit (SWMU) 1 for which previously there were no tabulated child residential NALs or background values.

Because the residential NAL is used in the risk assessment for identification of potential COPCs, it was necessary to develop child resident NALs consistent with the approach documented in the RMD to identify COPCs in the risk assessment. The noncancer NAL is based on the child resident (hazard index of 0.1) and the NAL for carcinogens is based on the aggregate resident (26-year exposure) (excess lifetime cancer risk of 1E-06).

These NALs are presented in Table D1.1. Screened against these values, these 13 constituents would not be COPCs.

Table D1.1. Additional No Action Level Screening Values

Chemical Abstract Number	Analyte	Units	Residential (Child)		
			Hazard	Cancer	NAL
67641	Acetone	mg/kg	6.07E+03	N/A	6.07E+03
65850	Benzoic Acid	mg/kg	1.43E+04	N/A	1.43E+04
85687	Butyl Benzyl Phthalate	mg/kg	7.15E+02	1.10E+02	1.10E+02
75150	Carbon disulfide	mg/kg	7.68E+01	N/A	7.68E+01
108907	Chlorobenzene	mg/kg	2.77E+01	N/A	2.77E+01
1319773	Cresols	mg/kg	3.58E+02	N/A	3.58E+02
95501	1,2-Dichlorobenzene	mg/kg	1.81E+02	N/A	1.81E+02
84742	Di-n-butyl phthalate	mg/kg	3.58E+02	N/A	3.58E+02
91576	2-Methylnaphthalene	mg/kg	1.23E+01	N/A	1.23E+01
75092	Methylene chloride	mg/kg	3.50E+01	5.69E+01	3.50E+01
86306	n-Nitrosodiphenylamine	mg/kg	7.15E+01	4.25E+01	4.25E+01
108952	Phenol	mg/kg	1.07E+03	N/A	1.07E+03
10198400	Cobalt-60	pCi/g	N/A	7.21E-02	7.21E-02

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ATTACHMENT D2

PROUCL OUTPUT

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UCL Statistics for Uncensored Full Data Sets

Exposure Unit 1

User Selected Options	
Date/Time of Computation	ProUCL 5.17/20/2016 12:34:47 PM
From File	ProUCLInput-Surface.xls
Full Precision	OFF
Confidence Coefficient	95%
umber of Bootstrap Operations	2000

Cesium-137

General Statistics

Total Number of Observations	14	Number of Distinct Observations	5
		Number of Missing Observations	0
Minimum	0.00271	Mean	0.396
Maximum	0.753	Median	0.396
SD	0.186	Std. Error of Mean	0.0497
Coefficient of Variation	0.47	Skewness	-0.0859

Normal GOF Test

Shapiro Wilk Test Statistic	0.763	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.874	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.357	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.226	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.484	95% Adjusted-CLT UCL (Chen-1995)	0.476
		95% Modified-t UCL (Johnson-1978)	0.483

Gamma GOF Test

A-D Test Statistic	2.674	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.75	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.463	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.233	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.569	k star (bias corrected MLE)	1.28
Theta hat (MLE)	0.252	Theta star (bias corrected MLE)	0.309
nu hat (MLE)	43.93	nu star (bias corrected)	35.85
MLE Mean (bias corrected)	0.396	MLE Sd (bias corrected)	0.35
		Approximate Chi Square Value (0.05)	23.15
Adjusted Level of Significance	0.0312	Adjusted Chi Square Value	21.8

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.613	95% Adjusted Gamma UCL (use when n<50)	0.651

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.494	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.874	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.457	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.226	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-5.911	Mean of logged Data	-1.279
Maximum of Logged Data	-0.284	SD of logged Data	1.392

Assuming Lognormal Distribution

95% H-UCL	2.816	90% Chebyshev (MVUE) UCL	1.469
95% Chebyshev (MVUE) UCL	1.839	97.5% Chebyshev (MVUE) UCL	2.352
99% Chebyshev (MVUE) UCL	3.361		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.477	95% Jackknife UCL	0.484
95% Standard Bootstrap UCL	0.475	95% Bootstrap-t UCL	0.48
95% Hall's Bootstrap UCL	0.496	95% Percentile Bootstrap UCL	0.471
95% BCA Bootstrap UCL	0.471		
90% Chebyshev(Mean, Sd) UCL	0.545	95% Chebyshev(Mean, Sd) UCL	0.612
97.5% Chebyshev(Mean, Sd) UCL	0.706	99% Chebyshev(Mean, Sd) UCL	0.89

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	0.612

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be reliable. Chen's and Johnson's methods provide adjustments for positively skewed data sets.

Chromium

General Statistics

Total Number of Observations	14	Number of Distinct Observations	8
		Number of Missing Observations	0
Minimum	10.3	Mean	17.75
Maximum	34	Median	18.38
SD	5.626	Std. Error of Mean	1.504
Coefficient of Variation	0.317	Skewness	1.735

Normal GOF Test

Shapiro Wilk Test Statistic	0.774	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.874	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.341	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.226	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	20.41	95% Adjusted-CLT UCL (Chen-1995)	20.97
		95% Modified-t UCL (Johnson-1978)	20.53

Gamma GOF Test

A-D Test Statistic	1.005	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.734	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.297	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.229	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	12.44	k star (bias corrected MLE)	9.818
Theta hat (MLE)	1.427	Theta star (bias corrected MLE)	1.808
nu hat (MLE)	348.2	nu star (bias corrected)	274.9
MLE Mean (bias corrected)	17.75	MLE Sd (bias corrected)	5.665
		Approximate Chi Square Value (0.05)	237.5
Adjusted Level of Significance	0.0312	Adjusted Chi Square Value	232.9

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	20.54	95% Adjusted Gamma UCL (use when n<50)	20.95

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.865	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.874	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.283	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.226	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	2.332	Mean of logged Data	2.836
Maximum of Logged Data	3.526	SD of logged Data	0.291

Assuming Lognormal Distribution

95% H-UCL	20.7	90% Chebyshev (MVUE) UCL	21.89
95% Chebyshev (MVUE) UCL	23.78	97.5% Chebyshev (MVUE) UCL	26.4
99% Chebyshev (MVUE) UCL	31.56		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	20.22	95% Jackknife UCL	20.41
95% Standard Bootstrap UCL	20.1	95% Bootstrap-t UCL	21.09
95% Hall's Bootstrap UCL	33.43	95% Percentile Bootstrap UCL	20.35
95% BCA Bootstrap UCL	20.87		
90% Chebyshev(Mean, Sd) UCL	22.26	95% Chebyshev(Mean, Sd) UCL	24.3
97.5% Chebyshev(Mean, Sd) UCL	27.14	99% Chebyshev(Mean, Sd) UCL	32.71

Suggested UCL to Use

95% Student's-t UCL	20.41	or 95% Modified-t UCL	20.53

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Neptunium-237

General Statistics

Total Number of Observations	14	Number of Distinct Observations	5
		Number of Missing Observations	0
Minimum	0.00148	Mean	0.176
Maximum	0.663	Median	0.176
SD	0.156	Std. Error of Mean	0.0417
Coefficient of Variation	0.888	Skewness	2.421

Normal GOF Test

Shapiro Wilk Test Statistic	0.607	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.874	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.429	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.226	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.25	95% Adjusted-CLT UCL (Chen-1995)	0.273
		95% Modified-t UCL (Johnson-1978)	0.254

Gamma GOF Test

A-D Test Statistic	2.141	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.76	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.417	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.235	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.007	k star (bias corrected MLE)	0.838
Theta hat (MLE)	0.175	Theta star (bias corrected MLE)	0.21
nu hat (MLE)	28.18	nu star (bias corrected)	23.48
MLE Mean (bias corrected)	0.176	MLE Sd (bias corrected)	0.192
		Approximate Chi Square Value (0.05)	13.45
Adjusted Level of Significance	0.0312	Adjusted Chi Square Value	12.45

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.307	95% Adjusted Gamma UCL (use when n<50)	0.331

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.676	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.874	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.431	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.226	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-6.516	Mean of logged Data	-2.312
Maximum of Logged Data	-0.411	SD of logged Data	1.538

Assuming Lognormal Distribution

95% H-UCL	1.611	90% Chebyshev (MVUE) UCL	0.664
95% Chebyshev (MVUE) UCL	0.839	97.5% Chebyshev (MVUE) UCL	1.082
99% Chebyshev (MVUE) UCL	1.559		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.244	95% Jackknife UCL	0.25
95% Standard Bootstrap UCL	0.242	95% Bootstrap-t UCL	0.288
95% Hall's Bootstrap UCL	0.57	95% Percentile Bootstrap UCL	0.256
95% BCA Bootstrap UCL	0.268		
90% Chebyshev(Mean, Sd) UCL	0.301	95% Chebyshev(Mean, Sd) UCL	0.358
97.5% Chebyshev(Mean, Sd) UCL	0.436	99% Chebyshev(Mean, Sd) UCL	0.591

Suggested UCL to Use

99% Chebyshev (Mean, Sd) UCL	0.591

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Plutonium-239/240

General Statistics

Total Number of Observations	14	Number of Distinct Observations	5
		Number of Missing Observations	0
Minimum	0.0186	Mean	3.065
Maximum	9.05	Median	3.065
SD	2.021	Std. Error of Mean	0.54
Coefficient of Variation	0.659	Skewness	1.779

Normal GOF Test

Shapiro Wilk Test Statistic	0.614	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.874	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.429	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.226	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	4.021	95% Adjusted-CLT UCL (Chen-1995)	4.228
		95% Modified-t UCL (Johnson-1978)	4.064

Gamma GOF Test

A-D Test Statistic	2.942	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.756	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.463	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.234	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.199	k star (bias corrected MLE)	0.99
Theta hat (MLE)	2.555	Theta star (bias corrected MLE)	3.096
nu hat (MLE)	33.58	nu star (bias corrected)	27.72
MLE Mean (bias corrected)	3.065	MLE Sd (bias corrected)	3.08
		Approximate Chi Square Value (0.05)	16.71
Adjusted Level of Significance	0.0312	Adjusted Chi Square Value	15.58

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	5.084	95% Adjusted Gamma UCL (use when n<50)	5.452

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.55	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.874	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.468	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.226	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-3.985	Mean of logged Data	0.648
Maximum of Logged Data	2.203	SD of logged Data	1.534

Assuming Lognormal Distribution

95% H-UCL	30.64	90% Chebyshev (MVUE) UCL	12.71
95% Chebyshev (MVUE) UCL	16.06	97.5% Chebyshev (MVUE) UCL	20.71
99% Chebyshev (MVUE) UCL	29.84		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	3.953	95% Jackknife UCL	4.021
95% Standard Bootstrap UCL	3.917	95% Bootstrap-t UCL	4.295
95% Hall's Bootstrap UCL	8.976	95% Percentile Bootstrap UCL	3.928
95% BCA Bootstrap UCL	4.339		
90% Chebyshev(Mean, Sd) UCL	4.685	95% Chebyshev(Mean, Sd) UCL	5.419
97.5% Chebyshev(Mean, Sd) UCL	6.438	99% Chebyshev(Mean, Sd) UCL	8.439

Suggested UCL to Use

99% Chebyshev (Mean, Sd) UCL	8.439

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Thorium-230

General Statistics

Total Number of Observations	14	Number of Distinct Observations	5
		Number of Missing Observations	0
Minimum	1.06	Mean	22.15
Maximum	65	Median	22.15
SD	14.41	Std. Error of Mean	3.851
Coefficient of Variation	0.651	Skewness	1.823

Normal GOF Test

Shapiro Wilk Test Statistic	0.613	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.874	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.429	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.226	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	28.97	95% Adjusted-CLT UCL (Chen-1995)	30.49
		95% Modified-t UCL (Johnson-1978)	29.28

Gamma GOF Test

A-D Test Statistic	2.829	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.749	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.429	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.232	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.677	k star (bias corrected MLE)	1.366
Theta hat (MLE)	13.2	Theta star (bias corrected MLE)	16.22
nu hat (MLE)	46.96	nu star (bias corrected)	38.23
MLE Mean (bias corrected)	22.15	MLE Sd (bias corrected)	18.95
		Approximate Chi Square Value (0.05)	25.07
Adjusted Level of Significance	0.0312	Adjusted Chi Square Value	23.67

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	33.77	95% Adjusted Gamma UCL (use when n<50)	35.78

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.593	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.874	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.453	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.226	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	0.0583	Mean of logged Data	2.771
Maximum of Logged Data	4.174	SD of logged Data	1.089

Assuming Lognormal Distribution

95% H-UCL	70.2	90% Chebyshev (MVUE) UCL	53.17
95% Chebyshev (MVUE) UCL	64.94	97.5% Chebyshev (MVUE) UCL	81.28
99% Chebyshev (MVUE) UCL	113.4		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	28.48	95% Jackknife UCL	28.97
95% Standard Bootstrap UCL	28.38	95% Bootstrap-t UCL	30.93
95% Hall's Bootstrap UCL	63.49	95% Percentile Bootstrap UCL	28.46
95% BCA Bootstrap UCL	31.14		
90% Chebyshev(Mean, Sd) UCL	33.7	95% Chebyshev(Mean, Sd) UCL	38.94
97.5% Chebyshev(Mean, Sd) UCL	46.2	99% Chebyshev(Mean, Sd) UCL	60.47

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	38.94

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Uranium-238

General Statistics			
Total Number of Observations	14	Number of Distinct Observations	5
		Number of Missing Observations	0
Minimum	0.894	Mean	1.783
Maximum	3.31	Median	1.783
SD	0.545	Std. Error of Mean	0.146
Coefficient of Variation	0.305	Skewness	1.268
Normal GOF Test			
Shapiro Wilk Test Statistic	0.673	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.874	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.357	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.226	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	2.041	95% Adjusted-CLT UCL (Chen-1995)	2.075
		95% Modified-t UCL (Johnson-1978)	2.049
Gamma GOF Test			
A-D Test Statistic	2.345	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.734	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.396	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.229	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	11.87	k star (bias corrected MLE)	9.372
Theta hat (MLE)	0.15	Theta star (bias corrected MLE)	0.19
nu hat (MLE)	332.3	nu star (bias corrected)	262.4
MLE Mean (bias corrected)	1.783	MLE Sd (bias corrected)	0.582
		Approximate Chi Square Value (0.05)	225.9
Adjusted Level of Significance	0.0312	Adjusted Chi Square Value	221.4
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	2.071	95% Adjusted Gamma UCL (use when n<50)	2.113
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.698	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.874	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.412	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.226	Data Not Lognormal at 5% Significance Level	
Data Not Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	-0.112	Mean of logged Data	0.536
Maximum of Logged Data	1.197	SD of logged Data	0.309

Assuming Lognormal Distribution

95% H-UCL	2.11	90% Chebyshev (MVUE) UCL	2.234
95% Chebyshev (MVUE) UCL	2.437	97.5% Chebyshev (MVUE) UCL	2.718
99% Chebyshev (MVUE) UCL	3.271		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	2.023	95% Jackknife UCL	2.041
95% Standard Bootstrap UCL	2.012	95% Bootstrap-t UCL	2.061
95% Hall's Bootstrap UCL	2.408	95% Percentile Bootstrap UCL	2.029
95% BCA Bootstrap UCL	2.047		
90% Chebyshev(Mean, Sd) UCL	2.22	95% Chebyshev(Mean, Sd) UCL	2.418
97.5% Chebyshev(Mean, Sd) UCL	2.692	99% Chebyshev(Mean, Sd) UCL	3.232

Suggested UCL to Use

95% Student's-t UCL	2.041	or 95% Modified-t UCL	2.049

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

UCL Statistics for Uncensored Full Data Sets
Exposure Unit 2

User Selected Options	
Date/Time of Computation	ProUCL 5.17/20/2016 12:36:51 PM
From File	ProUCLInput-Subsurface_a.xls
Full Precision	OFF
Confidence Coefficient	95%
umber of Bootstrap Operations	2000

Arsenic

General Statistics

Total Number of Observations	12	Number of Distinct Observations	12
		Number of Missing Observations	0
Minimum	3.92	Mean	6.493
Maximum	11.5	Median	6.1
SD	2.436	Std. Error of Mean	0.703
Coefficient of Variation	0.375	Skewness	0.824

Normal GOF Test

Shapiro Wilk Test Statistic	0.907	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.859	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.173	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.243	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	7.755	95% Adjusted-CLT UCL (Chen-1995)	7.828
		95% Modified-t UCL (Johnson-1978)	7.783

Gamma GOF Test

A-D Test Statistic	0.362	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.731	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.179	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.246	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	8.351	k star (bias corrected MLE)	6.319
Theta hat (MLE)	0.777	Theta star (bias corrected MLE)	1.028
nu hat (MLE)	200.4	nu star (bias corrected)	151.7
MLE Mean (bias corrected)	6.493	MLE Sd (bias corrected)	2.583
		Approximate Chi Square Value (0.05)	124.2
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	120.4

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	7.929	95% Adjusted Gamma UCL (use when n<50)	8.178

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.936	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.859	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.164	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.243	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	1.366	Mean of logged Data	1.81
Maximum of Logged Data	2.442	SD of logged Data	0.361

Assuming Lognormal Distribution

95% H-UCL	8.092	90% Chebyshev (MVUE) UCL	8.535
95% Chebyshev (MVUE) UCL	9.465	97.5% Chebyshev (MVUE) UCL	10.76
99% Chebyshev (MVUE) UCL	13.29		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	7.649	95% Jackknife UCL	7.755
95% Standard Bootstrap UCL	7.627	95% Bootstrap-t UCL	8.154
95% Hall's Bootstrap UCL	7.865	95% Percentile Bootstrap UCL	7.652
95% BCA Bootstrap UCL	7.709		
90% Chebyshev(Mean, Sd) UCL	8.602	95% Chebyshev(Mean, Sd) UCL	9.558
97.5% Chebyshev(Mean, Sd) UCL	10.88	99% Chebyshev(Mean, Sd) UCL	13.49

Suggested UCL to Use

95% Student's-t UCL	7.755

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Chromium

General Statistics

Total Number of Observations	12	Number of Distinct Observations	11
		Number of Missing Observations	0
Minimum	5.6	Mean	24.66
Maximum	94	Median	16.5
SD	22.82	Std. Error of Mean	6.586
Coefficient of Variation	0.925	Skewness	2.952

Normal GOF Test

Shapiro Wilk Test Statistic	0.601	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.859	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.359	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.243	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	36.49	95% Adjusted-CLT UCL (Chen-1995)	41.49
		95% Modified-t UCL (Johnson-1978)	37.43

Gamma GOF Test

A-D Test Statistic	0.979	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.741	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.255	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.248	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.295	k star (bias corrected MLE)	1.776
Theta hat (MLE)	10.75	Theta star (bias corrected MLE)	13.88
nu hat (MLE)	55.07	nu star (bias corrected)	42.63
MLE Mean (bias corrected)	24.66	MLE Sd (bias corrected)	18.5
		Approximate Chi Square Value (0.05)	28.66
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	26.93

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	36.68	95% Adjusted Gamma UCL (use when n<50)	39.05

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.885	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.859	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.209	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.243	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	1.723	Mean of logged Data	2.972
Maximum of Logged Data	4.543	SD of logged Data	0.659

Assuming Lognormal Distribution

95% H-UCL	38.74	90% Chebyshev (MVUE) UCL	37.84
95% Chebyshev (MVUE) UCL	44.22	97.5% Chebyshev (MVUE) UCL	53.07
99% Chebyshev (MVUE) UCL	70.45		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	35.5	95% Jackknife UCL	36.49
95% Standard Bootstrap UCL	34.85	95% Bootstrap-t UCL	56.53
95% Hall's Bootstrap UCL	79.34	95% Percentile Bootstrap UCL	36.64
95% BCA Bootstrap UCL	43.18		
90% Chebyshev(Mean, Sd) UCL	44.42	95% Chebyshev(Mean, Sd) UCL	53.37
97.5% Chebyshev(Mean, Sd) UCL	65.79	99% Chebyshev(Mean, Sd) UCL	90.2

Suggested UCL to Use

95% H-UCL	38.74

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
Jse of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution

Manganese

General Statistics

Total Number of Observations	12	Number of Distinct Observations	12
		Number of Missing Observations	0
Minimum	293	Mean	594.8
Maximum	902	Median	562.9
SD	198.3	Std. Error of Mean	57.24
Coefficient of Variation	0.333	Skewness	0.202

Normal GOF Test

Shapiro Wilk Test Statistic	0.953	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.859	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.136	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.243	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	697.6	95% Adjusted-CLT UCL (Chen-1995)	692.5
		95% Modified-t UCL (Johnson-1978)	698.1

Gamma GOF Test

A-D Test Statistic	0.217	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.731	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.136	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.245	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	9.383	k star (bias corrected MLE)	7.093
Theta hat (MLE)	63.39	Theta star (bias corrected MLE)	83.85
nu hat (MLE)	225.2	nu star (bias corrected)	170.2
MLE Mean (bias corrected)	594.8	MLE Sd (bias corrected)	223.3
		Approximate Chi Square Value (0.05)	141.1
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	137

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	717.8	95% Adjusted Gamma UCL (use when n<50)	739

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.961	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.859	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.118	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.243	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	5.68	Mean of logged Data	6.334
Maximum of Logged Data	6.805	SD of logged Data	0.351

Assuming Lognormal Distribution

95% H-UCL	738.5	90% Chebyshev (MVUE) UCL	779.3
95% Chebyshev (MVUE) UCL	862.4	97.5% Chebyshev (MVUE) UCL	977.7
99% Chebyshev (MVUE) UCL	1204		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	688.9	95% Jackknife UCL	697.6
95% Standard Bootstrap UCL	687.1	95% Bootstrap-t UCL	699.5
95% Hall's Bootstrap UCL	684.5	95% Percentile Bootstrap UCL	686.4
95% BCA Bootstrap UCL	683.3		
90% Chebyshev(Mean, Sd) UCL	766.5	95% Chebyshev(Mean, Sd) UCL	844.3
97.5% Chebyshev(Mean, Sd) UCL	952.2	99% Chebyshev(Mean, Sd) UCL	1164

Suggested UCL to Use

95% Student's-t UCL	697.6

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

PCB, Total

General Statistics

Total Number of Observations	12	Number of Distinct Observations	5
		Number of Missing Observations	0
Minimum	0.017	Mean	0.841
Maximum	9.5	Median	0.0335
SD	2.728	Std. Error of Mean	0.787
Coefficient of Variation	3.244	Skewness	3.461

Normal GOF Test

Shapiro Wilk Test Statistic	0.342	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.859	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.504	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.243	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	2.255	95% Adjusted-CLT UCL (Chen-1995)	2.977
		95% Modified-t UCL (Johnson-1978)	2.386

Gamma GOF Test

A-D Test Statistic	2.72	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.844	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.389	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.268	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.258	k star (bias corrected MLE)	0.249
Theta hat (MLE)	3.258	Theta star (bias corrected MLE)	3.375
nu hat (MLE)	6.195	nu star (bias corrected)	5.979
MLE Mean (bias corrected)	0.841	MLE Sd (bias corrected)	1.685
		Approximate Chi Square Value (0.05)	1.629
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	1.309

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	3.086	95% Adjusted Gamma UCL (use when n<50)	3.842

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.685	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.859	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.268	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.243	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-4.075	Mean of logged Data	-2.911
Maximum of Logged Data	2.251	SD of logged Data	1.842

Assuming Lognormal Distribution

95% H-UCL	3.868	90% Chebyshev (MVUE) UCL	0.61
95% Chebyshev (MVUE) UCL	0.785	97.5% Chebyshev (MVUE) UCL	1.029
99% Chebyshev (MVUE) UCL	1.507		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	2.136	95% Jackknife UCL	2.255
95% Standard Bootstrap UCL	2.102	95% Bootstrap-t UCL	87.93
95% Hall's Bootstrap UCL	43.56	95% Percentile Bootstrap UCL	2.406
95% BCA Bootstrap UCL	3.212		
90% Chebyshev(Mean, Sd) UCL	3.203	95% Chebyshev(Mean, Sd) UCL	4.273
97.5% Chebyshev(Mean, Sd) UCL	5.758	99% Chebyshev(Mean, Sd) UCL	8.675

Suggested UCL to Use

99% Chebyshev (Mean, Sd) UCL	8.675

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Silver

General Statistics			
Total Number of Observations	12	Number of Distinct Observations	9
		Number of Missing Observations	0
Minimum	0.029	Mean	8.307
Maximum	73.9	Median	0.291
SD	21.01	Std. Error of Mean	6.065
Coefficient of Variation	2.529	Skewness	3.27
Normal GOF Test			
Shapiro Wilk Test Statistic	0.451	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.859	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.352	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.243	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	19.2	95% Adjusted-CLT UCL (Chen-1995)	24.4
		95% Modified-t UCL (Johnson-1978)	20.15
Gamma GOF Test			
A-D Test Statistic	1.061	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.826	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.296	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.266	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.296	k star (bias corrected MLE)	0.277
Theta hat (MLE)	28.08	Theta star (bias corrected MLE)	29.94
nu hat (MLE)	7.1	nu star (bias corrected)	6.658
MLE Mean (bias corrected)	8.307	MLE Sd (bias corrected)	15.77
		Approximate Chi Square Value (0.05)	1.985
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	1.62
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	27.86	95% Adjusted Gamma UCL (use when n<50)	34.14
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.936	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.859	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.254	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.243	Data Not Lognormal at 5% Significance Level	
Data appear Approximate Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	-3.54	Mean of logged Data	-0.219
Maximum of Logged Data	4.303	SD of logged Data	2.29

Assuming Lognormal Distribution

95% H-UCL	527.3	90% Chebyshev (MVUE) UCL	20.01
95% Chebyshev (MVUE) UCL	26.15	97.5% Chebyshev (MVUE) UCL	34.67
99% Chebyshev (MVUE) UCL	51.41		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	18.28	95% Jackknife UCL	19.2
95% Standard Bootstrap UCL	18	95% Bootstrap-t UCL	71.22
95% Hall's Bootstrap UCL	65.46	95% Percentile Bootstrap UCL	19.84
95% BCA Bootstrap UCL	25.8		
90% Chebyshev(Mean, Sd) UCL	26.5	95% Chebyshev(Mean, Sd) UCL	34.75
97.5% Chebyshev(Mean, Sd) UCL	46.19	99% Chebyshev(Mean, Sd) UCL	68.66

Suggested UCL to Use

99% Chebyshev (Mean, Sd) UCL	68.66

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Total PAH

General Statistics

Total Number of Observations	12	Number of Distinct Observations	7
		Number of Missing Observations	0
Minimum	0.00634	Mean	0.479
Maximum	2.3	Median	0.36
SD	0.592	Std. Error of Mean	0.171
Coefficient of Variation	1.237	Skewness	3.065

Normal GOF Test

Shapiro Wilk Test Statistic	0.544	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.859	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.417	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.243	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.786	95% Adjusted-CLT UCL (Chen-1995)	0.921
		95% Modified-t UCL (Johnson-1978)	0.811

Gamma GOF Test

A-D Test Statistic	1.389	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.76	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.345	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.253	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.907	k star (bias corrected MLE)	0.736
Theta hat (MLE)	0.528	Theta star (bias corrected MLE)	0.65
nu hat (MLE)	21.77	nu star (bias corrected)	17.66
MLE Mean (bias corrected)	0.479	MLE Sd (bias corrected)	0.558
		Approximate Chi Square Value (0.05)	9.148
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	8.228

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.924	95% Adjusted Gamma UCL (use when n<50)	1.028

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.739	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.859	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.405	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.243	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-5.061	Mean of logged Data	-1.38
Maximum of Logged Data	0.833	SD of logged Data	1.496

Assuming Lognormal Distribution

95% H-UCL	4.449	90% Chebyshev (MVUE) UCL	1.584
95% Chebyshev (MVUE) UCL	2.005	97.5% Chebyshev (MVUE) UCL	2.589
99% Chebyshev (MVUE) UCL	3.737		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.76	95% Jackknife UCL	0.786
95% Standard Bootstrap UCL	0.745	95% Bootstrap-t UCL	1.312
95% Hall's Bootstrap UCL	2.141	95% Percentile Bootstrap UCL	0.804
95% BCA Bootstrap UCL	0.957		
90% Chebyshev(Mean, Sd) UCL	0.991	95% Chebyshev(Mean, Sd) UCL	1.224
97.5% Chebyshev(Mean, Sd) UCL	1.546	99% Chebyshev(Mean, Sd) UCL	2.179

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	1.224

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Uranium-234

	General Statistics		
Total Number of Observations	12	Number of Distinct Observations	3
		Number of Missing Observations	0
Minimum	1.69	Mean	5.35
Maximum	9.01	Median	5.35
SD	1.561	Std. Error of Mean	0.451
Coefficient of Variation	0.292	Skewness	-1.63E-15
	Normal GOF Test		
Shapiro Wilk Test Statistic	0.6	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.859	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.417	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.243	Data Not Normal at 5% Significance Level	
	Data Not Normal at 5% Significance Level		
	Assuming Normal Distribution		
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	6.159	95% Adjusted-CLT UCL (Chen-1995)	6.091
		95% Modified-t UCL (Johnson-1978)	6.159
	Gamma GOF Test		
A-D Test Statistic	2.813	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.73	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.459	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.245	Data Not Gamma Distributed at 5% Significance Level	
	Data Not Gamma Distributed at 5% Significance Level		
	Gamma Statistics		
k hat (MLE)	9.67	k star (bias corrected MLE)	7.308
Theta hat (MLE)	0.553	Theta star (bias corrected MLE)	0.732
nu hat (MLE)	232.1	nu star (bias corrected)	175.4
MLE Mean (bias corrected)	5.35	MLE Sd (bias corrected)	1.979
		Approximate Chi Square Value (0.05)	145.8
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	141.7
	Assuming Gamma Distribution		
95% Approximate Gamma UCL (use when n>=50))	6.437	95% Adjusted Gamma UCL (use when n<50)	6.625
	Lognormal GOF Test		
Shapiro Wilk Test Statistic	0.536	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.859	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.472	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.243	Data Not Lognormal at 5% Significance Level	
	Data Not Lognormal at 5% Significance Level		
	Lognormal Statistics		
Minimum of Logged Data	0.525	Mean of logged Data	1.625
Maximum of Logged Data	2.198	SD of logged Data	0.377

Assuming Lognormal Distribution

95% H-UCL	6.845	90% Chebyshev (MVUE) UCL	7.212
95% Chebyshev (MVUE) UCL	8.025	97.5% Chebyshev (MVUE) UCL	9.153
99% Chebyshev (MVUE) UCL	11.37		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	6.091	95% Jackknife UCL	6.159
95% Standard Bootstrap UCL	N/A	95% Bootstrap-t UCL	N/A
95% Hall's Bootstrap UCL	N/A	95% Percentile Bootstrap UCL	N/A
95% BCA Bootstrap UCL	N/A		
90% Chebyshev(Mean, Sd) UCL	6.702	95% Chebyshev(Mean, Sd) UCL	7.314
97.5% Chebyshev(Mean, Sd) UCL	8.163	99% Chebyshev(Mean, Sd) UCL	9.833

Suggested UCL to Use

95% Student's-t UCL	6.159	or 95% Modified-t UCL	6.159

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be reliable. Chen's and Johnson's methods provide adjustments for positively skewed data sets.

Uranium-235

General Statistics

Total Number of Observations	12	Number of Distinct Observations	3
		Number of Missing Observations	0
Minimum	0.0707	Mean	0.291
Maximum	0.511	Median	0.291
SD	0.0939	Std. Error of Mean	0.0271
Coefficient of Variation	0.323	Skewness	2.059E-15

Normal GOF Test

Shapiro Wilk Test Statistic	0.6	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.859	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.417	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.243	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.34	95% Adjusted-CLT UCL (Chen-1995)	0.335
		95% Modified-t UCL (Johnson-1978)	0.34

Gamma GOF Test

A-D Test Statistic	2.847	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.731	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.466	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.246	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	7.215	k star (bias corrected MLE)	5.467
Theta hat (MLE)	0.0403	Theta star (bias corrected MLE)	0.0532
nu hat (MLE)	173.2	nu star (bias corrected)	131.2
MLE Mean (bias corrected)	0.291	MLE Sd (bias corrected)	0.124
		Approximate Chi Square Value (0.05)	105.7
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	102.3

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.361	95% Adjusted Gamma UCL (use when n<50)	0.373

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.519	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.859	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.479	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.243	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-2.649	Mean of logged Data	-1.306
Maximum of Logged Data	-0.671	SD of logged Data	0.453

Assuming Lognormal Distribution

95% H-UCL	0.399	90% Chebyshev (MVUE) UCL	0.416
95% Chebyshev (MVUE) UCL	0.47	97.5% Chebyshev (MVUE) UCL	0.545
99% Chebyshev (MVUE) UCL	0.692		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.335	95% Jackknife UCL	0.34
95% Standard Bootstrap UCL	N/A	95% Bootstrap-t UCL	N/A
95% Hall's Bootstrap UCL	N/A	95% Percentile Bootstrap UCL	N/A
95% BCA Bootstrap UCL	N/A		
90% Chebyshev(Mean, Sd) UCL	0.372	95% Chebyshev(Mean, Sd) UCL	0.409
97.5% Chebyshev(Mean, Sd) UCL	0.46	99% Chebyshev(Mean, Sd) UCL	0.56

Suggested UCL to Use

95% Student's-t UCL	0.34	or 95% Modified-t UCL	0.34

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Uranium-238

General Statistics			
Total Number of Observations	12	Number of Distinct Observations	3
		Number of Missing Observations	0
Minimum	1.8	Mean	5.83
Maximum	9.86	Median	5.83
SD	1.718	Std. Error of Mean	0.496
Coefficient of Variation	0.295	Skewness	9.166E-16

Normal GOF Test

Shapiro Wilk Test Statistic	0.6	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.859	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.417	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.243	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	6.721	95% Adjusted-CLT UCL (Chen-1995)	6.646
		95% Modified-t UCL (Johnson-1978)	6.721

Gamma GOF Test

A-D Test Statistic	2.816	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.731	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.46	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.245	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	9.398	k star (bias corrected MLE)	7.104
Theta hat (MLE)	0.62	Theta star (bias corrected MLE)	0.821
nu hat (MLE)	225.5	nu star (bias corrected)	170.5
MLE Mean (bias corrected)	5.83	MLE Sd (bias corrected)	2.187
		Approximate Chi Square Value (0.05)	141.3
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	137.2

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	7.035	95% Adjusted Gamma UCL (use when n<50)	7.242

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.534	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.859	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.473	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.243	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	0.588	Mean of logged Data	1.709
Maximum of Logged Data	2.288	SD of logged Data	0.384

Assuming Lognormal Distribution

95% H-UCL	7.502	90% Chebyshev (MVUE) UCL	7.9
95% Chebyshev (MVUE) UCL	8.803	97.5% Chebyshev (MVUE) UCL	10.06
99% Chebyshev (MVUE) UCL	12.52		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	6.646	95% Jackknife UCL	6.721
95% Standard Bootstrap UCL	N/A	95% Bootstrap-t UCL	N/A
95% Hall's Bootstrap UCL	N/A	95% Percentile Bootstrap UCL	N/A
95% BCA Bootstrap UCL	N/A		
90% Chebyshev(Mean, Sd) UCL	7.318	95% Chebyshev(Mean, Sd) UCL	7.992
97.5% Chebyshev(Mean, Sd) UCL	8.928	99% Chebyshev(Mean, Sd) UCL	10.77

Suggested UCL to Use

95% Student's-t UCL	6.721	or 95% Modified-t UCL	6.721

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

ATTACHMENT D3

TOXICITY VALUES AND INFORMATION USED IN SWMU 1 RISK ANALYSIS AND TOXICITY PROFILES

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D3.1 TOXICITY VALUES AND INFORMATION USED IN SWMU 1 RISK ANALYSIS

Toxicity values and information for chemicals and radionuclides of potential concern used in SWMU 1 risk analysis are presented in Table D3.1.

Table D3.1. Toxicity Values and Information Used in SWMU 1 Risk Analysis*

Ana Type	Analyte	GI Absorption Factor	RfDo mg / (kg×day)	RfDd mg / (kg×day)	RfC (mg/m^3)	Sfo [mg / (kg×day)]$^{-1}$	SFos (Res) (pCi)$^{-1}$	SFos (Ind) (pCi)$^{-1}$	SFd (pCi)$^{-1}$	Sfe [(pCi × year)/g]$^{-1}$	IUR (µg/m^3)	VF Res (m^3/kg)	VF Ind (m^3/kg)	EPA ABS	Kp (cm/hr)	Lambda (year)$^{-1}$
I	Aluminum	1.00E+00	1.00E+00	1.00E+00	5.00E-03										1.00E-03	
I	Antimony	1.50E-01	4.00E-04	6.00E-05											1.00E-03	
I	Arsenic	1.00E+00	3.00E-04	3.00E-04	1.50E-05	1.50E+00			1.50E+00		4.30E-03			3.00E-02	1.00E-03	
I	Chromium	1.30E-02	1.50E+00	1.95E-02	1.00E-04						8.40E-02				1.00E-03	
I	Cobalt	1.00E+00	3.00E-04	3.00E-04	6.00E-06						9.00E-03				4.00E-04	
I	Manganese	4.00E-02	2.40E-02	9.60E-04	5.00E-05										1.00E-03	
I	Silver	4.00E-02	5.00E-03	2.00E-04											6.00E-04	
I	Thallium	1.00E+00	1.00E-05	1.00E-05											1.00E-03	
I	Vanadium	2.60E-02	5.04E-03	1.31E-04	1.00E-04										1.00E-03	
O	PCB, Total	1.00E+00				2.00E+00			2.00E+00		5.71E-04	7.85E+05	7.85E+05	1.40E-01	5.45E-01	
O	Total PAH	1.00E+00				7.30E+00			7.30E+00		1.10E-03			1.30E-01	7.13E-01	
R	Cesium-137	1.00E+00					4.26E-11	3.18E-11		2.53E-06	1.12E-10					2.30E-02
R	Neptunium-237	5.00E-04					1.41E-10	4.96E-11		8.55E-07	2.87E-08					3.23E-07
R	Plutonium-239/240	5.00E-04					2.28E-10	1.21E-10		2.09E-10	5.55E-08					2.87E-05
R	Thorium-230	5.00E-04					1.66E-10	7.73E-11		8.45E-10	3.41E-08					9.19E-06
R	Uranium-234	2.00E-02					1.48E-10	5.11E-11		2.53E-10	2.78E-08					2.82E-06
R	Uranium-235	2.00E-02					1.54E-10	5.00E-11		5.76E-07	2.50E-08					9.84E-10
R	Uranium-238	2.00E-02					1.97E-10	5.62E-11		1.19E-07	2.37E-08					1.55E-10

*These values were taken from the 2016 Risk Methods Document (DOE 2016) and verified in October 2016.

D3.2 TOXICITY PROFILES FOR INORGANIC COMPOUND SWMU 1 CONTAMINANTS OF CONCERN

D3.1.2 ARSENIC (RAIS)

Arsenic is a naturally occurring element widely distributed in the earth's crust. In the environment, arsenic is combined with oxygen, chlorine, and sulfur to form inorganic arsenic compounds. Arsenic in animals and plants combines with carbon and hydrogen to form organic arsenic compounds. Inorganic arsenic compounds are used mainly to preserve wood. Organic arsenic compounds are used as pesticides, primarily on cotton plants. Arsenic cannot be destroyed in the environment. It can change its form, only. Arsenic in air either will settle to the ground or will be washed out of the air by rain. Many arsenic compounds can dissolve in water. Fish and shellfish can accumulate arsenic, but the arsenic in fish is mostly in a form that is not harmful. The toxicity of inorganic arsenic depends on its valence state and also on the physical and chemical properties of the compound in which it occurs.

Water soluble inorganic arsenic compounds are absorbed through the gastrointestinal (GI) tract and lungs; distributed primarily to the liver, kidney, lung, spleen, aorta, and skin; and excreted mainly in the urine at rates as high as 80%. Symptoms of acute inorganic arsenic poisoning in humans are nausea, anorexia, vomiting, epigastric and abdominal pain, and diarrhea. Dermatitis (exfoliative erythroderma), muscle cramps, cardiac abnormalities, hepatotoxicity, bone marrow suppression and hematologic abnormalities (anemia), vascular lesions, and peripheral neuropathy (motor dysfunction, paresthesia) also have been reported. Oral doses as low as 20–60 µg/kg/day have been reported to cause toxic effects in some individuals. Severe exposures can result in acute encephalopathy, congestive heart failure, stupor, convulsions, paralysis, coma, and death. The acute lethal dose to humans has been estimated to be about 0.6 mg/kg/day.

General symptoms of chronic arsenic poisoning in humans are weakness, general debility and lassitude, loss of appetite and energy, loss of hair, hoarseness of voice, loss of weight, and mental disorders. Primary target organs are the skin (hyperpigmentation and hyperkeratosis), nervous system (peripheral neuropathy), and vascular system. Anemia, leukopenia, hepatomegaly, and portal hypertension also have been reported. In addition, possible reproductive effects include a high male to female birth ratio.

Epidemiological studies have revealed an association between arsenic concentrations in drinking water and increased incidences of skin cancers, as well as cancers of the liver, bladder, respiratory, and GI tracts. Occupational exposure studies have shown a clear correlation between exposure to arsenic and lung cancer mortality. Several studies have shown that inorganic arsenic can increase the risk of lung cancer, skin cancer, bladder cancer, liver cancer, kidney cancer, and prostate cancer. The World Health Organization, the DHHS, and the EPA have determined that inorganic arsenic is a human carcinogen and is classified A, human carcinogen.

Cancer slope factors for arsenic are available from EPA's IRIS. The value used in the baseline human health risk assessment (BHHRA) is 1.50E+00 $[mg/(kg \times day)]^{-1}$ for the oral and dermal exposure routes. The slope factor for the dermal exposure route was calculated by assuming a GI absorption factor of 1.0. The inhalation unit risk value used is 4.30E-03 $\mu g/m^3$.

Chronic RfDs for arsenic also are available in RAIS. The oral and dermal values used in the BHHRA were 3.00E-04 mg/(kg × day) for both. The dermal RfD was calculated by assuming a GI absorption factor of 1.0.

D3.1.4 CHROMIUM (RAIS)

Elemental chromium does not occur in nature, but it is present in ores, primarily chromite. Chromium can be found in rocks, animals, plants, soil, and in volcanic dust and gases. Chromium is present in the environment in several different forms (oxidation states). The most common forms are chromium (0), chromium (III), and chromium (VI). No taste or odor is associated with chromium compounds. Chromium (III) occurs naturally in the environment and is an essential nutrient that helps the body use sugar, protein, and fat. Chromium (VI) and chromium (0) are generally produced by industrial processes. The metal chromium, chromium (0), is used for making steel. Chromium (VI) and chromium (III) are used for chrome plating, dyes and pigments, leather tanning, and wood preserving. Chromium enters the body through the lungs, digestive tract and, to a lesser extent, the skin. Inhalation is the most important route for occupational exposure. Nonoccupational exposure occurs via ingestion of chromium-containing food and water. Breathing high levels of chromium (VI) can cause irritation to the nose, such as runny nose, nosebleeds, and ulcers and holes in the nasal septum. Ingesting large amounts of chromium (VI) can cause stomach upsets and ulcers, convulsions, kidney and liver damage, and even death. Skin contact with certain chromium (VI) compounds can cause skin ulcers. Some people are extremely sensitive to chromium (VI) or chromium (III). Allergic reactions consisting of severe redness and swelling of the skin have been noted. Several studies have shown that chromium (VI) compounds can increase the risk of lung cancer when inhaled. Animal studies have also shown an increased risk of cancer. There is also evidence for an increased risk of developing nasal, pharyngeal, and gastrointestinal carcinomas. Chromium (III) carcinogenicity is unknown. However, the classification of chromium (VI) as a known human carcinogen raises a concern for the carcinogenic potential of trivalent chromium.

The cancer inhalation unit risk for chromium (VI) from RAIS was used in the BHHRA. The value used was 8.40E-02 $\mu g/m^3$ for the inhalation route of exposure. Slope factors for the oral and dermal routes of exposure are not available for chromium(III).

Consistent with the Risk Methods Document, the chronic RfDs from RAIS associated with chromium (III) were used in the BHHRA (DOE 2016). The values used were 1.50E+00 and 1.95E-02 mg/(kg × day) for the oral and dermal routes, respectively. The dermal RfD was calculated by assuming a GI absorption factor of 1.30E-02.

D3.3 TOXICITY PROFILES FOR ORGANIC COMPOUND SWMU 1 CONTAMINANTS OF CONCERN

D3.3.1 TOTAL PAHS (RAIS)

Total PAHs are evaluated in this BHHRA by weighting the concentration of each PAH to convert it to benzo(a)pyrene equivalents as described in the 2016 Risk Methods Document and then evaluating the sum of the concentrations based on the toxicity of benzo(a)pyrene (DOE 2016). The PAHs included in this calculation for the PAH class are benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-c,d)pyrene.

Benzo(a)pyrene is one of many chemicals known as PAHs. It exists as yellowish plates and needles. Benzo(a)pyrene is practically insoluble in water but is soluble in benzene, toluene, xylene and sparingly soluble in alcohol and methanol. No current commercial production or use of benzo(a)pyrene is known. It occurs ubiquitously in products of incomplete combustion and in fossil fuels. It has been identified in surface water, tap water, rain water, groundwater, waste water, and sewage sludge. Benzo(a)pyrene is primarily released to the air and removed from the atmosphere by photochemical oxidation and dry deposition to land or water. Biodegradation is the most important transformation process in soil or sediment.

No data are available on the systemic (noncarcinogenic) effects of benzo(a)pyrene in humans. Benzo(a)pyrene is readily absorbed following inhalation, oral, and dermal routes of administration. Following inhalation exposure, benzo(a)pyrene is rapidly distributed to several tissues in rats. The metabolism of benzo(a)pyrene is complex and includes the formation of a proposed ultimate carcinogen, benzo(a)pyrene 7,8 diol-9,10-epoxide. Dietary administration of doses as low as 10 mg/kg during gestation caused reduced fertility and reproductive capacity in mice offspring, and treatment by gavage with 120 mg/kg/day during gestation caused stillbirths, resorptions, and malformations.

Numerous epidemiologic studies have shown a clear association between exposure to various mixtures of PAHs containing benzo(a)pyrene (e.g., coke oven emissions, roofing tar emissions, and cigarette smoke) and increased risk of lung cancer and other tumors. Each of the mixtures also contained other potentially carcinogenic PAHs; therefore, it is not possible to evaluate the contribution of benzo(a)pyrene to the carcinogenicity of these mixtures. Based on EPA guidelines, benzo(a)pyrene was assigned to weight-of-evidence group B2, probable human carcinogen.

Cancer slope factors for benzo(a)pyrene are available from RAIS, and are described in the section on that chemical, as are other constants used for specific PAHs.

D3.3.2 TOTAL PCBS (HIGH RISK) (RAIS)

PCBs are inert, thermally and physically stable, and have dielectric properties. In the environment, the behavior of PCB mixtures is directly correlated to the degree of chlorination. They have been used in closed systems such as heat transfer liquids, hydraulic fluids and lubricants, and in open systems such as plasticizers, surface coatings, inks, adhesives, pesticide extenders, and for microencapsulation of dyes for carbonless duplicating papers. Aroclor is strongly sorbed to soil and remains immobile when leached with water; however, the mixture is highly mobile in the presence of organic solvents. PCBs are resistant to chemical degradation by oxidation or hydrolysis. PCBs have high bioconcentration factors and tend to accumulate in the fat of fish, birds, mammals, and humans.

PCBs are absorbed after oral, inhalation, or dermal exposure and are stored in adipose tissue. The major route of PCB excretion is in the urine and feces; however, more important is the elimination in human milk. Accidental human poisonings and data from occupational exposure to PCBs suggest initial dermal and mucosal disturbances followed by systemic effects that may manifest themselves several years post-exposure. Initial effects are enlargement and hypersecretion of the Meibomian gland of the eye, swelling of the eyelids, pigmentation of the fingernails and mucous membranes, fatigue, and nausea. These effects were followed by hyperkeratosis, darkening of the skin, acneiform eruptions, edema of the arms and legs, neurological symptoms, such as headache and limb numbness, and liver disturbance.

Data are suggestive but not conclusive concerning the carcinogenicity of PCBs in humans; however, hepatocellular carcinomas in three strains of rats and two strains of mice have led the EPA to classify PCBs as group B2, probable human carcinogen.

Cancer slope factors for the total class of PCBs (based on high risk) are available from RAIS. The slope factor used in the BHHRA for the oral and dermal exposure routes is 2.00E+00 $[mg/(kg \times day)]^{-1}$. The slope factor for the dermal exposure route was calculated by assuming a GI absorption factor of 90%. The inhalation unit risk value used is 5.71E-04 $\mu g/m^3$.

Consistent with the 2016 Risk Methods Document, risks for the individual aroclors are not estimated in this BHHRA (DOE 2016).

D3.4 TOXICITY PROFILES FOR RADIONUCLIDE SWMU 1 CONTAMINANTS OF CONCERN

Radionuclides are unstable atoms of chemical elements that will emit charged particles or energy or both to achieve a more stable state. These charged particles are termed “alpha and beta radiation”; energy is termed “neutral gamma rays.” Interaction of these charged particles (and gamma rays) with matter will produce ionization events, or radiation, which may cause living cell tissue damage. Because the deposition of energy by ionizing radiation is a random process, sufficient energy may be deposited (in a critical volume) within a cell and result in cell modification or death. In addition, ionizing radiation has sufficient energy that interactions with matter will produce an ejected electron and a positively charged ion (known as free radicals) that are highly reactive and may combine with other elements, or compounds within a cell, to produce toxins or otherwise disrupt the overall chemical balance of the cell. These free radicals also can react with deoxyribonucleic acid (DNA), causing genetic damage, cancer induction, or even cell death.

Radionuclides are characterized by the type and energy level of the radiation emitted. Radiation emissions fall into two major categories: particulate (electrons, alpha particles, beta particles, and protons) or electromagnetic radiation (gamma and X-rays). Therefore, all radionuclides are classified by the EPA as Group A carcinogens based on their property of emitting ionizing radiation and on the extensive weight-of-evidence provided by epidemiological studies of humans with cancers induced by high doses of radiation. Alpha particles are emitted at a characteristic energy level for differing radionuclides. The alpha particle has a charge of +2 and a comparably large size. Alpha particles have the ability to react (and/or ionize) with other molecules, but they have very little penetrating power and lack the ability to pass through a piece of paper or human skin. However, alpha-emitting radionuclides are of concern when there is a potential for inhalation or ingestion of the radionuclide. Alpha particles are directly ionizing and deposit their energy in dense concentrations [termed high linear energy transfer (LET)], resulting in short paths of highly localized ionization reactions. The probability of cell damage increases as a result of the increase in ionization events occurring in smaller areas; this also may be the reason for increased cancer incidence caused by inhalation of radon gas. In addition, the cancer incidence in smokers may be directly attributed to the naturally occurring alpha emitter, polonium-210, in common tobacco products.

Beta emissions generally refer to beta negative particle emissions. Radionuclides with an excess of neutrons achieve stability by beta decay. Beta radiation, like alpha radiation, is directly ionizing but, unlike alpha activity, beta particles deposit their energy along a longer track length (low LET), resulting in more space between ionization events. Beta-emitting radionuclides can cause injury to the skin and superficial body tissue, but are most destructive when inhaled or ingested. Many beta emitters are similar chemically to naturally occurring essential nutrients and will, therefore, tend to accumulate in certain specific tissues. For example, strontium-90 is chemically similar to calcium and, as a result, accumulates in the bones, where it causes continuous exposure. The health effects of beta particle emissions depend upon the target organ. Those seeking the bones would cause a prolonged exposure to the bone marrow and affect blood cell formation, possibly resulting in leukemia, other blood disorders, or bone cancers. Those seeking the liver would result in liver diseases or cancer, while those seeking the thyroid would cause thyroid and metabolic disorders. In addition, beta radiation may lead to damage of genetic material (DNA), causing hereditary defects.

Gamma emissions are the energy that has been released from transformations of the atomic nucleus. Gamma emitters and x-rays behave similarly, but differ in their origin: gamma emissions originate in nuclear transformations, and x-rays result from changes in the orbiting electron structure. Radionuclides that emit gamma radiation can induce internal and external effects. Gamma rays have high penetrating ability in living tissue and are capable of reaching all internal body organs. Without such sufficient shielding as lead, concrete, or steel, gamma radiation can penetrate the body from the outside and does not require ingestion or inhalation to penetrate sensitive organs. Gamma rays are characterized as low-LET radiation, as is beta radiation; however, the behavior of beta radiation differs from that of gamma radiation in that beta particles deposit most of their energy in the medium through which they pass, while gamma rays often escape the medium because of higher energies, thereby creating difficulties in determining actual internal exposure. For this reason, direct whole-body measurements are necessary to detect gamma radiation, while urine/fecal analyses are usually effective in detecting beta radiation.

People receive gamma radiation continuously from naturally occurring radioactive decay processes going on in the earth's surface, from radiation naturally occurring inside their bodies, from the atmosphere as fallout from nuclear testing or explosions, and from space or cosmic sources. Cesium-137 (Cs-137) (from nuclear fallout) decays to barium-137, the highest contributor to fallout-induced gamma radiation. Beta radiation from the soil is a less penetrating form of radiation, but has many contributing sources. Potassium-40, Cs-137, lead-214, and bismuth-214 are among the most common environmental beta emitters. Tritium is also a beta emitter but contributes little to the soil beta radiation because of the low energy of its emission and its low concentration in the atmosphere. Alpha radiation also is emitted by the soil, but is not measurable more than a few centimeters from the ground surface. The majority of alpha emissions are attributable to radon-222 and radon-220 and their decay products. This contributes to what is called background exposure to radiation.

The general health effects of radiation can be divided into stochastic (related to dose) and nonstochastic (not related to dose) effects. The risk of development of cancer from exposure to radiation is a stochastic effect. Examples of nonstochastic effects include acute radiation syndrome and cataract formation, which occur only at high levels of exposures.

Radiation can damage cells in different ways. It can cause damage to DNA within the cell, and the cell either may not be able to recover from this type of damage or may survive but function abnormally. If an abnormally functioning cell divides and reproduces, a tumor or mutation in the tissue may develop. The rapidly dividing cells that line the intestines and stomach and the blood cells in bone marrow are extremely sensitive to this damage. Organ damage results from the damage caused to the individual cells. This type of damage has been reported with doses of 10 to 500 rads (0.1 to 5.0 gray, in SI units). Acute radiation sickness is seen only after doses of > 50 rads 0.5 gray), which is a dose rate usually achieved only in a nuclear accident.

When the radiation-damaged cells are reproductive cells, genetic damage can occur in the offspring of the person exposed. The developing fetus is especially sensitive to radiation. The type of malformation that may occur is related to the stage of fetal development and the cells that are differentiating at the time of exposure. Radiation damage to children exposed in the womb is related to the dose the pregnant mother receives. Mental retardation is a possible effect of fetal radiation exposure.

The most widely studied population that has had known exposure to radiation is the atomic bomb survivors of Hiroshima and Nagasaki, Japan. Data indicate an increase in the rate of leukemia and cancers in this population. However, the rate at which cancer incidence is significantly affected by low radiation exposures, such as results of exposure to natural background and industrially contaminated sites, is still undergoing study and is uncertain. In studies conducted to determine the rate of cancer and leukemia increase, as well as genetic defects, several radionuclides must be considered.

D3.2.2.1 Cesium-137 (EPA)

Radioactive Cs-137 is produced when uranium and plutonium absorb neutrons and undergo fission. Examples of the uses of this process are nuclear reactors and nuclear weapons. The splitting of uranium and plutonium in fission creates numerous fission products. Cs-137 is one of the more well-known fission products. Cesium, as well as Cs-137, is a soft, malleable, silvery white metal. Cesium is one of only three metals that is a liquid near room temperature (83°F). The half-life of Cs-137 is 30 years.

People may also be exposed from contaminated sites: Walking on Cs-137 contaminated soil could result in external exposure to gamma radiation. Leaving the contaminated area would prevent additional exposure. Coming in contact with waste materials at contaminated sites could also result in external exposure to gamma radiation. Leaving the area would also end the exposure. If Cs-137 contaminated soil becomes air-borne as dust, breathing the dust would result in internal exposure. Because the radiation emitting material is then in the body, leaving the site would not end the exposure. Drinking Cs-137 contaminated water, also would place the Cs-137 inside the body, where it would expose living tissue to gamma and beta radiation.

People may ingest Cs-137 with food and water, or may inhale it as dust. If Cs-137 enters the body, it is distributed fairly uniformly throughout the body's soft tissues, resulting in exposure of those tissues. Slightly higher concentrations of the metal are found in muscle, while slightly lower concentrations are found in bone and fat. Compared to some other radionuclides, Cs-137 remains in the body for a relatively short time. It is eliminated through the urine. Exposure to Cs-137 also may be external (that is, exposure to its gamma radiation from outside the body).

Like all radionuclides, exposure to radiation from Cs-137 results in increased risk of cancer. Everyone is exposed to very small amounts of Cs-137 in soil and water as a result of atmospheric fallout. Exposure to waste materials, from contaminated sites, or from nuclear accidents can result in cancer risks much higher than typical environmental exposures.

If exposures are very high, serious burns, and even death, can result. Instances of such exposure are very rare. One example of a high-exposure situation would be the mishandling a strong industrial Cs-137 source. The magnitude of the health risk depends on exposure conditions. These include such factors as strength of the source, length of exposure, distance from the source, and whether there was shielding between you and the source (such as metal plating).

Inhalation and external exposure cancer slope factors used in the BHHRA for Cs-137 are 1.12E-10 risk/pCi and 2.53E-06 risk/yr per pCi/g soil, respectively. Oral cancer slope factors used in the BHHRA were 4.26E-11 risk/pCi for the residential and recreational scenarios and 3.18E-11 risk/pCi for the industrial, excavation, and outdoor worker scenarios. A dermal cancer slope factor was not calculated because this route of exposure is not evaluated in the BHHRA. Systemic toxicity due to exposure to Cs-137 is not quantified in the BHHRA.

D3.2.2.2 Neptunium-237

Specific literary information for neptunium-237 (Np-237) is limited. However, available literature states that during neutron bombardment, Np-237 breaks down to plutonium-238 (Pu-238), which produces small masses of high capacity energy that is useful for satellites and spacecraft (Moskalev et al. 1979).

The most common route of Np-237 exposure is inhalation of aerosols. According to studies conducted on rats, acute effects include injury to the liver and kidney and circulation disorders. Long-term effects include osteosarcomas and lung cancer. Extremely high doses cause immediate or premature death by destruction of the lungs (Moskalev et al. 1979).

Inhalation and external exposure cancer slope factors used in the BHHRA for Np-237 are 2.87E-08 risk/pCi and 8.55E-07 risk/yr per pCi/g soil, respectively. Oral cancer slope factors used in the BHHRA were 1.41E-10 risk/pCi for the residential and recreational scenarios and 4.96E-11 risk/pCi for the industrial, excavation, and outdoor worker scenarios. A dermal cancer slope factor was not calculated because this route of exposure is not evaluated in the BHHRA. Oral, dermal, and inhalation RfDs are not available for this element; therefore, systemic toxicity due to exposure to Np-237 is not quantified in the BHHRA.

D3.2.2.3 Plutonium-239/240 (EPA)

Plutonium is created from uranium in nuclear reactors. When uranium-238 (U-238) absorbs a neutron, it becomes uranium-239 which ultimately decays to plutonium-239 (Pu-239). Different isotopes of uranium and different combinations of neutron absorptions and radioactive decay create different isotopes of plutonium.

Plutonium is a silvery-grey metal that becomes yellowish when exposed to air. It is solid under normal conditions, and is chemically reactive. Plutonium has at least 15 different isotopes, all of which are radioactive. The most common ones are Pu-238, Pu-239, and plutonium-240 (Pu-240). Pu-238 has a half-life of 87.7 years. Pu-239 has a half-life of 24,100, and Pu-240 has a half-life 6,560 years. The isotope Pu-238 gives off useable heat, because of its radioactivity.

Pu-239 is used to make nuclear weapons. For example, the bomb dropped on Nagasaki, Japan, in 1945, contained Pu-239. The plutonium in the bomb undergoes fission in an arrangement that assures enormous energy generation and destructive potential.

All isotopes of plutonium undergo radioactive decay. As plutonium decays, it releases radiation and forms other radioactive isotopes. For example, Pu-238 emits an alpha particle and becomes uranium-234 (U-234); Pu-239 emits an alpha particle and becomes uranium-235 (U-235). This process happens slowly since the half-lives of plutonium isotopes tend to be relatively long; Pu-238 has a half-life of 87.7 years; Pu-239 has a half-life is 24,100 years, and Pu-240 has a half-life of 6,560 years. The decay process continues until a stable, nonradioactive element is formed. Pu-239 and Pu-240 are reported together because they are difficult to differentiate in analytical tests.

People who live near nuclear weapons production or testing sites may have increased exposure to plutonium, primarily through particles in the air, but possibly from water as well. Plants growing in contaminated soil can absorb small amounts of plutonium.

People may inhale plutonium as a contaminant in dust. It also can be ingested with food or water. Most people have extremely low ingestion and inhalation of plutonium. However, people who live near government weapons production or testing facilities may have increased exposure. Plutonium exposure external to the body poses very little health risk.

The stomach does not absorb plutonium very well, and most plutonium swallowed with food or water passes from the body through the feces. When inhaled, plutonium can remain in the lungs depending upon its particle size and how well the particular chemical form dissolves. The chemical forms that dissolve less easily may lodge in the lungs or move out with phlegm, and either be swallowed or spit out. But, the lungs may absorb chemical forms that dissolve more easily and pass them into the bloodstream.

Once in the bloodstream, plutonium moves throughout the body and into the bones, liver, or other body organs. Plutonium that reaches body organs generally stays in the body for decades and continues to expose the surrounding tissue to radiation.

External exposure to plutonium poses very little health risk, since plutonium isotopes emit alpha radiation, and almost no beta or gamma radiation. In contrast, internal exposure to plutonium is an extremely serious health hazard. It generally stays in the body for decades, exposing organs and tissues to radiation, and increasing the risk of cancer. Plutonium is also a toxic metal, and may cause damage to the kidneys.

Inhalation and external exposure cancer slope factors used in the BHHRA for Pu-239/240 are 5.55E-08-risk/pCi and 2.09E-10 risk/yr per pCi/g soil, respectively. Oral cancer slope factors used in the BHHRA were 2.28E-10 risk/pCi for the residential and recreational scenarios and 1.21E-10 risk/pCi for the industrial, excavation, and outdoor worker scenarios. A dermal cancer slope factor was not calculated because this route of exposure is not evaluated in the BHHRA. Systemic toxicity due to exposure to Pu-239/240 is not quantified in the BHHRA.

D3.2.2.4 Thorium-230 (EPA and ATSDR)

Thorium (Th) is a soft, silvery white metal. Pure thorium will remain shiny for months in air, but if it contains impurities, it tarnishes to black when exposed to air. When heated, thorium oxide glows bright white, a property that makes it useful in lantern mantles. It dissolves slowly in water. Th-232 has a half-life of 14 billion (14×10^9) years, and decays by alpha emission, with accompanying gamma radiation. Th-232 is the top of a long decay series that contains key radionuclides such as radium-228, its direct decay product, and radon-220. Two other isotopes of thorium, which can be significant in the environment, are Th-230 and Th-228. Both belong to other decay series. They also decay by alpha emission, with accompanying gamma radiation, and have half-lives of 75,400 years and 1.9 years, respectively. Only a small portion of naturally occurring thorium exists as Th-230. More than 99% of natural thorium exists in the form of Th-232. Th-230 breaks down into two parts—a small part called “alpha” radiation and a large part called the decay product. The decay product also is not stable and continues to break down through a series of decay products until a stable product is formed. During these decay processes, radioactive substances are produced. These include radium and radon. These substances give off radiation, including alpha and beta particles, and gamma radiation. The half-life for Th-230 is 75,400 years.

Small amounts of thorium are present in all rocks, soil, water, plants, and animals. Soil contains an average of about 6 parts of thorium per million parts of soil (6 ppm). Where high concentrations occur in rock, thorium may be mined and refined, producing waste products such as mill tailings. If not properly controlled, wind and water can introduce the tailings into the wider environment. Commercial and federal facilities that have processed thorium also may have released thorium to the air, water, or soil. Man-made thorium isotopes are rare and almost never enter the environment.

Since thorium is naturally present in the environment, people are exposed to tiny amounts in air, food, and water. The amounts usually are very small and pose little health hazard. Thorium is also present in many consumer products such as ceramic glazes, lantern mantles, and welding rods. People who live near a facility that mines or mills thorium or manufactures products with thorium may receive higher exposures. Also, people who work with thorium in various industries may receive higher exposures.

People may inhale contaminated dust, or swallow thorium with food or water. Living near a thorium-contaminated site or working in an industry where thorium is used increases the chance of exposure to thorium.

If inhaled as dust, some thorium may remain in the lungs for long periods of time, depending on the chemical form. If ingested, thorium typically leaves the body through feces and urine within several days. The small amount of thorium left in the body will enter the bloodstream and be deposited in the bones where it may remain for many years. There is some evidence that the body may absorb thorium through the skin, but that would not likely be the primary means of entry.

The principal concern from low to moderate level exposure to ionizing radiation is increased risk of cancer. Studies have shown that inhaling thorium dust causes an increased risk of developing lung cancer and cancer of the pancreas. Bone cancer risk also is increased because thorium may be stored in bone.

Inhalation and external exposure cancer slope factors used in the BHHRA for Th-230 are 3.41E-08 risk/pCi and 8.45E-10 risk/yr per pCi/g soil, respectively. Oral cancer slope factors used in the BHHRA were 1.66E-10 risk/pCi for the residential and recreational scenarios and 7.73E-11 risk/pCi for the industrial, excavation, and outdoor worker scenarios. A dermal cancer slope factor was not calculated because this route of exposure is not evaluated in the BHHRA. Systemic toxicity due to exposure to Th-230 is not quantified in the BHHRA.

D3.2.2.5 Uranium-234, Uranium-235, Uranium-238

Uranium is an alpha-emitting, radioactive, heavy metal that occurs naturally in nearly all rocks and soils. Twenty-two isotopic forms of uranium have been identified, mainly associated with nuclear reactor operations or high-energy physics experiments; the most prevalent isotopes found in the environment are the three naturally-occurring isotopes: uranium-234 (U-234), uranium-235 (U-235), and uranium-238 (U-238). Most uranium isotopes undergo decay by alpha emission, a few undergo beta emission, and several isotopes, including U-238, also can undergo spontaneous fission. Uranium isotopes decay to daughter radioactive elements such as radium and radon (ATSDR 2013).

The rate of decay (or half-life) for most uranium isotopes is long; the half-lives of U-238, U-235 and U-234 are 4.5 billion years, 700 million years, and 250,000 years, respectively. Naturally-occurring uranium is an isotopic mixture containing 99.284% U-238, 0.711% U-235, and 0.005% U-234 by mass and 49% U-238, 2% U-235, and 49% U-234 by radioactivity (ATSDR 2013).

Chemical and radiological health effects of uranium differ based on three groupings of uranium isotope mixtures (natural uranium, enriched uranium, and depleted uranium) and the various compounds in which uranium usually is found. Like natural uranium, depleted uranium is primarily composed of U-238, but has a smaller amount of U-235 and U-234. Thus, depleted uranium is less radioactive than natural uranium (ATSDR 2013).

The preponderance of the available toxicity data comes from animal studies of natural uranium; studies over the last 20 years also have evaluated the toxicity of enriched uranium in animals and depleted uranium in military personnel with embedded depleted uranium fragments and in animals. Comparisons across studies provide evidence that the chemical toxicities of natural, depleted, and enriched uranium are identical because chemical action depends only on chemical properties. Current evidence from animal studies suggests that the toxicity of uranium is due mainly to its chemical damage to kidney tubular cells following exposure to soluble uranium compounds and the respiratory tract following chronic inhalation exposure to insoluble uranium compounds. Other potential targets of toxicity include the reproductive system and the developing organism (ATSDR 2013).

Uranium is absorbed poorly following inhalation, oral, or dermal exposure and the amount absorbed is heavily dependent on the solubility of the compound (ATSDR 2013).

Cancer slope factors used in the BHHRA for U-234, U-235, and U-238 are as follows:

- Ingestion (residential and recreational scenarios) (risk/pCi)—U-234=1.48E-10, U-235=1.54E-10, U-238=1.97E-10;
- Ingestion (industrial, excavation, and outdoor worker scenarios) (risk/pCi)—U-234=5.11E-11, U-235= 5.00E-11, U-238= 5.62E-11;
- Inhalation (risk/pCi)—U-234= 2.78E-08, U-235= 2.50E-08, U-238= 2.37E-08;
- External exposure (risk/yr per pCi)—U-234= 2.53E-10, U-235= 5.76E-07, U-238= 1.19E-07.

The slope factors for U-238 include ingrowth of short-lived degradation products. A dermal cancer slope factor was not calculated for the uranium isotopes because this route of exposure is not considered significant for radionuclides and is not evaluated in the BHHRA. Oral, dermal, and inhalation RfDs are available for uranium, but systemic toxicity was not evaluated in this BHHRA because uranium metal was not identified as a chemical or radionuclide of potential concern.

D3.5 REFERENCES

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ATTACHMENT D4

SUMMARY OF SWMU 1 RISK CHARACTERIZATION USING KENTUCKY ABS VALUES

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D4. SUMMARY OF SWMU 1 RISK CHARACTERIZATION USING KENTUCKY ABS VALUES

Attachment D4 presents an alternative approach for dermal risk characterization of metals in the Baseline Human Health Risk Assessment. This alternative approach uses KY dermal absorptions (ABS) values, rather than those in the U.S. Environmental Protection (EPA) Agency Risk Assessment Guidance for Superfund (RAGS) Part E, which lists ABS values for all metals, except arsenic and cadmium, as zero.

These summaries are similar to those presented in Tables D.43 through D.47. They present land use scenarios of concern, contaminants of concern (COCs), and pathways of concern. In addition, each table lists the following:

- Receptor risks for each land use scenario of concern;
- Percent contribution by pathway to the total risk; and
- Percent each COC contributes to the total risk.

The chemical-specific values listed in Attachment D3, including the ABS factors, are from the U.S. EPA values presented in the 2016 Risk Methods Document.

Table D4.1 KY ABS Values

Ana Type	Analyte	GI Absorption Factor	KY ABS
I	Aluminum	1.00E+00	5.00E-02
I	Antimony	1.50E-01	5.00E-02
I	Arsenic	1.00E+00	3.00E-02
I	Chromium	1.30E-02	1.30E-02
I	Cobalt	1.00E+00	5.00E-02
I	Manganese	4.00E-02	4.00E-02
I	Silver	4.00E-02	4.00E-02
I	Thallium	1.00E+00	5.00E-02
I	Vanadium	2.60E-02	5.00E-02*
O	PCB, Total	1.00E+00	1.40E-01
O	Total PAH	1.00E+00	1.30E-01
O	Vinyl Chloride	1.00E+00	2.50E-01

*The Kentucky (KY) ABS value used for vanadium is consistent with Table B.5 of the 2016 Risk Methods Document, but was not the appropriate value of 2.60E-02. Use of the 2016 Risk Methods Document value (of 5.00E-02) will overestimate the potential risk from vanadium for the uncertainty, but does not change the outcome of the overall calculation for vanadium.

Table D4.2. Alternate Summary of Risk Characterization Using KY ABS Values for SWMU 1, EU 1

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Current Industrial Worker (surface soil)	**< 1E-06**	*No COCs		Ingestion Dermal Inhalation External exposure		**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Industrial Worker (surface soil)	**1.1E-05**	Cesium-137 Neptunium-237 Thorium-230 Uranium-238	51% 22% 11% 11%	Ingestion Dermal Inhalation External exposure	12% 0% 4% 84%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface soil)	**1.6E-05**	Cesium-137 Neptunium-237 Plutonium-239/240 Thorium-230 Uranium-238	25% 11% 14% 42% 7%	Ingestion Dermal Inhalation External exposure	57% 0% 2% 41%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface and subsurface soil)	**3.9E-05**	Arsenic Total PAH Cesium-137 Neptunium-237 Plutonium-239/240 Thorium-230 Uranium-238	38% 18% 15% 4% 6% 16% 3%	Ingestion Dermal Inhalation External exposure	62% 15% 1% 22%	**2.1**	Cobalt Manganese Thallium Vanadium	7% 52% 17% 15%	Ingestion Dermal Inhalation	31% 69% 0%
Excavation Worker (surface and subsurface soil)	**8.1E-06**	Arsenic Total PAH Cesium-137 Thorium-230	36% 17% 17% 15%	Ingestion Dermal Inhalation External exposure	60% 15% 1% 24%	**2.1**	Cobalt Manganese Thallium Vanadium	7% 52% 17% 15%	Ingestion Dermal Inhalation	31% 69% 0%
Future Adult Resident (surface soil)	**4.0E-05**	Cesium-137 Neptunium-237 Plutonium-239/240 Thorium-230 Uranium-238	44% 19% 6% 20% 10%	Ingestion Dermal Inhalation External exposure	25% 0% 2% 73%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Resident (surface soil)	See Future Adult Resident					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Table D4.2. Alternate Summary of Risk Characterization Using KY ABS Values for SWMU 1, EU 1 (Continued)

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Future Adult Recreational User (surface soil)	**7.4E-06**	Cesium-137 Thorium-230	30% 37%	Ingestion Dermal Inhalation External exposure	50% 0% 1% 49%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Teen Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Total ELCR and total HI represent total risk or hazard summed across all routes of exposure for all COPCs.
*No COCs = There are no COCs.
ELCR for Future Adult Resident and Future Child Resident are the combined lifetime scenario.
ELCR for Future Adult Recreational User, Future Teen Recreational User and Future Child Recreational User are the combined lifetime scenario.
See Risk Methods Document for additional information (DOE 2016).

Table D4.3. Alternate Summary of Risk Characterization Using KY ABS Values for SWMU 1, EU 2

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Current Industrial Worker (surface soil)	**2.3E-06**	PCB, Total	84%	Ingestion Dermal Inhalation External exposure	8% 75% 2% 14%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Industrial Worker (surface soil)	**4.8E-05**	PCB, Total Uranium-235 Uranium-238	84% 3% 12%	Ingestion Dermal Inhalation External exposure	8% 75% 2% 14%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface soil)	**6.1E-05**	PCB, Total Uranium-234 Uranium-235 Uranium-238	87% 2% 2% 9%	Ingestion Dermal Inhalation External exposure	46% 44% 1% 8%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface and subsurface soil)	**7.8E-05**	Arsenic PCB, Total Total PAH Uranium-238	19% 49% 24% 4%	Ingestion Dermal Inhalation External exposure	54% 40% 1% 4%	**1.2**	Manganese Silver	62% 29%	Ingestion Dermal Inhalation	18% 82% 0%
Excavation Worker (surface and subsurface soil)	**1.6E-05**	Arsenic PCB, Total Total PAH	19% 49% 24%	Ingestion Dermal Inhalation External exposure	54% 40% 1% 4%	**1.2**	Manganese Silver	62% 29%	Ingestion Dermal Inhalation	18% 82% 0%
Future Adult Resident (surface soil)	**1.8E-04**	PCB, Total Uranium-234 Uranium-235 Uranium-238	85% 1% 3% 11%	Ingestion Dermal Inhalation External exposure	22% 64% 2% 13%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Resident (surface soil)	See Future Adult Resident					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Table D4.3. Alternate Summary of Risk Characterization Using KY ABS Values for SWMU 1, EU 2 (Continued)

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Future Adult Recreational User (surface soil)	**7.1E-05**	PCB, Total Uranium-238	94% 4%	Ingestion Dermal Inhalation External exposure	22% 74% 0% 4%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Teen Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Total ELCR and total HI represent total risk or hazard summed across all routes of exposure for all COPCs.
*No COCs = There are no COCs.
ELCR for Future Adult Resident and Future Child Resident are the combined lifetime scenario.
ELCR for Future Adult Recreational User, Future Teen Recreational User and Future Child Recreational User are the combined lifetime scenario.
See Risk Methods Document for additional information (DOE 2016).

Table D4.4. Alternate Summary of Risk Characterization Using KY ABS Values for SWMU 1, EU 3

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Current Industrial Worker (surface soil)	**2.2E-06**	PCB, Total	82%	Ingestion Dermal Inhalation External exposure	9% 84% 2% 6%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Industrial Worker (surface soil)	**3.8E-05**	PCB, Total Total PAH Uranium-238	82% 12% 6%	Ingestion Dermal Inhalation External exposure	9% 84% 2% 6%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface soil)	**5.0E-05**	PCB, Total Total PAH Uranium-238	83% 13% 4%	Ingestion Dermal Inhalation External exposure	48% 48% 1% 3%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface and subsurface soil)	**4.4E-05**	Arsenic PCB, Total Total PAH Cesium-137 Uranium-238	31% 46% 14% 3% 5%	Ingestion Dermal Inhalation External exposure	56% 36% 1% 7%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Excavation Worker (surface and subsurface soil)	**9.0E-06**	Arsenic PCB, Total Total PAH	31% 46% 14%	Ingestion Dermal Inhalation External exposure	56% 35% 1% 8%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Adult Resident (surface soil)	**1.4E-04**	PCB, Total Total PAH Uranium-238	82% 12% 6%	Ingestion Dermal Inhalation External exposure	22% 71% 2% 5%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Resident (surface soil)	See Future Adult Resident					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Table D4.4. Alternate Summary of Risk Characterization Using KY ABS Values for SWMU 1, EU 3 (Continued)

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Future Adult Recreational User (surface soil)	**6.1E-05**	PCB, Total Total PAH Uranium-238	85% 13% 2%	Ingestion Dermal Inhalation External exposure	22% 77% 0% 1%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Teen Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Total ELCR and total HI represent total risk or hazard summed across all routes of exposure for all COPCs.
*No COCs = There are no COCs.
ELCR for Future Adult Resident and Future Child Resident are the combined lifetime scenario.
ELCR for Future Adult Recreational User, Future Teen Recreational User and Future Child Recreational User are the combined lifetime scenario.
See Risk Methods Document for additional information (DOE 2016).

Table D4.5. Alternate Summary of Risk Characterization Using KY ABS Values for SWMU 1, EU 4

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Current Industrial Worker (surface soil)	**1.3E-06**	PCB, Total	96%	Ingestion Dermal Inhalation External exposure	9% 86% 6% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Industrial Worker (surface soil)	**2.3E-05**	PCB, Total	96%	Ingestion Dermal Inhalation External exposure	9% 86% 6% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface soil)	**2.9E-05**	PCB, Total	98%	Ingestion Dermal Inhalation External exposure	48% 49% 3% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface and subsurface soil)	**3.2E-06**	Cesium-137	69%	Ingestion Dermal Inhalation External exposure	7% 6% 18% 68%	**1**	Manganese Vanadium	75% 25%	Ingestion Dermal Inhalation	11% 89% 0%
Excavation Worker (surface and subsurface soil)	**<1E-06**	*No COCs		Ingestion Dermal Inhalation External exposure		**1**	Manganese Vanadium	75% 25%	Ingestion Dermal Inhalation	11% 89% 0%
Future Adult Resident (surface soil)	**8.2E-05**	Chromium PCB, Total	2% 98%	Ingestion Dermal Inhalation External exposure	22% 74% 4%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Resident (surface soil)	See Future Adult Resident					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Table D4.5. Alternate Summary of Risk Characterization Using KY ABS Values for SWMU 1, EU 4 (Continued)

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Future Adult Recreational User (surface soil)	**3.6E-05**	PCB, Total	99%	Ingestion Dermal Inhalation External exposure	21% 78% 1%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Teen Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Total ELCR and total HI represent total risk or hazard summed across all routes of exposure for all COPCs.
*No COCs = There are no COCs.
ELCR for Future Adult Resident and Future Child Resident are the combined lifetime scenario.
ELCR for Future Adult Recreational User, Future Teen Recreational User and Future Child Recreational User are the combined lifetime scenario.
See Risk Methods Document for additional information (DOE 2016).

Table D4.6. Alternate Summary of Risk Characterization Using KY ABS Values for SWMU 1, EU 5

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Current Industrial Worker (surface soil)	**<1E-06**	*No COCs		Ingestion Dermal Inhalation External exposure		**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Industrial Worker (surface soil)	**2.0E-06**	Total PAH	55%	Ingestion Dermal Inhalation External exposure	9% 90% 1% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface soil)	**2.7E-06**	PCB, Total Total PAH	44% 56%	Ingestion Dermal Inhalation External exposure	50% 49% 0% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Outdoor Worker (surface and subsurface soil)	**3.6E-05**	Arsenic PCB, Total Total PAH	92% 3% 4%	Ingestion Dermal Inhalation External exposure	79% 20% 0% 0%	**2.7**	Arsenic Cobalt Manganese	8% 7% 83%	Ingestion Dermal Inhalation	23% 77% 0%
Excavation Worker (surface and subsurface soil)	**7.2E-06**	Arsenic	92%	Ingestion Dermal Inhalation External exposure	79% 20% 0% 0%	**2.7**	Arsenic Cobalt Manganese	8% 7% 83%	Ingestion Dermal Inhalation	23% 77% 0%
Future Adult Resident (surface soil)	**7.5E-06**	PCB, Total Total PAH	45% 55%	Ingestion Dermal Inhalation External exposure	24% 75% 1% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Resident (surface soil)	See Future Adult Resident					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Table D4.6. Alternate Summary of Risk Characterization Using KY ABS Values for SWMU 1, EU 5 (Continued)

Receptor	Total ELCR	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI	COCs	% Total HI	Routes of Exposure	% Total HI
Future Adult Recreational User (surface soil)	**3.4E-06**	PCB, Total Total PAH	44% 56%	Ingestion Dermal Inhalation External exposure	22% 78% 0% 0%	**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Teen Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	
Future Child Recreational User (surface soil)	See Future Adult Recreational User					**< 1**	*No COCs		Ingestion Dermal Inhalation	

Total ELCR and total HI represent total risk or hazard summed across all routes of exposure for all COPCs.
*No COCs = There are no COCs.
ELCR for Future Adult Resident and Future Child Resident are the combined lifetime scenario.
ELCR for Future Adult Recreational User, Future Teen Recreational User and Future Child Recreational User are the combined lifetime scenario.
See Risk Methods Document for additional information (DOE 2016).

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ATTACHMENT D5

NONDETECT UNCERTAINTY EVALUATION

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D5. NONDETECT UNCERTAINTY EVALUATION

Chemicals or radionuclides of potential concern (COPCs) were selected for each exposure unit (EU) in Solid Waste Management Unit 1 for those analytes that were detected above background and where maximum detected value is greater than the no action level (NAL) (for the child residential scenario) (DOE 2016). For those analytes that never were detected within an EU, even if the detection limit is greater than the NAL, the analyte was not considered a COPC. Uncertainties are associated with this assumption. To assist in evaluating this uncertainty, the maximum detection limit was used as an exposure point concentration, and hazard index (HI) and excess lifetime cancer risk (ELCR) were calculated for the nondetected analyses. This attachment presents the results of these calculations.

Constituents with detection limits greater than the NAL and background concentrations were screened as COPCs, as previously discussed in this Baseline Human Health Risk Assessment. Similar to Attachment D1, constituents with no previously tabulated NAL are presented in Table D5.1. The results of the screening are presented in Table D5.2.

Chronic daily intakes (CDIs) calculated for the current industrial worker for noncarcenogens and carcinogens are shown in Tables D5.3 and D5.4. HI and ELCR for this scenario are calculated in Tables D5.5 and D5.6, respectively. These calculations showed no hazard greater than 0.1 and no ELCR greater than 1E-06. There were no constituents that would have been deemed a contaminant of concern for this scenario.

REFERENCES

DOE (U.S. Department of Energy) 2016. *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* Volume 1, *Human Health, U.S. Department of Energy, Paducah, Kentucky,* DOE/LX/07-0107&D2/R7/V1, U.S. Department of Energy, Paducah, KY, June.

EPA (U.S. Environmental Protection Agency) 1991. *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions*, OSWER Directive 9355.0-30.

Table D5.1. Additional No Action Level Screening Values for Nondetected Constituents

Chemical Abstract Number	Analyte	Units	Residential (Child)		
			Hazard	Cancer	NAL
79345	1,1,2,2-Tetrachloroethane	mg/kg	1.56E+02	6.04E-01	6.04E-01
120821	1,2,4-Trichlorobenzene	mg/kg	5.78E+00	2.40E+01	5.78E+00
78875	1,2-Dichloropropane	mg/kg	1.58E+00	1.01E+00	1.01E+00
106467	1,4-Dichlorobenzene	mg/kg	3.36E+02	2.61E+00	2.61E+00
95954	2,4,5-Trichlorophenol	mg/kg	3.58E+02		3.58E+02
88062	2,4,6-Trichlorophenol	mg/kg	3.58E+00	1.89E+01	3.58E+00
120832	2,4-Dichlorophenol	mg/kg	1.07E+01		1.07E+01
105679	2,4-Dimethylphenol	mg/kg	7.15E+01		7.15E+01
51285	2,4-Dinitrophenol	mg/kg	7.15E+00		7.15E+00
121142	2,4-Dinitrotoluene	mg/kg	7.08E+00	6.62E-01	6.62E-01
606202	2,6-Dinitrotoluene	mg/kg	1.08E+00	1.40E-01	1.40E-01
78933	2-Butanone	mg/kg	2.70E+03		2.70E+03
91587	2-Chloronaphthalene	mg/kg	2.46E+02		2.46E+02
95578	2-Chlorophenol	mg/kg	3.91E+01		3.91E+01
591786	2-Hexanone	mg/kg	2.02E+01		2.02E+01
534521	2-Methyl-4,6-dinitrophenol	mg/kg	2.86E-01		2.86E-01
95487	2-Methylphenol	mg/kg	1.79E+02		1.79E+02
91941	3,3'-Dichlorobenzidine	mg/kg		4.63E-01	4.63E-01
99092	3-Nitrobenzenamine	mg/kg	1.07E+00	9.91E+00	1.07E+00
59507	4-Chloro-3-methylphenol	mg/kg	3.58E+02		3.58E+02
106478	4-Chlorobenzenamine	mg/kg	1.43E+01	1.04E+00	1.04E+00
108101	4-Methyl-2-pentanone	mg/kg	5.26E+02		5.26E+02
100516	Benzenemethanol	mg/kg	1.43E+04		1.43E+04
111911	Bis(2-chloroethoxy)methane	mg/kg	1.07E+01		1.07E+01
111444	Bis(2-chloroethyl) ether	mg/kg		2.30E-01	2.30E-01
108601	Bis(2-chloroisopropyl) ether	mg/kg	3.13E+02	4.94E+00	4.94E+00
75252	Bromoform	mg/kg	1.56E+02	1.93E+01	1.93E+01
74839	Bromomethane	mg/kg	6.83E-01		6.83E-01
75003	Chloroethane	mg/kg	1.35E+03		1.35E+03
74873	Chloromethane	mg/kg	1.10E+01	1.77E+00	1.77E+00
10061015	*cis*-1,3-Dichloropropene[a]	mg/kg	7.19E+00	1.84E+00	1.84E+00
132649	Dibenzofuran	mg/kg	5.77E+00		5.77E+00
124481	Dibromochloromethane	mg/kg	1.56E+02	8.28E+00	8.28E+00
84662	Diethyl phthalate	mg/kg	2.86E+03		2.86E+03
117840	Di-n-octylphthalate	mg/kg	3.58E+01		3.58E+01
87683	Hexachlorobutadiene	mg/kg	7.82E+00	1.19E+00	1.19E+00
77474	Hexachlorocyclopentadiene	mg/kg	1.77E-01		1.77E-01
67721	Hexachloroethane	mg/kg	4.49E+00	1.83E+00	1.83E+00
78591	Isophorone	mg/kg	7.15E+02	2.19E+02	2.19E+02
98953	Nitrobenzene	mg/kg	1.27E+01	5.14E+00	5.14E+00
100016	p-Nitroaniline	mg/kg	1.43E+01	1.04E+01	1.04E+01
110861	Pyridine	mg/kg	7.82E+00		7.82E+00
100425	Styrene	mg/kg	6.00E+02		6.00E+02
10061026	*trans*-1,3-Dichloropropene[a]	mg/kg	7.19E+00	1.84E+00	1.84E+00
108054	Vinyl acetate	mg/kg	9.06E+01		9.06E+01

[a] 1,3-dicloropropene (Chemical Abstract Number 542-75-6) is used as a surrogate for *cis*-1,3-dicloropropene and *trans*-1,3-dicloropropene.

Table D5.2. Surface Soil COPCs for Nondetected Analyses

EU	Chemical/Radionuclide	Maximum Nondetect Reporting Limit	Units	Surface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
1	1,2,4-Trichlorobenzene	4.30E-01	mg/kg		5.78E+00	NoA
1	1,2-Dichlorobenzene	4.30E-01	mg/kg		1.81E+02	NoA
1	1,3-Dichlorobenzene	4.30E-01	mg/kg			NoC
1	1,4-Dichlorobenzene	4.30E-01	mg/kg		2.61E+00	NoA
1	2,4,5-Trichlorophenol	2.20E+00	mg/kg		3.58E+02	NoA
1	2,4,6-Trichlorophenol	4.30E-01	mg/kg		3.58E+00	NoA
1	2,4-Dichlorophenol	4.30E-01	mg/kg		1.07E+01	NoA
1	2,4-Dimethylphenol	4.30E-01	mg/kg		7.15E+01	NoA
1	2,4-Dinitrophenol	2.20E+00	mg/kg		7.15E+00	NoA
1	2,4-Dinitrotoluene	4.30E-01	mg/kg		6.62E-01	NoA
1	2,6-Dinitrotoluene	4.30E-01	mg/kg		1.40E-01	Yes
1	2-Chloronaphthalene	4.30E-01	mg/kg		2.46E+02	NoA
1	2-Chlorophenol	4.30E-01	mg/kg		3.91E+01	NoA
1	2-Methyl-4,6-dinitrophenol	2.20E+00	mg/kg		2.86E-01	Yes
1	2-Methylnaphthalene	4.30E-01	mg/kg		1.23E+01	NoA
1	2-Methylphenol	4.30E-01	mg/kg		1.79E+02	NoA
1	2-Nitrobenzenamine	2.20E+00	mg/kg		3.56E+01	NoA
1	2-Nitrophenol	4.30E-01	mg/kg			NoC
1	3,3'-Dichlorobenzidine	8.60E-01	mg/kg		4.63E-01	Yes
1	3-Nitrobenzenamine	2.20E+00	mg/kg		1.07E+00	Yes
1	4-Bromophenyl phenyl ether	4.30E-01	mg/kg			NoC
1	4-Chloro-3-methylphenol	4.30E-01	mg/kg		3.58E+02	NoA
1	4-Chlorobenzenamine	4.30E-01	mg/kg		1.04E+00	NoA
1	4-Chlorophenyl phenyl ether	4.30E-01	mg/kg			NoC
1	4-Nitrophenol	2.20E+00	mg/kg			NoC
1	Acenaphthene	5.00E-01	mg/kg		1.85E+02	NoA
1	Acenaphthylene	5.00E-01	mg/kg		1.85E+02	NoA
1	Anthracene	5.00E-01	mg/kg		9.23E+02	NoA
1	Benzenemethanol	4.30E-01	mg/kg		1.43E+04	NoA
1	Benzo(ghi)perylene	5.00E-01	mg/kg			NoC
1	Benzoic acid	2.20E+00	mg/kg		1.43E+04	NoA
1	Bis(2-chloroethoxy)methane	4.30E-01	mg/kg		1.07E+01	NoA
1	Bis(2-chloroethyl) ether	4.30E-01	mg/kg		2.30E-01	Yes
1	Bis(2-chloroisopropyl) ether	4.30E-01	mg/kg		4.94E+00	NoA
1	Butyl benzyl phthalate	4.30E-01	mg/kg		1.10E+02	NoA
1	Dibenzofuran	4.30E-01	mg/kg		5.77E+00	NoA
1	Diethyl phthalate	4.30E-01	mg/kg		2.86E+03	NoA
1	Dimethyl phthalate	4.30E-01	mg/kg			NoC
1	Di-n-octylphthalate	4.30E-01	mg/kg		3.58E+01	NoA
1	Fluoranthene	5.00E-01	mg/kg		1.23E+02	NoA
1	Fluorene	5.00E-01	mg/kg		1.23E+02	NoA
1	Hexachlorobenzene	4.30E-01	mg/kg		2.12E-01	Yes
1	Hexachlorobutadiene	4.30E-01	mg/kg		1.19E+00	NoA
1	Hexachlorocyclopentadiene	4.30E-01	mg/kg		1.77E-01	Yes
1	Hexachloroethane	4.30E-01	mg/kg		1.83E+00	NoA
1	Isophorone	4.30E-01	mg/kg		2.19E+02	NoA
1	m,p-cresol	3.80E-01	mg/kg		3.58E+02	NoA
1	Naphthalene	5.00E-01	mg/kg		3.83E+00	NoA

Table D5.2. Surface Soil COPCs for Nondetected Analyses (Continued)

EU	Chemical/Radionuclide	Maximum Nondetect Reporting Limit	Units	Surface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
1	Nitrobenzene	4.30E-01	mg/kg		5.14E+00	NoA
1	N-Nitroso-di-n-propylamine	4.30E-01	mg/kg		2.97E-02	Yes
1	N-Nitrosodiphenylamine	4.30E-01	mg/kg		4.25E+01	NoA
1	Pentachlorophenol	2.20E+00	mg/kg		2.54E-01	Yes
1	Phenanthrene	5.00E-01	mg/kg		1.85E+02	NoA
1	Phenol	4.30E-01	mg/kg		1.07E+03	NoA
1	p-Nitroaniline	2.20E+00	mg/kg		1.04E+01	NoA
1	Pyrene	5.00E-01	mg/kg		9.23E+01	NoA
1	Pyridine	3.80E-01	mg/kg		7.82E+00	NoA
1	1,1,1-Trichloroethane	6.00E-03	mg/kg		8.15E+02	NoA
1	1,1,2,2-Tetrachloroethane	6.00E-03	mg/kg		6.04E-01	NoA
1	1,1,2-Trichloroethane	6.00E-03	mg/kg		1.50E-01	NoA
1	1,1-Dichloroethane	6.00E-03	mg/kg		3.55E+00	NoA
1	1,1-Dichloroethene	6.00E-03	mg/kg		2.27E+01	NoA
1	1,2-Dichloroethane	6.00E-03	mg/kg		4.64E-01	NoA
1	1,2-Dichloroethene	6.00E-03	mg/kg		7.04E+01	NoA
1	1,2-Dichloropropane	6.00E-03	mg/kg		1.01E+00	NoA
1	2-Butanone	1.20E-02	mg/kg		2.70E+03	NoA
1	2-Hexanone	1.20E-02	mg/kg		2.02E+01	NoA
1	4-Methyl-2-pentanone	1.20E-02	mg/kg		5.26E+02	NoA
1	Acetone	3.40E-02	mg/kg		6.07E+03	NoA
1	Benzene	6.00E-03	mg/kg		1.16E+00	NoA
1	Bromodichloromethane	6.00E-03	mg/kg		2.93E-01	NoA
1	Bromoform	6.00E-03	mg/kg		1.93E+01	NoA
1	Bromomethane	1.20E-02	mg/kg		6.83E-01	NoA
1	Carbon tetrachloride	6.00E-03	mg/kg		6.53E-01	NoA
1	Chlorobenzene	6.00E-03	mg/kg		2.77E+01	NoA
1	Chloroethane	1.20E-02	mg/kg		1.35E+03	NoA
1	Chloromethane	1.20E-02	mg/kg		1.77E+00	NoA
1	*cis*-1,3-Dichloropropene	6.00E-03	mg/kg		1.84E+00	NoA
1	Dibromochloromethane	6.00E-03	mg/kg		8.28E+00	NoA
1	Ethylbenzene	6.00E-03	mg/kg		5.78E+00	NoA
1	Methylene chloride	3.10E-02	mg/kg		3.50E+01	NoA
1	Styrene	6.00E-03	mg/kg		6.00E+02	NoA
1	Tetrachloroethene	6.00E-03	mg/kg		8.10E+00	NoA
1	Total Xylene	6.00E-03	mg/kg		6.47E+01	NoA
1	*trans*-1,3-Dichloropropene	6.00E-03	mg/kg		1.84E+00	NoA
1	Vinyl acetate	1.20E-02	mg/kg		9.06E+01	NoA
1	Vinyl chloride	1.20E-02	mg/kg		5.92E-02	NoA
2	Americium-241	-2.40E-03	pCi/g		3.03E+00	NoA
2	Neptunium-237	3.04E-03	pCi/g	1.00E-01	2.39E-01	NoAB
2	Plutonium-238	4.28E-03	pCi/g	7.30E-02	4.42E+00	NoAB
2	1,2,4-Trichlorobenzene	4.00E-01	mg/kg		5.78E+00	NoA
2	1,2-Dichlorobenzene	4.00E-01	mg/kg		1.81E+02	NoA
2	1,3-Dichlorobenzene	4.00E-01	mg/kg			NoC
2	1,4-Dichlorobenzene	4.00E-01	mg/kg		2.61E+00	NoA
2	2,4,5-Trichlorophenol	4.00E-01	mg/kg		3.58E+02	NoA
2	2,4,6-Trichlorophenol	4.00E-01	mg/kg		3.58E+00	NoA

Table D5.2. Surface Soil COPCs for Nondetected Analyses (Continued)

EU	Chemical/Radionuclide	Maximum Nondetect Reporting Limit	Units	Surface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
2	2,4-Dichlorophenol	4.00E-01	mg/kg		1.07E+01	NoA
2	2,4-Dimethylphenol	4.00E-01	mg/kg		7.15E+01	NoA
2	2,4-Dinitrophenol	8.00E-01	mg/kg		7.15E+00	NoA
2	2,4-Dinitrotoluene	2.40E-01	mg/kg		6.62E-01	NoA
2	2,6-Dinitrotoluene	2.40E-01	mg/kg		1.40E-01	Yes
2	2-Chloronaphthalene	4.00E-01	mg/kg		2.46E+02	NoA
2	2-Chlorophenol	4.00E-01	mg/kg		3.91E+01	NoA
2	2-Methyl-4,6-dinitrophenol	8.00E-01	mg/kg		2.86E-01	Yes
2	2-Methylnaphthalene	4.00E-01	mg/kg		1.23E+01	NoA
2	2-Methylphenol	4.00E-01	mg/kg		1.79E+02	NoA
2	2-Nitrobenzenamine	8.00E-01	mg/kg		3.56E+01	NoA
2	2-Nitrophenol	4.00E-01	mg/kg			NoC
2	3,3'-Dichlorobenzidine	2.40E-01	mg/kg		4.63E-01	NoA
2	3-Nitrobenzenamine	8.00E-01	mg/kg		1.07E+00	NoA
2	4-Bromophenyl phenyl ether	4.00E-01	mg/kg			NoC
2	4-Chloro-3-methylphenol	4.00E-01	mg/kg		3.58E+02	NoA
2	4-Chlorobenzenamine	4.00E-01	mg/kg		1.04E+00	NoA
2	4-Chlorophenyl phenyl ether	4.00E-01	mg/kg			NoC
2	4-Nitrophenol	8.00E-01	mg/kg			NoC
2	Acenaphthene	4.00E-01	mg/kg		1.85E+02	NoA
2	Acenaphthylene	4.00E-01	mg/kg		1.85E+02	NoA
2	Anthracene	4.00E-01	mg/kg		9.23E+02	NoA
2	Benzenemethanol	4.00E-01	mg/kg		1.43E+04	NoA
2	Benzo(ghi)perylene	4.00E-01	mg/kg			NoC
2	Benzoic acid	2.00E+00	mg/kg		1.43E+04	NoA
2	bis(2-chloroethoxy)methane	4.00E-01	mg/kg		1.07E+01	NoA
2	bis(2-chloroethyl) ether	4.00E-01	mg/kg		2.30E-01	Yes
2	bis(2-chloroisopropyl) ether	4.00E-01	mg/kg		4.94E+00	NoA
2	bis(2-Ethylhexyl)phthalate	4.00E-01	mg/kg		1.49E+01	NoA
2	Butyl benzyl phthalate	4.00E-01	mg/kg		1.10E+02	NoA
2	Dibenzofuran	4.00E-01	mg/kg		5.77E+00	NoA
2	Diethyl phthalate	4.00E-01	mg/kg		2.86E+03	NoA
2	Dimethyl phthalate	4.00E-01	mg/kg			NoC
2	Di-n-butyl phthalate	4.00E-01	mg/kg		3.58E+02	NoA
2	Di-n-octylphthalate	4.00E-01	mg/kg		3.58E+01	NoA
2	Fluoranthene	4.00E-01	mg/kg		1.23E+02	NoA
2	Fluorene	4.00E-01	mg/kg		1.23E+02	NoA
2	Hexachlorobenzene	4.10E-03	mg/kg		2.12E-01	NoA
2	Hexachlorobutadiene	2.40E-01	mg/kg		1.19E+00	NoA
2	Hexachlorocyclopentadiene	4.00E-01	mg/kg		1.77E-01	Yes
2	Hexachloroethane	4.00E-01	mg/kg		1.83E+00	NoA
2	Isophorone	4.00E-01	mg/kg		2.19E+02	NoA
2	m,p-cresol	4.00E-01	mg/kg		3.58E+02	NoA
2	Naphthalene	4.00E-01	mg/kg		3.83E+00	NoA
2	Nitrobenzene	4.00E-01	mg/kg		5.14E+00	NoA
2	n-Nitroso-di-n-propylamine	4.00E-01	mg/kg		2.97E-02	Yes
2	N-Nitrosodiphenylamine	4.00E-01	mg/kg		4.25E+01	NoA
2	Pentachlorophenol	7.20E-01	mg/kg		2.54E-01	Yes

Table D5.2. Surface Soil COPCs for Nondetected Analyses (Continued)

EU	Chemical/Radionuclide	Maximum Nondetect Reporting Limit	Units	Surface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
2	Phenanthrene	4.00E-01	mg/kg		1.85E+02	NoA
2	Phenol	4.00E-01	mg/kg		1.07E+03	NoA
2	p-Nitroaniline	8.00E-01	mg/kg		1.04E+01	NoA
2	Pyrene	4.00E-01	mg/kg		9.23E+01	NoA
2	Pyridine	4.00E-01	mg/kg		7.82E+00	NoA
3	1,2,4-Trichlorobenzene	4.00E-01	mg/kg		5.78E+00	NoA
3	1,2-Dichlorobenzene	4.00E-01	mg/kg		1.81E+02	NoA
3	1,3-Dichlorobenzene	4.00E-01	mg/kg			NoC
3	1,4-Dichlorobenzene	2.30E+00	mg/kg		2.61E+00	NoA
3	2,4,5-Trichlorophenol	2.30E+00	mg/kg		3.58E+02	NoA
3	2,4,6-Trichlorophenol	2.30E+00	mg/kg		3.58E+00	NoA
3	2,4-Dichlorophenol	4.00E-01	mg/kg		1.07E+01	NoA
3	2,4-Dimethylphenol	4.00E-01	mg/kg		7.15E+01	NoA
3	2,4-Dinitrophenol	2.30E+00	mg/kg		7.15E+00	NoA
3	2,4-Dinitrotoluene	3.30E-01	mg/kg		6.62E-01	NoA
3	2,6-Dinitrotoluene	3.30E-01	mg/kg		1.40E-01	Yes
3	2-Chloronaphthalene	4.00E-01	mg/kg		2.46E+02	NoA
3	2-Chlorophenol	4.00E-01	mg/kg		3.91E+01	NoA
3	2-Methyl-4,6-dinitrophenol	1.65E+00	mg/kg		2.86E-01	Yes
3	2-Methylnaphthalene	4.00E-01	mg/kg		1.23E+01	NoA
3	2-Methylphenol	2.30E+00	mg/kg		1.79E+02	NoA
3	2-Nitrobenzenamine	1.65E+00	mg/kg		3.56E+01	NoA
3	2-Nitrophenol	4.00E-01	mg/kg			NoC
3	3,3'-Dichlorobenzidine	3.30E-01	mg/kg		4.63E-01	NoA
3	3-Nitrobenzenamine	1.65E+00	mg/kg		1.07E+00	Yes
3	4-Bromophenyl phenyl ether	4.00E-01	mg/kg			NoC
3	4-Chloro-3-methylphenol	4.00E-01	mg/kg		3.58E+02	NoA
3	4-Chlorobenzenamine	4.00E-01	mg/kg		1.04E+00	NoA
3	4-Chlorophenyl phenyl ether	4.00E-01	mg/kg			NoC
3	4-Nitrophenol	1.65E+00	mg/kg			NoC
3	Acenaphthene	5.00E-01	mg/kg		1.85E+02	NoA
3	Acenaphthylene	5.00E-01	mg/kg		1.85E+02	NoA
3	Anthracene	5.00E-01	mg/kg		9.23E+02	NoA
3	Benzenemethanol	4.00E-01	mg/kg		1.43E+04	NoA
3	Benzo(ghi)perylene	5.00E-01	mg/kg			NoC
3	Benzoic acid	2.00E+00	mg/kg		1.43E+04	NoA
3	Bis(2-chloroethoxy)methane	4.00E-01	mg/kg		1.07E+01	NoA
3	Bis(2-chloroethyl) ether	4.00E-01	mg/kg		2.30E-01	Yes
3	Bis(2-chloroisopropyl) ether	4.00E-01	mg/kg		4.94E+00	NoA
3	Bis(2-ethylhexyl)phthalate	4.00E-01	mg/kg		1.49E+01	NoA
3	Butyl benzyl phthalate	4.00E-01	mg/kg		1.10E+02	NoA
3	Dibenzofuran	4.00E-01	mg/kg		5.77E+00	NoA
3	Diethyl phthalate	4.00E-01	mg/kg		2.86E+03	NoA
3	Dimethyl phthalate	4.00E-01	mg/kg			NoC
3	Di-n-butyl phthalate	4.00E-01	mg/kg		3.58E+02	NoA
3	Di-n-octylphthalate	4.00E-01	mg/kg		3.58E+01	NoA
3	Fluoranthene	5.00E-01	mg/kg		1.23E+02	NoA
3	Fluorene	5.00E-01	mg/kg		1.23E+02	NoA

Table D5.2. Surface Soil COPCs for Nondetected Analyses (Continued)

EU	Chemical/Radionuclide	Maximum Nondetect Reporting Limit	Units	Surface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
3	Hexachlorobenzene	2.30E+00	mg/kg		2.12E-01	Yes
3	Hexachlorobutadiene	2.30E+00	mg/kg		1.19E+00	Yes
3	Hexachlorocyclopentadiene	4.00E-01	mg/kg		1.77E-01	Yes
3	Hexachloroethane	2.30E+00	mg/kg		1.83E+00	Yes
3	Isophorone	4.00E-01	mg/kg		2.19E+02	NoA
3	m,p-Cresol	2.30E+00	mg/kg		3.58E+02	NoA
3	Naphthalene	5.00E-01	mg/kg		3.83E+00	NoA
3	Nitrobenzene	2.30E+00	mg/kg		5.14E+00	NoA
3	N-Nitroso-di-n-propylamine	4.00E-01	mg/kg		2.97E-02	Yes
3	N-Nitrosodiphenylamine	4.00E-01	mg/kg		4.25E+01	NoA
3	Pentachlorophenol	2.30E+00	mg/kg		2.54E-01	Yes
3	Phenanthrene	5.00E-01	mg/kg		1.85E+02	NoA
3	Phenol	4.00E-01	mg/kg		1.07E+03	NoA
3	p-Nitroaniline	1.65E+00	mg/kg		1.04E+01	NoA
3	Pyrene	5.00E-01	mg/kg		9.23E+01	NoA
3	Pyridine	2.30E+00	mg/kg		7.82E+00	NoA
3	1,1,1-Trichloroethane	5.00E-03	mg/kg		8.15E+02	NoA
3	1,1-Dichloroethene	1.00E-02	mg/kg		2.27E+01	NoA
3	1,2-Dichloroethane	1.00E-02	mg/kg		4.64E-01	NoA
3	2-Butanone	1.00E-02	mg/kg		2.70E+03	NoA
3	Benzene	1.00E-02	mg/kg		1.16E+00	NoA
3	Carbon tetrachloride	1.00E-02	mg/kg		6.53E-01	NoA
3	Chlorobenzene	1.00E-01	mg/kg		2.77E+01	NoA
3	Chloroform	1.00E-02	mg/kg		3.16E-01	NoA
3	Tetrachloroethene	1.00E-02	mg/kg		8.10E+00	NoA
3	Vinyl chloride	1.00E-02	mg/kg		5.92E-02	NoA
4	Antimony	1.22E+01	mg/kg	2.10E-01	3.13E+00	Yes
4	Molybdenum	6.00E+00	mg/kg		3.91E+01	NoA
4	Silver	1.00E+01	mg/kg	2.30E+00	3.91E+01	NoA
4	Thallium	1.80E+01	mg/kg	2.10E-01	7.82E-02	Yes
4	1,2,4-Trichlorobenzene	3.90E-01	mg/kg		5.78E+00	NoA
4	1,2-Dichlorobenzene	3.90E-01	mg/kg		1.81E+02	NoA
4	1,3-Dichlorobenzene	3.90E-01	mg/kg			NoC
4	1,4-Dichlorobenzene	3.90E-01	mg/kg		2.61E+00	NoA
4	2,4,5-Trichlorophenol	1.90E+00	mg/kg		3.58E+02	NoA
4	2,4,6-Trichlorophenol	3.90E-01	mg/kg		3.58E+00	NoA
4	2,4-Dichlorophenol	3.90E-01	mg/kg		1.07E+01	NoA
4	2,4-Dimethylphenol	3.90E-01	mg/kg		7.15E+01	NoA
4	2,4-Dinitrophenol	1.90E+00	mg/kg		7.15E+00	NoA
4	2,4-Dinitrotoluene	3.90E-01	mg/kg		6.62E-01	NoA
4	2,6-Dinitrotoluene	3.90E-01	mg/kg		1.40E-01	Yes
4	2-Chloronaphthalene	3.90E-01	mg/kg		2.46E+02	NoA
4	2-Chlorophenol	3.90E-01	mg/kg		3.91E+01	NoA
4	2-Methyl-4,6-dinitrophenol	1.90E+00	mg/kg		2.86E-01	Yes
4	2-Methylnaphthalene	3.90E-01	mg/kg		1.23E+01	NoA
4	2-Methylphenol	3.90E-01	mg/kg		1.79E+02	NoA
4	2-Nitrobenzenamine	1.90E+00	mg/kg		3.56E+01	NoA
4	2-Nitrophenol	3.90E-01	mg/kg			NoC

Table D5.2. Surface Soil COPCs for Nondetected Analyses (Continued)

EU	Chemical/Radionuclide	Maximum Nondetect Reporting Limit	Units	Surface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
4	3,3'-Dichlorobenzidine	7.80E-01	mg/kg		4.63E-01	Yes
4	3-Nitrobenzenamine	1.90E+00	mg/kg		1.07E+00	Yes
4	4-Bromophenyl phenyl ether	3.90E-01	mg/kg			NoC
4	4-Chloro-3-methylphenol	3.90E-01	mg/kg		3.58E+02	NoA
4	4-Chlorobenzenamine	3.90E-01	mg/kg		1.04E+00	NoA
4	4-Chlorophenyl phenyl ether	3.90E-01	mg/kg			NoC
4	4-Nitrophenol	1.90E+00	mg/kg			NoC
4	Acenaphthene	4.80E-01	mg/kg		1.85E+02	NoA
4	Acenaphthylene	4.80E-01	mg/kg		1.85E+02	NoA
4	Anthracene	4.80E-01	mg/kg		9.23E+02	NoA
4	Benzenemethanol	3.90E-01	mg/kg		1.43E+04	NoA
4	Benzo(ghi)perylene	4.80E-01	mg/kg			NoC
4	Benzoic acid	1.90E+00	mg/kg		1.43E+04	NoA
4	Bis(2-chloroethoxy)methane	3.90E-01	mg/kg		1.07E+01	NoA
4	Bis(2-chloroethyl) ether	3.90E-01	mg/kg		2.30E-01	Yes
4	Bis(2-chloroisopropyl) ether	3.90E-01	mg/kg		4.94E+00	NoA
4	Bis(2-ethylhexyl)phthalate	3.90E-01	mg/kg		1.49E+01	NoA
4	Butyl benzyl phthalate	3.90E-01	mg/kg		1.10E+02	NoA
4	Dibenzofuran	3.90E-01	mg/kg		5.77E+00	NoA
4	Diethyl phthalate	3.90E-01	mg/kg		2.86E+03	NoA
4	Dimethyl phthalate	3.90E-01	mg/kg			NoC
4	Di-n-butyl phthalate	3.90E-01	mg/kg		3.58E+02	NoA
4	Di-n-octylphthalate	3.90E-01	mg/kg		3.58E+01	NoA
4	Fluorene	4.80E-01	mg/kg		1.23E+02	NoA
4	Hexachlorobenzene	3.90E-01	mg/kg		2.12E-01	Yes
4	Hexachlorobutadiene	3.90E-01	mg/kg		1.19E+00	NoA
4	Hexachlorocyclopentadiene	3.90E-01	mg/kg		1.77E-01	Yes
4	Hexachloroethane	3.90E-01	mg/kg		1.83E+00	NoA
4	Isophorone	3.90E-01	mg/kg		2.19E+02	NoA
4	Naphthalene	4.80E-01	mg/kg		3.83E+00	NoA
4	Nitrobenzene	3.90E-01	mg/kg		5.14E+00	NoA
4	N-Nitroso-di-n-propylamine	3.90E-01	mg/kg		2.97E-02	Yes
4	N-Nitrosodiphenylamine	3.90E-01	mg/kg		4.25E+01	NoA
4	Pentachlorophenol	1.90E+00	mg/kg		2.54E-01	Yes
4	p-Nitroaniline	1.90E+00	mg/kg		1.04E+01	NoA
4	Total PAH	4.80E-01	mg/kg		6.55E-03	Yes
4	1,1,1-Trichloroethane	6.00E-03	mg/kg		8.15E+02	NoA
4	1,1,2,2-Tetrachloroethane	6.00E-03	mg/kg		6.04E-01	NoA
4	1,1,2-Trichloroethane	6.00E-03	mg/kg		1.50E-01	NoA
4	1,1-Dichloroethane	6.00E-03	mg/kg		3.55E+00	NoA
4	1,1-Dichloroethene	6.00E-03	mg/kg		2.27E+01	NoA
4	1,2-Dichloroethane	6.00E-03	mg/kg		4.64E-01	NoA
4	1,2-Dichloroethene	6.00E-03	mg/kg		7.04E+01	NoA
4	1,2-Dichloropropane	6.00E-03	mg/kg		1.01E+00	NoA
4	2-Butanone	1.20E-02	mg/kg		2.70E+03	NoA
4	2-Hexanone	1.20E-02	mg/kg		2.02E+01	NoA
4	4-Methyl-2-pentanone	1.20E-02	mg/kg		5.26E+02	NoA
4	Acetone	1.20E-02	mg/kg		6.07E+03	NoA

Table D5.2. Surface Soil COPCs for Nondetected Analyses (Continued)

EU	Chemical/Radionuclide	Maximum Nondetect Reporting Limit	Units	Surface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
4	Benzene	6.00E-03	mg/kg		1.16E+00	NoA
4	Bromodichloromethane	6.00E-03	mg/kg		2.93E-01	NoA
4	Bromoform	6.00E-03	mg/kg		1.93E+01	NoA
4	Bromomethane	1.20E-02	mg/kg		6.83E-01	NoA
4	Carbon disulfide	6.00E-03	mg/kg		7.68E+01	NoA
4	Carbon tetrachloride	6.00E-03	mg/kg		6.53E-01	NoA
4	Chlorobenzene	6.00E-03	mg/kg		2.77E+01	NoA
4	Chloroethane	1.20E-02	mg/kg		1.35E+03	NoA
4	Chloroform	6.00E-03	mg/kg		3.16E-01	NoA
4	Chloromethane	1.20E-02	mg/kg		1.77E+00	NoA
4	*cis*-1,3-Dichloropropene	6.00E-03	mg/kg		1.84E+00	NoA
4	Dibromochloromethane	6.00E-03	mg/kg		8.28E+00	NoA
4	Ethylbenzene	6.00E-03	mg/kg		5.78E+00	NoA
4	Methylene chloride	6.00E-03	mg/kg		3.50E+01	NoA
4	Styrene	6.00E-03	mg/kg		6.00E+02	NoA
4	Tetrachloroethene	6.00E-03	mg/kg		8.10E+00	NoA
4	Toluene	6.00E-03	mg/kg		4.89E+02	NoA
4	Total Xylene	6.00E-03	mg/kg		6.47E+01	NoA
4	*trans*-1,3-Dichloropropene	6.00E-03	mg/kg		1.84E+00	NoA
4	Trichloroethene	6.00E-03	mg/kg		4.12E-01	NoA
4	Vinyl acetate	1.20E-02	mg/kg		9.06E+01	NoA
4	Vinyl chloride	1.20E-02	mg/kg		5.92E-02	NoA
5	Antimony	9.75E+00	mg/kg	2.10E-01	3.13E+00	Yes
5	Silver	1.00E+01	mg/kg	2.30E+00	3.91E+01	NoA
5	Thallium	1.95E+01	mg/kg	2.10E-01	7.82E-02	Yes
5	1,2,4-Trichlorobenzene	4.10E-01	mg/kg		5.78E+00	NoA
5	1,2-Dichlorobenzene	4.10E-01	mg/kg		1.81E+02	NoA
5	1,3-Dichlorobenzene	4.10E-01	mg/kg			NoC
5	1,4-Dichlorobenzene	4.10E-01	mg/kg		2.61E+00	NoA
5	2,4,5-Trichlorophenol	2.10E+00	mg/kg		3.58E+02	NoA
5	2,4,6-Trichlorophenol	4.10E-01	mg/kg		3.58E+00	NoA
5	2,4-Dichlorophenol	4.10E-01	mg/kg		1.07E+01	NoA
5	2,4-Dimethylphenol	4.10E-01	mg/kg		7.15E+01	NoA
5	2,4-Dinitrophenol	2.10E+00	mg/kg		7.15E+00	NoA
5	2,4-Dinitrotoluene	4.10E-01	mg/kg		6.62E-01	NoA
5	2,6-Dinitrotoluene	4.10E-01	mg/kg		1.40E-01	Yes
5	2-Chloronaphthalene	4.10E-01	mg/kg		2.46E+02	NoA
5	2-Chlorophenol	4.10E-01	mg/kg		3.91E+01	NoA
5	2-Methyl-4,6-dinitrophenol	2.10E+00	mg/kg		2.86E-01	Yes
5	2-Methylphenol	4.10E-01	mg/kg		1.79E+02	NoA
5	2-Nitrobenzenamine	2.10E+00	mg/kg		3.56E+01	NoA
5	2-Nitrophenol	4.10E-01	mg/kg			NoC
5	3,3'-Dichlorobenzidine	8.20E-01	mg/kg		4.63E-01	Yes
5	3-Nitrobenzenamine	2.10E+00	mg/kg		1.07E+00	Yes
5	4-Bromophenyl phenyl ether	4.10E-01	mg/kg			NoC
5	4-Chloro-3-methylphenol	4.10E-01	mg/kg		3.58E+02	NoA
5	4-Chlorobenzenamine	4.10E-01	mg/kg		1.04E+00	NoA
5	4-Chlorophenyl phenyl ether	4.10E-01	mg/kg			NoC

Table D5.2. Surface Soil COPCs for Nondetected Analyses (Continued)

EU	Chemical/Radionuclide	Maximum Nondetect Reporting Limit	Units	Surface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
5	4-Nitrophenol	2.10E+00	mg/kg			NoC
5	Acenaphthene	4.80E-01	mg/kg		1.85E+02	NoA
5	Acenaphthylene	4.80E-01	mg/kg		1.85E+02	NoA
5	Anthracene	4.80E-01	mg/kg		9.23E+02	NoA
5	Benzenemethanol	4.10E-01	mg/kg		1.43E+04	NoA
5	Benzo(ghi)perylene	4.80E-01	mg/kg			NoC
5	Benzoic acid	2.10E+00	mg/kg		1.43E+04	NoA
5	Bis(2-chloroethoxy)methane	4.10E-01	mg/kg		1.07E+01	NoA
5	Bis(2-chloroethyl) ether	4.10E-01	mg/kg		2.30E-01	Yes
5	Bis(2-chloroisopropyl) ether	4.10E-01	mg/kg		4.94E+00	NoA
5	Butyl benzyl phthalate	4.10E-01	mg/kg		1.10E+02	NoA
5	Dibenzofuran	4.10E-01	mg/kg		5.77E+00	NoA
5	Diethyl phthalate	4.10E-01	mg/kg		2.86E+03	NoA
5	Dimethyl phthalate	4.10E-01	mg/kg			NoC
5	Di-n-butyl phthalate	4.10E-01	mg/kg		3.58E+02	NoA
5	Di-n-octylphthalate	4.10E-01	mg/kg		3.58E+01	NoA
5	Fluorene	4.80E-01	mg/kg		1.23E+02	NoA
5	Hexachlorobenzene	4.10E-01	mg/kg		2.12E-01	Yes
5	Hexachlorobutadiene	4.10E-01	mg/kg		1.19E+00	NoA
5	Hexachlorocyclopentadiene	4.10E-01	mg/kg		1.77E-01	Yes
5	Hexachloroethane	4.10E-01	mg/kg		1.83E+00	NoA
5	Isophorone	4.10E-01	mg/kg		2.19E+02	NoA
5	Nitrobenzene	4.10E-01	mg/kg		5.14E+00	NoA
5	N-Nitroso-di-n-propylamine	4.10E-01	mg/kg		2.97E-02	Yes
5	N-Nitrosodiphenylamine	4.10E-01	mg/kg		4.25E+01	NoA
5	Pentachlorophenol	2.10E+00	mg/kg		2.54E-01	Yes
5	Phenol	4.10E-01	mg/kg		1.07E+03	NoA
5	p-Nitroaniline	2.10E+00	mg/kg		1.04E+01	NoA
5	1,1,1-Trichloroethane	6.00E-03	mg/kg		8.15E+02	NoA
5	1,1,2,2-Tetrachloroethane	6.00E-03	mg/kg		6.04E-01	NoA
5	1,1,2-Trichloroethane	6.00E-03	mg/kg		1.50E-01	NoA
5	1,1-Dichloroethane	6.00E-03	mg/kg		3.55E+00	NoA
5	1,1-Dichloroethene	6.00E-03	mg/kg		2.27E+01	NoA
5	1,2-Dichloroethane	6.00E-03	mg/kg		4.64E-01	NoA
5	1,2-Dichloroethene	6.00E-03	mg/kg		7.04E+01	NoA
5	1,2-Dichloropropane	6.00E-03	mg/kg		1.01E+00	NoA
5	2-Butanone	1.30E-02	mg/kg		2.70E+03	NoA
5	2-Hexanone	1.30E-02	mg/kg		2.02E+01	NoA
5	4-Methyl-2-pentanone	1.30E-02	mg/kg		5.26E+02	NoA
5	Acetone	5.50E-02	mg/kg		6.07E+03	NoA
5	Benzene	6.00E-03	mg/kg		1.16E+00	NoA
5	Bromodichloromethane	6.00E-03	mg/kg		2.93E-01	NoA
5	Bromoform	6.00E-03	mg/kg		1.93E+01	NoA
5	Bromomethane	1.30E-02	mg/kg		6.83E-01	NoA
5	Carbon disulfide	6.00E-03	mg/kg		7.68E+01	NoA
5	Carbon tetrachloride	6.00E-03	mg/kg		6.53E-01	NoA
5	Chlorobenzene	6.00E-03	mg/kg		2.77E+01	NoA
5	Chloroethane	1.30E-02	mg/kg		1.35E+03	NoA

Table D5.2. Surface Soil COPCs for Nondetected Analyses (Continued)

EU	Chemical/Radionuclide	Maximum Nondetect Reporting Limit	Units	Surface Background Concentration[a]	Child Resident NAL[b]	COPC?[c]
5	Chloroform	6.00E-03	mg/kg		3.16E-01	NoA
5	Chloromethane	1.30E-02	mg/kg		1.77E+00	NoA
5	*cis*-1,3-Dichloropropene	6.00E-03	mg/kg		1.84E+00	NoA
5	Dibromochloromethane	6.00E-03	mg/kg		8.28E+00	NoA
5	Ethylbenzene	6.00E-03	mg/kg		5.78E+00	NoA
5	Styrene	6.00E-03	mg/kg		6.00E+02	NoA
5	Tetrachloroethene	6.00E-03	mg/kg		8.10E+00	NoA
5	Toluene	6.00E-03	mg/kg		4.89E+02	NoA
5	Total Xylene	6.00E-03	mg/kg		6.47E+01	NoA
5	*trans*-1,3-Dichloropropene	6.00E-03	mg/kg		1.84E+00	NoA
5	Trichloroethene	6.00E-03	mg/kg		4.12E-01	NoA
5	Vinyl acetate	1.30E-02	mg/kg		9.06E+01	NoA
5	Vinyl chloride	1.30E-02	mg/kg		5.92E-02	NoA

[a] See Table D.3.
[b] Risk-based screening values are from DOE 2016, Attachment D1, or Table D5.1. The screening values are the lesser of the HI and ELCR NALs used for the child resident of 0.1 and 1E-06, respectively (DOE 2016). For chemicals that did not have an NAL, one was calculated by similar methods.
[c] Explanations for chemicals not being COPCs are listed below.
A – Maximum result is less than child resident NAL.
B – Maximum result is less than background value.
C – No toxicity information is available for screening.

Table D5.3. Noncarcinogenic CDIs for the Current Industrial Worker Exposed to Surface Soil for Nondetect Uncertainty Evaluation

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation
1	2,6-Dinitrotoluene	mg/kg	4.30E-01	1.03E-08	7.20E-08	8.87E-12
1	2-Methyl-4,6-dinitrophenol	mg/kg	2.20E+00	5.27E-08	3.72E-07	4.54E-11
1	3-Nitrobenzenamine	mg/kg	2.20E+00	5.27E-08	3.72E-07	4.54E-11
1	Hexachlorobenzene	mg/kg	4.30E-01	1.03E-08		8.09E-08
1	Hexachlorocyclopentadiene	mg/kg	4.30E-01	1.03E-08		6.46E-07
1	N-Nitroso-di-n-propylamine	mg/kg	4.30E-01	1.03E-08	7.27E-08	8.87E-12
1	Pentachlorophenol	mg/kg	2.20E+00	5.27E-08	9.30E-07	4.54E-11
2	2,6-Dinitrotoluene	mg/kg	2.40E-01	5.75E-09	4.02E-08	4.95E-12
2	2-Methyl-4,6-dinitrophenol	mg/kg	8.00E-01	1.92E-08	1.35E-07	1.65E-11
2	Hexachlorocyclopentadiene	mg/kg	4.00E-01	9.59E-09		6.01E-07
2	n-Nitroso-di-n-propylamine	mg/kg	4.00E-01	9.59E-09	6.76E-08	8.25E-12
2	Pentachlorophenol	mg/kg	7.20E-01	1.73E-08	3.04E-07	1.48E-11
3	2,6-Dinitrotoluene	mg/kg	3.30E-01	7.91E-09	5.52E-08	6.81E-12
3	2-Methyl-4,6-dinitrophenol	mg/kg	1.65E+00	3.96E-08	2.79E-07	3.40E-11
3	3-Nitrobenzenamine	mg/kg	1.65E+00	3.96E-08	2.79E-07	3.40E-11
3	Hexachlorobenzene	mg/kg	2.30E+00	5.51E-08		4.32E-07
3	Hexachlorobutadiene	mg/kg	2.30E+00	5.51E-08		2.72E-06
3	Hexachlorocyclopentadiene	mg/kg	4.00E-01	9.59E-09		6.01E-07
3	Hexachloroethane	mg/kg	2.30E+00	5.51E-08		3.67E-06
3	N-Nitroso-di-n-propylamine	mg/kg	4.00E-01	9.59E-09	6.76E-08	8.25E-12
3	Pentachlorophenol	mg/kg	2.30E+00	5.51E-08	9.72E-07	4.74E-11

Table D5.3. Noncarcinogenic CDIs for the Current Industrial Worker Exposed to Surface Soil for Nondetect Uncertainty Evaluation (Continued)

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation
4	Antimony	mg/kg	1.22E+01	2.92E-07		2.52E-10
4	Thallium	mg/kg	1.80E+01	4.32E-07		3.71E-10
4	2,6-Dinitrotoluene	mg/kg	3.90E-01	9.35E-09	6.53E-08	8.04E-12
4	2-Methyl-4,6-dinitrophenol	mg/kg	1.90E+00	4.55E-08	3.21E-07	3.92E-11
4	3-Nitrobenzenamine	mg/kg	1.90E+00	4.55E-08	3.21E-07	3.92E-11
4	Hexachlorobenzene	mg/kg	3.90E-01	9.35E-09		7.33E-08
4	Hexachlorocyclopentadiene	mg/kg	3.90E-01	9.35E-09		5.86E-07
4	N-Nitroso-di-n-propylamine	mg/kg	3.90E-01	9.35E-09	6.60E-08	8.04E-12
4	Pentachlorophenol	mg/kg	1.90E+00	4.55E-08	8.03E-07	3.92E-11
4	Total PAH	mg/kg	4.80E-01	1.15E-08	1.06E-07	9.90E-12
5	Antimony	mg/kg	9.75E+00	2.34E-07		2.01E-10
5	Thallium	mg/kg	1.95E+01	4.67E-07		4.02E-10
5	2,6-Dinitrotoluene	mg/kg	4.10E-01	9.83E-09	6.86E-08	8.45E-12
5	2-Methyl-4,6-dinitrophenol	mg/kg	2.10E+00	5.03E-08	3.55E-07	4.33E-11
5	3-Nitrobenzenamine	mg/kg	2.10E+00	5.03E-08	3.55E-07	4.33E-11
5	Hexachlorobenzene	mg/kg	4.10E-01	9.83E-09		7.71E-08
5	Hexachlorocyclopentadiene	mg/kg	4.10E-01	9.83E-09		6.16E-07
5	N-Nitroso-di-n-propylamine	mg/kg	4.10E-01	9.83E-09	6.93E-08	8.45E-12
5	Pentachlorophenol	mg/kg	2.10E+00	5.03E-08	8.88E-07	4.33E-11

Table D5.4. Carcinogenic CDIs for the Current Industrial Worker Exposed to Surface Soil for Nondetect Uncertainty Evaluation

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation
1	2,6-Dinitrotoluene	mg/kg	4.30E-01	3.68E-09	2.57E-08	3.17E-09
1	3,3'-Dichlorobenzidine	mg/kg	8.60E-01	7.36E-09	5.19E-08	6.33E-09
1	3-Nitrobenzenamine	mg/kg	2.20E+00	1.88E-08	1.33E-07	1.62E-08
1	Bis(2-chloroethyl) ether	mg/kg	4.30E-01	3.68E-09		4.62E-05
1	Hexachlorobenzene	mg/kg	4.30E-01	3.68E-09		2.89E-05
1	N-Nitroso-di-n-propylamine	mg/kg	4.30E-01	3.68E-09	2.60E-08	3.17E-09
1	Pentachlorophenol	mg/kg	2.20E+00	1.88E-08	3.32E-07	1.62E-08
2	2,6-Dinitrotoluene	mg/kg	2.40E-01	2.05E-09	1.43E-08	1.77E-09
2	bis(2-chloroethyl) ether	mg/kg	4.00E-01	3.42E-09		4.30E-05
2	n-Nitroso-di-n-propylamine	mg/kg	4.00E-01	3.42E-09	2.42E-08	2.95E-09
2	Pentachlorophenol	mg/kg	7.20E-01	6.16E-09	1.09E-07	5.30E-09
3	2,6-Dinitrotoluene	mg/kg	3.30E-01	2.83E-09	1.97E-08	2.43E-09
3	3-Nitrobenzenamine	mg/kg	1.65E+00	1.41E-08	9.96E-08	1.22E-08
3	Bis(2-chloroethyl) ether	mg/kg	4.00E-01	3.42E-09		4.30E-05
3	Hexachlorobenzene	mg/kg	2.30E+00	1.97E-08		1.54E-04
3	Hexachlorobutadiene	mg/kg	2.30E+00	1.97E-08		9.72E-04
3	Hexachloroethane	mg/kg	2.30E+00	1.97E-08		1.31E-03
3	N-Nitroso-di-n-propylamine	mg/kg	4.00E-01	3.42E-09	2.42E-08	2.95E-09
3	Pentachlorophenol	mg/kg	2.30E+00	1.97E-08	3.47E-07	1.69E-08
4	Antimony	mg/kg	1.22E+01	1.04E-07		8.99E-08
4	Thallium	mg/kg	1.80E+01	1.54E-07		1.33E-07
4	2,6-Dinitrotoluene	mg/kg	3.90E-01	3.34E-09	2.33E-08	2.87E-09
4	3,3'-Dichlorobenzidine	mg/kg	7.80E-01	6.68E-09	4.71E-08	5.74E-09
4	3-Nitrobenzenamine	mg/kg	1.90E+00	1.63E-08	1.15E-07	1.40E-08

Table D5.4. Carcinogenic CDIs for the Current Industrial Worker Exposed to Surface Soil for Nondetect Uncertainty Evaluation (Continued)

EU	COPC	Units	EPC	Ingestion	Dermal	Inhalation
4	Bis(2-chloroethyl) ether	mg/kg	3.90E-01	3.34E-09		4.19E-05
4	Hexachlorobenzene	mg/kg	3.90E-01	3.34E-09		2.62E-05
4	N-Nitroso-di-n-propylamine	mg/kg	3.90E-01	3.34E-09	2.36E-08	2.87E-09
4	Pentachlorophenol	mg/kg	1.90E+00	1.63E-08	2.87E-07	1.40E-08
4	Total PAH	mg/kg	4.80E-01	4.11E-09	3.77E-08	3.54E-09
5	Antimony	mg/kg	9.75E+00	8.35E-08		7.18E-08
5	Thallium	mg/kg	1.95E+01	1.67E-07		1.44E-07
5	2,6-Dinitrotoluene	mg/kg	4.10E-01	3.51E-09	2.45E-08	3.02E-09
5	3,3'-Dichlorobenzidine	mg/kg	8.20E-01	7.02E-09	4.95E-08	6.04E-09
5	3-Nitrobenzenamine	mg/kg	2.10E+00	1.80E-08	1.27E-07	1.55E-08
5	Bis(2-chloroethyl) ether	mg/kg	4.10E-01	3.51E-09		4.41E-05
5	Hexachlorobenzene	mg/kg	4.10E-01	3.51E-09		2.75E-05
5	N-Nitroso-di-n-propylamine	mg/kg	4.10E-01	3.51E-09	2.48E-08	3.02E-09
5	Pentachlorophenol	mg/kg	2.10E+00	1.80E-08	3.17E-07	1.55E-08

Table D5.5. HIs for the Current Industrial Worker for Nondetect Uncertainty Evaluation

COPC	EPC (mg/kg or pCi/g)	Ingestion	Dermal	Inhalation	HI	% Contribution across All Pathways
EU 1						
2,6-Dinitrotoluene	4.30E-01	0.0	0.0		0.0	4%
2-Methyl-4,6-dinitrophenol	2.20E+00	0.0	0.0		0.0	74%
3-Nitrobenzenamine	2.20E+00	0.0	0.0	0.0	0.0	20%
Hexachlorobenzene	4.30E-01	0.0			0.0	0%
Hexachlorocyclopentadiene	4.30E-01	0.0		0.0	0.0	0%
N-Nitroso-di-n-propylamine	4.30E-01	0.0	0.0		0.0	0%
Pentachlorophenol	2.20E+00	0.0	0.0		0.0	3%
Totals		0.0	0.0	0.0	**0.0**	
% Contribution within a Pathway		12%	88%	0%		
EU 2						
2,6-Dinitrotoluene	2.40E-01	0.0	0.0		0.0	7%
2-Methyl-4,6-dinitrophenol	8.00E-01	0.0	0.0		0.0	90%
Hexachlorocyclopentadiene	4.00E-01	0.0		0.0	0.0	0%
n-Nitroso-di-n-propylamine	4.00E-01	0.0	0.0		0.0	0%
Pentachlorophenol	7.20E-01	0.0	0.0		0.0	3%
Totals		0.0	0.0	0.0	**0.0**	
% Contribution within a Pathway		12%	88%	0%		
EU 3						
2,6-Dinitrotoluene	3.30E-01	0.0	0.0		0.0	4%
2-Methyl-4,6-dinitrophenol	1.65E+00	0.0	0.0		0.0	70%
3-Nitrobenzenamine	1.65E+00	0.0	0.0	0.0	0.0	19%
Hexachlorobenzene	2.30E+00	0.0			0.0	1%
Hexachlorobutadiene	2.30E+00	0.0			0.0	1%
Hexachlorocyclopentadiene	4.00E-01	0.0		0.0	0.0	0%
Hexachloroethane	2.30E+00	0.0		0.0	0.0	1%
N-Nitroso-di-n-propylamine	4.00E-01	0.0	0.0		0.0	0%
Pentachlorophenol	2.30E+00	0.0	0.0		0.0	4%
Totals		0.0	0.0	0.0	**0.0**	
% Contribution within a Pathway		15%	85%	0%		

Table D5.5. HIs for the Current Industrial Worker for Nondetect Uncertainty Evaluation (Continued)

COPC	EPC (mg/kg or pCi/g)	Ingestion	Dermal	Inhalation	HI	% Contribution across All Pathways
EU 4						
Antimony	1.22E+01	0.0			0.0	1%
Thallium	1.80E+01	0.0			0.0	86%
2,6-Dinitrotoluene	3.90E-01	0.0	0.0		0.0	1%
2-Methyl-4,6-dinitrophenol	1.90E+00	0.0	0.0		0.0	9%
3-Nitrobenzenamine	1.90E+00	0.0	0.0	0.0	0.0	2%
Hexachlorobenzene	3.90E-01	0.0			0.0	0%
Hexachlorocyclopentadiene	3.90E-01	0.0		0.0	0.0	0%
N-Nitroso-di-n-propylamine	3.90E-01	0.0	0.0		0.0	0%
Pentachlorophenol	1.90E+00	0.0	0.0		0.0	0%
Total PAH	4.80E-01				0.0	0%
Totals		0.0	0.0	0.0	**0.0**	
% Contribution within a Pathway		89%	11%	0%		
EU 5						
Antimony	9.75E+00	0.0			0.0	1%
Thallium	1.95E+01	0.0			0.0	86%
2,6-Dinitrotoluene	4.10E-01	0.0	0.0		0.0	0%
2-Methyl-4,6-dinitrophenol	2.10E+00	0.0	0.0		0.0	9%
3-Nitrobenzenamine	2.10E+00	0.0	0.0	0.0	0.0	2%
Hexachlorobenzene	4.10E-01	0.0			0.0	0%
Hexachlorocyclopentadiene	4.10E-01	0.0		0.0	0.0	0%
N-Nitroso-di-n-propylamine	4.10E-01	0.0	0.0		0.0	0%
Pentachlorophenol	2.10E+00	0.0	0.0		0.0	0%
Totals		0.0	0.0	0.0	**0.1**	
% Contribution within a Pathway		89%	11%	0%		

Table D5.6. ELCR for the Current Industrial Worker for Nondetect Uncertainty Evaluation

COPC	EPC (mg/kg or pCi/g)	Ingestion	Dermal	Inhalation	ELCR	% Contribution across All Pathways
EU 1						
2,6-Dinitrotoluene	4.30E-01	5.5E-09			5.5E-09	7%
3,3'-Dichlorobenzidine	8.60E-01	3.3E-09	2.3E-08	2.2E-12	2.7E-08	34%
3-Nitrobenzenamine	2.20E+00	4.0E-10			4.0E-10	1%
Bis(2-chloroethyl) ether	4.30E-01	4.0E-09		1.5E-08	1.9E-08	25%
Hexachlorobenzene	4.30E-01	5.9E-09		1.3E-08	1.9E-08	24%
N-Nitroso-di-n-propylamine	4.30E-01	1.8E-11		8.2E-15	1.8E-11	0%
Pentachlorophenol	2.20E+00	7.5E-09		8.3E-14	7.5E-09	10%
Totals		2.7E-08	2.3E-08	2.9E-08	**7.9E-08**	
% Contribution within a Pathway		34%	30%	36%		
EU 2						
2,6-Dinitrotoluene	2.40E-01	3.1E-09			3.1E-09	13%
bis(2-chloroethyl) ether	4.00E-01	3.8E-09		1.4E-08	1.8E-08	76%
n-Nitroso-di-n-propylamine	4.00E-01	1.7E-11		7.7E-15	1.7E-11	0%
Pentachlorophenol	7.20E-01	2.5E-09		2.7E-14	2.5E-09	10%
Totals		9.3E-09		1.4E-08	**2.4E-08**	
% Contribution within a Pathway		40%		60%		

Table D5.6. ELCR for the Current Industrial Worker for Nondetect Uncertainty Evaluation (Continued)

COPC	EPC (mg/kg or pCi/g)	Ingestion	Dermal	Inhalation	ELCR	% Contribution across All Pathways
EU 3						
2,6-Dinitrotoluene	3.30E-01	4.2E-09			4.2E-09	2%
3-Nitrobenzenamine	1.65E+00	3.0E-10			3.0E-10	0%
Bis(2-chloroethyl) ether	4.00E-01	3.8E-09		1.4E-08	1.8E-08	10%
Hexachlorobenzene	2.30E+00	3.2E-08		7.1E-08	1.0E-07	60%
Hexachlorobutadiene	2.30E+00	1.5E-09		2.1E-08	2.3E-08	13%
Hexachloroethane	2.30E+00	7.9E-10		1.4E-08	1.5E-08	9%
N-Nitroso-di-n-propylamine	4.00E-01	1.7E-11		7.7E-15	1.7E-11	0%
Pentachlorophenol	2.30E+00	7.9E-09		8.6E-14	7.9E-09	5%
Totals		5.0E-08		1.2E-07	**1.7E-07**	
% Contribution within a Pathway		29%		71%		
EU 4						
2,6-Dinitrotoluene	3.90E-01	5.0E-09			5.0E-09	1%
3,3'-Dichlorobenzidine	7.80E-01	3.0E-09	2.1E-08	2.0E-12	2.4E-08	6%
3-Nitrobenzenamine	1.90E+00	3.4E-10			3.4E-10	0%
Bis(2-chloroethyl) ether	3.90E-01	3.7E-09		1.4E-08	1.8E-08	5%
Hexachlorobenzene	3.90E-01	5.3E-09		1.2E-08	1.7E-08	5%
N-Nitroso-di-n-propylamine	3.90E-01	1.6E-11		7.5E-15	1.6E-11	0%
Pentachlorophenol	1.90E+00	6.5E-09		7.1E-14	6.5E-09	2%
Total PAH	4.80E-01	3.0E-08	2.8E-07	3.9E-12	3.1E-07	81%
Totals		5.4E-08	3.0E-07	2.6E-08	**3.8E-07**	
% Contribution within a Pathway		14%	79%	7%		
EU 5						
2,6-Dinitrotoluene	4.10E-01	5.3E-09			5.3E-09	7%
3,3'-Dichlorobenzidine	8.20E-01	3.2E-09	2.2E-08	2.1E-12	2.5E-08	34%
3-Nitrobenzenamine	2.10E+00	3.8E-10			3.8E-10	1%
Bis(2-chloroethyl) ether	4.10E-01	3.9E-09		1.5E-08	1.8E-08	25%
Hexachlorobenzene	4.10E-01	5.6E-09		1.3E-08	1.8E-08	24%
N-Nitroso-di-n-propylamine	4.10E-01	1.7E-11		7.9E-15	1.7E-11	0%
Pentachlorophenol	2.10E+00	7.2E-09		7.9E-14	7.2E-09	10%
Totals		2.5E-08	2.2E-08	2.7E-08	**7.5E-08**	
% Contribution within a Pathway		34%	30%	36%		

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APPENDIX E

SCREENING ECOLOGICAL RISK ASSESSMENT

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CONTENTS

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FIGURES

TABLES

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ACRONYMS

COPEC	chemical or radionuclide of potential ecological concern
CSM	conceptual site model
DOE	U.S. Department of Energy
EPC	exposure point concentration
ESV	ecological screening value
HQ	hazard quotient
NFA	no further action
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PGDP	Paducah Gaseous Diffusion Plant
RI	remedial investigation
SERA	screening ecological risk assessment
SVOC	semivolatile organic compound
SWMU	solid waste management unit
UCL	upper confidence limit
VOC	volatile organic compound
WKWMA	West Kentucky Wildlife Management Area

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E.1. INTRODUCTION

E.1.1 SITE LOCATION

This appendix provides the results of the screening ecological risk assessment (SERA) completed for Soils Operable Unit (OU) Remedial Investigation (RI) Solid Waste Management Unit (SWMU) 1 at the Paducah Gaseous Diffusion Plant (PGDP), which is owned by the U.S. Department of Energy (DOE) (Figure E.1). Some of the area surrounding the PGDP facility is a recreational wildlife area, the West Kentucky Wildlife Management Area (WKWMA), with residential areas lying beyond the WKWMA. Private land in rural residential and agricultural areas also borders the PGDP facility.

E.1.2 SITE HISTORY

SWMU 1 is described in-depth in Chapter 5 of this RI Report Addendum.

E.2. PROBLEM FORMULATION

The first step in a SERA includes the problem formulation. This step encompasses development of the preliminary conceptual site model (CSM), determination of potentially complete exposure pathways and potentially contaminated media, selection of exposure endpoints, and selection of screening levels protective of the endpoints and potentially exposed receptors at the site.

E.2.1 PRELIMINARY CONCEPTUAL SITE MODEL

The preliminary CSM includes a description of the environmental setting, known site contaminants, and a figure (Figure E.2) representing the potential exposure pathways. The figure shows several pathways as incomplete because groundwater recharge to surface water is not expected as a potential release mechanism at SWMU 1. This preliminary CSM is used as the basis for selection of benchmark values used to screen the site for potential ecological risk. The primary ecological receptors (i.e., the exposure endpoints) shown in the preliminary CSM are terrestrial animals and terrestrial plants. Specific groups included in terrestrial animals and plants, which are the exposure endpoints shown in the preliminary CSM, include reptiles and amphibians, birds, and mammals (see Section E.2.1.1). Screening values are protective of these endpoints and are discussed in Section E.3.

E.2.1.1 Site Environmental Setting and Habitat Descriptions

SWMU 1 is located inside the Limited Area. Although there is potential for contamination below the surface to migrate laterally toward surface water, the direction of shallow groundwater flow is primarily downward and represents limited risks to terrestrial receptors near these sites. This section presents a brief summary of the ecosystem relevant to defining the CSM and exposure pathways. Table E.1 and the text below describe ground cover and proximity to surface water/drainageways for SWMU 1. Figure E.3 displays a photograph of SWMU 1.

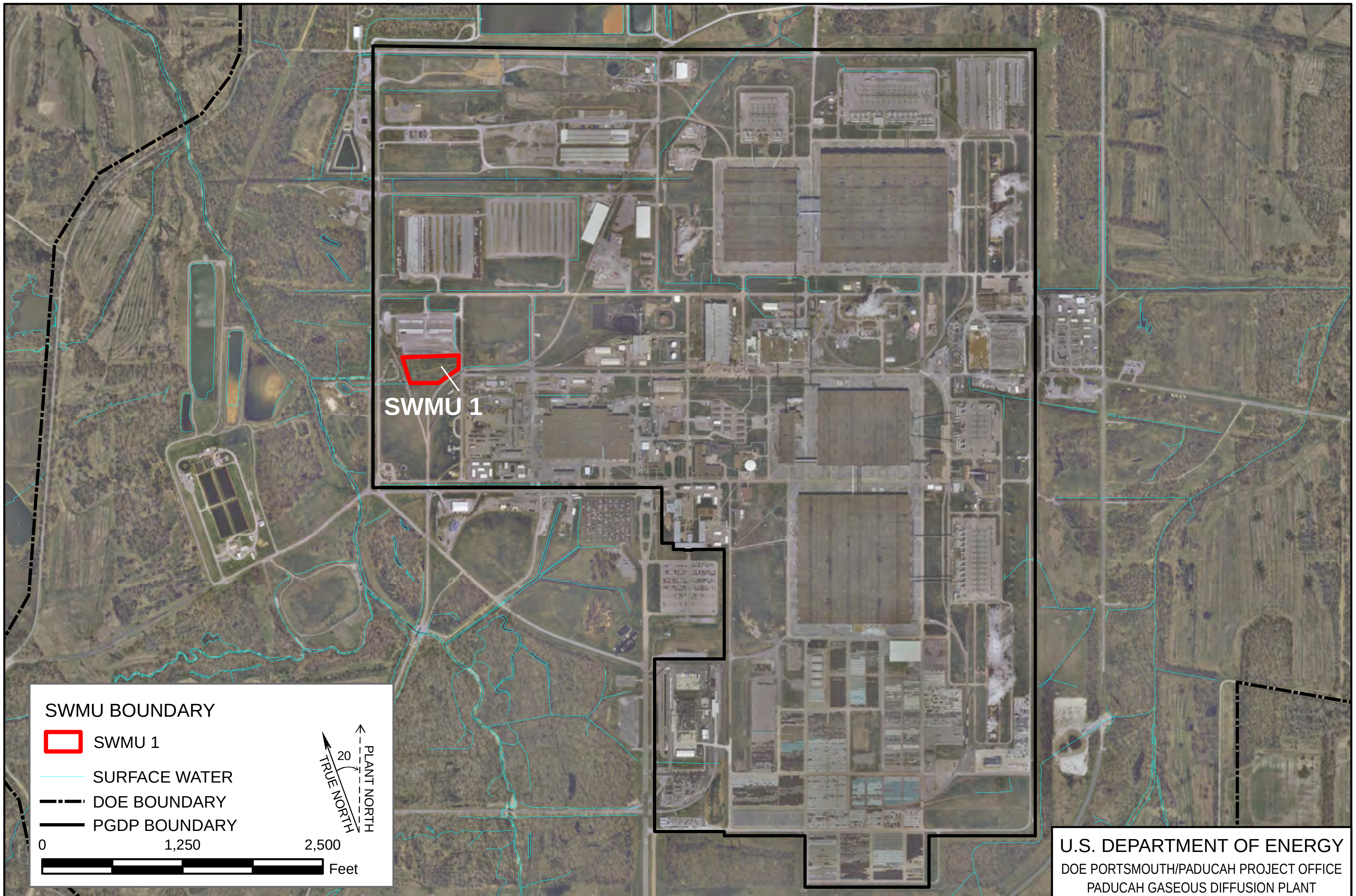

Figure E.1. Location of SWMU 1

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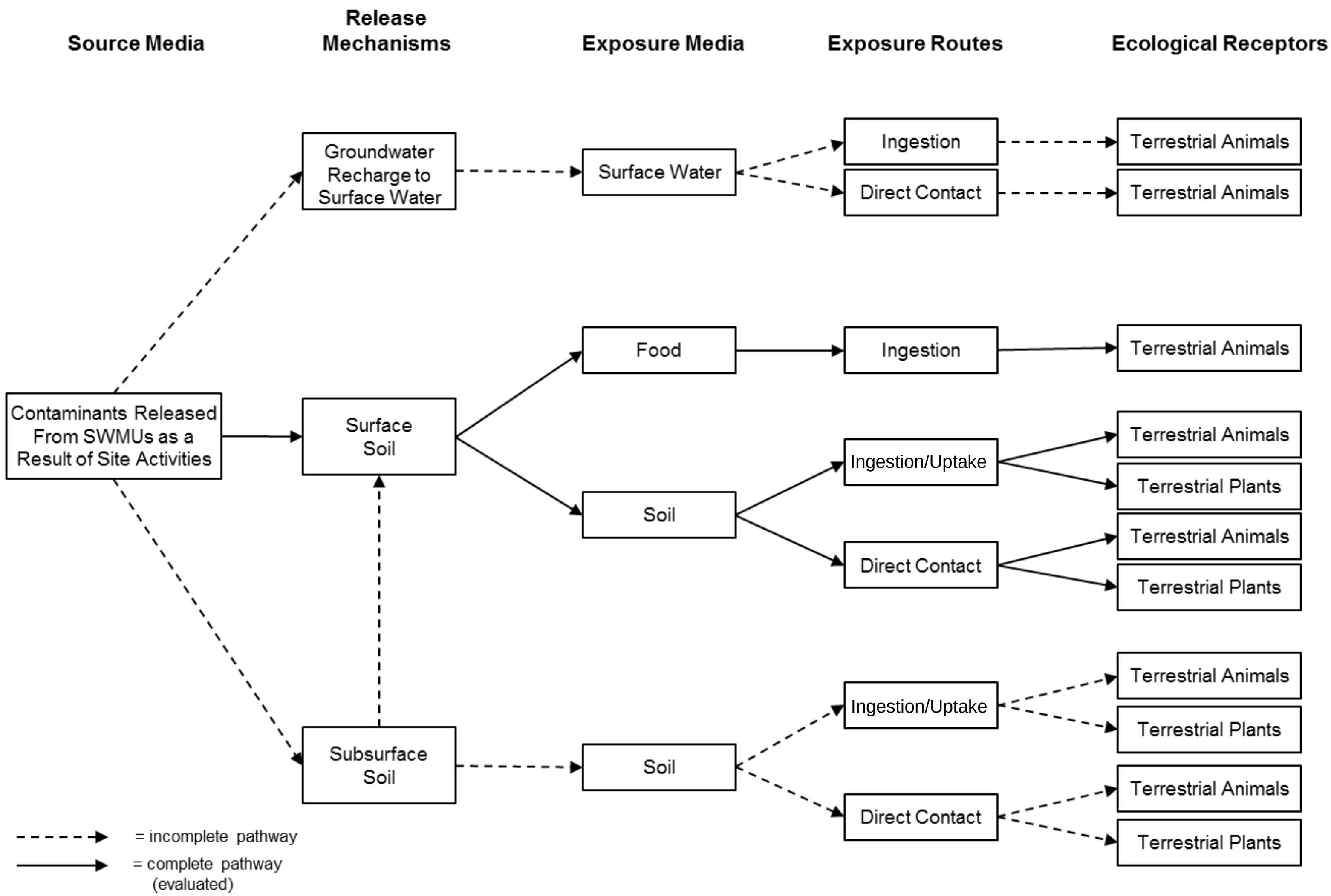

Figure E.2. Preliminary Conceptual Site Model for SWMU 1

Table E.1. Ecological Screening for SWMU 1

Description	Area Acres	Ground Cover	Near a Surface Water Body?	Total HQ[a]	Priority COPECs	Background (mg/kg)[b]	Maximum Detection or ½ Maximum Detection Limit (mg/kg)	Soil ESV (mg/kg)[b]	EPC (mg/kg)	HQ[a]
Oil Landfarm (disposal of waste oil)	2.29	Grass	Yes	468.1	Aluminum	13,000	11,100	50	8,574	171.5
					Antimony	0.21	7.5	0.27	9.763	36.2
					Iron	28,000	24,000	200	16,398	82.0
					Mercury	0.2	3	0.1	2.74	27.4
					PCB, Total	N/A	9.5	0.02	1.439	72.0
					Phenol	N/A	1.8	0.05	0.851	17.0

[a] The total HQ sums contributions from all of the chemical or radionuclide of potential ecological concern (COPECs) (listed in Table E3.1); only priority COPECs [i.e., the COPECs with hazard quotients (HQs) greater than 10, using the exposure point concentrations (EPCs) (Section E.3)] are shown in this table.
[b] Background values are for surface soil taken from DOE 2016; ecological screening values (ESVs) are taken from DOE 2015 and Attachment E1.

Figure E.3. Photograph of SWMU 1, August 2016 (Looking West)

The human health and ecological risk assessments used acreage for a SWMU based on Global Positioning System coordinates and mapping tools. This acreage is reflected in the figures within this document. Of note, the acreage presented in the Background section of this document may be inconsistent with acreage utilized in the risk assessments due to its being based on historical SWMU assessment report administrative boundaries, which typically were estimated utilizing a map/figure.

SWMU 1 was used as an oil landfarm for the disposal of waste oil. The SWMU is grass-covered and is approximately 2.29 acres. The SWMU is near a surface water body; its southeast border is a Kentucky Pollutant Discharge Elimination System outfall ditch.

The primary ecosystem in the area outside the industrial area around SWMU 1 is upland grassland interspersed with developed industrial areas. The vegetation over SWMU 1 is maintained with routine mowing (see Section 3.1) approximately eight times per year. SWMU 1 also is surrounded by roads and is within the PGDP fenced area. The buffer area and areas bordering the PGDP facility include forest, thickets, and agricultural land. Much of the PGDP facility is surrounded by the WKWMA, which includes managed native prairie and deciduous forest. Species documented to occur in the area include numerous small mammals, particularly shrews, mice, and voles. Numerous bird species, including doves, turkey, quail, bluebirds and other songbirds, hawks, and owls, are found in this area. There also are amphibians, reptiles (primarily lizards and turtles), and bats. Table E.2 lists species observed in the nonindustrial areas of PGDP and at the adjacent WKWMA.

Table E.2. Wildlife Species Present or Potentially Present at the PGDP Site*

Common Name	Scientific Name
Fish	
Black buffalo	*Ictiobus niger*
Blackspotted topminnow	*Fundulus olivaceus*
Creek chub	*Semotilus atromaculatus*
Bluegill sunfish	*Lepomis macrochirus*
Green sunfish	*Lepomis cyanellus*
Redspotted sunfish	*Lepomis miniatus*
Largemouth bass	*Micropterus salmoides*
Longear sunfish	*Lepomis megalotis*
Stoneroller	*Campostoma sp.*
Reptiles and Amphibians	
American toad	*Bufo americanus*
Bull frog	*Rana catesbeiana*
Eastern box turtle	*Terrapene carolina*
Leopard frog	*Rana sphenocephala*
Salamanders	Various species
Snakes	Various species
Green treefrog	*Hyla cinerea*
Woodhouse toad	*Bufo woodhousei*
Northern crawfish frog	*Rana areolata circulosa*
Green frog	*Rana clamitans melanota*
Upland chorus frog	*Pseudacris triseriata feriiarum*
Birds	
American robin	*Turdus migratorius*
American woodcock	*Scolopax minor*
Bald eagle	*Haliaeetus leucocephalus*
Barred owl	*Strix varia*
Belted kingfisher	*Ceryle alcyon*
Blue jay	*Cyanocitta cristata*
Blue-winged teal	*Anas discors*
Canada goose	*Branta canadensis*
Coot	*Fulica americana*
American crow	*Corvus brachyrhynchos*
Downy woodpecker	*Picoides pubescens*
Eastern bluebird	*Sialia sialus*
Eastern kingbird	*Tyrannus tyrannus*

Table E.2. Wildlife Species Present or Potentially Present at the PGDP Site* (Continued)

Common Name	Scientific Name
Bird (Continued)	
Eastern meadowlark	*Sturnella magna*
Eastern phoebe	*Sayornis phoebe*
Eastern wood pewee	*Contopus virens*
Gadwall duck	*Anas strepera*
Great blue heron	*Ardea herodias*
Great crested flycatcher	*Myiarchus crinitus*
Great-horned owl	*Bubo virginianus*
Hairy woodpecker	*Picoides villosus*
Hawks	Various species
Herons and egrets	Various species
Killdeer	*Charadrius vociferus*
Loggerhead shrike	*Lanius ludovicianus*
Mallard duck	*Anas platyrhynchus*
Mourning dove	*Zenaida macroura*
Northern bobwhite (aka bobwhite quail)	*Colinus virgianus*
Northern cardinal	*Cardinalis cardinalis*
Northern flicker	*Colaptes auratus*
Pileated woodpecker	*Dryocopus pileatus*
Red-bellied woodpecker	*Melanerpes erythrocephalus*
Red-shouldered hawk	*Buteo lineatus*
Red-tailed hawk	*Buteo jamaicensis*
Red-winged blackbird	*Agelaius phoeniceus*
Ruby-throated hummingbird	*Archilochus colubris*
Screech owl	*Megascops asio*
Song sparrow	*Melospiza melodia*
Swallows	Various species
Vireos	Various *vireo sp.*
Tufted titmouse	*Baeolophus bicolor*
Turkey vulture	*Cathartes aura*
Warblers	*Various species*
Chuck-will’s widow	*Caprimulgus carolinensis*
White-breasted nuthatch	*Sitta carolinensis*
Whip-poor-will	*Caprimulgis vocifierous*
Wild turkey	*Meleagris gallopavo*
Wood cock	*Scolopax minor*
Wood duck	*Aix sponsa*
Wrens	Various species
Yellow-billed cuckoo	*Coccyzus americanus*
Mammals	
American beaver	*Castor canadensis*
American mink (aka mink)	*Mustela vison*
Bobcat	*Lynx rufus*
Common muskrat	*Ondatra zibethicus*
Coyote	*Canis latrans*
Eastern cottontail	*Sylvilagus floridanus*
Eastern grey squirrel and fox squirrel	*Sciurus carolinensis*
Evening bat	*Nycticeceius humeralis*
Groundhog	*Marmota monax*
Indiana bat	*Myotis sodalis*
Mice	Various species
Moles	Various species

Table E.2. Wildlife Species Present or Potentially Present at the PGDP Site* (Continued)

Common Name	Scientific Name
Mammals (Continued)	
Opposum	*Didelphis virginiana*
Raccoon	*Procyon lotor*
Red fox	*Vuples vulpes*
Grey fox	*Urocyon cinereoargenteus*
Shrews	Various species
Skunk	*Mephitis mephitis*
Southeastern myotis bat	*Myotis sodalis*
Voles	Various species
White-tailed deer	*Odocoileus virginianus*

*The listed species are from the Surface Water OU Report (DOE 2008) and the WKWMA species information Web site (http://app.fw.ky.gov/Public_Lands_Search/detail.aspx?Kdfwr_id=137).

A number of state and federal listed, threatened, and endangered species may be present on the buffer areas within PGDP and the surrounding WKWMA land, though they are unlikely to be found on the maintained surface within SWMU 1 (DOE 2008). A recent ecological site survey was not included in the scope of the project for the Soils OU and was not available for evaluation at SWMU 1. These species are listed in Table E.3 of this document. The U.S. Fish and Wildlife Service has designated a portion of the DOE property as summer habitat for a maternity colony of Indiana bat. Summer bat habitat consists of trees greater than 5 inches in diameter at breast height (FWS 2015). As shown in Figure E.3, no trees are present at SWMU 1.

Table E.3. Federally Listed, Proposed, and Candidate Species Potentially Occurring within the Paducah Site Study Area[a]

Group	Common Name	Scientific Name	Endangered Species Act Status
Mammals[b]	Indiana Bat	*Myotis sodalis*	Endangered
	Northern Long-eared Bat	*Myotis septentrionalis*	Threatened
Clams	Clubshell	*Pleurobema clava*	Endangered
	Fanshell	*Cyprogenia stegaria*	Endangered
	Fat Pocketbook	*Potamilus capax*	Endangered
	Orangefoot Pimpleback	*Plethobasus cooperianus*	Endangered
	Pink Mucket	*Lampsilis abrupta*	Endangered
	Rabbitsfoot	*Quadrula cylindrica cylindrica*	Threatened
	Ring Pink	*Obovaria retusa*	Endangered
	Rough Pigtoe	*Pleurobema plenum*	Endangered
	Sheepnose Mussel	*Plethobasus cyphyus*	Endangered
	Spectaclecase	*Cumberlandia monodonta*	Endangered
Birds	Least Tern	*Sterna antillarum*	Endangered

[a] All of the listed species are identified as an Endangered, Threatened, or Candidate Species known or with the potential to be located within McCracken County, Kentucky, by the U.S. Fish and Wildlife Service (FWS 2016).
[b] Although Gray Bat appears to be included as an endangered species in McCracken County, further information available for counties within Kentucky in which the Gray Bat is known to or is believed to occur does not include McCracken.

E.2.1.2 Data

The dataset for surface soils (i.e., 0–1 ft bgs) used in the SERA is comprised of historical sampling events as well as data collected during the summer of 2016 for this RI (DOE 2014). Chapter 5 describes the data set used for SWMU 1. Data for the SERA are not subdivided by grid or exposure unit. Appendix B addresses data quality and applicability of the historical data.

For purposes of this SERA, high molecular weight polycyclic aromatic hydrocarbons (PAHs) consist of the following: benz(a)anthracene; benzo(a)pyrene; benzo(b)fluoranthene; benzo(k)fluoranthene; chrysene; dibenz(a,h)anthracene; fluoranthene; indeno(1,2,3-cd)pyrene; and pyrene. Low molecular weight PAHs consist of acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, and phenanthrene. Results of analyses for PAHs are summed and assessed within the group (i.e., high molecular weight PAHs and low molecular weight PAHs). Individual PAHs are not assessed.

E.2.1.3 Site Contaminants

Only surface soil contaminants at SWMU 1 were considered in the SERA. Site contaminants included inorganic chemicals, organic chemicals, and radionuclides.

E.2.1.4 Fate and Transport Mechanisms

Potential migration pathways for contaminants from soil at SWMU 1 include transport of contaminated surface soil off-site by surface water, migration of contaminants to the subsurface soil, migration to groundwater, and uptake of soil contaminants through the on-site food chain. In addition, subsurface contaminants may be brought to the surface through bioturbation by burrowing animals or uptake by vegetation on the site. Migration of contaminants through these pathways is not considered significant and is not evaluated within this SERA.

The surface soils at SWMU 1 are held in place by vegetation. Transport of surface soil off-site is likely to be minimal. Migration of contaminants to subsurface soil and through subsurface soil to groundwater is not likely to occur at SWMU 1. Contaminants in groundwater may be discharged to surface water at areas away from SWMU 1. Contaminants in surface soil are likely to be taken up into plants and soil invertebrates at these sites and would enter higher trophic level organisms through the food chain.

E.2.2 POTENTIALLY COMPLETE EXPOSURE PATHWAYS

The potential exposure pathways for ecological receptors are direct contact with and ingestion of soil and ingestion of plants or animals thereby exposed to substances in soil. Significant contaminant transport through runoff directly to surface water is unlikely because most of SWMU 1 has a vegetated surface. The scope of the Soils OU does not include any drainage ditches bounding the Soils OU SWMUs/AOCs. These ditches are components of the Surface Water Operable Unit. The pathways through which receptors could contact contaminants in surface soil include direct ingestion of soil, ingestion of plant or animals from the site as food, external exposure to ionizing radiation, and dermal contact with soil or surface water. A CSM reflective of current site conditions is shown in Figure E.2. This SERA evaluates ecological risks associated with surface soil only.

E.2.3 POTENTIALLY CONTAMINATED MEDIA

Soil is the media of concern for SWMU 1. The substances detected in surface soils [metals, radionuclides, and semivolatile organic compounds (SVOCs)] are capable of causing adverse effects on terrestrial receptors. This SERA evaluates only terrestrial receptors (see Section E.2.1) for COPECs.

Significant surface water contamination is not expected based on evaluations previously performed at other SWMUs within the site (UK 2007). As a result, ecological risks associated with exposure to surface water were not assessed in this SERA.

E.3. SCREENING-LEVEL EFFECTS EVALUATION

For SWMU 1, the maximum site concentration of the reported values of each potential contaminant was compared to a single ecological screening level selected from the Ecological Risk Methods Document. ESVs were taken from Tables A.2 and A.3 of the Ecological Risk Methods Document (DOE 2015). These ESVs are the PGDP no further action (NFA) values for soil. For detected radiological results for which no ESV was available in the Ecological Risk Methods Document, one was calculated following similar methodology. Additionally, detected chemicals for which an ESV is not listed in Table A.2, values from other sources were used. These values are presented in Attachment E1.

The maximum site concentration for a substance reported as detected in any sample is the larger of the maximum detected concentration and one-half of the maximum reported detection limit for the substance in samples reported as nondetect. Maximum detected site concentrations, frequencies of detection, and detection limit ranges are provided in Chapter 5. The maximum site concentration was used to calculate a HQ, using a ratio of the maximum site concentration with the ESV, as shown below:

$$\mathbf{HQ} = \frac{\mathbf{EPC}}{\mathbf{ESV}}$$

A screening list with HQs is provided in Attachment E2. For those chemicals with at least one detection and whose maximum HQ was greater than or equal to 1 and for which at least 10 results were available, an EPC was calculated as the 95% upper confidence limit (UCL) using ProUCL. The output from this program is included as Attachment E3. COPECs were evaluated further by calculating an HQ using the EPCs.

A total HQ then was calculated by summing the HQs within SWMU 1. Priority COPECs were selected from the chemicals at SWMU 1 showing HQs greater than 10 calculated with the EPC. "Priority COPECs" are identified in this RI as an aid to risk managers during decision making. Table E.1 summarized these values. Background values from the Human Health Risk Methods Document (DOE 2016) also are shown for comparison.

A summary of the results of the site data is provided in Table E.4, which lists the number of COPECs within each analytical suite [i.e., metals, radiological constituents, polychlorinated biphenyls (PCBs), SVOCs, and volatile organic compounds (VOCs)] retained for SWMU 1 for further consideration. As shown, SWMU 1 had one or more COPECs retained. The entire screening list is provided in Attachment E2.

Table E.4. Summary of Suite of COPECs Retained in Surface Soil

SWMU	Media	Number of Metals	Number of Rads	Number of PCBs	Number of SVOCs	Number of VOCs
1	Soil	18	---	1	3	1

---: no COPECs

E.4. UNCERTAINTIES

A number of uncertainties impact the potential usefulness of the results of this SERA. An uncertainty in these screening assessments is that the ecological screening levels are protective of entire suites of receptors, some of which may not be present at these disturbed sites. The grassy areas of these sites would be attractive to ecological receptors, but SWMU 1 is relatively small, and the surrounding industrial area may limit the extent to which ecological receptors use these areas. The potential risk from exposure to subsurface soil was not quantified in this SERA and, therefore, is unknown.

Because no pH data are available for SWMU 1, aluminum has been evaluated as if pH were less than 5.5. While soils in the vicinity of PGDP tend to have a low pH, ranging from 4.5 to 5.5 (DOE 1999) (see Section 3.5 of the main text), the pH of the soils for SWMU 1 is unknown. Aluminum, subsequently, may be evaluated further by collection of soil pH data. Because soil pH results can be variable, however, whether aluminum should be considered a COPEC at SWMU 1 is an uncertainty. Additionally, a number of chemicals were retained as COPECs for which no benchmarks were available. These chemicals, upon further evaluation may have no negative impacts on the ecological receptors.

These uncertainties, combined with the results of the SERA, indicate the need for further evaluation of SWMU 1. Risk managers may determine that the site does not need further evaluation (if exposure pathways are not complete or planned actions will eliminate the exposure pathway) or may recommend additional evaluation of the site to define better the potential ecological risk indicated by the results. Alternatively, the benchmarks used in the screenings presented here and in the NFA levels in the PGDP Ecological Risk Methods Document (DOE 2015) may be used as the ecologically based remedial goal options.

E.5. CONCLUSIONS

SWMU 1 retained a number of COPECs including metals, PCBs, SVOCs, and VOCs. COPECs are listed below.

Metals:

- Aluminum
- Antimony
- Beryllium
- Cadmium
- Calcium (retained because no ESV was available)
- Chromium
- Copper
- Iron
- Lead
- Manganese
- Mercury
- Molybdenum
- Nickel
- Selenium
- Silver
- Sodium (retained because no ESV was available)
- Thallium
- Uranium
- Vanadium
- Zinc

Total PCBs

SVOCs:

- 2-Methylnaphthalene
- High molecular weight PAHs
- Phenol

VOCs:

- Trichloroethene

Further, the following COPECs had an HQ, based on EPC, above 10: aluminum, antimony, iron, mercury, Total PCB, phenol. These COPECs are listed in Table E.1.

E.6. REFERENCES

DOE (U.S. Department of Energy) 2008. *Surface Water Operable Unit (On-Site) Site Investigation and Baseline Risk Assessment Report at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0001&D2/R1, U.S. Department of Energy, Paducah, KY, February.

DOE 2014. *Addendum to the Work Plan for the Soils Operable Unit Remedial Investigation/Feasibility Study at the Paducah Gaseous Diffusion Plant Paducah, Kentucky, Remedial Investigation 2, Sampling and Analysis Plan*, DOE/LX/07-0120&D2/R2/A1/R1, U.S. Department of Energy, Paducah, KY, August.

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FWS (U.S. Fish and Wildlife Service) 2015. *Conservation Strategy for Forest-Dwelling Bats in the Commonwealth of Kentucky*, Kentucky Field Office, April.

FWS 2016. "IPaC Trust Resources Report," generated from https://ecos.fws.gov/ipac/ for McCracken County, Kentucky, May 5.

UK (University of Kentucky) 2007. *Assessment of Radiation in Surface Water at the Paducah Gaseous Diffusion Plant*, Radiation Health Branch, Division of Public Health Protection and Safety, Department for Public Health, Cabinet for Health and Family Services, Frankfort, KY, January.

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ATTACHMENT E1

ADDITIONAL ESVs

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For detected radiological results for which no ecological screening value (ESV) was available for no further action (NFA) in the Ecological Risk Methods Document, one was calculated following similar methodology (DOE 2015). These ESVs are presented in Table E1.1.

Table E1.1. PGDP Soil NFA Screening Values for Additional Radionuclides

Radionuclide	NFA (pCi/g)
Cobalt-60	6.13E+02
Thorium-228	5.30E+02
Thorium-232	1.52E+03

NFA = activity (pCi/g) resulting in dose of 0.1 rad/day assuming secular equilibrium of parent and daughter products.
NFA values are from RESRAD-BIOTA, Version 1.5, Report for Level 2 (default values, except dose adjusted to 0.1 rad/day) RESRAD-BIOTA software is available at http://web.ead.anl.gov/resrad/home2/biota.cfm.

For detected chemicals for which an ESV is not listed in Table A.2 of the Ecological Risk Methods Document, values from other sources were used. These values are presented in Table E1.2.

Table E1.2. PGDP Soil NFA Screening Values for Additional Chemicals

Analyte	PGDP NFA Screening Value (mg/kg)	Source for Screening Value
Magnesium	4.40E+05	KDEP[a]
Iron	2.00E+02	KDEP[a]
Dibenzofuran	1.52E+00	KDEP[b]
2-Methylnaphthalene	2.02E-02	KDEP[b]
Bis(2-ethylhexyl)phthalate	9.26E-01	KDEP[a]
Carbon disulfide	9.40E-02	KDEP[a]
Methylene chloride	2.00E+00	KDEP[a]

[a] Kentucky Ecological Screening Values are provided in Appendix F of the Ecological Risk Methods Document (DOE 2015).
[b] Kentucky Ecological Screening Value for sediment used for screening.

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ATTACHMENT E2

SWMU 1 ECOLOGICAL SCREENING

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Table E2.1. Ecological Screening

Analysis	Unit	Bkgd[a]	Soil NFA[b]	Max Screening Value	HQ (Max)	Below Bkgd?	EPC[c]	HQ (EPC)
2-Methylnaphthalene	mg/kg		0.0202	0.215	10.64	No	0.195	9.65
Aluminum	mg/kg	13000	50	11100	222.00	Yes	8574	171.48
Antimony	mg/kg	0.21	0.27	7.5	27.78	No	9.763	36.16
Arsenic	mg/kg	12	18	8.9	0.49	Yes		
Barium	mg/kg	200	330	124	0.38	Yes		
Beryllium	mg/kg	0.67	2.5	8.3	3.32	No	3.678	1.47
Bis(2-ethylhexyl)phthalate	mg/kg		0.926	0.2	0.22	No		
Cadmium	mg/kg	0.21	0.36	1.5	4.17	No	1.159	3.22
Calcium	mg/kg	200000	N/A	31000		Yes		
Carbon disulfide	mg/kg		0.094	0.003	0.03	No		
Chloroform	mg/kg		0.02	0.005	0.25	No		
Chromium	mg/kg	16	26	137	5.27	No	30.45	1.17
Cobalt	mg/kg	14	13	12	0.92	Yes		
Copper	mg/kg	19	28	46.6	1.66	No	15.42	0.55
Di-n-butyl phthalate	mg/kg		200	0.205	0.00	No		
High molecular weight PAHs	mg/kg		1.1	3.93	3.57	No	2.061	1.87
Iron	mg/kg	28000	200	24000	120.00	Yes	16398	81.99
Lead	mg/kg	36	11	23	2.09	Yes	13.36	1.21
Low molecular weight PAHs	mg/kg		29	0.85	0.03	No		
Magnesium	mg/kg	7700	440000	11200	0.03	No		
Manganese	mg/kg	1500	220	1200	5.45	Yes	601.6	2.73
Mercury	mg/kg	0.2	0.1	3	30.00	No	2.74	27.40
Methylene chloride	mg/kg		2	0.0155	0.01	No		
Molybdenum	mg/kg		2	14.2	7.10	No	7.8	3.90
Nickel	mg/kg	21	38	63.8	1.68	No	18.01	0.47
PCB, Total	mg/kg		0.02	9.5	475.00	No	1.439	71.95
Phenol	mg/kg		0.05	1.8	36.00	No	0.851	17.02
Selenium	mg/kg	0.8	0.52	9.75	18.75	No	3.978	7.65
Silver	mg/kg	2.3	4.2	5	1.19	No	4.667	1.11
Sodium	mg/kg	320	N/A	181		Yes		
Thallium	mg/kg	0.21	1	12.5	12.50	No	9.258	9.26
Toluene	mg/kg		0.01	0.003	0.30	No		
Trichloroethene	mg/kg		0.001	0.015	15.00	No	0.00875	8.75
Uranium	mg/kg	4.9	5	26.5	5.30	No	28.96	5.79
Vanadium	mg/kg	38	7.8	33	4.23	Yes	18.98	2.43
Zinc	mg/kg	65	46	87.2	1.90	No	41.09	0.89
Americium-241	pCi/g		2160	0.998	0.00	No		
Cesium-137	pCi/g	0.49	20.8	0.753	0.04	No		
Cobalt-60	pCi/g		613	0.022	0.00	No		
Neptunium-237	pCi/g	0.1	814	0.663	0.00	No		
Plutonium-238	pCi/g	0.073	1750	0.111	0.00	No		
Plutonium-239/240	pCi/g	0.025	1270	9.05	0.01	No		
Technetium-99	pCi/g	2.5	2190	8.29	0.00	No		
Thorium-228	pCi/g	1.6	530	1.06	0.00	Yes		
Thorium-230	pCi/g	1.5	9980	65	0.01	No		
Thorium-232	pCi/g	1.5	1520	0.986	0.00	Yes		
Uranium-234	pCi/g	1.2	5140	9.01	0.00	No		
Uranium-235	pCi/g	0.06	2750	0.511	0.00	No		
Uranium-238	pCi/g	1.2	1570	9.86	0.01	No		
Total					**1017.3**			**468.1**

[a] Background (Bkgd) values are taken from Table A.12 of *Methods for Conducting Risk Assessment and Risk Evaluation at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* Volume 1, *Human Health*, DOE/LX/07-0107&D2/R7/V1, June 2016.

[b] Soil no further action (NFA) values are taken from DOE 2015 and Attachment E1. Where no NFA values are available, the table shows "N/A" to indicate the value is not available.

[c] Exposure point concentrations (EPCs) were calculated for those chemicals with at least one detection and whose maximum hazard quotient (HQ) was greater than or equal to 1 and for which at least 10 results were available. The EPC was calculated as the 95% upper confidence limit (UCL) using ProUCL. The output from this program is included as Attachment E3.

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ATTACHMENT E3

PROUCL OUTPUT

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UCL Statistics for Uncensored Full Data Sets

User Selected Options	
Date/Time of Computation	ProUCL 5.18/2/2016 8:42:44 AM
From File	ProUCLInput-Eco.xls
Full Precision	OFF
Confidence Coefficient	95%
umber of Bootstrap Operations	2000

2-Methylnaphthalene

General Statistics

Total Number of Observations	13	Number of Distinct Observations	6
		Number of Missing Observations	84
Minimum	0.165	Mean	0.186
Maximum	0.215	Median	0.195
SD	0.0184	Std. Error of Mean	0.0051
Coefficient of Variation	0.0988	Skewness	-0.146

Normal GOF Test

Shapiro Wilk Test Statistic	0.831	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.866	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.26	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.234	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.195	95% Adjusted-CLT UCL (Chen-1995)	0.194
		95% Modified-t UCL (Johnson-1978)	0.195

Gamma GOF Test

A-D Test Statistic	1.147	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.732	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.271	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.236	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	109.6	k star (bias corrected MLE)	84.32
Theta hat (MLE)	0.0017	Theta star (bias corrected MLE)	0.00221
nu hat (MLE)	2848	nu star (bias corrected)	2192
MLE Mean (bias corrected)	0.186	MLE Sd (bias corrected)	0.0203
		Approximate Chi Square Value (0.05)	2085
Adjusted Level of Significance	0.0301	Adjusted Chi Square Value	2070

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.196	95% Adjusted Gamma UCL (use when n<50)	0.197

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.818	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.866	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.262	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.234	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-1.802	Mean of logged Data	-1.686
Maximum of Logged Data	-1.537	SD of logged Data	0.0999

Assuming Lognormal Distribution

95% H-UCL	N/A	90% Chebyshev (MVUE) UCL	0.202
95% Chebyshev (MVUE) UCL	0.209	97.5% Chebyshev (MVUE) UCL	0.218
99% Chebyshev (MVUE) UCL	0.238		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.195	95% Jackknife UCL	0.195
95% Standard Bootstrap UCL	0.194	95% Bootstrap-t UCL	0.195
95% Hall's Bootstrap UCL	0.194	95% Percentile Bootstrap UCL	0.194
95% BCA Bootstrap UCL	0.194		
90% Chebyshev(Mean, Sd) UCL	0.201	95% Chebyshev(Mean, Sd) UCL	0.208
97.5% Chebyshev(Mean, Sd) UCL	0.218	99% Chebyshev(Mean, Sd) UCL	0.237

Suggested UCL to Use

95% Student's-t UCL	0.195	or 95% Modified-t UCL	0.195

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be reliable. Chen's and Johnson's methods provide adjustments for positively skewed data sets.

Aluminum

General Statistics

Total Number of Observations	19	Number of Distinct Observations	19
		Number of Missing Observations	78
Minimum	4290	Mean	7786
Maximum	11100	Median	8130
SD	1981	Std. Error of Mean	454.4
Coefficient of Variation	0.254	Skewness	-0.19

Normal GOF Test

Shapiro Wilk Test Statistic	0.951	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.901	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.151	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.197	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	8574	95% Adjusted-CLT UCL (Chen-1995)	8512
		95% Modified-t UCL (Johnson-1978)	8570

Gamma GOF Test

A-D Test Statistic	0.534	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.741	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.172	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.198	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	15.03	k star (bias corrected MLE)	12.69
Theta hat (MLE)	518	Theta star (bias corrected MLE)	613.5
nu hat (MLE)	571.1	nu star (bias corrected)	482.3
MLE Mean (bias corrected)	7786	MLE Sd (bias corrected)	2185
		Approximate Chi Square Value (0.05)	432.4
Adjusted Level of Significance	0.0369	Adjusted Chi Square Value	428.2

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	8685	95% Adjusted Gamma UCL (use when n<50)	8768

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.933	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.901	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.174	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.197	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	8.364	Mean of logged Data	8.926
Maximum of Logged Data	9.315	SD of logged Data	0.273

Assuming Lognormal Distribution

95% H-UCL	8791	90% Chebyshev (MVUE) UCL	9283
95% Chebyshev (MVUE) UCL	9955	97.5% Chebyshev (MVUE) UCL	10888
99% Chebyshev (MVUE) UCL	12720		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	8533	95% Jackknife UCL	8574
95% Standard Bootstrap UCL	8514	95% Bootstrap-t UCL	8552
95% Hall's Bootstrap UCL	8515	95% Percentile Bootstrap UCL	8537
95% BCA Bootstrap UCL	8509		
90% Chebyshev(Mean, Sd) UCL	9149	95% Chebyshev(Mean, Sd) UCL	9767
97.5% Chebyshev(Mean, Sd) UCL	10624	99% Chebyshev(Mean, Sd) UCL	12307

Suggested UCL to Use

95% Student's-t UCL 8574

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be reliable. Chen's and Johnson's methods provide adjustments for positively skewed data sets.

Antimony

General Statistics

Total Number of Observations	19	Number of Distinct Observations	13
		Number of Missing Observations	78
Minimum	0.16	Mean	3.185
Maximum	7.5	Median	4.49
SD	2.881	Std. Error of Mean	0.661
Coefficient of Variation	0.905	Skewness	0.205

Normal GOF Test

Shapiro Wilk Test Statistic	0.819	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.901	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.266	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.197	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	4.332	95% Adjusted-CLT UCL (Chen-1995)	4.306
		95% Modified-t UCL (Johnson-1978)	4.337

Gamma GOF Test

A-D Test Statistic	1.899	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.782	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.283	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.207	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.717	k star (bias corrected MLE)	0.639
Theta hat (MLE)	4.44	Theta star (bias corrected MLE)	4.983
nu hat (MLE)	27.26	nu star (bias corrected)	24.29
MLE Mean (bias corrected)	3.185	MLE Sd (bias corrected)	3.984
		Approximate Chi Square Value (0.05)	14.07
Adjusted Level of Significance	0.0369	Adjusted Chi Square Value	13.39

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	5.5	95% Adjusted Gamma UCL (use when n<50)	5.778

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.766	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.901	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.298	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.197	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-1.833	Mean of logged Data	0.319
Maximum of Logged Data	2.015	SD of logged Data	1.592

Assuming Lognormal Distribution

95% H-UCL	18.46	90% Chebyshev (MVUE) UCL	9.912
95% Chebyshev (MVUE) UCL	12.46	97.5% Chebyshev (MVUE) UCL	15.99
99% Chebyshev (MVUE) UCL	22.94		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	4.273	95% Jackknife UCL	4.332
95% Standard Bootstrap UCL	4.244	95% Bootstrap-t UCL	4.346
95% Hall's Bootstrap UCL	4.305	95% Percentile Bootstrap UCL	4.265
95% BCA Bootstrap UCL	4.25		
90% Chebyshev(Mean, Sd) UCL	5.169	95% Chebyshev(Mean, Sd) UCL	6.067
97.5% Chebyshev(Mean, Sd) UCL	7.314	99% Chebyshev(Mean, Sd) UCL	9.763

Suggested UCL to Use

99% Chebyshev (Mean, Sd) UCL	9.763

Recommended UCL exceeds the maximum observation

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Beryllium

General Statistics			
Total Number of Observations	19	Number of Distinct Observations	19
		Number of Missing Observations	78
Minimum	0.225	Mean	1.286
Maximum	8.3	Median	0.527
SD	2.391	Std. Error of Mean	0.549
Coefficient of Variation	1.859	Skewness	2.777

Normal GOF Test		
Shapiro Wilk Test Statistic	0.43	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.901	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.453	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.197	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	2.238	95% Adjusted-CLT UCL (Chen-1995)	2.562
		95% Modified-t UCL (Johnson-1978)	2.296

Gamma GOF Test		
A-D Test Statistic	3.513	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.777	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.422	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.206	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics			
k hat (MLE)	0.805	k star (bias corrected MLE)	0.713
Theta hat (MLE)	1.598	Theta star (bias corrected MLE)	1.804
nu hat (MLE)	30.59	nu star (bias corrected)	27.09
MLE Mean (bias corrected)	1.286	MLE Sd (bias corrected)	1.523
		Approximate Chi Square Value (0.05)	16.22
Adjusted Level of Significance	0.0369	Adjusted Chi Square Value	15.49

Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	2.148	95% Adjusted Gamma UCL (use when n<50)	2.25

Lognormal GOF Test		
Shapiro Wilk Test Statistic	0.716	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.901	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.344	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.197	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics			
Minimum of Logged Data	-1.494	Mean of logged Data	-0.485
Maximum of Logged Data	2.116	SD of logged Data	0.987

Assuming Lognormal Distribution

95% H-UCL	1.833	90% Chebyshev (MVUE) UCL	1.698
95% Chebyshev (MVUE) UCL	2.029	97.5% Chebyshev (MVUE) UCL	2.489
99% Chebyshev (MVUE) UCL	3.392		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	2.189	95% Jackknife UCL	2.238
95% Standard Bootstrap UCL	2.177	95% Bootstrap-t UCL	12.3
95% Hall's Bootstrap UCL	9.065	95% Percentile Bootstrap UCL	2.136
95% BCA Bootstrap UCL	2.503		
90% Chebyshev(Mean, Sd) UCL	2.932	95% Chebyshev(Mean, Sd) UCL	3.678
97.5% Chebyshev(Mean, Sd) UCL	4.712	99% Chebyshev(Mean, Sd) UCL	6.745

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	3.678

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Cadmium

General Statistics

Total Number of Observations	22	Number of Distinct Observations	16
		Number of Missing Observations	75
Minimum	0.0245	Mean	0.653
Maximum	1.5	Median	0.845
SD	0.545	Std. Error of Mean	0.116
Coefficient of Variation	0.835	Skewness	0.137

Normal GOF Test

Shapiro Wilk Test Statistic	0.865	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.185	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.853	95% Adjusted-CLT UCL (Chen-1995)	0.847
		95% Modified-t UCL (Johnson-1978)	0.853

Gamma GOF Test

A-D Test Statistic	1.543	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.783	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.256	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.193	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.756	k star (bias corrected MLE)	0.683
Theta hat (MLE)	0.863	Theta star (bias corrected MLE)	0.955
nu hat (MLE)	33.27	nu star (bias corrected)	30.07
MLE Mean (bias corrected)	0.653	MLE Sd (bias corrected)	0.789
		Approximate Chi Square Value (0.05)	18.55
Adjusted Level of Significance	0.0386	Adjusted Chi Square Value	17.87

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	1.058	95% Adjusted Gamma UCL (use when n<50)	1.098

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.797	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.272	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-3.711	Mean of logged Data	-1.217
Maximum of Logged Data	0.405	SD of logged Data	1.63

Assuming Lognormal Distribution

95% H-UCL	3.955	90% Chebyshev (MVUE) UCL	2.255
95% Chebyshev (MVUE) UCL	2.829	97.5% Chebyshev (MVUE) UCL	3.625
99% Chebyshev (MVUE) UCL	5.189		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.844	95% Jackknife UCL	0.853
95% Standard Bootstrap UCL	0.841	95% Bootstrap-t UCL	0.862
95% Hall's Bootstrap UCL	0.838	95% Percentile Bootstrap UCL	0.83
95% BCA Bootstrap UCL	0.858		
90% Chebyshev(Mean, Sd) UCL	1.001	95% Chebyshev(Mean, Sd) UCL	1.159
97.5% Chebyshev(Mean, Sd) UCL	1.378	99% Chebyshev(Mean, Sd) UCL	1.809

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	1.159

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Chromium

General Statistics

Total Number of Observations	47	Number of Distinct Observations	23
		Number of Missing Observations	54
Minimum	4.5	Mean	16.35
Maximum	137	Median	9.5
SD	22.19	Std. Error of Mean	3.236
Coefficient of Variation	1.357	Skewness	4.618

Normal GOF Test

Shapiro Wilk Test Statistic	0.371	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.946	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.38	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.128	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	21.78	95% Adjusted-CLT UCL (Chen-1995)	24
		95% Modified-t UCL (Johnson-1978)	22.14

Gamma GOF Test

A-D Test Statistic	8.071	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.762	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.313	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.131	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.944	k star (bias corrected MLE)	1.834
Theta hat (MLE)	8.41	Theta star (bias corrected MLE)	8.914
nu hat (MLE)	182.7	nu star (bias corrected)	172.4
MLE Mean (bias corrected)	16.35	MLE Sd (bias corrected)	12.07
		Approximate Chi Square Value (0.05)	143
Adjusted Level of Significance	0.0449	Adjusted Chi Square Value	142.2

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	19.7	95% Adjusted Gamma UCL (use when n<50)	19.82

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.668	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.946	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.281	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.128	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	1.504	Mean of logged Data	2.515
Maximum of Logged Data	4.92	SD of logged Data	0.576

Assuming Lognormal Distribution

95% H-UCL	17.22	90% Chebyshev (MVUE) UCL	18.45
95% Chebyshev (MVUE) UCL	20.22	97.5% Chebyshev (MVUE) UCL	22.67
99% Chebyshev (MVUE) UCL	27.49		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	21.67	95% Jackknife UCL	21.78
95% Standard Bootstrap UCL	21.62	95% Bootstrap-t UCL	39.25
95% Hall's Bootstrap UCL	44.18	95% Percentile Bootstrap UCL	22.07
95% BCA Bootstrap UCL	24.41		
90% Chebyshev(Mean, Sd) UCL	26.06	95% Chebyshev(Mean, Sd) UCL	30.45
97.5% Chebyshev(Mean, Sd) UCL	36.56	99% Chebyshev(Mean, Sd) UCL	48.55

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	30.45

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Copper

General Statistics

Total Number of Observations	44	Number of Distinct Observations	26
		Number of Missing Observations	57
Minimum	6	Mean	13.74
Maximum	46.6	Median	13
SD	6.63	Std. Error of Mean	0.999
Coefficient of Variation	0.483	Skewness	3.181

Normal GOF Test

Shapiro Wilk Test Statistic	0.715	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.944	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.231	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.132	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	15.42	95% Adjusted-CLT UCL (Chen-1995)	15.89
		95% Modified-t UCL (Johnson-1978)	15.5

Gamma GOF Test

A-D Test Statistic	1.258	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.751	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.165	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.134	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	6.577	k star (bias corrected MLE)	6.144
Theta hat (MLE)	2.088	Theta star (bias corrected MLE)	2.235
nu hat (MLE)	578.8	nu star (bias corrected)	540.7
MLE Mean (bias corrected)	13.74	MLE Sd (bias corrected)	5.541
		Approximate Chi Square Value (0.05)	487.8
Adjusted Level of Significance	0.0445	Adjusted Chi Square Value	486.1

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	15.23	95% Adjusted Gamma UCL (use when n<50)	15.28

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.937	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.944	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.138	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.132	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	1.792	Mean of logged Data	2.542
Maximum of Logged Data	3.842	SD of logged Data	0.377

Assuming Lognormal Distribution

95% H-UCL	15.15	90% Chebyshev (MVUE) UCL	16.01
95% Chebyshev (MVUE) UCL	17.09	97.5% Chebyshev (MVUE) UCL	18.6
99% Chebyshev (MVUE) UCL	21.55		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	15.38	95% Jackknife UCL	15.42
95% Standard Bootstrap UCL	15.39	95% Bootstrap-t UCL	16.37
95% Hall's Bootstrap UCL	24.24	95% Percentile Bootstrap UCL	15.6
95% BCA Bootstrap UCL	16.07		
90% Chebyshev(Mean, Sd) UCL	16.73	95% Chebyshev(Mean, Sd) UCL	18.09
97.5% Chebyshev(Mean, Sd) UCL	19.98	99% Chebyshev(Mean, Sd) UCL	23.68

Suggested UCL to Use

95% Student's-t UCL	15.42	or 95% Modified-t UCL	15.5

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Iron

General Statistics

Total Number of Observations	44	Number of Distinct Observations	43
		Number of Missing Observations	57
Minimum	4457	Mean	15271
Maximum	24000	Median	14756
SD	4446	Std. Error of Mean	670.2
Coefficient of Variation	0.291	Skewness	-0.28

Normal GOF Test

Shapiro Wilk Test Statistic	0.982	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.944	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.0649	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.132	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	16398	95% Adjusted-CLT UCL (Chen-1995)	16343
		95% Modified-t UCL (Johnson-1978)	16393

Gamma GOF Test

A-D Test Statistic	0.621	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.748	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0958	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.133	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	10.03	k star (bias corrected MLE)	9.359
Theta hat (MLE)	1523	Theta star (bias corrected MLE)	1632
nu hat (MLE)	882.5	nu star (bias corrected)	823.6
MLE Mean (bias corrected)	15271	MLE Sd (bias corrected)	4992
		Approximate Chi Square Value (0.05)	758
Adjusted Level of Significance	0.0445	Adjusted Chi Square Value	755.9

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	16593	95% Adjusted Gamma UCL (use when n<50)	16639

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.914	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.944	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.121	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.132	Data appear Lognormal at 5% Significance Level

Data appear Approximate Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	8.402	Mean of logged Data	9.583
Maximum of Logged Data	10.09	SD of logged Data	0.344

Assuming Lognormal Distribution

95% H-UCL	16929	90% Chebyshev (MVUE) UCL	17827
95% Chebyshev (MVUE) UCL	18936	97.5% Chebyshev (MVUE) UCL	20476
99% Chebyshev (MVUE) UCL	23500		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	16374	95% Jackknife UCL	16398
95% Standard Bootstrap UCL	16326	95% Bootstrap-t UCL	16378
95% Hall's Bootstrap UCL	16405	95% Percentile Bootstrap UCL	16397
95% BCA Bootstrap UCL	16288		
90% Chebyshev(Mean, Sd) UCL	17282	95% Chebyshev(Mean, Sd) UCL	18193
97.5% Chebyshev(Mean, Sd) UCL	19457	99% Chebyshev(Mean, Sd) UCL	21940

Suggested UCL to Use

95% Student's-t UCL	16398

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be reliable. Chen's and Johnson's methods provide adjustments for positively skewed data sets.

Lead

General Statistics

Total Number of Observations	47	Number of Distinct Observations	22
		Number of Missing Observations	54
Minimum	0.102	Mean	9.647
Maximum	23	Median	7.5
SD	5.835	Std. Error of Mean	0.851
Coefficient of Variation	0.605	Skewness	1.024

Normal GOF Test

Shapiro Wilk Test Statistic	0.793	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.946	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.251	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.128	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	11.08	95% Adjusted-CLT UCL (Chen-1995)	11.18
		95% Modified-t UCL (Johnson-1978)	11.1

Gamma GOF Test

A-D Test Statistic	3.096	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.759	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.256	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.13	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.497	k star (bias corrected MLE)	2.352
Theta hat (MLE)	3.863	Theta star (bias corrected MLE)	4.101
nu hat (MLE)	234.8	nu star (bias corrected)	221.1
MLE Mean (bias corrected)	9.647	MLE Sd (bias corrected)	6.29
		Approximate Chi Square Value (0.05)	187.7
Adjusted Level of Significance	0.0449	Adjusted Chi Square Value	186.7

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	11.36	95% Adjusted Gamma UCL (use when n<50)	11.42

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.673	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.946	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.315	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.128	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-2.283	Mean of logged Data	2.053
Maximum of Logged Data	3.135	SD of logged Data	0.822

Assuming Lognormal Distribution

95% H-UCL	14.18	90% Chebyshev (MVUE) UCL	15.2
95% Chebyshev (MVUE) UCL	17.18	97.5% Chebyshev (MVUE) UCL	19.93
99% Chebyshev (MVUE) UCL	25.33		

Nonparametric Distribution Free UCL Statistics
Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	11.05	95% Jackknife UCL	11.08
95% Standard Bootstrap UCL	11.06	95% Bootstrap-t UCL	11.28
95% Hall's Bootstrap UCL	11.05	95% Percentile Bootstrap UCL	11.08
95% BCA Bootstrap UCL	11.11		
90% Chebyshev(Mean, Sd) UCL	12.2	95% Chebyshev(Mean, Sd) UCL	13.36
97.5% Chebyshev(Mean, Sd) UCL	14.96	99% Chebyshev(Mean, Sd) UCL	18.11

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	13.36

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Manganese

General Statistics

Total Number of Observations	44	Number of Distinct Observations	42
		Number of Missing Observations	57
Minimum	4.39	Mean	448.7
Maximum	1200	Median	399.5
SD	232.7	Std. Error of Mean	35.08
Coefficient of Variation	0.519	Skewness	1.158

Normal GOF Test

Shapiro Wilk Test Statistic	0.921	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.944	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.159	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.132	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	507.7	95% Adjusted-CLT UCL (Chen-1995)	513
		95% Modified-t UCL (Johnson-1978)	508.7

Gamma GOF Test

A-D Test Statistic	1.264	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.756	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.161	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.134	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.784	k star (bias corrected MLE)	2.609
Theta hat (MLE)	161.2	Theta star (bias corrected MLE)	172
nu hat (MLE)	245	nu star (bias corrected)	229.6
MLE Mean (bias corrected)	448.7	MLE Sd (bias corrected)	277.8
		Approximate Chi Square Value (0.05)	195.5
Adjusted Level of Significance	0.0445	Adjusted Chi Square Value	194.5

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	526.9	95% Adjusted Gamma UCL (use when n<50)	529.8

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.697	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.944	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.226	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.132	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	1.479	Mean of logged Data	5.916
Maximum of Logged Data	7.09	SD of logged Data	0.834

Assuming Lognormal Distribution

95% H-UCL	693.8	90% Chebyshev (MVUE) UCL	740.2
95% Chebyshev (MVUE) UCL	840.1	97.5% Chebyshev (MVUE) UCL	978.7
99% Chebyshev (MVUE) UCL	1251		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	506.4	95% Jackknife UCL	507.7
95% Standard Bootstrap UCL	507.1	95% Bootstrap-t UCL	517.3
95% Hall's Bootstrap UCL	520.3	95% Percentile Bootstrap UCL	508.5
95% BCA Bootstrap UCL	513.1		
90% Chebyshev(Mean, Sd) UCL	554	95% Chebyshev(Mean, Sd) UCL	601.6
97.5% Chebyshev(Mean, Sd) UCL	667.8	99% Chebyshev(Mean, Sd) UCL	797.8

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	601.6

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Mercury

General Statistics

Total Number of Observations	47	Number of Distinct Observations	16
		Number of Missing Observations	54
Minimum	0.0199	Mean	1.815
Maximum	3	Median	3
SD	1.455	Std. Error of Mean	0.212
Coefficient of Variation	0.802	Skewness	-0.404

Normal GOF Test

Shapiro Wilk Test Statistic	0.618	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.946	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.388	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.128	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	2.171	95% Adjusted-CLT UCL (Chen-1995)	2.15
		95% Modified-t UCL (Johnson-1978)	2.169

Gamma GOF Test

A-D Test Statistic	7.783	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.808	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.397	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.136	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.568	k star (bias corrected MLE)	0.546
Theta hat (MLE)	3.195	Theta star (bias corrected MLE)	3.325
nu hat (MLE)	53.38	nu star (bias corrected)	51.31
MLE Mean (bias corrected)	1.815	MLE Sd (bias corrected)	2.456
		Approximate Chi Square Value (0.05)	35.86
Adjusted Level of Significance	0.0449	Adjusted Chi Square Value	35.45

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	2.596	95% Adjusted Gamma UCL (use when n<50)	2.626

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.682	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.946	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.384	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.128	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-3.917	Mean of logged Data	-0.501
Maximum of Logged Data	1.099	SD of logged Data	1.995

Assuming Lognormal Distribution

95% H-UCL	12.72	90% Chebyshev (MVUE) UCL	8.945
95% Chebyshev (MVUE) UCL	11.21	97.5% Chebyshev (MVUE) UCL	14.34
99% Chebyshev (MVUE) UCL	20.51		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	2.164	95% Jackknife UCL	2.171
95% Standard Bootstrap UCL	2.171	95% Bootstrap-t UCL	2.177
95% Hall's Bootstrap UCL	2.115	95% Percentile Bootstrap UCL	2.186
95% BCA Bootstrap UCL	2.13		
90% Chebyshev(Mean, Sd) UCL	2.451	95% Chebyshev(Mean, Sd) UCL	2.74
97.5% Chebyshev(Mean, Sd) UCL	3.14	99% Chebyshev(Mean, Sd) UCL	3.926

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	2.74

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be reliable. Chen's and Johnson's methods provide adjustments for positively skewed data sets.

Molybdenum

General Statistics

Total Number of Observations	34	Number of Distinct Observations	13
		Number of Missing Observations	67
Minimum	2.245	Mean	5.378
Maximum	14.2	Median	3
SD	3.24	Std. Error of Mean	0.556
Coefficient of Variation	0.603	Skewness	0.891

Normal GOF Test

Shapiro Wilk Test Statistic	0.818	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.933	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.327	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.15	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	6.318	95% Adjusted-CLT UCL (Chen-1995)	6.383
		95% Modified-t UCL (Johnson-1978)	6.332

Gamma GOF Test

A-D Test Statistic	2.696	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.753	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.331	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.152	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.148	k star (bias corrected MLE)	2.89
Theta hat (MLE)	1.708	Theta star (bias corrected MLE)	1.861
nu hat (MLE)	214.1	nu star (bias corrected)	196.5
MLE Mean (bias corrected)	5.378	MLE Sd (bias corrected)	3.164
		Approximate Chi Square Value (0.05)	165.1
Adjusted Level of Significance	0.0422	Adjusted Chi Square Value	163.6

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	6.402	95% Adjusted Gamma UCL (use when n<50)	6.457

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.832	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.933	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.323	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.15	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	0.809	Mean of logged Data	1.515
Maximum of Logged Data	2.653	SD of logged Data	0.579

Assuming Lognormal Distribution

95% H-UCL	6.583	90% Chebyshev (MVUE) UCL	7.037
95% Chebyshev (MVUE) UCL	7.802	97.5% Chebyshev (MVUE) UCL	8.864
99% Chebyshev (MVUE) UCL	10.95		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	6.292	95% Jackknife UCL	6.318
95% Standard Bootstrap UCL	6.308	95% Bootstrap-t UCL	6.359
95% Hall's Bootstrap UCL	6.341	95% Percentile Bootstrap UCL	6.309
95% BCA Bootstrap UCL	6.33		
90% Chebyshev(Mean, Sd) UCL	7.045	95% Chebyshev(Mean, Sd) UCL	7.8
97.5% Chebyshev(Mean, Sd) UCL	8.848	99% Chebyshev(Mean, Sd) UCL	10.91

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	7.8

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Nickel

General Statistics

Total Number of Observations	47	Number of Distinct Observations	26
		Number of Missing Observations	54
Minimum	2.3	Mean	10.45
Maximum	63.8	Median	6.5
SD	11.89	Std. Error of Mean	1.735
Coefficient of Variation	1.138	Skewness	2.641

Normal GOF Test

Shapiro Wilk Test Statistic	0.696	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.946	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.247	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.128	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	13.36	95% Adjusted-CLT UCL (Chen-1995)	14.01
		95% Modified-t UCL (Johnson-1978)	13.47

Gamma GOF Test

A-D Test Statistic	2.085	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.773	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.214	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.132	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.232	k star (bias corrected MLE)	1.168
Theta hat (MLE)	8.477	Theta star (bias corrected MLE)	8.945
nu hat (MLE)	115.8	nu star (bias corrected)	109.8
MLE Mean (bias corrected)	10.45	MLE Sd (bias corrected)	9.666
		Approximate Chi Square Value (0.05)	86.59
Adjusted Level of Significance	0.0449	Adjusted Chi Square Value	85.94

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	13.24	95% Adjusted Gamma UCL (use when n<50)	13.34

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.875	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.946	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.234	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.128	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	0.833	Mean of logged Data	1.888
Maximum of Logged Data	4.156	SD of logged Data	0.935

Assuming Lognormal Distribution

95% H-UCL	13.99	90% Chebyshev (MVUE) UCL	14.88
95% Chebyshev (MVUE) UCL	17.04	97.5% Chebyshev (MVUE) UCL	20.05
99% Chebyshev (MVUE) UCL	25.94		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	13.3	95% Jackknife UCL	13.36
95% Standard Bootstrap UCL	13.25	95% Bootstrap-t UCL	14.33
95% Hall's Bootstrap UCL	15.1	95% Percentile Bootstrap UCL	13.4
95% BCA Bootstrap UCL	14.01		
90% Chebyshev(Mean, Sd) UCL	15.65	95% Chebyshev(Mean, Sd) UCL	18.01
97.5% Chebyshev(Mean, Sd) UCL	21.28	99% Chebyshev(Mean, Sd) UCL	27.71

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	18.01

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

PCB, Total

General Statistics			
Total Number of Observations	101	Number of Distinct Observations	18
		Number of Missing Observations	0
Minimum	0.025	Mean	0.841
Maximum	9.5	Median	0.065
SD	1.377	Std. Error of Mean	0.137
Coefficient of Variation	1.637	Skewness	2.896

Normal GOF Test		
Shapiro Wilk Test Statistic	0.585	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.321	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0884	Data Not Normal at 5% Significance Level
Data Not Normal at 5% Significance Level		

Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	1.069	95% Adjusted-CLT UCL (Chen-1995)	1.109
		95% Modified-t UCL (Johnson-1978)	1.075

Gamma GOF Test		
A-D Test Statistic	12.69	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.831	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.346	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.095	Data Not Gamma Distributed at 5% Significance Level
Data Not Gamma Distributed at 5% Significance Level		

Gamma Statistics			
k hat (MLE)	0.447	k star (bias corrected MLE)	0.441
Theta hat (MLE)	1.881	Theta star (bias corrected MLE)	1.909
nu hat (MLE)	90.37	nu star (bias corrected)	89.02
MLE Mean (bias corrected)	0.841	MLE Sd (bias corrected)	1.267
		Approximate Chi Square Value (0.05)	68.27
Adjusted Level of Significance	0.0476	Adjusted Chi Square Value	68

Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	1.097	95% Adjusted Gamma UCL (use when n<50)	1.101

Lognormal GOF Test		
Shapiro Wilk Test Statistic	0.759	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.334	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.0884	Data Not Lognormal at 5% Significance Level
Data Not Lognormal at 5% Significance Level		

Lognormal Statistics			
Minimum of Logged Data	-3.689	Mean of logged Data	-1.618
Maximum of Logged Data	2.251	SD of logged Data	1.739

Assuming Lognormal Distribution

95% H-UCL	1.512	90% Chebyshev (MVUE) UCL	1.534
95% Chebyshev (MVUE) UCL	1.836	97.5% Chebyshev (MVUE) UCL	2.255
99% Chebyshev (MVUE) UCL	3.078		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	1.067	95% Jackknife UCL	1.069
95% Standard Bootstrap UCL	1.064	95% Bootstrap-t UCL	1.108
95% Hall's Bootstrap UCL	1.163	95% Percentile Bootstrap UCL	1.081
95% BCA Bootstrap UCL	1.118		
90% Chebyshev(Mean, Sd) UCL	1.252	95% Chebyshev(Mean, Sd) UCL	1.439
97.5% Chebyshev(Mean, Sd) UCL	1.697	99% Chebyshev(Mean, Sd) UCL	2.205

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	1.439

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Phenol

General Statistics

Total Number of Observations	13	Number of Distinct Observations	7
		Number of Missing Observations	84
Minimum	0.165	Mean	0.31
Maximum	1.8	Median	0.195
SD	0.448	Std. Error of Mean	0.124
Coefficient of Variation	1.448	Skewness	3.595

Normal GOF Test

Shapiro Wilk Test Statistic	0.345	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.866	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.507	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.234	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.531	95% Adjusted-CLT UCL (Chen-1995)	0.647
		95% Modified-t UCL (Johnson-1978)	0.552

Gamma GOF Test

A-D Test Statistic	3.636	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.749	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.488	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.241	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.607	k star (bias corrected MLE)	1.287
Theta hat (MLE)	0.193	Theta star (bias corrected MLE)	0.241
nu hat (MLE)	41.78	nu star (bias corrected)	33.47
MLE Mean (bias corrected)	0.31	MLE Sd (bias corrected)	0.273
		Approximate Chi Square Value (0.05)	21.24
Adjusted Level of Significance	0.0301	Adjusted Chi Square Value	19.86

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.488	95% Adjusted Gamma UCL (use when n<50)	0.522

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.444	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.866	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.437	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.234	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-1.802	Mean of logged Data	-1.515
Maximum of Logged Data	0.588	SD of logged Data	0.639

Assuming Lognormal Distribution

95% H-UCL	0.411	90% Chebyshev (MVUE) UCL	0.411
95% Chebyshev (MVUE) UCL	0.478	97.5% Chebyshev (MVUE) UCL	0.57
99% Chebyshev (MVUE) UCL	0.751		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.514	95% Jackknife UCL	0.531
95% Standard Bootstrap UCL	0.504	95% Bootstrap-t UCL	3.812
95% Hall's Bootstrap UCL	2.394	95% Percentile Bootstrap UCL	0.557
95% BCA Bootstrap UCL	0.682		
90% Chebyshev(Mean, Sd) UCL	0.683	95% Chebyshev(Mean, Sd) UCL	0.851
97.5% Chebyshev(Mean, Sd) UCL	1.086	99% Chebyshev(Mean, Sd) UCL	1.546

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	0.851

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Selenium

General Statistics

Total Number of Observations	47	Number of Distinct Observations	17
		Number of Missing Observations	54
Minimum	0.0446	Mean	2.167
Maximum	9.75	Median	1.5
SD	2.848	Std. Error of Mean	0.415
Coefficient of Variation	1.315	Skewness	2.134

Normal GOF Test

Shapiro Wilk Test Statistic	0.551	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.946	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.465	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.128	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	2.864	95% Adjusted-CLT UCL (Chen-1995)	2.988
		95% Modified-t UCL (Johnson-1978)	2.886

Gamma GOF Test

A-D Test Statistic	4.562	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.785	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.354	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.134	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.874	k star (bias corrected MLE)	0.833
Theta hat (MLE)	2.479	Theta star (bias corrected MLE)	2.602
nu hat (MLE)	82.18	nu star (bias corrected)	78.27
MLE Mean (bias corrected)	2.167	MLE Sd (bias corrected)	2.375
		Approximate Chi Square Value (0.05)	58.89
Adjusted Level of Significance	0.0449	Adjusted Chi Square Value	58.35

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	2.88	95% Adjusted Gamma UCL (use when n<50)	2.906

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.84	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.946	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.319	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.128	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-3.111	Mean of logged Data	0.102
Maximum of Logged Data	2.277	SD of logged Data	1.247

Assuming Lognormal Distribution

95% H-UCL	3.897	90% Chebyshev (MVUE) UCL	3.94
95% Chebyshev (MVUE) UCL	4.662	97.5% Chebyshev (MVUE) UCL	5.665
99% Chebyshev (MVUE) UCL	7.635		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	2.85	95% Jackknife UCL	2.864
95% Standard Bootstrap UCL	2.845	95% Bootstrap-t UCL	3.139
95% Hall's Bootstrap UCL	2.852	95% Percentile Bootstrap UCL	2.881
95% BCA Bootstrap UCL	3.053		
90% Chebyshev(Mean, Sd) UCL	3.413	95% Chebyshev(Mean, Sd) UCL	3.978
97.5% Chebyshev(Mean, Sd) UCL	4.762	99% Chebyshev(Mean, Sd) UCL	6.301

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	3.978

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Silver

General Statistics

Total Number of Observations	47	Number of Distinct Observations	13
		Number of Missing Observations	54
Minimum	0.09	Mean	3.353
Maximum	5	Median	5
SD	2.065	Std. Error of Mean	0.301
Coefficient of Variation	0.616	Skewness	-0.534

Normal GOF Test

Shapiro Wilk Test Statistic	0.689	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.946	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.383	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.128	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	3.859	95% Adjusted-CLT UCL (Chen-1995)	3.824
		95% Modified-t UCL (Johnson-1978)	3.855

Gamma GOF Test

A-D Test Statistic	5.84	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.774	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.374	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.132	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.177	k star (bias corrected MLE)	1.116
Theta hat (MLE)	2.85	Theta star (bias corrected MLE)	3.005
nu hat (MLE)	110.6	nu star (bias corrected)	104.9
MLE Mean (bias corrected)	3.353	MLE Sd (bias corrected)	3.175
		Approximate Chi Square Value (0.05)	82.26
Adjusted Level of Significance	0.0449	Adjusted Chi Square Value	81.62

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	4.276	95% Adjusted Gamma UCL (use when n<50)	4.309

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.684	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.946	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.343	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.128	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-2.409	Mean of logged Data	0.728
Maximum of Logged Data	1.609	SD of logged Data	1.325

Assuming Lognormal Distribution

95% H-UCL	8.442	90% Chebyshev (MVUE) UCL	8.362
95% Chebyshev (MVUE) UCL	9.967	97.5% Chebyshev (MVUE) UCL	12.2
99% Chebyshev (MVUE) UCL	16.57		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	3.849	95% Jackknife UCL	3.859
95% Standard Bootstrap UCL	3.841	95% Bootstrap-t UCL	3.835
95% Hall's Bootstrap UCL	3.819	95% Percentile Bootstrap UCL	3.817
95% BCA Bootstrap UCL	3.81		
90% Chebyshev(Mean, Sd) UCL	4.257	95% Chebyshev(Mean, Sd) UCL	4.667
97.5% Chebyshev(Mean, Sd) UCL	5.235	99% Chebyshev(Mean, Sd) UCL	6.351

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	4.667

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be reliable. Chen's and Johnson's methods provide adjustments for positively skewed data sets.

Thallium

General Statistics

Total Number of Observations	22	Number of Distinct Observations	15
		Number of Missing Observations	75
Minimum	0.12	Mean	4.413
Maximum	12.5	Median	0.309
SD	5.214	Std. Error of Mean	1.112
Coefficient of Variation	1.182	Skewness	0.514

Normal GOF Test

Shapiro Wilk Test Statistic	0.714	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.36	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	6.326	95% Adjusted-CLT UCL (Chen-1995)	6.372
		95% Modified-t UCL (Johnson-1978)	6.346

Gamma GOF Test

A-D Test Statistic	2.677	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.814	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.3	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.197	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.457	k star (bias corrected MLE)	0.425
Theta hat (MLE)	9.663	Theta star (bias corrected MLE)	10.39
nu hat (MLE)	20.09	nu star (bias corrected)	18.69
MLE Mean (bias corrected)	4.413	MLE Sd (bias corrected)	6.771
		Approximate Chi Square Value (0.05)	9.889
Adjusted Level of Significance	0.0386	Adjusted Chi Square Value	9.413

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	8.338	95% Adjusted Gamma UCL (use when n<50)	8.761

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.763	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.27	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-2.12	Mean of logged Data	0.0737
Maximum of Logged Data	2.526	SD of logged Data	1.959

Assuming Lognormal Distribution

95% H-UCL	42.5	90% Chebyshev (MVUE) UCL	15.3
95% Chebyshev (MVUE) UCL	19.54	97.5% Chebyshev (MVUE) UCL	25.43
99% Chebyshev (MVUE) UCL	36.99		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	6.241	95% Jackknife UCL	6.326
95% Standard Bootstrap UCL	6.19	95% Bootstrap-t UCL	6.48
95% Hall's Bootstrap UCL	6.171	95% Percentile Bootstrap UCL	6.201
95% BCA Bootstrap UCL	6.218		
90% Chebyshev(Mean, Sd) UCL	7.748	95% Chebyshev(Mean, Sd) UCL	9.258
97.5% Chebyshev(Mean, Sd) UCL	11.36	99% Chebyshev(Mean, Sd) UCL	15.47

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	9.258

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Trichloroethene

General Statistics

Total Number of Observations	14	Number of Distinct Observations	6
		Number of Missing Observations	59
Minimum	0.001	Mean	0.00421
Maximum	0.015	Median	0.00275
SD	0.00389	Std. Error of Mean	0.00104
Coefficient of Variation	0.923	Skewness	2.28

Normal GOF Test

Shapiro Wilk Test Statistic	0.613	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.874	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.408	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.226	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.00606	95% Adjusted-CLT UCL (Chen-1995)	0.0066
		95% Modified-t UCL (Johnson-1978)	0.00616

Gamma GOF Test

A-D Test Statistic	1.882	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.745	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.378	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.231	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.134	k star (bias corrected MLE)	1.724
Theta hat (MLE)	0.00197	Theta star (bias corrected MLE)	0.00244
nu hat (MLE)	59.75	nu star (bias corrected)	48.28
MLE Mean (bias corrected)	0.00421	MLE Sd (bias corrected)	0.00321
		Approximate Chi Square Value (0.05)	33.33
Adjusted Level of Significance	0.0312	Adjusted Chi Square Value	31.69

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.0061	95% Adjusted Gamma UCL (use when n<50)	0.00642

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.797	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.874	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.338	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.226	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-6.908	Mean of logged Data	-5.721
Maximum of Logged Data	-4.2	SD of logged Data	0.67

Assuming Lognormal Distribution

95% H-UCL	0.00629	90% Chebyshev (MVUE) UCL	0.00629
95% Chebyshev (MVUE) UCL	0.00731	97.5% Chebyshev (MVUE) UCL	0.00873
99% Chebyshev (MVUE) UCL	0.0115		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.00592	95% Jackknife UCL	0.00606
95% Standard Bootstrap UCL	0.00588	95% Bootstrap-t UCL	0.0113
95% Hall's Bootstrap UCL	0.0155	95% Percentile Bootstrap UCL	0.00607
95% BCA Bootstrap UCL	0.00668		
90% Chebyshev(Mean, Sd) UCL	0.00733	95% Chebyshev(Mean, Sd) UCL	0.00875
97.5% Chebyshev(Mean, Sd) UCL	0.0107	99% Chebyshev(Mean, Sd) UCL	0.0146

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	0.00875

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Uranium

General Statistics			
Total Number of Observations	34	Number of Distinct Observations	7
		Number of Missing Observations	67
Minimum	2.86	Mean	22.72
Maximum	26.5	Median	26.5
SD	8.351	Std. Error of Mean	1.432
Coefficient of Variation	0.368	Skewness	-1.829

Normal GOF Test

Shapiro Wilk Test Statistic	0.479	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.933	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.498	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.15	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	25.14	95% Adjusted-CLT UCL (Chen-1995)	24.59
		95% Modified-t UCL (Johnson-1978)	25.07

Gamma GOF Test

A-D Test Statistic	9.077	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.753	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.505	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.152	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.411	k star (bias corrected MLE)	3.129
Theta hat (MLE)	6.661	Theta star (bias corrected MLE)	7.259
nu hat (MLE)	231.9	nu star (bias corrected)	212.8
MLE Mean (bias corrected)	22.72	MLE Sd (bias corrected)	12.84
		Approximate Chi Square Value (0.05)	180
Adjusted Level of Significance	0.0422	Adjusted Chi Square Value	178.6

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	26.85	95% Adjusted Gamma UCL (use when n<50)	27.08

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.489	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.933	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.494	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.15	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	1.051	Mean of logged Data	2.969
Maximum of Logged Data	3.277	SD of logged Data	0.697

Assuming Lognormal Distribution

95% H-UCL	32.1	90% Chebyshev (MVUE) UCL	34.2
95% Chebyshev (MVUE) UCL	38.53	97.5% Chebyshev (MVUE) UCL	44.55
99% Chebyshev (MVUE) UCL	56.38		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	25.07	95% Jackknife UCL	25.14
95% Standard Bootstrap UCL	25.02	95% Bootstrap-t UCL	24.81
95% Hall's Bootstrap UCL	24.63	95% Percentile Bootstrap UCL	24.83
95% BCA Bootstrap UCL	24.69		
90% Chebyshev(Mean, Sd) UCL	27.02	95% Chebyshev(Mean, Sd) UCL	28.96
97.5% Chebyshev(Mean, Sd) UCL	31.66	99% Chebyshev(Mean, Sd) UCL	36.97

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	28.96

Recommended UCL exceeds the maximum observation

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be reliable. Chen's and Johnson's methods provide adjustments for positively skewed data sets.

Vanadium

General Statistics

Total Number of Observations	44	Number of Distinct Observations	20
		Number of Missing Observations	57
Minimum	0.253	Mean	12.38
Maximum	33	Median	4
SD	10.04	Std. Error of Mean	1.514
Coefficient of Variation	0.811	Skewness	0.506

Normal GOF Test

Shapiro Wilk Test Statistic	0.784	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.944	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.344	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.132	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	14.93	95% Adjusted-CLT UCL (Chen-1995)	15
		95% Modified-t UCL (Johnson-1978)	14.95

Gamma GOF Test

A-D Test Statistic	4.46	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.77	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.332	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.136	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.344	k star (bias corrected MLE)	1.268
Theta hat (MLE)	9.21	Theta star (bias corrected MLE)	9.766
nu hat (MLE)	118.3	nu star (bias corrected)	111.6
MLE Mean (bias corrected)	12.38	MLE Sd (bias corrected)	11
		Approximate Chi Square Value (0.05)	88.2
Adjusted Level of Significance	0.0445	Adjusted Chi Square Value	87.49

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	15.67	95% Adjusted Gamma UCL (use when n<50)	15.79

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.776	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.944	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.304	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.132	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-1.374	Mean of logged Data	2.1
Maximum of Logged Data	3.497	SD of logged Data	1.018

Assuming Lognormal Distribution

95% H-UCL	19.88	90% Chebyshev (MVUE) UCL	20.78
95% Chebyshev (MVUE) UCL	24.09	97.5% Chebyshev (MVUE) UCL	28.68
99% Chebyshev (MVUE) UCL	37.69		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	14.87	95% Jackknife UCL	14.93
95% Standard Bootstrap UCL	14.8	95% Bootstrap-t UCL	15.16
95% Hall's Bootstrap UCL	15	95% Percentile Bootstrap UCL	14.94
95% BCA Bootstrap UCL	14.9		
90% Chebyshev(Mean, Sd) UCL	16.92	95% Chebyshev(Mean, Sd) UCL	18.98
97.5% Chebyshev(Mean, Sd) UCL	21.84	99% Chebyshev(Mean, Sd) UCL	27.44

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	18.98

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Zinc

General Statistics

Total Number of Observations	44	Number of Distinct Observations	30
		Number of Missing Observations	57
Minimum	23.1	Mean	37.91
Maximum	87.2	Median	34.2
SD	12.54	Std. Error of Mean	1.891
Coefficient of Variation	0.331	Skewness	2.014

Normal GOF Test

Shapiro Wilk Test Statistic	0.795	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.944	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.238	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.132	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	41.09	95% Adjusted-CLT UCL (Chen-1995)	41.64
		95% Modified-t UCL (Johnson-1978)	41.19

Gamma GOF Test

A-D Test Statistic	2.022	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.748	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.196	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.133	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	12.07	k star (bias corrected MLE)	11.27
Theta hat (MLE)	3.14	Theta star (bias corrected MLE)	3.365
nu hat (MLE)	1063	nu star (bias corrected)	991.4
MLE Mean (bias corrected)	37.91	MLE Sd (bias corrected)	11.3
		Approximate Chi Square Value (0.05)	919.3
Adjusted Level of Significance	0.0445	Adjusted Chi Square Value	917

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	40.89	95% Adjusted Gamma UCL (use when n<50)	40.99

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.904	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.944	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.173	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.132	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	3.14	Mean of logged Data	3.593
Maximum of Logged Data	4.468	SD of logged Data	0.278

Assuming Lognormal Distribution

95% H-UCL	40.71	90% Chebyshev (MVUE) UCL	42.58
95% Chebyshev (MVUE) UCL	44.76	97.5% Chebyshev (MVUE) UCL	47.79
99% Chebyshev (MVUE) UCL	53.75		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	41.02	95% Jackknife UCL	41.09
95% Standard Bootstrap UCL	41.01	95% Bootstrap-t UCL	41.82
95% Hall's Bootstrap UCL	42.48	95% Percentile Bootstrap UCL	41.16
95% BCA Bootstrap UCL	41.49		
90% Chebyshev(Mean, Sd) UCL	43.59	95% Chebyshev(Mean, Sd) UCL	46.16
97.5% Chebyshev(Mean, Sd) UCL	49.72	99% Chebyshev(Mean, Sd) UCL	56.73

Suggested UCL to Use

95% Student's-t UCL	41.09	or 95% Modified-t UCL	41.19

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

UCL Statistics for Uncensored Full Data Sets

User Selected Options	
Date/Time of Computation	ProUCL 5.18/2/2016 1:08:36 PM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	95%
'umber of Bootstrap Operations	2000

High MW PAHs

General Statistics

Total Number of Observations	19	Number of Distinct Observations	12
		Number of Missing Observations	0
Minimum	0.78	Mean	1.779
Maximum	3.69	Median	1.755
SD	0.709	Std. Error of Mean	0.163
Coefficient of Variation	0.399	Skewness	0.867

Normal GOF Test

Shapiro Wilk Test Statistic	0.925	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.901	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.148	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.197	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	2.061	95% Adjusted-CLT UCL (Chen-1995)	2.081
		95% Modified-t UCL (Johnson-1978)	2.066

Gamma GOF Test

A-D Test Statistic	0.424	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.742	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.163	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.199	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	6.692	k star (bias corrected MLE)	5.671
Theta hat (MLE)	0.266	Theta star (bias corrected MLE)	0.314
nu hat (MLE)	254.3	nu star (bias corrected)	215.5
MLE Mean (bias corrected)	1.779	MLE Sd (bias corrected)	0.747
		Approximate Chi Square Value (0.05)	182.5
Adjusted Level of Significance	0.0369	Adjusted Chi Square Value	179.9

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	2.1	95% Adjusted Gamma UCL (use when n<50)	2.131

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.944	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.901	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.19	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.197	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-0.249	Mean of logged Data	0.499
Maximum of Logged Data	1.306	SD of logged Data	0.41

Assuming Lognormal Distribution

95% H-UCL	2.16	90% Chebyshev (MVUE) UCL	2.3
95% Chebyshev (MVUE) UCL	2.534	97.5% Chebyshev (MVUE) UCL	2.858
99% Chebyshev (MVUE) UCL	3.496		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	2.046	95% Jackknife UCL	2.061
95% Standard Bootstrap UCL	2.029	95% Bootstrap-t UCL	2.114
95% Hall's Bootstrap UCL	2.16	95% Percentile Bootstrap UCL	2.05
95% BCA Bootstrap UCL	2.07		
90% Chebyshev(Mean, Sd) UCL	2.267	95% Chebyshev(Mean, Sd) UCL	2.488
97.5% Chebyshev(Mean, Sd) UCL	2.795	99% Chebyshev(Mean, Sd) UCL	3.397

Suggested UCL to Use

95% Student's-t UCL	2.061

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

APPENDIX F

ANALYTICAL DATA

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ANALYTICAL DATA FOR SWMU 1

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