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Primary Document

Remedial Investigation Report for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

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Remedial Investigation Report for the Burial Grounds Operable Unit at Paducah Gaseous Diffusion Plant Paducah, Kentucky

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Prepared for the
U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
PADUCAH REMEDIATION SERVICES, LLC
managing the
Environmental Remediation Activities at the
Paducah Gaseous Diffusion Plant
under contract DE-AC30-06EW05001

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ACRONYMS

amsl	above mean sea level
ARAR	applicable or relevant and appropriate requirement
ASB	angled soil boring
ATSDR	Agency for Toxic Substances and Disease Registry
SAT123D	Analytical Transient 1-,2-,3- Dimensional
BGOU	Burial Grounds Operable Unit
bgs	below ground surface
BRA	baseline risk assessment
CDI	chronic daily intake
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 of potential concern
CWA	Clean Water Act
D&D	decontamination and decommissioning
DAF	dilution attenuation factor
DCE	dichloroethene
DNAPL	dense nonaqueous-phase liquid
DOE	U.S. Department of Energy
DQO	data quality objective
EDD	electronic data deliverable
ELCR	excess lifetime cancer risk
EM	electromagnetic
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment
FFA	Federal Facility Agreement
f_{oc}	organic content
FS	feasibility study
GC	gas chromatograph
GC/MS	gas chromatograph/mass spectrometer
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HQ	hazard quotient
HU	hydrostratigraphic unit
IRIS	EPA's Integrated Risk Information System
K_d	soil/water distribution coefficient
KDEP	Kentucky Department for Environmental Protection
KEEC	Kentucky Energy and Environment Cabinet
K_{oc}	organic partition coefficient
KPDES	Kentucky Pollutant Discharge Elimination System
KSNPC	Kentucky State Nature Preserves Commission
LCS	laboratory control sample
MCL	maximum contaminant level
MS	matrix spike
MSA	method of standard additions

MSD	matrix spike duplicate
MW	monitoring well
NA	not applicable
NAL	no action level
NCEA	National Center for Environmental Assessment
NCP	National Contingency Plan
ND	not detected
NFA	no further action
NOAA	National Oceanic and Atmospheric Administration
NSDD	North-South Diversion Ditch
NWP	Nationwide Permit
OU	operable unit
Paducah OREIS	Paducah Oak Ridge Environmental Information System
PAH	polyaromatic hydrocarbon
PCB	polychlorinated biphenyl
PEMS	Project Environmental Measurements System
PGDP	Paducah Gaseous Diffusion Plant
pH	negative logarithm of the hydrogen-ion concentration
POC	pathway of concern
POE	point of exposure
PTW	principal threat waste
QA	quality assurance
QC	quality control
RAIS	Risk Assessment Information System
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RGA	Regional Gravel Aquifer
RGO	remedial goal option
RI	remedial investigation
RPD	relative percent difference
SADA	Statistical Analysis and Decision Assistance
SERA	screening-level ecological risk assessment
SESOIL	Seasonal Soil Compartment Model
SI	site investigation
SMO	Sample Management Office
SMP	site management plan
SOP	standard operating procedure
SSL	soil screening level
SVOC	semivolatile organic compound
SWMU	solid waste management unit
TAL	target analyte list
TCE	trichloroethene
TCL	target compound list
TVA	Tennessee Valley Authority
UCRS	Upper Continental Recharge System
UF_6	uranium hexafluoride
USEC	United State Enrichment Corporation
USGS	U. S. Geological Survey
VOC	volatile organic compound

WAG	Waste Area Grouping
WKWMA	West Kentucky Wildlife Management Area

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EXECUTIVE SUMMARY

The Paducah Gaseous Diffusion Plant (PGDP) is an active 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 Paducah Federal Facility Agreement (FFA). PGDP was placed on the National Priorities List in 1994. DOE, U.S. Environmental Protection Agency (EPA), and the Commonwealth of Kentucky entered into the FFA in 1998 (EPA 1998).

BURIAL GROUNDS OPERABLE UNIT SUMMARY

The Burial Grounds Operable Unit (BGOU) is one of five media-specific operable units (OUs) at PGDP being used to evaluate and implement remedial actions. DOE, EPA, and the Commonwealth of Kentucky have agreed upon five strategic cleanup initiatives as follows (from the Site Management Plan DOE 2007a):

- BGOU Strategic Initiative,
- Decontamination and Decommissioning OU Strategic Initiative,
- Groundwater OU Strategic Initiative,
- Soils OU Strategic Initiative, and
- Surface Water OU Strategic Initiative.

The scope of the BGOU Strategic Initiative includes a remedial investigation (RI), baseline risk assessment, feasibility study (FS), remedy selection, and implementation of actions, as necessary, for protection of human health and the environment.

This BGOU RI assesses contamination associated with eight solid waste management units (SWMUs) that include PGDP's landfills and burial grounds; seven (SWMUs 2, 3, 4, 5, 6, 7, and 30) are located within the main PGDP secure area, and one (SWMU 145) is located within a controlled access area to the north of the main PGDP area. Two other SWMUs in the BGOU are the C-746-S and C-746-T Landfills, which are closed landfills that were not included in this RI. The following are the potential source units addressed by the BGOU RI.

- SWMU 2 C-749 Uranium Burial Ground
- SWMU 3 C-404 Low-Level Radioactive Waste Burial Ground
- SWMU 4 C-747 Contaminated Burial Yard and C-748-B Burial Area
- SWMU 5 C-746-F Burial Yard
- SWMU 6 C-747-B Burial Ground
- SWMUs 7 and 30 C-747-A Burial Ground and Burn Area
- SWMU 145 Area P (residential/inert borrow area) and old North-South Diversion Ditch disposal trench (the area for SWMU 145 includes that beneath SWMUs 9 and 10)

Subsequent to development of the BGOU RI/FS Work Plan (DOE 2006a) and concurrent with the field investigation, an interview with a former plant operator identified potential areas of buried metal within the C-746-P and C-746-P1 Scrap Yards (SWMU 13). Assessment and remedial measures, if required, for these potential burial areas fall within the scope of the BGOU Strategic Initiative. The characterization of the potential burial areas of SWMU 13 will be addressed with a Field Sampling Plan addendum to the BGOU RI/FS Work Plan and follow-on site investigation that will be documented in the BGOU FS. The results will be discussed with the FFA parties and, if further action is necessary, a path forward will be determined.

Remedial decisions for sediments within the BGOU SWMUs fall primarily within the scope of the Surface Water OU Strategic Initiative. Ditches of the northwest plant area that drain to the C-613 Sediment Basin will be addressed by the Comprehensive Site OU evaluation, after completion of the other strategic initiatives.[1]

The Groundwater OU Strategic Initiative will address dissolved-phase groundwater contamination in the Regional Gravel Aquifer (RGA) beneath the BGOU SWMUs; however, secondary sources of groundwater contamination that are derived from the BGOU burial grounds, such as the potential dense nonaqueous-phase liquid (DNAPL) source zones beneath SWMUs 4, 7, and 30, remain within the scope of the BGOU for assessment and remedial action, if required.

The BGOU RI/FS Work Plan (DOE 2006a) identified the following four primary goals for this RI and the follow-up FS:

- Goal 1. Characterize the nature of the source zone;
- Goal 2. Define the extent of the source zone and contamination in soil and other secondary sources at all units;
- Goal 3. Determine surface and subsurface transport mechanisms and pathways; and
- Goal 4. Support the evaluation of remedial technologies.

NATURE AND EXTENT OF CONTAMINATION (GOALS 1 AND 2)

Materials that were disposed of in each of the SWMUs of the BGOU contained hazardous substances. The conceptual model applicable to all of the BGOU SWMUs is that releases from these SWMUs have impacted soils below or adjacent to the source zones and, through vertical infiltration in the soil, have the potential to contaminate the groundwater underlying these sources. Analysis of soil and groundwater from the area of each SWMU documents the presence of metals, organic compounds, and radionuclides above screening levels. Soil and groundwater sampling results are compared with screening levels to identify the list of potential contaminants to be evaluated for the purposes of determining nature and extent of contamination. Section 4 summarizes the characterization of the area of these SWMUs as part of the BGOU RI and as well as from previous investigation efforts.

Principal threat waste (PTW) is defined by EPA as “source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human

[1] The BGOU RI risk assessment includes the available surface soils and sediments analyses for samples from within the BGOU SWMUs to complete evaluation of the exposure scenarios specified in the Work Plan (residential, industrial, and recreational).

health or the environment should exposure occur" (EPA 1991). EPA also recognizes that "although no threshold level of risk has been established to identify principal threat waste, a general rule of thumb is to consider as a principal threat those source materials with toxicity and mobility characteristics that combine to pose a potential risk several orders of magnitude greater than the risk level that is acceptable for the current or reasonably anticipated future land use, given realistic exposure scenarios" (EPA 1997).

For the BGOU SWMUs, the trichloroethene (TCE) DNAPL at SWMUs 4, 7, and 30 and uranium at SWMUs 2 and 3 potentially are PTW. Dissolved contaminant trends in the RGA indicate that SWMU 4 and the adjoining areas of SWMUs 7 and 30 could contain TCE sources as DNAPL. The mobility and toxicity of DNAPLs make them PTW.

The uranium at SWMU 2 presents risk greater than 1E-03 under some hypothetical exposure scenarios. Some forms of the buried uranium could be considered potential PTW where toxicity and mobility combine to pose such a risk to human health. These hypothetical exposure scenarios assume a direct contact exposure to buried waste (DOE 1997a). The uranium metal present at SWMUs 2 and 3 likely is not mobile due to its insolubility in water. The Data Summary and Interpretation Report (DOE 1997a) concluded that only some forms of uranium present may be mobile (e.g., uranyl fluoride at SWMU 2). Uncertainties concerning the risks associated with the toxicity and mobility of the uranium will be considered further during alternative evaluation in the FS.

Metals and radionuclides are the only analytes in subsurface soils (soils deeper than 1 ft) frequently detected[2] above screening criteria[3] used to identify contaminants for the assessment of nature and extent. As shown in Table ES.1, iron and manganese are the most prevalent of the frequently detected contaminants in subsurface soils, detected in more than 50% of samples representative of the nature and extent of contamination in six of the eight BGOU SWMUs.

Table ES.1. Subsurface Soil Analytes Frequently Detected Above Screening Levels

Source Area	Metals	Organic Compounds[a]	Radionuclides
SWMU 2	Arsenic, Iron, Manganese, Vanadium	--	--
SWMU 3	Arsenic	--	--
SWMU 4	Iron, Manganese, Vanadium	--	^{230}Th, U, ^{234}U, ^{238}U
SWMU 5	Iron, Manganese, Vanadium	--	--
SWMU 6	Iron, Manganese, Vanadium	--	--
SWMU 7	Arsenic, Iron, Manganese	--	$^{235/236}$U
SWMU 30	Iron, Manganese, Vanadium	--	$^{235/236}$U
SWMU 145	Arsenic	--	^{228}Th

[a] While no organic compounds exceeded the 50% criterion for this table, elevated TCE levels exist in a few soil and groundwater samples that are indicative of a TCE DNAPL source at SWMU 4 and SWMUs 7 and 30.

-- = none U = uranium ^{238}U = uranium-238
^{228}Th = thorium-228 ^{234}U = uranium-234
^{230}Th = thorium-230 $^{233/236}$U = uranium-235/236

[2] In this section, "frequently detected" for subsurface soils means detected in 50% or more of the samples at levels above either PGDP background or risk-based excavation worker no action levels, where applicable. For groundwater, "frequently detected" means detected in 50% or more of the samples at levels above all screening criteria.

[3] Screening criteria for subsurface soils for the assessment of nature and extent were PGDP background levels and risk-based excavation worker no action levels. The identification of COPCs for groundwater fate and transport modeling screened the subsurface soils against PGDP-specific Soil Screening Levels.

Metals are the most common of the frequently detected contaminants in both Upper Continental Recharge System (UCRS) and RGA groundwater samples. Iron and manganese are commonly present above screening levels[4] and are the predominant contaminants in the UCRS (Table ES.2). Iron is less prevalent in the RGA (Table ES.3).

Table ES.2. UCRS Groundwater Analytes Frequently Detected Above Screening Level

Source Area	Metals	Organic Compounds	Radionuclides
SWMU 2	Beryllium, Iron, Manganese, Uranium, Vanadium	1,1-DCE; TCE	^{234}U, ^{238}U
SWMU 3	Arsenic, Iron, Manganese, Molybdenum	TCE	^{99}Tc
SWMU 4	Arsenic, Iron, Lead, Manganese	*cis*-1,2-DCE; TCE	^{99}Tc
SWMU 5	Arsenic, Iron, Lead, Manganese, Molybdenum	--	--
SWMU 6	Arsenic, Iron, Lead, Manganese, Molybdenum, Uranium	--	^{99}Tc, ^{234}U, ^{238}U
SWMU 7	Arsenic, Iron, Lead, Manganese, Molybdenum, Nickel	*cis*-1,2-DCE; TCE; Vinyl chloride	^{222}Rn, ^{234}U, ^{238}U
SWMU 30	Arsenic, Iron, Lead, Manganese, Molybdenum, Nickel, Uranium, Vanadium	TCE	^{234}U, ^{238}U
SWMU 145	Arsenic, Iron, Manganese	--	^{222}Rn, ^{238}U

-- = none
DCE = dichloroethene
^{222}Rn = radon-222
TCE = trichloroethene
^{99}Tc = technetium-99
^{234}U = uranium-234
^{238}U = uranium-238

Table ES.3. RGA Groundwater Analytes Frequently Detected Above Screening Level

Source Area	Metals	Organic Compounds	Radionuclides
SWMU 2	Arsenic, Beryllium, Iron, Manganese, Vanadium	1,1-DCE; TCE	^{234}U, ^{238}U
SWMU 3	Manganese	TCE	--
SWMU 4	Arsenic, Manganese, Iron, Lead	1,1-DCE; Carbon Tetrachloride; Chloroform; *cis*-1,2-DCE; TCE; Vinyl Chloride	--
SWMU 5	Iron, Lead, Manganese	--	--
SWMU 6	Arsenic, Iron, Lead, Manganese	TCE	--
SWMU 7	Arsenic, Iron, Lead, Manganese, Nickel	TCE	^{99}Tc
SWMU 30	Iron, Manganese	TCE	^{222}Rn, ^{99}Tc
SWMU 145	Arsenic, Iron, Manganese	--	--

-- = none
DCE = dichloroethene
^{222}Rn = radon-222
TCE = trichloroethene
^{99} Tc = technetium-99
^{234}U = uranium-234
^{238}U = uranium-238

[4] The screening criteria for UCRS groundwater are maximum contaminant levels (MCLs) and risk-based child resident no action levels. RGA screening criteria include PGDP background levels in addition to MCLs and risk-based child resident no action levels.

FATE AND TRANSPORT (GOAL 3)

Modeling assessed fate and transport of contaminants for two pathways: (1) dissolved-phase transport through the aquifer and (2) vapor transport to a residential basement.[5] Section 5 and Appendix E document the fate and transport modeling applied to the BGOU RI.

Previous work has shown that the primary pathway for groundwater flow and the site-related contaminants is predominantly vertical migration through the UCRS, followed by lateral migration in the RGA. Contaminated groundwater could migrate to the points of exposure (POEs). The POEs evaluated were at the SWMU, at the plant boundary, at the property boundary, and near the Ohio River (either at the Little Bayor Creek seeps or at the Ohio River, depending on modeled groundwater flow paths beginning at each SWMU) (Figure ES.1). Additionally, the BGOU RI includes a comprehensive evaluation of on-site risk at the SWMU that supports assessment of a SWMU boundary POE (see Table ES.4 for analytes predicted to exceed maximum contaminant levels at POEs). Not all SWMUs have transport pathways to all of the POEs. For example, SWMU 145 is located outside of the plant boundary and does not contribute to the Little Bayou seeps. SWMUs 3, 6, 7, and 30 were determined to be the only SWMUs with groundwater flow paths to the Little Bayou seeps POE, although there is some uncertainty with other SWMU flow paths.

Table ES.4. Analytes Predicted to Exceed Maximum Contaminant Levels at the Points of Exposure

Source Area	Contaminant	SWMU	Plant Boundary	Property Boundary	Little Bayou seeps	Ohio River
SWMU 2	Arsenic	**Yes**[a]	No[b]	No	N/A[c]	No
	cis-1,2-DCE	**Yes**	**Yes**	**Yes**	N/A	**Yes**
	TCE	**Yes**	**Yes**	**Yes**	N/A	**Yes**
SWMU 3	Arsenic	**Yes**	No	No	No	N/A
	^{99}Tc	**Yes**	**Yes**	**Yes**	No	N/A
	Uranium	**Yes**	No	No	No	N/A
SWMU 4	Arsenic	**Yes**	No	No	N/A	No
	cis-1,2-DCE	**Yes**	**Yes**	**Yes**	N/A	No
	^{99}Tc	**Yes**	**Yes**	**Yes**	N/A	No
	TCE	**Yes**	**Yes**	**Yes**	N/A	**Yes**
	Vinyl Chloride	**Yes**	**Yes**	**Yes**	N/A	No
SWMU 5	No analytes predicted to exceed MCLs at POEs					
SWMU 6	No analytes predicted to exceed MCLs at POEs					
SWMU 7	1,1-DCE	**Yes**	**Yes**	No	No	N/A
	Arsenic	**Yes**	**Yes**	No	No	N/A
	^{99}Tc	**Yes**	No	No	No	N/A
	TCE	**Yes**	**Yes**	No	No	N/A
	Vinyl Chloride	**Yes**	**Yes**	No	No	N/A
SWMU 30	Arsenic	**Yes**	**Yes**	No	No	N/A
	TCE	**Yes**	**Yes**	**Yes**	**Yes**	N/A
SWMU 145	Antimony	**Yes**	N/A	No	N/A	No
	Arsenic	**Yes**	N/A	No	N/A	No
	^{99}Tc	**Yes**	N/A	**Yes**	N/A	**Yes**

[a] Yes = The modeled analyte concentration exceeds its maximum contaminant level
[b] No = The modeled analyte concentration does not exceed its maximum contaminant
[c] N/A = Not applicable: the POE does not apply to the SWMU.
DCE = dichloroethene
MCL = maximum contaminant level
TCE = trichloroethene
^{99}Tc = technetium-99

[5] Assessment of surface water runoff and sediments is principally the scope of the Surface Water OU.

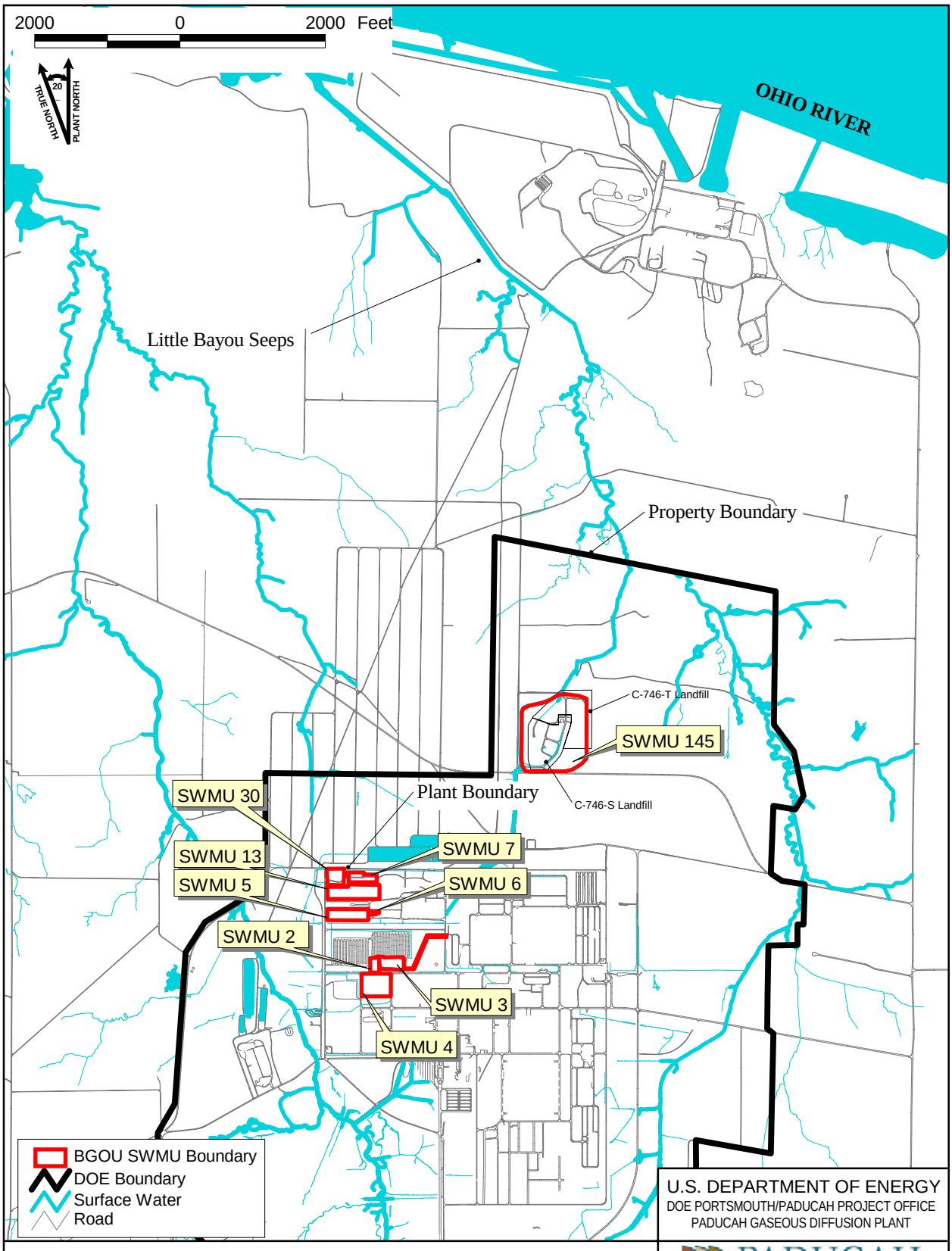

Figure ES.1. Location of BGOU SWMUs and Potential POEs

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Vapor transport modeling assessed contaminant concentrations in a hypothetical residential basement at the SWMU and in hypothetical residential basements at the plant boundary and property boundary POEs (Table ES.5). At some POEs, the excess lifetime cancer risk (ELCR) or hazard posed by hypothetical exposure to the modeled air concentration exceeded 1E-06 or 0.1, respectively. Currently there are no buildings or pipelines connected to buildings located over the contaminated material at the BGOU SWMUs. The existing buildings at PGDP are slated to be decontaminated and demolished after the plant closes; therefore, the on-site industrial worker scenario was not evaluated.

Table ES.5. Analytes with Basement Air Concentrations of Concern Based on Vapor Transport Modeling Results at the Points of Exposure

Source Area	Contaminant	SWMU Boundary	Plant Boundary	Property Boundary
SWMU 2	TCE	**Yes**[a]	**Yes**	**Yes**
	cis-1,2-DCE	**Yes**	No[b]	No
SWMU 3	TCE	**Yes**	No	No
	Mercury[c]	Yes	No	No
SWMU 4	TCE	**Yes**	**Yes**	**Yes**
	Vinyl Chloride	**Yes**	**Yes**	No
	cis-1,2-DCE	**Yes**	No	No
SWMU 5	No analytes with basement air concentrations of concern			
SWMU 6	No analytes with basement air concentrations of concern			
SWMU 7	TCE	**Yes**	No	No
	Vinyl Chloride	**Yes**	No	No
	1,1-DCE	**Yes**	**Yes**	No
	Mercury	Yes	No	No
SWMU 30	TCE	**Yes**	**Yes**	**Yes**
	1,1-DCE	**Yes**	**Yes**	No
	Mercury	Yes	No	No
SWMU 145	Mercury	Yes	No	No

DCE = dichloroethene SWMU = solid waste management unit TCE = trichloroethene

[a] Yes = Modeled air concentration equals or exceeds 1.0E-06 excess lifetime cancer risk (ELCR) or 0.1 hazard quotient (HQ)

[b] No = Modeled air concentration is less than 1.0E-06 ELCR or 0.1 HQ

[c] The vapor transport modeling for mercury was conservatively based on the metallic form, which has a Henry's Law Constant of 1.07E-02 atm-m^3/mol. The rate of vaporization of mercury and certain of its inorganic compounds decrease in the sequence Hg > Hg_2Cl_2 > $HgCl_2$ > HgS > HgO. The Henry's Law Constant decreases dramatically down the sequence (for example, $HgCl_2$ has a value of 7.09E-10 atm-m^3/mol).

RISK ASSESSMENT (GOAL 4)

PGDP is an industrial facility. The reasonably anticipated future use of the area within the current plant boundary is expected to remain industrial. This expectation should be considered when using the risk information provided in the report to support risk management decision making.

For soil, results from previous risk assessments were used. The BGOU Work Plan did not call for additional surface (0-1 ft bgs) or subsurface (0-10 ft bgs) soil sampling at most SWMUs. The risk for the on-site resident for soil exceeds 1E-04 and the hazard index (HI) is greater than 1 at all SWMUs except for SWMUs 2, 3, and SWMU 145 (which were not evaluated for soil exposure for this scenario). The contaminants that are risk drivers for soil are aluminum, arsenic, beryllium, chromium, iron, nickel, Total polyaromatic hydrocarbons (PAHs), uranium (as a metal), uranium-234, uranium-238, vanadium, and zinc.

Residential use of groundwater was evaluated at the SWMU boundary, plant boundary, property boundary, and Ohio River (or seeps) for all SWMUs except SWMU 6 [SWMU 6 had no groundwater chemicals of potential concern (COPCs)] and SWMU 145 (SWMU 145 was not evaluated at the plant boundary since it lies outside that boundary). At the SWMU boundary, risks and hazards from groundwater use for all evaluated SWMUs exceeded 1E-04 risk and exceeded an HI of 1. The major contaminants driving the groundwater risks and hazards at the SWMU boundary POE are arsenic; antimony; Aroclor-1260; *cis*-1,2-dichloroethene (DCE); 1-1-DCE; manganese; naphthalene; Total PCBs; TCE; technetium-99; uranium; and vinyl chloride. At the plant boundary, risks and hazards from groundwater for SWMUs 2, 3, 4, 5, 7, and 30 exceeded 1E-04 risk or exceeded an HI of 1. At the property boundary, risks and hazards from groundwater for SWMUs 2, 4, 7, 30, and 145 exceeded 1E-04 risk or exceeded an HI of 1. At the Ohio River (or seeps), risks and hazards from groundwater for SWMUs 2, 4, 7, and 30 exceeded 1E-04 risk or exceeded an HI of 1. The major contaminants driving the groundwater risks and hazards at the property boundary and Ohio River (or Little Bayor Creek seeps) POEs are arsenic, *cis*-1,2-DCE, 1,1-DCE, TCE, technetium-99, and vinyl chloride. While the migration of contamination from the potential TCE DNAPL zones at SWMU 4 and SWMUs 7 and 30 were not modeled due to uncertainties in source term development, a qualitative analysis completed considering results from the previous studies done for the PGDP (e.g., C-400 DNAPL source) indicates that TCE migration from these sources would have resulted in potential risks exceeding 1E-04 at all POEs.

For exposure to soil, at least one of the on-site receptor scenarios (industrial worker, excavation worker, or recreational user), all SWMUs (except SWMU 145 where the scenarios were not assessed) have an ELCR > 1.0E-06. For at least one of these scenarios, SWMUs 4, 5, 6, 7, and 30 have HIs > 1. Soil exposures to industrial or excavation workers are more relevant to the potential future uses of the site.

For the excavation worker who is exposed to both surface soil and subsurface soil (soil from 0 to 10 ft depth), HIs were greater than one at SWMUs 4, 5, 6, 7, and 30. Risks for the excavation worker exceeded 1E-04 at SWMUs 4, 5, 6, 7, and 30. The risk drivers for the excavation worker scenario were arsenic, beryllium, Total PAHs, uranium, uranium-235, and uranium-238.

Given the reasonably anticipated future industrial use of the areas within the plant boundary, the most likely future and current scenario is the industrial worker. The ELCR for the future industrial worker scenario exceeded 1E-04 at SWMUs 2, 3, 4, 5, 6, 7, and 30 primarily due to risk from arsenic, beryllium, Total PAHs, uranium-235, and uranium-238. The HI exceeds 1 for the industrial worker at SWMUs 4, 7, and 30; aluminum, beryllium, chromium, iron, manganese, uranium, and vanadium are the hazard drivers. Risks for the current industrial worker (at 16 days per year of exposure) were less than those for the future industrial worker; risks for the current industrial worker exceeded 1E-04 at SWMUs 4, 5, 6, 7, and 30. Table ES.6 details the exposure pathways and contaminants of concern associated with dominant risk for each SWMU for exposure to subsurface soil and groundwater.

The inclusion of beryllium as a risk driver is a result of incorporating the historical risk assessments. At the time those risk assessments were developed, beryllium still was evaluated as a carcinogen. Since then, the oral cancer slope factor for beryllium has been withdrawn and no longer is used for PGDP risk assessments. As a result, the total ELCR becomes much lower at those SWMUs where beryllium is a contaminant of concern. For SWMUs 4 and 6, removal of the contribution of beryllium to the ELCR reduces the total ELCR to within the EPA risk range for the industrial worker scenario.

Table ES.6. Exposure Routes and Exposure Pathways and Contaminants of Concern Associated with Dominant Risk for Each SWMU for Exposure to Subsurface Soil and Groundwater

Source Area	HI	ELCR
SWMU 2	– Ingestion of groundwater and household inhalation of vapors(TCE; *cis*-1,2-DCE)	– Household inhalation of vapors (TCE) – Ingestion of groundwater (TCE) – External exposure to subsurface soil (uranium-235, uranium-238)
SWMU 3	– Ingestion of groundwater (arsenic, uranium)	– Ingestion of groundwater (arsenic, ^{99}Tc) – External exposure to subsurface soil (uranium-235, uranium-238)
SWMU 4	– Ingestion of groundwater (TCE) – Dermal exposure to soil (chromium, iron)	– Household inhalation of vapors and dermal exposure (TCE, vinyl chloride) – Dermal exposure to subsurface soil (beryllium)
SWMU 5	– Ingestion of RGA groundwater (arsenic, naphthalene) – Ingestion of vegetables (arsenic, aluminum)	– Ingestion of RGA groundwater (arsenic)
SWMU 6	– Ingestion of vegetables (chromium) – Dermal exposure to soil (chromium)	– Dermal exposure to subsurface soil (PAHs, beryllium) – Ingestion of vegetables (PAHs, beryllium)
SWMU 7	– Ingestion of RGA groundwater (TCE, arsenic, Total PCBs) – Ingestion of vegetables (iron, uranium) – Dermal exposure to soil (vanadium, iron, uranium)	– Household inhalation of vapors and ingestion of RGA groundwater (1,1-DCE) – Dermal exposure and ingestion of vegetables (beryllium, uranium-238)
SWMU 30	– Ingestion of RGA groundwater (TCE) – Ingestion of subsurface soil (uranium) – Dermal exposure to soil (vanadium, iron)	– Household inhalation of vapors (TCE) – Ingestion of vegetables (beryllium, uranium-238)
SWMU 145	– Ingestion of RGA groundwater (antimony, arsenic)	– Ingestion of RGA groundwater (Total PCBs)

DCE = dichloroethene
PAH = polyaromatic hydrocarbon
PCB = polychlorinated biphenyl
RGA = Regional Gravel Aquifer
^{99}Tc = technetium-99
TCE = trichloroethene

The BGOU RI includes a summary of previous ecological risk assessments for SWMUs 2, 4, 5, 6, 7, and 30. Neither SWMU 3 nor SWMU 145 has been assessed for ecological risk. SWMU 3 is covered by a Resource Conservation and Recovery Act (RCRA) cap, and SWMU 145 is located beneath the C-746-S and -T Landfills, which also are covered by caps. Comparison of site characterization data against No Further Action screening levels determined that all of the SWMUs have metals and organic compounds (in surface soil) that are COPCs for ecological risk to the environment, while SWMUs 7 and 30 have a radionuclide COPC (in surface soil).

CONCLUSIONS

The following are the major contaminant distribution findings for sources investigated in the BGOU RI.

- Environmental media, specifically subsurface soil and groundwater, have been impacted by releases of contaminants at all of the BGOU SWMUs.

- TCE trends in the RGA indicate that TCE DNAPL likely is present at SWMU 4 and in the vicinity of the shared border between SWMUs 7 and 30. (See Sections 3.9.4, 4.5.2, and 4.8.2.) Concentrations of TCE at SWMU 4 suggest this potential TCE DNAPL may be present both in the waste cells and underlying soils of the UCRS and in the matrix of the RGA. TCE trends at SWMUs 7 and 30 indicate that this potential TCE DNAPL source is likely constrained to the UCRS soils.

- The Baseline Human Health Risk Assessment completed as part of the BGOU RI indicates that ELCRs greater than the upper end of EPA's acceptable risk range (i.e., 1E-04) and HIs greater than 1 exist at all SWMUs; therefore, an FS is appropriate for impacted media at each SWMU. The metals arsenic, beryllium, and uranium; the organic compounds Total PAHs and Total PCBs; and the radionuclides uranium-235 and uranium-238 are common contaminants that present the dominant risks from exposure to surface and subsurface soil. The major contaminants driving the groundwater risks at the on-site POEs are arsenic, Aroclor-1260, 1,1-DCE, TCE, technetium-99, and vinyl chloride.

- Migration of contaminants through groundwater from all but SWMU 6 to locations at the SWMU boundary, the plant boundary, property boundary, and near the Ohio River also posed greater than *de minimis* risks to a hypothetical residential groundwater user. Arsenic, TCE, 1,1-DCE, technetium-99, and vinyl chloride are the primary risk drivers.

- The Screening Ecological Risk Assessment retained a number of COPCs, primarily metals, at each of the sites. Each SWMU requires further ecological evaluation.

The BGOU RI/FS Work Plan developed decision rules for the BGOU Strategic Initiative. Table ES.7 presents the decision rules (DOE 2006a).

The risk levels associated with contamination at all of the SWMUs and associated with groundwater contamination derived from all of the SWMUs meet the criteria of the decision rules to progress to evaluate actions that will mitigate risk to protect human health and the environment and to achieve applicable or relevant and appropriate requirements (ARARs); to seek an ARAR waiver in accordance with EPA guidance; or to propose alternative standards. The following are the preliminary BGOU remedial action objectives:

- Contribute to protection of current and future residential receptors from exposure to contaminated groundwater by reducing/controlling sources of groundwater contamination;

- Protect industrial workers from exposure to waste and contaminated soils; and

- Treat or remove principal threat wastes wherever practicable, consistent with 40 *CFR* § 300.430 (a)(iii)(A).

A follow-on FS will develop and evaluate remedial action alternatives for the BGOU SWMUs.

Table ES.7. Decision Rules for the BGOU Strategic Initiative

GOAL	DECISION RULE		
		***If* statement**	***Then* statement**
Nature of Contamination	1a	If the concentration of analytes found in the source zone could result in a cumulative ELCR greater than 1×10^{-6} or a cumulative HI greater than 1 through contact with contaminated media, **or** if the concentration of analytes in the source zone could result in detrimental impacts to nonhuman receptors through contact with contaminated media as indicated by exceeding ecological screening criteria, **and** if the concentrations of analytes in the source zone are greater than those expected to occur naturally in the environment,	then evaluate actions that will mitigate risk; otherwise pursue a "no further action" decision (see D1b and D1c)
	1b	If concentrations of analytes found in the source zone exceed ARARs,	then evaluate actions that will bring contamination within the source zone into compliance with ARARs; seek an ARAR waiver (such as technical impracticability, inconsistent application of state standards, interim measure, greater risk to human health and the environment, equivalent standard of performance) in accordance with EPA guidance; or propose/obtain alternative standards
	1c	If contaminants found at the site are known to transform or degrade into chemicals that could lead to increased risks to human health or the environment or into chemicals for which there are ARARs, **and** if the concentrations of these contaminants could result in risks greater than those defined in D1a or concentrations greater than ARARs,	then evaluate actions that will mitigate potential future risk or obtain compliance with ARARs; seek an ARAR waiver (such as technical impracticability, inconsistent application of state standards, interim measure, greater risk to human health and the environment, equivalent standard of performance) in accordance with EPA guidance; or propose/obtain alternative standards
Extent of Contamination	2a	If secondary contamination sources are found, **and** if the concentration of analytes within the secondary contamination source is found to potentially result in a cumulative ELCR greater than 1×10^{-6} or a cumulative HI greater than 1 through contact with contaminated media at the unit, **and** if the concentrations of analytes are greater than those expected to occur naturally in the environment,	then evaluate actions that will mitigate risk; otherwise, do not consider secondary contamination sources when making remedial decisions for the unit

Table ES.7. Decision Rules for the BGOU Strategic Initiative (Continued)

GOAL	DECISION RULE		
		***If* statement**	***Then* statement**
Fate and Transport	3a	If contaminants are found in the source zone, **or** if secondary contamination sources are found, **and** if these contaminants are found to be migrating or may migrate from the source zone or from secondary contamination sources at concentrations that may potentially result in a cumulative ELCR greater than 1×10^{-6} or a cumulative HI greater than 1 through use of contaminated media at downgradient points of exposure, **and** the concentrations of analytes are greater than those expected to occur naturally in the environment,	then evaluate actions that will mitigate risk; otherwise, do not consider risk posed by migratory pathways when evaluating remedial alternatives for the unit (see D3b)
	3b	If contaminants are found in the source zone, **or** if secondary contamination sources are found, **and** if these contaminants are found to be migrating or may migrate from the source zone or from the secondary contamination source at concentrations that exceed ARARs,	then evaluate actions that will bring migratory concentrations into compliance with ARARs; seek an ARAR waiver (such as technical impracticability, inconsistent application of state standards, interim measure, greater risk to human health and the environment, equivalent standard of performance) in accordance with EPA guidance; or propose/obtain alternative standards; otherwise, do not consider ARARs when examining migratory pathways during the evaluation of remedial actions (see D3a)
Risk Assessment	4a	If Decision D1a, D1b, D1c, D2a, D3a, or D3b indicate that response actions are needed,	then evaluate response actions to mitigate risk in the source zone

UNCERTAINTIES/ASSUMPTIONS

The BGOU Work Plan identified data gaps on a SWMU-by-SWMU basis that were necessary to be filled in order to move forward with the FS. The Work Plan was 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 and subsurface transport mechanisms, and to support evaluation of remedial technologies in the FS.

Nature of the Source Zone

A key project assumption for the upcoming FS is that the available historical documentation and soil and groundwater characterization data are sufficient relative to waste characteristics, to chemical and physical properties, and to waste volume estimates to evaluate general response actions, to screen technology types, and to conduct detailed alternative analysis for the BGOU. The potential impact of source zone uncertainties on alternatives analysis will be further documented and analyzed in the FS. While the BGOU RI field investigation sampled directly beneath the waste units using angled borings, it remains possible that the buried waste contains hazards or constituents that current sample results do not characterize (historical disposal records and waste manifests are incomplete for some SWMUs). A related uncertainty is that the field investigation was unable to sample to the middle of a few of the larger SWMUs[6] (SWMUs 5 and 145, particularly); therefore, there are some uncertainties in the nature and extent of the contaminant source that will need to be managed during the decision making process.

Many of the SWMUs have been investigated previously. The BGOU RI uses a combination of historical and current sample results of soil and groundwater from the area of each SWMU. The results of previous investigations and RI sampling document and confirm the presence of metals, organic compounds, and radionuclides in the BGOU burial grounds. The associated samples were collected and analyzed over several previous and continuing investigations, as well as the BGOU RI, using several methods. Quality control/quality assurance practices at PGDP, now and previously, limit the uncertainty associated with the sampling and analysis process. To minimize the potential for "age" to bias the analysis of the data, the historical sample analyses used in the BGOU RI are limited to groundwater samples collected in January 1995 and later and soil samples collected in June 1996 and later. This criterion, which was established during scoping for the BGOU RI and is documented in Section 5 of the BGOU RI Work Plan, maximizes the number of historical sample analyses available to the RI, while providing a reasonable assurance of the comparability of the data. There are limited monitoring wells in close proximity to some SWMUs, but temporary borings provide a snapshot of the conditions where groundwater samples could be obtained.

The potential for acidic leachate at each SWMU is uncertain due to the lack of disposal records. SWMUs with the greatest potential for acidic leachate are SWMU 6 (exhaust fans with perchloric acid) and SWMU 4 (records of chemicals buried are incomplete). It should be noted that angled borings beneath SWMU 6 found no evidence of acidic leachate. The potential for acid leaching at the SWMUs will be evaluated further relative to the importance of acid leaching in screening, and detailed analysis of alternatives in the FS.

Because all drummed waste was assumed to have been released to the environment during disposal or through degradation, samples from soils surrounding the buried wastes were used to evaluate potential

[6] Soil samples that best characterize releases from the SWMUs are limited to the UCRS (the shallowest 50 to 60 ft of soils). The shallowest angle of drilling/sampling that could be achieved in the deeper soil borings was 45 degrees from vertical; thus, the furthest distance under the burial grounds that could be sampled ranged from 30 to less than 60 ft, depending on the depth of the burial pit and depth to top of RGA.

contaminant migration and risks associated with the SWMUs. This approach resulted in the inclusion of SWMUs with drummed waste exhibiting risk and hazard values that exceeded acceptable levels; therefore, though the integrity of buried drums is an uncertainty, the overall objectives of the RI analysis were met. The risk assessment concluded that these uncertainties related to the source zone were not estimated to have a large effect on the risk characterization and do no affect future decision making.

The BGOU FS may identify the need for remedial design support or additional source delineation after final selection of media-specific remedial goals and remedial alternatives. In addition, monitoring of the source zones will be evaluated in the FS.

Extent of the source zone and secondary sources

Secondary sources of groundwater contamination that are derived from the BGOU burial grounds, such as the potential DNAPL source zone beneath SWMU 4, are within the scope of the BGOU for evaluation and remedial action. The evidence for UCRS DNAPL presence is documented in previous investigations (DOE 2007b) and discussed in the RI. Collection of UCRS groundwater samples was attempted from 32 angled borings in order to detect releases or secondary sources that may be related to the SWMUs. Of the 32 attempts, 17 boring locations provided enough groundwater to collect a sample. Assessment of the secondary source in the UCRS at SWMUs 7 and 30 was based on both historical and newly generated data, while the assessment of the secondary source in both the UCRS and RGA at SWMU 4 is based primarily on historical data. Because the UCRS water samples supplement only the characterization of the BGOU SWMUs (the analysis of subsurface soil samples is the primary measure that supports the assessment of nature and extent and risk) and secondary sources, the lack of UCRS water samples from all soil borings does not limit the planned assessment of the SWMUs. The volumetric extent of secondary source contamination has been approximated and constitutes a project assumption for evaluation of the alternatives. The impact of source volume or DNAPL uncertainties will be evaluated and further discussed in the FS.

Surface and subsurface transport mechanisms

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. Contaminated groundwater could migrate to the POEs identified for the BGOU SWMUs as the plant boundary, property boundary, surface seeps at Little Bayou Creek, and near the Ohio River. Not all SWMUs have transport pathways to all of the POEs. For example, SWMU 145 is located outside of the plant boundary and does not contribute to the Little Bayou seeps. SWMUs 3, 6, 7, and 30 were determined to be the only SWMUs contributing to the Little Bayou seeps POE. While there is some uncertainty related to modeling in predicting whether a SWMU would contribute to the Little Bayou seeps, this uncertainty should not affect remedial decisions.

The location of the water table varies in burial ground SWMUs. Most of the buried waste at SWMU 2 is saturated. The westward slope of the water table below SWMU 2 indicates that the water table must be equally shallow beneath SWMU 3. Because SWMU 3 is an aboveground facility with a RCRA multi-layered cap, all but the base of the landfill wastes likely are unsaturated. The stratigraphy of SWMU 4 is comparable to that of SWMUs 2 and 3. It appears that the hydrogeologic setting is similar, and the water table likely extends up into the waste burial pits. At SWMUs 5 and 6, even the shallowest wastes (with top near 365 ft amsl), likely are buried below the water table (at an elevation of approximately 367 ft amsl on the north side of SWMU 5). The SWMUs 7 and 30 RI (DOE 1998a) determined that a shallow water table exists approximately 5 ft bgs (Figure 3.22) and within the burial cells. UCRS piezometer and well

measurements documented a strong downward gradient within the area. The elevation of the water table remains poorly documented at SWMU 145. Some buried waste at SWMU 145 likely is saturated.

Uncertainty does exist with regard to the dissolved oxygen in the UCRS at SWMUs 4 and 6 due to a lack of data. The majority of dissolved oxygen measurements from UCRS wells range from near zero to four mg/L and oxidation/reduction potential commonly ranges from -100 to 300 microVolts, with the majority of measurements greater than zero. Line plots in Figure 3.9 of the RI further demonstrate trends of dissolved oxygen (517 measurements) and oxidation/reduction potential (136 measurements) in the UCRS at the BGOU SWMUs. Due to the relative abundance of measurements for most SWMUs that demonstrate that the cumulative trend is likely to be representative of conditions at each SWMU, the oxidation/reduction potential in the UCRS at SWMUs 4 and 6 will be assumed to be similar to that in the UCRS at other BGOU SWMUs. The impact of this assumption will be evaluated further in the FS. If determined necessary to support implementation of a remedial alternative, dissolved oxygen could be measured as part of a remedial design support investigation for SWMUs 4 and 6.

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1. INTRODUCTION

The Paducah Gaseous Diffusion Plant (PGDP), located approximately 10 miles west of Paducah, Kentucky, and 3.5 miles south of the Ohio River in the western part of McCracken County, is an active uranium enrichment facility owned by the U.S. Department of Energy (DOE). Bordering the PGDP reservation to the northeast, between the plant and the Ohio River, is a Tennessee Valley Authority (TVA) reservation on which is located the electricity generating Shawnee Steam Plant (Figure 1.1).

PGDP was owned and managed first by the Atomic Energy Commission and then the Energy Research and Development Administration, DOE's predecessors; DOE then managed PGDP until 1993. On July 1, 1993, Martin Marietta Utility Services and later the United States Enrichment Corporation (USEC) assumed management and operation of the PGDP enrichment facilities under a lease agreement with DOE. DOE still owns the enrichment complex and is responsible for environmental management activities associated with past operation of PGDP (CERCLIS# KY8-890-008-982). DOE is the lead agency for remedial actions in accordance with the Paducah Federal Facility Agreement (FFA), and the U.S. Environmental Protection Agency (EPA) and the Kentucky Energy and Environment Cabinet (KEEC) are regulatory oversight agencies (EPA 1998).

The Burial Grounds Operable Unit (BGOU) consists of contamination associated with PGDP's landfills and burial grounds and additional disposal areas that might exist beneath the scrap yards. Burial grounds addressed by this remedial investigation (RI) are listed below and shown in Figure 1.2 (DOE 2006a).

- Solid Waste Management Unit (SWMU) 2—C-749 Uranium Burial Ground
- SWMU 3—C-404 Low-Level Radioactive Waste Burial Ground
- SWMU 4—C-747 Contaminated Burial Yard and C-748-B Burial Area
- SWMU 5—C-746-F Burial Yard
- SWMU 6—C-747-B Burial Ground
- SWMUs 7 and 30—C-747-A Burial Ground and Burn Area;
- SWMU 145—Area P (the residential/inert borrow area) and old North-South Diversion Ditch (NSDD) disposal trench (the area for SWMU 145 includes that beneath SWMUs 9 and 10)

Subsequent to development of the BGOU RI/Feasibility Study (FS) Work Plan (DOE 2006a) and concurrent with the field investigation, an interview with a former plant operator identified potential areas of buried metal within the C-746-P and C-746-P1 Scrap Yards (SWMU 13). Assessment and remedial measures, if required, for these potential burial areas fall within the scope of the BGOU Strategic Initiative, but are in addition to the scope defined in the BGOU RI/FS Work Plan. The characterization of the potential burial areas of SWMU 13 will be addressed with a Sampling and Analysis Plan addendum to the BGOU RI/FS Work Plan and follow-on site investigation that will be documented in the BGOU FS. The results will be discussed with the FFA parties and, if further action is necessary, a path forward will be determined.

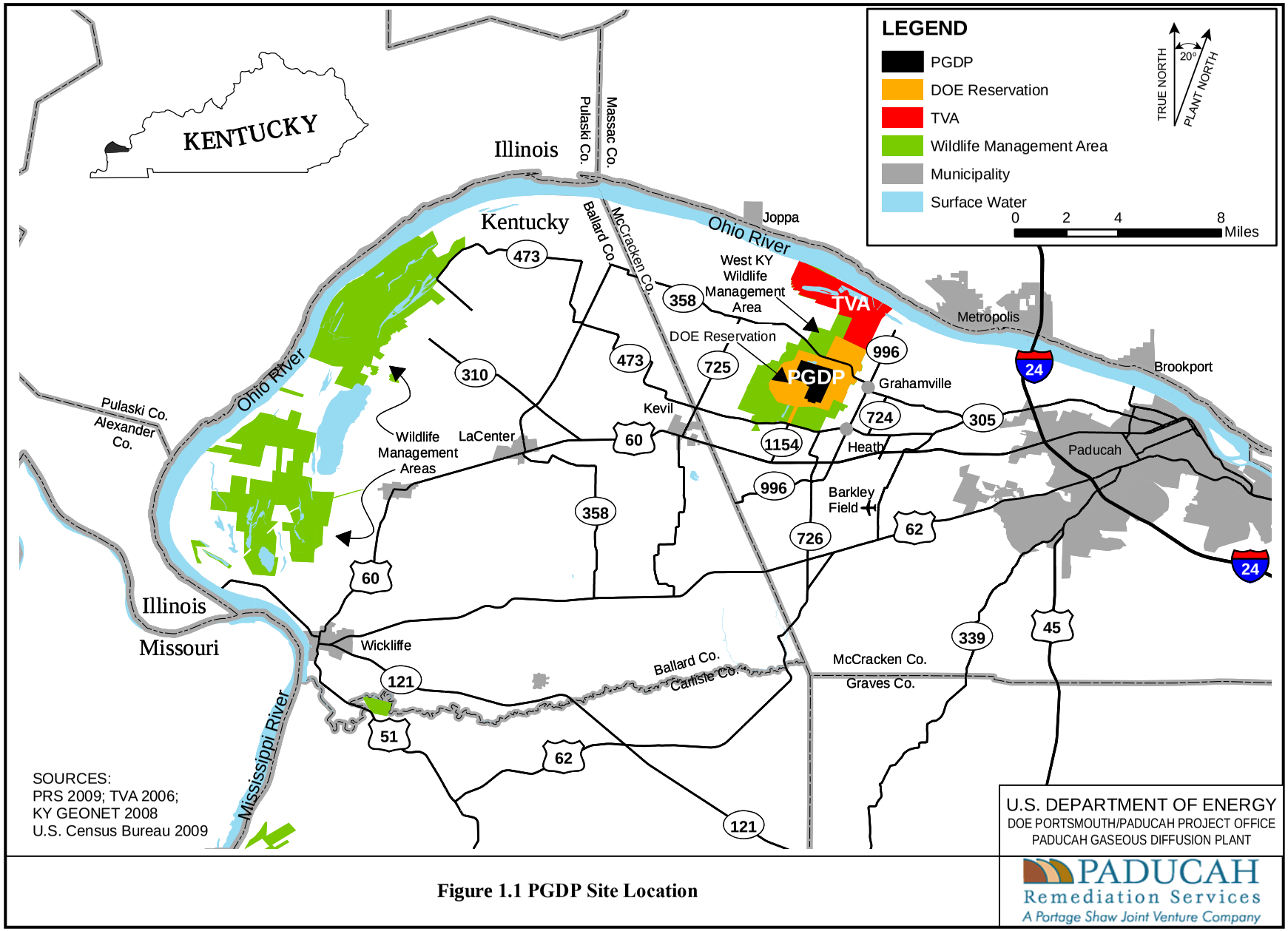

Figure 1.1 PGDP Site Location

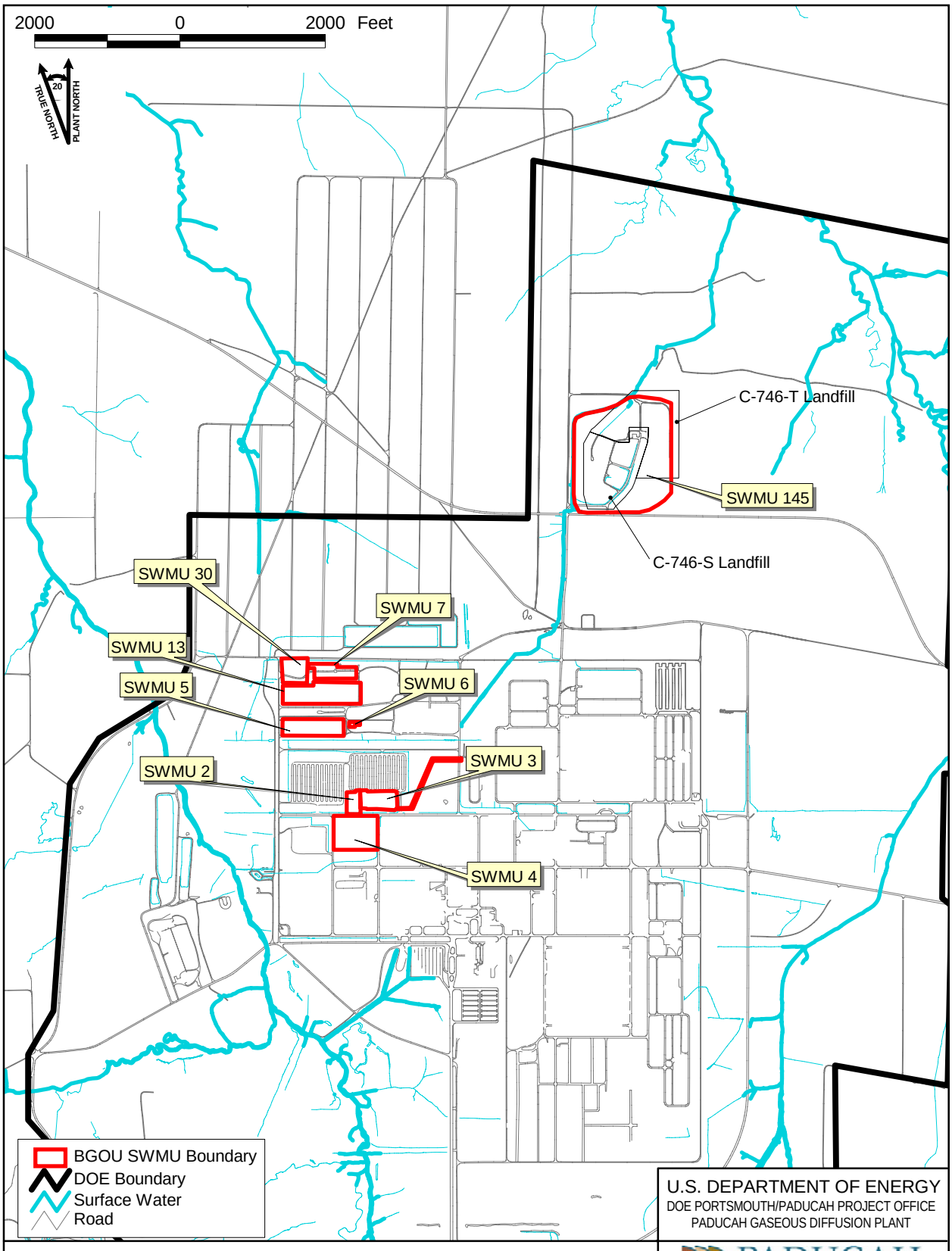

Figure 1.2. BGOU SWMUs

Figure No. \BGOU\d2-ri sect1.apr
DATE 12-16-08

1.1 PURPOSE OF REPORT

The BGOU RI followed the investigation outlined in the BGOU RI/FS Work Plan (DOE 2006a). 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 regarding the problem statement developed through the DQO process and documented in the BGOU RI/FS Work Plan:

> Hazardous substances that have been contained in, or passed through, the BGOU SWMUs may have been released to surface water or into surrounding soil or are contained in burial cell materials. These substances may have infiltrated into groundwater below the unit and been transported through subsurface pathways. The nature and extent of contamination have been adequately defined for some SWMUs, and risk assessments have been prepared. For others, the nature and extent of contamination have not been adequately defined to assess whether potential contaminants pose unacceptable risks to human health and the environment at the SWMUs and at downgradient exposure points. Data gaps should be identified, and "closed," so that a comprehensive RI/FS report can be prepared for the eight SWMUs within the BGOU.

The objectives of the RI included characterization of nature, extent, and magnitude of source zones and secondary sources (such as contaminated soil) at the burial ground SWMUs listed on page 1-1. Additionally, the purpose of the RI is to determine surface and subsurface transport mechanisms and to support an evaluation of remedial technologies. These goals (DOE 2006a) are listed specifically in Table 1.1.

This report documents the results of the RI and Baseline Risk Assessment (BRA). Recommended remedial action objectives will be presented in the forthcoming FS.

1.2 PROJECT SCOPE

The BGOU RI primarily consisted of a field investigation of the following burial grounds: C-749 (SWMU 2); C-404 (SWMU 3); C-747 and C-748-B (SWMU 4); C-746-F (SWMU 5); C-747-B (SWMU 6); C-747-A (SWMUs 7 and 30); and the residential/inert borrow area and old NSDD disposal trench (SWMU 145).

1.2.1 Scope

The BGOU RI focused on the burial grounds listed previously and the immediately affected areas adjacent to and beneath the burial cells down to the Regional Gravel Aquifer (RGA) interface to determine if the cells are contributing to groundwater contamination. As stated in the Site Management Plan (SMP), a primary objective for this project is to contribute to the protection of off-site residents by addressing sources of groundwater contamination (DOE 2007a).

The Groundwater Operable Unit (OU) Strategic Initiative will address dissolved-phase groundwater contamination in the RGA beneath the BGOU SWMUs; however, secondary sources of groundwater contamination that are derived from the BGOU burial grounds, such as the potential dense nonaqueous-phase liquid (DNAPL) source zone beneath a burial ground, remain within the scope of the BGOU for assessment and remedial action, if required.

Table 1.1. Goals Identified for the BGOU RI

GOAL 1: CHARACTERIZE NATURE OF SOURCE ZONE
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?
1-5: What are the chemical and physical properties of associated material at the source areas?
GOAL 2: DEFINE EXTENT OF SOURCE ZONE AND CONTAMINATION IN SOIL AND OTHER SECONDARY SOURCES AT ALL UNITS
2-1: What are the past, current, and potential future migratory paths?
2-2: What are the past, current, and potential future release mechanisms?
2-3: What are the contaminant concentrations or activity gradients?
2-4: What is the vertical and lateral extent of contamination?
2-5: What is the relationship of the UCRS gradient to the source, to surface water bodies, and to the RGA?
GOAL 3: DETERMINE SURFACE AND SUBSURFACE TRANSPORT MECHANISMS AND PATHWAYS
3-1: What are the contaminant migration trends?
3-2: To what area is the dissolved-phase plume migrating?
3-3: What are the effects of underground utilities and plant operations on migration pathways including ditches?
3-4: What is the role of the UCRS in contaminant transport?
3-5: What are the physical and chemical properties of the formations and subsurface matrices?
GOAL 4: SUPPORT EVALUATION OF REMEDIAL ALTERNATIVES
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 or secondary contamination source)?
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 or secondary contamination sources?

UCRS = Upper Continental Recharge System

The DQO process was used to focus the sampling strategy on SWMU-specific media, contamination, and migration pathways, and identifying data needs. Data collected during the BGOU RI, together with historical data presented in the BGOU RI/FS Work Plan (DOE 2006a), meet the project DQOs and are used within this RI Report.

The following list summarizes the activities that were conducted as part of the RI (not all activities were performed at each SWMU):

- Collection of geophysical data;
- Collection of surface soil, subsurface soil, and groundwater samples;
- Laboratory analysis of the samples;
- Evaluation of nature and extent of contamination related to each source unit;

- Numeric modeling of contaminant fate and transport and estimation of future exposure point concentrations at the DOE property boundary; and

- Determination of ecological and human health risks associated with each site.

Consistent with the BGOU RI/FS Work Plan, the nature and extent of surface soils (0–1 ft bgs) and sediments within the BGOU SWMUs are not included in the BGOU RI/FS.[1] Surface soils within two of the BGOU SWMUs (SWMUs 3[2] and 7), however, were sampled during this RI, as specified in the BGOU RI/FS Work Plan (DOE 2006a), to provide additional information. Results from these surface soil samples are presented with the BGOU analytical data.

Further, the BGOU RI sought to identify additional disposal areas that might exist beneath the scrap yards, consistent with the scope of the BGOU, as described in the SMP (DOE 2007a). One such potential area, within the existing SWMU 13, was identified by an employee interview and confirmed by a geophysics survey. The results of the geophysics survey are presented within this report in Section 2; however, this geophysical information and data available for this area will be evaluated under a separate site investigation. Other areas surveyed with geophysics included the following:

- SWMU 7 (to delineate "Pit E")
- SWMUs 7 and 30 (to delineate pits in areas formerly covered by Drum Mountain)
- SWMU 6 (to delineate pits)

To deal with uncertainties identified in the BGOU, the observational approach was used in the design of the sampling strategy for the BGOU RI/FS. The key concepts are as follows:

- The RI strategy is based on a specified "most probable site condition," which, for the BGOU RI/FS, assumes that contamination is potentially adversely impacting human health and welfare or an impact on the environment has occurred.

- Reasonable deviations from the most probable site condition are identified. The reasonable deviation for the BGOU RI/FS is that no contamination is adversely impacting human health and welfare or the environment. Site conditions should not differ significantly from the postulated conditions shown in the conceptual models.

1.2.2 Rationale for Field Sampling

Sampling activities focused on the soils and groundwater beneath the burial pits to a depth of 60 ft bgs in order to detect any releases that may be related to the SWMUs (Section 2 includes the depths of samples). Angled soil borings were utilized to collect samples for this objective. Surface[2] and subsurface soils adjacent to but not beneath the burial pits were not part of this investigation and will be evaluated through the Soils OU. Likewise, the RGA was not part of this investigation and will be evaluated through the Groundwater OU (with the exception of borings advanced to the RGA to evaluate upgradient and

[1] A discussion of nature and extent of surface soils and sediment is discussed in previous investigations (DOE 1994; 1997a; 1998a; 2000a). The BGOU RI risk assessment includes results from previous RI risk assessments (for risks from direct exposure to environmental media) and groundwater modeling results from this RI (for various points of exposure). These results are used to evaluate the exposure scenarios specified in the Work Plan (residential, industrial, and recreational). The modeled points of exposure include the SWMU boundary, DOE plant boundary, DOE property boundary, Little Bayou Creek seeps, and the Ohio River.

[2] The SWMU 3 surface soils characterized by the BGOU RI are associated with a former pipeline located to the east of C-404.

downgradient contaminant levels at SWMU 7). Assessment of the potential secondary source (TCE DNAPL) in the Upper Continental Recharge System (UCRS) at SWMUs 7 and 30 was based on both historical and newly generated data, while the assessment of the potential secondary source in both the UCRS and RGA at SWMU 4 is based primarily on historical data. Due to low groundwater yield, not all UCRS groundwater samples could be collected. Of the 32 attempts, only 18 were successful. Borings adjacent to the NSDD were advanced to a depth of 15 ft bgs to evaluate impacts from the pipeline that once discharged leachate from SWMU 3 into the NSDD. Figure 1.3 illustrates the conceptual design of the soil borings to collect these samples.

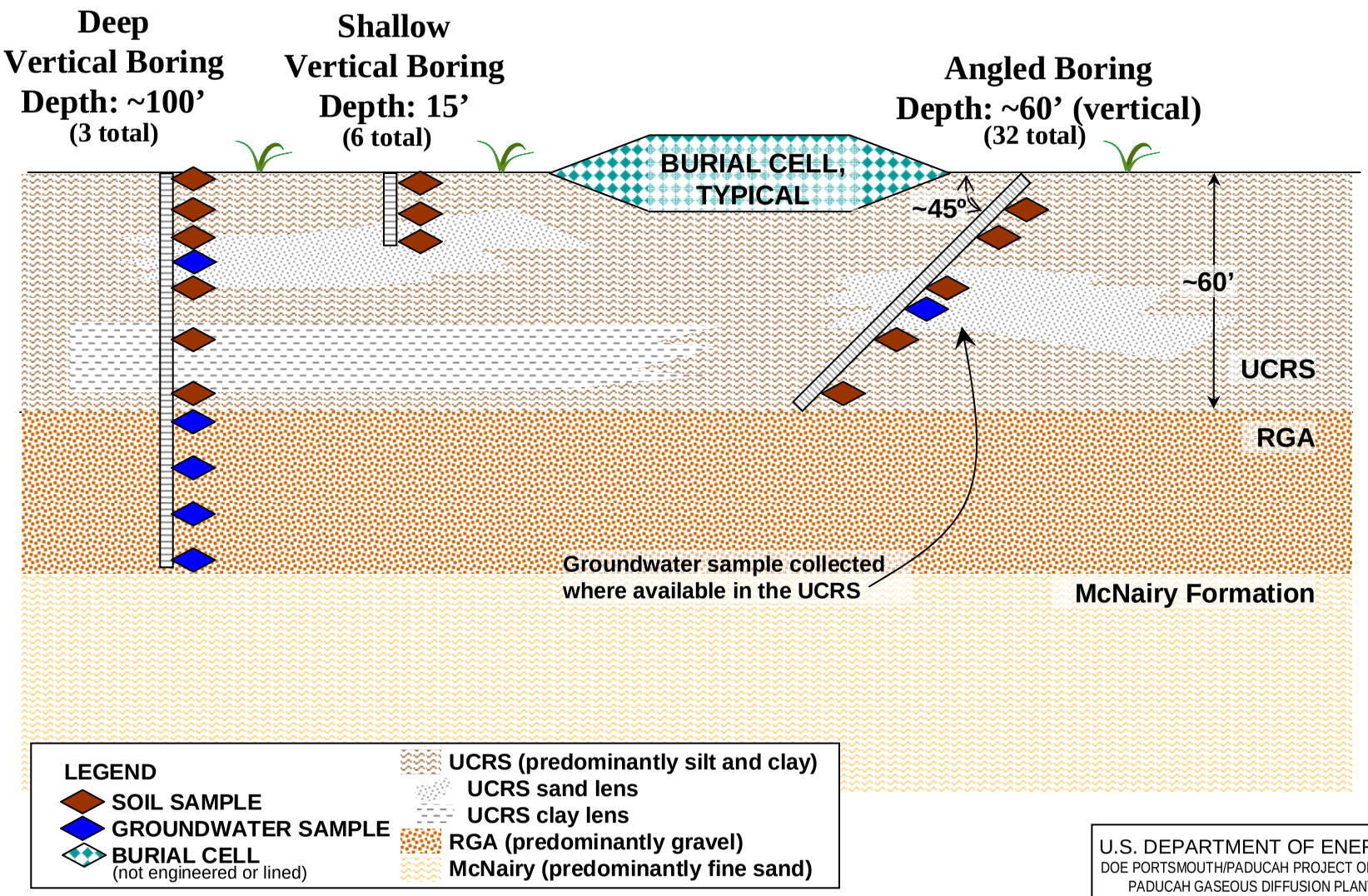

Figure 1.3. Conceptual Illustration of BGOU Drilling

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

PADUCAH
Remediation Services
A Portage Shaw Joint Venture Company

1.3 SITE BACKGROUND

The burial grounds addressed by this RI are discussed in detail in the following sections. Table 1.2 summarizes this information. Much of the information regarding areas, dates of operations, and cap material is summarized from former operating contractor reports and the closure report for SWMU 3 (Union Carbide 1973; Union Carbide 1975; Union Carbide 1978; Union Carbide 1982; DOE 1987).

Table 1.2. Summary of BGOU SWMUs

Sub Unit	Dates of Operation	Area of Waste	Cap[a]	Known or Expected Contents (Special Hazards)
SWMU 2 C-749 Uranium Burial Ground				
	1951–1977	32,000 ft^2	6-inch clay 18-inch soil	Uranium (pyrophoric uranium), waste oil [polychlorinated biphenyl (PCB?)], TCE
SWMU 3 C-404 Low-Level Radioactive Waste Burial Ground				
	1952–1986	53,000 ft^2	RCRA multilayered cap	Uranium precipitated from aqueous solutions, uranium tetrafluoride, uranium metal, uranium oxides, degreasing sludge, and radioactively contaminated trash
SWMU 4 C-747 Burial Yard and C-748-B Burial Area				
C-747	1951 to 1958	8,300 ft^2	2 to 3 ft soil 6-inch clay	Debris (radiologically contaminated) from uranium hexafluoride feed plant
C-748-B	potentially 1973–1987	278,400 ft^2	2 to 3 ft soil 6-inch clay	Proposed chemical landfill[b]
SWMU 5 C-746-F Burial Yard				
	1965–1987	197,400 ft^2	2 to 3 ft soil	Radionuclide-contaminated scrap metal, slag from nickel and aluminum smelters
SWMU 6 C-747-B Burial Ground				
Area H	1971	180 ft^2 (6 ft deep)	3 ft soil	Magnesium scrap
Area I	1966	280 ft^2 (8 ft deep)	5 ft soil	Exhaust fans (contaminated with perchloric acid)
Area J	Early 1960s	4,000 ft^2 (6 ft deep)	3 ft soil	Contaminated aluminum
Area K	1968–1969	180 ft^2 (6 ft deep)	3 ft soil	Magnesium scrap
Area L	1969	600 ft^2 (6 ft deep)	3 ft soil	Modine trap
SWMU 7 C-747-A Burial Ground				
Pit B	?	10,320 ft^2 (6–7 ft deep)	3 ft soil	Noncombustible trash, contaminated material and equipment
Pit C	?	10,320 ft^2 (6–7 ft deep)	3 ft soil	Noncombustible trash, contaminated material and equipment, Uranium-contaminated concrete pieces of reactor tray bases from fluorination process of uranium tetrafluoride to uranium hexafluoride
Pit D	?	1,485 ft^2 (6–7 ft deep)	3 ft soil	
Pit E	?	2,145 ft^2 (6–7 ft deep)	3 ft soil	Uranium-contaminated concrete pieces of reactor tray bases
Pits F1–F5	?	1,600 ft^2 (6–7 ft deep)	3 ft soil	Uranium-contaminated scrap metal, equipment, empty uranium/magnesium powder drums
Pit G	?	3,294 ft^2 (6–7 ft deep)	3 ft soil	Noncombustible trash, contaminated material and equipment
SWMU 30 C-747-A Burn Area				
Pit A	1951–1970	128,000 ft^2 (12 ft deep)	4 ft soil	Ash and debris from combustible trash, possibly uranium-contaminated
SWMU 145 Area P				
	1952–1980	44 acres		Construction debris

[a] The source material used for capping is unknown (with the exception of the SWMU 3 Resource Conservation and Recovery Act (RCRA) cap that came from the Old Hickory Clay Company).
[b] The "Proposed Chemical Landfill" is the only name used to describe this burial area (Union Carbide 1973).

Several RI documents have been produced containing data pertinent to the various SWMUs within the BGOU. In most cases, the previously prepared documents grouped several SWMUs together and did not study one particular SWMU. These documents and the various monitoring wells (MWs) installed throughout PGDP provide considerable usable historical data in addition to that generated during the BGOU RI. Historical data to be used for the BGOU is documented in the BGOU RI/FS Work Plan (DOE 2006a). Additionally, the historical data set was updated to include measurements collected from monitoring wells between the periods of work plan development and RI development.

Table 1.3 identifies the previously completed reports and/or investigations primarily used.

Table 1.3. Summary of Previous Investigations of BGOU

Dates	Title	SWMU 2	SWMU 3	SWMU 4	SWMU 5	SWMU 6	SWMU 7	SWMU 30	SWMU 145
1989	Post Closure Permit Application C-404 Low-Level Radioactive Waste Burial Ground		✓						
1990–1992	Phase II Site Investigation	✓	✓	✓	✓	✓	✓	✓	
1996	Closure Plan C-404 Low-Level Radioactive Waste Burial Ground		✓						
1996–1997	WAG 22 SWMUs 2 and 3 Remedial Investigation and Addendum (including SWMU 2 Data Summary Report)	✓	✓						
1996–1998	WAG 22 SWMUs 7 and 30 RI/FS						✓	✓	
1998–2001	WAG 3 RI/FS			✓	✓	✓			
1999–2001	Data Gaps Investigation			✓	✓		✓	✓	✓
2000–2001	Old NSDD Sampling								✓
2002–2003	Scrap Yards Site Characterization				✓	✓	✓	✓	
2003–2004	C-746-S and -T Landfill Site Investigation								✓
2004	Southwest Plume Site Investigation			✓					
2006	Burial Grounds RI/FS Work Plan	✓	✓	✓	✓	✓	✓	✓	✓

In addition to the reports of previous RIs, the following documents provide significant information on the content and volume of the burial grounds:

- *The Discard of Scrap Materials by Burial at the Paducah Plant* (Union Carbide 1973) and
- *The Disposal of Solid Waste at the Paducah Gaseous Diffusion Plant* (Union Carbide 1978).

1.3.1 C-749 Uranium Burial Ground (SWMU 2)

1.3.1.1 Site description

The C-749 Uranium Burial Ground (SWMU 2) is located within the west-central portion of the plant. SWMU 2 encompasses an area of approximately 32,000 ft^2, with approximate dimensions of 160 ft by 200 ft. Records indicate that when the burial ground was in use, pits were excavated to an estimated depth

of 7 to 17 ft. After the burial ground no longer was in use, the area was covered with a 6-inch thick clay cap and an 18-inch thick soil layer covered with vegetation (DOE 1995a). Figure 1.4 illustrates the burial ground, showing the historical grid layout as documented (Union Carbide 1975).

1.3.1.2 Site history

SWMU 2 was used from 1951 to 1977 for the disposal of uranium and uranium-contaminated wastes. Disposal records for SWMU 2 indicate that 270 tons of uranium, 59,000 gal of oils, and 450 gal of trichloroethene (TCE) were disposed in the unit (DOE 1999a). Disposal records also indicate that drummed wastes buried in the unit consist primarily of uranium metal from machine shop turnings, shavings, and sawdust. Other wastes at the unit consist of drummed uranyl fluoride and TCE. Because small pieces of uranium metal may be pyrophoric (spontaneously burn in air), operating practices of that time required placing the material in drums and submerging the material in petroleum-based oil and synthetic oil to avoid contact with air.

Most of the waste in the unit is believed to consist of pyrophoric uranium metal in the form of machine shop turnings, shavings, and sawdust. Pyrophoric uranium metal usually was placed in 20-, 30-, or 55-gal drums. Occasionally, underground fires were reported as a result of oxidation of pyrophoric uranium metal, but no documentation of these fires is available. No subsidence has been observed as a result of volume reductions due to the fires. It is possible that the oils used may have included some polychlorinated biphenyl (PCB)-contaminated oils. Other forms of uranium, including oxides of uranium (solid and dissolved in aqueous solutions), uranyl-fluoride solutions, uranium-zirconium alloy, slag, and uranium tetrafluoride, were buried in small quantities (DOE 1996).

The most likely scenario is that the uranium buried at PGDP is in the metallic state or is coated with uranium (IV) oxide. Neither of these forms of uranium is very susceptible to leaching. The kinetics of dissolution of the buried metal and uranium (IV) oxide is controlled by the amount of oxygen and carbon dioxide that leaches through the waste. Site records show that much of the metal was coated with oil, possibly PCB oil. Such oils are resistant to chemical and biological degradation and from leaching by percolating waters. In addition, oils, as they slowly degrade, consume oxygen, which lowers the oxidation-reduction potential. Under such conditions, uranium dissolution is negligible (ORNL 1998).

No documentation of technetium-99 disposal at SWMU 2 exists; however, during the years of feed plant operation from 1953 to 1964 and from 1968 intermittently through 1977, recycled uranium feed material from nuclear reactors was reprocessed through the feed plant, resulting in the introduction of reactor-produced radioactive impurities, such as technetium-99, into the enrichment process. It is possible that a portion of the uranium-contaminated wastes disposed of in burial grounds at PGDP contains technetium-99 from reprocessing activities (DOE 1994).

Materials contaminated with TCE also are known to have been disposed of at SWMU 2. In August 1984, the western portion of the area designated as containing uranyl fluoride solution and contaminated TCE on Figure 1.4 was excavated with the intent of removing TCE in the soil or drums due to concern about the integrity of TCE-containing drums (15 30-gal drums) reportedly disposed of in this area. It is reported that during excavation, four 30-gal drums (one of these drums contained a uranium and TCE sludge and the others were of such poor integrity that the contents could not be ascertained) and 35 55-gal drums (30 of these drums contained uranium sludges, not TCE, one drum contained TCE, and the rest were of such poor integrity their contents could not be ascertained) were recovered. The 55-gal drum containing TCE was placed in an overpack for proper disposal. None of the 15 30-gal drums containing TCE was found intact. Additionally, the liquid portion of the uranium solutions found in the other drums was transferred to new drums for proper disposal (Ashburn 1984). The remaining materials (everything except the 55-gal

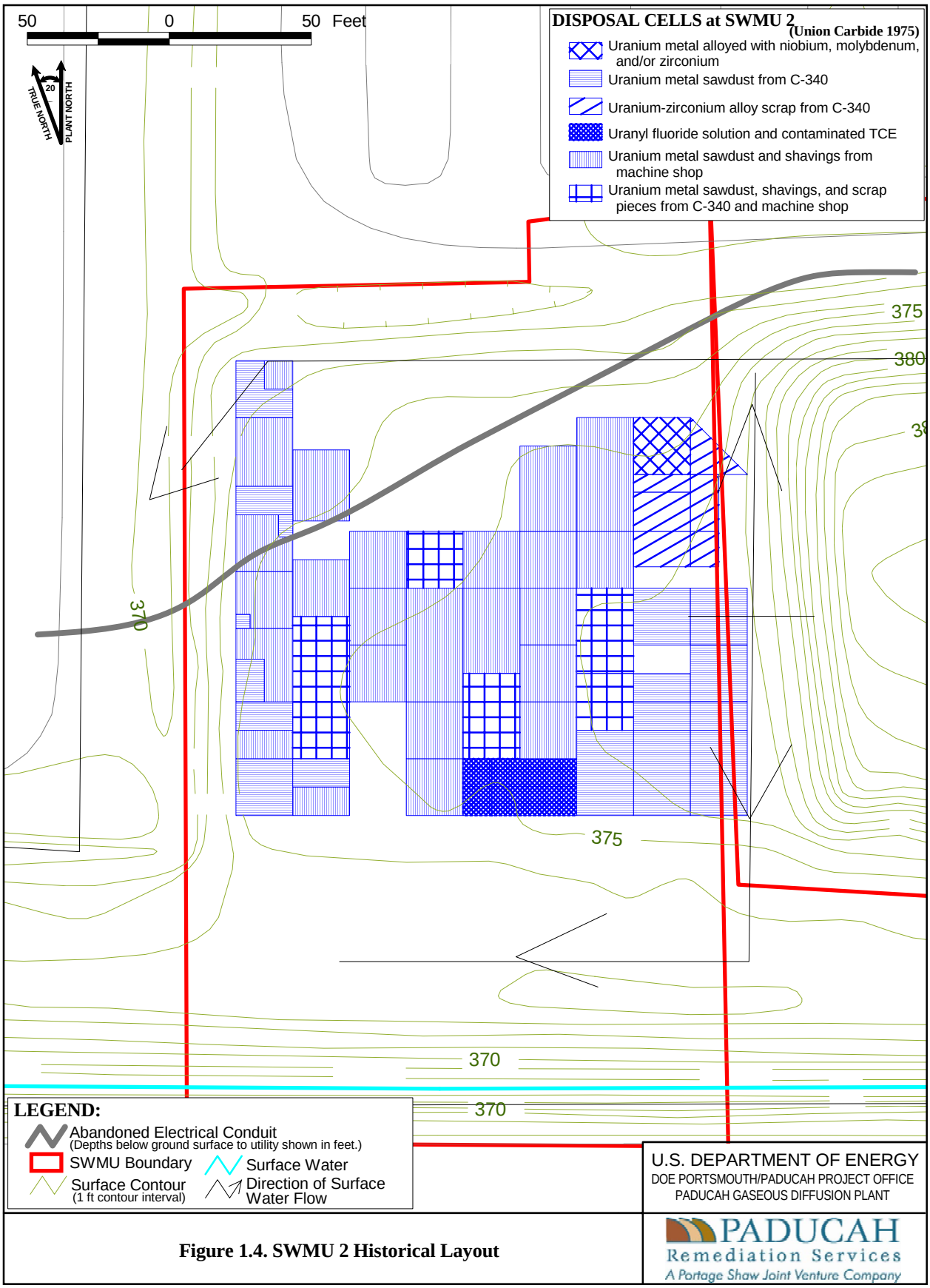

Figure 1.4. SWMU 2 Historical Layout

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drum containing TCE that was overpacked and the liquid portion of the uranium solutions that was transferred to new drums) were returned to the pit and covered with soil. It is important to note the grid and inventory from records did not match what was found during this excavation, which means there is additional uncertainty with the quality of the disposal records.

1.3.2 C-404 Low-Level Radioactive Waste Burial Ground (SWMU 3)

1.3.2.1 Site description

The C-404 Low-Level Radioactive Waste Burial Ground (SWMU 3) is 1.2 acres located in the west-central portion of the PGDP secured area. The unit originally was constructed as a rectangular, aboveground surface impoundment measuring 387 ft by 137 ft, with a floor area of approximately 53,000 ft^2. The floor of the surface impoundment was constructed of well-tamped earth and clay dikes to a height of 6 ft. The C-404 impoundment was designed with an overflow weir at its southwest corner. When the impoundment overflowed, the effluent flowed west in a ditch (not the NSDD) and eventually discharged through what is now Kentucky Pollutant Discharge Elimination System (KPDES) Outfall 015. Figure 1.5 shows C-404 along with a schematic of this design. Historic effluent/leachate discharges later were rerouted to the NSDD via what is now an abandoned pipeline leading from the northeast corner of the landfill.

1.3.2.2 Site history

SWMU 3 operated as a surface impoundment from approximately 1952 until early 1957. During this time, all influents to the impoundment originated from C-400. In 1957, the C-404 surface impoundment was converted to a solid waste disposal facility for solid uranium-contaminated wastes. The waste consists of uranium precipitated from aqueous solutions, uranium tetrafluoride, uranium metal, uranium oxides, degreasing sludge, and radioactively contaminated trash. There are no records documenting the cleanout of sludges and sediments from the pond when it was converted to a landfill. When the C-404 impoundment was converted into a disposal facility, a sump was installed at the weir. Leachate was pumped from the sump through an underground transfer line. The transfer line discharged into a northeast-southwest ditch just east of C-404. From this ditch, the leachate flowed into the NSDD. NSDD historically carried PGDP effluents north to Little Bayou Creek. The date of termination of the leachate discharge through the underground transfer line into the NSDD has not been determined. It is known that, prior to landfill closure in 1986, this underground transfer line to the NSDD was not in operation, and leachate from the C-404 Landfill was being collected in the sump for treatment at the C-400-D Lime Precipitation Unit in the C-400 Facility. At some time following closure of the C-404 Landfill, treatment of leachate from C-404 at C-400 was discontinued, and treatment of the leachate was transferred to the C-752 Remedial Action Waste Holding Facility. Some of the constituents found in the leachate and their ranges have included fluoride (4.8-10.0 mg/L); TCE (1-22 mg/L); PCBs (0.41-1.18µg/L); neptunium-237 (0.42-11.7 pCi/L); technetium-99 (90.6-365 pCi/L); and uranium-238 (2,160-37,900 pCi/L).

The upper tier of waste within C-404 contains drummed waste similar to that collected in the impoundment plus smelter furnace liners and drums of Extraction-Procedure-Toxicity, characteristically hazardous, waste [Resource Conservation and Recovery Act (RCRA) waste codes D006 (for cadmium), D008 (for lead), and D010 (for selenium)]. The drums of extraction-procedure were produced in C-400 during treatment of wastes including sodium bisulfate solution, hydrochloric acid, chromic acid, nickel stripper solution, miscellaneous acids and alkalies, and aqueous solutions containing metals. A partial clay cap was installed on the eastern end of the landfill in 1982 (DOE 1987).

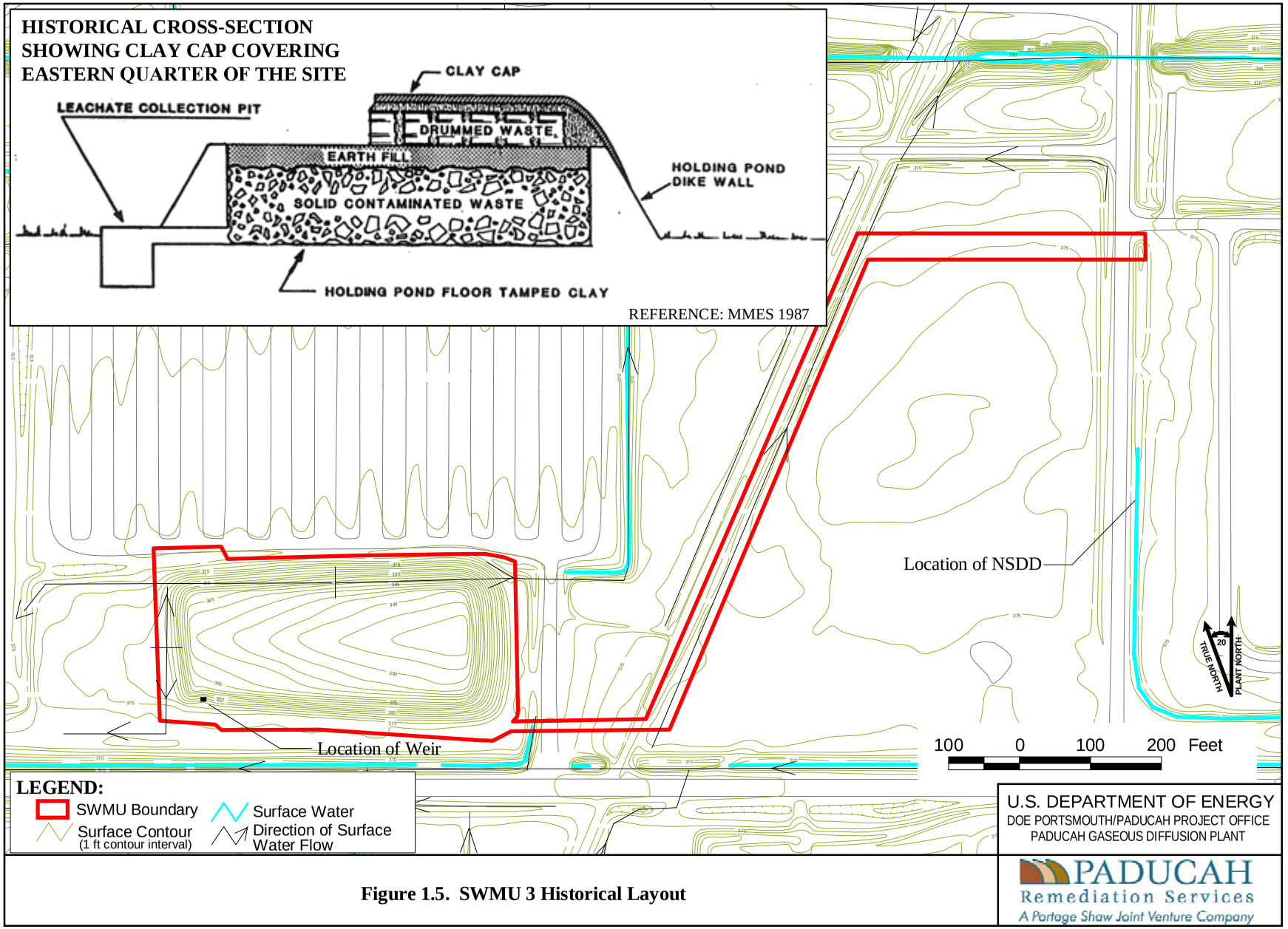

Figure 1.5. SWMU 3 Historical Layout

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Some of the chemicals of potential concern (COPCs) known to be associated with C-400 include TCE; nitric acid; sulfuric acid; radionuclides (Americium-241, cesium, thorium-230, neptunium-237, plutonium-239, technetium-99, uranium-234, -235, and -238; hexavalent chromium discharge; fluoride/fluorine; lime/sodium hydroxide; heavy metals from cleaning; and PCBs.

Approximately 6,615,000 lb of uranium-contaminated wastes were disposed at SWMU 3. The total volume is approximately 260,000 ft^3. Some uranium contaminated waste also is contaminated with TCE, radionuclides, and metals. In 1986, the disposal of waste at C-404 Landfill was halted, and a portion of the disposed waste was found to be RCRA-hazardous. The landfill was covered with a RCRA multilayered cap and certified closed in 1987. It currently is regulated under RCRA as a land disposal unit and compliance is required by a RCRA postclosure permit issued in 1992. The closure plan required continued groundwater monitoring (DOE 1989). A permit modification was submitted in May 2008, revising the MW network for the unit (DOE 2008a) to add a new upgradient well, MW420. MW420 is screened in the upper RGA.

1.3.3 C-747 Contaminated Burial Yard and C-748-B Burial Area (SWMU 4)

1.3.3.1 Site description

The C-747 Contaminated Burial Yard and the C-748-B Burial Area (SWMU 4) is located in the western section of the PGDP secured area. SWMU 4 (which covers an area of approximately 286,700 ft^2) is bounded on the north, east, and west by plant roads and on the south by an active railroad spur (Figure 1.6). This SWMU is an open field that, at one time, was used for the burial and disposal of various waste materials in designated burial cells. A short, narrow, gravel road that enters from the west is nearly completely grass-covered. Except for this rarely used road, the entire site is covered with a variety of field grasses and clovers. The site typically is mowed once a month from April through September. SWMU 4 is bounded on three sides (north, east, and west) by shallow drainage swales that direct surface runoff to the northwest corner of the site. There is an elevation difference of approximately 10 ft between the highest point in the SWMU to the adjacent drainage swales. The entire burial yard was covered with 2 to 3 ft of soil material and a 6-inch clay cap was placed over the area in 1982 (DOE 1998b).

1.3.3.2 Site history

The C-747 Burial Yard was in operation from 1951 to 1958 for the disposal of radiologically contaminated and uncontaminated debris originating from the C-410 uranium hexafluoride (UF_6) feed plant. The area originally consisted of two pits covering an area of approximately 8,300 ft^2 (50 ft by 15 ft and 50 ft by 150 ft) (Union Carbide 1978).

Some of the trash was burned before burial. According to PGDP personnel, a majority of the contaminated metal was buried in the northern part of the yard. When the yard was closed, a smaller pit was reported to have been excavated for the disposal of radiologically contaminated scrap metal.

The C-748-B Burial Area, located on the west side of C-747, is identified as a Proposed Chemical Landfill Site in the 1973 Union Carbide document on waste disposal. The original SWMU Assessment Report dated August 24, 1987, for SWMU 4 included only the C-747 Contaminated Burial Yard. The C-748-B Burial Area was incorporated into various descriptions of SWMU 4 starting in the mid-1990s as a result of a geophysical survey. As a result of this addition, the area of the SWMU was changed from 8,300 ft^2 to 286,700 ft^2 (DOE 2007c).

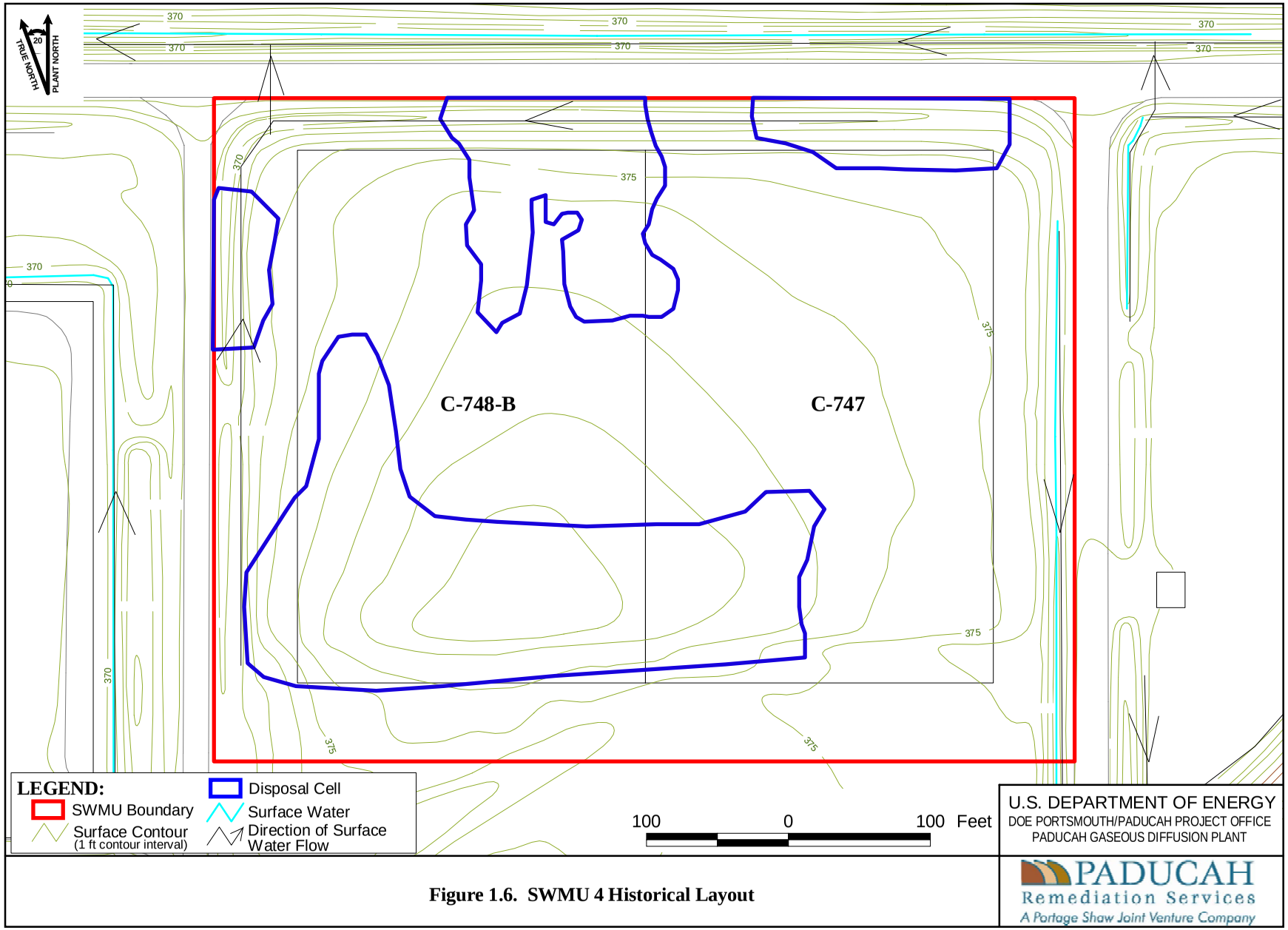

Figure 1.6. SWMU 4 Historical Layout

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SWMU 4 also may have received sludges designated for disposal at the C-404 Burial Ground. The source of these sludges is unknown, but the Waste Area Grouping (WAG) 3 RI Work Plan (DOE 1998b) indicated that the sludges potentially included uranium-contaminated solid waste and ^{99}Tc-contaminated magnesium fluoride. The total volume of material disposed at this site is unknown. Potential contaminants associated with this SWMU include uranium, technetium-99, metals, and TCE.

During the summer of 1996, a small sinkhole (approximately 3 ft across and 3 ft deep) developed in the southern burial cell, apparently from settling of material within the SWMU. The sinkhole was backfilled with soil. This hole previously had been reported in the WAG 3 RI Report and the BGOU Work Plan as having developed in the fall of 1999.

In the fall of 1999, employee interviews led to designating the C-747 Burial Yard as a classified area. Access subsequently was restricted based on security considerations.

1.3.4 C-746-F Burial Yard (SWMU 5)

1.3.4.1 Site description

The C-746-F Burial Yard is located in the northwestern section of the PGDP secured area. SWMU 5 (which covers an area of approximately 197,400 ft^2) is located adjacent to a scrap yard to the north (C-746-P/P1) and SWMU 6 to the east. Disposal pits were located on a grid system. Documentation of the size of these grids ranges from 10 by 10 ft cells to 20 by 20 ft cells excavated to a depth of 6 to 15 ft bgs. Figure 1.7 shows these cells as 20 by 20 ft. Worker interviews indicate this spacing is roughly accurate; however, historical aerial photographs indicate the earliest grid spacing may have been smaller. The fence around SWMU 5 has regularly spaced reflectors, which may have been used by workers as a reference in defining the waste cell grid in the field.

Waste placed in the yard disposal pits was covered with 2 to 3 ft of soil. SWMU 5 is fenced to limit access to authorized personnel only. The ground surface is covered with short grasses and various flowering herbaceous plants (DOE 1998b).

1.3.4.2 Site history

SWMU 5 was in operation from 1965 to 1987. The burial pits were used for the burial of components from the "Work for Others" activities, some radionuclide-contaminated scrap metal, and slag from the nickel and aluminum smelters. Metals and radioisotopes are the primary potential contaminants of interest at this SWMU. The total quantity of wastes buried at the yard could be up to 896,000 ft^3, assuming an average quantity of 2,800 ft^3 waste placed in each cell and 320 cells receiving waste. Chemically unstable or incompatible compound/metal wastes are thought to have been placed here also. This conclusion is supported by the occurrence of an underground fire (thought to have occurred circa 1975–1976) in the southeast corner of the yard. This fire burned for several weeks, and individuals observing the fire reported that the ground surface appeared to become unstable. The source and/or cause were never determined; however, subsequent worker interviews indicate the fire was thought to be a reaction from hot slag in contact with water, producing acetylene gas. The fire extinguished itself without intervention, and no testing was performed to prove or disprove this theory. Common practice following this incident was to allow slag to cool before placing it in the burial yard. No data are available related to contaminant releases from the fire.

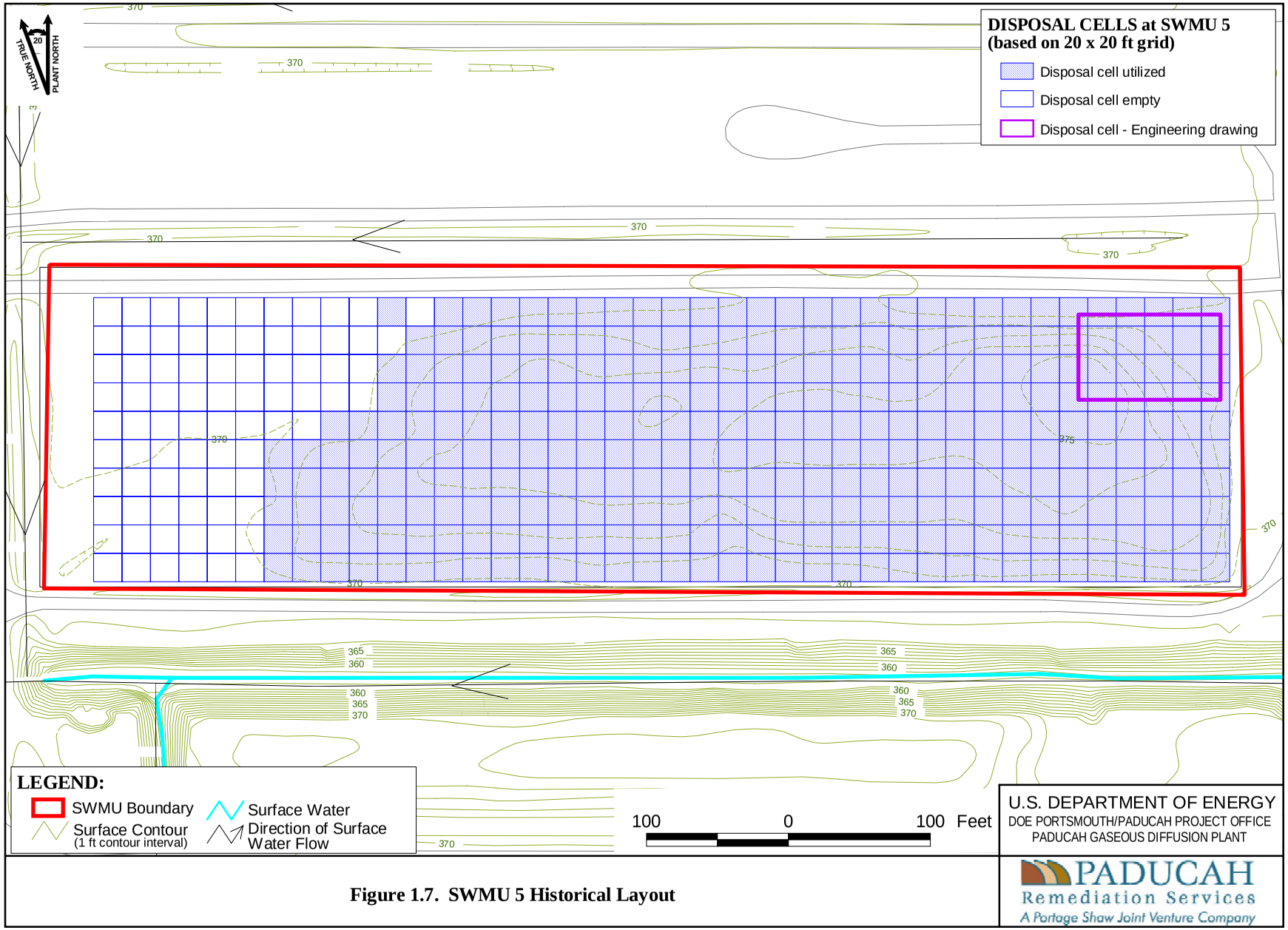

Figure 1.7. SWMU 5 Historical Layout

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1.3.5 C-747-B Burial Ground (SWMU 6)

1.3.5.1 Site description

The C-747-B Burial Ground is located in the northwestern section of the plant area east of SWMU 5. The entire burial area covers an area of approximately 13,500 ft2, which is divided into five separate burial cells (Figure 1.8). The following are the dimensions of each of the cells.

- Area H—This disposal site covers an area of about 12 by 15 ft and is about 6 ft deep. A 3 ft cover of soil was placed on top of the buried drums.

- Area I—This discard pit is approximately 8 by 35 ft and is about 8 ft deep. The waste was covered with about 5 ft of soil. A smaller pit located near the northwest corner of Area I, designated I-2 on Figure 1.8, is approximately 6 ft by 6 ft.

- Area J—This burial site is about 4,000 ft^2 (37 by 110 ft) and was excavated to a depth of about 6 ft. The area was covered with about 3 ft of soil.

- Area K—This disposal site consists of an area of about 12 by 15 ft and is about 6 ft deep. A 3 ft cover of soil was placed on top of the buried drums.

- Area L—This burial area is about 20 by 30 ft and about 6 ft deep. The disposed waste was covered with about 3 ft of soil.

SWMU 6 is relatively flat and is bounded to the north by a set of abandoned railroad tracks, to the east by a 5-ft wide by 4-ft deep drainage ditch that drains into Ditch 001, and unnamed gravel roads to the west and south. The ground surface is medium to tall grasses (up to 3 ft high) with occasional pockets of young trees and shrubs (DOE 1998b).

1.3.5.2 Site history

SWMU 6 was in operation from 1960 to 1976. Each of the burial cells was used for the disposal of a different waste. Each cell and its contents were identified in the WAG 3 RI Report (DOE 2000a) as follows:

- Area H—Magnesium Scrap Burial Area. The scrap buried at this location is magnesium, in various shapes, generated in the machine shop. A total of about ten drums of scrap was buried during midsummer 1971.

- Area I—Exhaust Fan Burial Area. Eight exhaust hood blowers removed from C-710 were discarded to this pit. These blowers, which were about 15 inch in diameter and weighed about 100 lb each, were discarded in 1966 because of contamination with perchloric acid. Each blower was spaced about 4 ft apart in the hole. In 1976, additional exhaust fans from C-710 were buried in pit I-2.

- Area J—Contaminated Aluminum Burial Area. The contaminated scrap buried in this hole involved about 100 to 150 drums of aluminum scrap in the form of nuts, bolts, plates, trimmings, etc., that were generated in the converter and compressor shop. This scrap was buried in the early 1960s.

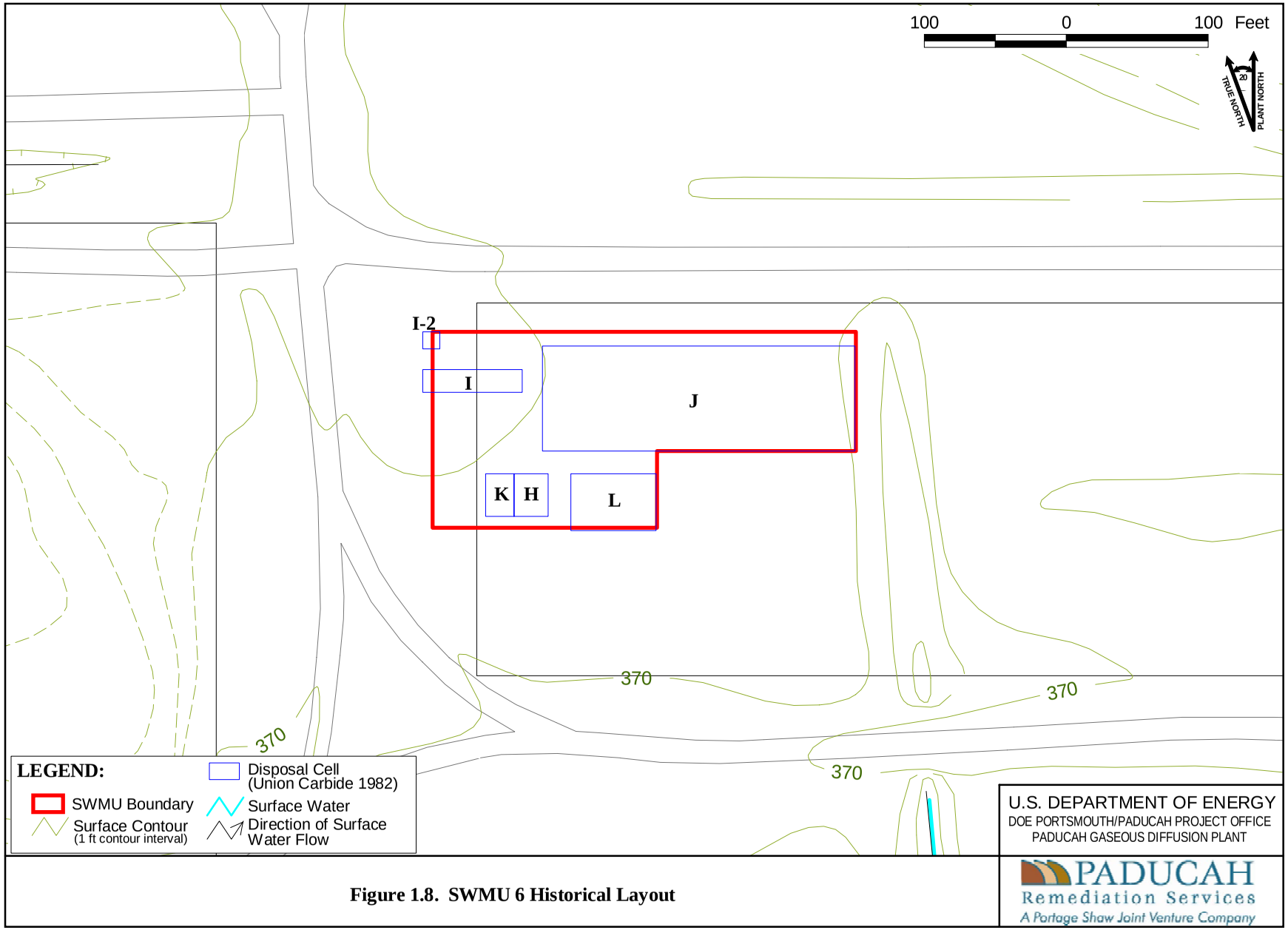

Figure 1.8. SWMU 6 Historical Layout

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- Area K—Magnesium Scrap Burial Area. The scrap buried at this location is magnesium in various shapes generated in the machine shop. A total of about 20 drums of scrap was buried on September 3, 1968, and December 23, 1969.
- Area L—Modine Trap Burial Area. A single contaminated modine trap was buried in this area. The cold trap was about 4 ft in diameter, approximately 15 ft long, and weighed about 5,000 lb. This equipment was buried on March 5, 1969.

The WAG 3 RI Report (DOE 2000a), stated that approximately 50% of the surface area of SWMU 6 was used to store radioactively contaminated equipment and materials. These items include industrial forklifts and transport carts, flatbed trailers, generators, concrete pipes, and other miscellaneous items. This stored equipment has been removed. The area no longer is used for storage (DOE 2007d).

1.3.6 C-747-A Burial Ground (SWMU 7)

1.3.6.1 Site description

The C-747-A area is located in the northwest corner of the PGDP secured area. SWMU 7 comprises the eastern two-thirds of C-747-A. The SWMU is bounded on the north and south sides by perimeter ditches, on the west side by the C-747-A Burn Area (SWMU 30), and on the east side by the C-746-E Contaminated Scrap Yard. SWMU 7 covers approximately 240,900 ft^2 and includes six discrete burial pit areas described below and illustrated in Figure 1.9 (DOE 1998c).

- Pit B—This pit is approximately 60 by 172 ft. According to the Phase II Site Investigation (SI) geophysical survey, the actual excavation extends beyond the designated boundaries and may connect with the adjacent burial pit (Pit C). A geophysical survey conducted for this RI interprets B and C as separate pits.
- Pit C—This pit is approximately the same size as Pit B. Based on the Phase II geophysical survey, Pit C and Pit B may be one continuous pit; however, a geophysical survey conducted for this RI interprets B and C as separate pits.
- Pit D—This pit is approximately 15 by 99 ft.
- Pit E (outside the eastern boundary of SWMU 7 and within the C-746-E Contaminated Scrap Yard)—This pit is approximately 15 by 143 ft.
- Pits F1–F5—These pits are all small (average size of each pit is approximately 20 by 80 ft). Engineering drawings indicate a sixth "F" pit that was not labeled.
- Pit G—This pit was documented as approximately 27 by 122 ft.

Records indicate the burial pits, in general, were excavated to a depth of 6 to 7 ft bgs, filled with wastes, and covered with approximately 3 ft of earth (Union Carbide 1978); however, geophysical surveys during the Phase II SI indicated waste in pits to a depth of 8-15 ft (CH2M HILL 1992).

A stockpile of radiologically contaminated scrap drums, locally known as Drum Mountain, formerly was located on the southeast corner covering Pit G. Interviews with a former operator who worked in the SWMU 7 area indicate Drum Mountain was created only after the area between the F Pits and Pit G had been filled with similar material. This interview was corroborated by geophysical evidence (see Section 2.1).

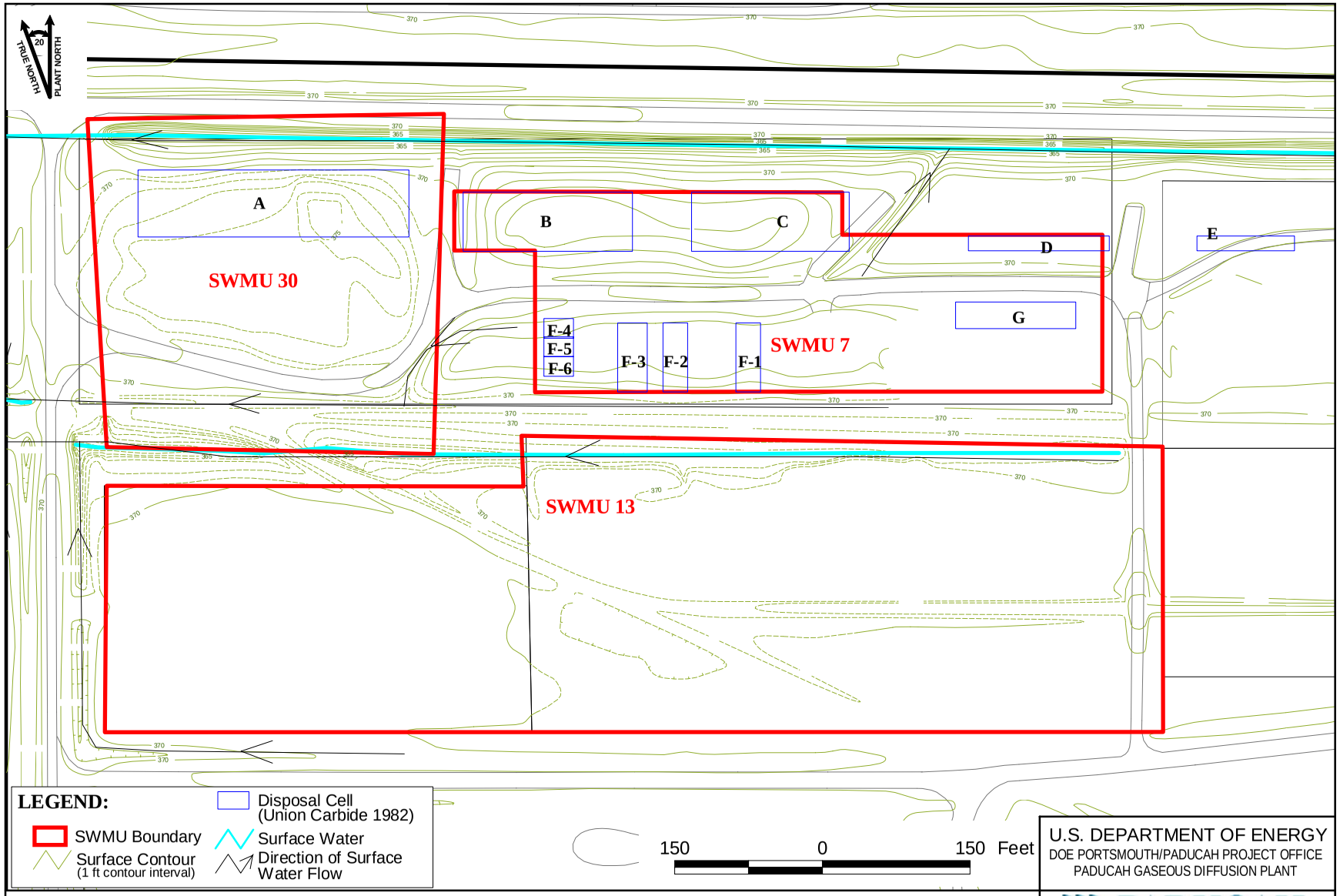

Figure 1.9. SWMUs 7 and 30 Historical Layout

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The land surface slopes within SWMU 7. Burial Pits B and C form a slight hill on the north side of SWMU 7, and Burial Pit F forms a lesser mound on the south side of the SWMU. Pit D underlies a level area north of where Drum Mountain once was located. Shallow drainage swales occur on the west side of Burial Pit B, between Burial Pits C and D. The ground surface of the west half of the SWMU is covered by grassy vegetation, except where gravel roads extend through the site. A PGDP scrap metal project covered the west half of the SWMU with 1 to 2 ft of gravel as a working base for truck and tractor traffic. This gravel also prevents exposure to contaminated soils resulting from the earlier removal of scrap material in Drum Mountain.

Infrastructure has been placed in the area in support of the Scrap Metal Removal Action project. This infrastructure includes an extensive gravel pad constructed to support a truck scale in the area of Burial Pit G.

The upper 20 ft of soils at SWMU 7 consist of surface soil, fill, and loess, alternatively described as silt or clay, in the area boreholes. Surface soils, to a depth of 6 inches, were sampled and described during the Phase II SI. Soil textures range from sand with gravel to lean clay with gravel. During the Phase II SI, double-ring infiltrometer tests were conducted on surface soils at SWMU 7. Average long-term infiltration rates ranged less than 5.7 ft/day (CH2M HILL 1992). Logs of deeper soil borings demonstrate that coarse textures generally are limited to the upper 2 ft, with the exception of the burial pits that are now known to be as much as 10 ft deep.

The surface water that drains from SWMU 7 into the surrounding ditches is carried west through Outfall 001 into Bayou Creek. In 2002, a sedimentation basin was constructed to contain runoff from PGDP scrap yards. Runoff now flows into the sedimentation basin and is released periodically into Outfall 001.

1.3.6.2 Site history

PGDP used the burial pits for disposal of wastes from 1957 to 1979. Burial Pits B, C, and G were used for disposal of noncombustible, contaminated and uncontaminated trash, material, and equipment. Contaminated concrete removed from the C-410 Feed Plant during May and June 1960 was placed in Burial Pits D and E. Burial Pit F was used for disposal of uranium-contaminated scrap metal and equipment. Empty uranium and magnesium powder drums also were reported to have been buried in Burial Pit F (Union Carbide 1978).

The following summarizes what is known about the disposed waste in the burial pits.

- Pit B—Buried material includes noncombustible trash and contaminated and noncombustible material and equipment (however, no specific disposal records exist).

- Pit C—Historic records indicate that both Pit B and C received the same material.

- Pit D—Documented buried material consists of uranium-contaminated concrete pieces of reactor tray bases from C-410 used during the fluorination process of uranium tetrafluoride to uranium hexafluoride.

- Pit E—Documented buried material consists of uranium-contaminated concrete pieces of reactor tray bases.

- Pits F1–F5—Documented buried material consists of uranium-contaminated scrap metal and equipment and empty uranium and magnesium powder drums (engineering drawings indicate there was a sixth "F" pit that was not numbered).

- Pit G—Documented buried material consists of noncombustible trash and contaminated and noncombustible material and equipment.

In addition to these burial pits, the Phase II SI geophysical investigation also identified another anomaly in the shape of a rough circular area (15 ft diameter) between SWMU 30 and SWMU 7, west of the F-4 and F-5 Pits (see Section 2). There is no information confirming the presence or the nature of any buried wastes associated with this anomaly.

1.3.7 C-747-A Burn Area (SWMU 30)

1.3.7.1 Site description

SWMU 30 includes the western one-third of C-747-A. It consists of an historical burn-and-burial pit (Burial Pit A) and the location of a former incinerator. The SWMU is bounded on the north and south sides by ditches, on the west side by a plant road, and on the east side by SWMU 7 (Figure 1.9). The unit encompasses approximately 128,000 ft^2. The pit is reported to have been excavated to a depth of 12 ft and covered with 4 ft of earth. The land surface slopes gently, and a slight mound rises over Burial Pit A. SWMU 30 is bordered by drainage ditches on the north and south side. Grassy vegetation covers the ground, except where gravel roads extend through the site.

Phase II SI surface soil sample sites H-361 through H-366, H-370, and H-373 provide characterization of surface soil texture from eight locations across SWMU 30. The upper 6 inches of soil ranges from lean clay to sand. Surface soil samples from the Burial Pit A area tend to be lean clay with gravel, whereas surface soil textures from the south side of SWMU 7 range from lean clay to silty sand with gravel (DOE 1998c). The Phase II SI included double-ring infiltrometer tests on surface soils at three locations. Average long-term infiltration rates were less than 6×10^{-3} ft/day for two of the tests. All deeper soil borings, including Phase II SI borings H-211 and H-212, MW 66, and boring S-2, encountered surficial fill materials to depths of 2 to 12 ft.

1.3.7.2 Site history

SWMU 30 was used from 1951 to 1970 to burn combustible trash, which may have contained uranium contamination. An incinerator was constructed for use at SWMU 30, but the exact time frame is uncertain. The incinerator was a steel mesh, "tee pee" shaped structure primarily used to burn paper, wood, cardboard, and other combustibles. Ash and debris were buried below ground in Burial Pit A beginning in 1962, when use of an on-site incinerator was discontinued. It is assumed ash from incineration was buried at SWMU 30 rather than taken elsewhere at the site. Site maps and a surface electromagnetic geophysical survey of the Phase II SI identify the location of Burial Pit A. Prior to identification by Phase II SI surface geophysics testing; it was believed that remnants of the former incinerator were not present. Further research identified images of the incinerator at the location. This disposal site covers an area of about 250 ft by 50 ft. Geophysical data from the Phase II SI indicate that the actual area of excavation does not exactly match the rectangular outline and extends beyond the rectangular outline to the north and east. Material disposed in Pit A included contaminated and uncontaminated trash, ash, and debris.

In addition to Pit A, the Phase II SI geophysical investigation also identified another anomaly in the shape of a rough circle approximately 43 ft in diameter (see Section 2). The SWMUs 7 and 30 RI confirmed this anomaly likely was the metal reinforcement within the footer and retaining walls of the former incinerator and/or parts of the unit buried there upon decommissioning (DOE 1998c).

1.3.8 Area P (SWMU 145)

1.3.8.1 Site description

Area P (SWMU 145) is located north of the PGDP security area and is defined by encompassing the area underneath SWMUs 9 and 10 (the C-746-S and -T Landfills, respectively). The SWMU is approximately 44 acres and began operation in the early 1950s. Currently, the C-746-S and -T Landfills are located on top of SWMU 145, but are not included in SWMU 145 (DOE 1999b), as illustrated in the conceptual drawing, Figure 1.10. The boundaries of the area previously had not been well defined outside of the area utilized by the C-746-S and -T Landfills.

1.3.8.2 Site history

SWMU 145 began operation in the early 1950s. A 1973 document *The Discard of Scrap Materials by Burial at the Paducah Plant* (Union Carbide 1973), states this area was used by the contractor during the construction of PGDP to discard all types of scrap and waste materials. Use of the area for discarding of scrap and waste by subcontractors was continued until the early 1980s. Construction debris, such as concrete, roofing materials, wire, wood, shingles with asbestos, and welding rods, are expected to have been disposed in the area. Approximately once a year, the accumulated scrap piles were moved by plant personnel into piles or earth depressions and, whenever practicable, covered with dirt. The area was later permitted for the construction and operation of the C-746-S and -T Landfills (BJC 2001a). The C-746-S Landfill began operation in 1981. Figure 1.11 shows historical aerial photographs of the area and depicts evident ground scarring, likely indicating disposal areas.

Several monitoring wells are present in the area for permit-related monitoring. Since 2003, these wells have indicated the presence of PCBs in the RGA (see Section 4).

1.4 REPORT ORGANIZATION

This RI report was prepared following the guidance found in Appendix D of the FFA for PGDP (EPA 1998). The outline of this report followed the guidance presented in Appendix D of the *Work Plan for the Burial Grounds Operable Unit Remedial Investigation/Feasibility Study at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2006a).

These sections are consistent with the FFA. The following are their locations within this report.

- Chapter 1—Introduction
- Chapter 2—Study Area Investigation
- Chapter 3—Physical Characteristics of the Study Area
- Chapter 4—Nature and Extent of Contamination
- Chapter 5—Fate and Transport
- Chapter 6—Baseline Risk Assessment
- Chapter 7—Summary and Conclusions
- Chapter 8—References

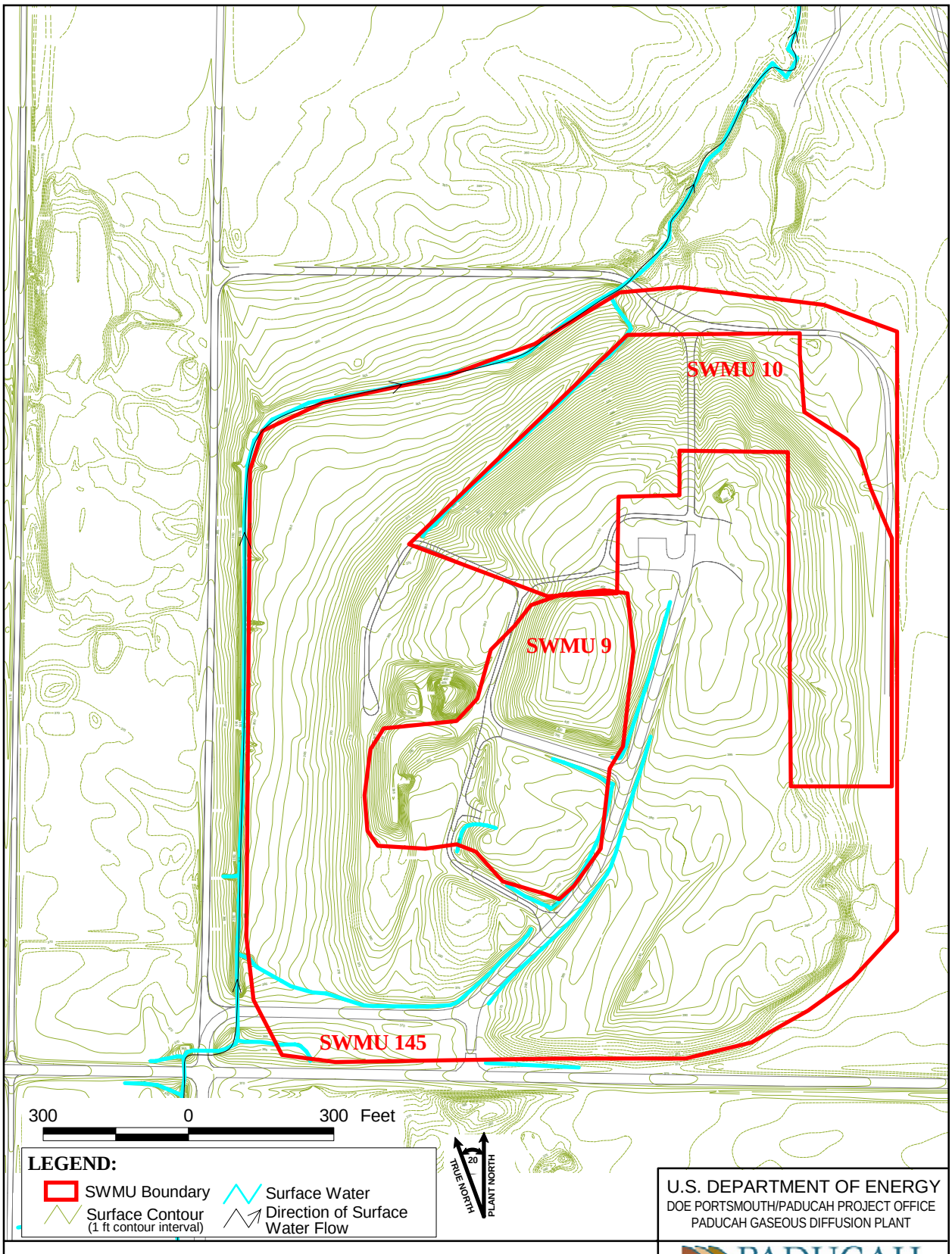
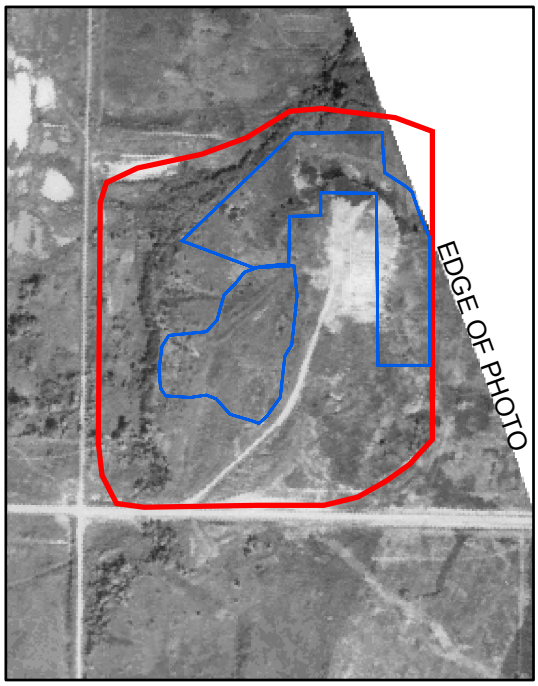
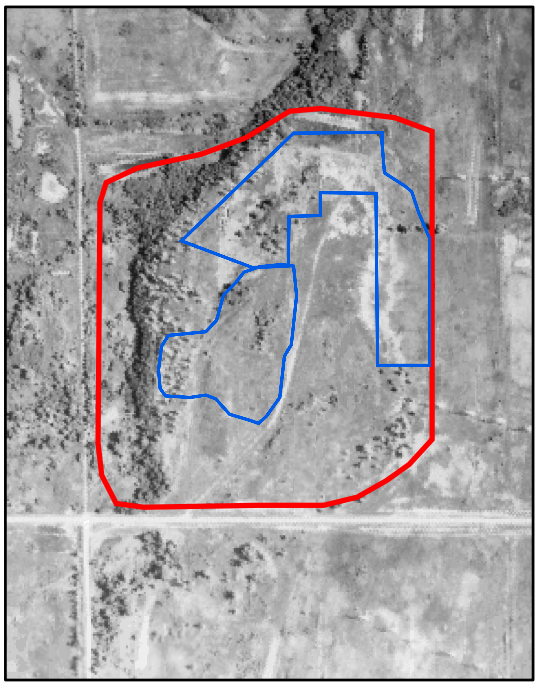


Figure 1.10. SWMU 145 Historical Layout

Figure No. \BGOU\RI.apr
DATE 12-18-07

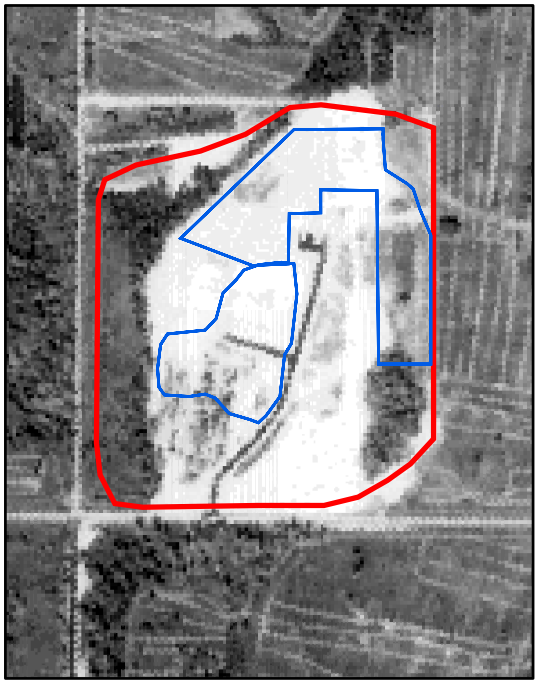


1959 Aerial Photograph



1964 Aerial Photograph

1975 Aerial Photograph



1981 Aerial Photograph

LEGEND

CURRENT SWMU 145 BOUNDARY

CURRENT SWMUs 9 and 10 BOUNDARIES

0 300 600 1,200 Feet

28

TRUE NORTH

PLANT NORTH

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Figure 1.11. Historical Aerial Photographs of SWMU 145

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

- Appendix A—Technical Memorandum for Field Activities
- Appendix B—Lithologic Logs and Well Construction Diagrams, Groundwater Stabilization Logs, and Well Development Logs
- Appendix C—Analytical Data and Quality Assurance (QA)/Quality Control (QC) Evaluation Results
- Appendix D—Three-Dimensional Visualization Figures
- Appendix E—Fate and Transport Modeling
- Appendix F—Baseline Human Health Risk Assessment
- Appendix G—Review of Ecological Risk Assessments

2. STUDY AREA INVESTIGATION

Section 2 includes all field activities associated with site characterization of the BGOU. Technical memoranda documenting details of field activities are included in Appendix A.

2.1 GEOPHYSICAL INVESTIGATIONS

Current geophysical investigations were combined with historical geophysical information to create a more complete picture of the burial area.

As part of the RI field activities, geophysical surveys of SWMUs 2, 5, 7, 30, and 145 were conducted prior to sampling activities. The BGOU represented a difficult target for geophysical characterization because the SWMUs contain a heterogeneous collection of wastes and backfill soils, and some of these SWMUs consist of multiple burial pits of various depths. Geophysical surveys were not planned to be conducted at SWMUs 2 and 5 during scoping of the work plan; however, in support of the excavation/penetration permits procedure, geophysical surveys were conducted in proposed drilling locations where there was uncertainty in waste boundaries to ensure waste cells were not encountered.

An electromagnetic (EM)-61 magnetometer survey was conducted at the surface of these SWMUs to delineate the location and extent of the burial pits. The EM-61 survey was implemented for the most part along continuous lines primarily spaced 5 ft apart in a grid layout. A data logger was employed for data acquisition, and resultant geophysical anomalies were marked in the field and plotted using plant coordinates to an electronic overlay.

In addition to the current geophysical surveys, historical geophysical information is available for SWMUs 2, 4, 5, 6, 7, and 30. Results of the geophysical surveys conducted for the BGOU RI and historical information gathered during this RI is presented in Figures 2.1 through 2.6. The geophysical anomalies to the north and east of the SWMU 6 boundary shown in Figure 2.4 represent equipment (forklifts, mowers, metal debris) that was stored or parked on the surface. While the historical geophysical survey did not cover all of the waste cells (H, I, K, and L) at SWMU 6, engineering drawings were adequate to indicate where buried material was located.

The area within SWMU 13 identified by an employee interview was confirmed by a geophysics survey. The results of this survey are presented in Figure 2.7. After the site investigation, the geophysical information and data for this area will be evaluated and discussed with the FFA parties and, if further action is necessary, a path forward will be determined.

2.2 CONTAMINANT SOURCE INVESTIGATIONS

In order to evaluate contaminant sources, angled soil borings were utilized to collect samples from the soils and groundwater beneath the burial pits. Available information from aerial photographs, historical and current geophysics, engineering drawings, and previous RIs was used to determine the most probable location of the burial pit. Angled soil borings then were placed to collect samples from beneath the burial pits and/or cells. These temporary borings provide a “snapshot” of the current conditions at the time of sampling. Figures 2.8 through 2.14 show the locations of these angled borings.

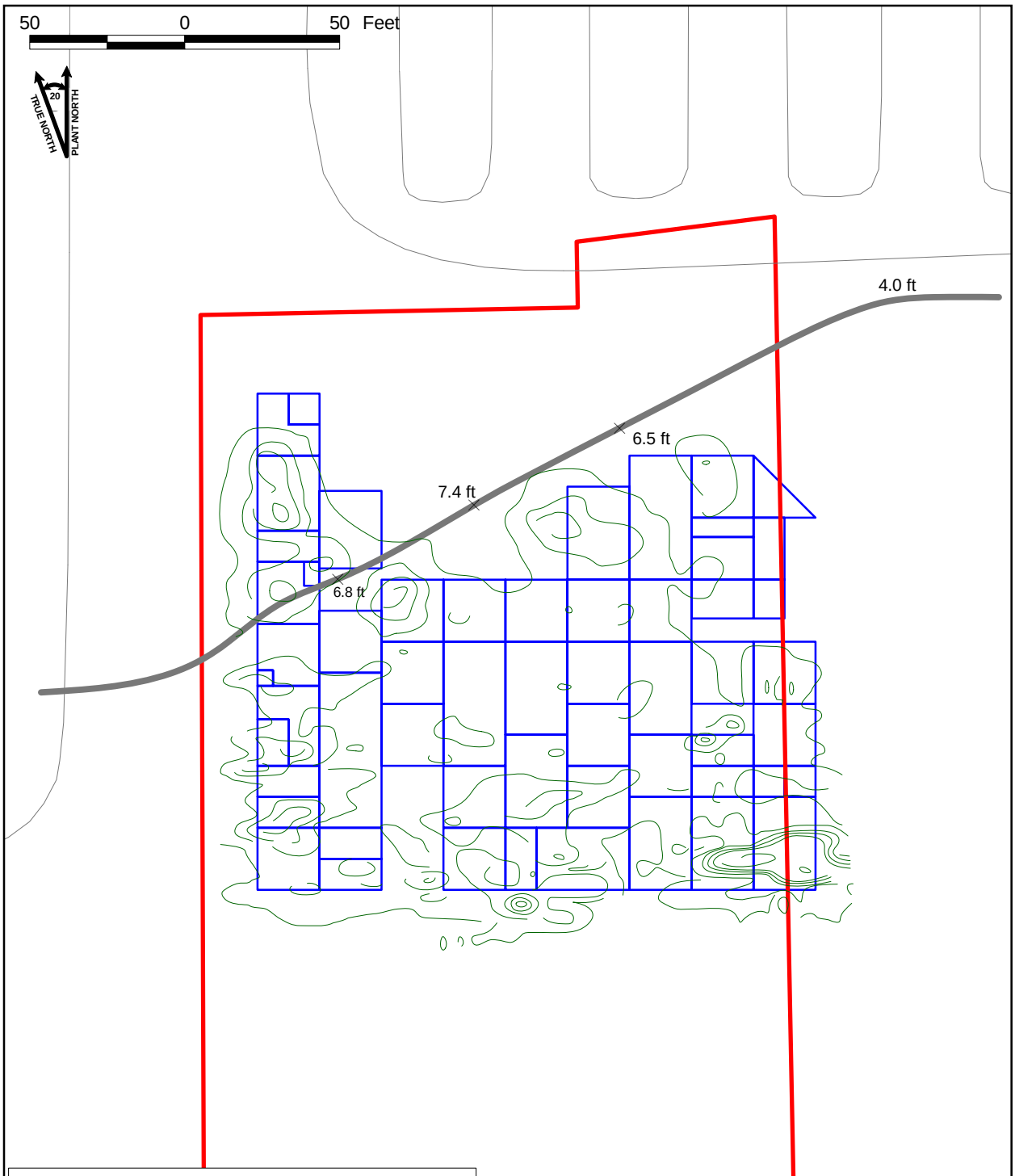

Figure 2.1. SWMU 2 Geophysics

Figure No. \BGOU\RI.apr
DATE 12-16-08

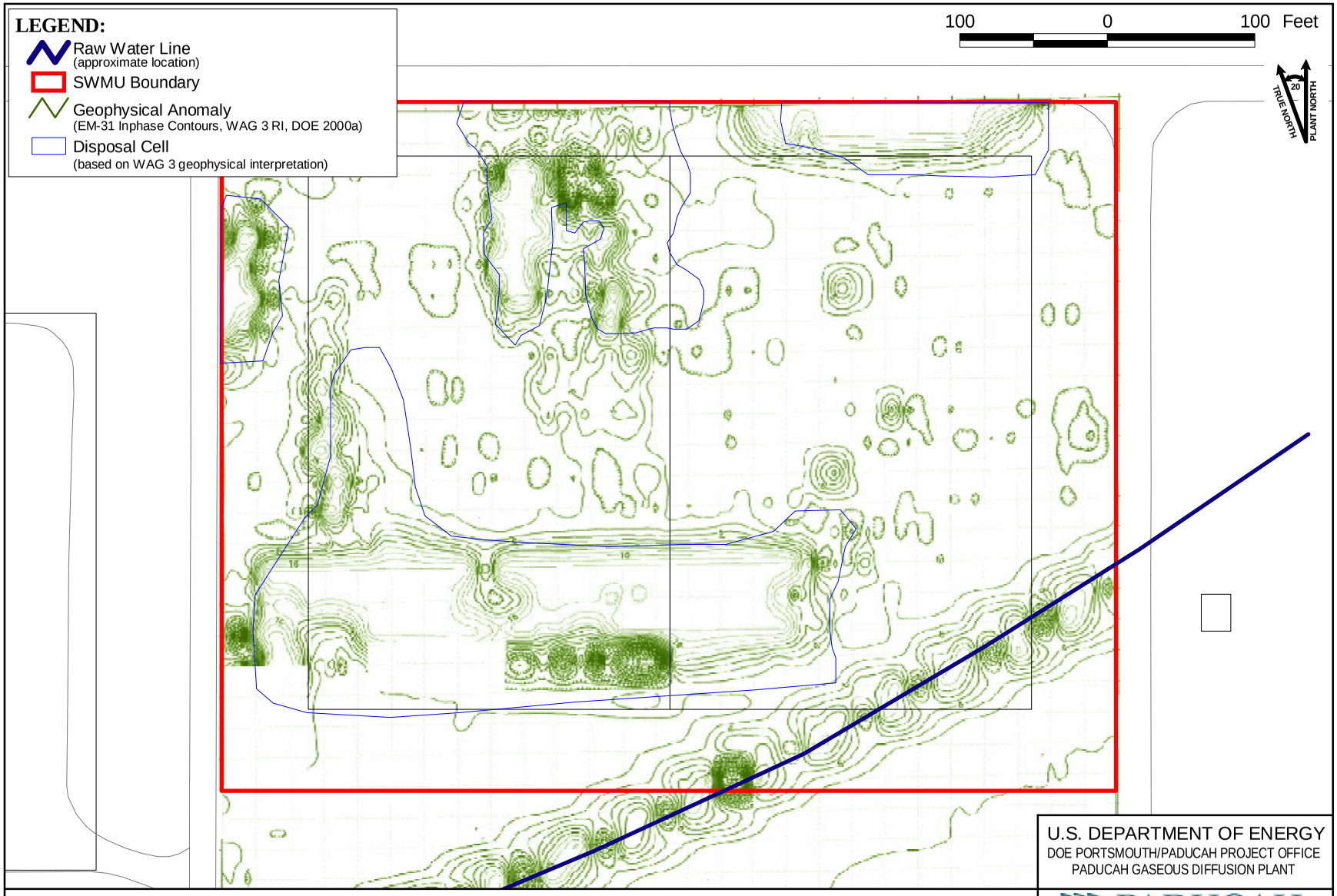

Figure 2.2. SWMU 4 Geophysics

Figure No. \BGOU\RI.apr
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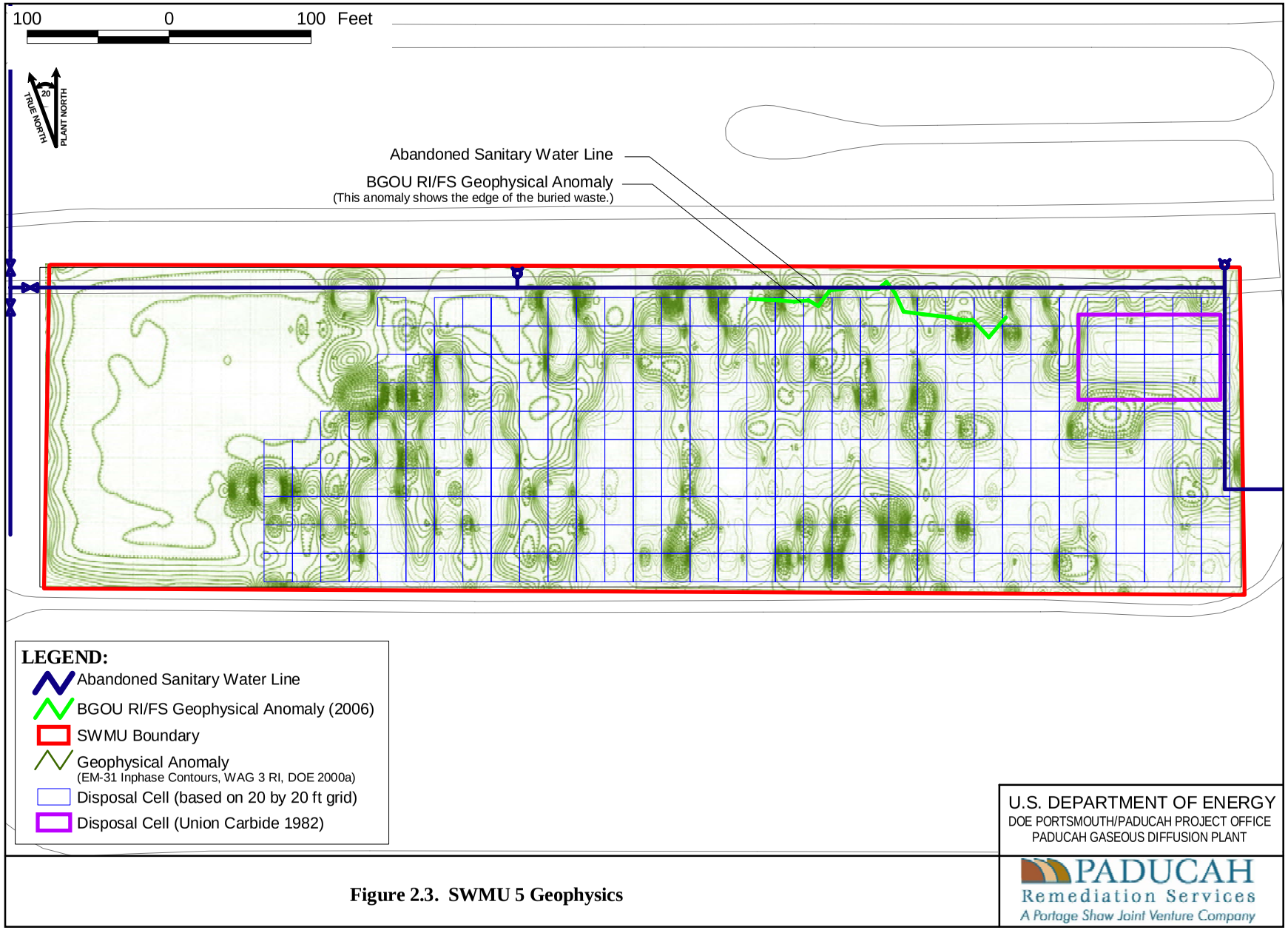

Figure 2.3. SWMU 5 Geophysics

Figure No. \BGOU\RI.apr
DATE 03-16-09

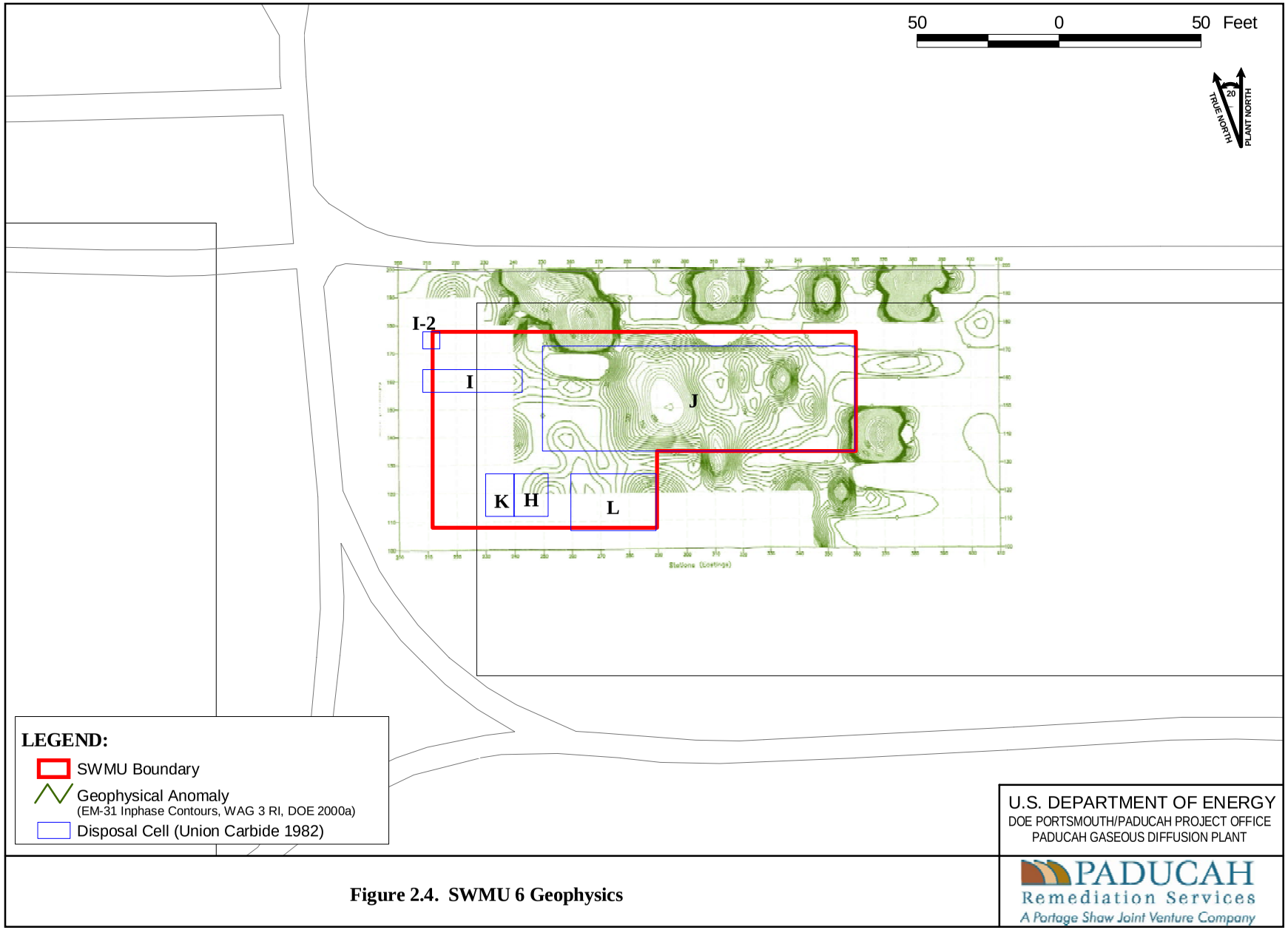

Figure 2.4. SWMU 6 Geophysics

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DATE 12-16-08

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100 0 100 Feet

TRUE NORTH 28 PLANT NORTH

A

B

C

D

E

G

"F" pits

43' anomaly

15' anomaly

SWMU 30

SWMU 7

LEGEND

- SWMU Boundary
- Disposal Cell (Union Carbide 1982)
- BGOU RI/FS Geophysical Anomaly (2006) (Point depths to top of anomaly given in feet)
- BGOU RI/FS Geophysical Anomaly (Single Point) (Point depths to top of anomaly given in feet, for anomalies deeper than 2 ft)
- Interpreted Geophysical Anomaly (SI Phase 2, CH2M Hill 1992)

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Figure 2.5. SWMUs 7 and 30 Geophysics

Figure No. bgou\ri swmus 7-30.mxd
DATE 12-16-08

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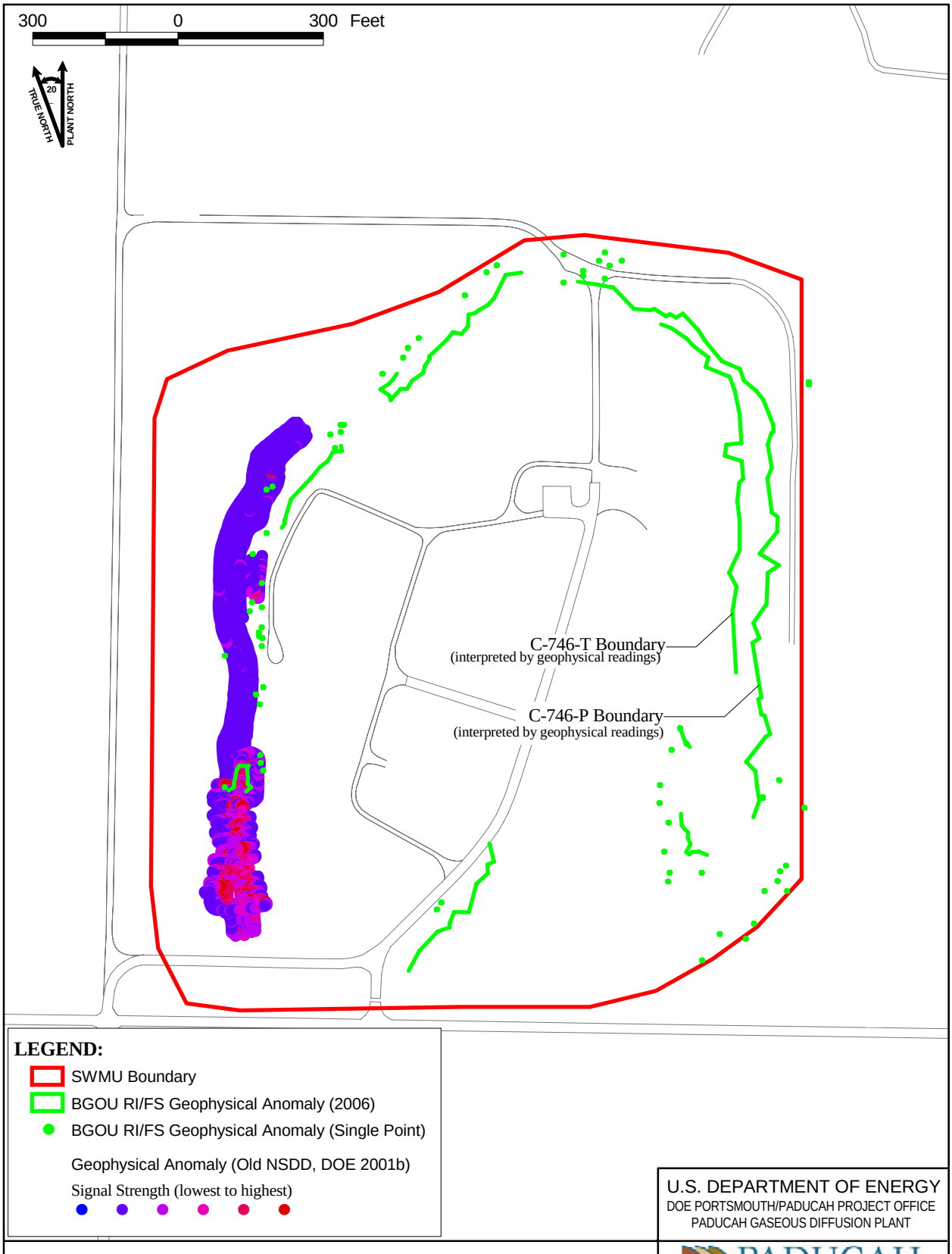

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Figure 2.6. SWMU 145 Geophysics

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Figure No. \BGOU\RI.apr
DATE 12-16-08

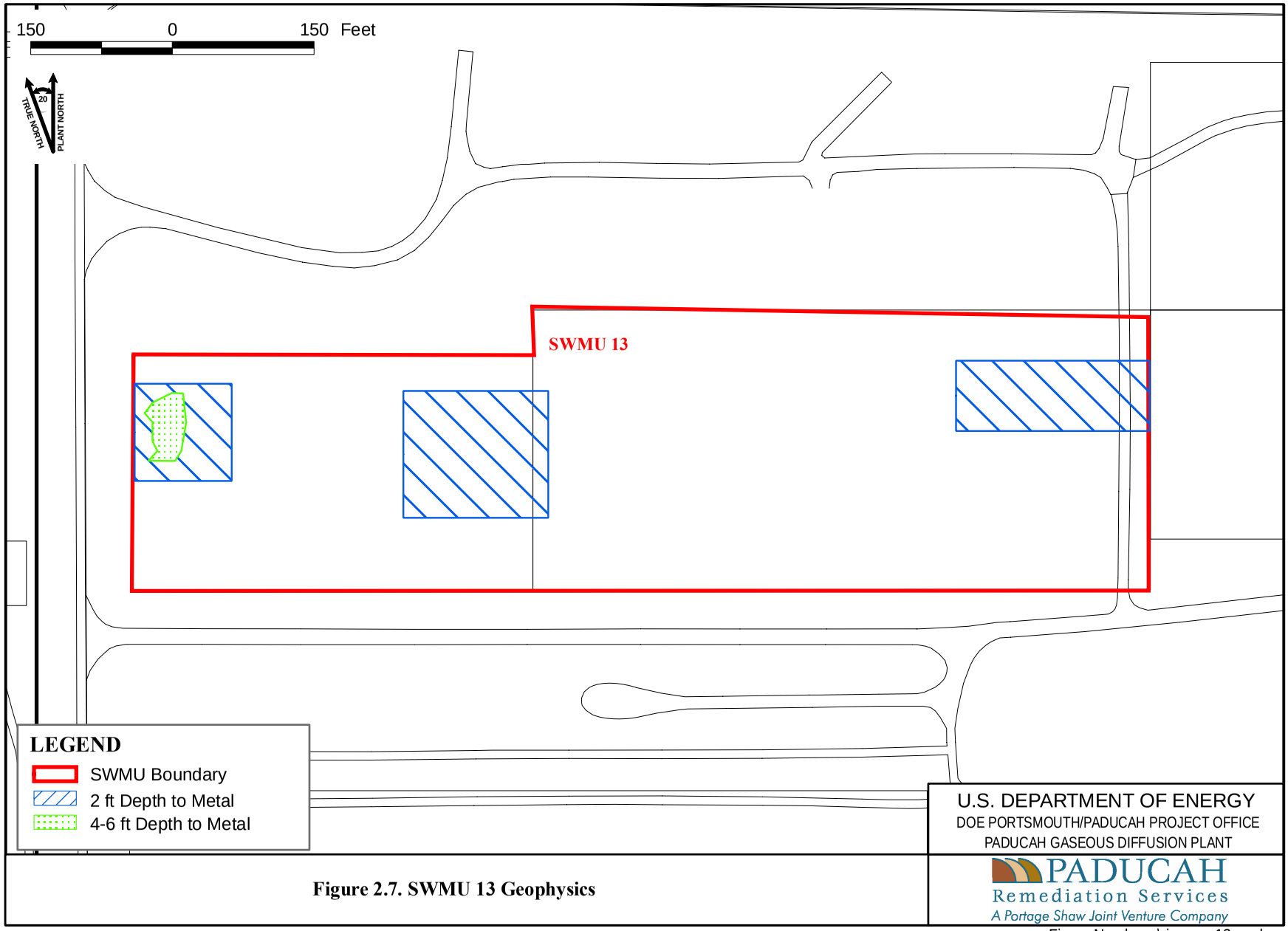
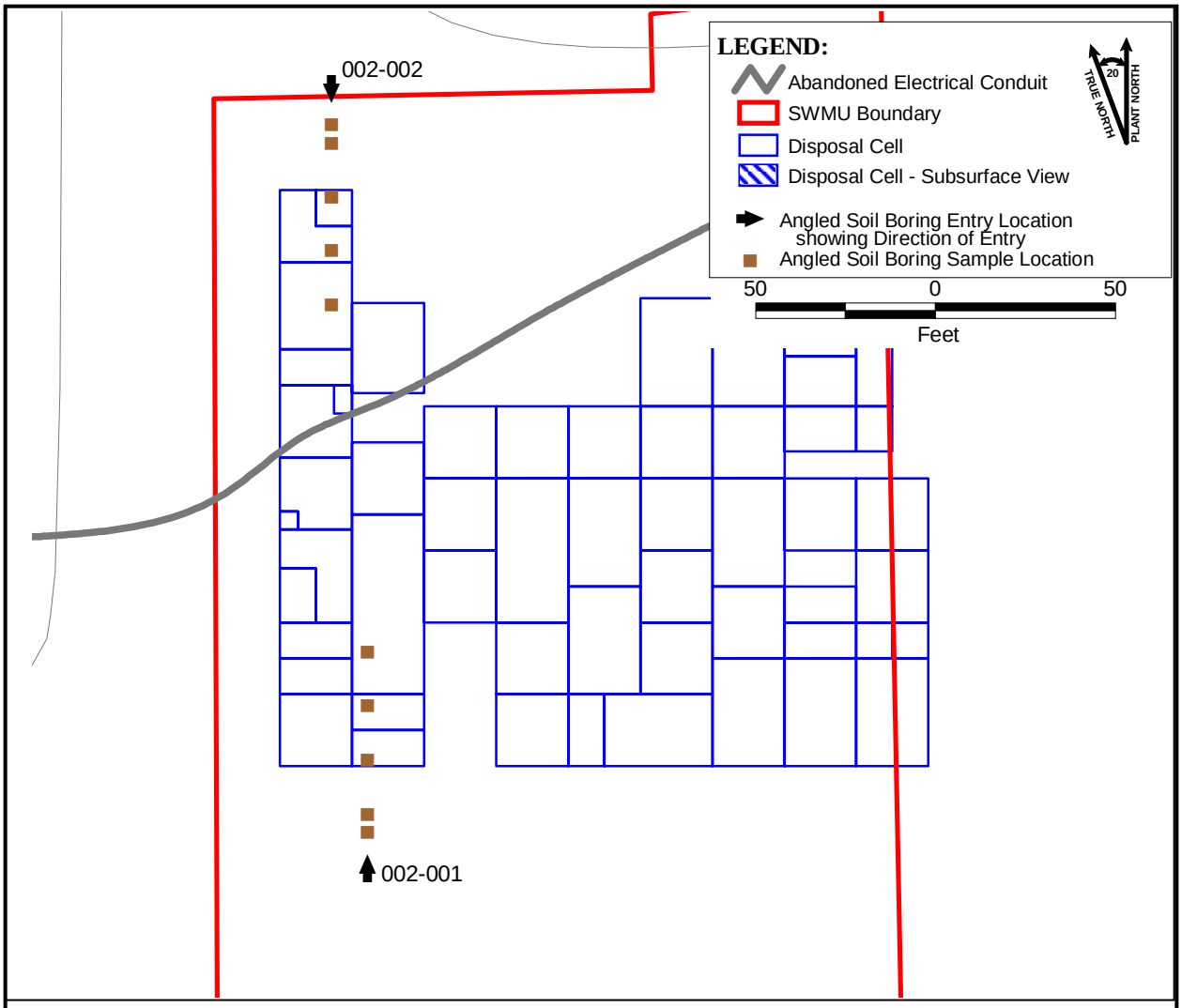


Figure 2.7. SWMU 13 Geophysics



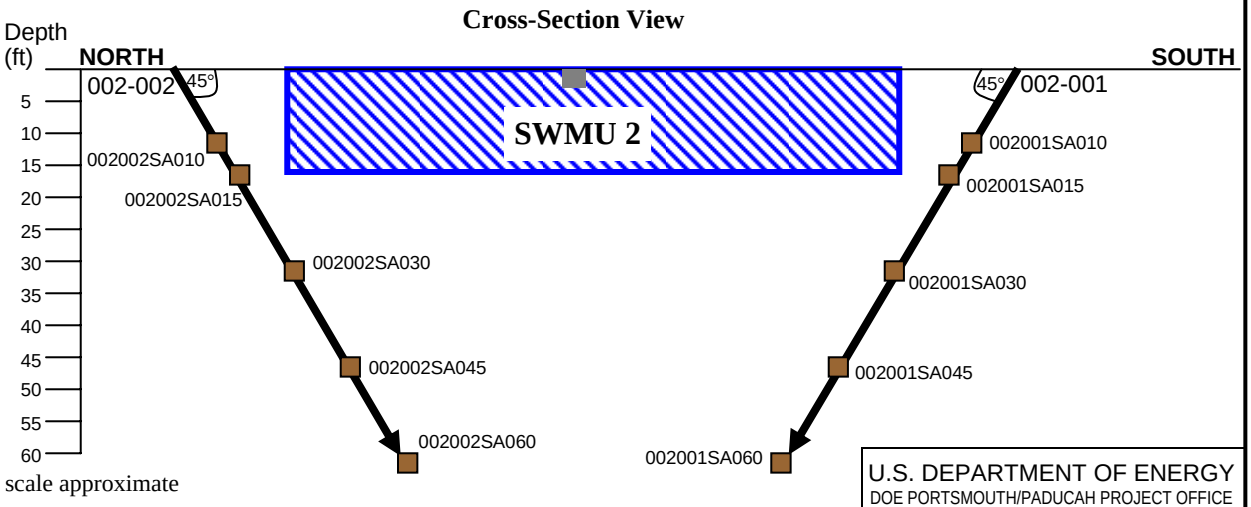


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Figure 2.8. SWMU 2 Angled Boring Locations

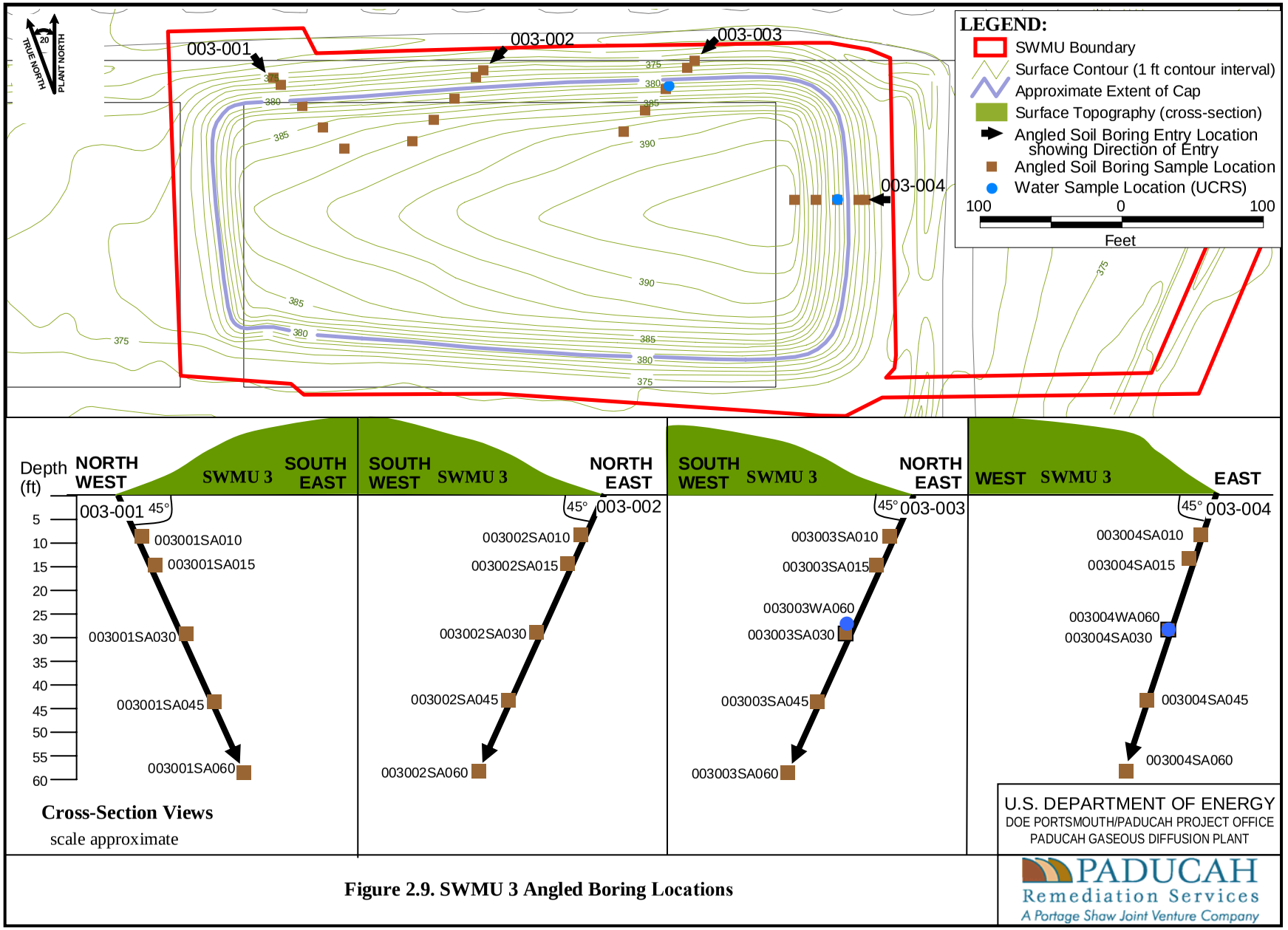
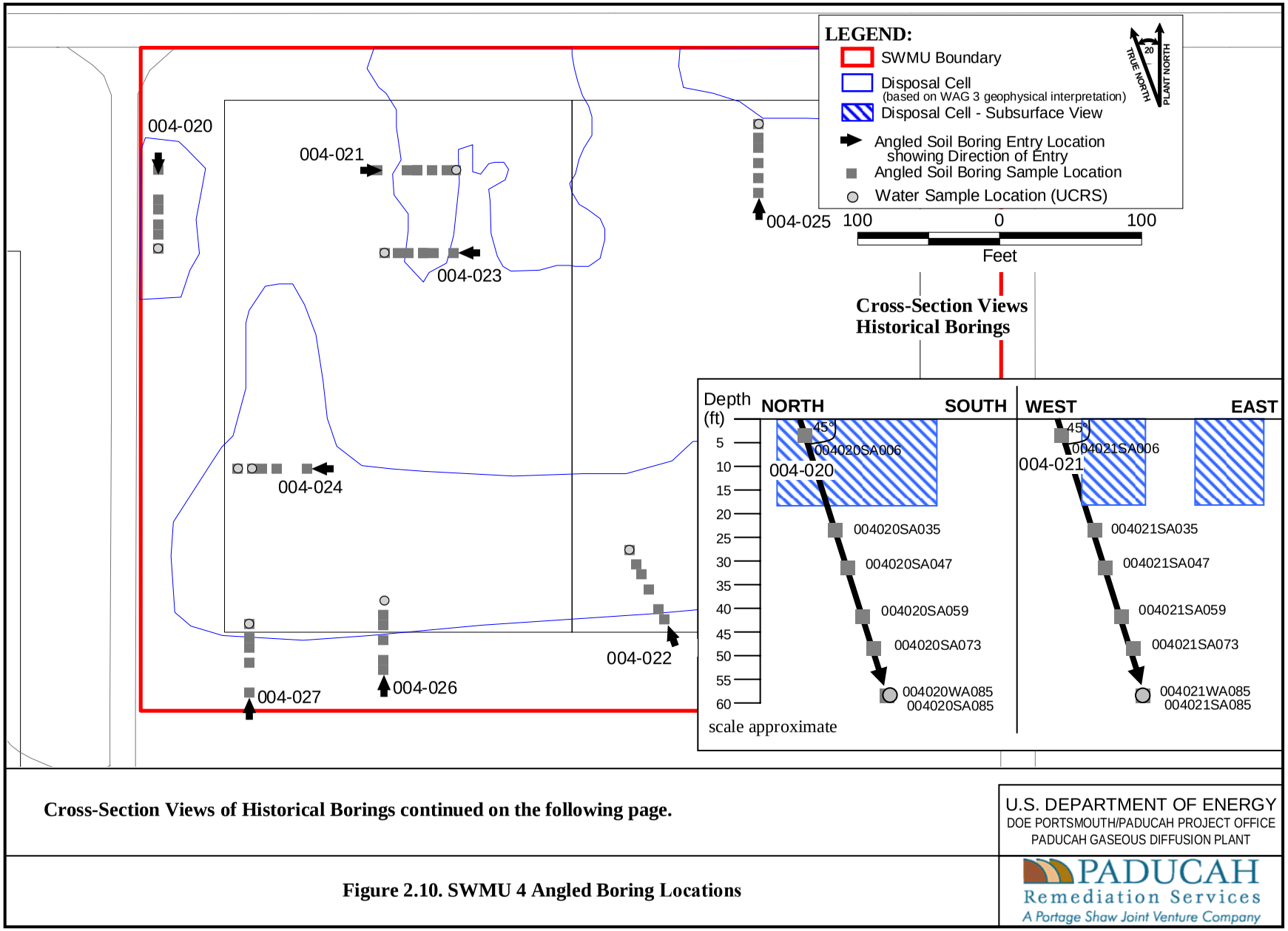


Figure 2.9. SWMU 3 Angled Boring Locations



Cross-Section Views of Historical Borings continued on the following page.

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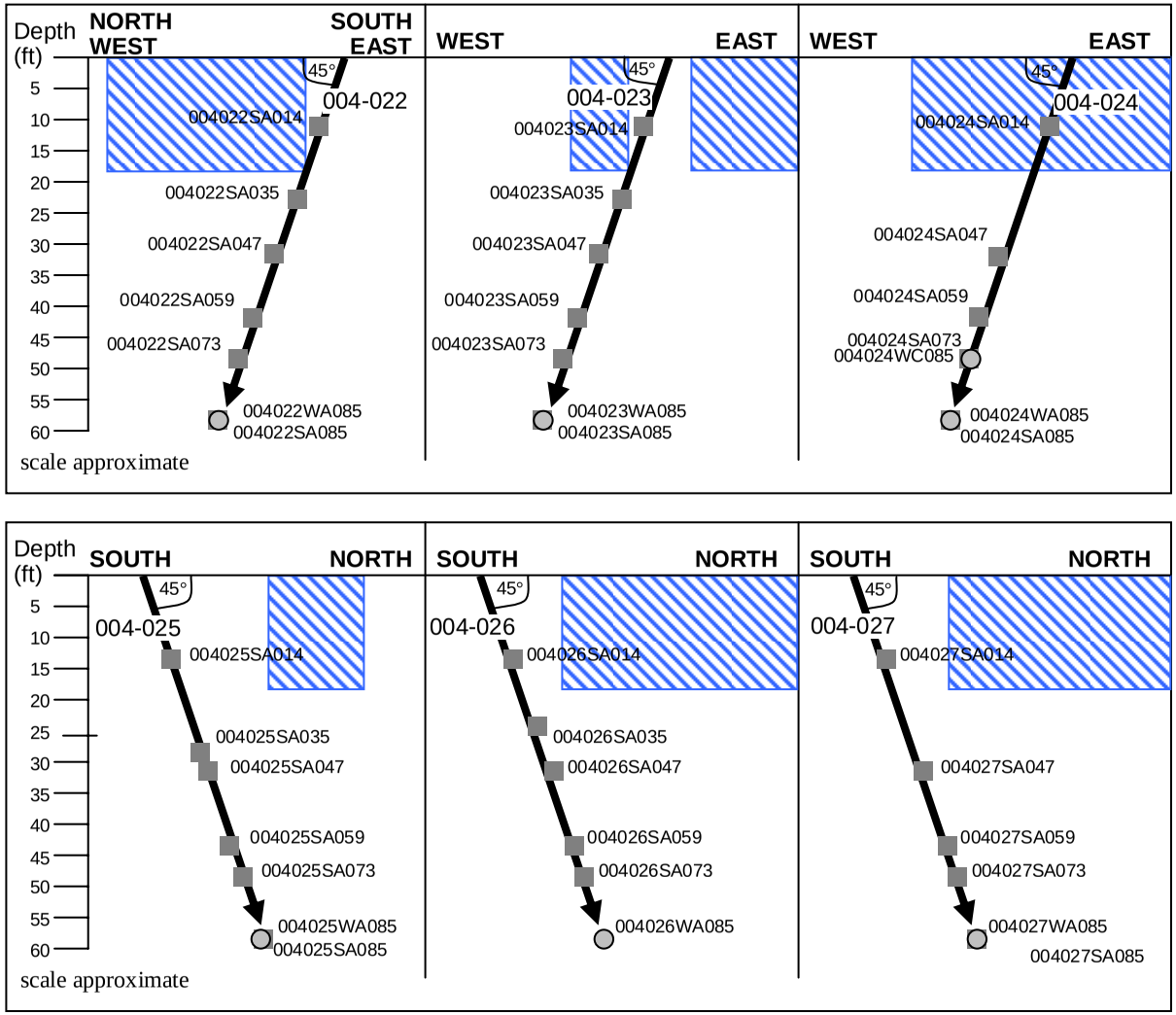
Figure 2.10. SWMU 4 Angled Boring Locations



Cross-Section Views
Historical Borings

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Figure 2.10. SWMU 4 Angled Boring Locations (Continued)

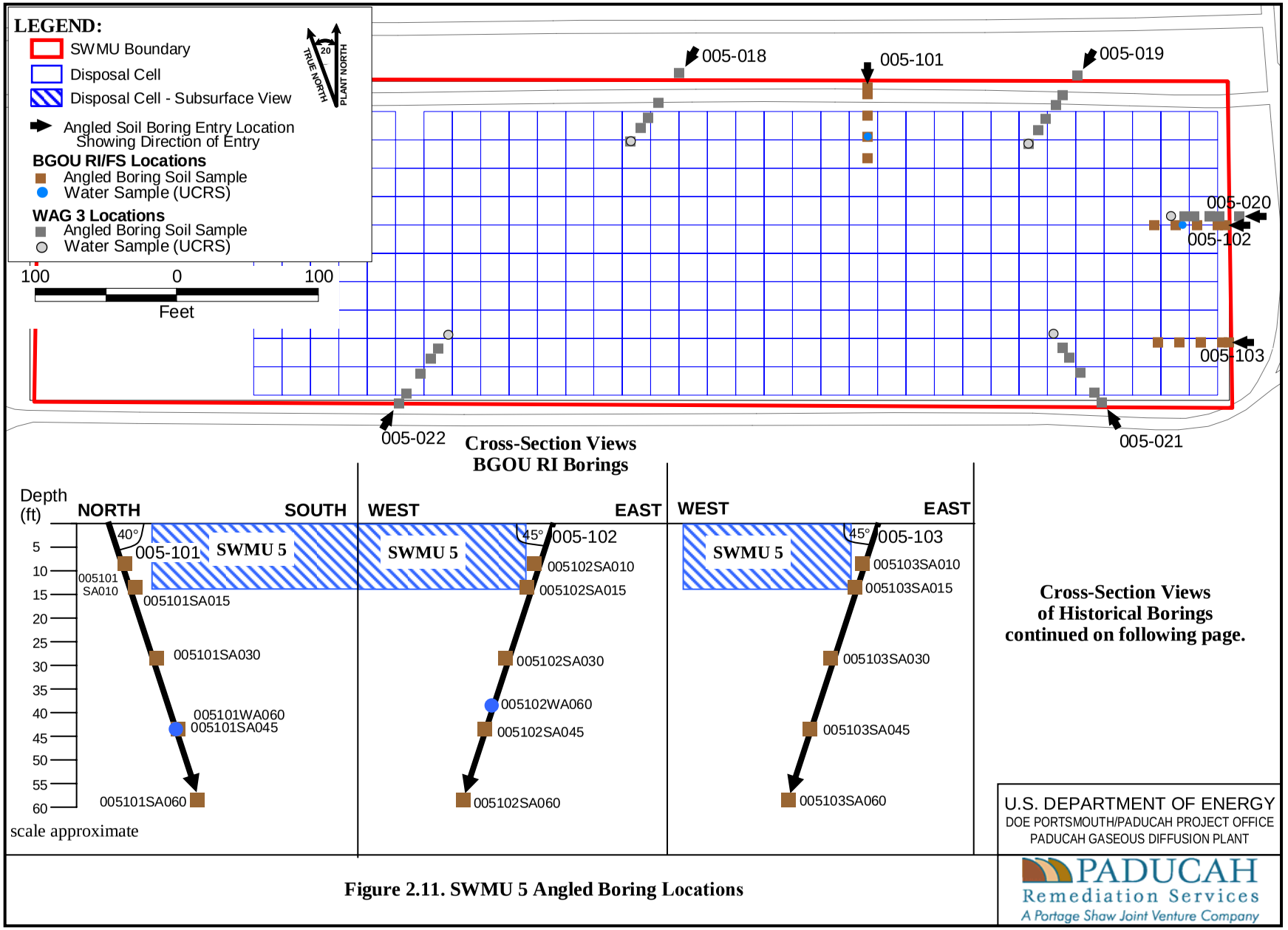


Figure 2.11. SWMU 5 Angled Boring Locations

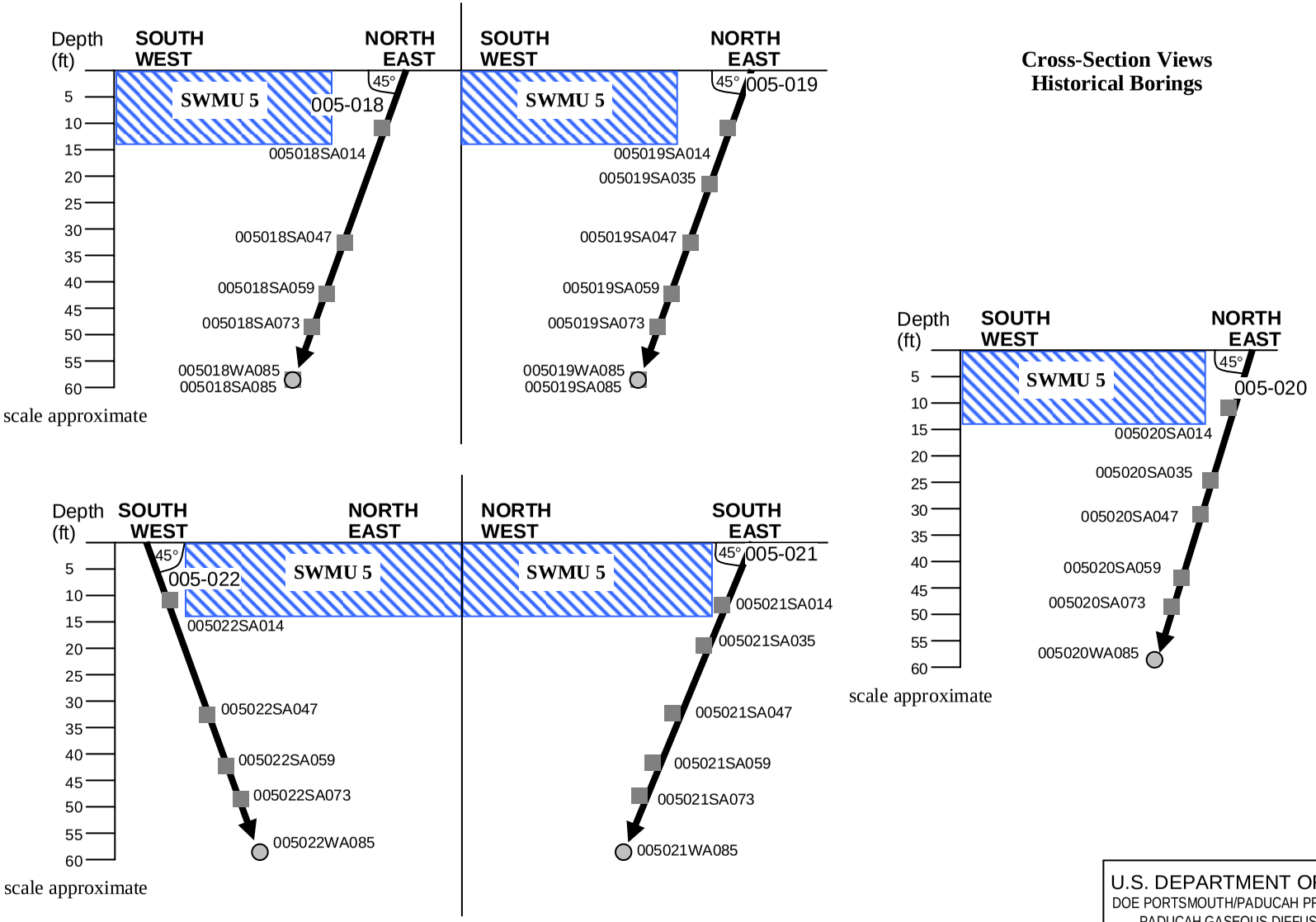
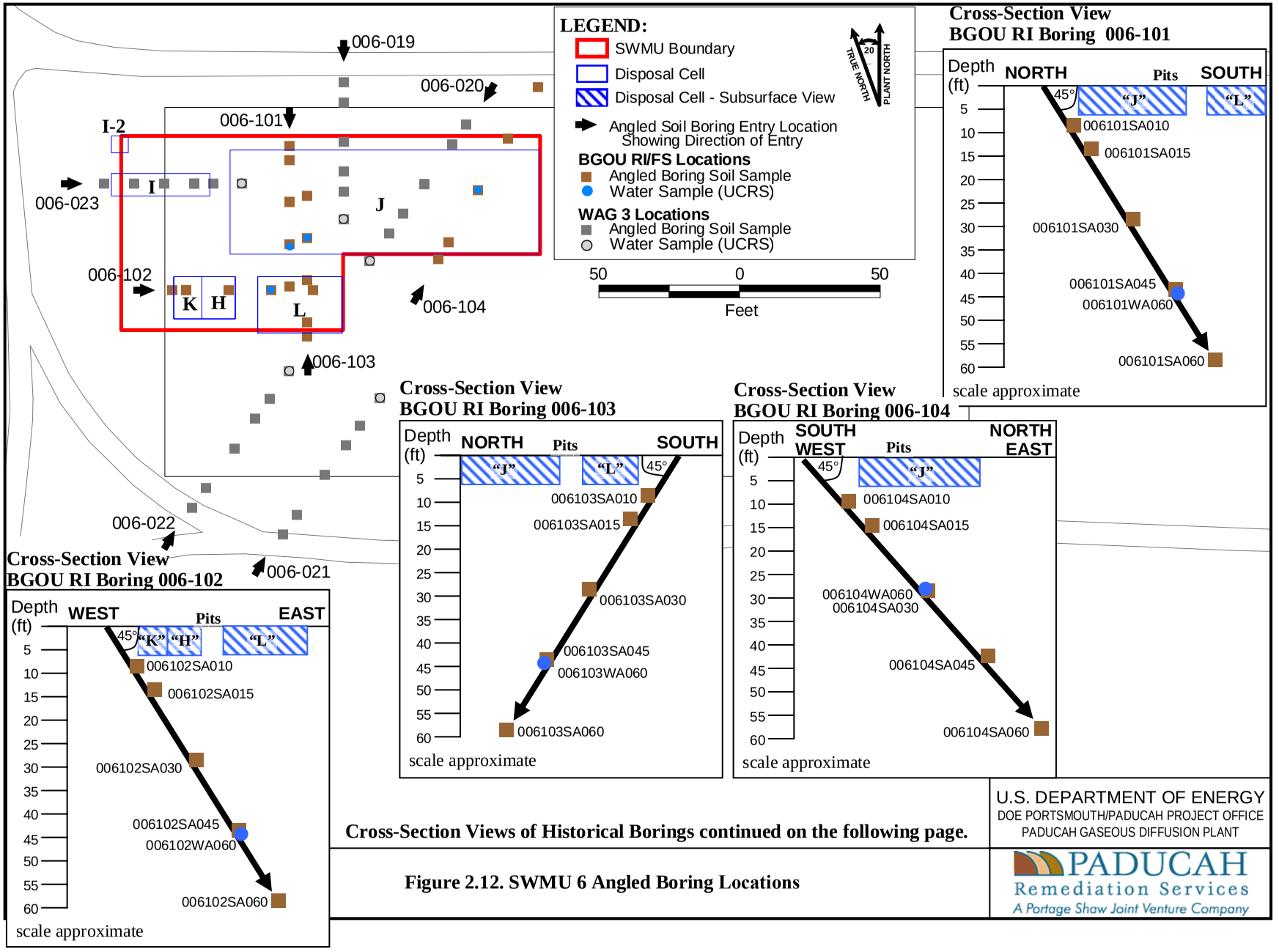


Figure 2.11. SWMU 5 Angled Boring Locations (Continued)



Cross-Section Views of Historical Borings continued on the following page.

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Figure 2.12. SWMU 6 Angled Boring Locations

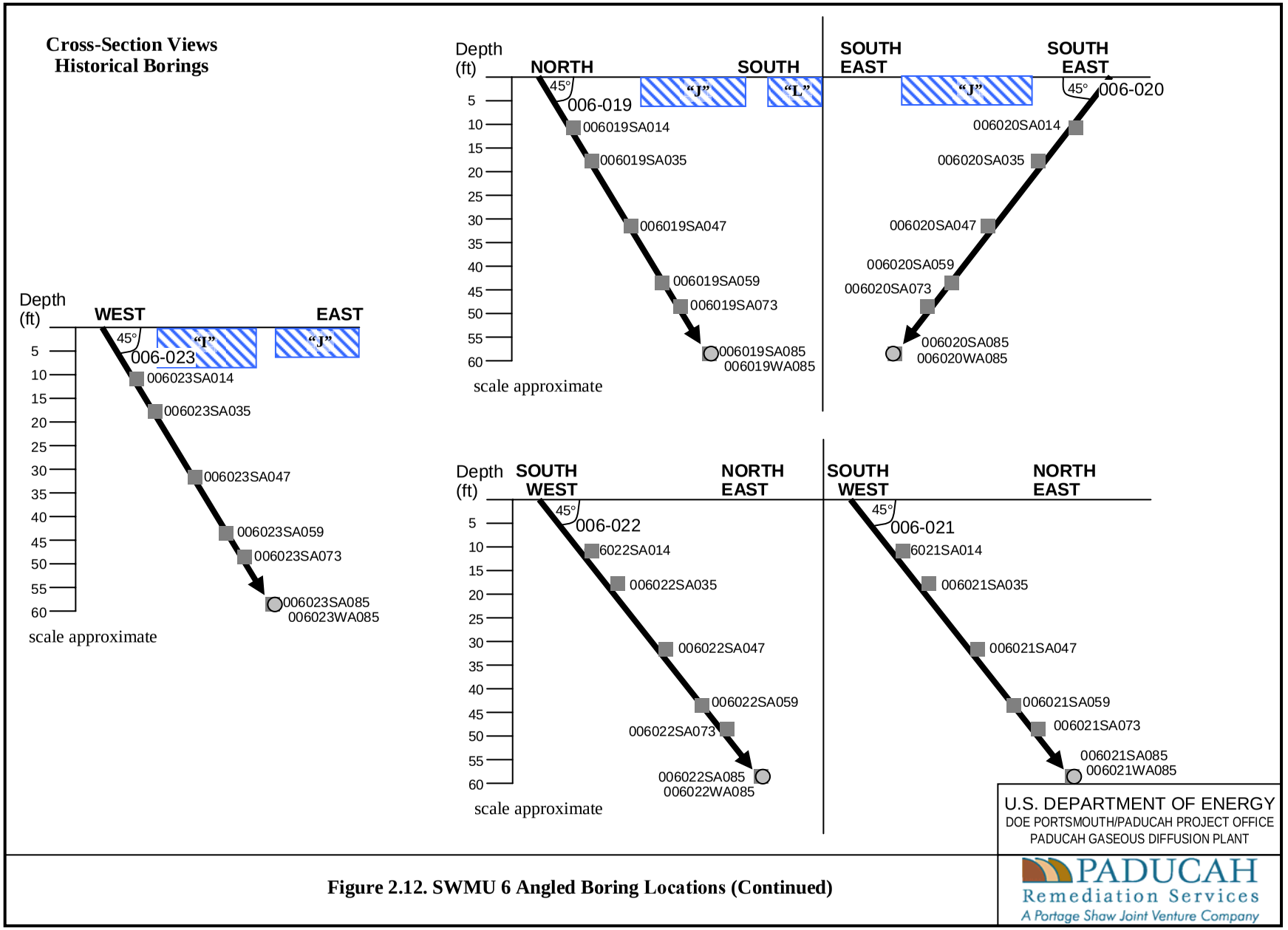

Figure 2.12. SWMU 6 Angled Boring Locations (Continued)

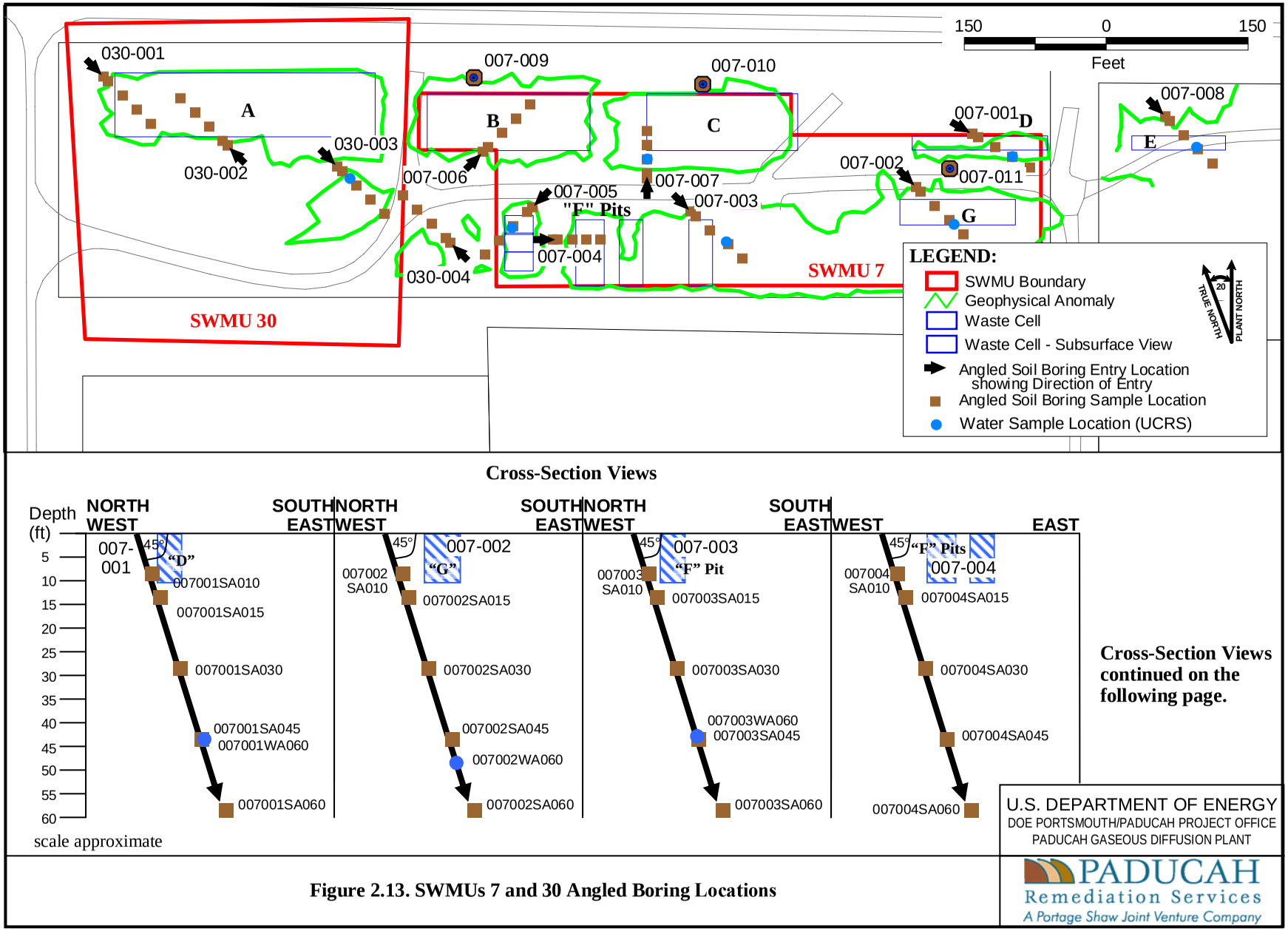

Figure 2.13. SWMUs 7 and 30 Angled Boring Locations

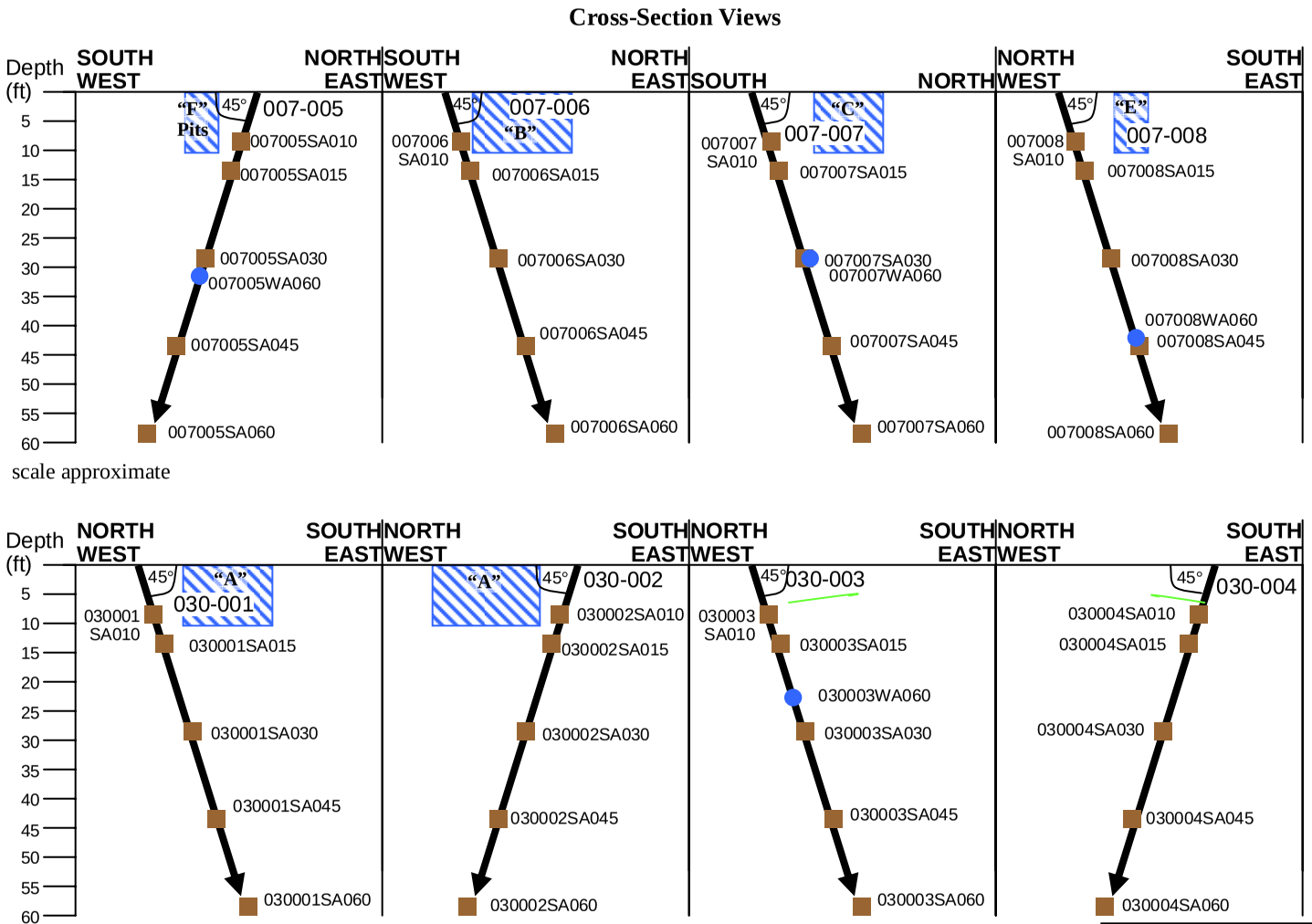

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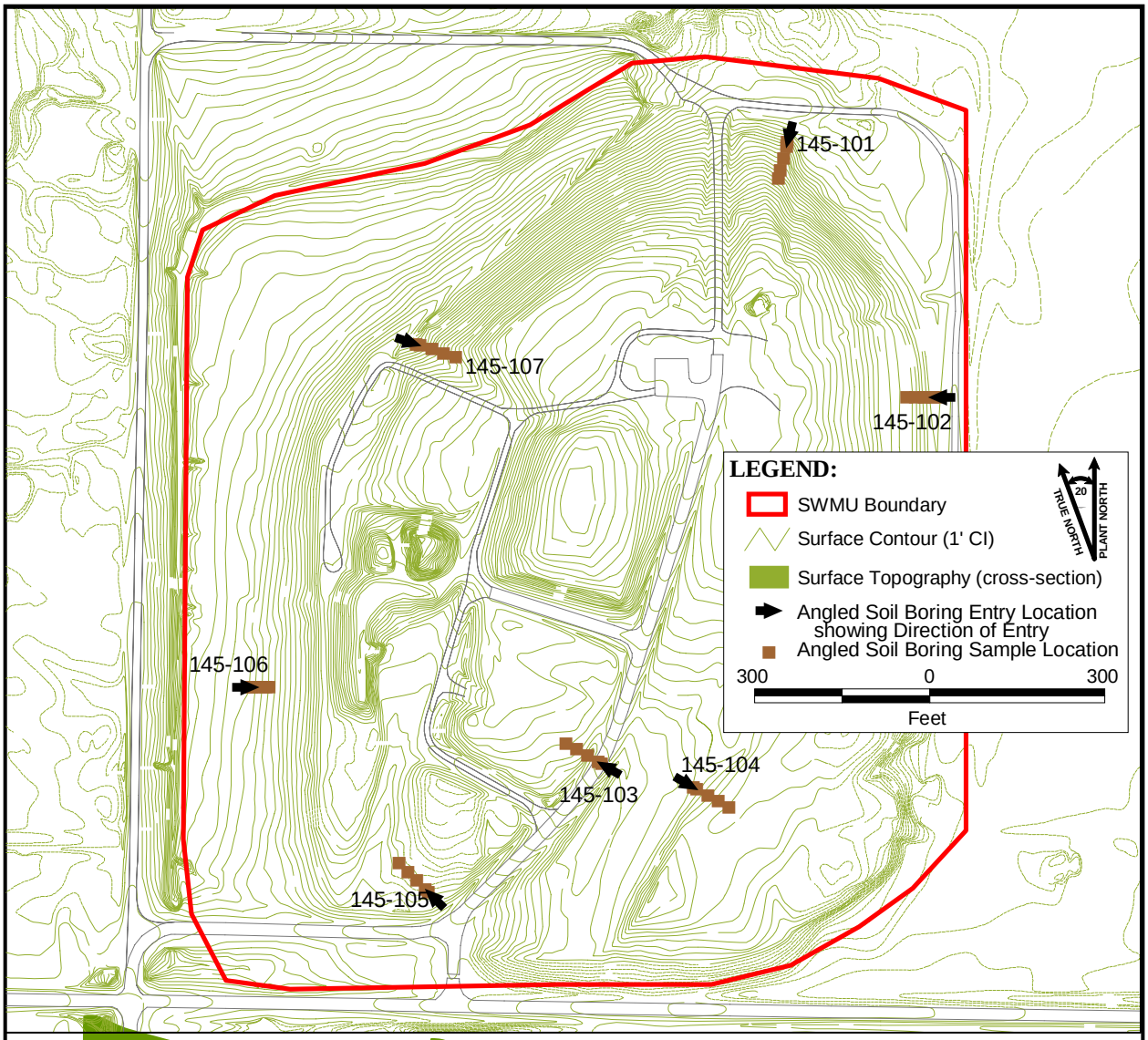
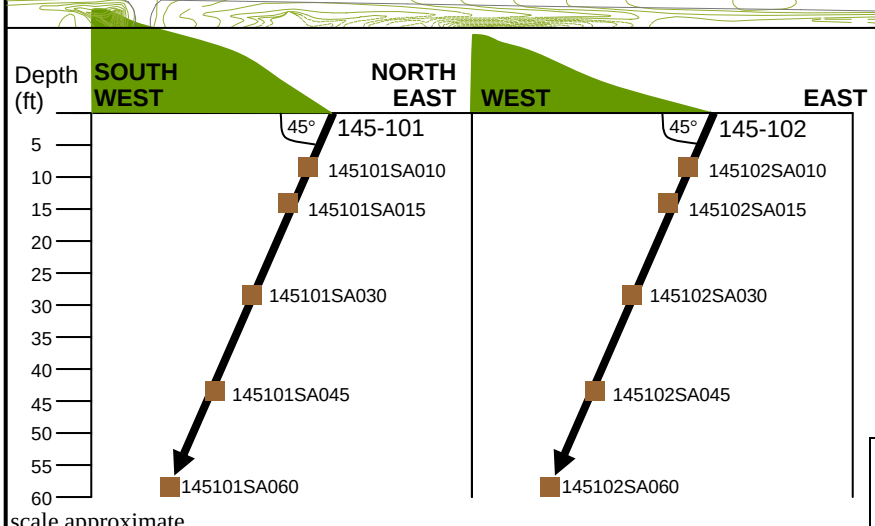
Figure 2.13. SWMUs 7 and 30 Angled Boring Locations (Continued)





Cross-Section Views continued on following page

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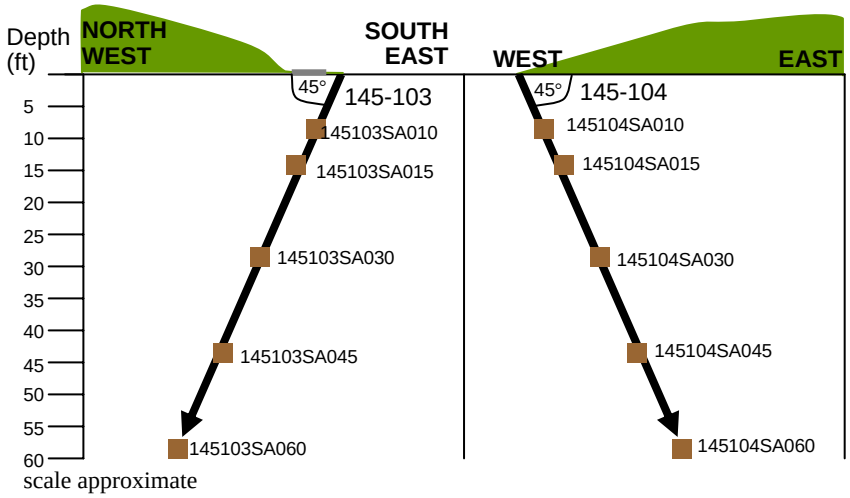
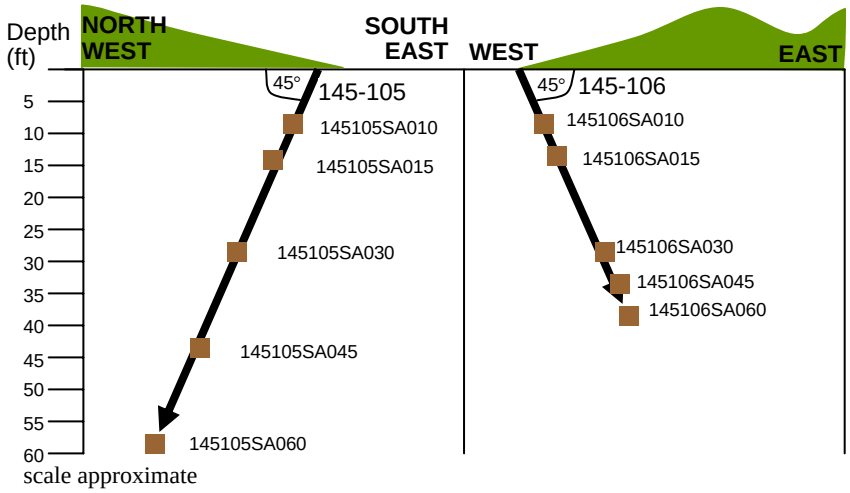
Figure 2.14. SWMU 145 Angled Boring Locations

Cross-Section Views





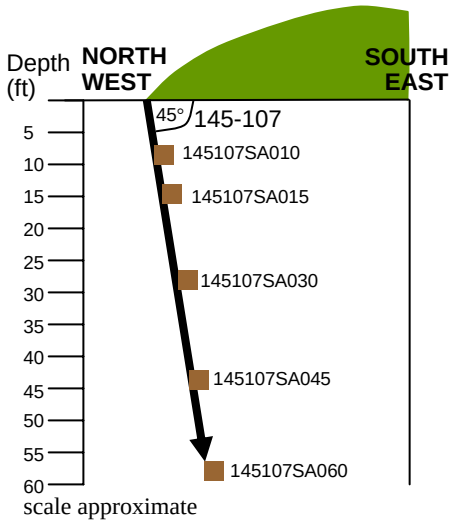


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Figure 2.14. SWMU 145 Angled Boring Locations (Continued)

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The locations of the angled soil borings and deep vertical soil borings were determined in order to avoid drilling into any burial cells. Set-back calculations, the use of geophysics, and historical process knowledge were utilized to determine pit boundaries and depths. During the drilling of Boring 104 at SWMU 145, the field effort was stopped when a safety meter detected a gas coming from the drill stem near the lower explosive limit. According to the recollection of a landfill operator who had worked at the site for several years, roofing material had been disposed of and covered with soil in the area, though not expected to be the source of the gas. Gas samples were collected and analyzed immediately by the USEC laboratory. The gas was determined to be methane. It is believed the methane was migrating from buried material in the area. The borehole was allowed to vent and sampling was completed during the next two weeks.

2.3 SOIL INVESTIGATIONS

Subsurface soil samples from the angled borings were collected generally from 7 to 11 ft, 11 to 14 ft, 28 to 32 ft, 42 to 46 ft, and 57 to 60 ft bgs (a total of five sets of soil samples per boring) in order to effectively identify probable and potential contaminant migration and exposure pathways, as directed by the BGOU Work Plan (DOE 2006a). Soil samples were not collected at or near the surface in angled borings because these borings were installed at a given distance from the burial cell, outside the influence of a burial pit. Locations of these soil samples, relative to their surface penetration, are shown in Figures 2.8 through 2.14. Table 2.1 summarizes soil sampling and analysis from the BGOU RI. Appendix C provides the soil and groundwater analytical results in a searchable database on compact disk.

In addition to the angled borings, subsurface soil samples were collected from both shallow and deep vertical borings (see Figures 2.8 through 2.14). Ten shallow borings were installed along a former drainage ditch that connected the C-404 Landfill and the NSDD. Samples from these borings were collected at the surface and from 1 to 5 ft, 5 to 10 ft, and 10 to 15 ft. Three deep vertical borings were installed within SWMU 7. Samples from these borings were collected at the surface and from 3 to 5 ft, 8 to 10 ft, 13 to 15 ft, 28 to 30 ft, 43 to 45 ft, and 58 to 60 ft.

Table 2.1. Summary of BGOU RI Soil Sampling and Analysis

Location	Activity	Number of Borings	Sampling Interval (ft bgs)[a]	Analyses per Sampling Interval	Sampling Rationale
SWMU 2	Angled Borings	2	7-11 11-14 28-32 42-46 57-60	Metals PCBs Radionuclides VOCs	Sampling intended to characterize soils beneath typical waste cell.
SWMU 3	Angled Borings	4	7-11 11-14 28-32 42-46 57-60	Metals PCBs Radionuclides VOCs	Sampling intended to characterize soils beneath waste cell.
	Shallow Vertical Borings	10	0-1 1-5 5-10 10-15	Metals PCBs Radionuclides	Sampling intended to characterize soils along former discharge ditch.

Table 2.1. Summary of BGOU RI Soil Sampling and Analysis (Continued)

Location	Activity	Number of Borings	Sampling Interval (ft bgs)[a]	Analyses per Sampling Interval	Sampling Rationale
SWMU 5	Angled Borings	3	7-11 11-14 28-32 42-46 57-60	Metals PCBs Radionuclides	Sampling intended to characterize soils beneath typical waste cell.
SWMU 6	Angled Borings	4	7-11 11-14 28-32 42-46 57-60	Metals PCBs Radionuclides	Sampling intended to characterize soils beneath typical waste cell.
SWMU 7	Angled Borings	8	7-11 11-14 28-32 42-46 57-60	Metals PCBs Radionuclides SVOCs VOCs	Sampling intended to characterize soils beneath geophysics-defined waste cells.
	Deep Vertical Borings	3	0-1 3-5 8-10 13-15 28-30 43-45 58-60	Metals PCBs Radionuclides SVOCs VOCs	Sampling intended to characterize soils downgradient of typical waste cell.
SWMU 30	Angled Borings	4	7-11 11-14 28-32 42-46 57-60	Metals PCBs Radionuclides SVOCs VOCs	Sampling intended to characterize soils beneath geophysics-defined waste cells.
SWMU 145	Angled Borings	7	7-11 11-14 28-32 42-46 57-60	Metals PCBs Radionuclides VOCs	Sampling intended to characterize soils beneath geophysics-defined waste cell boundary and areas of disturbance defined in historical photos.

[a] Sampling Interval reported in vertical depth.
PCB = polychlorinated biphenyl
SVOC = semivolatile organic compound
VOC = volatile organic compound

2.4 GROUNDWATER INVESTIGATIONS

Collection of an UCRS groundwater sample was attempted for each angled boring. Of the 32 attempts, 18 boring locations provided enough groundwater to collect a sample. Locations of these samples are shown in Figures 2.8 through 2.14.

RGA groundwater samples in addition to UCRS groundwater samples were collected from the deep vertical borings. Generally, UCRS samples were collected from 30 to 45 ft bgs; while RGA samples were collected at 10 ft intervals beginning at 60 ft bgs to the base of the RGA. RGA groundwater samples were collected only at SWMU 7 during this RI. Table 2.2 summarizes groundwater sampling and analysis from the BGOU RI.

Table 2.2. Summary of BGOU RI Groundwater Sampling and Analysis

Location	Activity	Boring	Sampling Interval (ft bgs)[a]	Analyses per Sampling Interval	Comments
SWMU 2	Angled Borings	002-001 002-002	None collected None collected	Metals PCBs, VOCs Radionuclides	Groundwater not present in sufficient quantity for samples.
SWMU 3	Angled Borings	003-001 003-002 003-003 003-004	None collected None collected 28 30	Metals PCBs Radionuclides VOCs	Groundwater present in two of four borings in sufficient quantity for samples.
SWMU 5	Angled Borings	005-101 005-102 005-103	45 40 None collected	Metals PCBs Radionuclides	Groundwater present in two of three borings in sufficient quantity for samples.
SWMU 6	Angled Borings	006-101 006-102 006-103 006-104	46 45 45 45	Metals PCBs Radionuclides	Groundwater present in all four borings in sufficient quantity for samples.
SWMU 7	Angled Borings	007-001 007-002 007-003 007-004 007-005 007-006 007-007 007-008	45 50 43 None collected 45 None collected 45 43	Metals PCBs Radionuclides SVOCs VOCs	Groundwater present in six of eight borings in sufficient quantity for samples.
	Deep Vertical Borings	007-009 007-010 007-011 	50 69[b] 80[b] 90[b] 45 60[b] 66[b] 80[b] 90[b] 100[c] 45 60[b] 70[b] 80[b] 90[b]	Metals PCBs Radionuclides SVOCs VOCs	Groundwater samples collected in UCRS and at 10 ft intervals within the RGA.
SWMU 30	Angled Borings	030-001 030-002 030-003 030-004	None collected None collected 23 None collected	Metals PCBs Radionuclides SVOCs, VOCs	Groundwater present in one of four borings in sufficient quantity for samples.
SWMU 145	Angled Borings	145-101 145-102 145-103 145-104 145-105 145-106 145-107	None collected None collected None collected None collected None collected None collected None collected	Metals PCBs Radionuclides VOCs	Groundwater not present in sufficient quantity for samples.

[a] Sampling interval reported in vertical depth, not drilled length.
[b] RGA
[c] Suspected McNairy
PCB = polychlorinated biphenyl; SVOC = semivolatile organic compound; VOC = volatile organic compound

Groundwater-productive intervals are uncommon in the UCRS. The following steps were followed to identify target sample depths and ensure the quality of the groundwater samples.

(1) Prior to drilling, identify likely depths of saturated, permeable horizons in the UCRS (typically a sand unit or soil unit containing appreciable sand content) from soil boring logs of area boreholes.

(2) As drilling proceeds, examine soil samples to determine the presence of saturated, permeable soils and monitor indications of water [i.e., drilling progress, drill cuttings (when using augers), and indications of water within the borehole (e.g., wet center rods)] to identify target horizons for UCRS groundwater samples.

(3) Upon drilling into a target groundwater-producing horizon in the UCRS, pull back the drill string several ft to expose the walls of the borehole and allow groundwater to flow into the open drill string.

(4) Measure depth to groundwater to determine the presence of water and the rate of rise of water within the drill string.

(5) If the target soils are water-productive, lower a clean sampling pump within the drill string. Position the sampling pump at least five ft above the base of the drill string, if possible, to minimize the potential of "sand locking" the pump inside the drill string.[1]

(6) Purge up to two to three gal[2] of water, as necessary, to reduce the turbidity of the discharge water.

(7) Upon completion of the purge of initial, turbid water, route the discharge water through a flow-through cell equipped with a water quality monitor and document the stability of water quality criteria over time.

(8) Upon documenting stable water quality in the discharge stream, route the discharge stream through a sampling port, isolating the water in the sample stream from the flow-through cell.

(9) Collect the water sample. Because the discharge water often remained turbid and the analytical laboratory was not able to analyze volatile organic and semivolatile organic samples containing excessive turbidity, the field crew often filled bottles for these analyses last in an attempt to collect water samples with less turbidity.

(10) After collecting the UCRS groundwater sample and recovery of the sample pump, measure the depth to water in the borehole and then resume drilling and collection of soil samples. For the three vertical boreholes at SWMU 7, continue the borehole into the RGA, collecting groundwater samples at 10 ft depth intervals.

2.5 DEVIATIONS FROM ORIGINALLY PLANNED SAMPLE LOCATIONS

To deal with uncertainties identified in the BGOU, the observational approach was used in the design of the sampling strategy for the BGOU RI/FS. Site conditions and results of the geophysical investigation

[1] Field experience revealed that sand settling out of the water column, as the soil borings were pumped, often accumulated in the base of the drill string. Later attempts to recover the pump could wedge the pump inside the drill string.

[2] For most soil borings that did not produce clear water, two to three gal of initial purge water was adequate to assess the potential of producing a better quality water sample.

necessitated movement of some of the RI borings from their originally planned location. Movement of these locations was communicated among the parties and agreed to beforehand. All boring relocations were successful from the standpoint that no unexpected materials were encountered during drilling.

2.5.1 SWMU 2

Site conditions, results of a geophysical investigation, and a historical records search necessitated moving final placement of both SWMU 2 borings.

The angled boring 002-002 was formerly proposed at the center, northern edge of the unit. The boring was moved in order to place it north of burial areas (see Figure 2.8), which reportedly contain uranium sawdust and shavings from routine C-340 operations and machining operations. Buried material in this area is expected to be representative of other waste buried at C-749 (DOE 1995b).

The angled boring 002-001 initially was proposed to be moved slightly south to avoid penetrating the abandoned electrical conduit; however, the setup location for the drilling was too close to the cylinder yard to the west of SWMU 2. Historical sampling of the waste itself is available in this area [boring location SWMU2-12 of the SWMU 2 Interim Remedial Design Investigation (DOE 1997a)]; therefore, 002-001 was moved to the southern edge of the unit, angling to the north.

2.5.2 SWMU 3

Movement of planned boring locations to their final placement varied only slightly to allow for set-back to avoid penetrating the C-404 cap or the bottom of the burial cell.

2.5.3 SWMU 5

Final locations of these borings were moved only slightly in consultation with KEEC personnel. Angled boring 005-101 was relocated to the east to split the difference between historical WAG 3 borings 005-018 and 005-019. Angled boring 005-102 was relocated to the eastern boundary from the northern boundary and angled to the west to target a specific burial pit found on engineering drawings. The angle of angled boring 005-103 was changed from southwest to due west in order to drill in a perpendicular orientation to the adjacent waste cell.

2.5.4 SWMU 6

Site conditions and results of the geophysical investigation necessitated movement of two borings as described below.

The originally planned location for Boring 006-101 was adjacent to Burial Area I, angling to the east, beneath Burial Area J. Area I is reported to contain exhaust fans contaminated with perchloric acid buried in 1966. Since perchloric acid presents a serious explosion hazard, “Danger” signs had been placed at the edges of the burial pit. In order to avoid disturbance of the acid, 006-101 was relocated to the north, angling to the south under the western third of Area J.

Boring 006-102 was adjusted southward slightly to better intersect the center of Burial Areas K, H, and L. The location of the burial areas as indicated on the engineering drawing compared favorably to the areas delineated by geophysics in the field.

2.5.5 SWMUs 7 and 30

Site conditions and results of the geophysical investigation necessitated moving final placement of several of these borings.

Boring 030-001 was impossible to complete as originally planned under the current site conditions. The ditch to the north of the planned boring location is wide and filled with water. Between the ditch and the "Pit A" is a silt fence placed as part of an interim corrective measure, preventing the drill rig from setting up in the planned location. Boring 030-001 was moved approximately 62 ft west and angled under the pit to the southeast.

Although the previous geophysical survey did not indicate buried items in the originally planned location, the current survey showed Boring 030-002 within the boundary of buried material. Boring 030-002 was moved approximately 50 ft south and 70 ft west. The revised location was adequate to provide equivalent information regarding potential contamination leaching from Pit A.

Borings 007-011 (45 ft north and 15 ft west) and 007-002 (10 ft east and 60 ft north) were moved from the originally planned location because the previous geophysical survey did not indicate the apparent large burial area, connecting the F Pit area and Pit G. When the previous geophysical survey took place, SWMU 12 (Drum Mountain) had not been removed and electromagnetic survey near the area was not possible. The new location provided equivalent information regarding potential contamination migrating from Pit G.

Boring 007-003-ASB (angled soil boring) was moved 50 ft north. The previous geophysical survey did not indicate the apparent large burial area, connecting the F Pit area and Pit G. When the previous geophysical survey took place, SWMU 12 (Drum Mountain) had not been removed and electromagnetic survey near the area was not possible. The new location provided equivalent information regarding potential contamination leaching from the F Pits.

Boring 007-005-ASB was moved 25 ft east and 80 ft north to the opposite side of the pits, allowing the boring to be closer to the geophysical anomalies.

2.5.6 SWMU 145

Sampling locations for SWMU 145 were better defined in a revision to the Work Plan (DOE 2006b) issued in November 2006. Historical aerial photographs from 1959, 1964, 1975, and 1981 were used to locate soil borings in areas that appeared to be waste disposal locations. Site conditions and results of the geophysical investigation necessitated movement of these borings' final placement only slightly.

Boring 145-101 encountered a shallower than expected RGA. (The planned samples for SWMU 145 were limited to UCRS soil and groundwater.) Adjustments were made to soil sample intervals at 145-106 and 145-107 to account for the shallow RGA at this location.

2.6 QUALITY ASSURANCE/QUALITY CONTROL

QC was monitored throughout the RI process. QC included field sampling, laboratory analysis, and data management.

2.6.1 Field QC

Field QC samples were collected to assess data quality. Appendix C provides the data from the field QC samples in a searchable database on compact disk. Table 2.3 lists the QC samples collected for each SWMU. The target frequency of collection for QC samples for the entire project was 1 in 20 for equipment rinseates, field blanks, and field duplicates. Overall, this target was met for the project. Trip blanks were collected at a frequency of one per sample cooler containing volatile organic compound (VOC) samples.

Table 2.3. Summary of BGOU RI QC Sampling

Location	QC Sample Type	Frequency of Collection[a]
SWMU 2	Equipment Rinseates	1/10
	Trip Blanks	4/10
	Field Blanks	1/10
	Field Duplicates	1/10
SWMU 3	Equipment Rinseates	3/46
	Trip Blanks	10/46
	Field Blanks	3/46
	Field Duplicates	2/46
SWMU 5	Equipment Rinseates	1/18
	Trip Blanks	N/A
	Field Blanks	1/18
	Field Duplicates	1/18
SWMU 6	Equipment Rinseates	2/24
	Trip Blanks	N/A
	Field Blanks	2/24
	Field Duplicates	2/24
SWMU 7	Equipment Rinseates	4/82
	Trip Blanks	24/82
	Field Blanks	4/82
	Field Duplicates	5/82
SWMU 30	Equipment Rinseates	1/21
	Trip Blanks	5/21
	Field Blanks	1/21
	Field Duplicates	1/21
SWMU 145	Equipment Rinseates	2/35
	Trip Blanks	10/35
	Field Blanks	2/35
	Field Duplicates	2/35
BGOU Summary	Equipment Rinseates	14/236
	Trip Blanks	53/194
	Field Blanks	14/236
	Field Duplicates	14/236

N/A = not applicable (no VOCs collected)
[a] Frequency of collection is the number of QA samples collected per number of regular samples collected.

2.6.2 Laboratory QC

The USEC Paducah laboratory performed all of the laboratory analyses of soil and groundwater samples for the BGOU RI. The laboratory was contracted through the DOE Sample Management Office (SMO) and is DOE-approved and Nuclear Regulatory Commission licensed. The USEC laboratory is a DOE approved laboratory audited annually for compliance with requirements. Approved SW-846 methods

were used for all samples, except those parameters for which other methods are necessary. The analysis followed SW-846 protocols, and Level C and Level D data packages were provided along with electronic data deliverables (EDDs). Filtered and unfiltered analyses were performed on metals and uranium isotopes. All other analyses were performed using unfiltered samples.

The following data qualifiers were used for reporting fixed-base laboratory results:

Inorganic Analysis

B	This flag is used when the analyte is found in the associated blank as well as in the sample.
U	The analyte was analyzed for, but not detected.
J	Indicates an estimated value.
E	The reported value is estimated because of the presence of interference. An explanatory note must be included under comments on the cover page (if the problem applies to all samples) or on the specific Form I (if it is an isolated problem).
M	Duplicate injection precision was not met.
N	Spiked sample recovery was not within control limits.
S	The reported value was determined by the method of standard additions (MSA).
W	Postdigestion spike for furnace atomic absorption analysis is out of control limits (85-115%), while sample absorbance is less than 50% of spike absorbance.
X	Other specific flags may be required to properly define the results.
*	Duplicate analysis was not within control limits.
+	Correlation coefficient for the MSA is less than 0.995.

Organic Analysis

U	Indicates compound was analyzed for, but not detected.
J	Indicates an estimated value. This flag is used under the following circumstances: (1) when estimating a concentration for tentatively identified compounds where a 1:1 response is assumed and (2) when the mass spectral and retention time data indicate the presence of a compound that meets the pesticide/PCB identification criteria, and the result is less than the contract-required quantitation limit, but greater than zero.
P	This flag is used for a pesticide/PCB target analyte when there is greater than 25% difference for detected concentrations between the two gas chromatograph (GC) columns.
C	This flag applies to pesticide results where the identification has been confirmed by gas chromatograph/mass spectrometer (GC/MS).
B	This flag is used when the analyte is found in the associated blank as well as in the sample.
E	This flag identifies compounds whose concentrations exceed the calibration range of the GC/MS instrument for that specific analysis.
D	This flag identifies all compounds identified in an analysis at a secondary dilution factor.
X	Other specific flags may be required to properly define the results.
Y	Indicates matrix spike (MS)/matrix spike duplicate (MSD) recovery and/or relative percent difference (RPD) failed to meet acceptance criteria.

Radionuclide Analysis

B	Method blank not statistically different from sample at 95% level of confidence.
D	Sample is statistically different from duplicate at 95% level of confidence.
L	Expected and measured value for laboratory control sample (LCS) is statistically different at 95% level of confidence.
M	Expected and measured value for MS is statistically different at 95% level of confidence.
T	Tracer recovery is < 20% or > 105%.
U	Indicates compound was analyzed for, but not detected.
X	Other specific flags may be required to properly define the results.

Precision, accuracy, and completeness objectives were presented in Table 11.3 of the BGOU RI Work Plan (DOE 2006a). An assessment of these objectives for laboratory analytical data was performed. The results of this assessment are provided in Table 2.4.

Precision refers to the level of agreement among repeated measurements of the same characteristic, usually under a given set of conditions. To determine the precision of the laboratory analysis, a routine program of replicate analyses is performed. The absolute difference between the two values calculated is referred to as the relative percent difference (RPD). Precision was determined for this RI by reviewing laboratory-applied qualifiers that pertain to laboratory duplicates (i.e., "M" and "*" for inorganic analyses, "Y" for organic analyses, and "D" for radionuclide analyses) over all analyses. QA objectives for precision given in the RI Work Plan are performance based, with RPDs that ranged from 13 to 50%. These objectives were met by the data collected during this RI.

Table 2.4. QA Assessment for Laboratory Measurements of RI Data

Parameter	Method	Matrix		Precision	Accuracy	Completeness[c]
TCL volatiles	SW-846[a] 8260	Soil	RI Data:	99%	99%	99%[d]
		Water	RI Data:	99%	99%	100%[d]
TCL semivolatiles	SW-846 8270	Soil	RI Data:	99%	99%	99%
		Water	RI Data:	100%	100%	100%
TAL metals	SW-846 6010, 6020, and 7000 series	Soil	RI Data:	95%	92%	94%[e]
		Water	RI Data:	94%	81%	97%[f]
TCL PCBs	SW-846 8082	Soil	RI Data:	97%	97%	99%
		Water	RI Data:	100%	100%	67%[g]
Gross alpha	SW-846 9310	Soil	RI Data:	100%	100%	99%
Gross beta	SW-846 9310	Soil	RI Data:	100%	100%	99%
^{234}U, ^{235}U, and ^{238}U	RL-7128[b]	Soil	RI Data:	100%	100%	99%
		Water	RI Data:	100%	100%	100%
^{99}Tc, ^{230}Th, ^{239}Pu, ^{137}Cs, and ^{237}Np	RL-7100, RL-7124, and RL-7128[b]	Soil	RI Data:	100%	100%	99%
		Water	RI Data:	96%	88%	93%

[a]EPA 1996. *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, Third Edition, SW-846, December.
[b]Laboratory-specific method, derived from DOE guidance.
[c]Completeness for groundwater samples calculated based on locations where groundwater was available for sampling.
[d]Completeness for acrolein analysis in soil samples was 45% and 77% in groundwater samples.
[e]Completeness for silver analysis in soil samples was 80%.
[f]Completeness for antimony, chromium, and nickel analyses in groundwater samples was 77%, 84%, and 87%, respectively.
[g]Completeness for PCBs in groundwater was less than the 90% objective due to ten samples being rejected by validation. Of the ten samples, eight were from SWMU 7 and two were from SWMU 6. Section 2.6.4 contains additional discussion.

TAL = Target Analyte List
TCL = Target Compound List
^{137}Cs = cesium-137
^{237}Np = neptunium-237
^{239}Pu = plutonium-239
PCB = polychlorinated biphenyl
^{99}Tc = technetium-99
^{230}Th = thorium-230
^{234}U = uranium-234
^{235}U = uranium-235
^{238}U = uranium-238

Accuracy refers to the nearness of a measurement to an accepted reference or true value. To determine the accuracy of an analytical method and/or the laboratory analysis, a periodic program of sample spiking is conducted. Accuracy for this RI was determined by reviewing laboratory-applied qualifiers that pertain to laboratory spikes over all analyses (i.e., "N" and "W" for inorganic analyses; "Y" for organic analyses;

and “B,” “M,” and “L” for radionuclide analyses). The accuracy range objective specified in the RI Work Plan was 80–100%. These objectives were met by the data collected during this RI.

Representativeness is the degree to which discrete samples accurately and precisely reflect a characteristic of a population, variations at a sampling location, or an environmental condition. Representativeness is a qualitative parameter and will be achieved through careful, informed selection of sampling sites, drilling sites, drilling depths, and analytical parameters and through the proper collection and handling of samples to avoid interference and minimize contamination and sample loss.

Completeness is a measure of the percentage of valid, viable data obtained from a measurement system compared with the amount expected under normal conditions. The goal of completeness is to generate a sufficient amount of valid data to satisfy project needs.

For this project, the completeness objective for laboratory measurements was 90%. This objective was met as intended by the RI data with the exception of PCBs in groundwater. Completeness for PCBs in groundwater was less than the 90% objective due to ten samples being rejected by validation. Of the ten samples, eight were from SWMU 7 and two were from SWMU 6. Section 2.6.4 contains additional discussion. These measurements were not used for decision calculations in this RI Report.[3]

Completeness also is a measure of samples collected during the field effort with respect to those targeted for collection in the work plan. All soil samples targeted for collection during this RI were collected with the exception of one surface soil sample at SWMU 7. Additionally, a sufficient volume of soils was not available from two intended locations for all analyses planned (metals were not analyzed from location 145-104 at 15 ft bgs and radionuclides were not analyzed from location 007-001 at 60 ft bgs). For boring 007-001, the entire sampling interval was not recovered (the sampling interval from 57 to 60 ft stated minimal sample recovered). For boring 145-104, the sample included wood fragments, which limited the amount of soil in the sample.

Groundwater sample objectives were fulfilled. The Work Plan (DOE 2006a) strategy for sampling groundwater in the UCRS was to sample water-bearing zones as they were available. Where sand and gravel zones were encountered in the UCRS that would yield sufficient water for the collection of a quality water sample, the field crew collected water samples for analysis. Of the 35 soil borings of the BGOU RI deeper than 15 ft (those targeted for groundwater sampling in the Work Plan), the RI collected UCRS groundwater samples from 18. Because the UCRS water samples only supplement the characterization of the BGOU SWMUs (the analysis of subsurface soil samples is the primary measure that supports the assessment of nature and extent and risk), the lack of UCRS water samples from all soil borings does not limit the planned assessment of the SWMUs.

For those borings that extended through the RGA, water samples were collected as scheduled in 10-ft depth increments throughout the thickness of the RGA. Table 2.5 summarizes the water samples that were collected and analyzed for the BGOU RI/FS. Of all of the water samples, the only sample to be partially collected was the UCRS sample from soil boring 006-103-ASB. This boring provided insufficient water for the collection of samples for analysis of dissolved metals and dissolved radionuclides levels.

[3] UCRS groundwater analyses of the BGOU RI soil borings are used primarily to supplement the assessment of soil analyses to identify significant sources of groundwater contamination. The BGOU RI risk assessment uses only analyses of UCRS groundwater collected from MWs within and adjacent to the SWMUs to calculate a conservative reasonable maximum risk estimate (see Attachment F2 of Appendix F). The low completion rate of UCRS groundwater PCB analyses does not limit significantly the nature and extent and risk assessments for the BGOU RI.

Table 2.5. Summary of BGOU RI Water Samples

Location	Soil Boring	Water Sample Depth Interval (ft)
UCRS Groundwater Samples		
SWMU 2	--[1]	NA[2]
SWMU 3	003-003-ASB	28-32
	003-004-ASB	28-32
SWMU 4	none planned	NA
SWMU 5	005-101-ASB	42-46
	005-102-ASB	40-41
SWMU 6	006-101-ASB	42-46
	006-102-ASB	18-19
	006-103-ASB	50-51
	006-104-ASB	42-46
SWMU 7	007-001-ASB	42-46
	007-002-ASB	50-51
	007-003-ASB	42-46
	007-005-ASB	42-46
	007-007-ASB	42-46[3]
	007-008-ASB	42-46
	007-009-VSB	45-55
	007-010-VSB	40-45 and 55-60
	007-011-VSB	40-45 and 55-60
SWMU 30	030-003-ASB	23
SWMU 145	--[1]	NA[2]
RGA Groundwater Samples		
SWMU 7	007-009-VSB	69, 80, 90[3]
	007-010-VSB	66, 80, 90, 100
	007-011-VSB	70, 80, 90

[1] None of the soil borings at this SWMU yielded UCRS water samples.
[2] No water sample was collected.
[3] A duplicate water sample was collected from this depth interval.

Comparability is the extent to which comparisons among different measurements of the same quantity or quality will yield valid conclusions. Comparability will be assessed in terms of field standard operating procedures (SOPs), analytical methods, QC, and data reporting. In addition, data validation assesses the processes employed by the laboratory that affect data comparability.

Historical data also was evaluated for precision and accuracy as described previously. This assessment was performed over all measurements for the projects associated with the BGOU SWMUs. Multiple laboratories analyzed samples for these projects. The comparison for the precision and accuracy of historical results encompassed the entire historical data set and did not differentiate between projects or laboratories. A summary of this assessment is provided in Table 2.6.

Table 2.6. Assessment for Laboratory Measurements of Historical Data Used in RI

Parameter	Method	Matrix	Precision[a]	Accuracy[a]
TCL volatiles	SW-846 8260	Soil	94%	94%
		Water	99%	99%
TCL semivolatiles	SW-846 8270	Soil	99%	99%
		Water	99%	99%
TAL metals	SW-846 6010, 6020, and 7000 series	Soil	81%	48%
		Water	99%	83%
TCL PCBs	SW-846 8082	Soil	100%	100%
		Water	100%	100%
^{234}U, ^{235}U, and ^{238}U	Various methods	Soil	100%	100%
		Water	100%	100%
^{99}Tc, ^{230}Th, ^{239}Pu, ^{137}Cs, and ^{237}Np	Various methods	Soil	99%	100%
		Water	99%	99%

[a] Values indicated are for the percent of valid values.
^{137}Cs = cesium-137
^{237}Np = neptunium-237
^{239}Pu = plutonium-239
^{99}Tc = technetium-99
^{230}Th = thorium-230
^{234}U = uranium-234
^{235}U = uranium-235
^{238}U = uranium-238

All historical analyses were within the criteria established by the RI Work Plan for RI data, with the exception of accuracy of metals analyses in soil.

2.6.3 Surveillances

A surveillance was completed during fieldwork to verify adherence to project specific plans and procedures. Surveillance results are documented and filed in the Document Management Center. The DOE SMO conducts routine laboratory surveillances of the laboratory through the Consolidated Audit Program. These surveillances of the BGOU laboratory were conducted in February 2006 and February 2007.

2.6.4 Data Management

The BGOU Project Environmental Measurements System (PEMS) was used to manage field-generated data; import laboratory-generated data; add data qualifiers based on data verification, validation, and assessment; and transfer data to the Paducah Oak Ridge Environmental Information System (Paducah OREIS). PEMS included a tracking system to identify, track, and monitor each sample and associated data from point of collection through final data reporting. The system included field measurements, chain-of-custody information, and a tracking system for tracking hard-copy data packages and EDDs. PEMS also included information for field planning and data evaluation.

All data packages and EDDs received from the laboratory were tracked, reviewed, and maintained in a secure environment. When first received, data packages were assigned a document control number and then logged into a tracking system. The following information was tracked: sample delivery group numbers, date received, document control number, number of samples, sample analyses, receipt of EDDs, and comments.

The data verification processes for laboratory data were implemented for both hard-copy data and EDDs. The data packages were reviewed to confirm that all samples had been analyzed for the requested parameters. Discrepancies were reported to the laboratory and the data validators. As part of a series of

internal integrity checks within PEMS, a check was run to identify which of the requested samples and analyses were not received in an EDD. Hard copy data packages were checked to confirm agreement with the associated EDD. Integrity checks in PEMS also were used to check the list of compounds generated by the laboratory to confirm that data were provided for all requested analytes. Discrepancies were reported to the laboratories for responses and/or correction and to the data validators.

Data verification within PEMS included standardization of analytical methods, chemical names and units, as well as checks for holding time violations and detections above background values.

PEMS system requirements included backups, security, change control, and interfacing with other data management systems. PEMS was housed on the Paducah network. System backups were performed nightly following standard Paducah network protocol. Updates made to the files were copied to a computer backup tape each night, and an entire backup was performed each week.

Security of PEMS and data used for the data management effort was considered essential to the success of the project. The security protocol followed by the data management team was consistent with that of the Paducah network. Access to the network is password-protected. Access to PEMS was limited, on an as-needed basis, to the data management personnel. Read-write, graded access to PEMS was limited to the data management team, which consisted of the PEMS Coordinator and the supporting data entry staff. The data management staff assisted other project members with data needs from PEMS by running requested queries.

A large volume of data was generated during the BGOU RI. To confirm that the data set could be used in the decision making process, the RI team performed various checks and reviews during and after the fieldwork to maintain data consistency and identify problem areas. These checks and reviews included electronic verification and manual assessments by the RI team, as well as independent validation of fixed-base laboratory data. Approximately 36,000 records were reviewed during the BGOU RI data assessment.

Data validation is a process performed for a data set by a qualified individual independent from sampling, laboratory, project management, and other decision making personnel for the project. Data validation is performed in accordance with EPA guidance. In the data validation process, the laboratory adherence to analytical method requirements is evaluated. Portage Environmental, Inc., validated data collected for this RI at a frequency of 100%.

As part of the data review process, findings were qualified as necessary to reflect data validation results. The following qualifiers were assigned by the data validators:

U Analyte or compound considered not detected above the reported detection limit.
J Analyte or compound identified; the associated numerical value is approximated.
UJ Analyte or compound not detected above the reported detection limit, and the reported detection limit is approximated due to quality deficiency.
R Result is not usable for its intended purpose, so data are of “information only” quality and should be supplemented with additional data for decision-making.
= Data were validated; however, no qualifier was added.

The majority of the data rejected by validation was acrolein analyses in soil (101 of the 177 samples collected) due to initial and continuing calibration relative response factors less than 0.05. Also rejected by validation in soil were silver and vanadium analyses (46 and 10 of 216 samples, respectively). These analyses were rejected due to the interference check sample, the MS and/or MSD, lab control sample, and post digestion spike recoveries being below the lower control limit and the MS/MSD pair exceeding the RPD limit.

The risk assessment does not identify either acrolein or silver as a chemical of potential concern (COPC) for the BGOU RI (nor have they been recognized commonly as site-related contaminants); thus, the rejection of these sample results likely has little importance. In contrast, vanadium is a COPC at several BGOU SWMUs. All soil samples with rejected vanadium analyses were collected from SWMU 145 (Figure 2.15). A significant percentage of the vanadium analyses of subsurface soils at SWMU 145 was rejected (10 of 34). Although the risk assessment does not identify vanadium as a COPC for SWMU 145, some uncertainty remains. There are 576 analyses of vanadium (non-rejected) among the historical data and RI data for the BGOU SWMUs. Comparison of these data with PGDP background values (37 mg/kg for subsurface soil and 38 mg/kg for surface soil) demonstrates that the vanadium is naturally occurring; 94% of the vanadium analyses are equal or less to the PGDP background values. Since most vanadium analyses are less than background, and vanadium exceedances were not concentrated in one area, but detected at five separate SWMUs, the rejected data should have little impact on remedial decisions to be made for SWMU 145.

Analyses of groundwater samples resulted in the following number of rejections: 7 of 26 acrolein samples; 7 antimony results, 5 chromium results, 1 mercury result, and 4 nickel results of 31 samples; 2 of 31 technetium-99 samples; and 11 of 31 PCB (total) and congeners samples. Acrolein was rejected because initial and continuing calibration relative response factors were <0.05. Metals were rejected for recoveries being below the lower control limits on one or more of the following controls: continuing calibration verification, interference check sample, lab control sample, the MS and/or MSD, and/or post digestion spike. Additionally, in some cases, the MS/MSD pair exceeded the RPD limit. Technetium-99 was rejected for unacceptable laboratory control sample bias, significant difference between the sample and the duplicate, and the MS and/or MSD recovery being below the lower control limit. PCBs were rejected because the decachlorobyphenyl surrogate was recovered at lower than acceptable QC limits and the results were nondetect; however, the tetrachloro-m-xylene surrogate also was used and recovered within acceptable QC limits.

The presence of the metals antimony, chromium, mercury, and nickel largely are naturally occurring in the PGDP groundwater. Thus, remedial decisions for the BGOU SWMUs should not be impacted by the rejected metals analyses. Because modeling results using soil data, and not UCRS groundwater, were used to assess risk, the rejected metals analyses have no impact in the assessment of leachability for metals in soils related to the SWMUs.

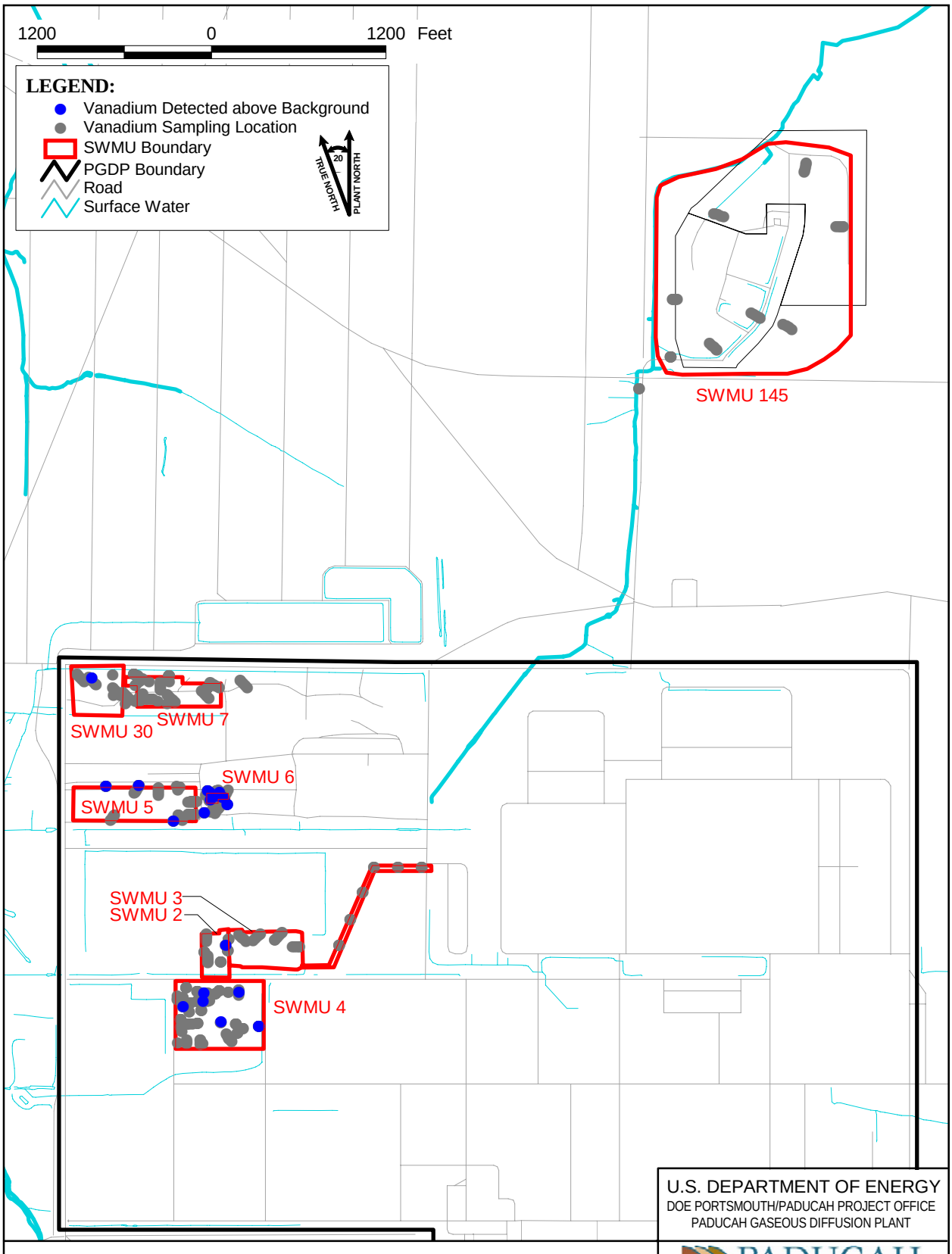

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Figure 2.15. Vanadium Detected Above Background in Subsurface Soils

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3. PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This chapter presents the physical and ecological characteristics of PGDP, in general, and of the BGOU SWMUs, in particular, that bear on contaminant release and migration. The discussion focuses from region- and PGDP-wide characteristics to SWMU-specific characteristics in sufficient detail to support subsequent evaluations of the nature and extent and the fate and transport of contaminants exiting the SWMUs and entering the external environment.

Numerous investigations detail physical characteristics of PGDP that are pertinent to the BGOU. In addition to the BGOU SWMU investigations identified in Table 1.2, the primary references include the following:

- *Results of the Site Investigation, Phase I, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (CH2M HILL 1991)
- *Results of the Site Investigation, Phase II, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (CH2M HILL 1992)
- *Report of the Paducah Gaseous Diffusion Plant Groundwater Investigation Phase III* (Clausen *et al.* 1992)
- *Environmental Investigations at the Paducah Gaseous Diffusion Plant, and Surrounding Area, McCracken County, Kentucky* (COE 1994)
- *Groundwater Monitoring Plan for the C-746-S Residential Landfill, Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (BJC 2001b)

This RI field effort focused on collection and analysis of soil and groundwater samples to address deficiencies in the existing characterization of the nature and extent of contamination. These field activities yielded additional analyses of the subsurface soils and groundwater that are incorporated into the SWMU-specific discussions. Other than the area of the historical ditch that routed effluent from SWMU 3 to the NSDD and the vertical borehole locations of SWMU 7, the BGOU RI did not include additional characterization of surface soils (see Section 1.2.1).

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 1.1). The PGDP industrial area occupies 748 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). TVA's Shawnee Steam Plant borders the DOE site to the northeast, between the plant 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, Illinois, 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 to 390 ft amsl within the PGDP plant boundary, where most of the BGOU SWMUs are located, and

from 360 to 410 ft at SWMU 145. 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 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,[1] 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).

Heavy rainfall associated with thunderstorms or low-pressure systems occurs occasionally at PGDP. Table 3.1 presents the predicted storm recurrence intervals for PGDP (Hershfield 1963; Johnson *et al.* 1993; DOE 1997a).

Table 3.1. Precipitation as a Function of Recurrence Interval and Storm Duration for the Site

Recurrence Interval (years)	Storm Duration (hours)						
	0.5	1	2	3	6	12	24
	Precipitation (inches)						
1	1.08	1.30	1.66	1.85	2.23	2.65	3.06
2	1.26	1.56	1.91	2.14	2.61	3.08	3.53
5	1.55	1.98	2.38	2.67	3.20	3.69	4.38
10	1.80	2.23	2.75	3.02	3.66	4.33	4.97
25	1.99	2.57	3.13	3.44	4.18	4.83	5.71
50	2.23	2.83	3.46	3.83	4.62	5.53	6.42
100	2.45	3.13	3.83	4.24	5.02	5.97	6.88
10,000*	3.80	4.94	5.99	6.59	7.85	9.32	10.85

* Extrapolated values calculated using least-squares methodology

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 situated 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

[1] For the recent five-year period June 2002 through May 2007, average monthly precipitation was slightly less (3.90 inches), ranging from 3.25 inches in October (monthly average low) to 4.94 inches in September (monthly average high).

channel. A U. S. Geological Survey (USGS) gaging station at Metropolis, Illinois (USGS 03611500), monitors the Ohio River stage near PGDP. River stage typically varies between 290 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, Illinois (February 2, 1937) was 343 ft.]

The plant overlies the divide between Little Bayou and 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 process effluents or surface water runoff from PGDP. Networks of ditches discharge effluent and surface water runoff from PGDP to the creeks. 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. 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 Steam Plant; and Metropolis Lake, located east of the Shawnee Steam 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. Section 3.9 presents the shallow geology specific to each of the BGOU SWMUs.

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 to 340 ft.

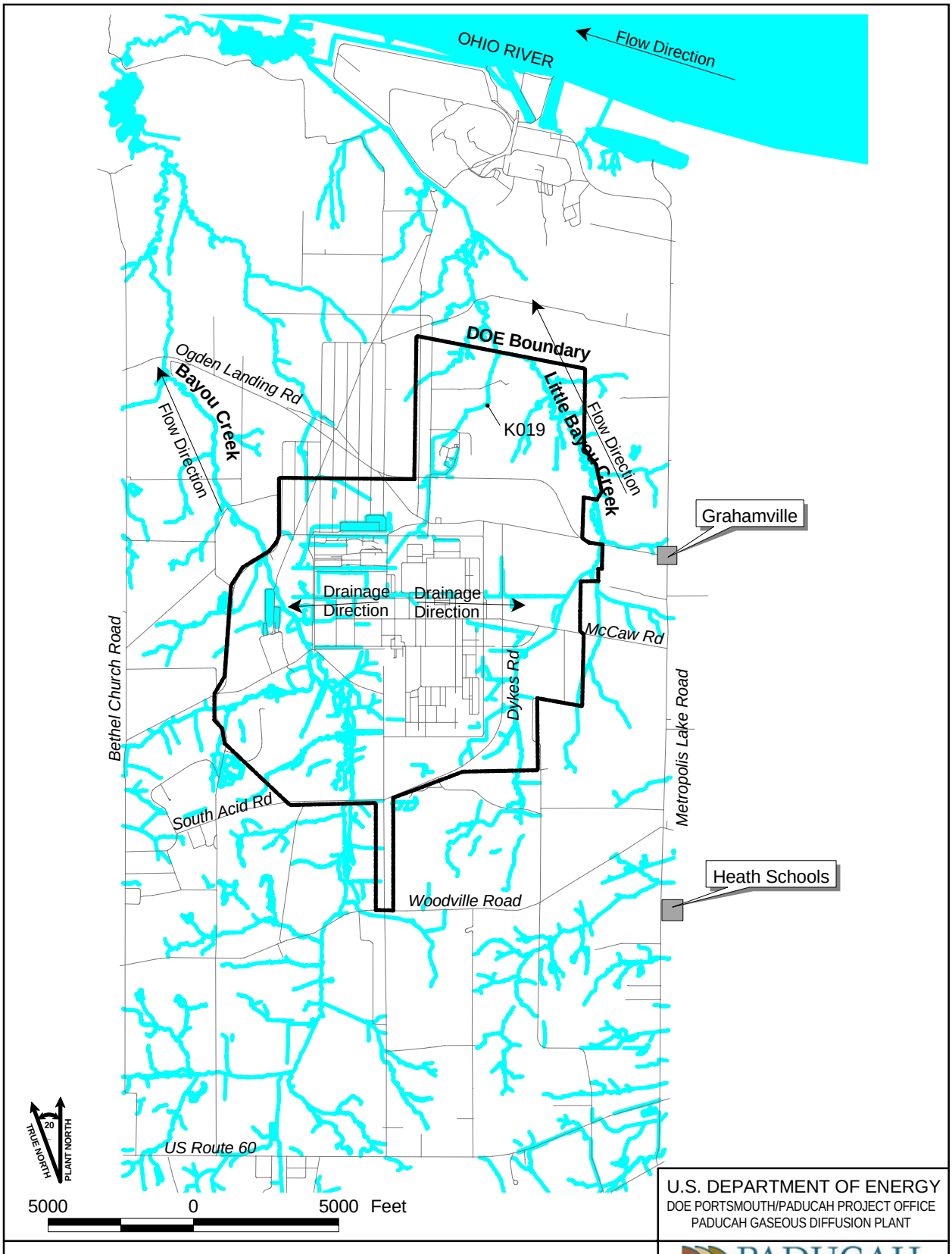

Figure 3.1 Surface Water Features in the Vicinity of the DOE Site

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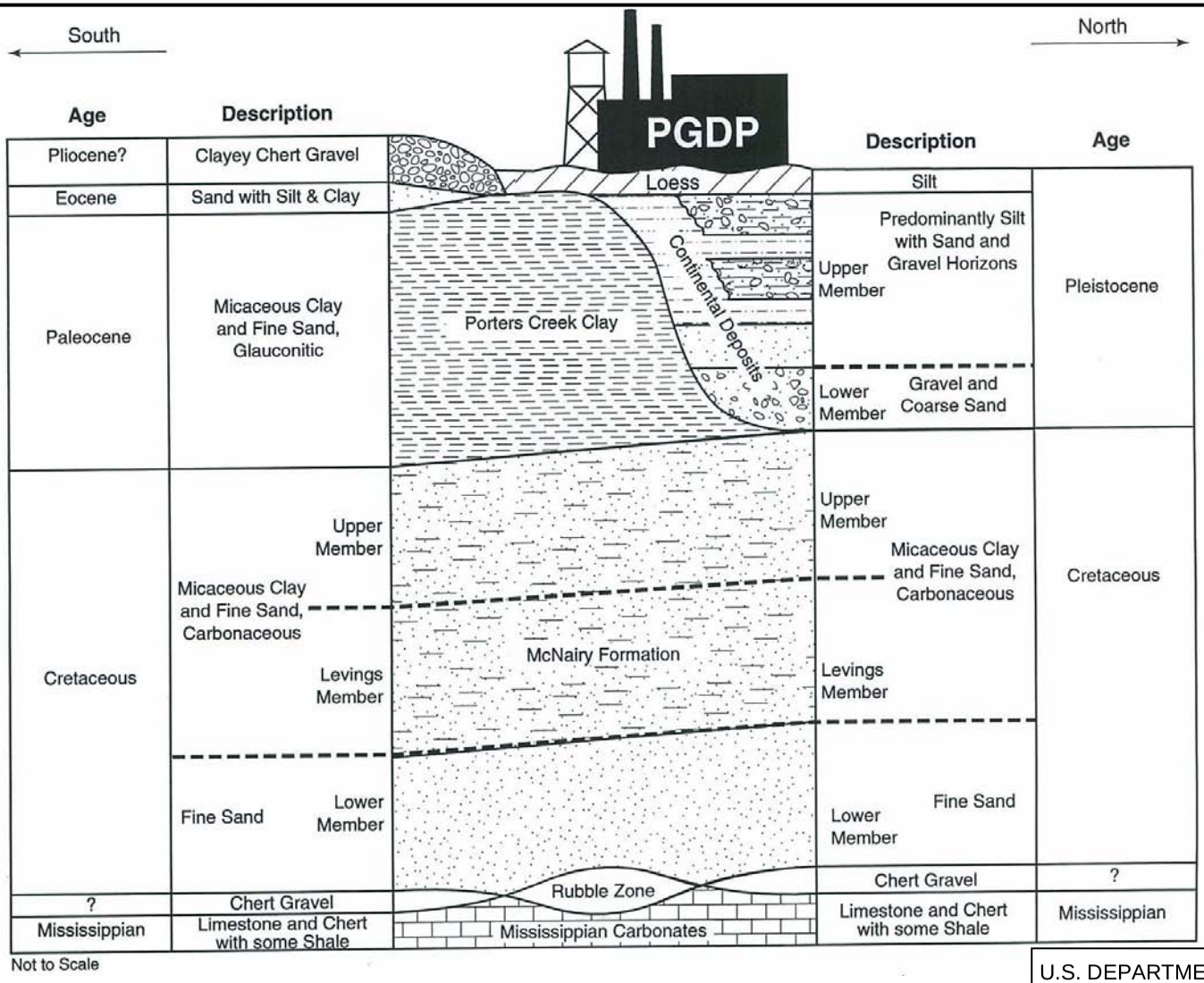

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Figure 3.2. PGDP Stratigraphic Sections

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.

3.4.5 Eocene Sands

Eocene sands occur south of PGDP 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.

3.4.6 Continental Deposits

Continental sediments [Pliocene(?)[2] 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 to 30 ft, occurring in the southern portion of the DOE site 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 to 345 ft amsl in the southeastern and eastern portions of the DOE site. The thickness of this unit typically ranges from 15 to 20 ft.

[2] A question mark indicates uncertain age.

- 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 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 is a Pleistocene age, fine-grained clastics facies that commonly overlies the Lower Continental Deposits. This unit ranges in thickness from 15 to 55 ft. 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 2003; 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 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 1998c). It should be noted that soils within the industrial area of PGDP 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.

The soils in the vicinity of PGDP tend to have a low buffering capacity, with a pH ranging from 4.5 to 5.5. Measurements of the cation exchange capacity of site soils range from 8.92 to 69.8 milliequivalents per liter (DOE 1999c). Under background conditions, the cation exchange capacity is sufficient to bind metals in the soils; however, acidic leachate will significantly increase metal solubility and mobility. The potential for acidic leachate at each SWMU is uncertain due to the lack of disposal records. SWMUs with the greatest potential for acidic leachate are SWMU 6 (exhaust fans with perchloric acid) and SWMU 4 (poor records of chemicals buried). There were no indications of acidic leachate or mobilized contaminants found at SWMU 6 during this RI. On the other hand, wastes that went into SWMU 3 were neutralized at C-400 prior to disposal and should present a low potential for generation of acidic leachate (leachate samples from SWMU 3, from 2003 to 2008, have a pH between 8.0 to 8.5).

3.6 HYDROGEOLOGY

The significant geologic units relative to shallow groundwater flow at PGDP include the Terrace Gravel and Porters Creek Clay (south sector 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. 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 PGDP. A shallow water table flow system is developed in the Terrace Gravel, where it overlies the Porters Creek Clay south of PGDP. 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 PGDP, 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 loosing reaches. Figure 3.3 presents hydraulic potential trends for the Terrace Gravel flow system.

(2) 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 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.

Direct measurements of the UCRS water table elevation are available only for the south-central PGDP industrial area, where water levels commonly occur in the screen interval of the wells, and the location of two source unit investigations (the SWMU 2 Interim Remedial Design Investigation and the SWMUs 7 and 30 RI) in the west PGDP industrial area. All other well measurements, where water levels occur above the well screen interval, provide lower bounds to the elevation of the water table. Figure 3.5 illustrates the general features of the UCRS water table for the PGDP industrial area (DOE 1997b). While Figure 3.5 shows data from November and December 1995, hydrographs of UCRS monitoring wells on-site indicate fluctuations of only a few ft over the past 10 years; therefore, this figure still provides an adequate representation of the UCRS water table. The main features of the water table are a broad trough in the northeast and central areas, a linear discharge area associated with a ditch in the northwest, and a lateral hydraulic gradient toward Bayou Creek on

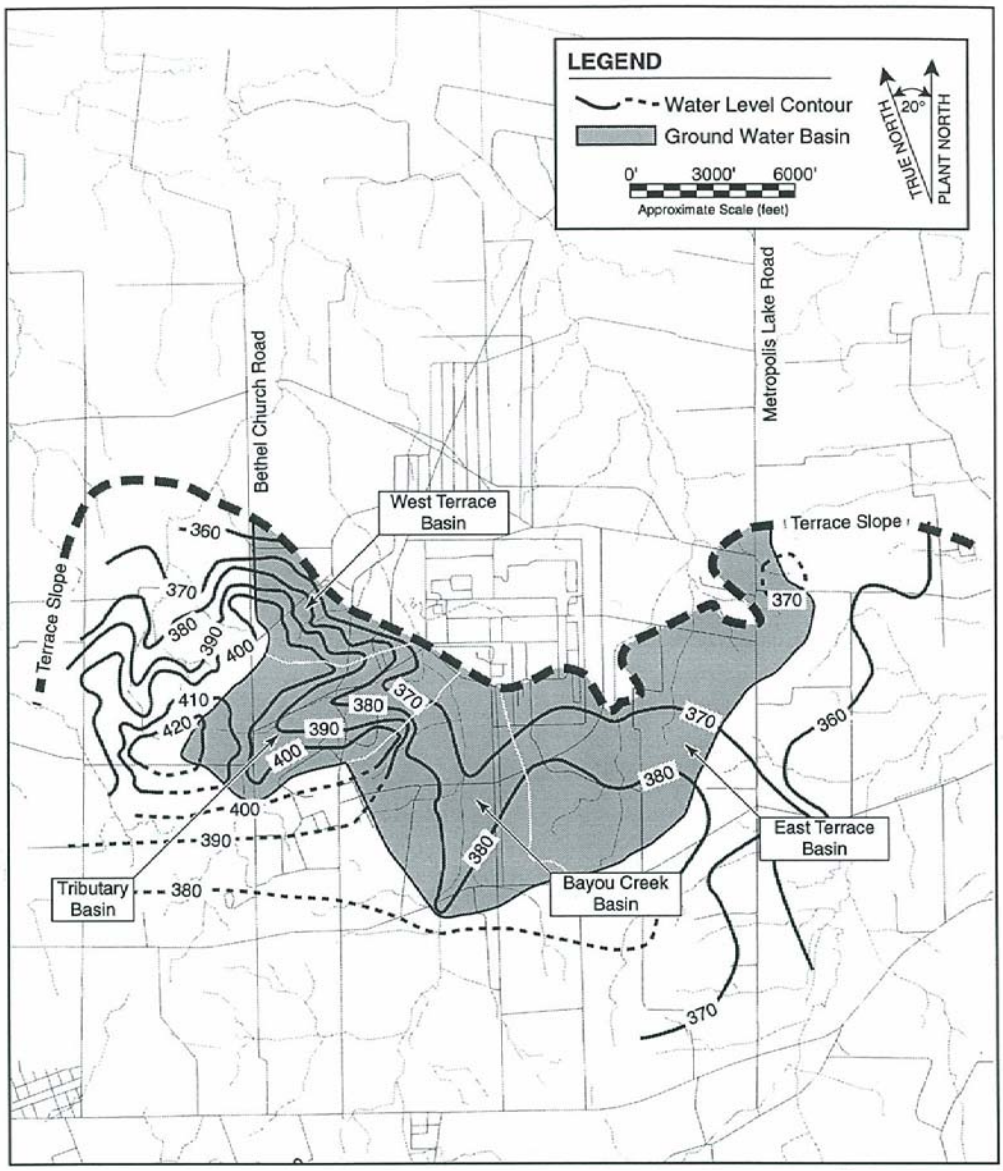

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Figure 3.3. Water Table Trends in the Terrace Deposits South of the PGDP

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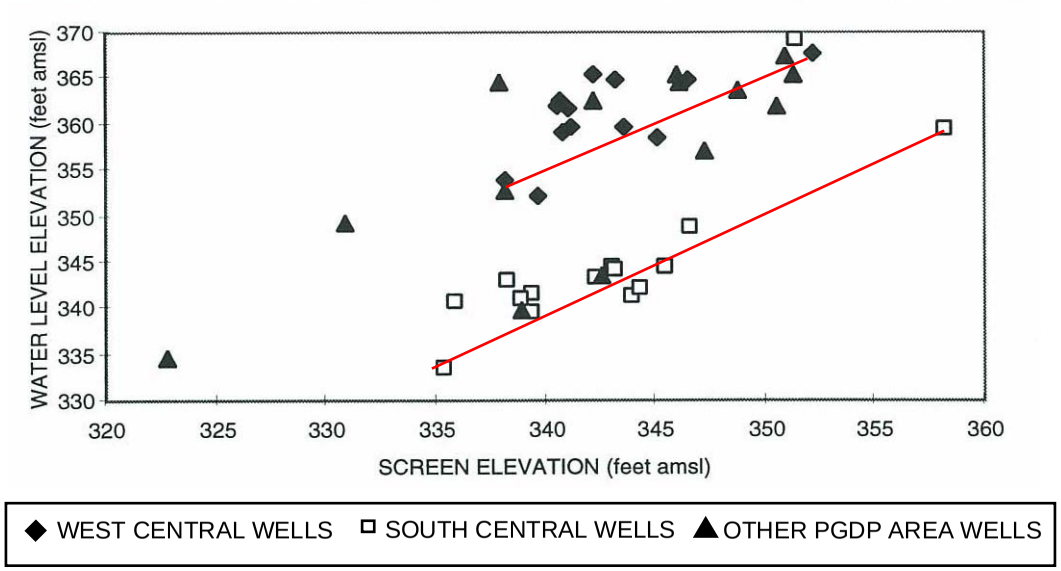

Figure 3.4. Plot of Water Level Versus Well Screen for Upper Continental Recharge System Wells

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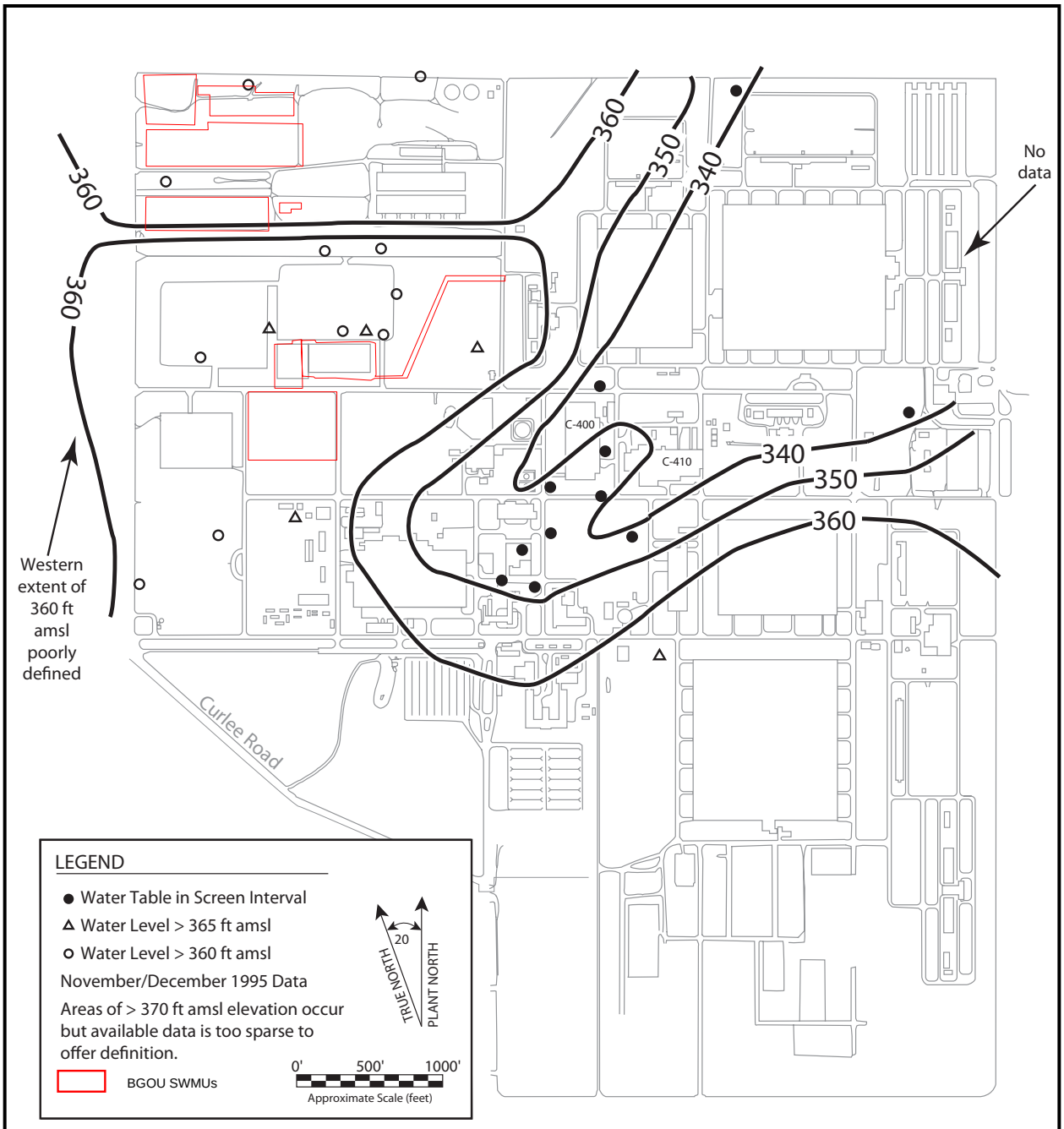

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Figure 3.5. Conceptual Water Table for PGDP

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the west side. In general, the water table is less than 20 ft deep in the western half of PGDP and as much as 40 ft deep in the northeastern corner.

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 their 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 1ft) and difficult to measure.

(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 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. Antrhopogenic 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.

(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 1996a).]

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.

3.6.1 Hydrogeologic Units

Five hydrogeologic units (HUs) are commonly used to discuss the shallow groundwater flow system beneath the DOE site and the contiguous lands to the north (Figure 3.6). In descending order, the HUs are described below:

- 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 has been based on agriculture, although there has been increased industrial development in recent years. PGDP's operations contractor, USEC, employs approximately 1,400 people, while the TVA Shawnee Steam Plant employs an additional 260 people. According to the 2000 U.S. Census, the total population within the 32 counties that lie within a 50-mile radius of PGDP is approximately 731,500; and approximately 88,500 people live within the three counties that contain the 10 mile radius of the plant (Massac County, Illinois and Ballard and McCracken Counties, Kentucky). The estimated population of Paducah, Kentucky, (2006) is approximately 25,600. Metropolis, Illinois, has an estimated population (2006) of approximately 6,400 (U.S Census Bureau 2007).

In addition to the residential population surrounding the plant, WKWMA draws thousands of visitors each year for recreational purposes. Visitors primarily use the area for hunting and fishing, but other activities include horseback riding, hiking, and bird watching. An estimated 5,000 fishermen visit the area each year.

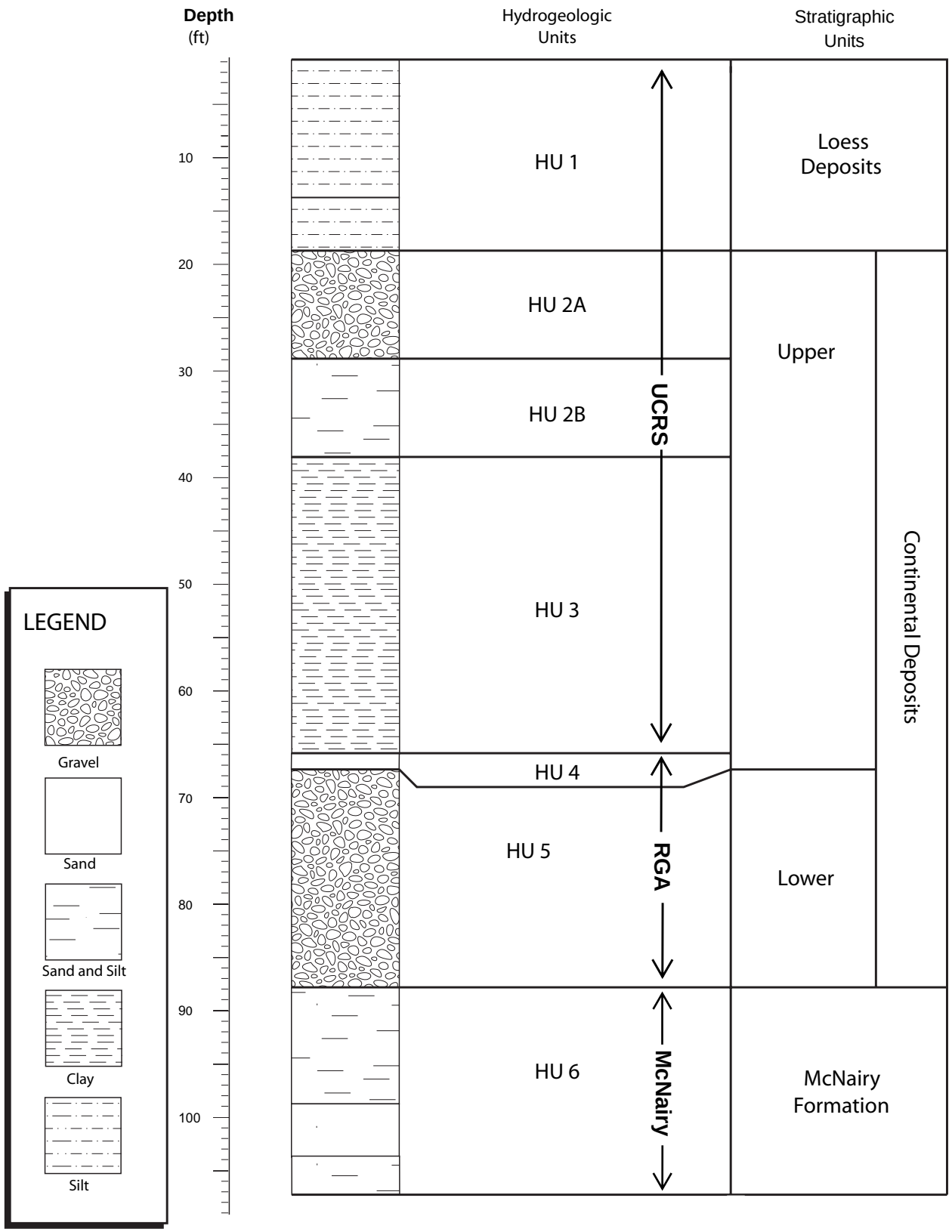

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Figure 3.6. Example Stratigraphic and Hydrogeologic Units

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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, bluejay, 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).

3.8.2 Aquatic Systems

The aquatic communities in and around the PGDP area that could be impacted by plant discharges include two perennial streams (Bayou Creek and Little Bayou Creek), the NSDD (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 smaller drainage areas. The dominant taxa in all surface waters include several species of sunfish, especially bluegill and green sunfish, as well as 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 (COE 1994) found that much of the built-up portions of the plant lie outside the 100- and 500-year floodplains of these streams. 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 National Oceanic and Atmospheric Administration's (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.

3.9 BGOU PHYSICAL CHARACTERISTICS

The following sections present the settings and physical characteristics of the BGOU SWMUs that govern contaminant migration.

3.9.1 BGOU Surface Features

The PGDP facility generally consists of three land uses, (1) areas of permanent structures and paved roads that are engineered to promote drainage, (2) UF_6 cylinder storage yards and scarp yards, and (3) former burial grounds and aboveground landfills. All of the SWMUs for the BGOU are former burial grounds or aboveground landfills. Drainage ditches that discharge into KPDES outfalls and then to Bayou Creek west of the plant skirt all of the BGOU SWMUs, except SWMU 145 (Figure 3.7). Runoff from SWMU 145 flows through the NSDD to Little Bayou Creek.

SWMU 2 is a uranium burial ground located immediately west of SWMU 3, in the west-central portion of the plant (Figure 1.4). Graveled storage yards bound SWMU 2, to the north and west, respectively. The main drainage ditch to KPDES Outfall 015 passes between SWMU 2 and Virginia Avenue, to the south. SWMU 2 is grass covered. The land surface at SWMU 2 is relatively flat (with a slight mound on the east side); surface elevations range from 370 to 375 ft amsl. PGDP maintains SWMU 2 as a Radioactive Materials Area, with applicable boundary access controls.

SWMU 3 (Figure 1.5) consists of an aboveground surface impoundment that was converted to a solid waste disposal facility (C-404) and a field to the east where a northeast-southwest ditch drained the C-404 surface impoundment to the NSDD. C-404 is a grass covered mound with steep, 10-ft high sides and a

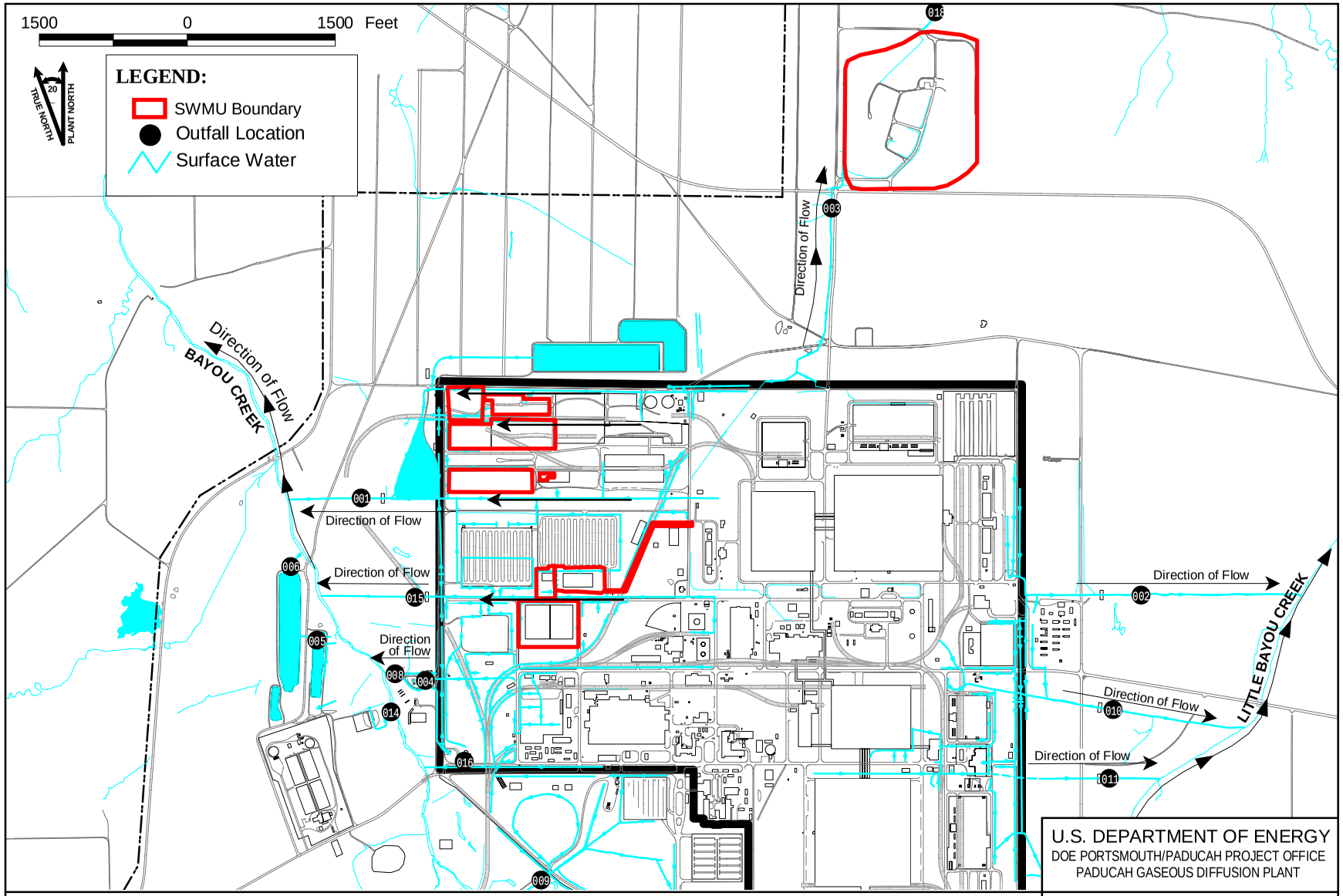


Figure 3.7. Drainage Ditch Systems at the BGOU SWMUs

passes between C-404 and Virginia Avenue, to the south. Gravel roads provide limited access to the east and south sides of C-404. PGDP maintains C-404 as a Radioactive Materials Area.

SWMU 4 is an open grass field that was used for the burial and disposal of waste materials. This SWMU is bounded on the north by Virginia Avenue, on the east by 6th Street, on the west by 4th Street, and on the south by an active railroad spur (Figure 1.6). Shallow drainage swales that direct surface runoff to the northwest corner of the site bound SWMU 4 on three sides (north, east, and west). Surface runoff passes beneath Virginia Avenue through a drainage culvert where it discharges into the main drainage ditch to KPDES Outfall 015. The ground surface of the burial area is graded so that surface runoff is directed toward the surrounding drainage swales. There is an elevation difference of approximately 10 ft between the highest point in the SWMU to the adjacent drainage swales. PGDP maintains a fence around SWMU 4 to control access.

SWMU 5 is a burial area in the northwest quadrant of the plant (Figure 1.7). Unnamed gravel roads parallel the north, south, and east sides, while a paved road lies to the west. Shallow drainage swales bordering the SWMU direct surface runoff to a settling pond (C-613) and then to KPDES Outfall 001. The ground surface is grass-covered with no significant surface structures. Approximately five ft of topographic relief exists between the mound of the burial area, which is offset to the east, and the sides of the SWMU. The SWMU is fenced to limit access to authorized personnel only.

The SWMU 6 burial plots (Figure 1.8) are located due east of SWMU 5. This area is relatively flat and is bounded by unnamed gravel roads to the west and south and to the north by a ditch that drains through the C-613 settling pond to KPDES Outfall 001. PGDP maintains the area as a grassed field with occasional shrubs. SWMU 6 is a Radioactive Materials Area with boundary chains to mark limited access.

SWMU 7 is a burial pit area in the northwest corner of the plant (Figure 1.9). Ditches of the KPDES Outfall 001 drainage system border SWMU 7 to the north and south. A scrap yard lies to the east. SWMU 30 adjoins SWMU 7 to the west. The earthen cover over the burial pits form slight hills (two ft high) on the north and south sides of SWMU 7. A gravel pad covers the east end of SWMU 7. PGDP maintains grass cover over the west burial pits. Boundary chains limit access to the west burial pits, which are delimited Radioactive Materials Areas and High Radioactive Materials Areas.

The same KPDES Outfall 001 drainage ditches bound SWMU 30 on the north and south sides. A paved road borders SWMU 30 on the west side. The surface of the SWMU 30 earthen cover ranges from an elevation of 375 ft at it highest point near the northeast corner of the SWMU to 371 ft near the edges of the burial pit. As at SWMU 7, PGDP maintains a grass cover over the burial pit and boundary chains limit access (Radioactive Materials Area).

SWMU 145 (Figure 1.10) is located to the north of the plant, beneath the C-746-S and -T Landfills. Boundaries of the waste fill are not well defined. The BGOU RI used review of historical aerial photography and geophysical surveys to delineate areas for characterization of the historic waste fill (see Section 2.1). Ogden Landing Road (Kentucky Highway 358) borders the south side of SWMU 145. PGDP's currently operating landfill (C-746-U) lies to the north of SWMU 145. The present trace of the NSDD passes on the west and north sides. Grasslands of the WKWMA adjoin SWMU 145 to the east. Area runoff drains through the NSDD. Fencing for the C-746-S and -T Landfills limits access to SWMU 145.

3.9.2 Underground Utilities and Plant Operations

Underground utilities are sparse in the area of the BGOU SWMUs. Because they are sparse in this area, it is likely that they have had no impact on contaminant migration from or into the SWMU areas. Plant

operations subsequent to waste operations at each of the SWMUs have contaminated surface soils. The common presence of polycyclic aromatic hydrocarbons (PAHs) and uranium in surface soil are related directly to past and on-going plant operation. Ditches bound all of the BGOU SWMUs and provide a potential pathway for contaminant migration. The Surface Water Operable Unit SI assesses the nature and extent of this contamination in most areas addressed by the BGOU RI. Ditches of the northwest plant area that drain to the C-613 Sedimentation Basin will be addressed by the Comprehensive Site OU evaluation, after completion of the other strategic initiatives.

3.9.3 BGOU Hydrogeology

The scope of the BGOU RI focused on contaminant migration in the soils of the Pleistocene Continental Deposits and in the groundwater of the UCRS and RGA flow systems. Appendix B provides the lithologic logs of the boreholes drilled for the BGOU RI. The following sections summarize the general characteristics of the UCRS and RGA and present hydrogeologic data for each SWMU based on field information obtained during the BGOU RI and previous studies. This presentation of the site hydrogeology uses the framework of the five HUs as summarized in Section 3.6.1.

Sorption. Cation exchange capacity and total organic carbon content are common measures of the sorption capacity of soils. The SWMU 2 Interim Remedial Design Investigation (DOE 1997a) characterized cation exchange capacity and total organic carbon content for each HU. Table 3.2 presents the data. Cation exchange capacity values for UCRS soils range from 15 to 26 milliequivalents per 100 g (meq/100 g). These values are typical of silty soils with some clay. Only three values are available for the RGA HU5 interval. The two lowest values of 9 and 10 meq/100 g are most representative of the overall RGA.

Total organic carbon content for the SWMU 2 data is similar for the UCRS and RGA. Values range from 0.05 to 0.24% (with a median value of 0.08%) for the UCRS measurements and 0.02 to 0.25% (with a median value of 0.05%) for the RGA measurements. The WAG 6 RI (DOE 1999c) also measured total organic carbon content of UCRS and RGA soils. Total organic carbon content measurements ranged from 0.002 to 0.2% (median of 0.04% for 20 measurements) in UCRS samples and from 0.003 to 0.3% (median of 0.02% for 38 measurements) in RGA samples.

The SWMUs 7 and 30 RI (DOE 1998a) and SWMU 2 Interim Remedial Design Investigation also characterized the uranium distribution ratio for all HUs because of the significance of potential uranium transport from the burial cells (Table 3.2). All measurements of the uranium distribution ratio are greater than 1, which means that uranium will preferentially partition from groundwater to the soils. The magnitude of the UCRS values (253 to 93,900 mL/g) indicates that common forms of uranium leachate are not likely to migrate from the burial grounds to the RGA. Even the sands and gravel units of the RGA would provide significant retention of uranium [uranium distribution coefficient (K_d) of 66.8 mL/g]. The fate and transport modeling for this RI, as documented in Appendix E, uses a K_d of 66.8 mL/g to minimize the potential of eliminating uranium as a contaminant of concern (COC) so that it can be properly addressed in the BGOU FS.

Table 3.2. Sorption Measurements from SWMUs 7 and 30 Remedial Investigation Report and the SWMU 2 Interim Remedial Design Investigation

	SWMUs 7 and 30	SWMU 2			
HU	**Uranium Distribution Ratio (mL/g)**	**Sample ID**	**Uranium Distribution Ratio (mL/g)**	**Cation Exchange Capacity (meq/100 g)**	**Total Organic Carbon Content (%)**
HU1	253 ± 10.0	S03211	3,200	NA	NA
		S05211	1,530	17.54	0.1020
		S17211	NA	20.80	0.0819
HU2 Sand	1,170 ± 264	S03212	9,080	NA	0.0701
		S05212	8,070	15.11	0.0869
		S13211	NA	17.87	0.2400
HU2 Silt		S03213	13,100	17.78	0.0465
		S05213	72,200	21.04	0.0968
		S17212	NA	18.18	0.0566
HU3	3,640 ± 2,060	S03214	93,900	NA	NA
		S05214	7,020	21.94	0.0862
		S09213	NA	23.02	0.0807
		S17213	NA	25.63	0.0720
HU4	761 ± 172	S13212	NA	23.80	0.1060
		S17214	NA	NA	0.0464
HU5	66.8 ± 3.82	S03215	4,950	NA	0.2530
		S05215	49,900	9.98	0.0453
		S09215	NA	NA	0.0394
		S13214	NA	23.72	0.0796
		S13215	NA	9.40	0.0321
		S17215	NA	NA	0.0199

NA = not available (not measured)

Groundwater Geochemistry. In areas that are not heavily influenced by dissolved contaminants, both UCRS and RGA groundwater tends to be mildly acidic and well buffered. As the groundwater migrates through the UCRS, bicarbonate replaces sulfate as the dominant anion (Clausen *et al.* 1992; DOE 1997a) with depth. The dominant cations in both UCRS and RGA water are commonly sodium followed by calcium.

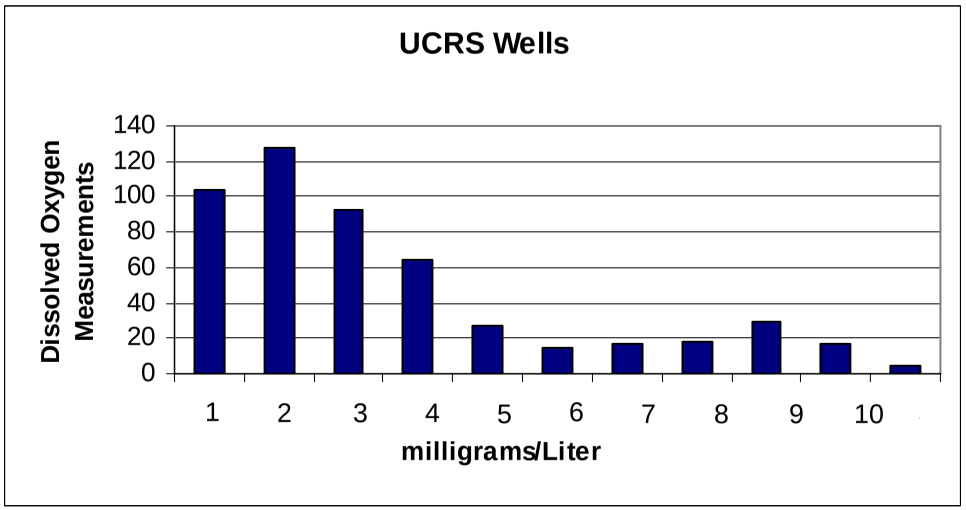
While there is a lack of data at a couple of SWMUs, sufficient UCRS and RGA monitoring well data are available to document the nature of dissolved oxygen levels and oxidation/reduction potential applicable to the BGOU SWMUs. Table 3.3 summarizes the available analyses for UCRS groundwater samples (collected from wells and temporary borings) for the BGOU SWMUs. There is uncertainty with regard to the dissolved oxygen in the UCRS at SWMUs 4 and 6 due to a lack of data. The presence of TCE degradation products in the UCRS at SWMU 4 provides some evidence of low dissolved oxygen at that unit. The majority of dissolved oxygen measurements (collected *ex situ*) from UCRS wells range from near zero to four mg/L (Figure 3.8) and oxidation/reduction potential commonly ranges from -100 to 300 microVolts, with the majority of measurements greater than zero. The line plots of Figure 3.9 further demonstrate trends of dissolved oxygen (517 measurements) and oxidation/reduction potential (136 measurements) in the UCRS at the BGOU SWMUs. Plots of the data for each SWMU (as available), overlaid on the cumulative trend plots, (Figures 3.10 and 3.11) illustrate the relative abundance of measurements for most SWMUs and demonstrate that the cumulative trend is likely to be representative of conditions at each SWMU, although some uncertainty remains with SWMUs 4 and 6 due to a lack of data.

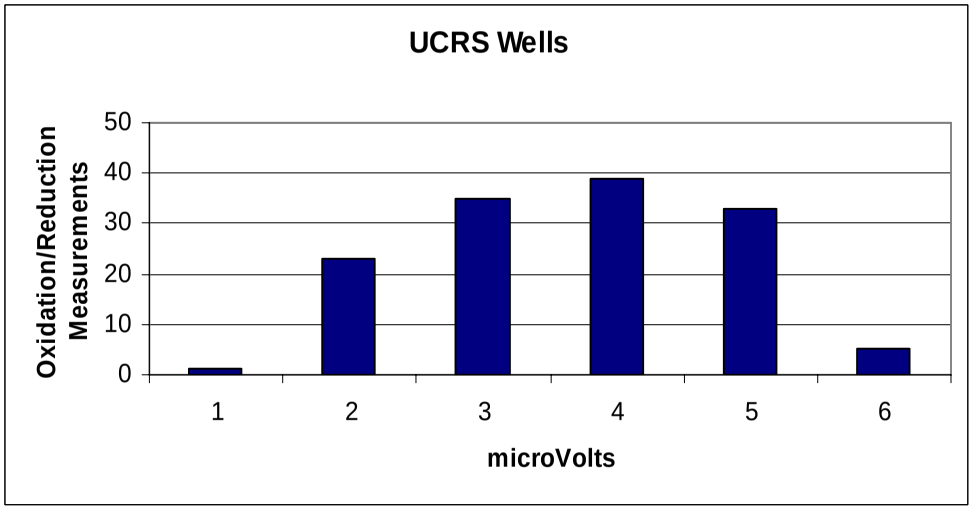
Table 3.3. Summary of Dissolved Oxygen and Oxidation/Reduction Potential Data of the UCRS (Samples from 64 ft depth or less) for the BGOU RI

SWMU	Sample Location	Sample Depth (ft)	Dissolved Oxygen		Oxidation/Reduction Potential	
			(mg/L)	Data Type	(mV)	Data Type
2	SWMU 2-3	63	6.3	C	112	C
	SWMU 2-9	24	11.5	C	174	C
		43	9.4	C	--	--
	SWMU 2-10	22	3.0	C	--	--
	SWMU 2-17	22	7.8	C	46	C
	PZ74	32–42	5.0	B	240	B
	MW154	16–18	4.5	A	303	C
	PZ334	8–10	5.7	A	224	B
	PZ335	8–10	2.8	B	254	B
	PZ336	8–10	5.5	B	244	B
3	MW85	30–40	8.2	A	225	A
	MW88	29–40	2.0	A	228	A
	MW91	29–39	6.8	A	223	A
	MW94	29–39	2.5	A	192	A
4	004-020	60	--	--	156	C
	004-021	60	--	--	183	C
	004-022	60	--	--	241	C
	004-105	64	--	--	144	C
	004-107	64	--	--	168	C
	004-108	64	--	--	84	C
	004-110	64	--	--	134	C
5	005-015	55–60	--	--	179	C
	005-018	60	--	--	220	C
	MW190	18–22	2.9	A	--	--
6	006-016	32–37	--	--	171	C
	006-018	22–27	--	--	175	C
	006-019	60	--	--	207	C
7	WBP-9A	11	1.6	B	164	B
	WBP-12A	9	2.3	B	64*	B
	MW186	18–23	0.8	A	157	A
30	WBP-4A	8	2.6	B	7*	B
	MW64	28–33	6.3	A	--	--
	MW187	22–26	2.0	A	198	A
145	145-021	59	--	A	24	A
	MW16	20–40	5.8	A	--	A
	MW18	35–55	0.7	A	--	A
	MW180	22–27	2.3	A	179	A
	MW182	15–20	1.5	A	-7*	A
	MW386	20–30	1.3	A	21	A
	MW390	28–38	2.7	A	197	A
	MW393	28–38	1.2	A	-13	A
	MW396	34–44	1.0	A	36	A

Data Type:
A = median of measurements of four or more sample events
B = average of measurements of two or three sample events
C = single value available

* Range includes negative and positive oxidation/reduction potential values
-- indicates no data available.





NOTE: Table 3.3 identifies the sample locations.

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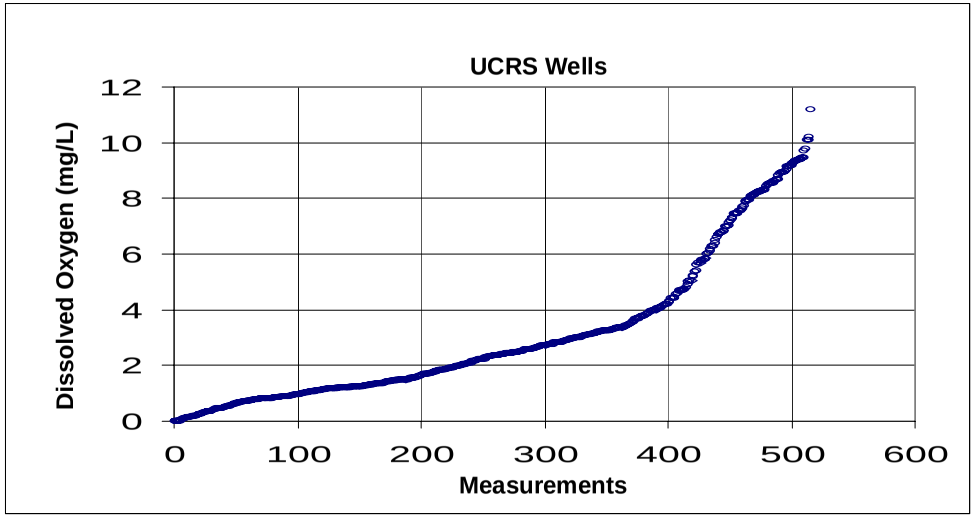
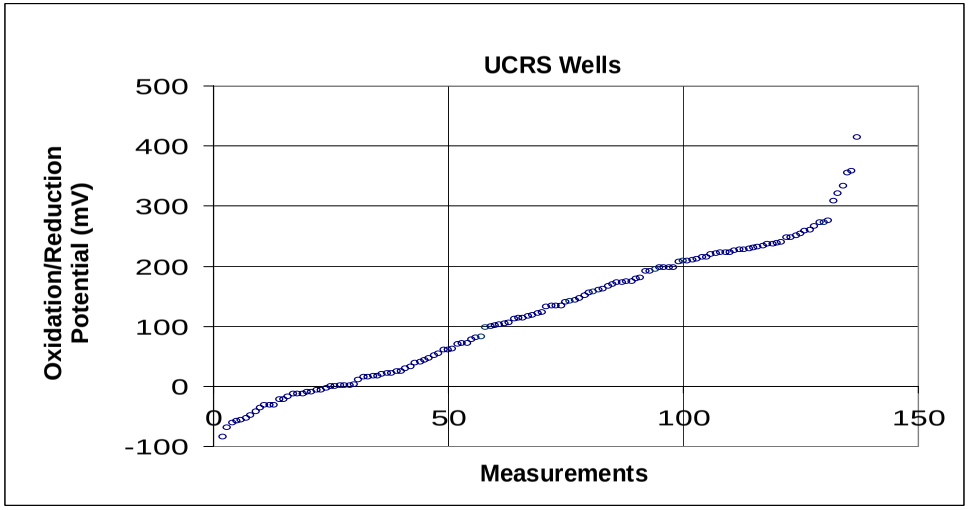
Figure 3.8. Distribution of Dissolved Oxygen and Oxidation/Reduction Potential Measurements in the UCRS for the BGOU SWMUs





NOTE: Table 3.3 identifies the sample locations.

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Figure 3.9. Dissolved Oxygen and Oxidation/Reduction Potential Measurements in the UCRS for the BGOU SWMUs

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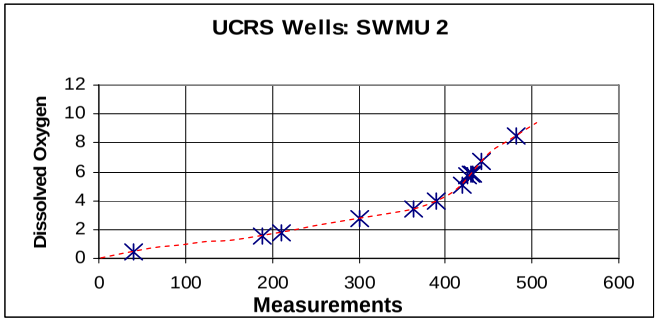

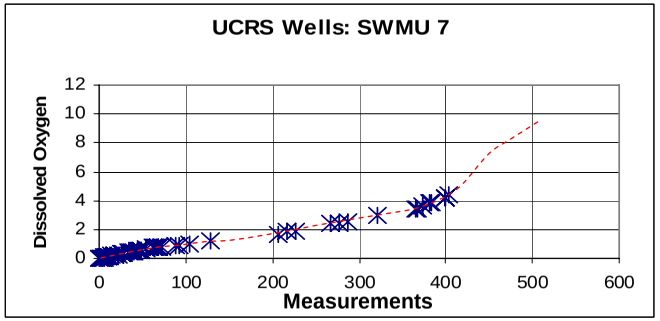

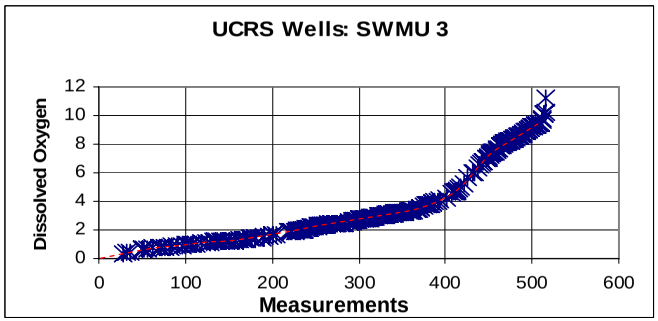

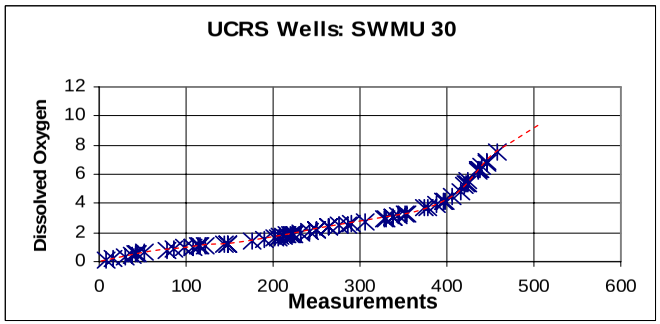

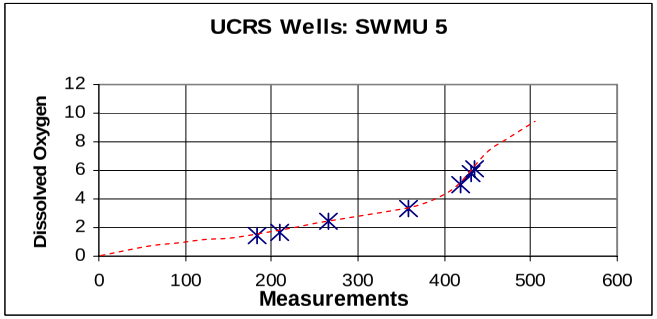

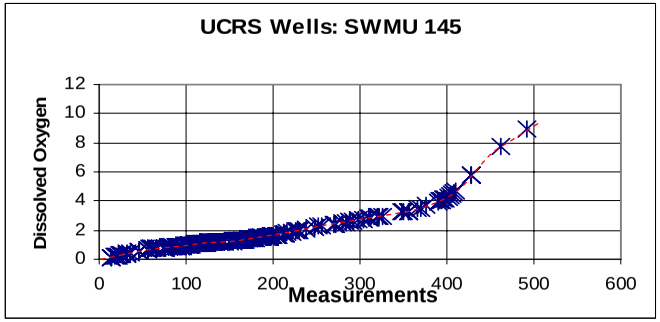

NOTE: Table 3.3 identifies the sample locations.

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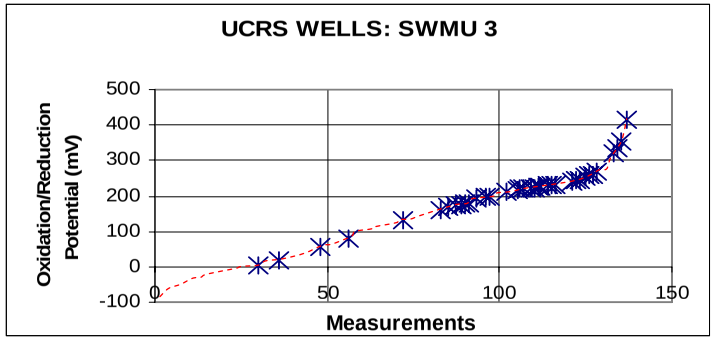
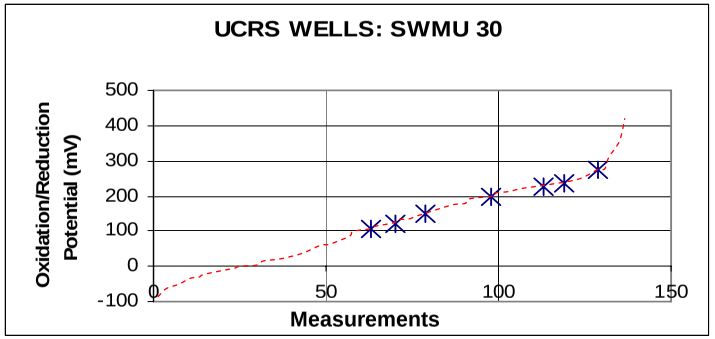
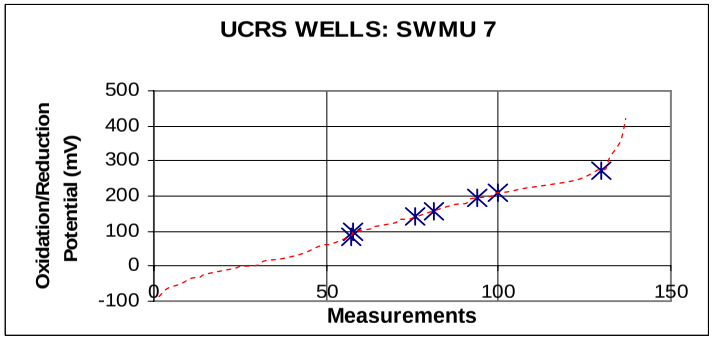
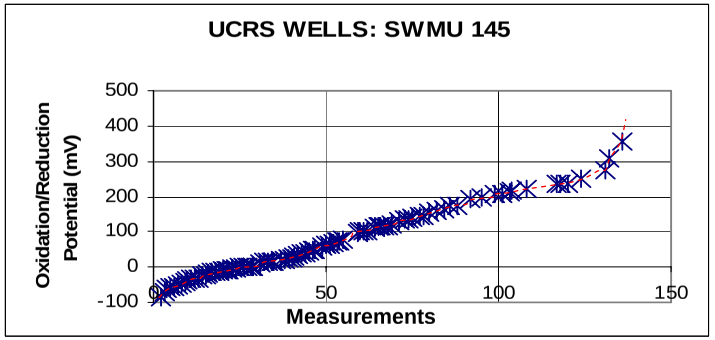
Figure 3.10. Dissolved Oxygen Measurements in the UCRS for Each BGOU SWMU









NOTE: Table 3.3 identifies the sample locations.

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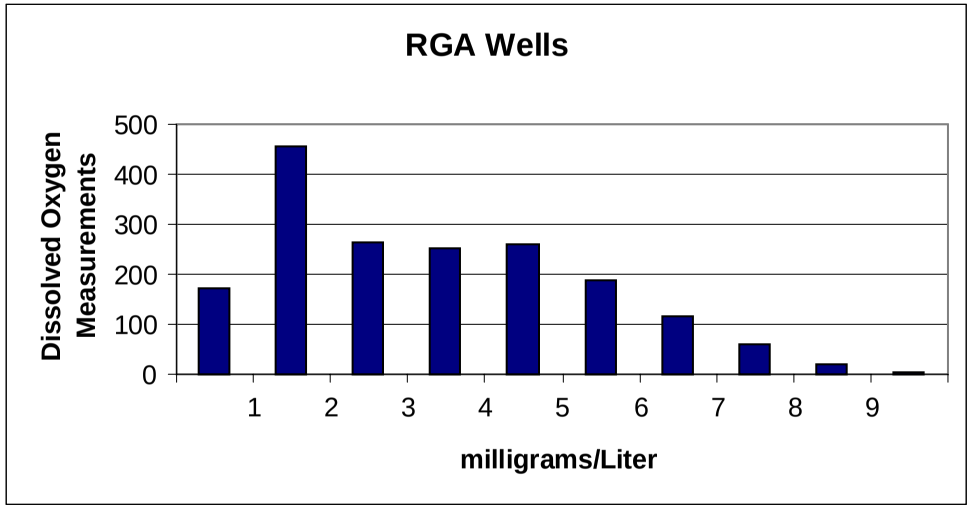
Figure 3.11. Oxidation/Reduction Potential Measurements in the UCRS for Each BGOU SWMU

Previous investigations of SWMU 2 (DOE 1997a) and SWMUs 7 and 30 (DOE 1998a) identified high levels of reductive dechlorination byproducts of TCE within and below some waste disposal areas. These byproducts [principally *cis*-1,2-dichloroethene (DCE) and vinyl chloride] are evidence that reducing conditions (little to no dissolved oxygen) have been present, and may continue to be present, locally within some of the burial cells where other organic wastes, such as oils, have been co-located. At SWMUs 7 and 30, this is confirmed with low dissolved oxygen concentrations in UCRS MW186.

The range of dissolved oxygen and oxidation/reduction potential is similar for the RGA beneath the BGOU SWMUs. Dissolved oxygen measurements commonly fall between near 0 mg/L and 6 mg/L (Figure 3.12). It should be noted that measurements of dissolved oxygen determined with flow-through cells, such as the method used at PGDP, are not accurate below 1 mg/L, which leads to uncertainty in the distribution; however, most measurements of dissolved oxygen obtained at the site (>75%) are greater than 1 mg/L. Oxidation/reduction potential of the RGA is confined in the 100 to 300 microvolts range. Line plots of the data (Figure 3.13) illustrate the trends of dissolved oxygen (1,799 measurements) and oxidation/reduction potential (574 measurements) in the RGA at the BGOU SWMUs. Plots of the data for each SWMU (as available), overlaid on the cumulative trend plot, (Figures 3.14 and 3.15) reveal that the dissolved oxygen and oxidation/reduction potential measurements at each SWMU are generally well distributed through the cumulative range. There is some uncertainty with SWMUs 5 and 6 due to a lack of data, but the distribution of dissolved oxygen in the RGA should be similar to that of nearby SWMUs.

RGA Hydraulic Potential. The potentiometric surface of the RGA trends north-northeast toward the regional hydraulic base level represented by the Ohio River. Representative values for hydraulic gradient at PGDP and to the north commonly range between 10^{-4} ft/ft and 10^{-3} ft/ft. In the area of the plant, the potentiometric surface remains relatively flat throughout the year. The area north of the DOE property boundary tends to be an area of higher hydraulic gradient, except following an extended rise in the Ohio River stage.

The hydraulic potential of the RGA near the center of the plant averages 328 ft amsl and commonly fluctuates five ft over a yearly high-and-low cycle. RGA water levels near the Ohio River are often 10 ft lower. Low pool elevation of the Ohio River north of PGDP is 290 ft amsl.



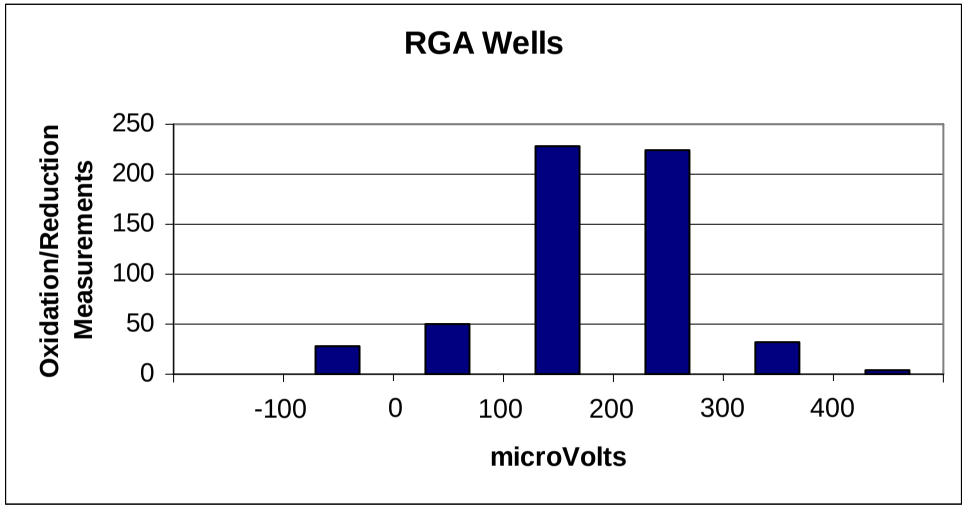


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Figure 3.12. Distribution of Dissolved Oxygen and Oxidation/Reduction Potential Measurements in the RGA for the BGOU SWMUs

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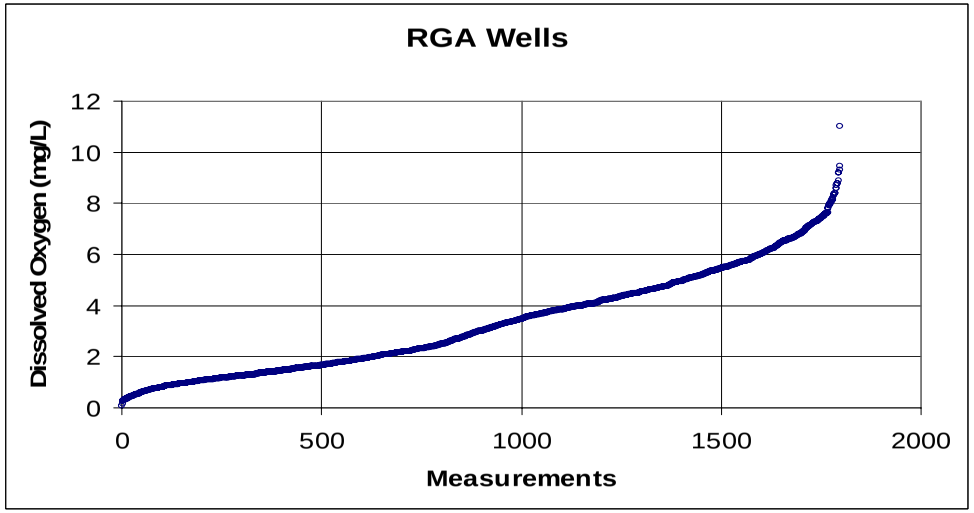

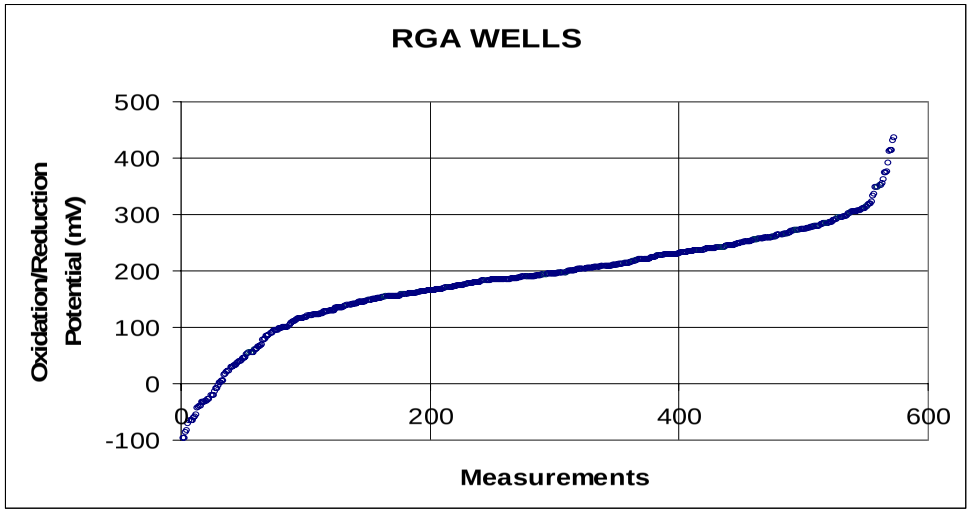

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Figure 3.13. Dissolved Oxygen and Oxidation/Reduction Potential Measurements in the RGA for the BGOU SWMUs

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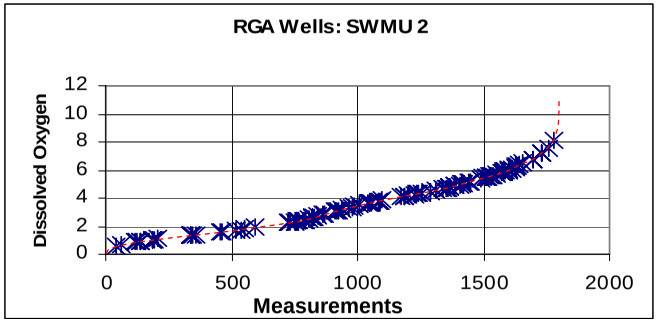

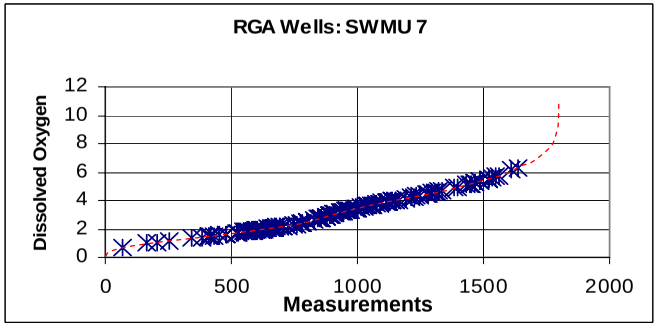

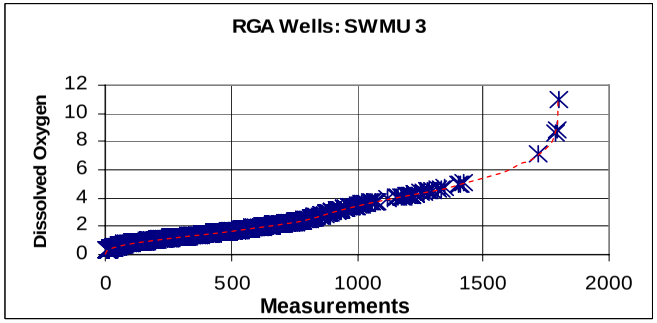

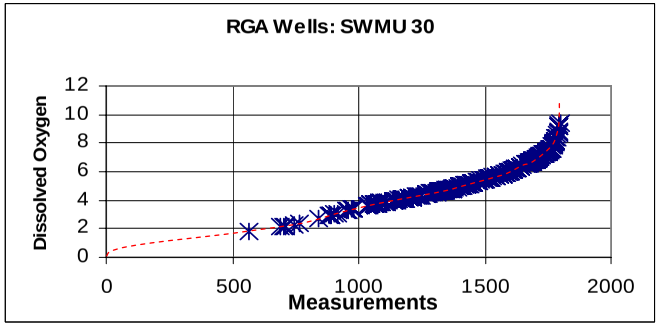

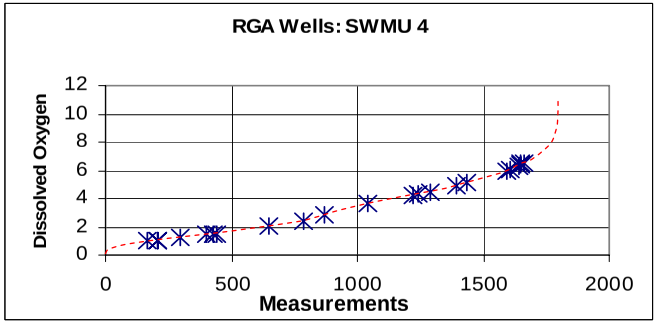

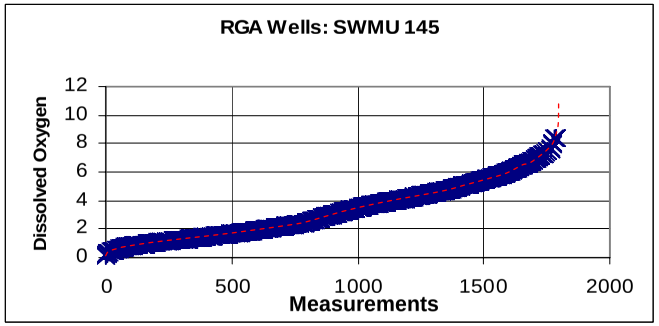

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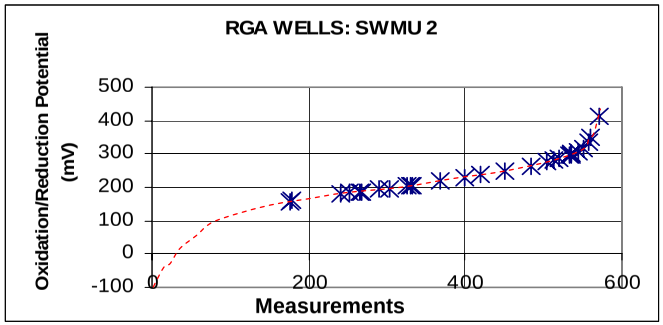
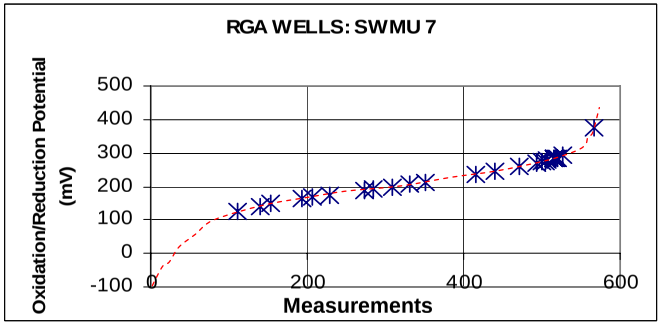
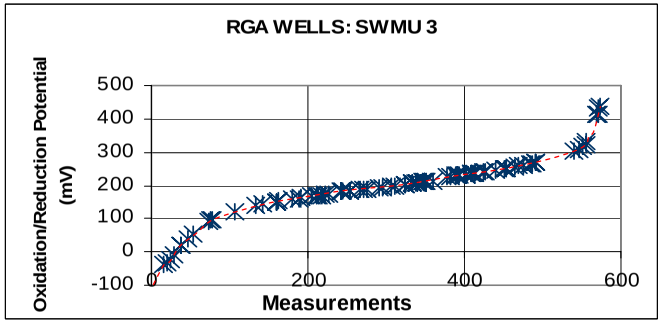
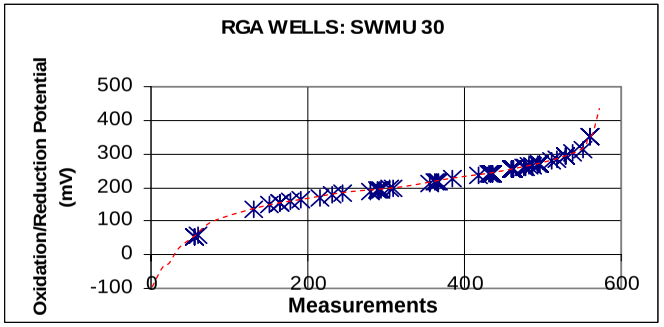
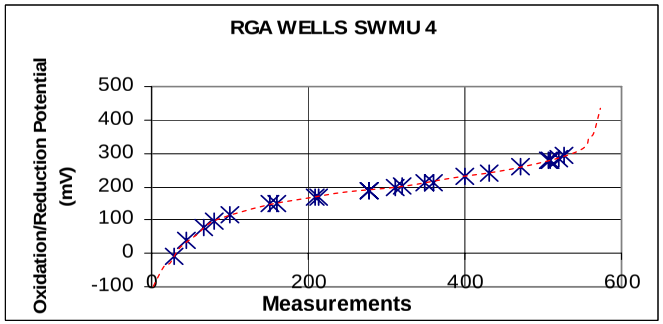
Figure 3.14. Dissolved Oxygen Measurements in the RGA for Each BGOU SWMU











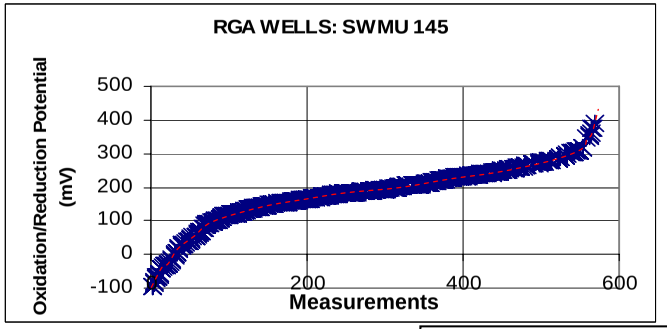


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Figure 3.15. Oxidation/Reduction Potential Measurements in the RGA for Each BGOU SWMU

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3.9.3.1 SWMUs 2 and 3 hydrogeologic interpretation

Waste Disposal Background. SWMUs 2 and 3 are adjacent waste disposal facilities located in the west-central portion of the plant. PGDP buried uranium and uranium-contaminated waste in cells excavated to depths of 7 to 17 ft at SWMU 2. SWMU 3 (C-404) operated as a rectangular, aboveground, surface impoundment from approximately 1952 until 1957, when PGDP converted the surface impoundment to a solid waste disposal facility for uranium-contaminated wastes. (See Sections 1.3.1 and 1.3.2)

Stratigraphy. The burial cells of SWMU 2 are excavated into the HU1 loess member (silt with some clay) of the Upper Continental Deposits. Some waste cells likely extend to near the base of the HU1 unit, at a depth of 18.5 ft. The underlying HU2 interval consists of upper and lower sand and gravel horizons, separated by an intervening clayey silt unit, to a depth of 40 ft. A nine-ft-thick silty clay interval (HU3) separates the HU2 sand and gravel horizons from the basal HU4 sand and the sands and gravels of the Lower Continental Deposits (HU5). SWMU 3 rests upon the top of the Upper Continental Deposits. East-west cross sections of the stratigraphy below SWMUs 2 and 3 (Figure 3.16, DOE 1995b) demonstrate the relative continuity of the HU2 sand and gravel intervals.

UCRS Groundwater Flow and Hydraulic Potential. Figure 3.17 (DOE 1997a) summarizes the key hydrogeologic parameters that govern groundwater flow through the UCRS at SWMU 2 (the parameters also are applicable to SWMU 3, but SWMU 3 doesn't have burial pits as shown in this figure). The SWMU 2 Interim Remedial Design Investigation Report (DOE 1997a) documents the depth and gradient of the water table using measurements from shallow monitoring wells and piezometers. Four rounds of measurements of water level during a one-week period in August, 1996 consistently demonstrate that the water table occurred within 10 ft of land surface, sloping toward a ditch on the west side. Most of the buried waste at SWMU 2 is saturated. The westward slope of the water table below SWMU 2 indicates that the water table must be equally shallow beneath SWMU 3. Because SWMU 3 is an aboveground facility with a RCRA multi-layered cap, the actual saturation level within the waste is unknown; however, with the shallow water table and generation of leachate, it is assumed that all but the base of the landfill wastes are likely unsaturated.[3]

RGA Groundwater Flow and Hydraulic Potential. The BGOU RI includes a hydrogeological assessment of SWMU 3 (PRS 2007a), which documents the primary groundwater pathways in the area RGA (Figure 3.18). Contaminant trends associated with the Southwest Plume demonstrate convincingly that the dominant groundwater pathway immediately south of SWMU 3 is to the northwest, in agreement with the larger Southwest Plume trend, which passes beneath the south end of SWMU 2. Beneath SWMU 3, the groundwater pathway veers northward.

The governing parameters determining the groundwater flow paths are the higher hydraulic conductivity corridors in the RGA marked by the Southwest Plume and the Northwest Plume to the south and north of SWMU 3, respectively, and the RGA potentiometric surface, which declines to the north. Edges of the Southwest Plume and Northwest Plume approximate boundaries of higher hydraulic conductivity in the HU5 sediments, through which the majority of groundwater flow occurs. Pumping tests of the RGA in the area of the main contaminant plumes on-site (Terran 1992; LMES 1996b) have determined the representative hydraulic conductivity to be 1,200 to 1,300 ft/day, which contrasts with the hydraulic conductivity of the RGA beneath SWMU 3, measured as 100 ft/day in a previous pumping test (Terran 1990).

[3] The continuing recovery of leachate from the facility indicates that some infiltration occurs and the base of the disposal cell must be saturated.

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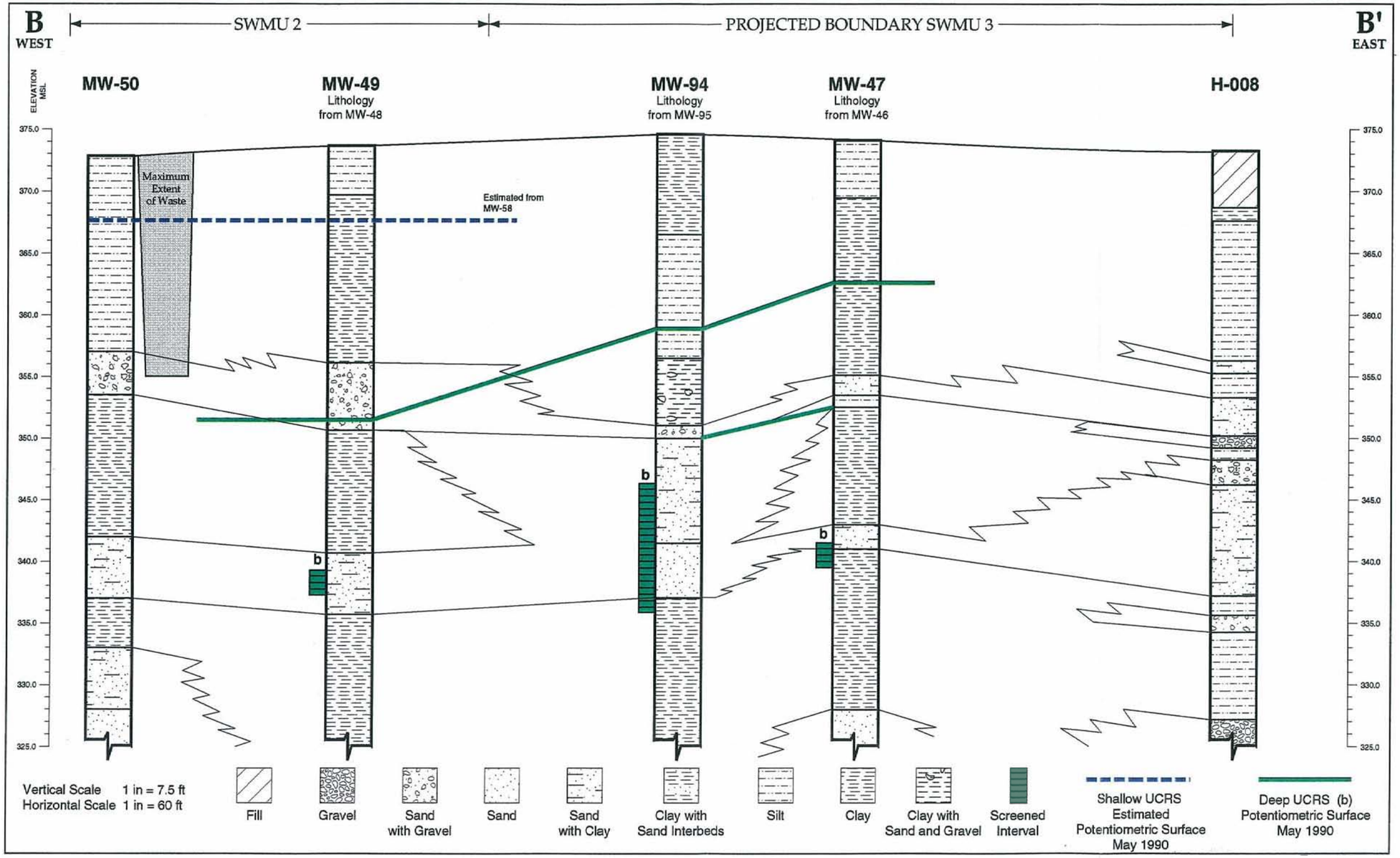

REFERENCE: DOE 1995b

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Figure 3.16. East-West Cross-Section of SWMUs 2 and 3

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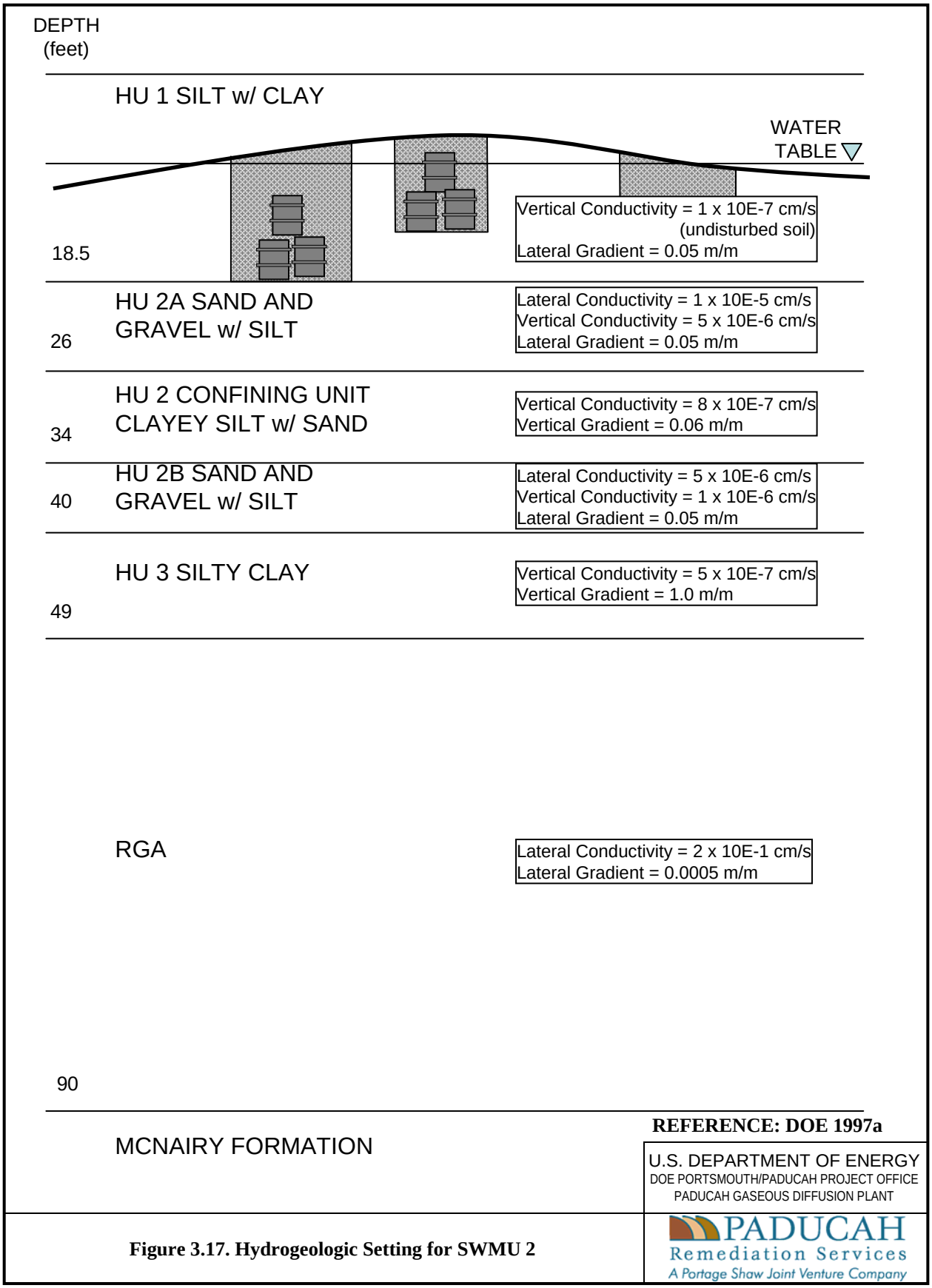
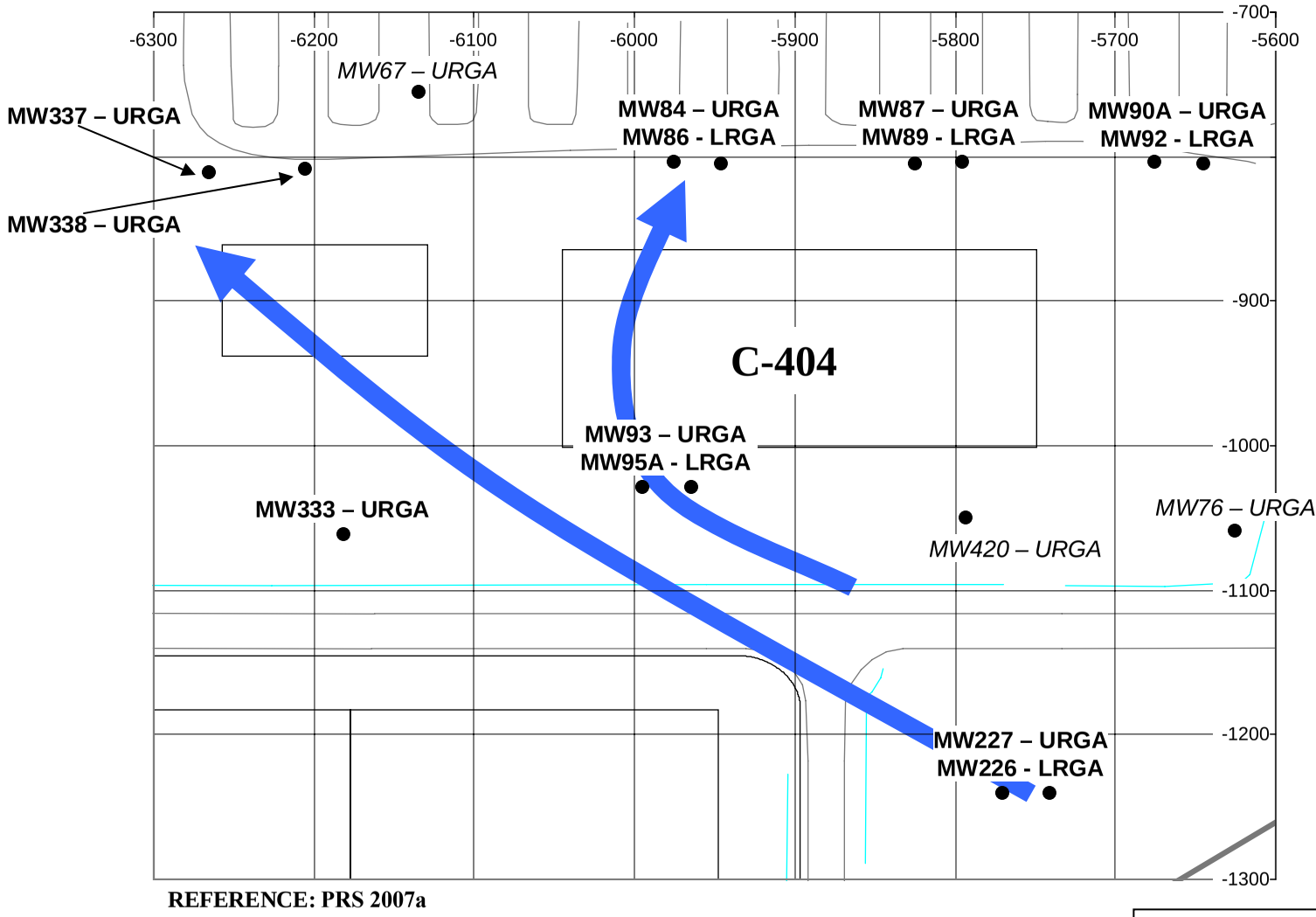


Figure 3.17. Hydrogeologic Setting for SWMU 2



REFERENCE: PRS 2007a

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Figure 3.18. Prevailing Groundwater Flow Directions in the RGA

Groundwater flow paths at the interface with a media of lower hydraulic conductivity will deflect into the lower conductivity material. The north flow beneath SWMU 3 is an intermediate flow path between the hydraulic conductivity "expressways" delineated by the Southwest Plume (to the south of SWMU 3) and the Northwest Plume (to the north of SWMU 3).

Average RGA groundwater flow velocity in the areas of the contaminant plumes is commonly 1 to 3 ft/day. Hydraulic potential gradients to the north and to the west are commonly similar in the SWMU 3 area. The northward groundwater flow rate beneath SWMU 3 is likely 0.1 to 0.3 ft/day, in step with the order-of-magnitude reduction in hydraulic conductivity beneath SWMU 3.

3.9.3.2 SWMU 4 hydrogeologic interpretation

Waste Disposal Background. SWMU 4 includes four burial pit areas to the south of SWMUs 2 and 3, excavated to a depth of approximately 15 ft for the disposal of various wastes (Section 1.3.3).

Stratigraphy. Like SWMU 2, the burial cells of SWMU 4 penetrate into the HU1 loess member (predominately silt) of the Upper Continental Deposits. These burial cells likely extend to near the base of HU1, at a depth of 15 to 20 ft. Lithologic logs of wells MW415 and MW417 document the presence of an upper and lower HU2 sand horizon, separated by an intervening silt member beneath SWMU 4. The HU2 occurs over the approximate depths of 20 to 40 ft. This, in turn, is underlain by the HU3 silt interval down to a depth of 50 ft. The HU4 sand is approximately 15 ft thick at SWMU 4. Sand and gravelly sand members of the Lower Continental Deposits (HU5) extend down to a depth of approximately 100 ft. The underlying McNairy Formation consists of fine sands and clays. Cross sections based on the numerous soil borings of the WAG 3 RI demonstrate the lateral continuity of these units beneath SWMU 4 (Figure 3.19, taken from DOE 2000a).

UCRS Groundwater Flow and Hydraulic Potential. The depth to the water table at SWMU 4 is uncertain since there are no direct measurements of the depth of the water table beneath SWMU 4. Since the stratigraphy and hydrogeology is comparable to that of SWMUs 2 and 3, and SWMU 4 is in close proximity to those SWMUs, it is reasonable to assume a similar depth to water in the UCRS (10 to 15 ft bgs). The water table likely extends up into the waste burial pits.

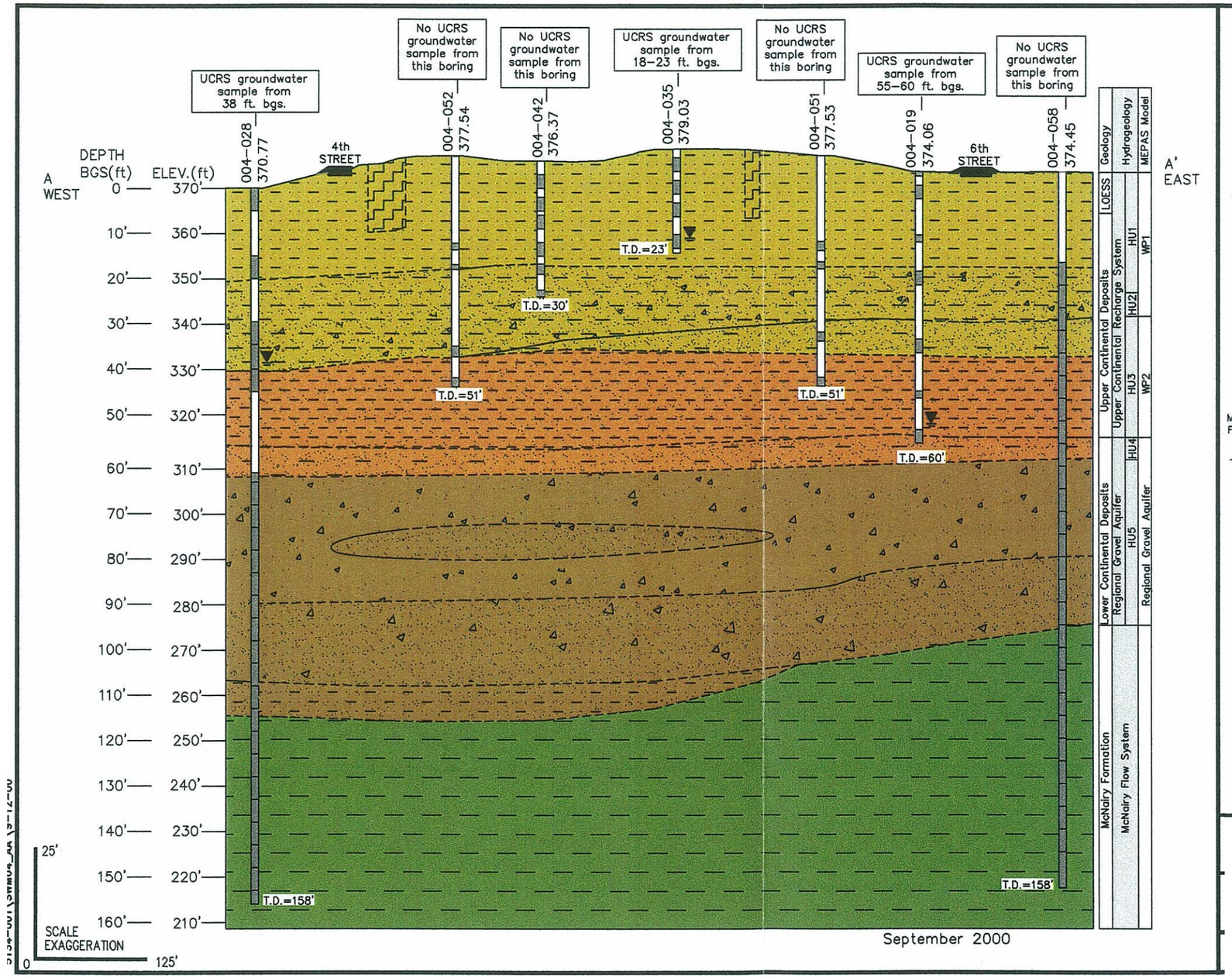
RGA Groundwater Flow and Hydraulic Potential. The northwest flow direction demonstrated for the immediate area to the south of SWMU 3 and the general west-northwest trend of the Southwest Plume define the dominant flow paths in the RGA beneath SWMU 4. It is anticipated that the hydraulic conductivity of the RGA is similar to that of other on-site areas containing the main contaminant plumes, 1,200 to 1,300 ft/day. Average RGA groundwater flow velocity in the areas of the contaminant plumes is commonly 1 to 3 ft/day.

3.9.3.3 SWMUs 5 and 6 hydrogeologic interpretation

Waste Disposal Background. SWMUs 5 and 6 are adjacent waste disposal facilities near the northwest corner of the PGDP industrial area. Both are burial grounds. The disposal pits of SWMU 5 extend 6 to 15 ft deep (Section 1.3.4). Those of SWMU 6 range from 6 to 8 ft deep (Section 1.3.5).

Stratigraphy. The burial cells of SWMUs 5 and 6 are excavated into the HU1 loess member (silt with some clay) of the Upper Continental Deposits. Only the deeper SWMU 5 pits likely extend to near the base of the HU1 unit, at a depth of 18 to 20 ft. Soil borings of the WAG 3 RI (Figure 3.20, taken from DOE 2000a) document that the HU2 interval in this area is a silty clay with sand and gravel lenses, to a depth of 30 ft below SWMU 6 and 40 ft below SWMU 5. The bottom of the HU3 interval, clay with variable amounts of silt and sand, occurs uniformly at depths of 58 to 60 ft. Soil borings infrequently identified a thin (5 to 7 ft thick) sand interval at the top of the RGA (HU4). In most soil borings, the RGA

is a mix of sand and gravel deposits. In the area of SWMUs 5 and 6, the upper McNairy consists primarily of clay, beginning at depths of 100 to 105 ft.



LITHOLOGY

- SILT/CLAY
- GRAVEL
- CLAY
- WASTE CELL
- SAND AND SILTY SAND AND/OR GRAVEL

HYDROGEOLOGY

HU1 ····· HU1 – THE UPPER FLUVIAL/ALLUVIAL SILTY CLAYS RUST BROWN TO GREY–BROWN; PLEISTOCENE AGE.

HU2 ····· HU2 – LOESS, CLAYEY SILTY SAND TO SANDY SILT, SAND LENSES ARE DISCONTINUOUS BUT CORRELATABLE, RUST BROWN TO YELLOW–BROWN; PLEISTOCENE AGE.

HU3 ····· HU3 – CLAY TO SILTY CLAY, VERY IMPERMEABLE CLAY THAT ACTS AS A SEMICONFINING TO CONFINING LAYER, PRIMARY CONSTITUENT OF THE UPPER CONTINENTAL DEPOSITS; LOWER PLEISTOCENE AGE.

HU4 ····· HU4 – SAND WITH GRAVEL AND SILT, CONSIDERED THE UPPER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.

HU5 ····· HU5 – GRAVEL WITH SAND AND SILT, CONSIDERED THE LOWER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.

MCNAIRY FLOW SYSTEM ····· MCNAIRY FORMATION – GREYISH–WHITE TO DARK MICACEOUS CLAY, OFTEN SILTY, INTERBEDDED WITH LIGHT GREY TO YELLOW–BROWN VERY FINE SAND. CRETACEOUS AGE.

NOTE:

GRAY INSERTS IN WELLS ARE LOCATIONS WHERE SAMPLES FOR LITHOLOGIC CHARACTERIZATION WERE COLLECTED.

▼ GROUNDWATER SAMPLE

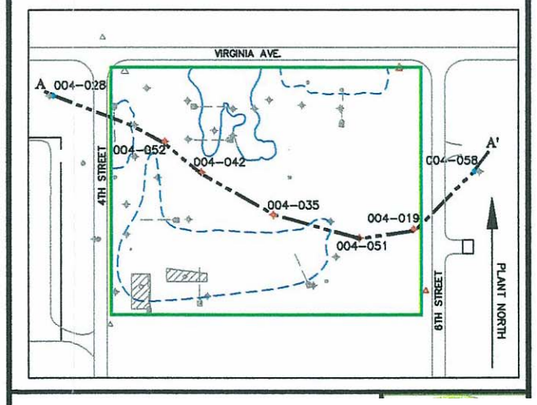


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Figure 3.19.WAG 3, SWMU 4 Lithologic Cross-Section A-A'

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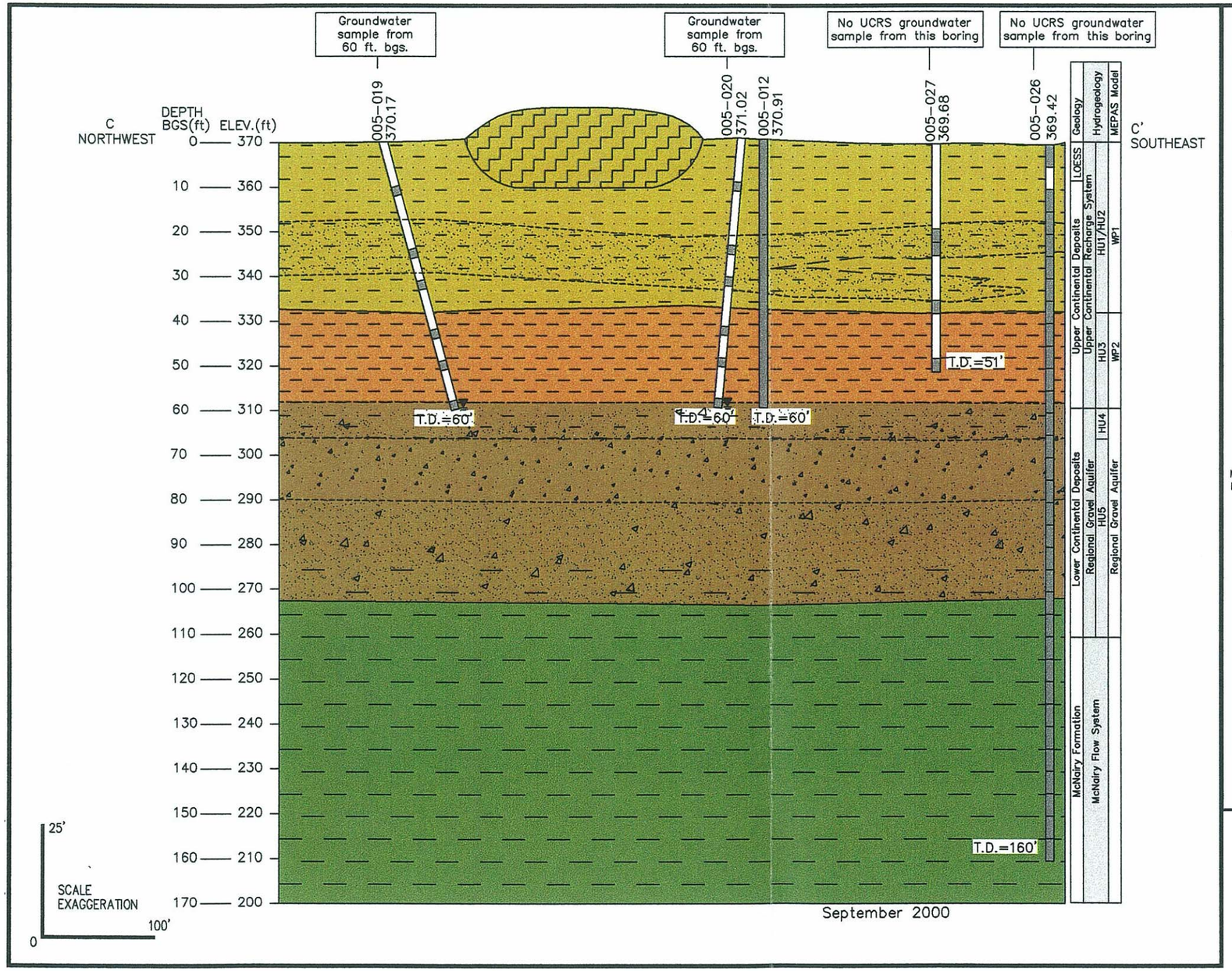

LITHOLOGY

- SILT/CLAY
- GRAVEL
- CLAY
- WASTE CELL
- SAND AND SILTY SAND AND/OR GRAVEL

HYDROGEOLOGY

HU1 ····· HU1 – THE UPPER FLUVIAL/ALLUVIAL SILTY CLAYS RUST BROWN TO GREY–BROWN; PLEISTOCENE AGE.

HU2 ····· HU2 – LOESS, CLAYEY SILTY SAND TO SANDY SILT, SAND LENSES ARE DISCONTINUOUS BUT CORRELATABLE, RUST BROWN TO YELLOW–BROWN; PLEISTOCENE AGE.

HU3 ····· HU3 – CLAY TO SILTY CLAY, VERY IMPERMEABLE CLAY THAT ACTS AS A SEMICONFINING TO CONFINING LAYER, PRIMARY CONSTITUENT OF THE UPPER CONTINENTAL DEPOSITS; LOWER PLEISTOCENE AGE.

HU4 ····· HU4 – SAND WITH GRAVEL AND SILT, CONSIDERED THE UPPER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.

HU5 ····· HU5 – GRAVEL WITH SAND AND SILT, CONSIDERED THE LOWER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.

MCNAIRY FLOW SYSTEM ····· MCNAIRY FORMATION – GREYISH WHITE TO DARK MICACEOUS CLAY, OFTEN SILTY, INTERBEDDED WITH LIGHT GREY TO YELLOW–BROWN VERY FINE SAND. CRETACEOUS AGE.

NOTE:

GRAY INSERTS IN WELLS ARE LOCATIONS WHERE SAMPLES FOR LITHOLOGIC CHARACTERIZATION WERE COLLECTED.

▼ GROUNDWATER SAMPLE

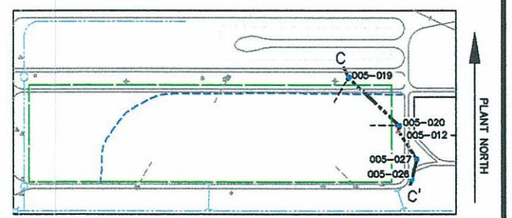

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Figure 3.20.WAG 3, SWMU 5 Lithologic Cross-Section C-C'

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UCRS Groundwater Flow and Hydraulic Potential. MW190, screened over the depth interval 17.5 to 22.5 ft bgs (elevation of 348.6 to 353.6 amsl) provides a direct measure of the hydraulic potential in HU2 on the north side of SWMU 5 and an approximation of the elevation of the water table in HU1. The average elevation of measured water levels in MW190 is 367.0 ft (4.1 ft bgs).

The base of the ditch on the south side of SWMUs 5 and 6, with a local elevation of 358 ft amsl, is a primary control on the elevation of the water table in the area (Figure 3.21). Because the ditch is a linear east-west discharge feature, the area's shallow groundwater flow is likely oriented north-south. The north-south distance between MW190 and the ditch is 350 ft. The difference in elevation of the average MW190 water level and the base of the ditch is 9 ft; thus, the gradient of the water table across SWMU 5 (and similar to that of SWMU 6) is oriented southward with an approximate value of 9/350 ft/ft (0.03 ft/ft). Because HU1 has low transmissivity, the gradient of the water table will tend to be less on the north side of SWMU 5 (although still southward) and significantly greater on the south side of SWMU 5 adjacent to the ditch.

The shallow depth to water in well MW190 (average of 4.1 ft) determines that the vertical hydraulic gradient within the HU1/HU2 hydrogeologic system must be negligible; thus, groundwater flow in HU1 in the area of SWMUs 5 and 6 has a south-oriented vector with a minimal vertical component. The limited shallow groundwater flow beneath SWMU 5 must discharge to the ditch.

Waste was buried to depths of 15 ft (approximate elevation of 355 ft) in SWMU 5; thus, at a minimum, the deepest buried waste cells are saturated over the bottom 3 ft of depth (358 ft amsl/base of ditch–355 ft amsl/base of waste). Assuming a minimal southward gradient of the water table across most of SWMUs 5 and 6, even the shallowest wastes (with top near 365 ft amsl) are likely buried below the water table (at an elevation of approximately 367 ft amsl on the north side of SWMU 5).

RGA Groundwater Flow and Hydraulic Potential. The high-concentration core of the Northwest Plume passes immediately to the east of SWMU 6 in the RGA. This plume vector defines the direction of RGA groundwater flow below SWMUs 5 and 6. It is anticipated that the hydraulic conductivity of the RGA beneath SWMUs 5 and 6 is similar to that of other on-site areas containing the main contaminant plumes, 1,200 to 1,300 ft/day. Average RGA groundwater flow velocity in the areas of the contaminant plumes is commonly 1 to 3 ft/day.

3.9.3.4 SWMUs 7 and 30 hydrogeologic interpretation

Waste Disposal Background. SWMUs 7 and 30 (C-747-A) are located in the extreme northwest corner of the industrial area of the plant. Both SWMUs are burial grounds. SWMU 7 consists of five distinct burial pit areas that range from 6 to 10 ft deep. (See Section 1.3.6) PGDP buried waste to 12 ft deep at SWMU 30. (See Section 1.3.7)

Stratigraphy. Like all other on-site BGOU SWMUs, the HU1 silt interval contains the burial cells of SWMUs 7 and 30. The base of HU1 is at a depth of 20 ft, approximately 8 ft below the deepest of the burial cells (SWMU 30). A single sand and gravel horizon, in a clay matrix, defines the underlying HU2 interval. The sand and gravel deposits commonly range between 5 and 10 ft thick. Silt and clay members, with a cumulative thickness of 20 to 35 ft, comprise the HU3 interval below SWMUs 7 and 30.

In the area of SWMUs 7 and 30, the RGA consists of an intermittent HU4 sand overlying 20 to 40 ft of the HU5 sand with gravel layers. The top of the RGA commonly occurs at depths of 45 to 60 ft (Figure 3.22, taken from DOE 1998a).

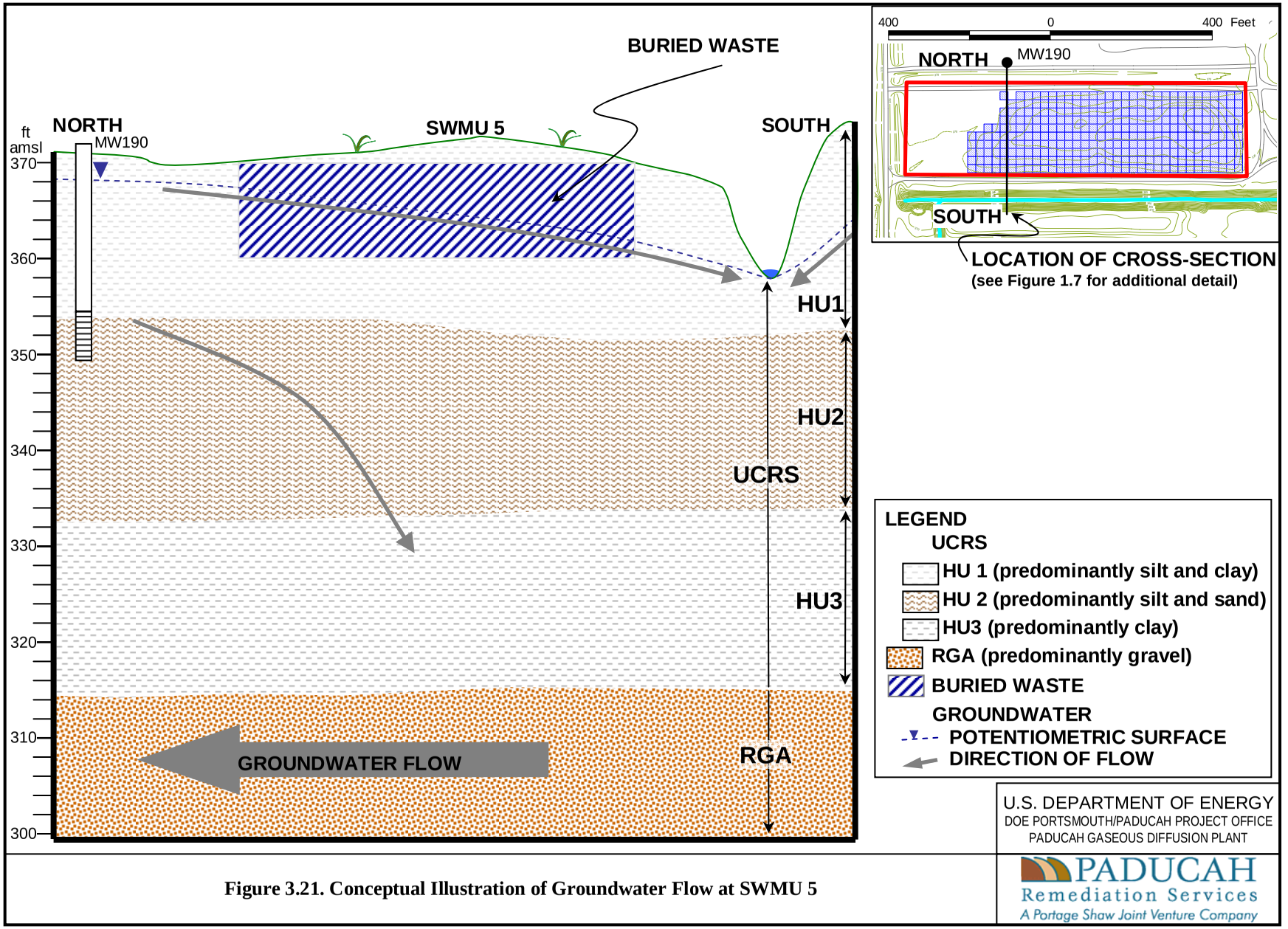
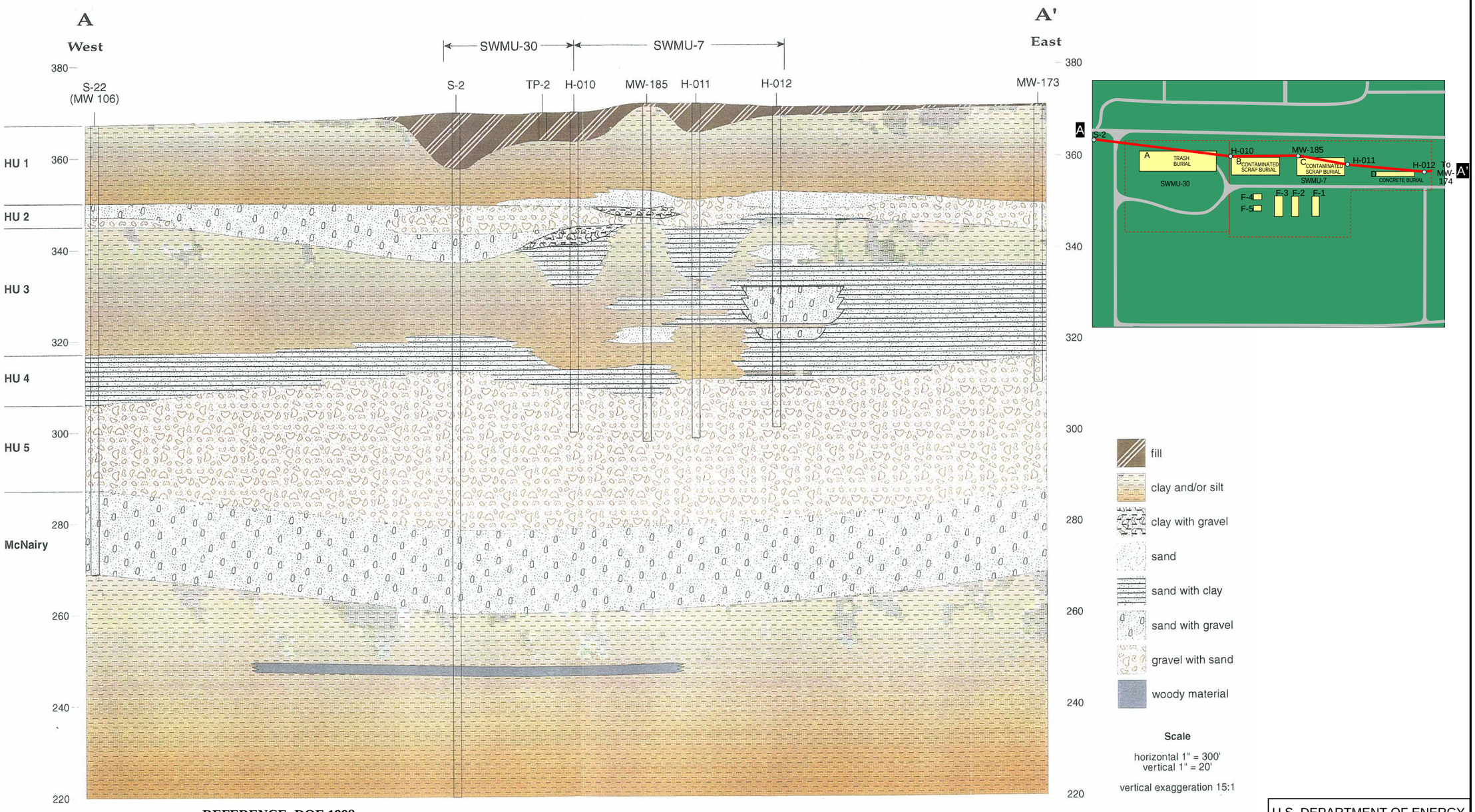


Figure 3.21. Conceptual Illustration of Groundwater Flow at SWMU 5



REFERENCE: DOE 1998c

Figure 3.22. SWMUs 7 and 30 Lithologic Cross-Section A-A'

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UCRS Groundwater Flow and Hydraulic Potential. The SWMUs 7 and 30 RI (DOE 1998a) determined that a shallow water table exists approximately 5 ft bgs (Figure 3.23) and within the burial cells. UCRS piezometer and well measurements documented a strong downward gradient within the area UCRS. The vertical downward hydraulic gradient is more than 10 times the lateral hydraulic gradient at SWMUs 7 and 30. This, along with lack of connectivity with shallow sand and gravel strata, leads to predominantly downward groundwater flow through the UCRS. These trends determine that dissolved contaminants from the burial grounds have potential to migrate into the RGA.

The elevation of the water table is above the elevation of the ditches that bound SWMUs 7 and 30 on the north and south sides;[4] however, neither ditch gains significant flow along the reaches adjacent to SWMUs 7 and 30. These observations indicate that the UCRS groundwater flow vector must be oriented steeply downward and that the area contributing infiltration to the ditches typically is limited to a thin border along the ditches.

RGA Groundwater Flow and Hydraulic Potential. The high-contamination core of the Northwest Plume passes beneath the west end of SWMU 7 in the RGA. All RGA flow in SWMUs 7 and 30 is to the northwest, as defined by the plume orientation. The south well field of the Northwest Plume containment system is located approximately 650 ft to the northwest of SWMU 7. A pumping test of EW231, an extraction well of the south well field, determines the hydraulic conductivity of the area RGA to be approximately 1,300 ft/day.

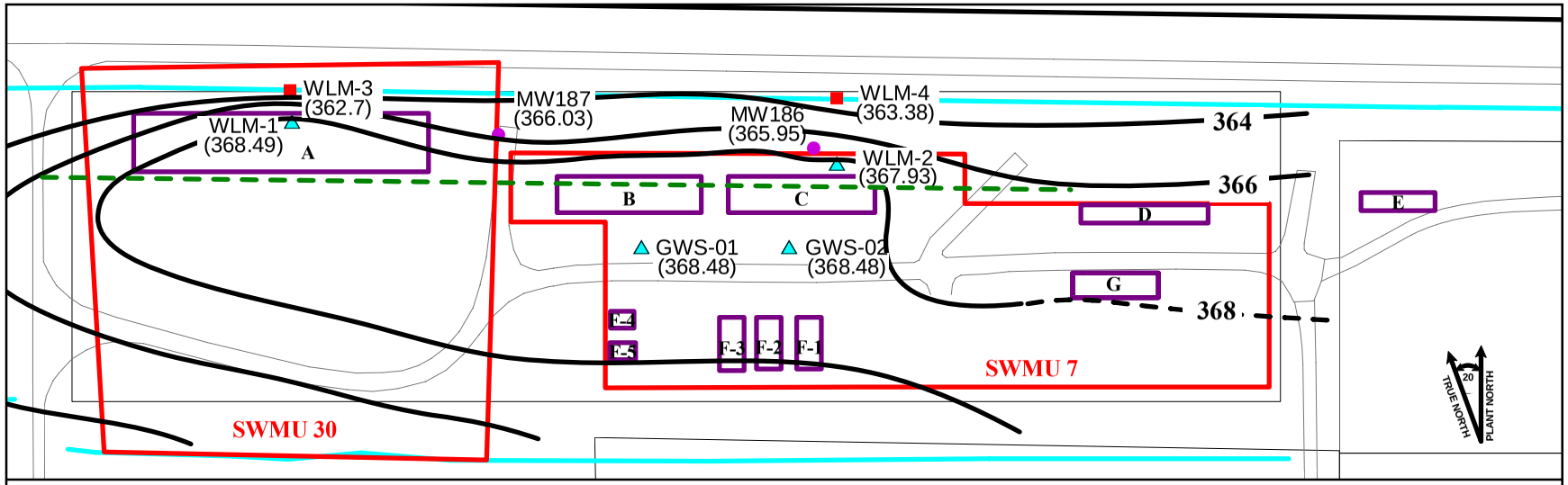
The TCE trend in MW66, located near the boundary between SWMUs 7 and 30, exhibits spikes that can be correlated with similar TCE spikes at MW248 in the south well field. The distance between the wells (650 ft) divided by the time lag between TCE "events" in MW66 and MW248 (6 months) defines the local groundwater flow rate to be 3.5 ft/d (Figure 3.24). Typical groundwater flow rates in the Northwest Plume are thought to range from 1 to 3 ft/day. The RGA groundwater flow velocity beneath SWMUs 7 and 30 is accelerated by groundwater extraction in the south well field.

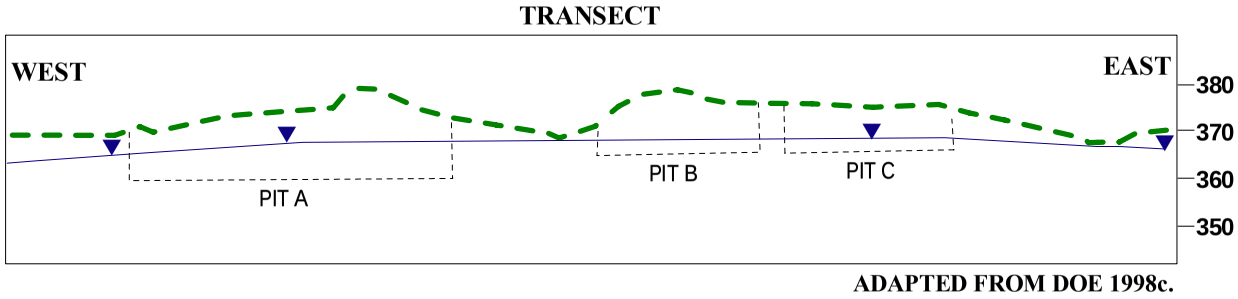
3.9.3.5 SWMU 145 hydrogeologic interpretation

Waste Disposal Background. The waste disposal practices of SWMU 145 (Area P) remain largely undocumented. Anecdotal evidence and historical aerial photographs are sufficient to show that PGDP contractors used the area for disposal of site-related construction debris as early as the construction period of the plant (circa 1952), continuing into the early 1980s. Approximately once a year, plant personnel moved the accumulated scrap into consolidated piles or earth depressions and, wherever practicable, covered them with dirt (Section 1.3.8). By 1973, the disposal area covered approximately 23 acres. Today the area underlies the C-746-S and -T Landfills complex, an area of 44 acres. Area P and the overlying C-746-S and -T Landfills complex form an isolated hill that rises 20 to 40 ft above the surrounding countryside, located 0.25 mile north of the PGDP industrial area.

Stratigraphy. The UCRS beneath SWMU 145 typically consists of a near continuous sequence of silt members down to the top of the RGA at depths of 40 to 60 ft. A thin (commonly less than 1 ft thick), intermittent, sand horizon at a depth of approximately 20 ft is the only vestige of the HU2 interval. The C-746-S and -T Landfills SI (DOE 2006c) determined that the top of the RGA has approximately 20 ft of relief (elevations of 310 to 330 ft) beneath SWMU 145. Where the RGA is deepest, the UCRS grades downward into a series of fine sand layers with silt interbeds overlying the RGA.

[4] The bottom elevation of the ditches on the north and south sides of SWMUs 7 and 30, as well as well and piezometer measurements within SWMUs 7 and 30 provided definitive control of the water table in those areas. The trends of the water table on the east and west ends of SWMUs 7 and 30 were assumed to resemble the land topography.





LEGEND:

- SWMU Boundary
- Burial pit - Work Plan (DOE 2006a)
- Water Level Contour
- Line of Transect
- Temporary Piezometer in UCRS
- UCRS Monitoring Well
- Staff Guage
- Water Table
- Ditch Center Line

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Figure 3.23. Plan View and Cross-section View of SWMUs 7 and 30 Illustrating the Relationship of the Water Table to the Waste Pits

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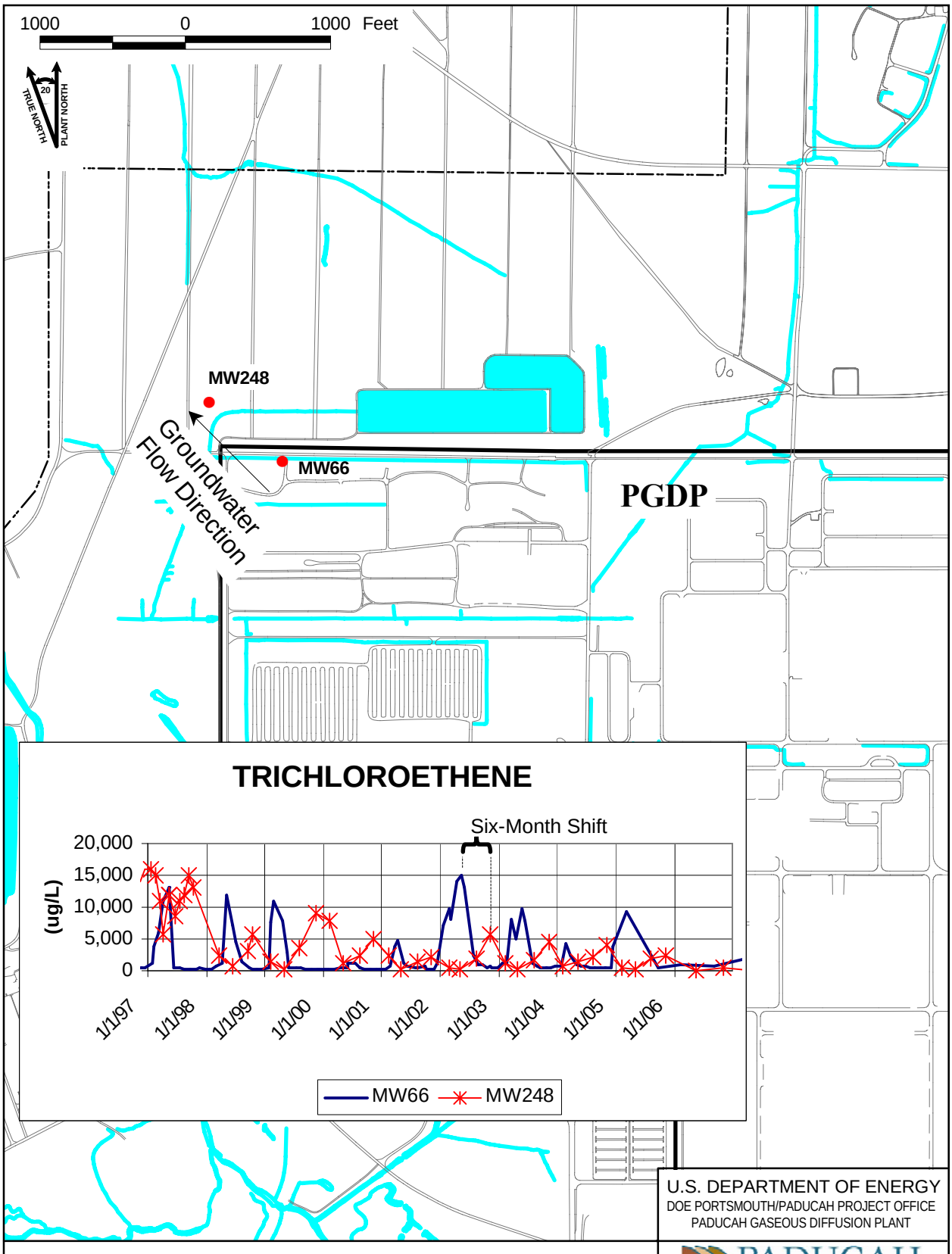

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Figure 3.24. Relationship of TCE Levels in MW66 and MW248

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Figure No. \BGOU\RI.apr
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An HU4 sand, averaging 5 ft thick, forms the top of the RGA. This, in turn, overlies 20 to 40 ft of gravely sand, made up of individual sand and gravel layers that range from 0.2 to 3.4 ft thick (Figure 3.25). The underlying McNairy Formation (top at an elevation of approximately 280 ft) consists of interbedded units of silt and fine sand.

UCRS Groundwater Flow and Hydraulic Potential. Water level elevations of shallow wells at SWMU 145 determine that a vertical hydraulic gradient of approximately 1 ft/ft is characteristic of the local UCRS (Figure 3.26). The area SI developed a conceptual water table map for the SWMU 145 area (Figure 3.27).[5] Lateral hydraulic gradients range from 0.03 to 0.12 ft/ft horizontally, as measured from the water table. The area SI analysis determined that lateral UCRS flow may be important where the horizontal hydraulic gradients are steepest, but that vertical flow predominates in the UCRS under most of SWMU 145.

RGA Groundwater Flow and Hydraulic Potential. The regional hydraulic gradient of the RGA in the SWMU 145 area is northward with a typical slope of 10^{-3} ft/ft. Water level measurements of RGA wells for the area SI documented the presence of a hydraulic potential mound beneath SWMU 145. The inferred groundwater flow directions, extending radially from SWMU 145 in the immediate vicinity of the burial ground, were consistent with trends of the direction of dissolved TCE contamination associated with the burial ground.

Groundwater modeling indicates that the hydraulic conductivity of the RGA in the area of SWMU 145 ranges between 200 to 500 ft/d. With the regional hydraulic gradient, average groundwater flow velocity in the RGA should range between 1 and 2 ft/d.

3.9.4 BGOU Hydrogeologic Conceptual Model

Observations from the BGOU RI are consistent with the following conceptual model of the flow system north of the Porters Creek Clay subcrop (Figure 3.28). A shallow water table exists in the area of the on-site BGOU SWMUs. The UCRS is saturated from the water table down. Groundwater flow through the UCRS (HU1, HU2, and HU3) is primarily downward to the top of the RGA (HU4 and HU5). This is due to vertical hydraulic gradients being much greater than lateral hydraulic gradients and also due to a lack of connectivity of the shallow sands and gravel units. Limited lateral dispersion results as groundwater and contaminants migrate vertically through the UCRS. The rate of vertical and horizontal movement (migration) is influenced by the physical properties of a particular contaminant including solubility, specific gravity, and the individual contaminant's affinity to adsorb to the surrounding soils and by the lithology of the individual HUs, most notably the HU1 interval, which contains the burial cells, and the HU3 interval, which serves as the upper semiconfining unit between the UCRS and the RGA. Once groundwater reaches the RGA, then the predominant flow is horizontal. The RGA serves as the primary exit pathway for groundwater from within the PGDP property boundary.

The previously known burial pits and waste cells are the sources of contamination identified in the shallow soils and UCRS groundwater of the BGOU SWMUs. Contaminants are migrating from the waste cells as a result of water infiltrating through the cells into the underlying soils and as a result of water migrating through potential secondary DNAPL sources at SWMU 4 (DOE 2007b) and SWMUs 7 and 30 (DOE 1998a). Once the contaminants reach the RGA, the rate of migration increases as a result of the higher hydraulic conductivity of the RGA sands and gravels. Regional groundwater flow is generally north to northwest in the RGA beneath the BGOU SWMUs.

[5] The elevation of the water table remains poorly documented at SWMU 145. Some buried waste at SWMU 145 is likely saturated.

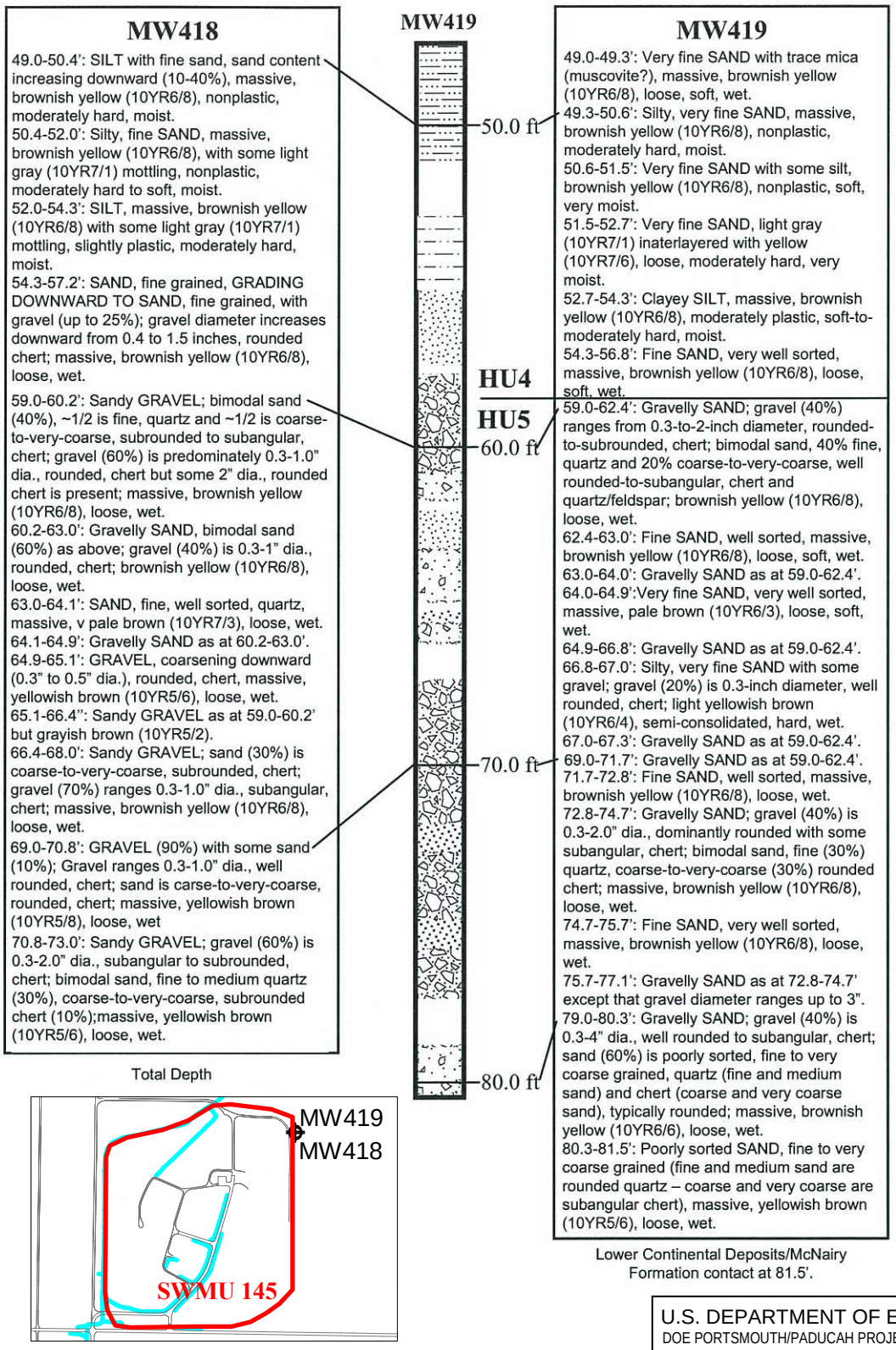

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Figure 3.25. Lower Continental Deposits Interval of Lithologic Logs for MW418 and MW419

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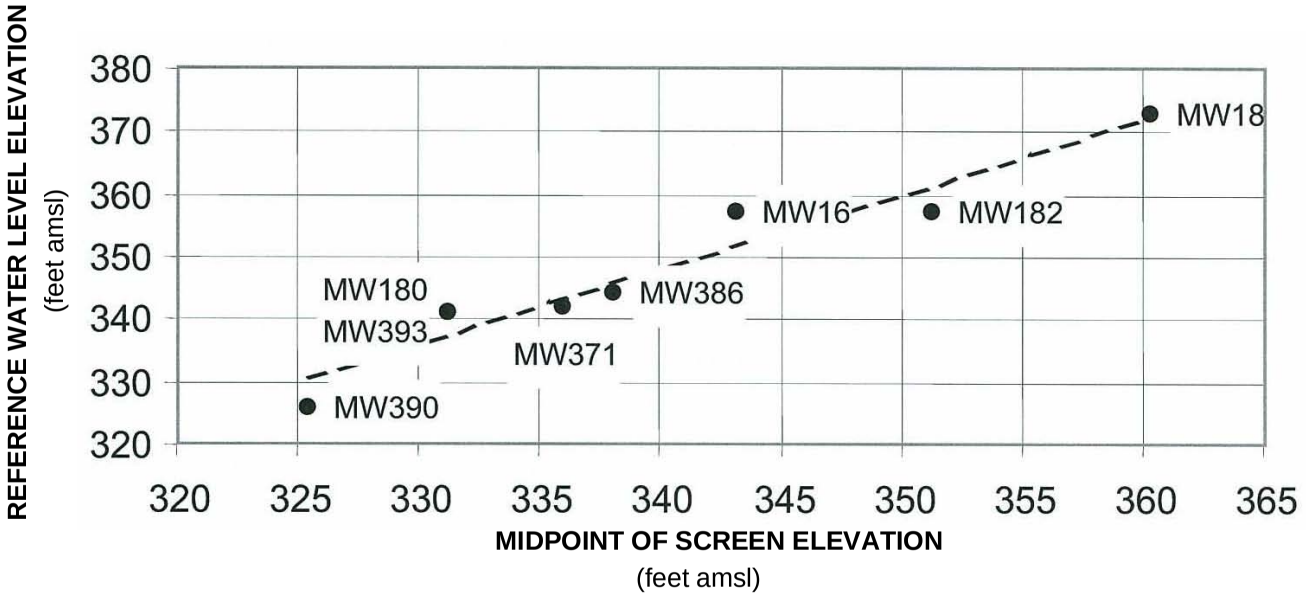

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Figure 3.26. UCRS Vertical Gradient

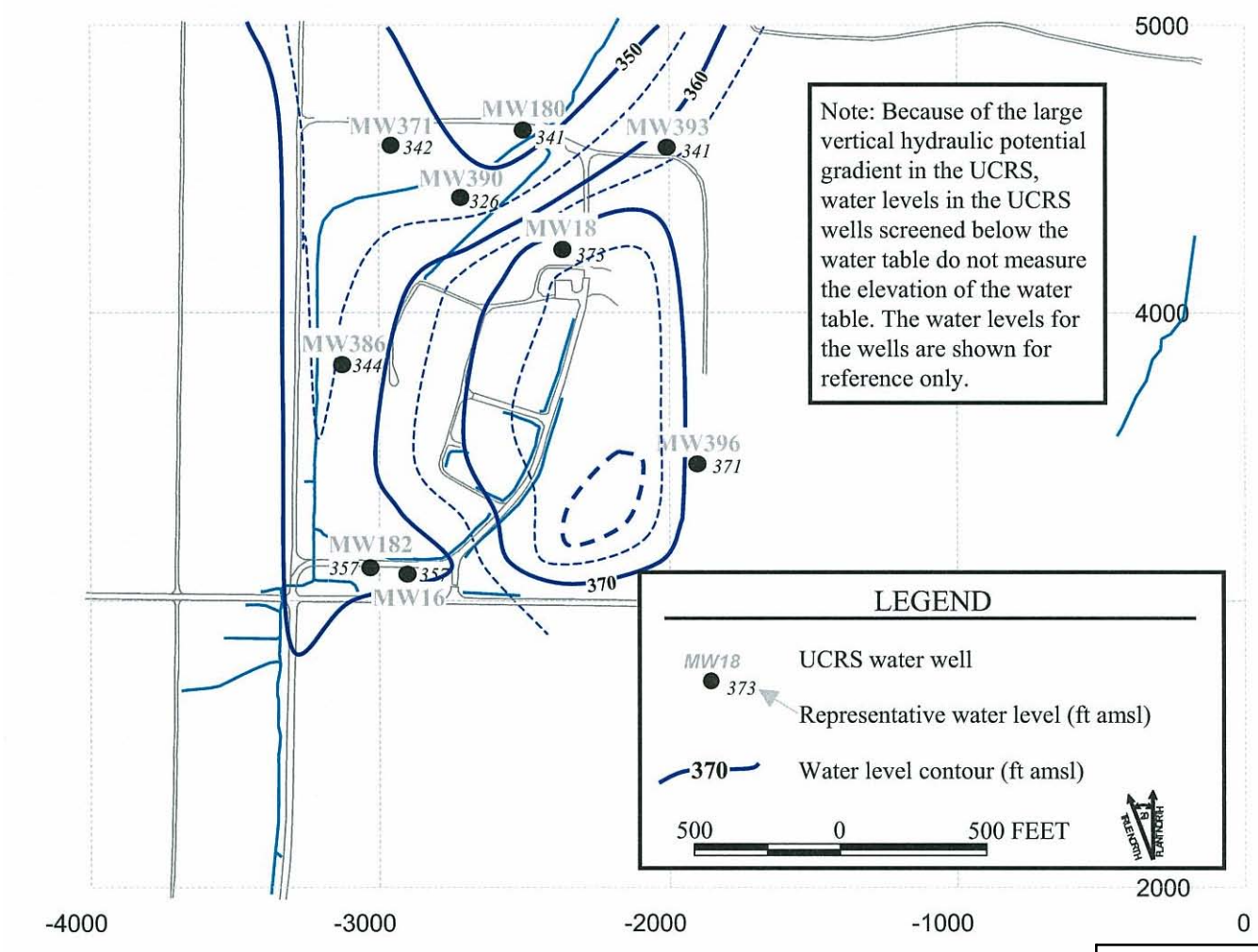

Figure 3.27. Conceptual Water Table Map in the Area of the C-746-S&-T Landfills Complex

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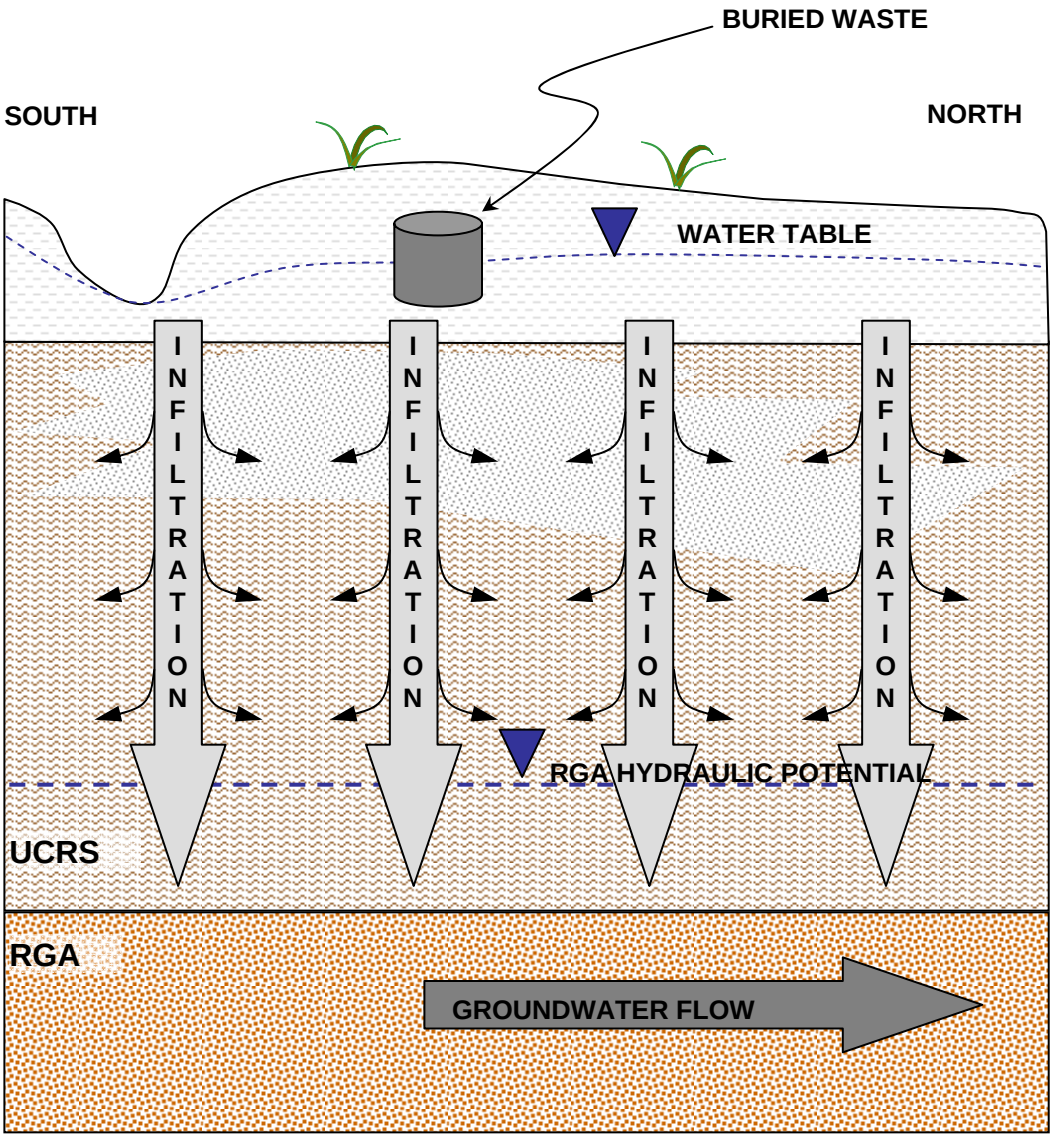

LEGEND

- UCRS (predominantly silt and clay)
- UCRS sand lens
- UCRS clay lens
- RGA (predominantly gravel)

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Figure 3.28. Conceptual Model of the Groundwater Flow System

For SWMU 4, the evidence of DNAPL presence is markedly higher dissolved TCE levels (commonly 1,000 to 4,000 µg/L) in the RGA on the west (downgradient) side of the SWMU. The area of higher TCE levels in the RGA spans the entire western side of SWMU 4, suggestive of a diffuse source of DNAPL contamination in the UCRS soils underlying the burial grounds. Subsurface soil samples also show TCE contamination near the southern burial pit. A discrete area of 10,000 µg/L in the lower RGA also implies the presence of a small pool of DNAPL (zone of higher DNAPL saturation) at the base of the RGA. Figure 3.29, taken from the Southwest Plume SI (DOE 2007b), summarizes the dissolved TCE levels in the RGA on the west side of SWMU 4.

MW66 is an upper RGA well[6] located near the shared boundary of SWMUs 7 and 30. The analyses of groundwater samples from MW66 reveal abrupt rises of dissolved TCE (Figure 3.30) that commonly occur in the first half of the calendar year, when RGA water levels are highest. In other words, there is a strong correlation of TCE spikes with periods of high hydraulic head. (TCE spikes often exceed 10,000 µg/L.) This suggests that when RGA hydraulic head is high, more TCE in the lower UCRS is dissolved into UCRS groundwater, which then moves downward into the RGA. These high-TCE events typically are limited to years where RGA water level exceeds 324 ft amsl.

In MW66, the contact of the RGA and the overlying UCRS soils occurs at an approximate elevation of 318 ft amsl. The relationship between abrupt rises in TCE levels and high RGA water levels indicates the likely presence of a DNAPL source zone near the boundary of SWMUs 7 and 30 at an elevation of 324 ft amsl, in the silt/clay horizon that overlies the RGA.

[6] MW66 is constructed with a 5-ft length well screen installed over the interval 308 to 313 ft amsl.

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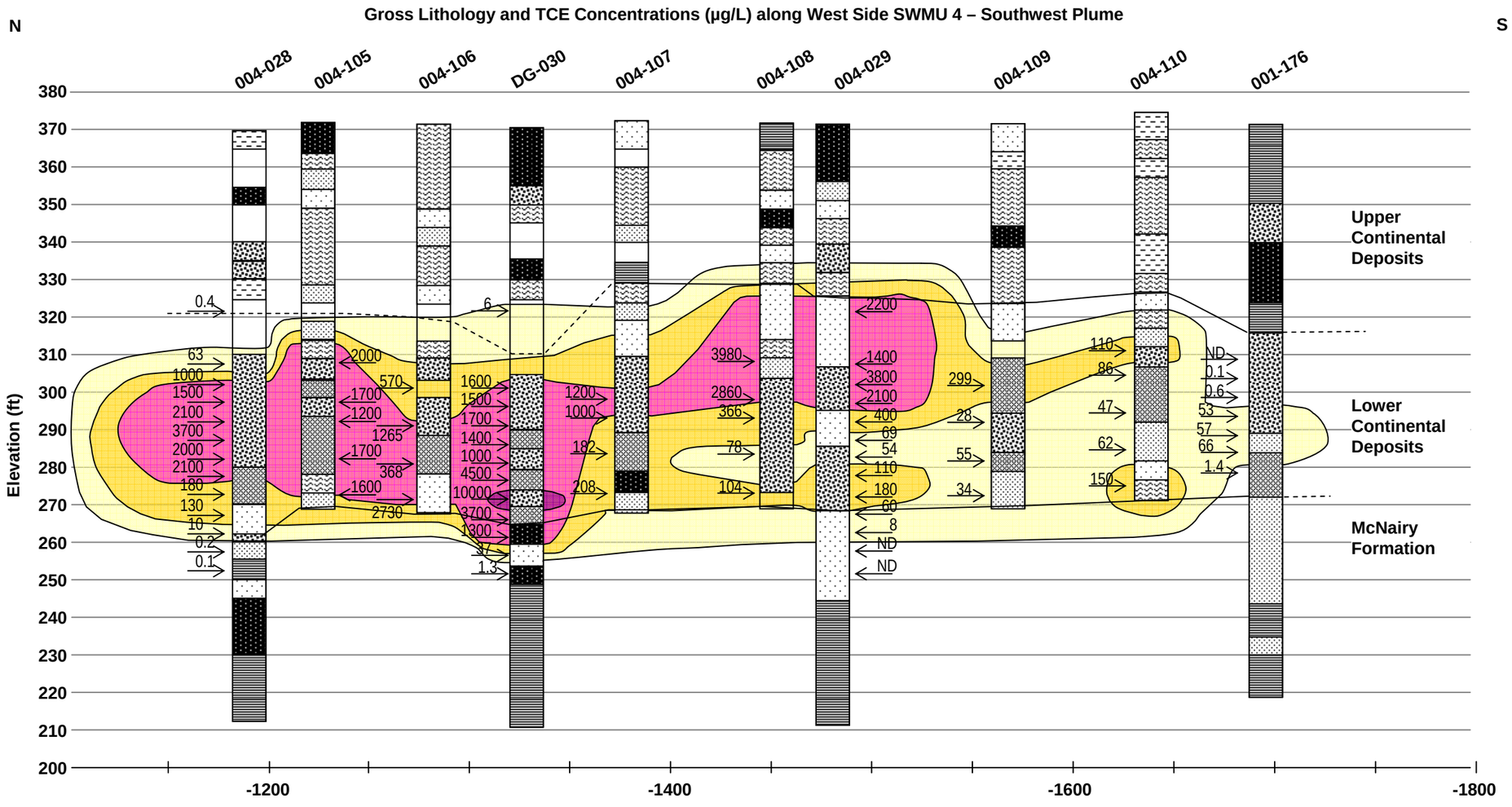
Gross Lithology and TCE Concentrations (µg/L) along West Side SWMU 4 – Southwest Plume



LEGEND

		Interpreted TCE Depiction
Sand	Clay	5- 100 µg/L
Fine Sand	Coarse Sand	100- 1,000 µg/L
Clayey Silt	Gravelly Sand	1,000- 10,000 µg/L
Silt	Stiff Clay	> 10,000 µg/L

001-176 sampled in June 1998;
004-028, DG-030, 004-029 sampled during WAG 3, Summer 1999;
All other data from SW Plume SI, Summer 2004

REFERENCE: DOE 2007d

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Figure 3.29. TCE Distribution within the RGA Downgradient of SWMU 4

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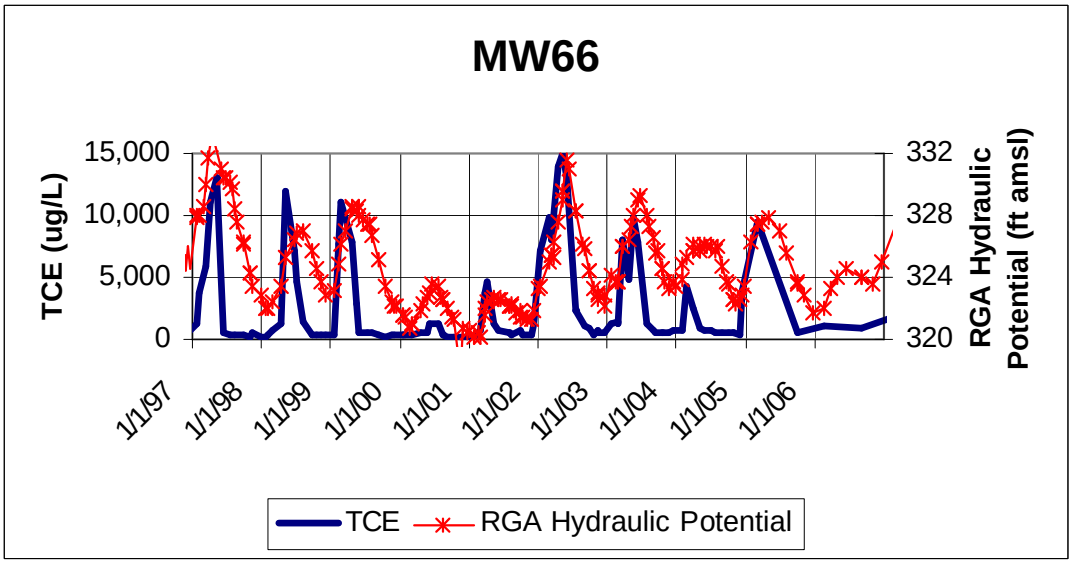

Figure 3.30. TCE Trends in MW66

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4. NATURE AND EXTENT OF CONTAMINATION

The SWMUs comprising the BGOU consist primarily of landfills and below ground burial cells in which various PGDP wastes have been placed. Infiltration descending through the buried waste could mobilize contaminants within the waste. Once mobilized, the most likely pathway of the contaminants would be downward through the UCRS soils, ultimately reaching the RGA (based on the hydrogeologic conceptual model presented in Chapter 3). Some lateral movement of contaminants would occur in the UCRS, but these pathways appear limited since the vertical hydraulic gradient is dominant and connectivity of the shallow sands and gravels also is limited.

Based on this conceptual model, any contamination resulting from buried waste found at the BGOU SWMUs would be expected to be found concentrated in the UCRS soils and groundwater immediately within and under the burial cells and landfills, with a lesser amount of contamination dispersed laterally from the cells. The emphasis of the BGOU RI was the evaluation of samples collected from angled soil borings to characterize the potential contaminants leaking from the bottoms of the cells. This chapter provides an assessment of data from the BGOU RI along with data from historical investigations to evaluate the nature and extent of contamination (vertical and lateral) associated with the BGOU SWMUs.

Environmental data from the BGOU RI field activities were merged with the historical data set used for development of the BGOU RI Work Plan (DOE 2006a). This data set is of sufficient quality to address the data needs identified during the DQO process. These data have been compiled and screened to identify COPCs to be addressed in the evaluation of the nature and extent of contaminants. This chapter presents summary tables containing analytical results for each of the sites (tables that show sample borings and depths only provide results above screening levels) and figures depicting the locations of the samples. Duplicate analyses do not appear in the summary tables. Appendix C provides a complete report of analytical results for all samples collected during this investigation and the historical data set in a searchable database on compact disk. Appendix D provides three-dimensional figures for various contaminants. Several of these key figures are presented in this chapter.

This report assesses the extent of contamination based on the presence of contaminants in subsurface soils (below 1 ft bgs) and UCRS and RGA groundwater. Samples from these media were analyzed for suites of constituents and reported as the following analytical groups: VOCs, semivolatile organic compounds (SVOCs), PCBs, metals, and radionuclides. The pathway for surface water contamination will be addressed further, as needed, in the FS.

An understanding of the potential releases is key to the rationale behind the sampling that was performed during the BGOU RI. Section 1.3 presents descriptions of the known processes and possible releases from each site that may have contributed to the nature and extent of contaminants.

4.1 DATA PROCESSING AND SCREENING

One objective of the data processing and screening of this RI was to identify potential site-related contaminants and delineate the vertical and horizontal extent of these potential contaminants. To achieve this goal, the RI compared the analytical results of this RI and historical data to PGDP media-specific

background concentrations[1, 2] and applicable screening values.[3] Where more than one screening value existed for groundwater analytes, the maximum screening value was used to limit the number of contaminants presented in the nature and extent assessment while remaining inclusive of risk-based criteria. Those analytes with no applicable screening value are not discussed in this section. Seven analytes known to be essential nutrients and known to be toxic only at extremely high concentrations were removed from the selection of contaminants in the groundwater data set. These analytes were calcium, chloride, iodine, magnesium, phosphorus, potassium, and sodium.

Data processing and screening for the BGOU were conducted as a multiphase process. First, data were screened to eliminate those sample results that were less than the minimum detection limit (or, in the case of radionuclides, did not exceed the total propagation error). These data then were compared with screening levels.[4] Screening levels for subsurface soil consisted of background levels at PGDP and risk-based no action levels (NALs) for the excavation worker as compiled from the Risk Methods Document (DOE 2001). (The COPC screening for groundwater fate and transport modeling compared analyte levels in subsurface soil against PGDP-specific Soil Screening Levels.) Groundwater samples with analytes above detection limits were compared to maximum contaminant levels (MCLs), if available, for specific chemicals. Risk-based child resident NALs were used to screen compounds or analytes that did not have an MCL. Additionally, background groundwater values for the RGA and McNairy were used for screening against their respective results. The combined data set of soil and groundwater analyses of the BGOU RI and related historical data is sufficient to address the goals of the BGOU RI (see Table 7.1).

Tables 4.1 through 4.4 contain the soil and groundwater standards used to screen BGOU data for the nature and extent assessment. If an analyte was detected at a level higher than these screening values, it was considered a contaminant for evaluation of nature and extent. (Section 6, Baseline Risk Assessment, continues the assessment of hazard associated with the COPCs. Appendix F explains the more thorough COPC screening process used in the risk assessment.) The following sections in this chapter discuss the contaminants found in the BGOU, using both historical and RI data.

Table 4.1. Background Values[a] for Subsurface Soils (DOE 2001)

Analytical Compound	Subsurface Soil Background Data (mg/kg or pCi/g)
Aluminum	12,000
Antimony	0.21
Arsenic	7.9
Barium	170
Beryllium	0.69
Boron	NA
Cadmium	0.21

[1] PGDP background levels for water drawn from the RGA and McNairy Formation are provisional values that are subject to change. Potential concerns regarding the background levels are the data set from which these values were derived and the statistical methods that were used to analyze the data set.
[2] Background values were unavailable for UCRS groundwater.
[3] For UCRS and RGA groundwater, the applicable screening criteria were MCLs, and child residence No Action Levels (and RGA background for RGA samples) (Tables 4.3 and 4.4). For subsurface soils, the applicable screening criteria were background (Table 4.1) and excavation worker No Action Levels (Table 4.2). The identification of analytes for groundwater fate and transport modeling (Section 5) screened the subsurface soils against PGDP-specific Soil Screening Levels.
[4] The data used to define analytes for the assessment of nature and extent (this section) and the risk assessment (Section 6 and Appendix F) differ. The nature and extent assessment includes all available subsurface soil (>1 ft depth) analyses within a SWMU while the risk assessment addresses soils of 10 ft depth or less (the excavation worker receptor). For groundwater, the nature and extent assessment is based on groundwater analyses within a SWMU while the risk assessment is based on modeled groundwater contaminant levels at the SWMU and at downgradient points of exposure.

Table 4.1. Background Values[a] for Subsurface Soils (DOE 2001) (Continued)

Analytical Compound	Subsurface Soil Background Data (mg/kg or pCi/g)
Calcium	6,100
Chromium	43
Chromium, hexavalent	NA
Cobalt	13
Copper	25
Cyanide	NA
Iron	28,000
Lead	23
Lithium	NA
Magnesium	2,100
Manganese	820
Mercury	0.13
Molybdenum	NA
Nickel	22
Potassium	950
Selenium	0.7
Silica	NA
Silver	2.7
Sodium	340
Strontium	NA
Thallium	0.34
Uranium (metal)	4.6
Vanadium	37
Zinc	60
Americium-241	NA
Cesium-137	0.28
Cobalt-60	NA
Neptunium-237	NA
Protactinium-233*	NA
Plutonium-238	NA
Plutonium-239	NA
Plutonium-239/240*	NA
Potassium-40	16
Protactinium-234m	NA
Radium	NA
Radium-226	1.5
Radon-222	NA
Strontium-90	NA
Technetium-99	2.8
Thorium-230	1.4
Thorium-234	NA

Table 4.1. Background Values[a] for Subsurface Soils (DOE 2001) (Continued)

Analytical Compound	Subsurface Soil Background Data (mg/kg or pCi/g)
Uranium (total)	NA
Uranium-233/234*	2.4
Uranium-234	2.4
Uranium-235	0.14
Uranium-235/236*	0.14
Uranium-238	1.2

[a]The PGDP studies of background levels for soils are *Background Concentrations and Human Health Risk-based Screening Criteria for Metals in Soil at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1417&D1 (DOE 1995c) and *Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1586&D2 (DOE 1997c).
*NOTE: Data for the undifferentiated isotopes neptunium-237/protactinium-233, plutonium-239/240, uranium-233/234, and uranium-235/236 were compared to the background values for neptunium-237, plutonium-239, uranium-234, and uranium-235, respectively.
NA = not available

Table 4.2. Risk-Based No Action Levels Used in BGOU Soil Screening (DOE 2001)

Chemical	No Action Level	Chemical	No Action Level
Inorganics (mg/kg)		***Radionuclides (pCi/g)***	
Antimony	0.492	Americium-241	1.74
Arsenic	0.324	Cobalt-60	0.0238
Beryllium	1.26	Cesium-137+Daughters	0.0858
Cadmium (Diet)	15.2	Neptunium-237+Daughters	0.271
Chromium (III) (Insoluble Salts)	476	Plutonium-238	11.7
Chromium (Total)	476	Plutonium -239	11.5
Chromium VI (particulates)	3.69	Plutonium -240	11.5
Copper	427	Radium-226+Daughters	0.0256
Iron	2,170	Radon-222+Daughters	33,900,000
Lead	50	Strontium-90+Daughters	7.44
Manganese	56.6	Technetium-99	362
Mercury	1.17	Thorium-228+Daughters	0.028
Molybdenum	66	Thorium -230	14.9
Nickel Soluble Salts	216	Thorium -232	13.5
Selenium	71.3	Uranium-234	19.8
Silver	41.2	Uranium -235+Daughters	0.395
Thallium (Thallium Chloride)	0.711	Uranium -238+Daughters	1.71
Uranium	11.3	Plutonium-239/240	11.5
Vanadium	4.4	Uranium-235/236	0.395
Zinc	2,660		
Organics (mg/kg)			
Acenaphthene	350	Fluorene	338
Acrylonitrile	0.248	HpCDD, 2,3,7,8-	0.000349
Anthracene	3340	HpCDF, 2,3,7,8-	0.000349
PCB-1016	0.168	HxCDD, 2,3,7,8-	0.0000349
PCB-1221	0.168	HxCDF, 2,3,7,8-	0.0000349
PCB-1232	0.168	Indeno[1,2,3-cd]pyrene	0.232
PCB-1242	0.168	Naphthalene	30.4
PCB-1248	0.168	OCDD	0.00349
PCB-1254	0.168	OCDF	0.00349
PCB-1260	0.168	PeCDD, 2,3,7,8-	0.00000699
Benz(a)anthracene	0.232	PeCDF, 1,2,3,7,8-	0.00000699
Benzene	1.4	PeCDF, 2,3,4,7,8-	0.0000699
Benzo(a)pyrene	0.0232	Phenanthrene	No value
Benzo(b)fluoranthene	0.232	Total PCBs (high risk)	0.168
Benzo(k)fluoranthene	2.32	Total PCBs (lowest risk)	4.81
Carbon Tetrachloride	0.51	Total PAHs	0.0232
Chloroform	0.166	Pyrene	181
Chrysene	23.2	TCDD, 2,3,7,8-	0.00000349
Dibenz(a,h)anthracene	0.0232	TCDF, 2,3,7,8-	0.0000349
1,1-DCE	0.119	Tetrachloroethylene	4.04
1,2-DCE	68.2	TCE	3.25
cis-1,2-DCE	17.1	Vinyl Chloride	0.141
trans-1,2-DCE	28.4	Xylene, Mixture	963
Ethylbenzene	28.7	Xylene, m-	5,560
Fluoranthene	242	Xylene, o-	5,590

Table 4.3. Background Values for Groundwater Drawing from the RGA and McNairy Formation[a] at PGDP (DOE 2001)

	(mg/L or pCi/L)	
Analytical Compound	**RGA**	**McNairy**
Aluminum	2.189	0.687
Aluminum, Dissolved	0.311	0.579
Antimony	0.060[b]	0.060[b]
Antimony, Dissolved	0.060[b]	0.060[b]
Arsenic	0.005[b]	0.005[b]
Arsenic, Dissolved	0.005[b]	0.005[b]
Barium	0.235	0.296
Barium, Dissolved	0.2	0.268
Beryllium	0.004[b]	0.017[b]
Beryllium, Dissolved	0.004[b]	0.004[b]
Cadmium	0.010[b]	0.010[b]
Cadmium, Dissolved	0.010[b]	0.010[b]
Calcium	41.238	38.858
Calcium, Dissolved	38.166	38.829
Chloride	91.021	19.708
Chromium	0.144	0.060[b]
Chromium, Dissolved	0.050[b]	0.050[b]
Cobalt	0.045[b]	0.096
Cobalt, Dissolved	0.045[b]	0.045[b]
Copper	0.036	0.057
Copper, Dissolved	0.02	0.013[b]
Fluoride	0.27	0.33
Iron	5.03	18.36
Iron, Dissolved	0.267	12.372
Lead	0.129	0.050[b]
Lead, Dissolved	0.098	0.050[b]
Magnesium	16.262	13.418
Magnesium, Dissolved	16.215	14.171
Manganese	0.119	0.941
Manganese, Dissolved	0.068	0.894
Mercury	0.0002[b]	0.0002[b]
Mercury, Dissolved	0.0002[b]	0.0002[b]
Molybdenum	0.050[b]	0.050[b]
Molybdenum, Dissolved	0.050[b]	0.050[b]
Nickel	0.682	0.109[b]
Nickel, Dissolved	0.305	0.050[b]
Nitrate as Nitrogen	15.561	1.474
Potassium	5.195	55.752
Potassium, Dissolved	4.096	51.205
Selenium	0.005[b]	0.005[b]
Selenium, Dissolved	0.005[b]	0.005[b]
Silica	26.401	36
Silver	0.011[b]	0.050[b]
Silver, Dissolved	0.060[b]	0.050[b]
Sodium	59.45	29.2
Sodium, Dissolved	60.433	27.98
Sulfate	19.947	28.9
Thallium	0.056[b]	0.644
Thallium, Dissolved	0.056[b]	0.056[b]
Uranium	0.002[b]	0.001[b]
Uranium, Dissolved	0.002[b]	0.001

Table 4.3. Background Values for Groundwater Drawing from the RGA and McNairy Formation[a] at PGDP (DOE 2001) (Continued)

	(mg/L or pCi/L)	
Analytical Compound	**RGA**	**McNairy**
Vanadium	0.134	0.126
Vanadium, Dissolved	0.134	0.126
Zinc	0.054	0.142
Zinc, Dissolved	0.049	0.116
Gross Alpha	5.8	11.9
Gross Beta	13.8	144.5
Neptunium-237	0.8	0.5
Plutonium-239	0.1	0.2
Radium-226	0.6	1.2
Radon-222	626	295
Techntium-99	22.3	20.6
Thorium-230	1.1	1.5
Total Radium	1.3	0.7
Uranium-234[c]	0.7	0.3
Uranium-235[c]	0.3	0.2
Uranium-238[c]	0.7	0.3

[a] Values are for those derived over all observations.
[b] Background value was derived qualitatively over all observations because analyte was never detected or was detected infrequently at a concentration near the analyte's detection limit.
[c] Uranium isotopic concentrations were derived from the mass concentration of uranium.

Table 4.4. Groundwater MCLs and Child Resident No Action Levels Used in BGOU Screening

Analytical Compound	**MCL (mg/L)**	**Child Resident No Action Level (mg/L)[a]**
Inorganics		
Antimony[b]	0.006	0.000564
Arsenic[b]	0.010	0.000035
Barium	2	0.104
Beryllium	0.004	0.00264
Cadmium	0.005	0.000661
Chromium[b]	0.1	1.76
Copper	1.3	0.0557
Cyanide	0.2	0.0284
Fluoride	4.0	No value
Iron	No MCL	0.449
Lead	0.015	0.015
Manganese	No MCL	0.035
Mercury[b]	0.002	0.000444
Molybdenum	No MCL	0.00753
Nickel[b]	No MCL	0.0301
Nitrate	10	2.14
Nitrite	1	0.151
Selenium	0.05	0.00754
Silver	No MCL	0.0075
Thallium[b]	0.002	0.00012

Table 4.4. Groundwater MCLs and Child Resident No Action Levels Used in BGOU Screening (Continued)

Analytical Compound	MCL (mg/L)	Child Resident No Action Level (mg/L)
Uranium	0.03	0.000906
Vanadium	No MCL	0.00925
Zinc	No MCL	0.45
Organics		
Acenaphthene	No MCL	0.0136
Acrylonitrile	No MCL	0.0000426
Anthracene	No MCL	0.0766
Benz(a)anthracene	No MCL	0.0000132
Benzene	0.005	0.000385
Benzo(a)pyrene	0.002	0.000000951
Benzo(b)fluoranthene	No MCL	0.00000951
Benzo(k)fluoranthene	No MCL	0.000168
Carbon tetrachloride	0.005	0.000181
Chloroform	No MCL	0.0000287
Chrysene	No MCL	0.00132
Chlorobenzene	0.1	0.00466
Dibenz(a,h)anthracene	No MCL	0.000000456
Dioxins/Furans (Total)	No MCL	6.09E-11
o-Dichlorobenzene	0.6	0.0166
p-Dichlorobenzene	0.075	0.000578
1,2-Dichloroethane	0.005	0.000147
1,1-DCE	0.007	0.000047
1,2-DCE	No MCL	0.00247
cis-1,2-DCE	0.07	0.00273
trans-1,2-DCE	0.1	0.00548
Methylene chloride	0.005	0.00426
Bis(2-ethylhexyl)phthalate	0.006	0.00312
Ethylbenzene	0.7	0.00468
Fluoranthene	No MCL	0.0226
Fluorene	No MCL	0.00972
Heptachlor	0.0004	0.0000114
HpCDD, 2,3,7,8-	No MCL	5.45E-09
HpCDF, 2,3,7,8-	No MCL	3.51E-08
HxCDD, 2,3,7,8-	No MCL	3.51E-09
HxCDF, 2,3,7,8-	No MCL	3.51E-09
Indeno(1,2,3-cd)pyrene	No MCL	0.00000631
Naphthalene	No MCL	0.000285
OCDD	No MCL	1.91E-08
OCDF	No MCL	2.03E-08
PeCDD, 2,3,7,8-	No MCL	2.5E-10
PeCDF, 1,2,3,7,8-	No MCL	1.48E-10
PeCDF, 2,3,4,7,8-	No MCL	1.29E-09
Total PCBs [b]	0.0005	0.0000793
PCB-1016	Total PCB applies	0.0000468
PCB-1221	Total PCB applies	0.000112
PCB-1232	Total PCB applies	0.000128
PCB-1242	Total PCB applies	0.000123
PCB-1248	Total PCB applies	0.0000775
PCB-1254	Total PCB applies	0.0000194
PCB-1260	Total PCB applies	0.0000428
Total PAHs	No MCL	0.000000951
Pyrene	No MCL	0.0182
TCDD, 2,3,7,8-	No MCL	6.09E-11
TCDF, 2,3,7,8-	No MCL	1.6E-09
Tetrachloroethene	0.005	0.000582

Table 4.4. Groundwater MCLs and Child Resident No Action Levels Used in BGOU Screening (Continued)

Analytical Compound	MCL (mg/L or pCi/L)	Child Resident No Action Level (mg/L or pCi/L)
Toluene	1	0.0338
1,2,4-Trichlorobenzene	0.07	0.00781
1,1,1-Trichloroethane	0.2	0.0335
1,1,2-Trichloroethane	0.005	0.000238
TCE	0.005	0.0016
Vinyl chloride	0.002	0.000035
Total Xylene	10	0.0653
m,p-Xylene	10	0.439
1,3-Dimethylbenzene	10	0.439
Radionuclides		
Americium-241	No MCL	0.371
Cobalt-60	No MCL	2.46
Cesium-137	No MCL	1.27
Neptunium-237	No MCL	0.573
Plutonium-238	No MCL	0.295
Plutonium-239	No MCL	0.286
Plutonium-240	No MCL	0.286
Radium-226	5	0.1
Radon-222	No MCL	0.866
Strontium-90	No MCL	0.522
Technetium-99	No MCL	14
Thorium-228	No MCL	0.129
Thorium-230	No MCL	0.424
Thorium-232	No MCL	0.382
Uranium-234[c]	0.030 mg/L	0.546
Uranium-235[c]	0.030 mg/L	0.538
Uranium-238[c]	0.030 mg/L	0.443

[a]NALs were taken from Table A.18 of the PGDP Risk Methods Document (2001) for PGDP Primary COPCs.
[b]These NALs were used for the following compounds with more than 1 NAL listed in Table A.18 of the PGDP Risk Methods Document (2001): Antimony (metallic); Arsenic, inorganic; Chromium (total); Mercury, inorganic salts; Nickel soluble salts; Thallium chloride; Total PCBs (low risk)
[c]The MCL for uranium is 0.030 mg/L (activity will vary depending on the specific isotope)
MCL = maximum contaminant level

4.2 SOURCES OF CONTAMINATION

Previous modeling has determined radionuclides such as technetium-99 (^{99}Tc), neptunium-237 (^{237}Np), plutonium-239 (^{239}Pu), uranium-234 (^{234}U), uranium-235 (^{235}U), and uranium-238 (^{238}U); VOCs such as TCE, 1,1-DCE, vinyl chloride, 1,2-DCE, carbon tetrachloride, and chloroform; metals; and some SVOCs as contributing to groundwater contamination. The COPCs from previous modeling for each SWMU are listed in Table 4.5. There was no previous modeling at SWMU 145.

Table 4.5. Summary of Historical Modeling Results

Location	Chemicals of Potential Concern Determined by Historical Groundwater Modeling
SWMU 2	TCE and other VOCs (*cis*-1,2-DCE and vinyl chloride) ^{99}Tc
SWMU 3	^{99}Tc and naphthalene
SWMU 4	VOCs (TCE; 1,1-DCE; vinyl chloride; 1,2-DCE; carbon tetrachloride, and chloroform), metals (arsenic, cobalt, copper, iron, and manganese), and radionuclides (^{237}Np, ^{239}Pu, ^{99}Tc, ^{234}U, ^{235}U, and ^{238}U).
SWMU 5	1,1-DCE; naphthalene; manganese; iron; and ^{99}Tc
SWMU 6	^{99}Tc and iron
SWMUs 7 and 30	^{99}Tc and vinyl chloride

Figures 4.1 through 4.16 present locations of all historical and RI sampling for soils and groundwater.

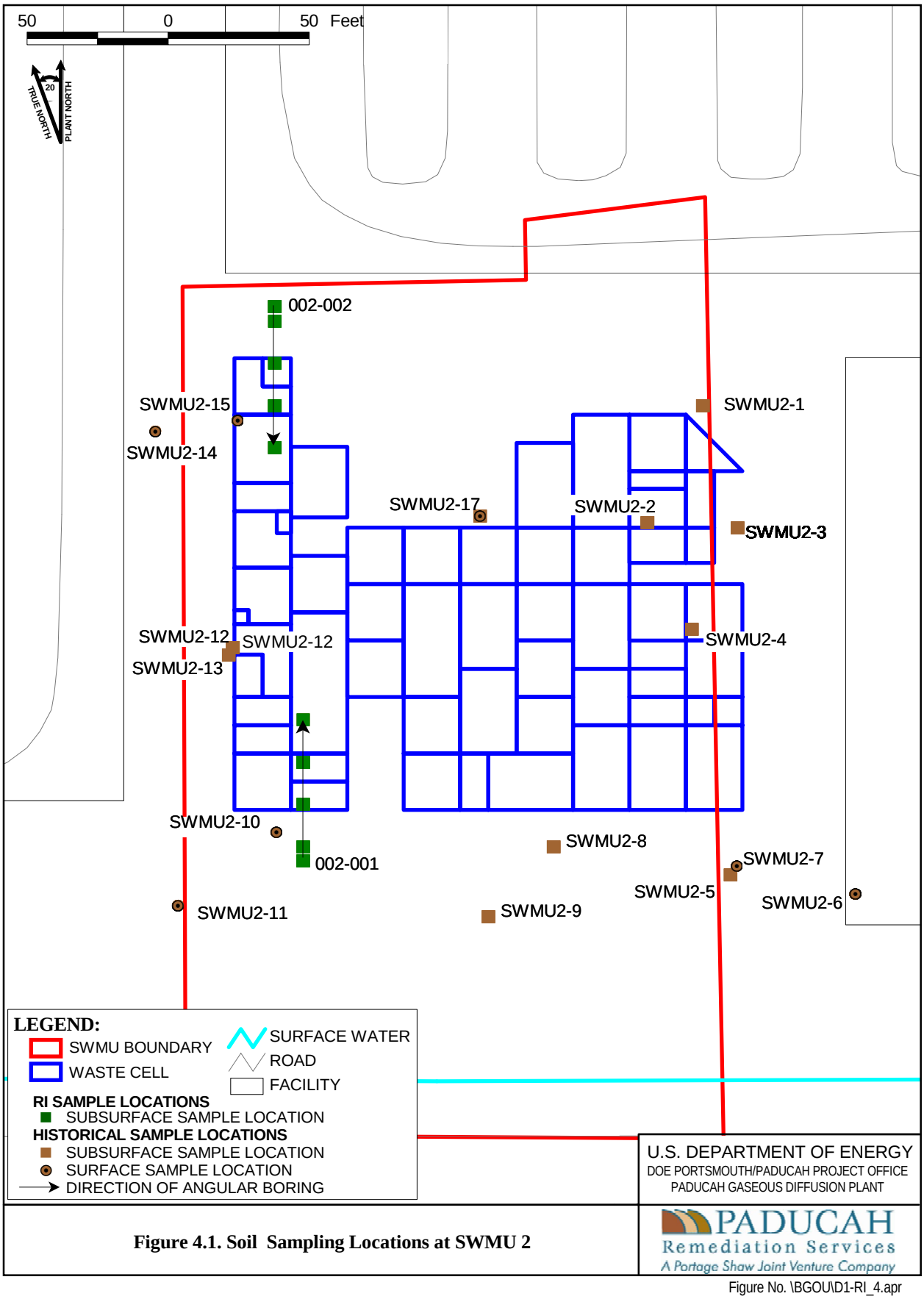

Figure 4.1. Soil Sampling Locations at SWMU 2

Figure No. \BGOU\D1-RI_4.apr
DATE 05-21-08

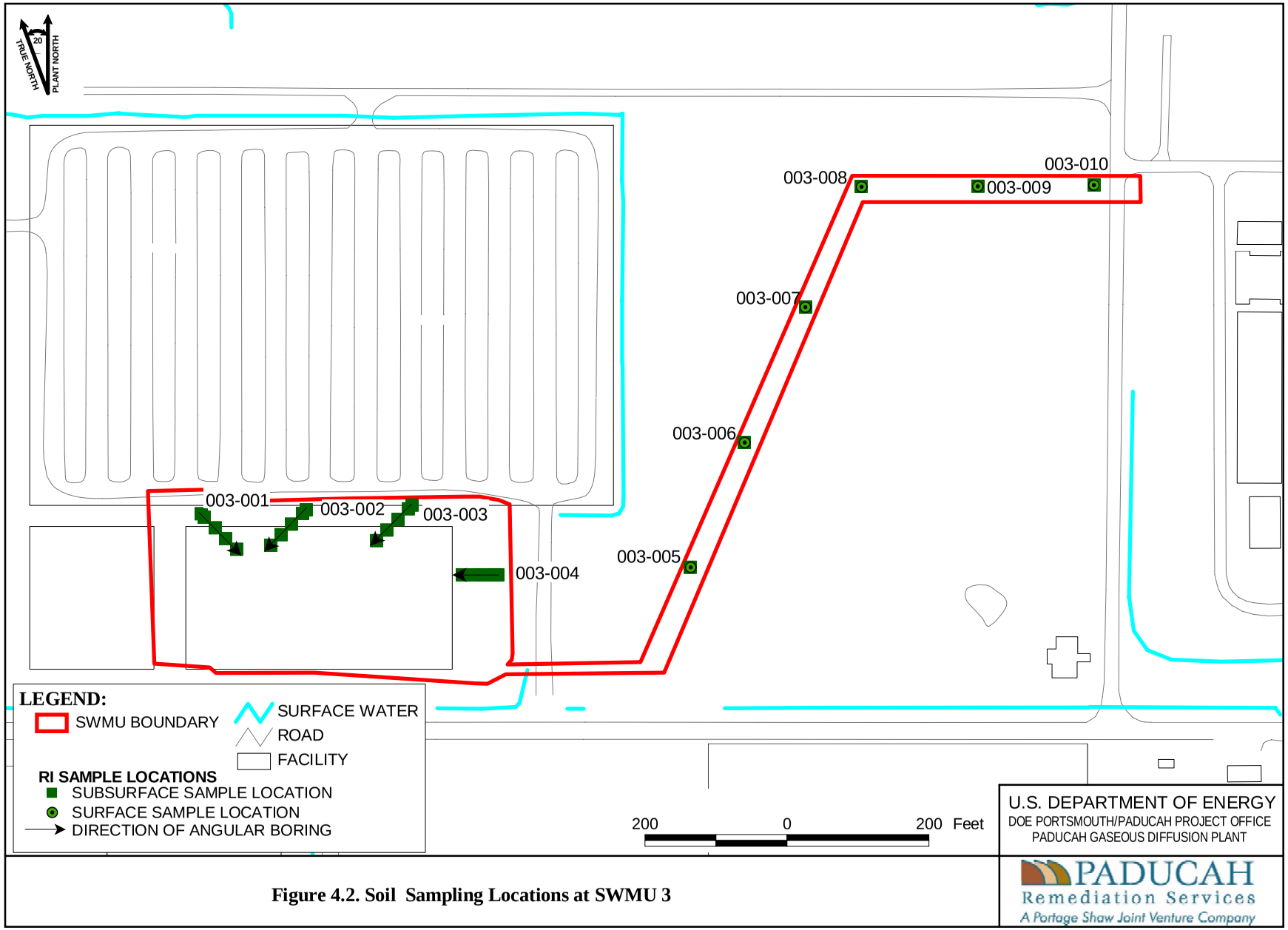

Figure 4.2. Soil Sampling Locations at SWMU 3

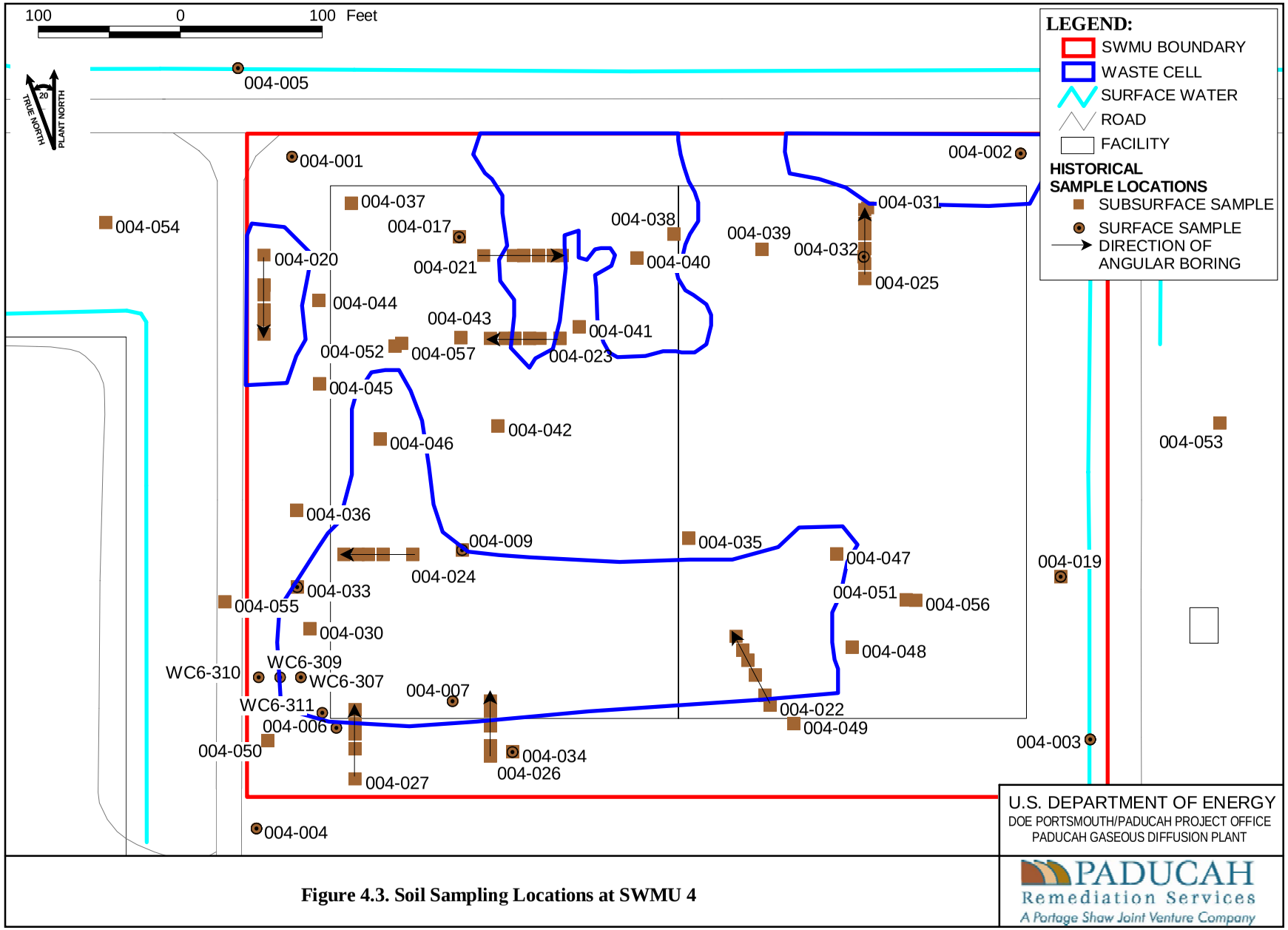

Figure 4.3. Soil Sampling Locations at SWMU 4

Figure No. \BGOU\D1-RI_4.apr
DATE 05-21-08

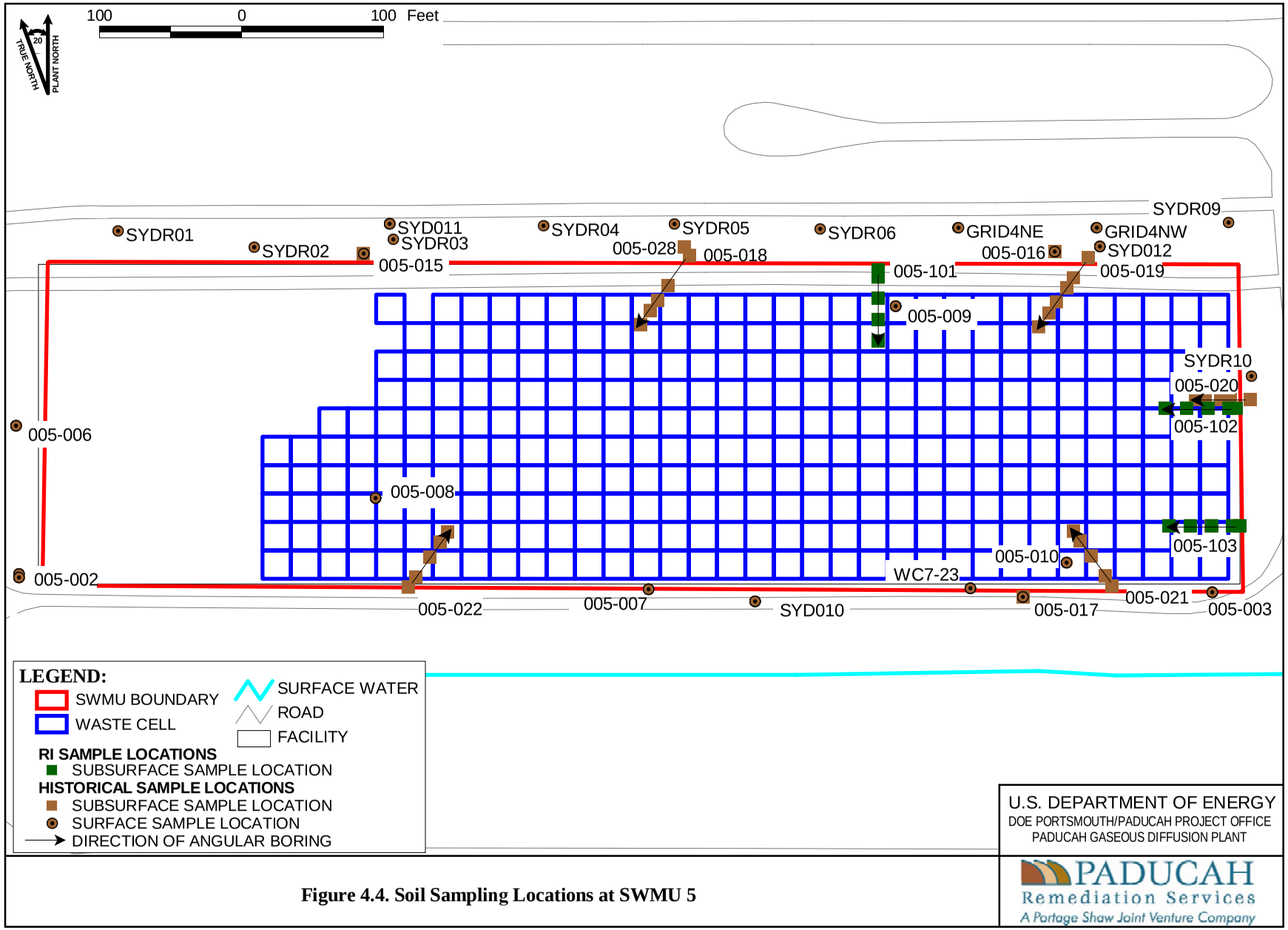

Figure 4.4. Soil Sampling Locations at SWMU 5

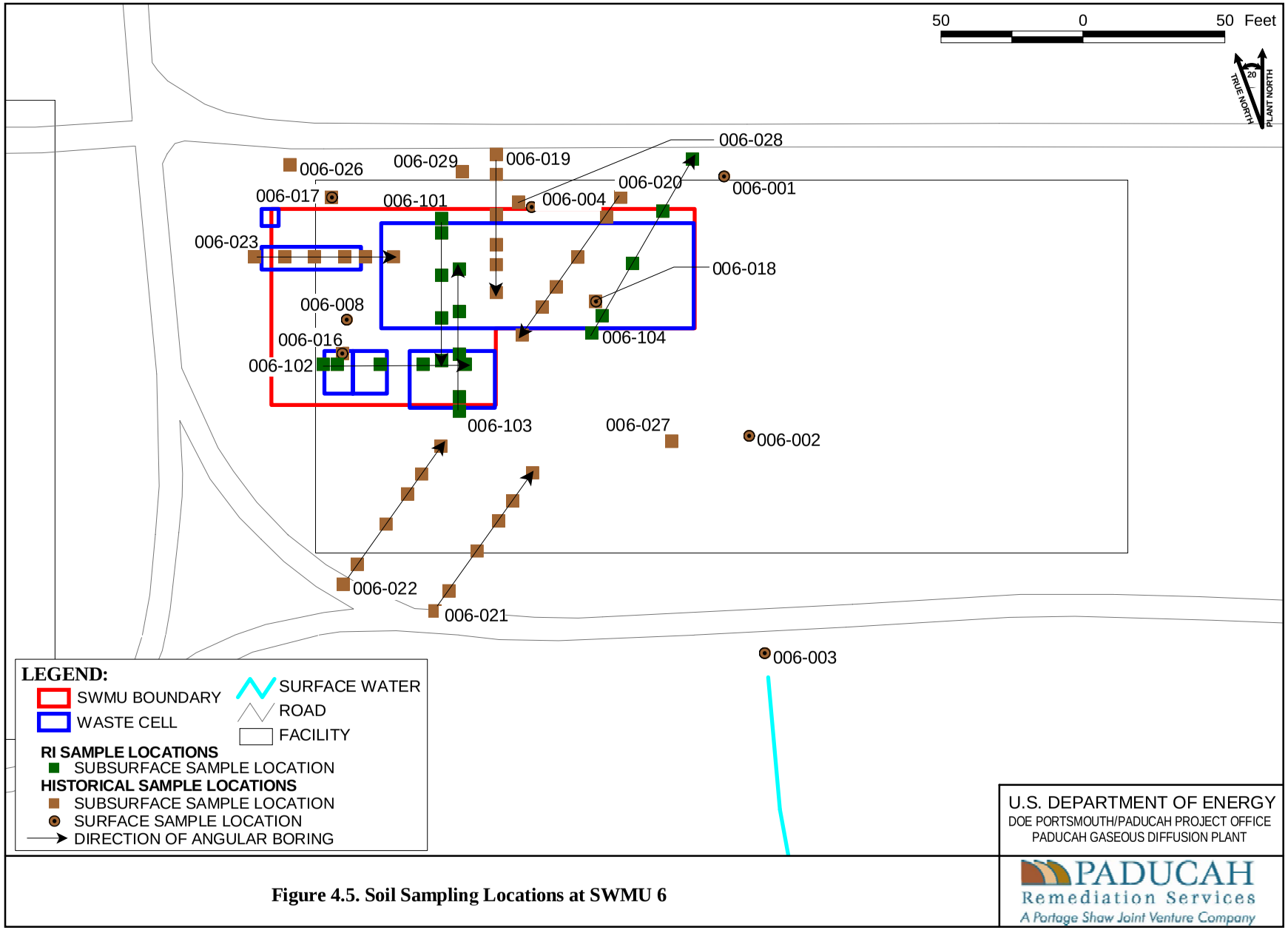

Figure 4.5. Soil Sampling Locations at SWMU 6

Figure No. \BGOU\D1-RI_4.apr
DATE 05-21-08

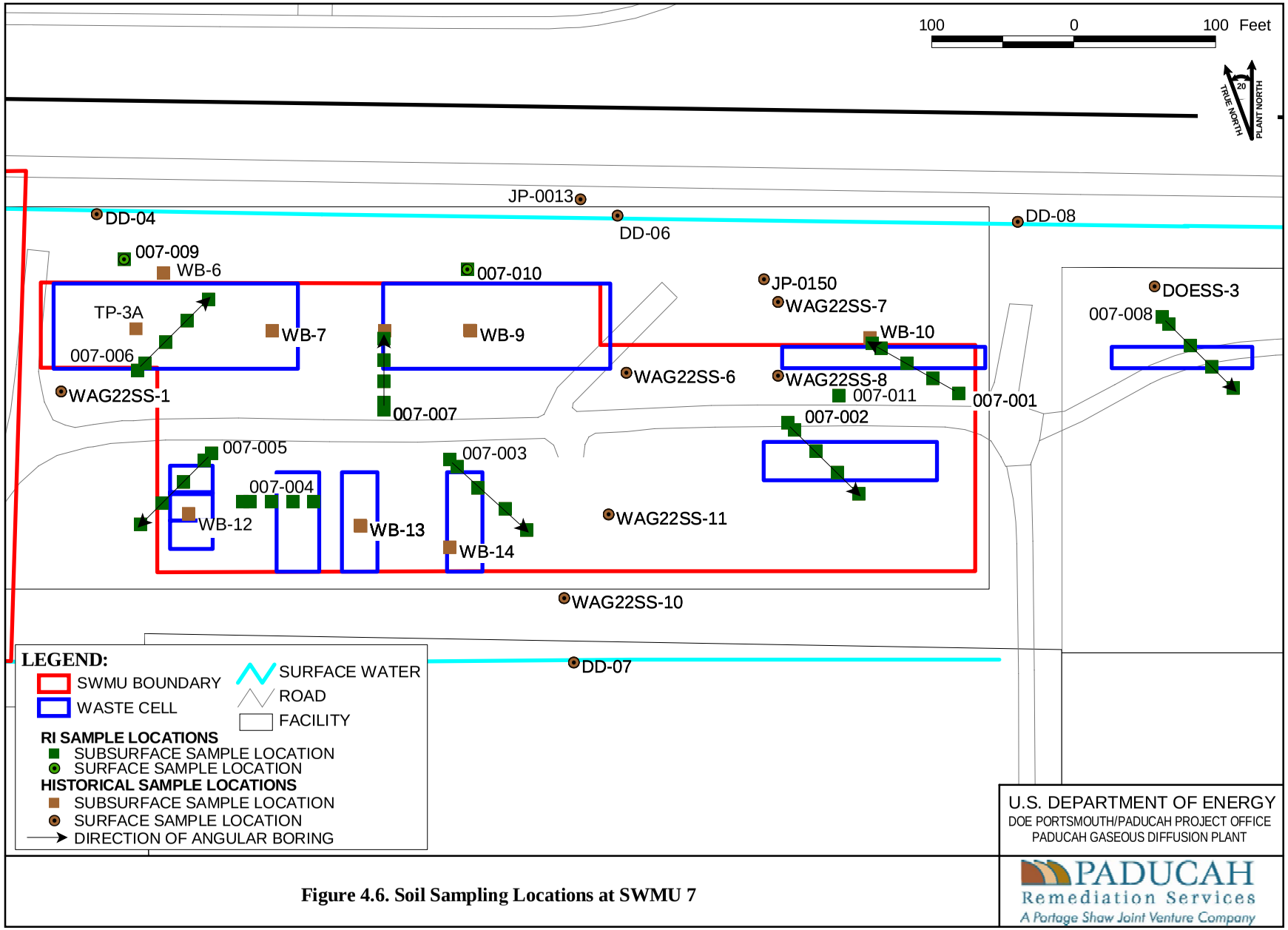

Figure 4.6. Soil Sampling Locations at SWMU 7

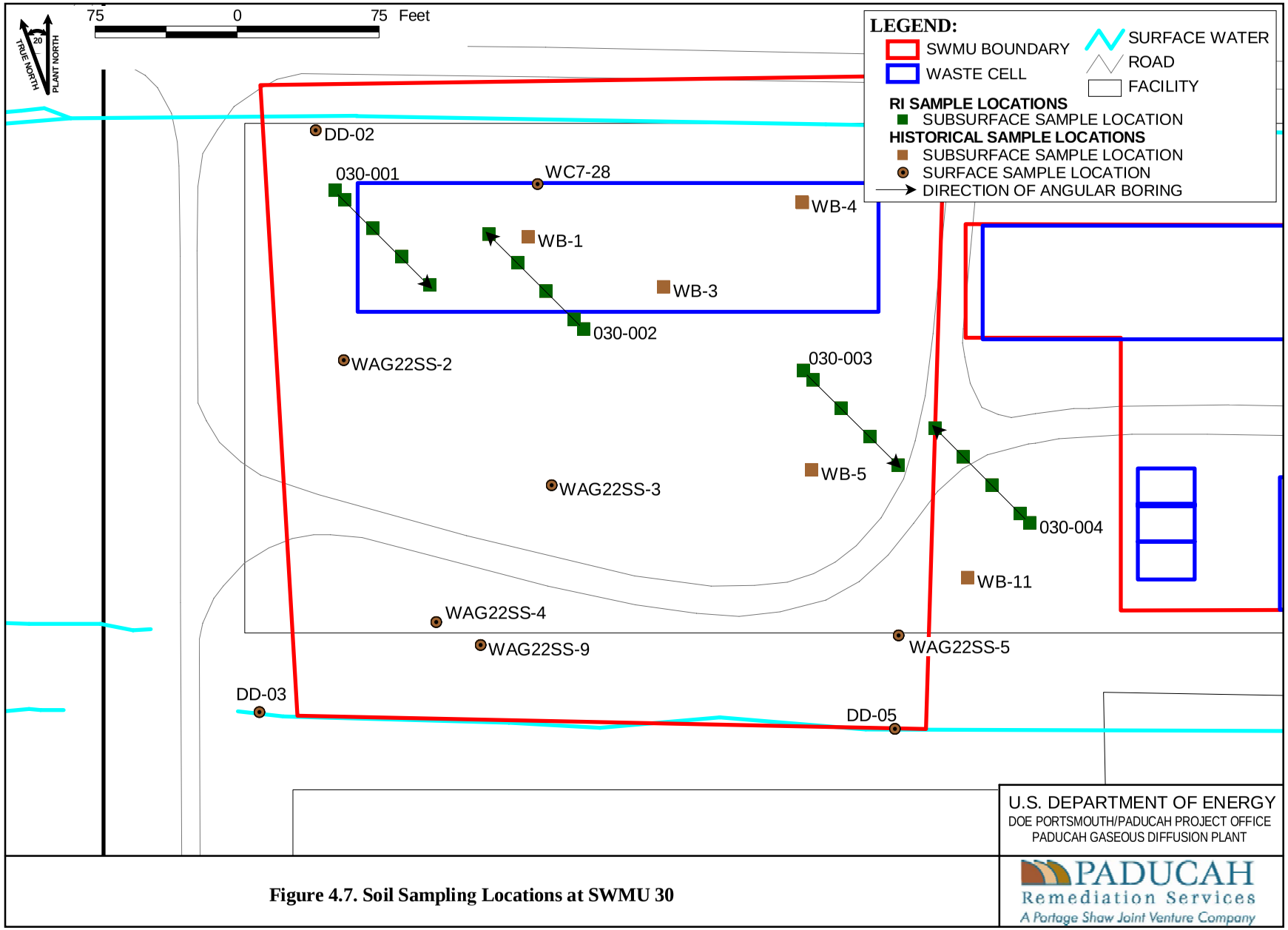

Figure 4.7. Soil Sampling Locations at SWMU 30

Figure No. \BGOU\D1-RI_4.apr
DATE 05-21-08

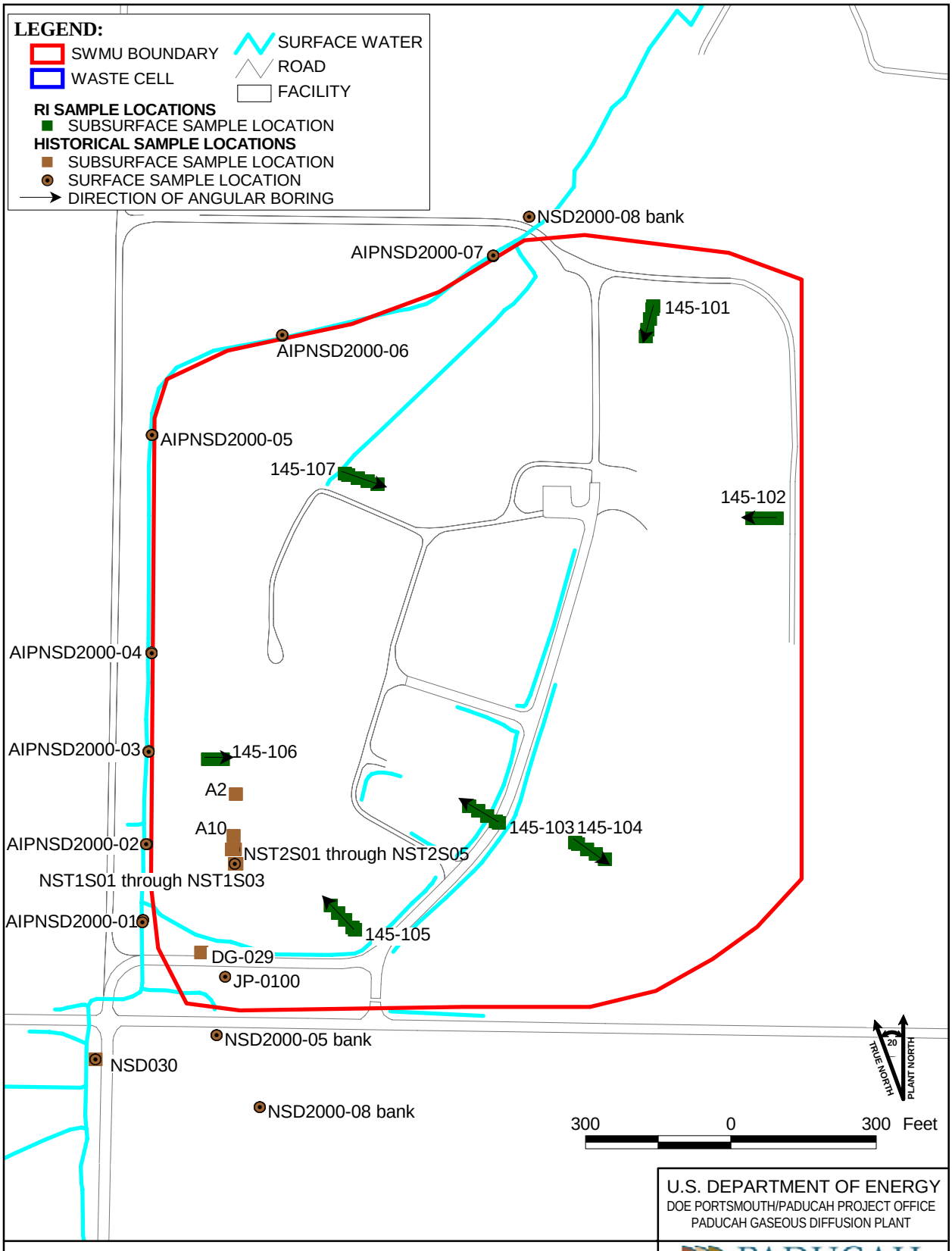

Figure 4.8. Soil Sampling Locations at SWMU 145

Figure No. \BGOU\D1-RI_4.apr
DATE 05-21-08

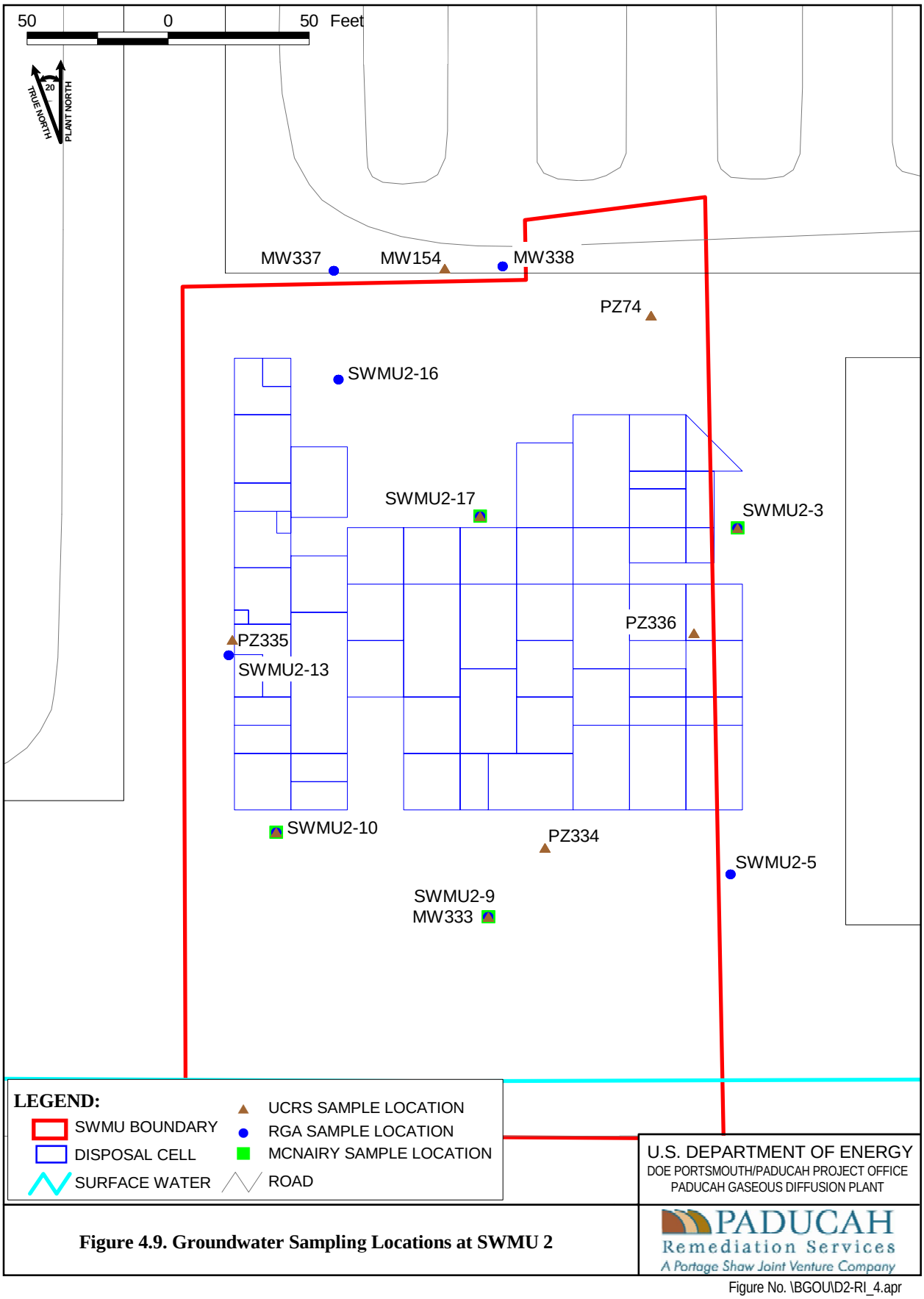

Figure 4.9. Groundwater Sampling Locations at SWMU 2

Figure No. \BGOU\D2-RI_4.apr
DATE 12-31-08

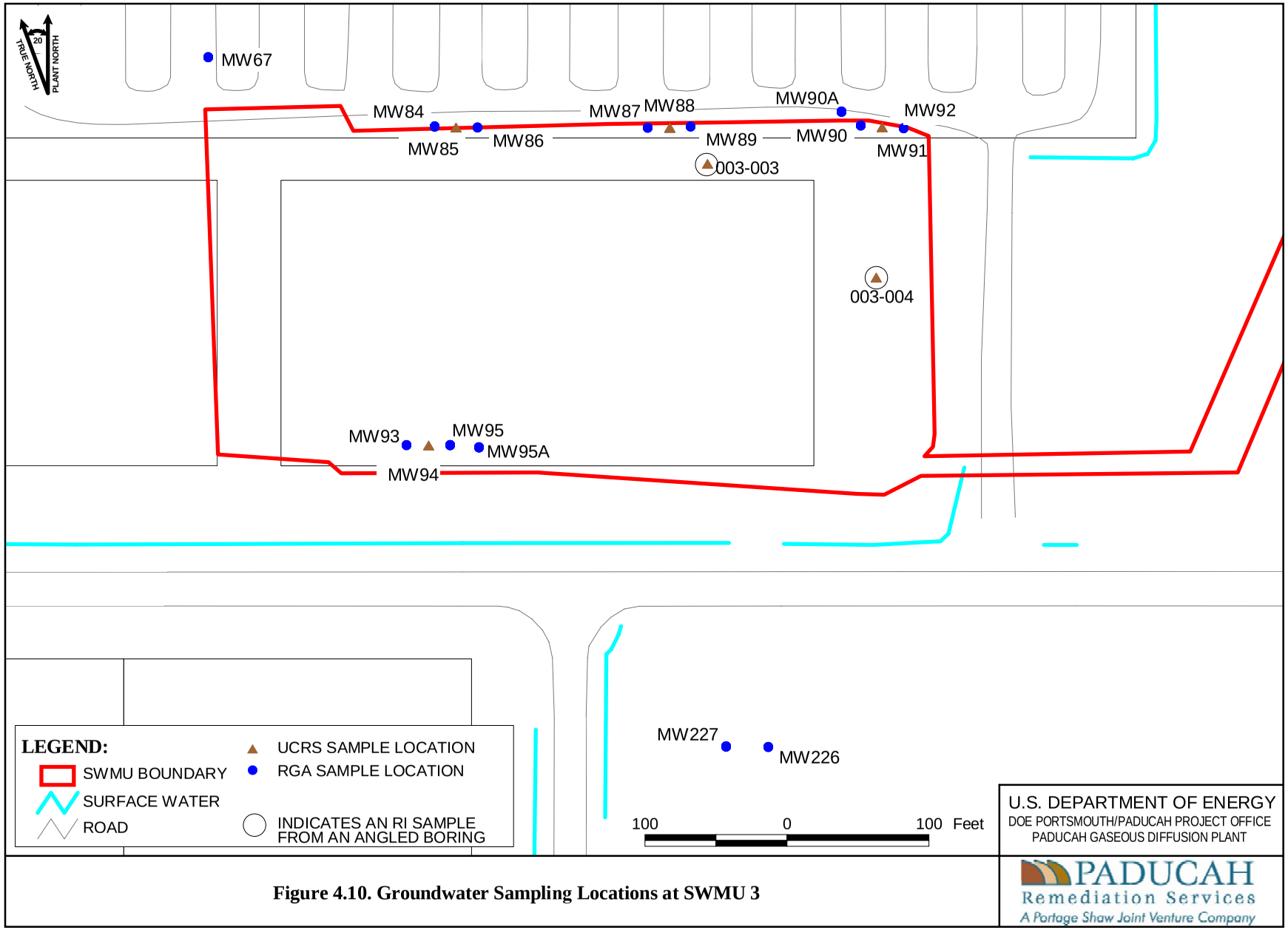

Figure 4.10. Groundwater Sampling Locations at SWMU 3

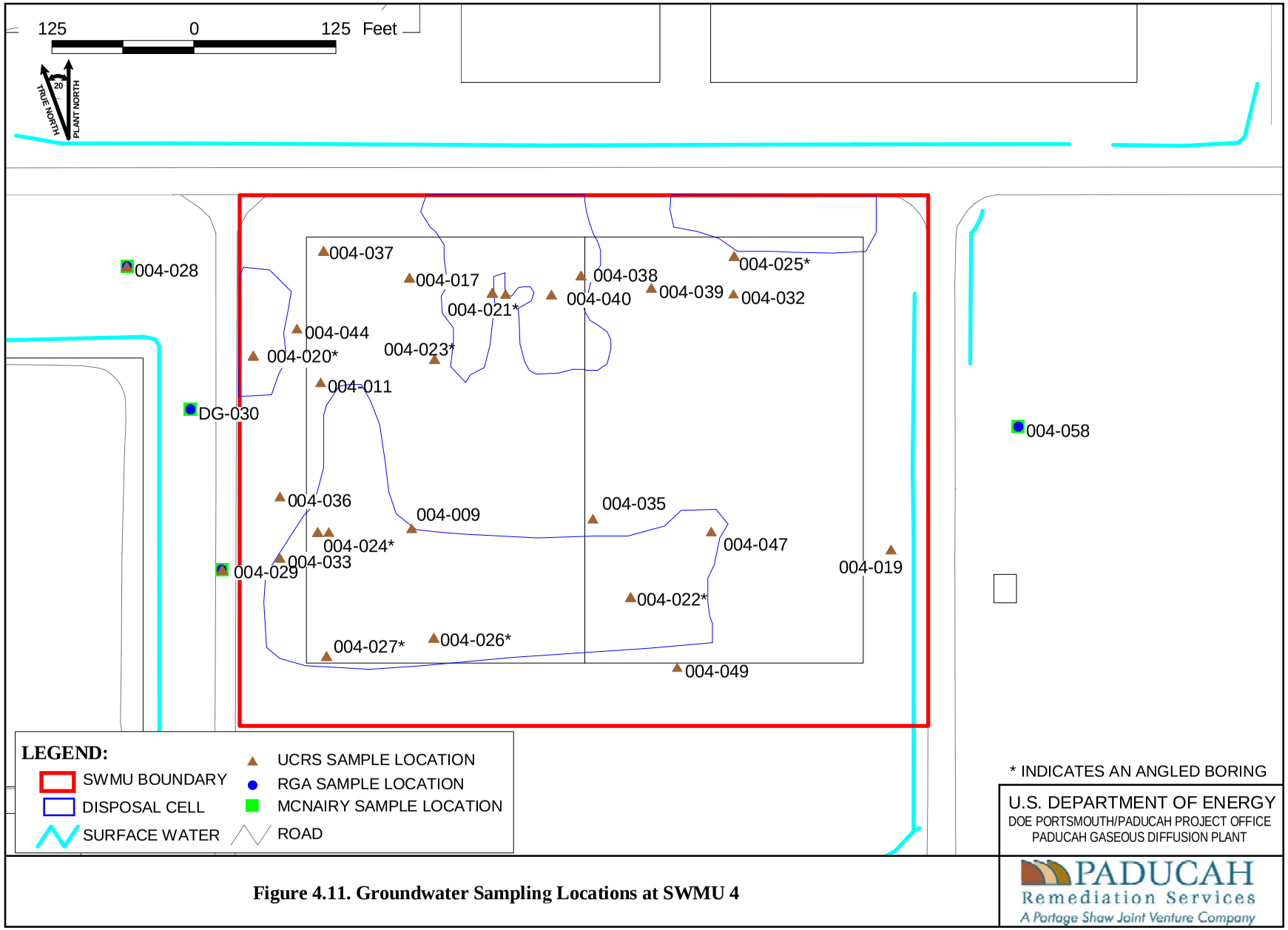

Figure 4.11. Groundwater Sampling Locations at SWMU 4

Figure No. \BGOU\D2-RI_4.apr
DATE 12-31-08

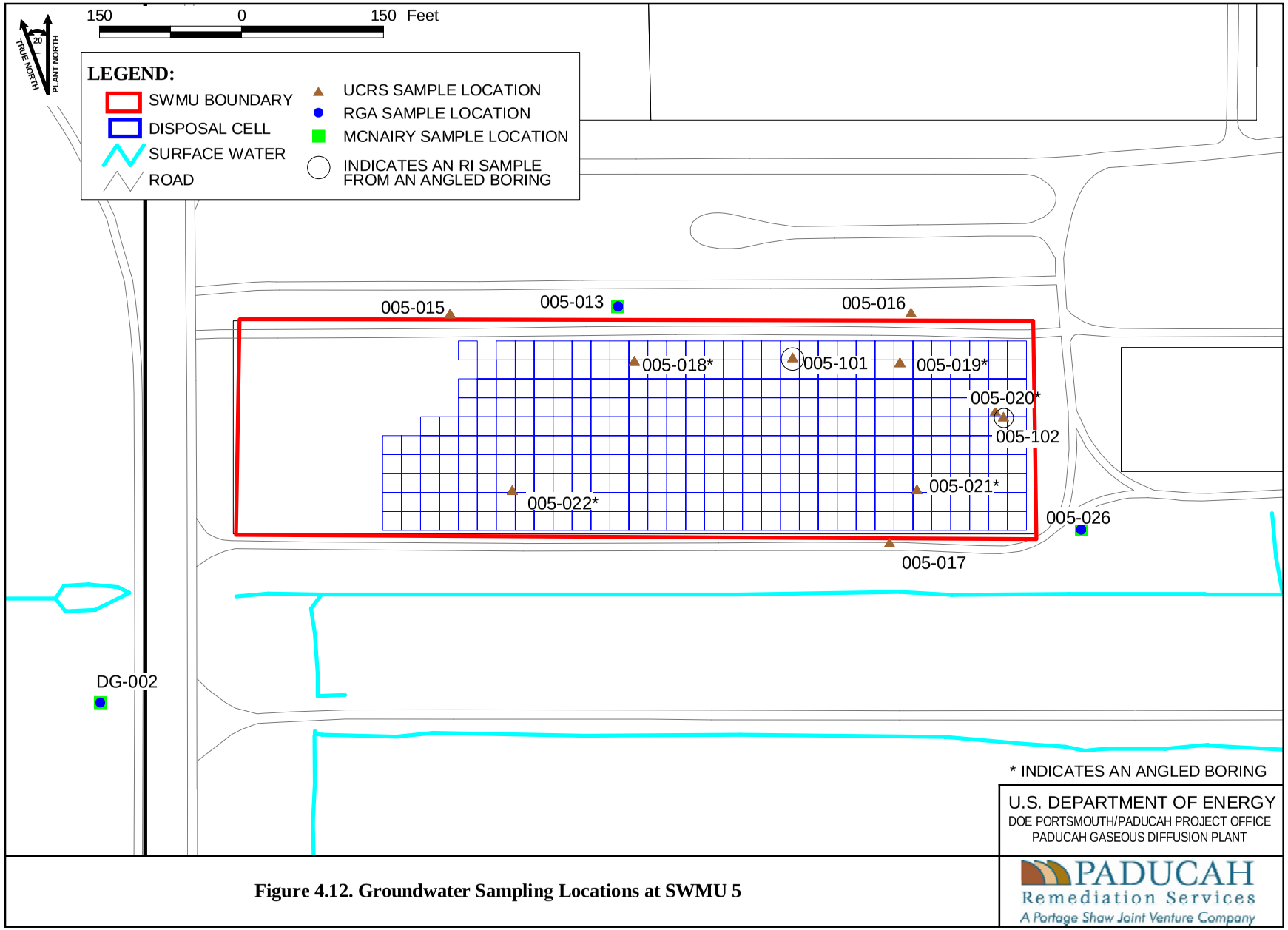

Figure 4.12. Groundwater Sampling Locations at SWMU 5

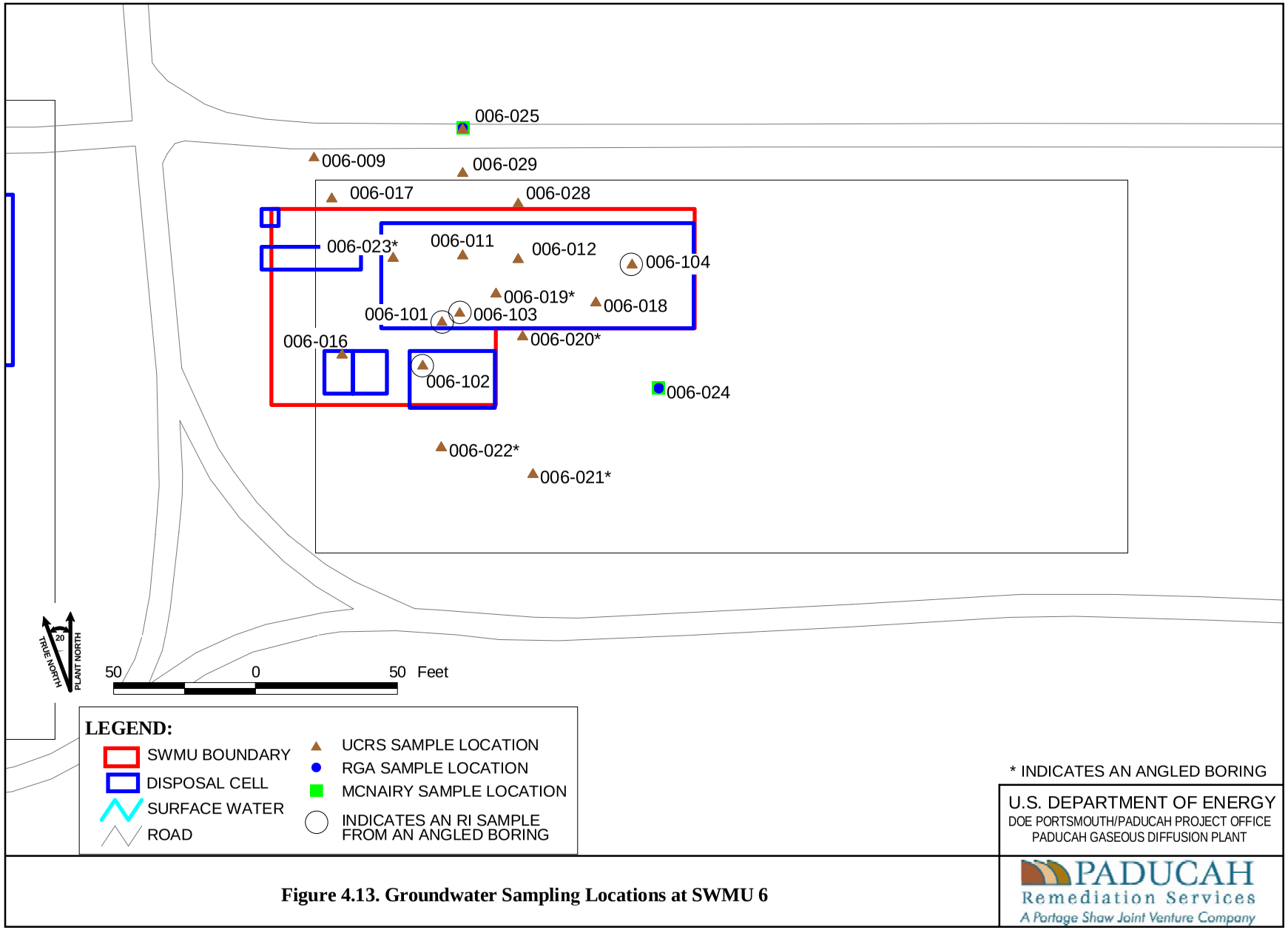

Figure 4.13. Groundwater Sampling Locations at SWMU 6

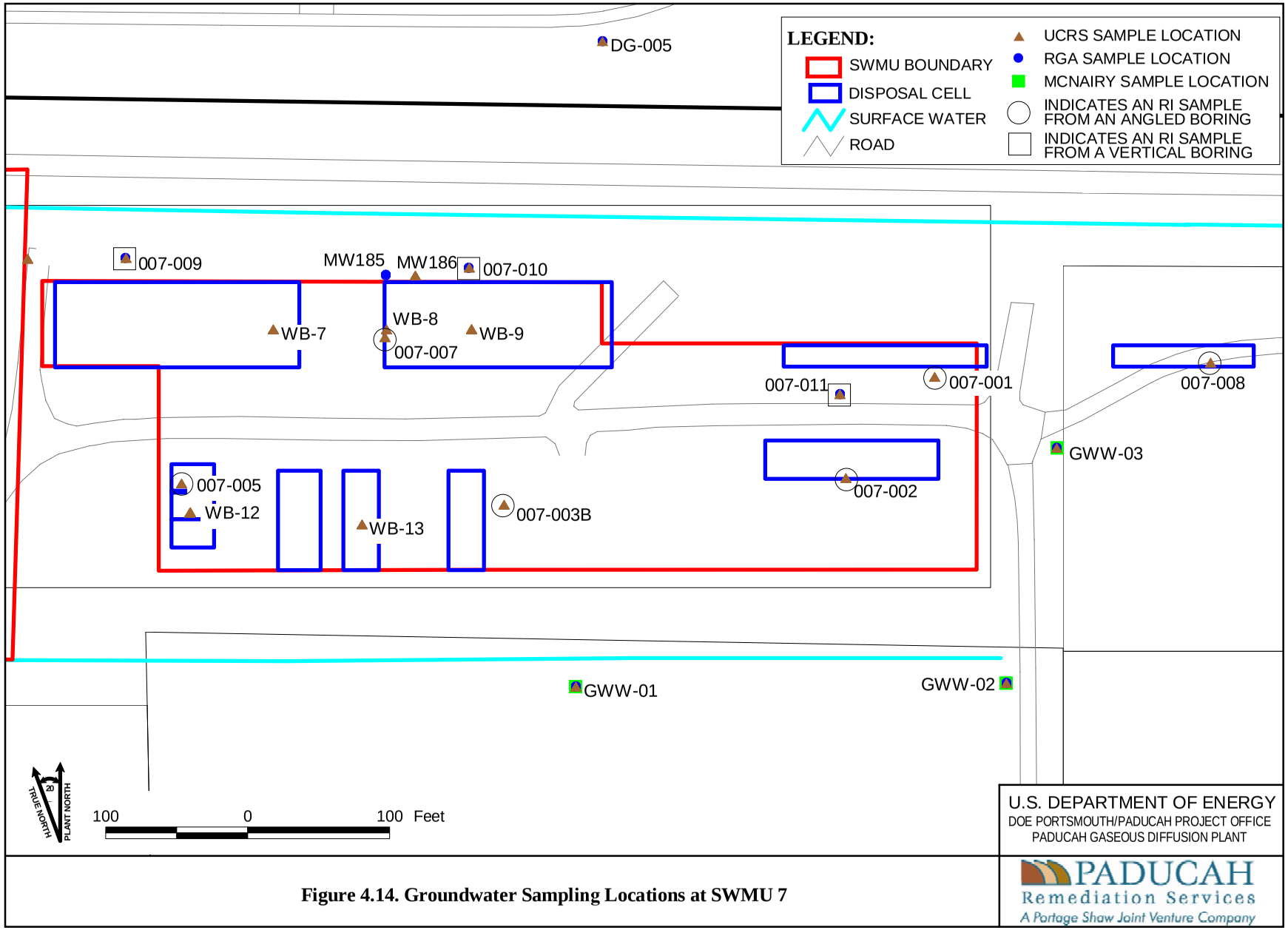

Figure 4.14. Groundwater Sampling Locations at SWMU 7

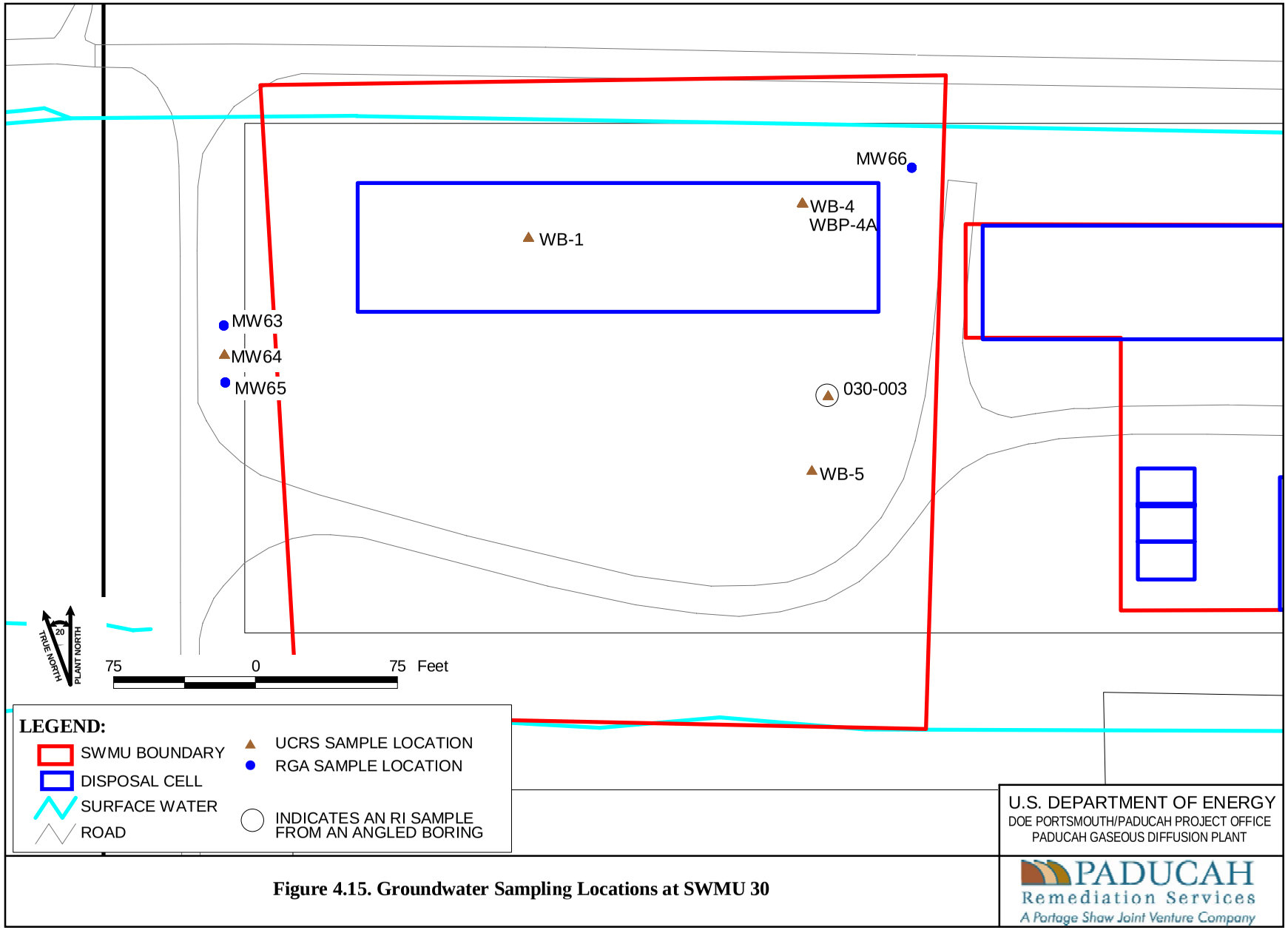

Figure 4.15. Groundwater Sampling Locations at SWMU 30

Figure No. \BGOU\D2-RI_4.apr
DATE 12-31-08

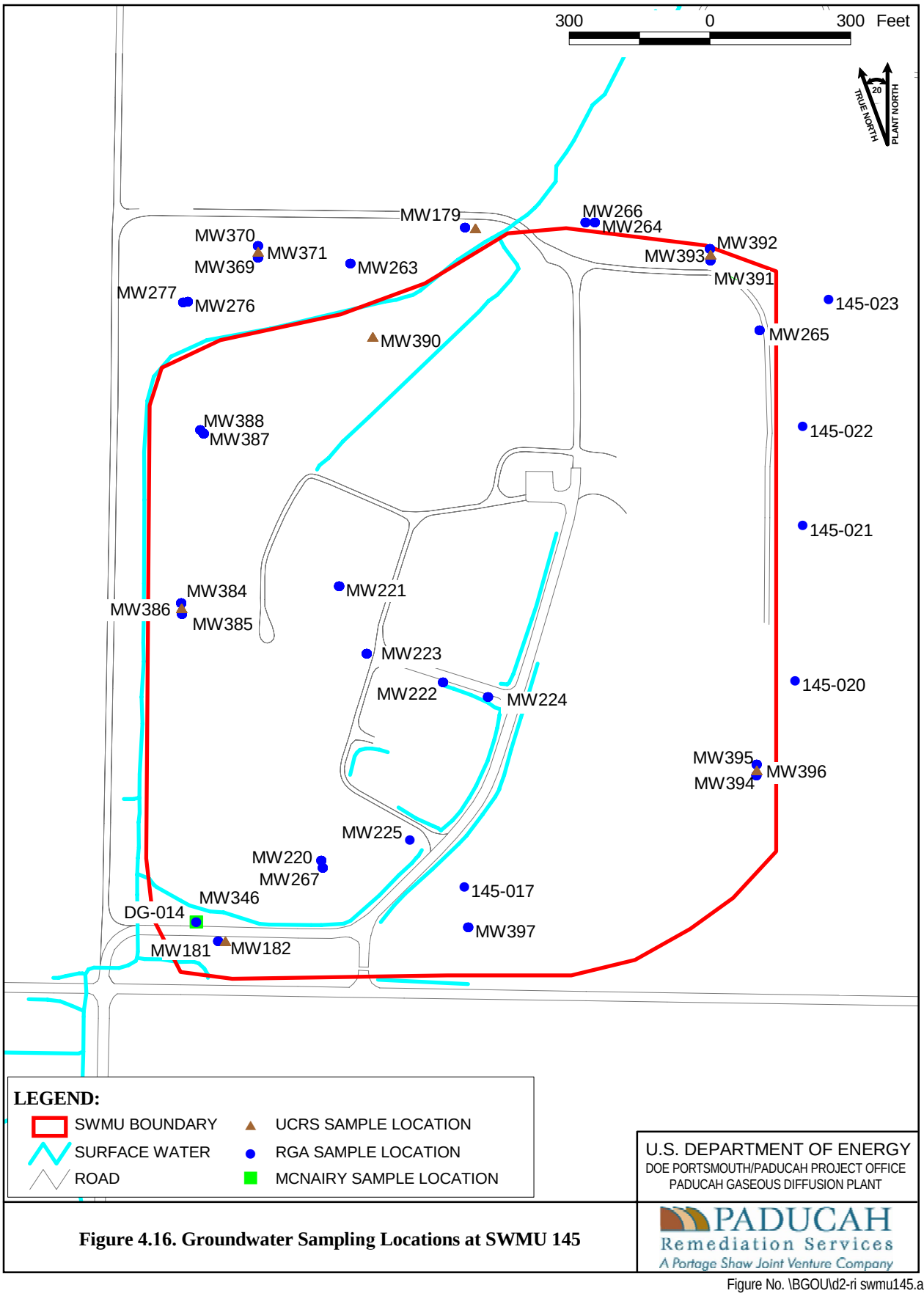

Figure 4.16. Groundwater Sampling Locations at SWMU 145

Figure No. \BGOU\d2-ri swmu145.apr
DATE 1-15-09

4.3 SWMU 2

4.3.1 Subsurface Soils

The RI collected subsurface soil samples from two angled borings at SWMU 2. Review of the RI data along with historical data identified the contaminants presented in Table 4.6. Table 4.7 lists the locations of the metals, organics, and radionuclides detected above screening levels.

As stated in Section 1.3.1.2, records for SWMU 2 indicate the waste consisted of uranium, oils (possibly containing PCBs), and TCE. The maximum result of uranium (1,500 mg/kg) was detected at a depth of 5 ft bgs in boring SWMU 2-12. This boring, from the SWMU 2 Interim Remedial Design Investigation, was one of several sample locations intended to characterize soils adjacent to a waste pit.[5] The next highest uranium result, 33 mg/kg at a depth of 12 ft bgs, was from boring SWMU 2-2 of the SWMU 2 Interim Remedial Design Investigation (also intended to characterize soils adjacent to a waste pit). The waste pits extend to a depth of approximately 17 ft. The most prevalent metals detected above background level in subsurface soil samples at SWMU 2 are arsenic, thallium, and uranium. Arsenic and thallium are commonly associated with uranium. Arsenic was detected above the screening levels throughout the depth of the angled borings (60 ft) installed by the RI (Figure 4.17). Based on Figure 4.17, the areas that exceed the background level are in the shallow soils on the eastern side of the SWMU and an isolated area at 45 ft bgs on the western side (the 60 ft sample at this location was less than background). Because this is a relatively small SWMU, these two zones may be connected spatially. Figure 4.18 shows the distribution of uranium at SWMU 2 with the highest concentrations being found at shallow depths on the western side of the burial ground.

TCE and its degradation products *cis*-1,2-DCE and vinyl chloride were detected at high levels (140 mg/kg, 130 mg/kg, and 1.4 mg/kg, respectively) in the historic sample location SWMU 2-2 at a depth of 12 ft bgs. (This is the only detection of *cis*-1,2-DCE above the excavation worker NAL in all analyses related to the BGOU SWMUs.) This boring was not in a known area of TCE burial in SWMU 2. Figure 4.19 presents the distribution of TCE in soil at SWMU 2. This shows the high level detected on the eastern side of the burial unit at location SWMU 2-2 and indicates the limited extent of TCE contamination in the soil. The RI data, which was used in modeling the source zone but is not shown in Figure 4.19, includes two detections of TCE at a level of 0.428 mg/kg (40 to 45 ft sample) and 0.366 mg/kg (60 ft sample) in borings 002-001 and 002-002, respectively. The degradation products also have a similar limited extent (see Appendix D). All other VOC detections in subsurface soils of SWMU 2 were less than 1 mg/kg. The distribution of *cis*-1,2-DCE is similar to that of TCE, with the exception that concentrations are less. Although PCBs were suspected to be associated with the waste buried in SWMU 2, PCBs were detected above 1 ppm in only one subsurface soil sample below a depth of 6 ft (the approximate depth of the top of buried waste). (The maximum PCB detection in shallower subsurface soils was 0.06 mg/kg.)

The highest activities of the uranium isotopes uranium-234 (155 pCi/g) and uranium-238 (947 pCi/g) were detected at historic sample location SWMU 2-12 at a depth of 5 ft bgs. (The waste sample recovered from the penetrated drum contained 7.6 pCi/g uranium-234 and 43.5 pCi/g uranium-238.) All other detections of uranium isotopes in subsurface soil were less than 10 pCi/g. The distribution of the uranium isotopes are very similar to that of uranium shown in Figure 4.18 (the extent of contamination that exceeds background is mostly in shallow soils on the western side of the unit).

[5] Boring SWMU2-12 penetrated and sampled a waste drum at a depth of 7 to 8 ft.

Table 4.6. SWMU 2 Subsurface Soil Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection	
	Historical Data	RI Data		Above Background Value	Above Excavation Worker NAL
Inorganics (mg/kg)					
Arsenic	22	13.7	28/29	8/29	28/29
Beryllium	1.3	1.05	19/29	4/29	1/29
Iron	N/A[b]	34,900	11/11	1/11	11/11
Manganese	1,200	481	29/29	2/29	25/29
Thallium	1.7	N/A	10/29	10/29	7/29
Uranium	1,500	15.3	12/58	10/58	7/58
Vanadium	38	23.2	28/29	1/29	27/29
Organics–Volatiles (mg/kg)					
cis-1,2-DCE	130	0.118	6/29	N/A	1/29
TCE	140	0.428	10/58	N/A	1/58
Vinyl chloride	1.4	N/A	1/29	N/A	1/29
Organics–PCBs (mg/kg)					
Total PCBs	4.2	N/A	5/28	N/A	1/28
PCB-1248	4.2	N/A	5/28	N/A	1/28
Radionuclides (pCi/g)					
Uranium-234	155	0.824	52/58	1/58	1/58
Uranium-235/236	25.8	N/A	46/47	3/47	1/47
Uranium-238	947	5.87	52/58	11/58	12/58

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

Table 4.7. SWMU 2 Locations of Subsurface Soil Contaminants

		RI Data		Historical Data									
Analysis	**Depth (ft)**	002-001	002-002	SWMU2-1	SWMU2-12	SWMU2-13	SWMU2-17	SWMU2-2	SWMU2-3	SWMU2-4	SWMU2-5	SWMU2-8	SWMU2-9
Inorganics (mg/kg)													
Arsenic	5				12			7.7					
	8			18						21		3.8	
	10-12	2.47	1.22	6.8	4.5			22		9.9		10	
	15-16	2.06	1.21	1.9	4.6					7.6		3.6	
	20			1.1	1.7					8.5		2.3	
	30	3.98	2.52										
	45	1.26	13.7										
	60	2.38	2.02										
Beryllium	5				0.65			0.42					
	8			1.3						0.49		0.51	
	10-12	ND	ND	0.52	0.55			0.82		0.51		0.58	
	15-16	ND	ND	0.38	0.75					0.45		0.37	
	20			0.29	0.39					0.55		0.49	
	30	ND	ND										
	45	ND	1.05										
	60	ND	ND										
Iron	10-12	8,250	5,950										
	15-16	7,900	6,830										
	20	13,600	10,600										
	30	7,110	34,900										
	45	7,190	12,800										
	60	8,250	5,950										
Manganese	5				770			370					
	8			850						180		130	
	10-12	49.9	119	440	620			1200		130		210	
	15-16	481	278	240	360					130		230	
	20			170	670					130		320	
	30	165	35										
	45	35.7	454										
	60	193	146										
Thallium	5				ND			ND					
	8			0.88						1.7		0.55	
	10-12	ND	ND	1.3	ND			ND		1.3		0.99	
	15-16	ND	ND	ND	ND					1.2		0.63	
	20			ND	ND					1.2		0.61	
	30	ND	ND										
	45	ND	ND										
	60	ND	ND										
Uranium	5				1500			ND					ND
	8			ND						ND		ND	
	10-12	ND	15.3	ND	ND	ND		33		ND		ND	
	15-16	ND	ND	ND	ND		ND		ND	ND	ND	ND	
	20-25			ND	ND	ND				ND	11	24	ND
	30-35	1.05	ND				ND		22		ND		
	40-45	ND	1.49			ND	ND		ND				ND

Table 4.7. SWMU 2 Locations of Subsurface Soil Contaminants (Continued)

		RI Data		Historical Data									
Analysis	**Depth (ft)**	002-001	002-002	SWMU2-1	SWMU2-12	SWMU2-13	SWMU2-17	SWMU2-2	SWMU2-3	SWMU2-4	SWMU2-5	SWMU2-8	SWMU2-9
Uranium (Continued)	50-55					ND	ND		ND		ND		4.9
	60-70	ND	ND						ND		ND		
	75					24							11
	85						13						
Vanadium	5				23			21					
	8			37						21		10	
	10-12	2.8	10.8	24	23			38		13		23	
	15-16	ND	11.9	11	33					11		13	
	20			6.5	15					17		12	
	30	21.4	15										
	45	17.8	23.2										
	60	6.85	16.9										
Organic–Volatiles (mg/kg)													
cis-1,2-DCE	5				ND			2.7					
	8			ND						0.0019		0.00093	
	10-12	ND	ND	ND	ND			130		ND		ND	
	15-16	ND	ND	ND	ND					ND		ND	
	20			ND	ND					ND		ND	
	30	ND	ND										
	45	0.118	ND										
	60	ND	0.0149										
TCE	5				0.28			ND					ND
	8			ND						ND		0.01	
	10-12	ND	ND	ND	ND	ND		140		ND		0.0025	
	15-16	ND	ND	ND	ND		ND		ND	ND	ND	0.0021	
	20-25			ND	ND	ND				ND	ND	0.0022	ND
	30-35	ND	ND				ND		ND		ND		
	40-45	0.428	ND			ND	ND		ND				0.0078
	50-55					ND	ND		ND		ND		
	60	ND	0.366										
Vinyl chloride	5				ND			ND					
	8			ND						ND		ND	
	10-12	ND	ND	ND	ND			1.4		ND		ND	
	15-16	ND	ND	ND	ND					ND		ND	
	20			ND	ND					ND		ND	
	30	ND	ND										
	45	ND	ND										
	60	ND	ND										
Organics–Pesticides and PCBs (mg/kg)													
Total PCBs	5				0.058			ND					
	8			ND						ND		ND	
	10-12	ND	ND	ND	0.031			4.2		ND		ND	
	15-16	ND	ND	ND	0.015					ND		ND	
	20				0.041					ND		ND	
	30	ND	ND										
	45	ND	ND										
	60	ND	ND										
PCB-1248	5				0.058			ND					
	8			ND						ND		ND	

Table 4.7. SWMU 2 Locations of Subsurface Soil Contaminants (Continued)

		RI Data		Historical Data									
Analysis	**Depth (ft)**	002-001	002-002	SWMU2-1	SWMU2-12	SWMU2-13	SWMU2-17	SWMU2-2	SWMU2-3	SWMU2-4	SWMU2-5	SWMU2-8	SWMU2-9
PCB-1248 (Continued)	10-12	ND	ND	ND	0.031			4.2		ND		ND	
	15-16	ND	ND	ND	0.015					ND		ND	
	20				0.041					ND		ND	
	30	ND	ND										
	45	ND	ND										
	60	ND	ND										
Radionuclides (pCi/g)													
Uranium-234	5				155			1.15					1.57
	8			1.72						1.04		0.98	
	10-12	ND	0.824	0.81	0.98	1.16		2.07		0.79		0.99	
	15-16	ND	ND	0.86	0.77		0.81		0.77	0.71	0.76	0.77	
	20-25			0.8	0.83	0.73				0.76	0.52	0.89	0.44
	30-35	0.35	0.176				0.93		0.58		0.87		
	40-45	ND	0.297			0.57	1.17		0.86				1.19
	50-55					1.2	0.6		0.93		0.69		0.6
	60	ND	0.25										
	70-75					0.26			0.63		0.48		0.52
	85						0.57						
	95					0.27			1.2				
Uranium-235/236	5				25.8			0.06					0.1
	8			0.19						0.03		0.06	
	10-12			0.07	0.06	0.1		0.38		0.06		0.14	
	15-16			0.08	0.04		0.1		0.07	0.04	0.06	0.1	
	20-25			0.04	0.09	0.09				0.09	0.03	0.08	0.05
	30-35						0.05		0.04		0.11		
	40-45					0.02	0.06		0.12				0.06
	50-55					0.07	0.05		0.07		0.06		0.04
	70-75					0.01			0.04		0.05		ND
	85						0.06						
	95					0.03			0.11				
Uranium-238	5				947			1.82					2.83
	8			6.25						1.08		0.95	
	10-12	ND	5.87	1.02	2.02	1.23		8.02		1.04		0.98	
	15-16	ND	ND	0.82	0.97		0.95		0.75	0.71	0.86	0.87	
	20-25			0.84	1.39	0.78				0.84	0.52	0.9	0.58
	30-35	0.319	0.132				0.97		0.62		0.8		
	40-45	ND	0.241			0.6	1.27		0.93				1.11
	50-55					1.26	0.71		1.14		0.8		0.75
	60	ND	0.206										
	70-75					0.21			0.69		0.52		0.23
	85						0.29						
	95					0.33			1.2				

ND = not detected above screening levels

Blank cells indicate interval was not sampled for the specified analysis. Maximum value shown for each depth interval.

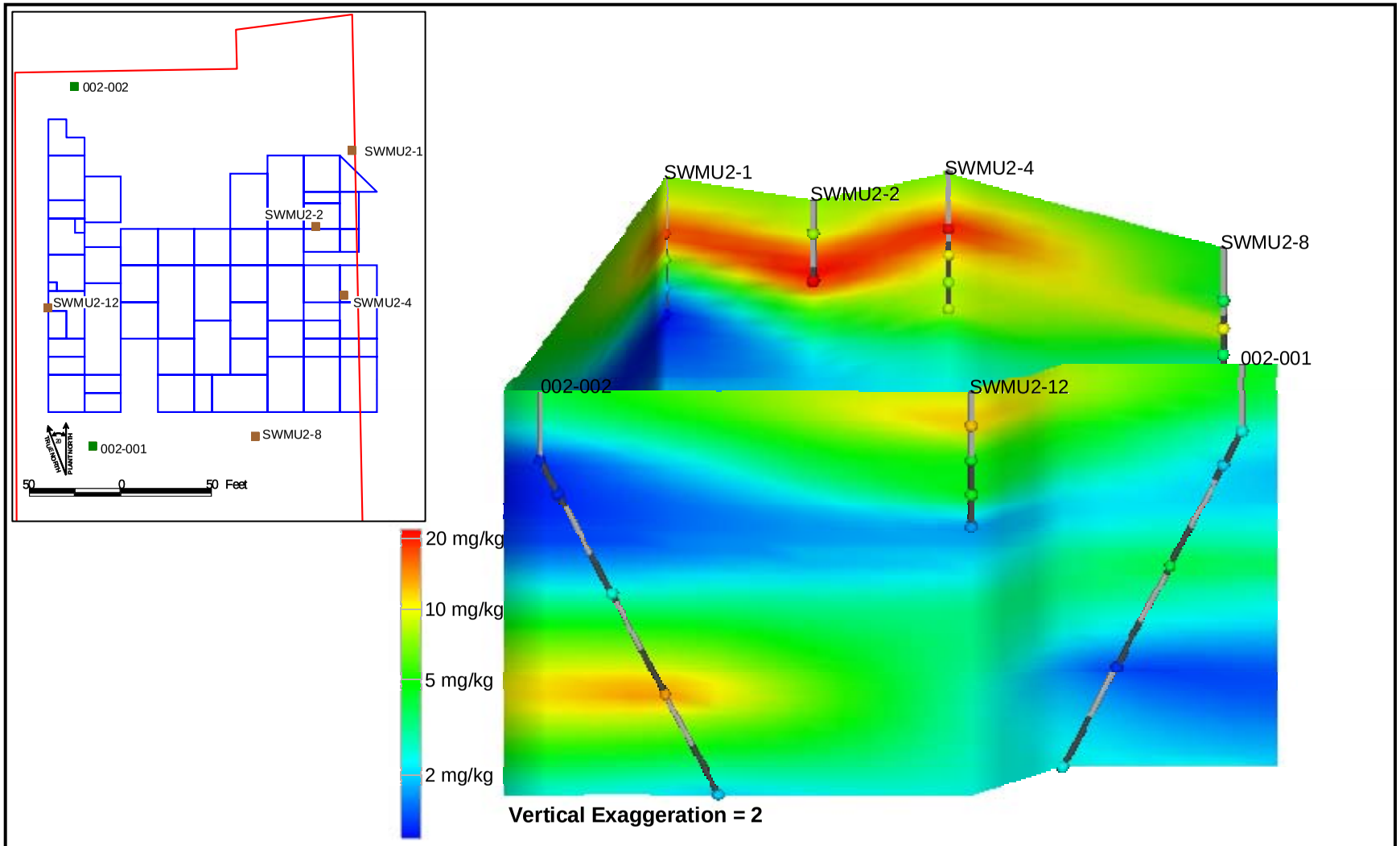

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Figure 4.17. SWMU 2 Arsenic in Soil (Looking East)

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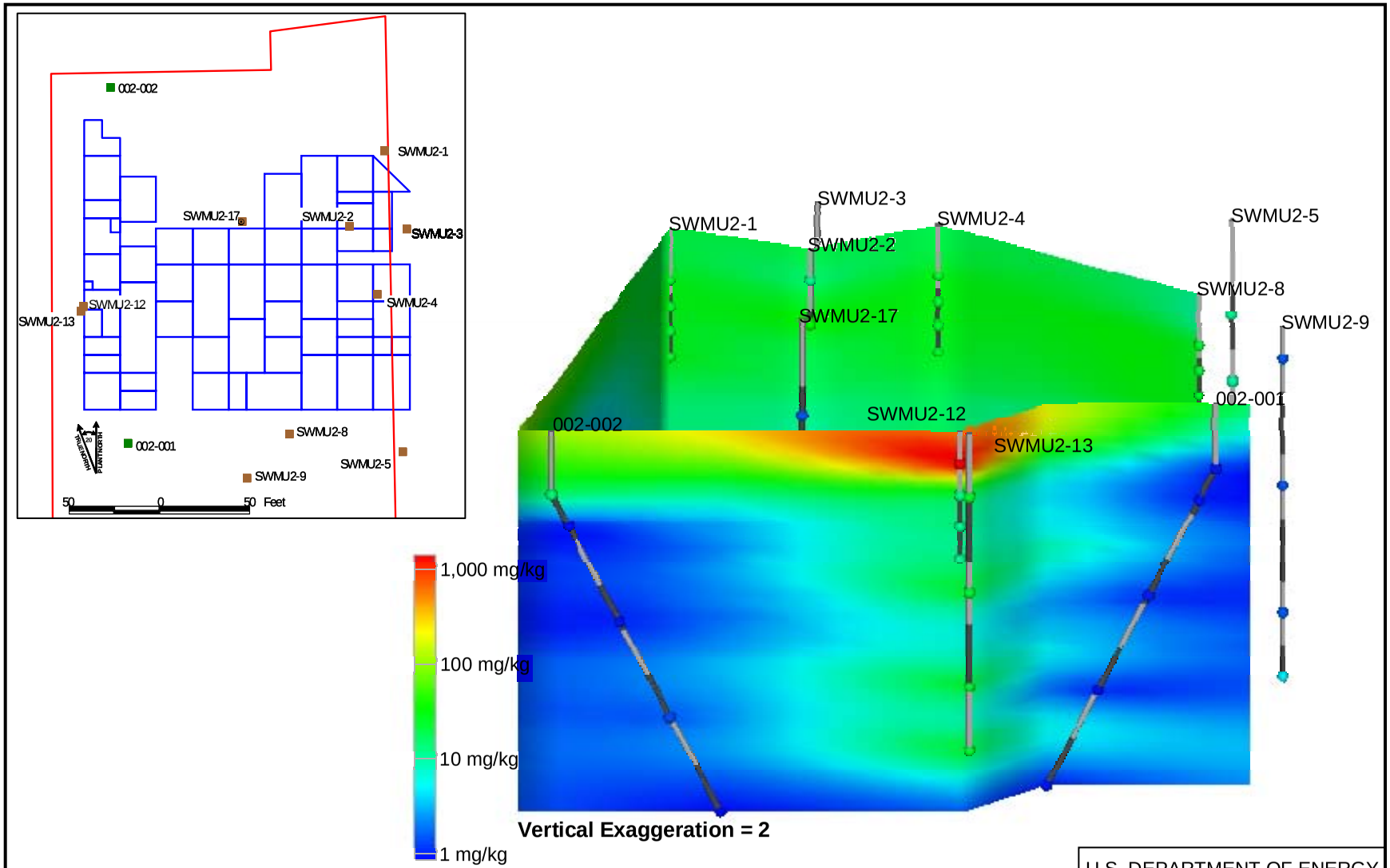
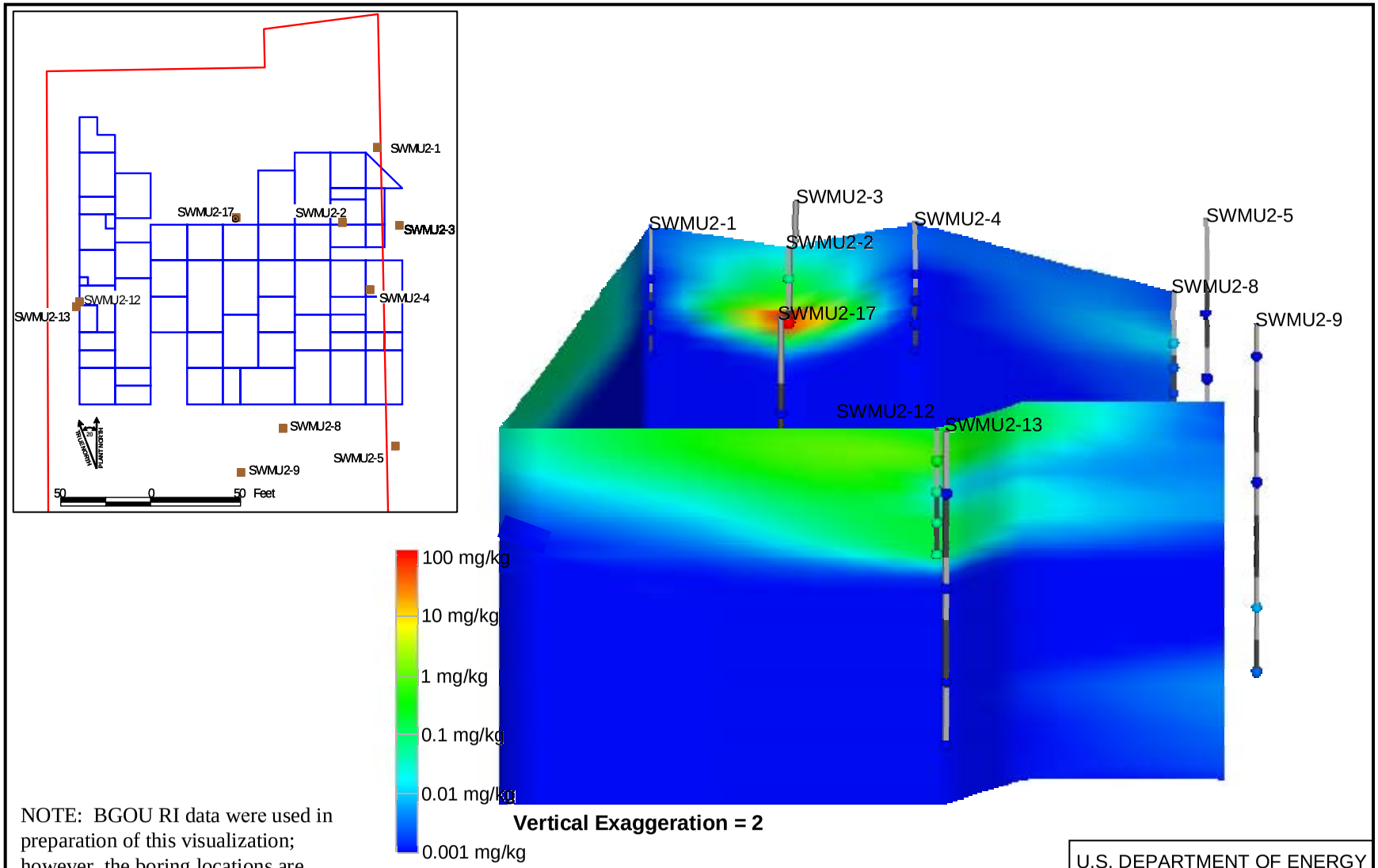


Figure 4.18. SWMU 2 Uranium in Soil (Looking East)



NOTE: BGOU RI data were used in preparation of this visualization; however, the boring locations are not shown.

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Figure 4.19. SWMU 2 TCE in Soil (Looking East)

4.3.2 SWMU 2 Groundwater

Groundwater samples were attempted at the two angled borings installed at SWMU 2 as part of this RI; however, none was collected (even where the UCRS is saturated, the low hydraulic conductivity of the unit restricts groundwater yield). A review of historical data, identified the contaminants listed in Tables 4.8, 4.9, and 4.10 for UCRS, RGA, and McNairy groundwater, respectively. Table 4.11 provides detail (depth, sample location, and analytical results) for SWMU 2 groundwater samples, including nondetects and detections above screening levels.

Table 4.8. SWMU 2 UCRS Groundwater Contaminants

Analysis	Maximum Result		Frequency of Detection[a]		
	Historical Data	RI Data		Above MCL	Above Child Resident NAL
Inorganics (mg/L)					
Beryllium	0.078	N/A[b]	5/6	3/6	3/6
Iron	14	N/A	1/1	N/A	1/1
Manganese	37	N/A	6/6	N/A	5/6
Uranium	0.075	N/A	7/15	3/15	7/15
Vanadium	4.1	N/A	5/6	N/A	5/6
Organics–Volatiles (mg/L)					
1,1-DCE	8.33	N/A	4/4	4/4	4/4
cis-1,2-DCE	0.28	N/A	4/12	2/12	2/12
TCE	0.04	N/A	7/12	6/12	6/12
Vinyl chloride	0.005	N/A	2/7	1/7	2/7
Radionuclides (pCi/L)					
Uranium-234	10.3	N/A	10/10	N/A	9/10
Uranium-238	55.8	N/A	10/10	N/A	9/10

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

Table 4.9. SWMU 2 RGA Groundwater Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection		
	Historical Data	RI Data		Above Back-ground	Above MCL	Above Child Resident NAL
Inorganics (mg/L)						
Arsenic	0.081	N/A[b]	3/4	2/4	2/4	3/4
Beryllium	0.092	N/A	24/28	21/28	21/28	21/28
Cadmium	0.012	N/A	1/4	1/4	1/4	1/4
Iron	23000	N/A	12/13	10/13	N/A	11/13
Manganese	96	N/A	28/28	25/28	N/A	25/28
Uranium	0.41	N/A	5/145	4/145	4/145	5/145
Vanadium	1.9	N/A	25/28	19/28	N/A	23/28
Organics–Volatiles (mg/L)						
1,1-DCE	47.9	N/A	20/39	N/A	20/39	20/39
Chloroform	0.0029	N/A	2/19	N/A	N/A	2/19
cis-1,2-DCE	0.75	N/A	31/137	N/A	10/137	24/137
TCE	5.35	N/A	113/137	N/A	97/137	109/137
Radionuclides (pCi/L)						
Uranium-234	50.6	N/A	24/33	19/33	N/A	22/33
Uranium-238	91.7	N/A	23/34	18/34	N/A	21/34

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

Table 4.10. SWMU 2 McNairy Groundwater Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection		
	Historical Data	RI Data		Above Back-ground	Above MCL	Above Child Resident NAL
Organics–Volatiles (mg/L)						
1,1-DCE	7.5	N/A[b]	4/4	N/A	4/4	4/4
TCE	0.055	N/A	7/9	N/A	4/9	5/9

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

Table 4.11. SWMU 2 Locations of Groundwater Contaminants

			Historical Data														
Unit	**Depth (ft)**	**Analysis**	MW154	MW333	MW337	MW338	PZ334	PZ335	PZ336	PZ74	SWMU2-10	SWMU2-13	SWMU2-16	SWMU2-17	SWMU2-3	SWMU2-5	SWMU2-9
UCRS	18-20	***Inorganics (mg/L)***															
		Beryllium	ND														
		Manganese	ND														
		Uranium	0				0.061	ND	0.023								
		Vanadium	ND														
		Organics-Volatiles (mg/L)															
		cis -1,2-DCE	ND														
		TCE	0.04														
		Vinyl chloride	ND														
		Radionuclides (pCi/L)															
		Uranium-234	0.73				5.62		2.55								
		Uranium-238	1.55				26.8		6.7								
	22-26	***Inorganics (mg/L)***															
		Beryllium									0.0069			ND			0.078
		Manganese									6.3			3			37
		Uranium									ND			ND			0.075
		Vanadium									0.42			0.012			4.1
		Organics-Volatiles (mg/L)															
		1,1-DCE												0.153	0.0143		8.33
		cis -1,2-DCE									ND			ND	0.28		ND
		TCE									ND			ND	0.039		ND
		Vinyl chloride									ND			ND	0.005		
		Radionuclides (pCi/L)															
		Uranium-234									1.76			10.3			4.11
		Uranium-238									2.57			55.8			3.96
	42-43	***Inorganics (mg/L)***															
		Beryllium								ND							0.023
		Iron								14							
		Manganese								0.07							7.1
		Uranium								ND							ND
		Vanadium								0.03							0.93

Table 4.11. SWMU 2 Locations of Groundwater Contaminants (Continued)

			Historical Data													
Unit	**Depth (ft)**	**Analysis**	MW154	MW333	MW337	MW338	PZ334	PZ335	PZ336	PZ74	SWMU2-10	SWMU2-13	SWMU2-16	SWMU2-17	SWMU2-3	SWMU2-5	SWMU2-9
UCRS	43	***Organics-Volatiles (mg/L)***															
		1,1-DCE															0.667
		cis -1,2-DCE								ND							ND
		TCE								0.013							0.01
		Vinyl chloride								ND							ND
		Radionuclides (pCi/L)															
		Uranium-234								ND							4.14
		Uranium-238								ND							3.72
RGA	58	***Inorganics (mg/L)***															
		Beryllium										0.069				0.0031	
		Iron										1800				93	
		Manganese										26				2.1	
		Uranium										ND				ND	
		Vanadium										1.9				0.065	
		Organics-Volatiles (mg/L)															
		1,1-DCE										1.79				2.16	
		cis -1,2-DCE										0.75				ND	
		TCE										5.35				ND	
		Radionuclides (pCi/L)															
		Uranium-234										14.2				0.75	
		Uranium-238										17.6				0.55	
	61-63	***Inorganics (mg/L)***															
		Beryllium									0.047				0.012		
		Manganese									20				3.5		
		Uranium									ND				ND		
		Vanadium									0.97				0.24		
		Organics-Volatiles (mg/L)															
		1,1-DCE									0.295				3.24		
		cis -1,2-DCE									ND				ND		
		TCE									0.12				ND		

Table 4.11. SWMU 2 Locations of Groundwater Contaminants (Continued)

			Historical Data													
Unit	**Depth (ft)**	**Analysis**	MW154	MW333	MW337	MW338	PZ334	PZ335	PZ336	PZ74	SWMU2-10	SWMU2-13	SWMU2-16	SWMU2-17	SWMU2-3	SWMU2-5	SWMU2-9
RGA	61-63	***Radionuclides (pCi/L)***															
		Uranium-234									1.01				3.84		
		Uranium-238									0.62				9.07		
	66-68	***Inorganics (mg/L)***															
		Beryllium										0.087	0.04	0.04		0.0061	
		Iron										2000		690		110	
		Manganese										39	32	26		1.5	
		Uranium										ND	0.15	ND		ND	
		Vanadium										1.7	0.6	0.83		0.11	
		Organics-Volatiles (mg/L)															
		1,1-DCE										0.356	4.21	0.0165		4.12	
		cis -1,2-DCE										0.221	ND	ND		ND	
		TCE										1.6	0.0043	ND		ND	
		Radionuclides (pCi/L)															
		Uranium-234										0.91	0.61	50.6		1.22	
		Uranium-238										0.76	2.12	55.1		0.94	
	71-72	***Inorganics (mg/L)***															
		Beryllium									0.092				0.038	0.0059	0.068
		Manganese									51				96	14	71
		Uranium									ND				ND	0.049	0.41
		Vanadium									1.5				0.6	0.12	1.2
		Organics-Volatiles (mg/L)															
		1,1-DCE									0.375					47.9	2.14
		cis -1,2-DCE									ND				ND	ND	ND
		TCE									0.1				ND	ND	0.015
		Radionuclides (pCi/L)															
		Uranium-234									ND				2.56	3	6.68
		Uranium-238									ND				7.55	2.92	6.53

Table 4.11. SWMU 2 Locations of Groundwater Contaminants (Continued)

			Historical Data														
Unit	**Depth (ft)**	**Analysis**	MW154	MW333	MW337	MW338	PZ334	PZ335	PZ336	PZ74	SWMU2-10	SWMU2-13	SWMU2-16	SWMU2-17	SWMU2-3	SWMU2-5	SWMU2-9
RGA	74-77	***Inorganics (mg/L)***															
		Arsenic			0.0175	ND							0.081				
		Beryllium			ND	ND						0.068	0.017	0.03			
		Cadmium			ND	ND							0.012				
		Iron			56	5.7						23000					
		Manganese			2.1	1.1						65	19	41			
		Uranium			ND	0.35						ND	ND	ND			
		Vanadium			0.052	ND						1.3	0.28	0.61			
		Organics-Volatiles (mg/L)															
		1,1-DCE			ND	ND						3.55	1.09	0.159			
		Chloroform			0.0029	0.0015											
		cis -1,2-DCE			0.062	0.0073						0.0605	ND	ND			
		TCE			0.78	0.14						0.422	0.0072	ND			
		Radionuclides (pCi/L)															
		Uranium-234			ND	0.56						3.35	13.9	12.3			
		Uranium-238			ND	0.67						3.94	91.7	14.9			
	79-82	***Inorganics (mg/L)***															
		Arsenic		0.0029													
		Beryllium		ND							0.015				0.021		0.016
		Cadmium		ND													
		Iron		6.2													
		Manganese		2.6							15				38		38
		Uranium		ND							ND				ND		ND
		Vanadium		0.0097							0.37				0.3		0.3
		Organics-Volatiles (mg/L)															
		1,1-DCE		ND							1.45				4.1		22.8
		Chloroform		ND													
		cis -1,2-DCE		0.2							ND				ND		ND
		TCE		1.6							0.052				0.0022		0.0089
		Radionuclides (pCi/L)															
		Uranium-234		9.66							1.14				3.55		0.56
		Uranium-238		ND							1.08				9.91		0.78

Table 4.11. SWMU 2 Locations of Groundwater Contaminants (Continued)

			Historical Data														
Unit	**Depth (ft)**	**Analysis**	MW154	MW333	MW337	MW338	PZ334	PZ335	PZ336	PZ74	SWMU2-10	SWMU2-13	SWMU2-16	SWMU2-17	SWMU2-3	SWMU2-5	SWMU2-9
RGA	87	***Inorganics (mg/L)***															
		Beryllium										0.035	0.029				
		Iron										1500					
		Manganese										43	23				
		Uranium										ND	ND				
		Vanadium										0.65	0.48				
		Organics-Volatiles (mg/L)															
		1,1-DCE										0.0651	0.008				
		cis -1,2-DCE										0.034	ND				
		TCE										0.37	0.011				
		Radionuclides (pCi/L)															
		Uranium-234										2.28	9.97				
		Uranium-238										2.56	57.8				
McNairy		***Organics-Volatiles (mg/L)***															
	87	1,1-DCE												3.3			
		TCE												0.0017			
	92-93	1,1-DCE									0.0715				7.5		
		TCE									0.0464				ND		0.055

ND = not detected above screening levels

Blank cells indicate interval was not sampled for the specified analysis. The maximum value is shown for each depth interval at each location.

UCRS characterization data are derived from three sources:

1) Samples from PZ74 (1996 through 1998) and MW154 (1990 through 1996);
2) Samples from temporary borings (SWMU2-3, SWMU2-9, SWMU2-10, and SWMU 2-17) drilled during the SWMU 2 Interim Remedial Design Investigation of 1996 (DOE 1997a); and
3) Samples from piezometers PZ334, PZ335, and PZ336 in 1998 to assess the potential mobility of dissolved uranium.

Locations MW154, PZ334, PZ335, and PZ336 directly monitor the horizon of the buried waste around the perimeter. Samples from all of the temporary borings at depths of 22 to 26 ft (within the HU2 interval of the UCRS) characterize groundwater immediately below the depth of the waste pits (excavated at depths of 7 to 17 ft). Locations PZ74 and SWMU2-9 (42-43 ft sample) sample the deeper HU3 interval within the UCRS.

The screen of the SWMU 2 analyses identified the metals beryllium, iron, manganese, uranium, and vanadium and the organics TCE; *cis*-1,2-DCE; and vinyl chloride (TCE and its reductive dechlorination products) and 1,1-DCE as UCRS contaminants. In addition, uranium-234 and uranium-238 levels frequently exceeded background and child resident NALs.

The only metal and radionuclides that exceeded screening criteria in the horizon of the burial cells were uranium and the uranium isotopes (similar to soil contamination shown in Figure 4.18). Beryllium, manganese, and vanadium, the uranium isotopes, and TCE and its degradation products occurred at levels that exceed screening criteria throughout the UCRS interval below the waste pits.

Characterization data for the RGA come from seven temporary borings of the SWMU 2 Interim Remedial Design Investigation of 1996 (DOE 1997a) and MW333, MW337, and MW338 (for the period 1996 to present). The metals that exceeded screening criteria include beryllium, iron, manganese, uranium, vanadium (also identified as UCRS contaminants) and arsenic and cadmium.

TCE, with a maximum value of 5.35 mg/L (5,350 μg/L), was the most widely detected organic contaminant in RGA groundwater at SWMU 2. Another VOC, 1,1-DCE, showed high levels in the RGA (47.9 mg/L) from historical boring SWMU 2-5. The hydrogeological assessment of the SWMUs 2 and 3 area (PRS 2007a) determined that an upgradient source is responsible for the high TCE levels in the area. Figure 4.20 shows SWMUs 2, 3, and 4 in relation to the underlying TCE plume in the RGA. It is difficult to separate any potential impacts to the RGA from SWMU 2 due to the migration of contamination from upgradient areas. Figures 4.21, 4.22, and 4.23 present trend graphs of TCE, ^{99}Tc, and *cis*-1,2-DCE, respectively, in RGA MWs. The increases in TCE and *cis*-1,2-DCE in MW333 and the increase in technetium-99 in MW337 are caused by upgradient sources. Similar patterns are seen upgradient in SWMU 3 MWs.

RGA groundwater samples from the location SWMU2-17 contained both uranium-234 and uranium-238 above screening criteria at 50.6 and 55.1 pCi/L, respectively. The analysis of a sample from location SWMU2-16 detected uranium-238 at 91.7 pCi/L.

Four of the temporary borings of the SWMU 2 Interim Remedial Design Investigation of 1996 (DOE 1997a), SWMU2-3, SWMU2-9, SWMU2-10, and SWMU2-17, characterized groundwater in the McNairy Formation immediately below the RGA. TCE and 1,1-DCE were the only groundwater contaminants identified by comparison against the RI screening criteria. All levels of metals and radionuclides in McNairy groundwater samples of SWMU 2 were less than PGDP background.

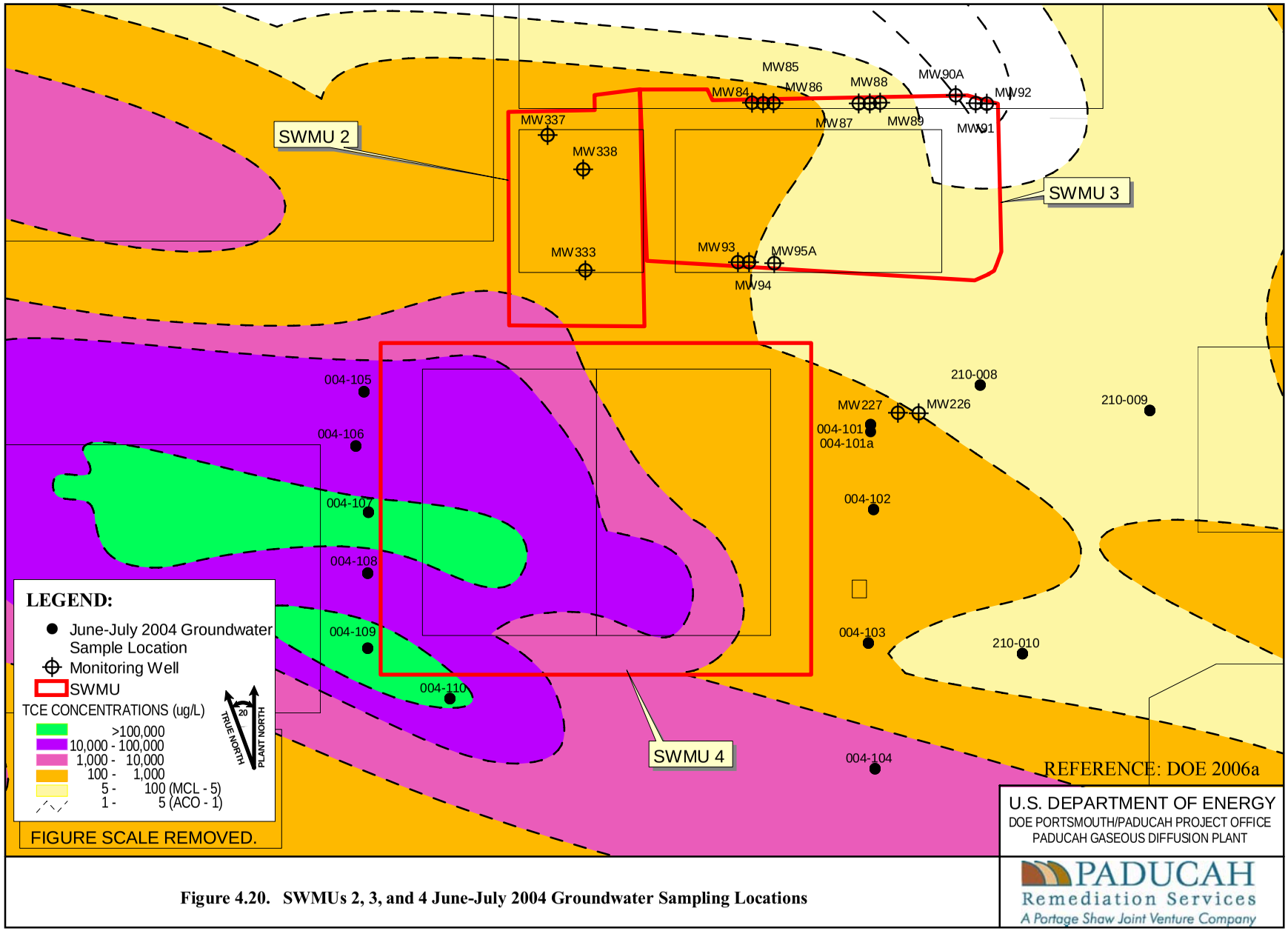


Figure 4.20. SWMUs 2, 3, and 4 June-July 2004 Groundwater Sampling Locations

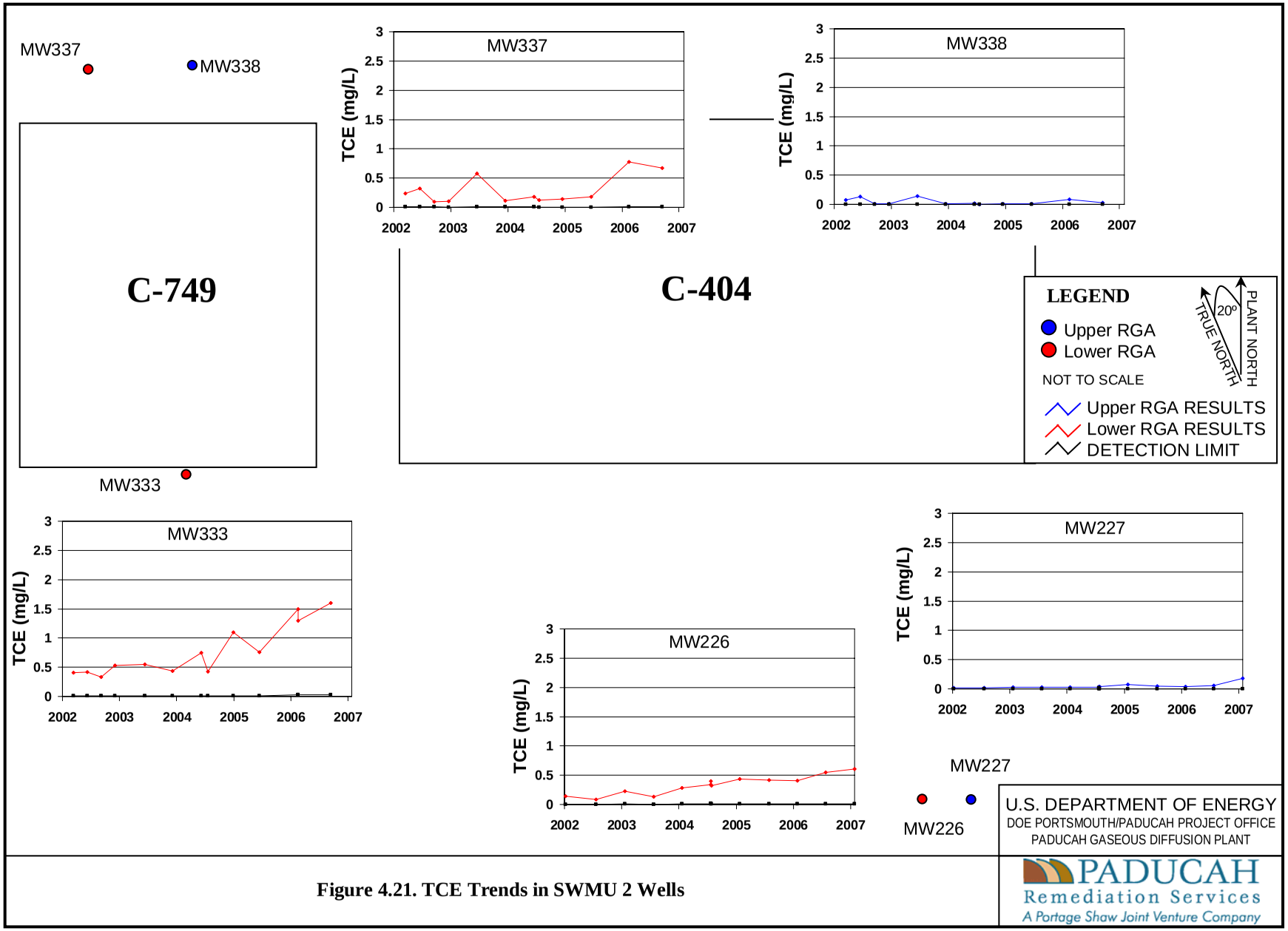


Figure 4.21. TCE Trends in SWMU 2 Wells

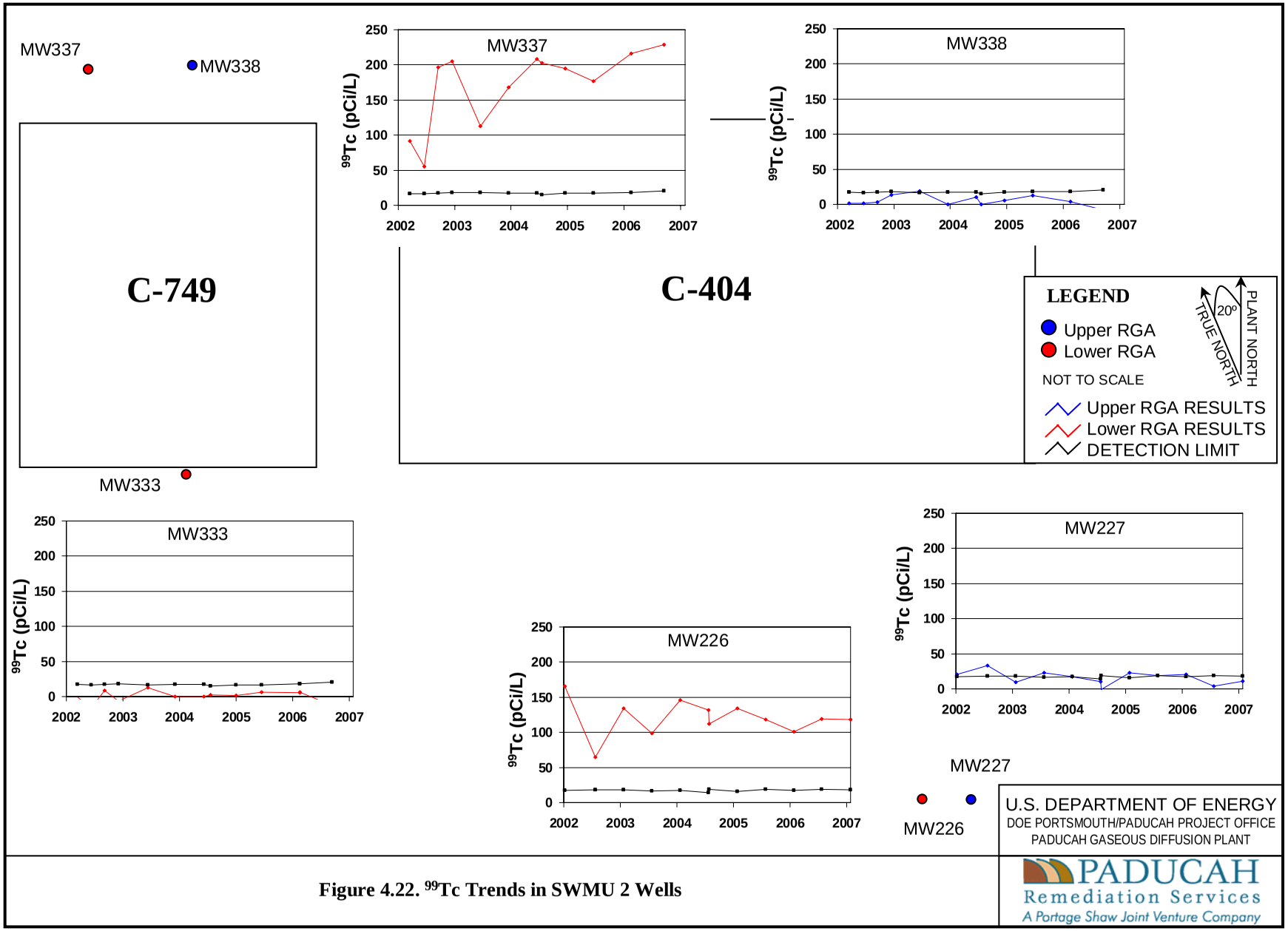


Figure 4.22. ^{99}Tc Trends in SWMU 2 Wells

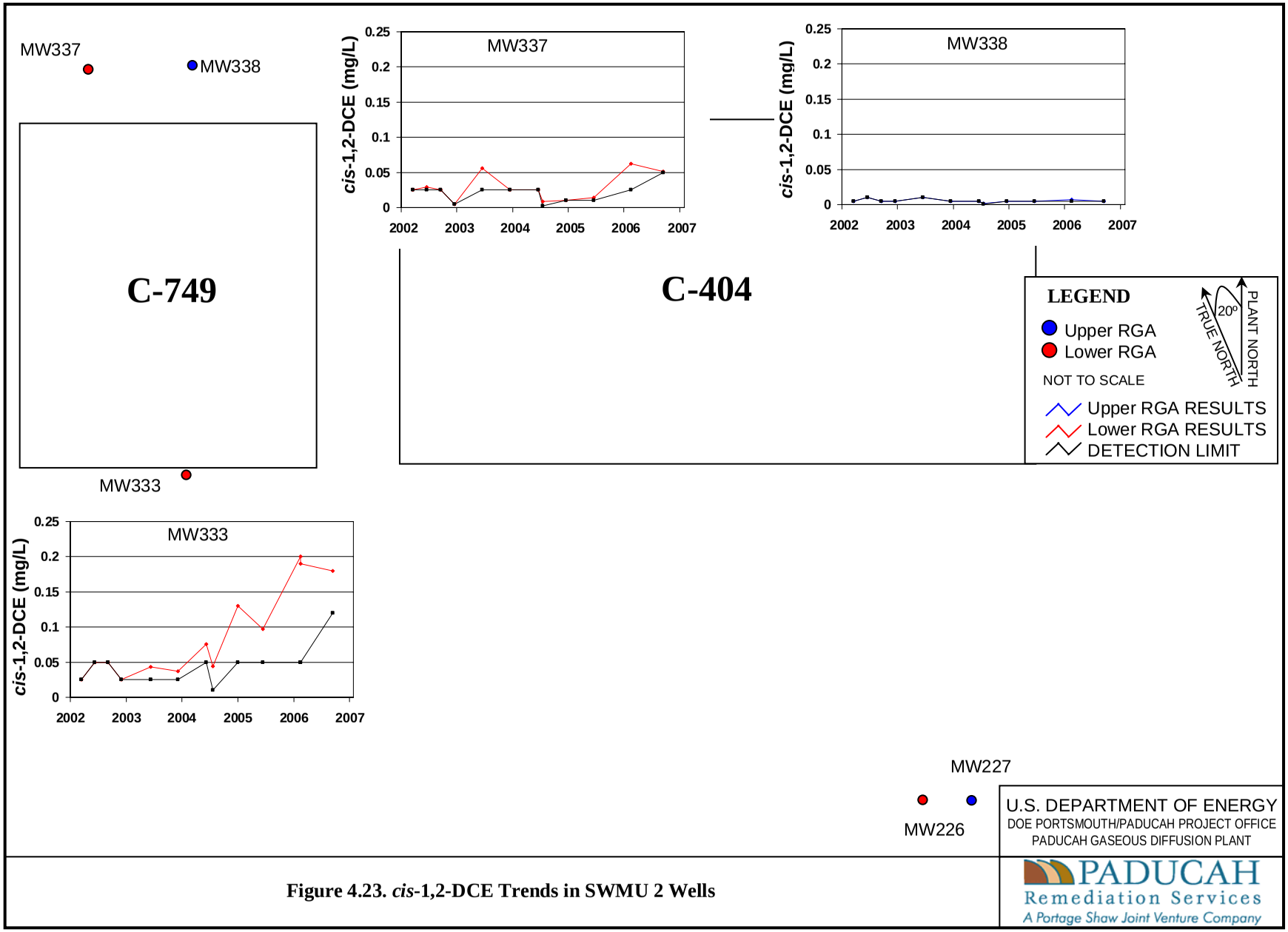


Figure 4.23. *cis*-1,2-DCE Trends in SWMU 2 Wells

4.4 SWMU 3

4.4.1 Subsurface Soils

No historical subsurface soil data were available for SWMU 3; however, subsurface soil samples were collected from four angled borings at C-404 as part of this RI. Six shallow borings also were drilled and sampled along the former discharge ditch associated with SWMU 3 as part of this RI. A review of RI data identified the contaminants listed in Table 4.12.

Table 4.12. SWMU 3 Subsurface Soil Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection	
	Historical Data	RI Data		Above Background Value	Above Excavation Worker NAL
Inorganics (mg/kg)					
Antimony	N/A[b]	11	3/40	3/40	3/40
Arsenic	N/A	8.25	36/40	1/40	36/40
Uranium	N/A	83.6	11/40	7/40	4/40
Radionuclides (pCi/g)					
Cesium-137	N/A	0.456	1/40	1/40	1/40
Uranium (total)	N/A	25.8	9/40	N/A	1/40
Uranium-234	N/A	3.02	14/40	1/40	1/40
Uranium-238	N/A	22.4	18/40	6/40	6/40

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

Table 4.13 shows the locations of the samples with metals and radionuclides detected above screening levels.

Wastes disposed of in SWMU 3 include all liquid effluents from C-400 operations from 1952 through 1957. C-404 continued to receive solid uranium-contaminated and radioactively contaminated wastes from 1957 until 1986.

The most prevalent metal detected above its background values in subsurface soil at SWMU 3 is uranium, followed by antimony. Uranium contamination has migrated to a depth of 10 to 15 ft under C-404 (both as a metal and as a radionuclide) and as much as 10 ft under the former discharge ditch (as a metal). Figure 4.24 provides the distribution of uranium based on the RI data. The higher concentrations are found in shallow soils on the western side of the unit. The 10 ft sample from boring 003-001 had a uranium concentration of 83.6 mg/kg, but this decreased to approximately 1 mg/kg or less in deeper samples indicating a limited extent to uranium contamination. Uranium was not detected above screening levels in the 15 ft samples along the former discharge ditch (Appendix D, page D-25). Cesium-137 was detected above screening in one sample at a depth of 5 ft in boring 003-005 along the former discharge ditch.

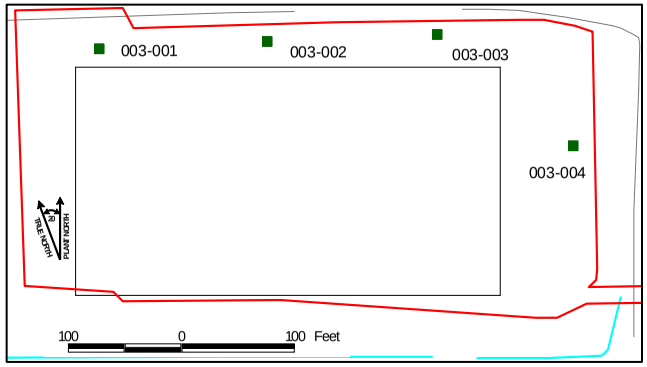
Antimony contamination is limited to a depth of 5 to 10 ft along the former discharge ditch. (SWMUs 3 and 145 are the only BGOU SWMUs to have antimony concentrations that exceed the contaminant screening criteria.) Arsenic was detected frequently in subsurface soil samples, but exceeded the PGDP background level in only 1 of 40 samples.

Table 4.13. SWMU 3 Locations of Subsurface Soil Contaminants

		RI – Angled Borings				RI – Ditch Samples					
Analysis	**Depth (ft)**	003-001	003-002	003-003	003-004	003-005	003-006	003-007	003-008	003-009	003-010
Inorganics (mg/kg)											
Antimony	5					ND	ND	9.89	11	ND	ND
	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	10.1
	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	30	ND	ND	ND	ND						
	45	ND	ND	ND	ND						
	60	ND	ND	ND	ND						
Arsenic	5					3.76	3.9	7.03	1.25	2.93	2.68
	10	5.69	3.09	2.47	3.81	4.67	2.96	2.57	1.4	2.02	2.61
	15	0.956	2.12	5.19	1.46	ND	1.68	2.3	1.18	1.16	1.27
	30	ND	3.32	ND	3.02						
	45	8.25	2.39	2.61	3.01						
	60	1.65	ND	1.28	2.36						
Uranium	5					19.9	5.3	15.8	ND	1.17	ND
	10	83.6	33.7	ND	1.78	ND	ND	6.09	ND	ND	ND
	15	ND	ND	5.18	ND	ND	ND	ND	ND	ND	ND
	30	1.05	ND	ND	ND						
	45	1.41	ND	ND	ND						
	60	ND	ND	ND	ND						
Radionuclides (pCi/g)											
Cesium-137	5					0.456	ND	ND	ND	ND	ND
	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	30	ND	ND	ND	ND						
	45	ND	ND	ND	ND						
	60	ND	ND	ND	ND						
Uranium	5				7.46	3.48	6.55	ND	ND	ND	
	10	8.53	25.8	ND	ND	ND	ND	2.7	ND	ND	ND
	15	0.464	ND	ND	ND	ND	ND	ND	ND	ND	ND
	30	ND	ND	ND	ND						
	45	0.602	ND	ND	ND						
	60	ND	ND	0.371	ND						
Uranium-234	5					1.08	0.533	0.913	ND	0.142	ND
	10	0.927	3.02	ND	ND	ND	ND	0.392	ND	ND	ND
	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	30	0.18	ND	ND	ND						
	45	0.305	0.144	ND	ND						
	60	0.178	0.211	0.249	ND						
Uranium-238	5					6.29	2.91	5.55	0.127	0.201	ND
	10	7.47	22.4	ND	0.2	0.142	ND	2.28	ND	ND	ND
	15	0.354	0.325	ND	ND	ND	ND	ND	ND	ND	ND
	30	0.192	ND	ND	ND						
	45	0.271	0.129	ND	ND						
	60	0.147	ND	0.19	ND						

ND = not detected above screening levels

Blank cells indicate interval was not sampled for the specified analysis. Maximum value is shown for each depth interval.



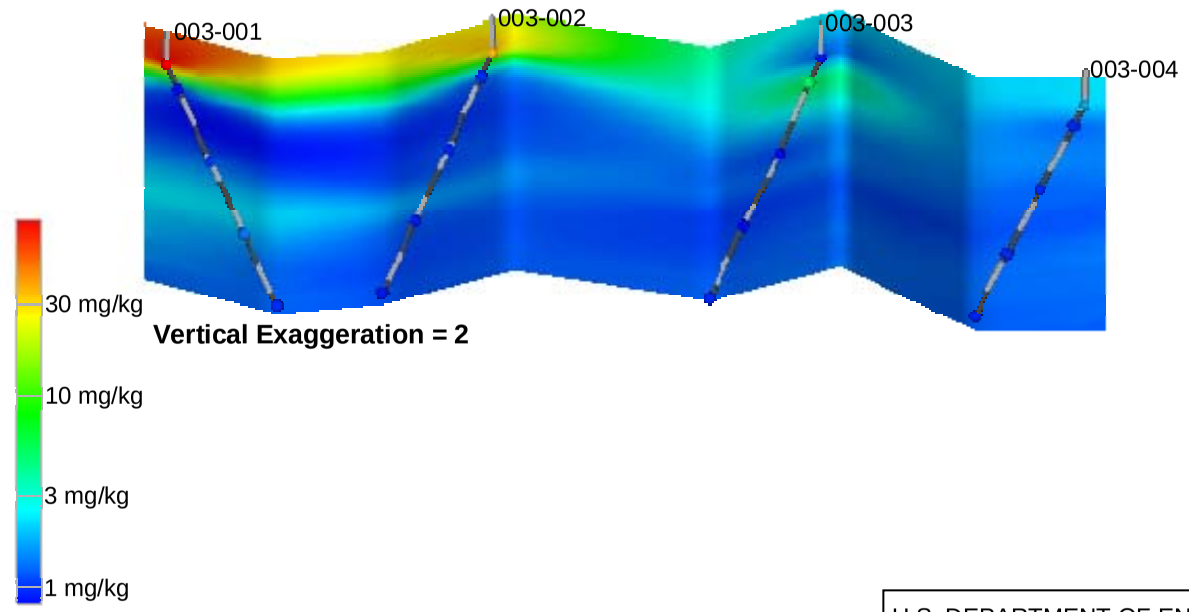


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Figure 4.24. SWMU 3 Uranium in Soil (Looking North)

PADUCAH Remediation Services
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4.4.2 SWMU 3 Groundwater

A large amount of historical UCRS and RGA groundwater data were available for SWMU 3. MW67 and MW76 were evaluated for inclusion in the SWMU 3 monitoring system, but only one new well installed during the RI (MW420) will be added to the compliance monitoring system. Results from those three wells are discussed below. Additionally, UCRS groundwater samples were collected from two of the four angled borings at SWMU 3 as part of this RI. The UCRS data sources included well samples collected from MW85, MW88, MW91, and MW94 for the period 1995 through present (these wells are screened between 29 and 40 ft bgs) and samples from the BGOU RI temporary borings 003-003 (at 28 ft) and 003-004 (at 30 ft). All of these samples represent the HU2 interval within the UCRS.

A review of RI and historical data identified the UCRS contaminants listed in Table 4.14. All sample locations documented levels of TCE, the radionuclides technetium-99 and uranium-238, and at least one metal (arsenic, iron, lead, manganese, molybdenum, and uranium) that exceed screening criteria. Arsenic and uranium are the only contaminants in this table that also are found in the SWMU 3 subsurface soil contaminant list.

Wells characterize the upper and lower RGA to monitor for potential contamination derived from C-404. Upper RGA wells include MW67, MW76, MW84, MW87, MW90/90A, MW93, and MW227. The lower RGA wells are MW86, MW89, MW92, MW95/95A, and MW226. The data base for screening RGA contaminants is the monitoring data for the period 1995 to present. RGA groundwater contaminants for SWMU 3 are listed in Table 4.15.

Table 4.14. SWMU 3 UCRS Groundwater Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection	
	Historical Data	RI Data		above MCL[a]	above Child Resident NAL
Inorganics (mg/L)					
Arsenic	0.012	N/A[b]	34/46	9/46	34/46
Arsenic, Dissolved	0.012	0.00159	36/39	8/39	4/39
Iron	N/A	43.5	2/2	N/A	2/2
Lead	0.00539	0.0172	4/46	2/46	2/46
Manganese	N/A	1.45	2/2	N/A	2/2
Molybdenum	N/A	0.0184	2/2	N/A	1/2
Uranium	0.0518	0.00193	14/150	2/150	14/150
Organics–Volatiles (mg/L)					
TCE	1.8	0.046	105/126	82/126	104/126
Radionuclides (pCi/L)					
Technetium-99	998	8.72	161/166	1/166	159/166
Uranium-234	14.39	2.33	11/27	N/A	10/27
Uranium-238	34.81	0.912	13/27	N/A	13/27

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

Table 4.15. SWMU 3 RGA Groundwater Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection		
	Historical Data	RI Data		Above Back-ground	Above MCL	Above Child Resident NAL
Inorganics (mg/L)						
Arsenic	0.12	N/A[b]	28/79	2/79	2/79	28/79
Iron	6.02	N/A	14/19	1/19	N/A	6/19
Manganese	1.4	N/A	19/19	10/19	N/A	14/19
Uranium	0.09	N/A	15/395	6/395	2/395	15/395
Organics–Volatiles (mg/L)						
1,1-DCE	0.012	N/A	7/19	N/A	1/19	7/19
Chloroform	0.0005	N/A	8/20	N/A	N/A	8/20
TCE	0.61	N/A	215/337	N/A	150/337	192/337
Radionuclides (pCi/L)						
Uranium-234	199.68	N/A	10/67	8/67	N/A	8/67
Uranium-238	210.83	N/A	11/67	8/67	N/A	10/67

[a] Frequency of detection is the number of detections of an analyte per number of analyses of regular and duplicate samples.
[b] N/A = not applicable

Arsenic, iron, manganese, and uranium concentrations in RGA groundwater samples (also contaminants in the UCRS) exceeded screening levels for metals at SWMU 3. All of these metals were found in both the upper and lower RGA with no significant differentiation with depth. 1,1-DCE and TCE exceeded screening levels for organics in RGA groundwater at SWMU 3. The hydrogeological assessment of SWMUs 2 and 3 that was completed as part of this RI (PRS 2007a) documents that an upgradient source accounts for the high TCE levels (refer to Figure 4.20). Because the 1,1-DCE detects occurred only in upgradient wells, it also appears to be related to an upgradient source. The only radionuclides in the SWMU 3 RGA groundwater samples to exceed background and MCLs were uranium-234 and uranium-238, occurring in both the upper and lower RGA. The uranium isotope activities were markedly higher in well cluster MW93/MW95A.

Two existing monitoring wells (MW67 and MW76) and a new well (MW420) were evaluated for inclusion in the SWMU 3 compliance monitoring system. MW67 and MW76 were rehabilitated and purged prior to sampling since they had not been used in a long time. After analytical results were available and discussions were held with KEEC, it was determined that MW67 and MW76 would not be included in the compliance monitoring system and only MW420 would be added. Table 4.16 shows the contaminants that exceed the screening levels in these wells. All three wells monitor the upper part of the RGA.

Table 4.16. RGA Groundwater Contaminants in MW67, MW76, and MW420

Analysis	Depth (ft)	MW67	MW76	MW420
Inorganics (mg/L)				
Arsenic	67-77	0.0156	ND	ND
Chromium		0.0155	ND	ND
Selenium		ND	0.00874	ND
Arsenic, Dissolved		0.0158	ND	ND
Chromium, Dissolved		0.0124	ND	ND
Organics–Volatiles (mg/L)				
1,1,1-Trichloroethane	67-77	ND	0.00019	ND
1,1,2-Trichloroethane		0.0011	ND	ND
1,1-Dichloroethane		0.0002	0.00025	ND
1,1-Dichloroethene		ND	ND	ND
Carbon disulfide		ND	ND	0.0012
Carbon tetrachloride		ND	ND	ND
Chloroform		0.034	0.0012	0.00067
cis-1,2-Dichloroethene		0.12	ND	ND
Methylene chloride		0.00043	ND	ND
Tetrachloroethene		ND	0.0017	ND
Toluene		ND	ND	0.001
trans-1,2-Dichloroethene		0.0011	ND	ND
Trichloroethene		1.1	0.46	0.21
Trichlorofluoromethane		ND	0.0005	ND
Vinyl chloride		0.00047	ND	ND
Radionuclides (pCi/L)				
Technetium-99	67-77	43.6	103	22.83
Uranium-238		0.31	0.305	ND

ND = not detected or not detected above screening levels

Groundwater monitoring under the RCRA permit for the unit, however, has shown statistically significant increases of TCE above background in one of three downgradient compliance wells in the upper RGA

(MW84). *C-404 Landfill Source Demonstration, Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (PRS 2007b) related the increase in TCE levels to trends in the Southwest Plume and does not indicate that SWMU 3 is the contributor. Additionally, trends of arsenic, chromium, selenium, technetium-99, uranium-234, and uranium-238 have required statistical analysis for contaminant determination. Figures 4.25 through 4.45 present trend graphs of these contaminants in UCRS and upper and lower RGA MWs. These graphs show both the result and the laboratory detection limit. In some cases, particularly with radiological constituents, the reported result is less than the detection limit (this would be qualified as a "nondetect" in the database). With these charts, it's best to focus on "long-term" trends rather than individual fluctuations. Some of the notable trends in UCRS MWs include increasing levels of arsenic in MW85 and increasing levels of chromium, TCE, and technetium-99 in MW91. TCE was decreasing in UCRS wells MW88 and MW94, and technetium-99 was decreasing in UCRS wells MW85, MW88, and MW94. It should be noted that any TCE source at SWMU 3 appears diminished due mostly to decreasing trends in UCRS MWs and no detections of TCE in SWMU 3 leachate since 2004.

Table 4.17 provides detail (depth, sample location, and analytical results) for SWMU 3 groundwater samples, including nondetects and detections above screening levels.

Table 4.17. SWMU 3 Locations of Groundwater Contaminants

			RI Data		Historical Data														
Unit	**Depth (ft)**	**Analysis**	003-003	003-004	MW226	MW227	MW67	MW84	MW85	MW86	MW87	MW88	MW89	MW90/ MW90A	MW91	MW92	MW93	MW94	MW95/ MW95A
UCRS	28-30	***Inorganics (mg/L)***																	
		Arsenic	ND	ND															
		Arsenic, Dissolved	0.00129	0.00159															
		Iron	43.5	24															
		Lead	0.0153	0.0172															
		Manganese	1.45	0.284															
		Molybdenum	0.0184	ND															
		Uranium	0.00178	0.00193															
		Organics-Volatiles (mg/L)																	
		TCE	0.042	0.046															
		Radionuclides (pCi/L)																	
		Technetium-99	ND	ND															
		Uranium-234	2.33	0.604															
		Uranium-238	0.912	0.793															
	33-35	***Inorganics (mg/L)***																	
		Arsenic										0.011			0.00389				
		Arsenic, Dissolved										0.0081			0.00225				
		Lead										ND			ND				
		Uranium										ND			ND				
		Organics-Volatiles (mg/L)																	
		TCE										1.8			0.079				
		Radionuclides (pCi/L)																	
		Technetium-99										524			998				
		Uranium-234										ND			ND				
		Uranium-238										ND			ND				
	39-41	***Inorganics (mg/L)***																	
		Arsenic							0.012									0.01	
		Arsenic, Dissolved							0.012									0.0025	
		Lead							ND									ND	
		Uranium							0.0518									0.00433	

Table 4.17. SWMU 3 Locations of Groundwater Contaminants (Continued)

			RI Data		Historical Data														
Unit	**Depth (ft)**	**Analysis**	003-003	003-004	MW226	MW227	MW67	MW84	MW85	MW86	MW87	MW88	MW89	MW90/ MW90A	MW91	MW92	MW93	MW94	MW95/ MW95A
UCRS	39-41	***Organics-Volatiles (mg/L)***																	
		TCE							0.045									0.11	
		Radionuclides (pCi/L)																	
		Technetium-99							406									660	
		Uranium-234							3.9									14.39	
		Uranium-238							23.3									34.81	
RGA	70-72	***Inorganics (mg/L)***																	
		Arsenic												0.00103					
		Iron					0.98							2.46					
		Manganese					ND							1.06					
		Uranium					ND							ND					
		Organics-Volatiles (mg/L)																	
		1,1-DCE												ND					
		Chloroform												0.00017					
		TCE					0.0022							0.0024					
		Radionuclides (pCi/L)																	
		Uranium-234					ND							ND					
		Uranium-238					ND							ND					
	74-76	***Inorganics (mg/L)***																	
		Arsenic				0.12		0.00319			0.00116			ND					
		Iron				3.14		ND			ND			ND					
		Manganese				0.144		ND			0.0396			0.491					
		Uranium				0.02		ND			ND			ND					
		Organics-Volatiles (mg/L)																	
		1,1-DCE				ND		ND			ND			ND					
		Chloroform				ND		ND			ND			0.00019					
		TCE				0.18		0.48			0.072			0.005					
		Radionuclides (pCi/L)																	
		Uranium-234				2.9		ND			ND								
		Uranium-238				6.69		ND			ND								
	80	***Inorganics (mg/L)***																	
		Arsenic															0.00159		
		Iron															ND		
		Manganese															ND		
		Uranium															ND		

Table 4.17. SWMU 3 Locations of Groundwater Contaminants (Continued)

			RI Data		Historical Data														
Unit	**Depth (ft)**	**Analysis**	003-003	003-004	MW226	MW227	MW67	MW84	MW85	MW86	MW87	MW88	MW89	MW90/ MW90A	MW91	MW92	MW93	MW94	MW95/ MW95A
RGA	80	***Organics-Volatiles (mg/L)***																	
		1,1-DCE															0.0018		
		Chloroform															ND		
		TCE															0.54		
		Radionuclides (pCi/L)																	
		Uranium-234															199.68		
		Uranium-238															210.83		
	85-90	***Inorganics (mg/L)***																	
		Arsenic			0.00195					0.004			ND			0.00105			0.00151
		Iron			6.02					ND			ND						ND
		Manganese			1.4					0.408			0.591						0.342
		Uranium			ND					0.05			ND			ND			0.09
		Organics-Volatiles (mg/L)																	
		1,1-DCE			0.012					ND			ND						0.0022
		Chloroform			ND					ND			ND						0.0005
		TCE			0.61					0.38			0.0026			ND			0.35
		Radionuclides (pCi/L)																	
		Uranium-234			ND					1.37			3.35			ND			55.4
		Uranium-238			ND					5.02			0.522			ND			7.85

ND = not detected above screening levels

Blank cells indicate interval was not sampled for the specified analysis. The maximum value is shown for each depth interval at each location.

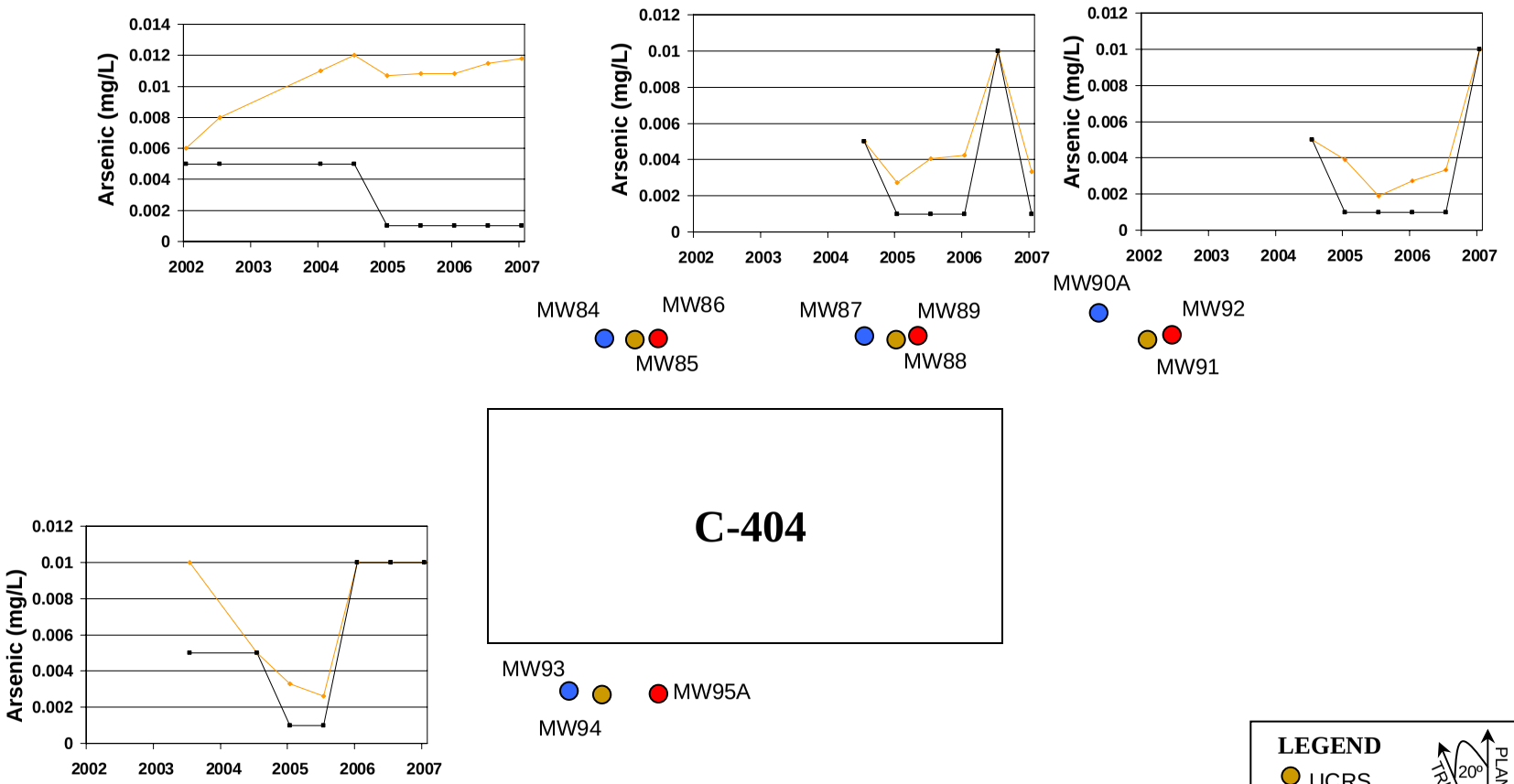

Figure 4.25. Arsenic Trends in UCRS Groundwater at SWMU 3

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

PADUCAH Remediation Services
A Portage Shaw Joint Venture Company

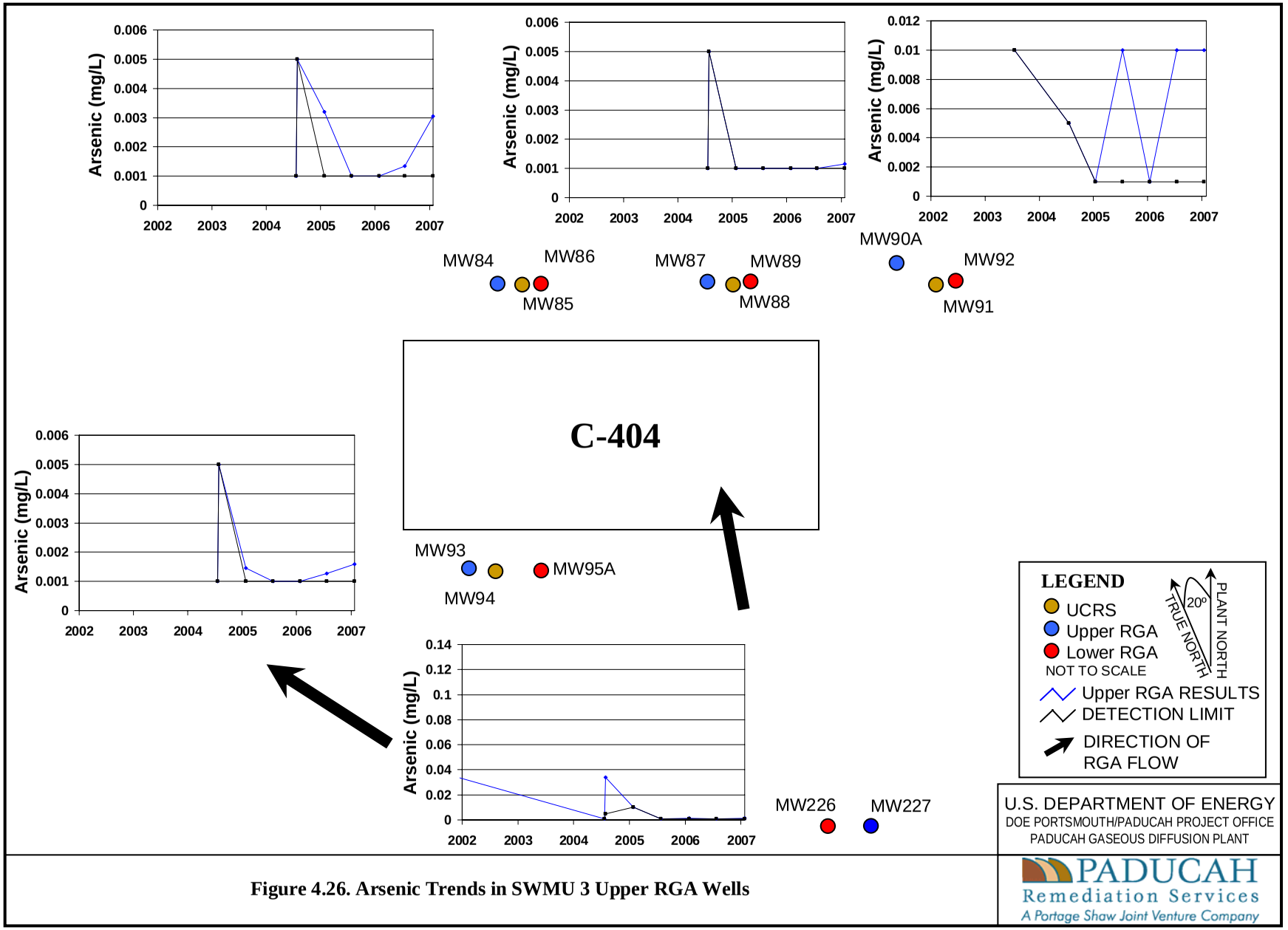

Figure 4.26. Arsenic Trends in SWMU 3 Upper RGA Wells

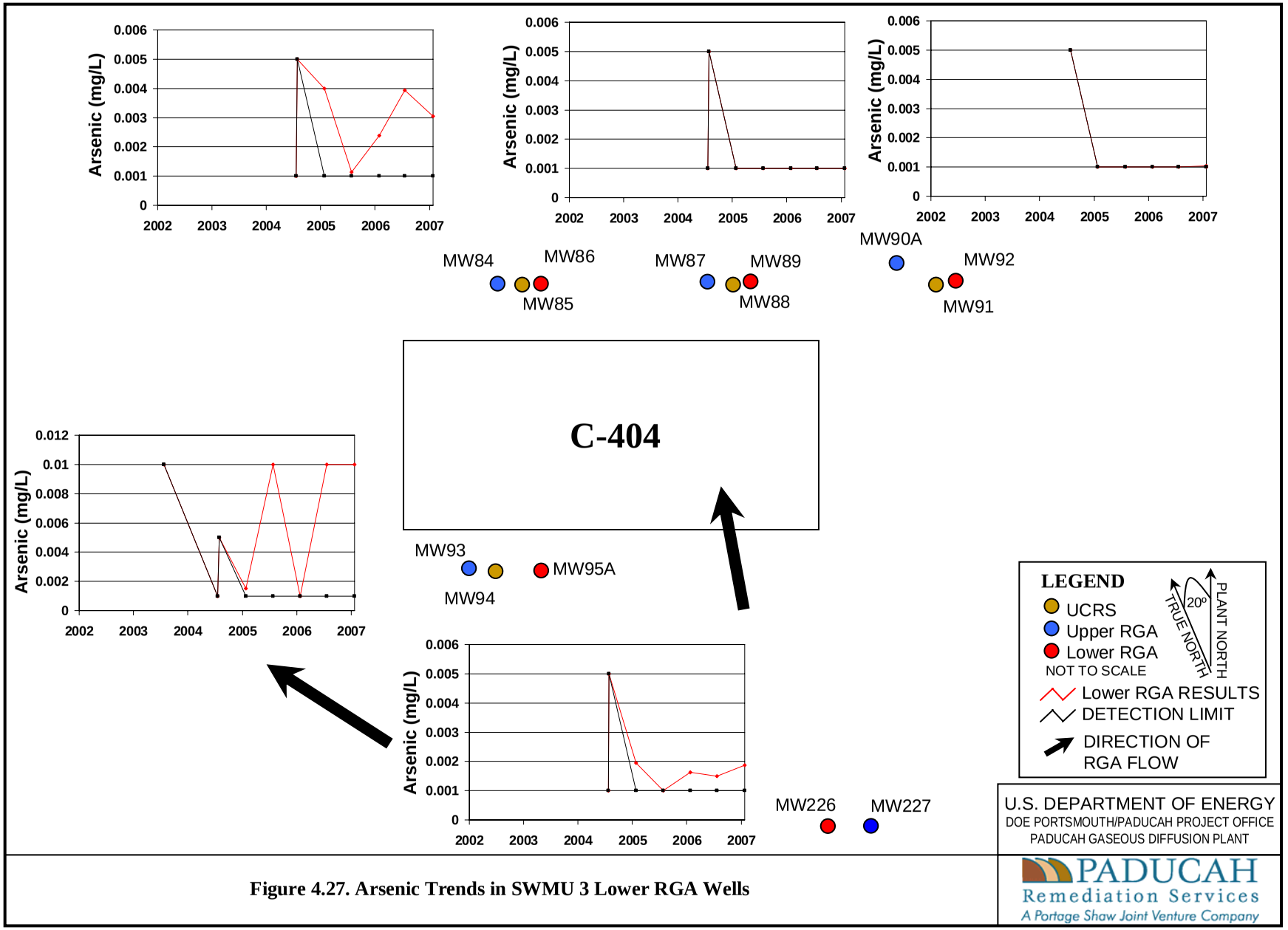

Figure 4.27. Arsenic Trends in SWMU 3 Lower RGA Wells

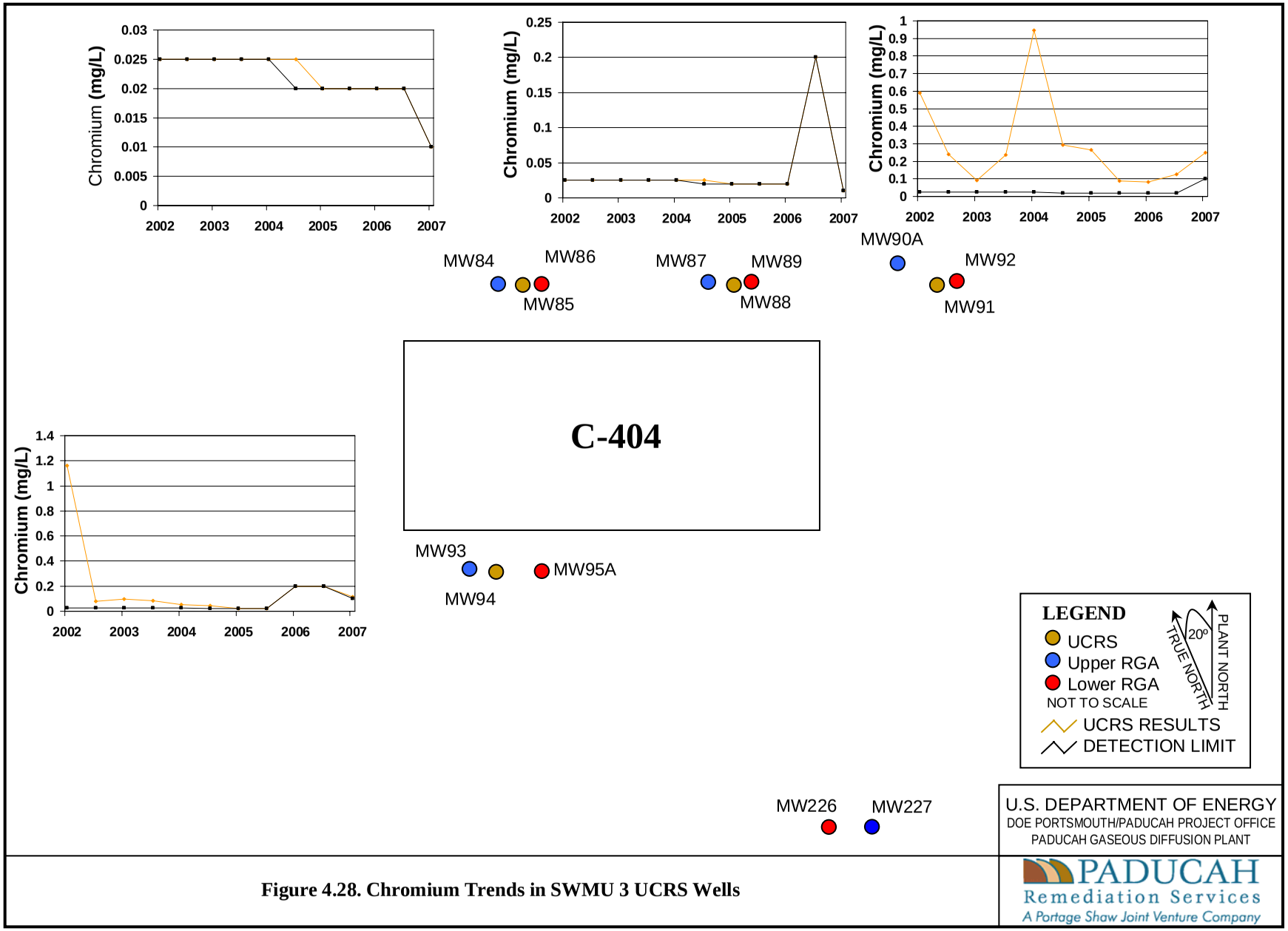

Figure 4.28. Chromium Trends in SWMU 3 UCRS Wells

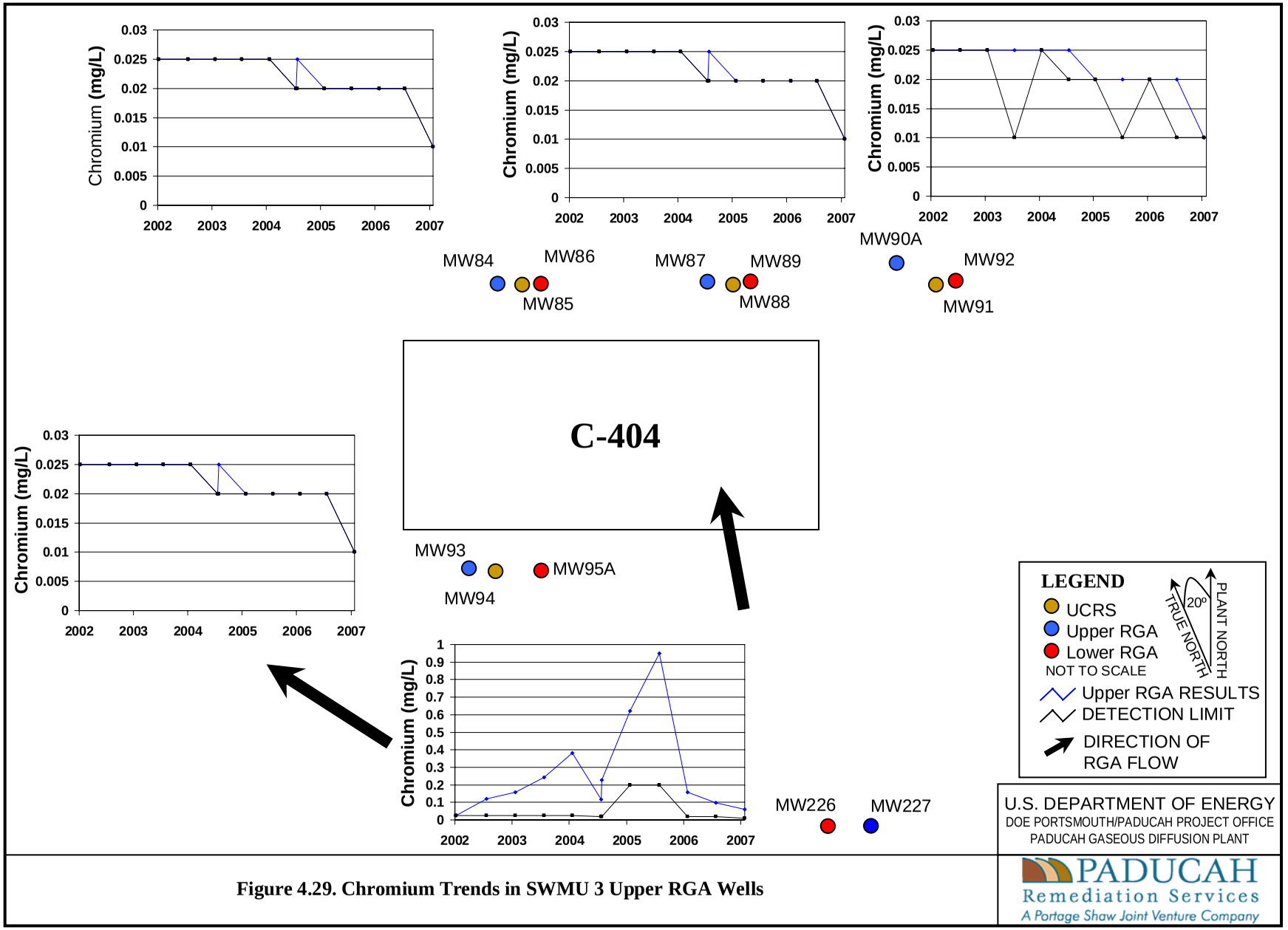

Figure 4.29. Chromium Trends in SWMU 3 Upper RGA Wells

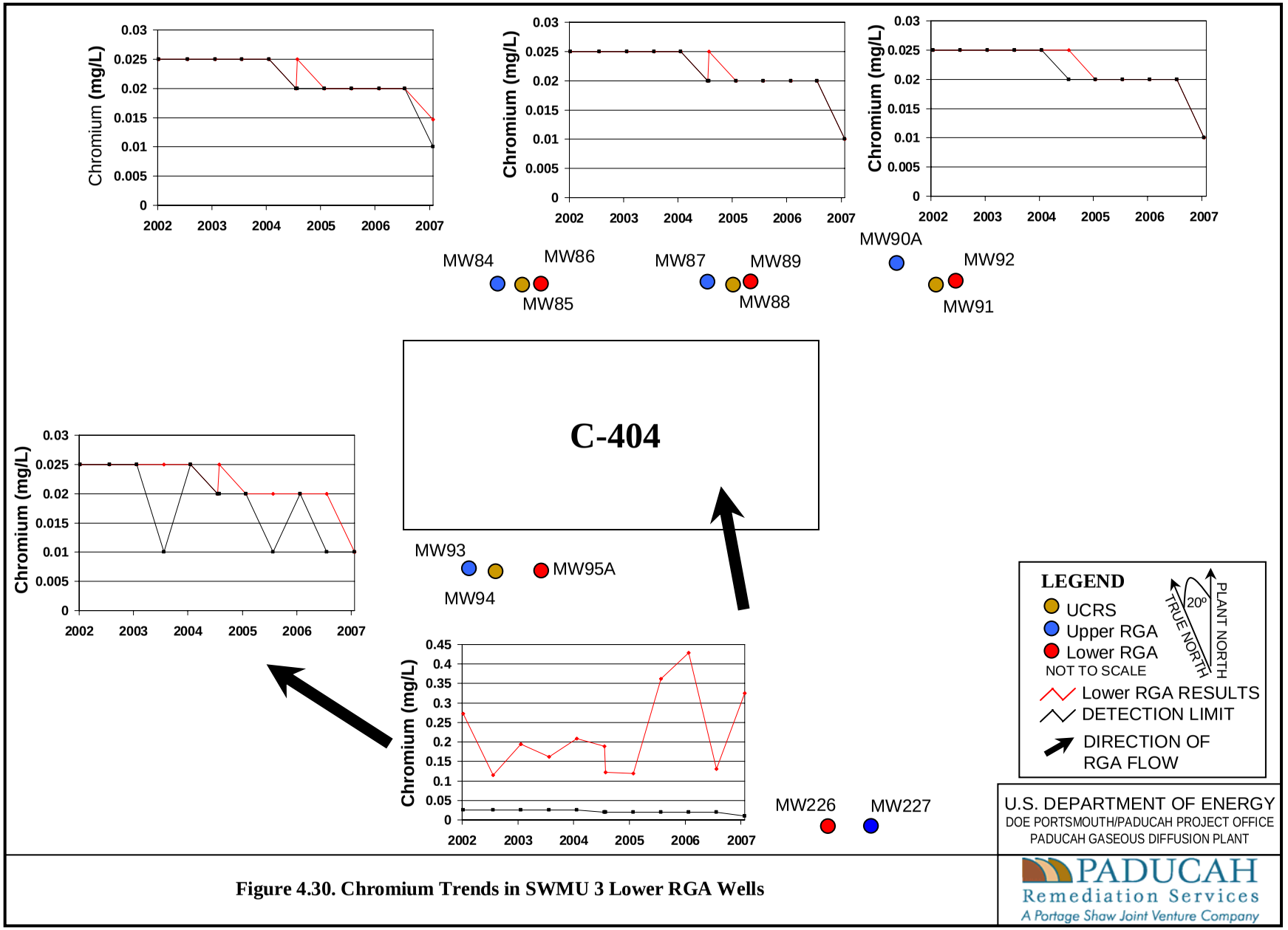

Figure 4.30. Chromium Trends in SWMU 3 Lower RGA Wells

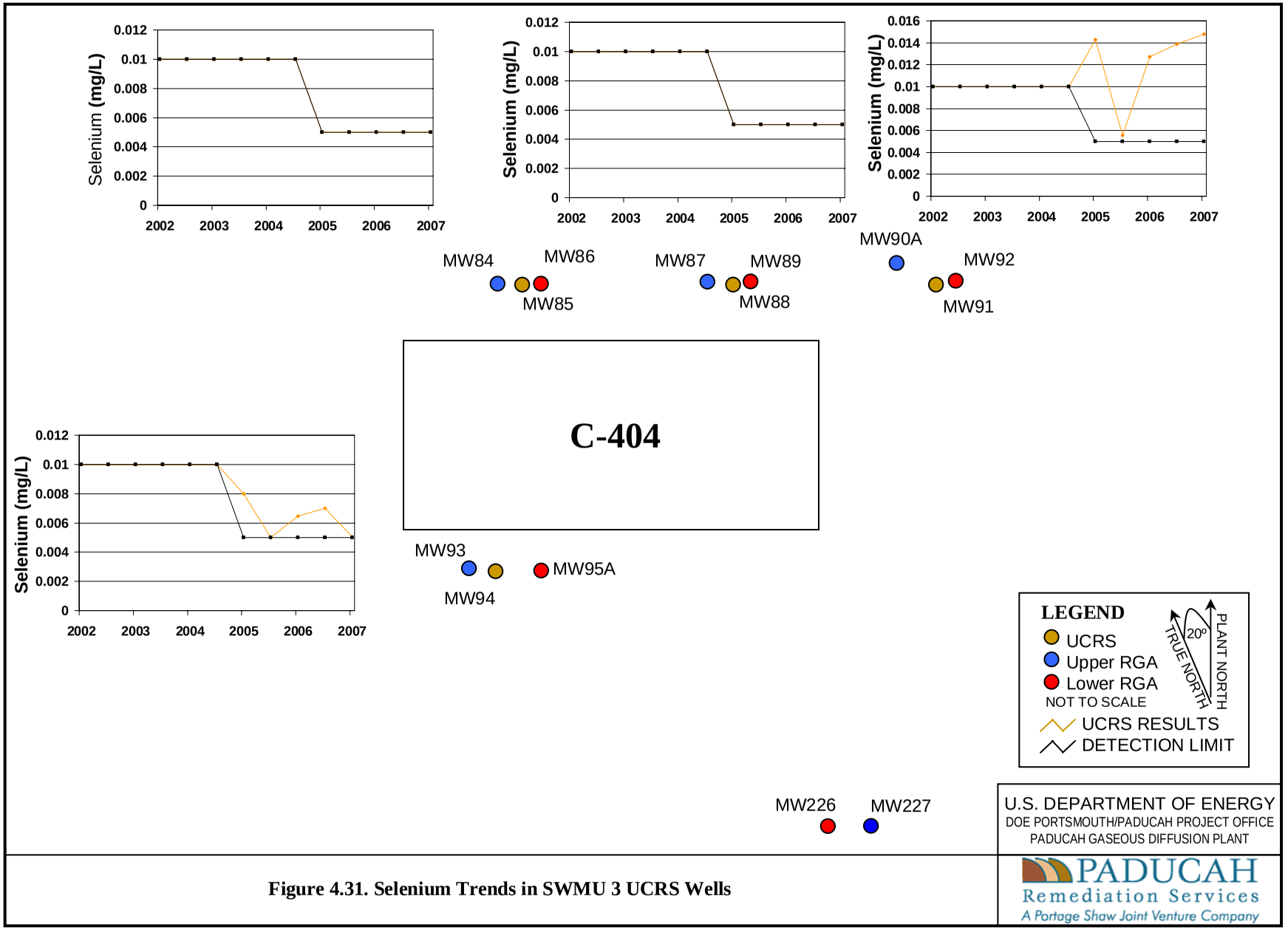

Figure 4.31. Selenium Trends in SWMU 3 UCRS Wells

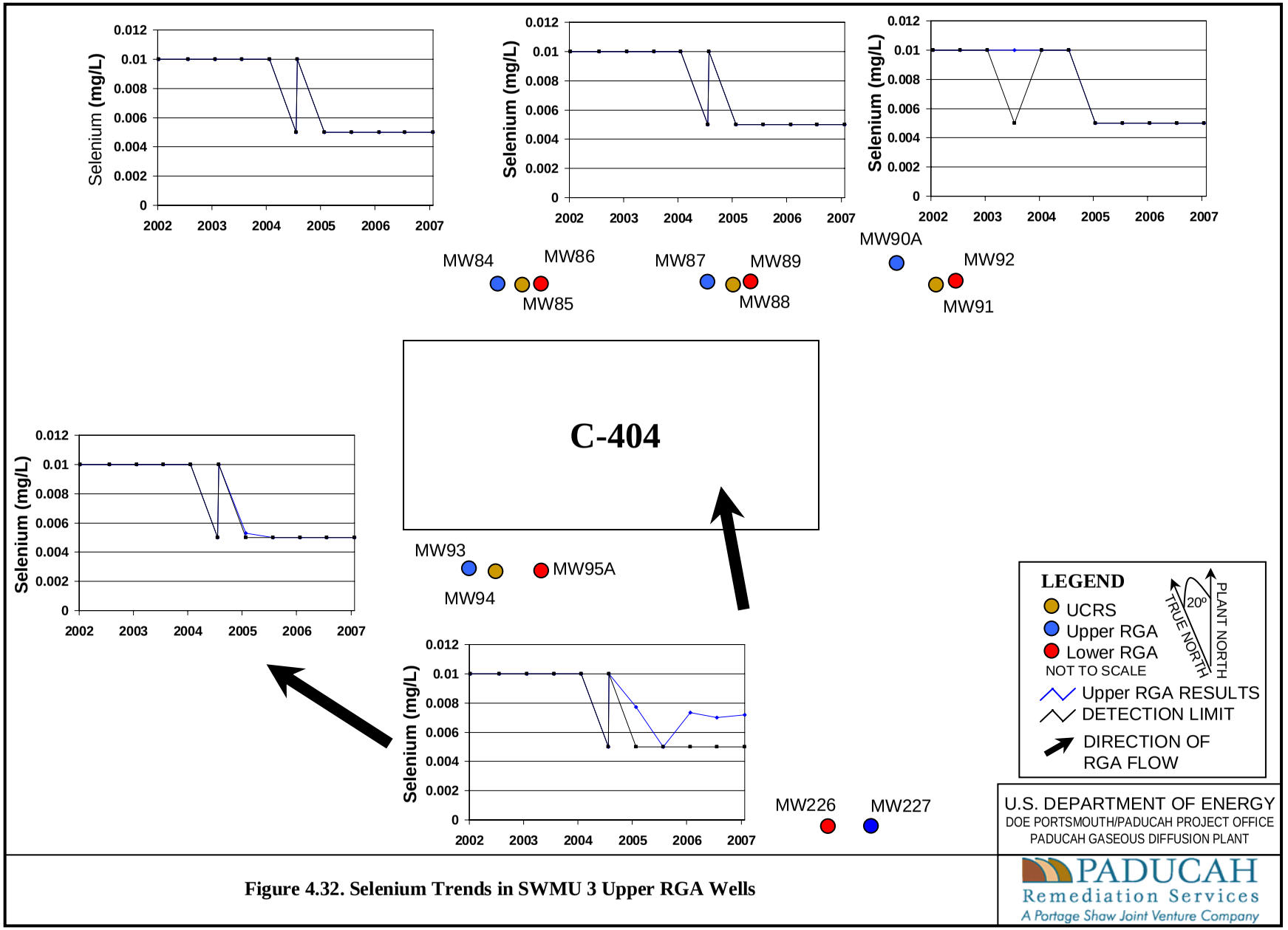

Figure 4.32. Selenium Trends in SWMU 3 Upper RGA Wells

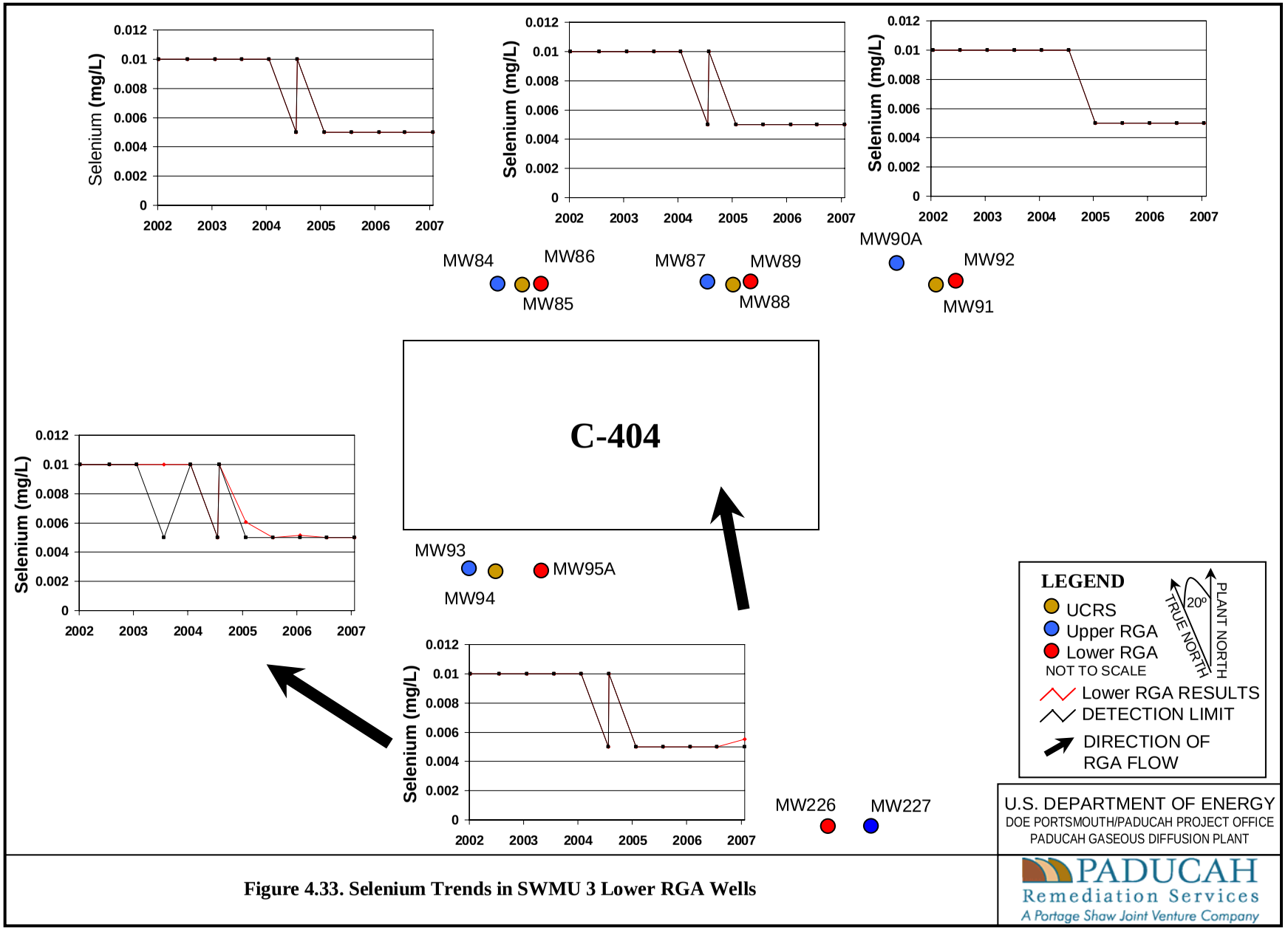

Figure 4.33. Selenium Trends in SWMU 3 Lower RGA Wells

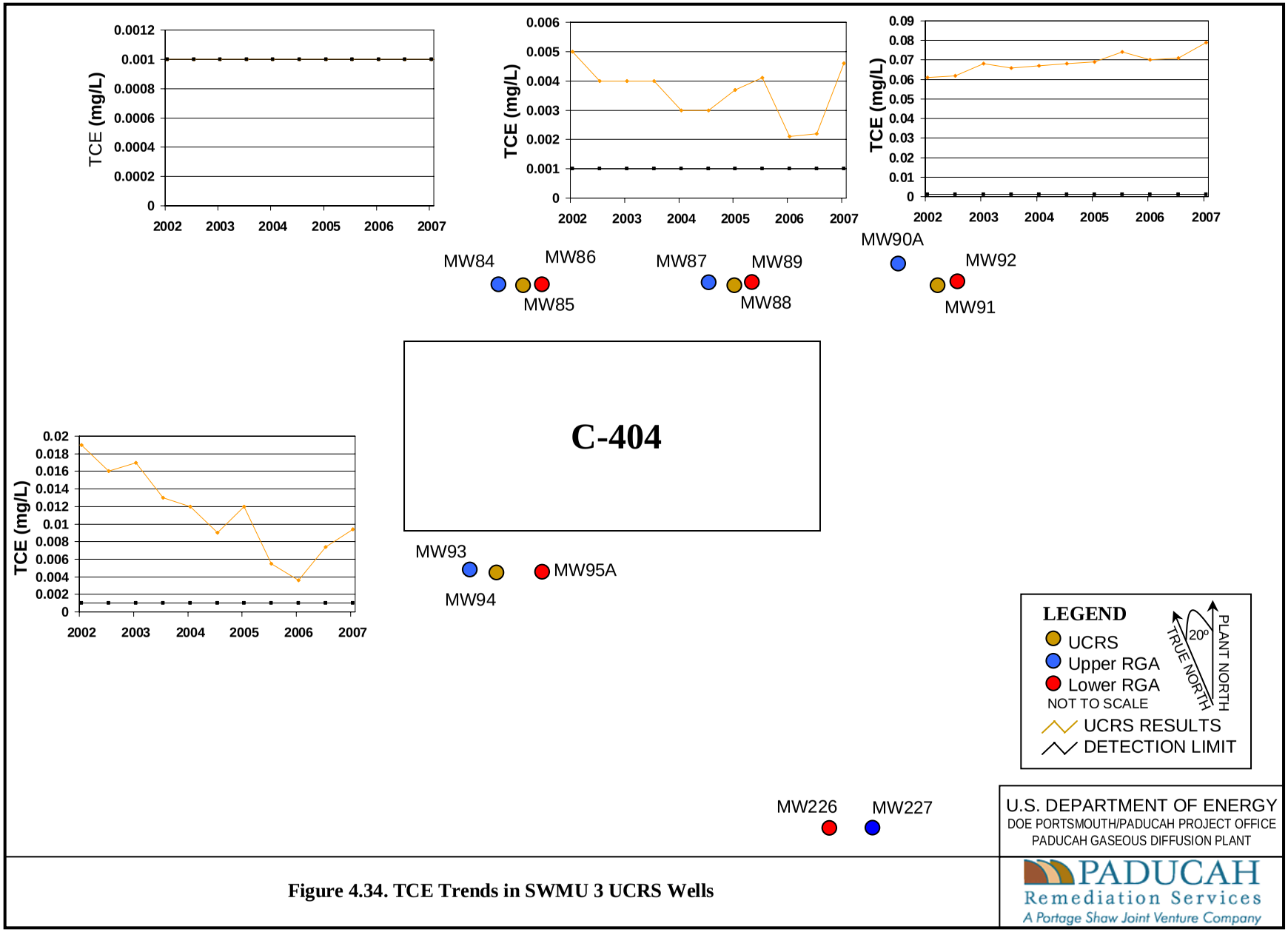

Figure 4.34. TCE Trends in SWMU 3 UCRS Wells

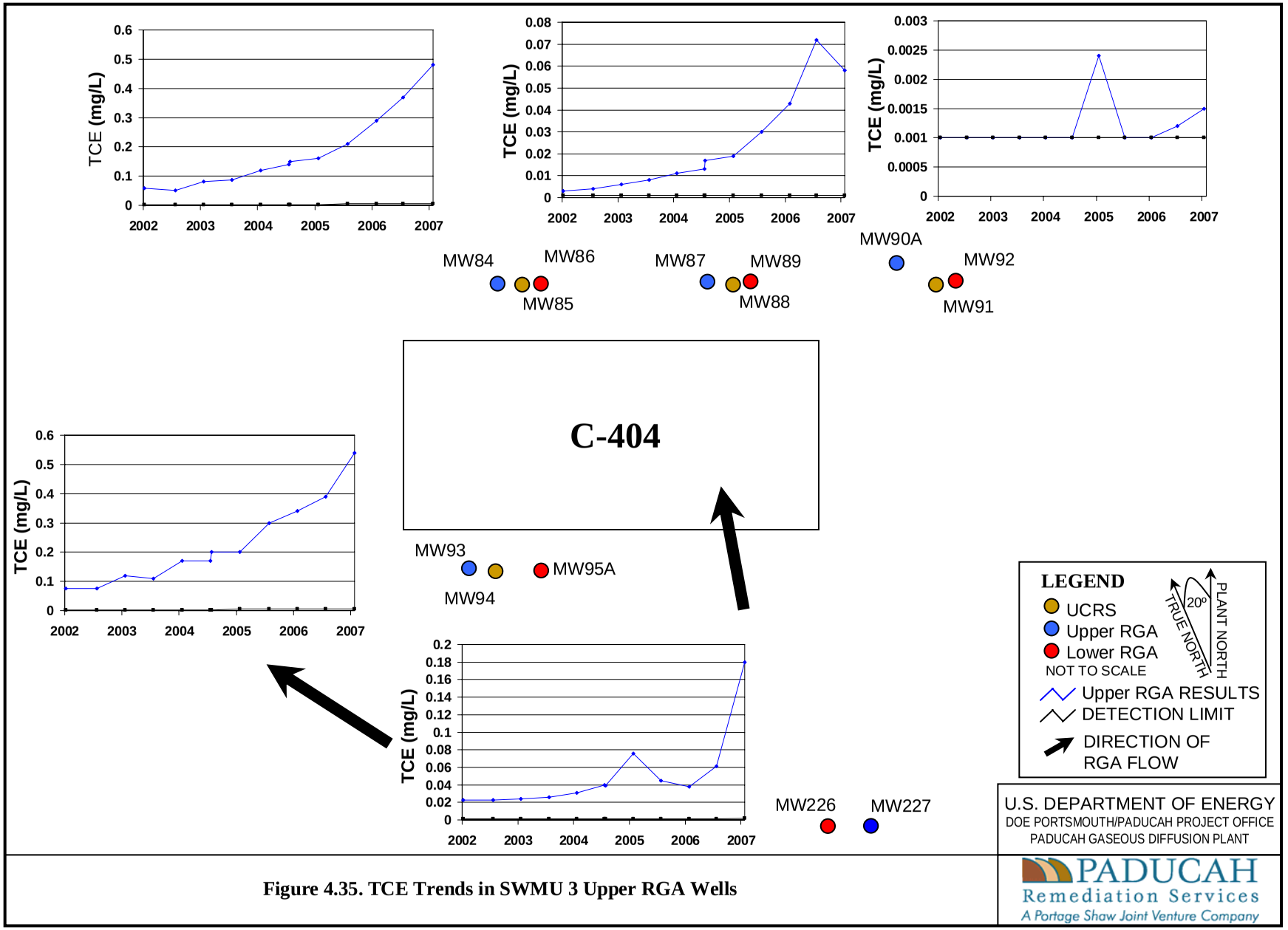

Figure 4.35. TCE Trends in SWMU 3 Upper RGA Wells

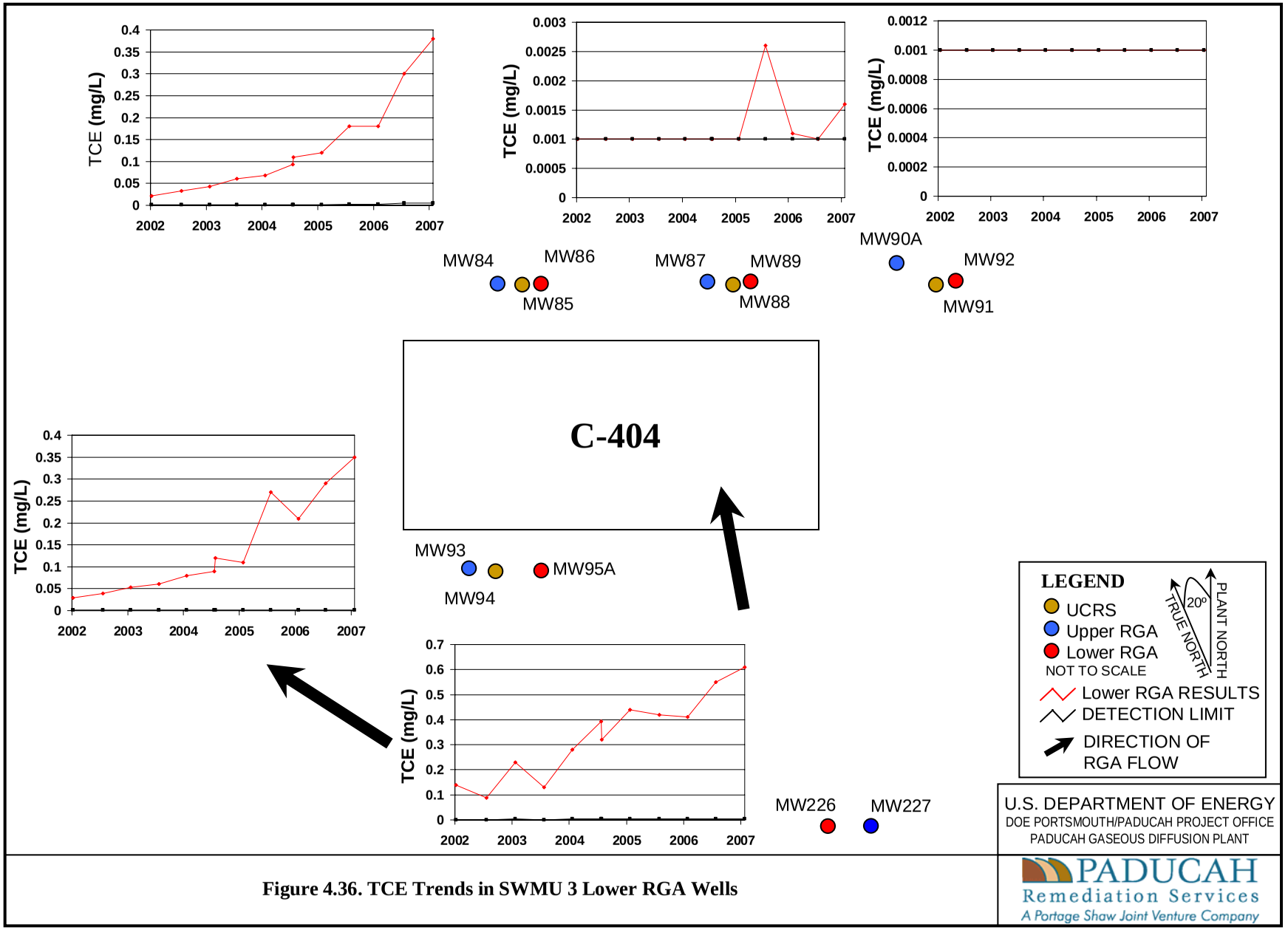

Figure 4.36. TCE Trends in SWMU 3 Lower RGA Wells

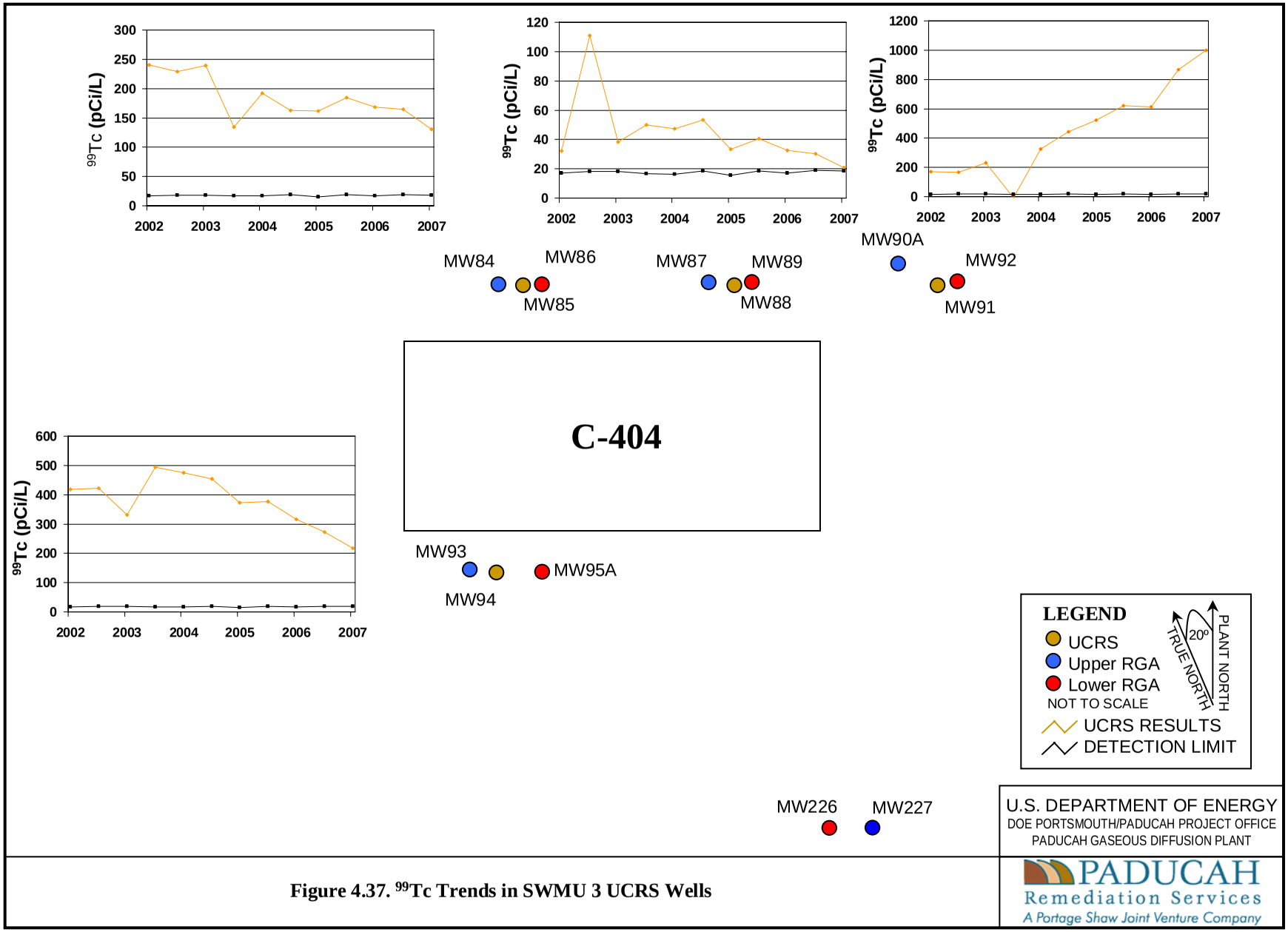

Figure 4.37. ^{99}Tc Trends in SWMU 3 UCRS Wells

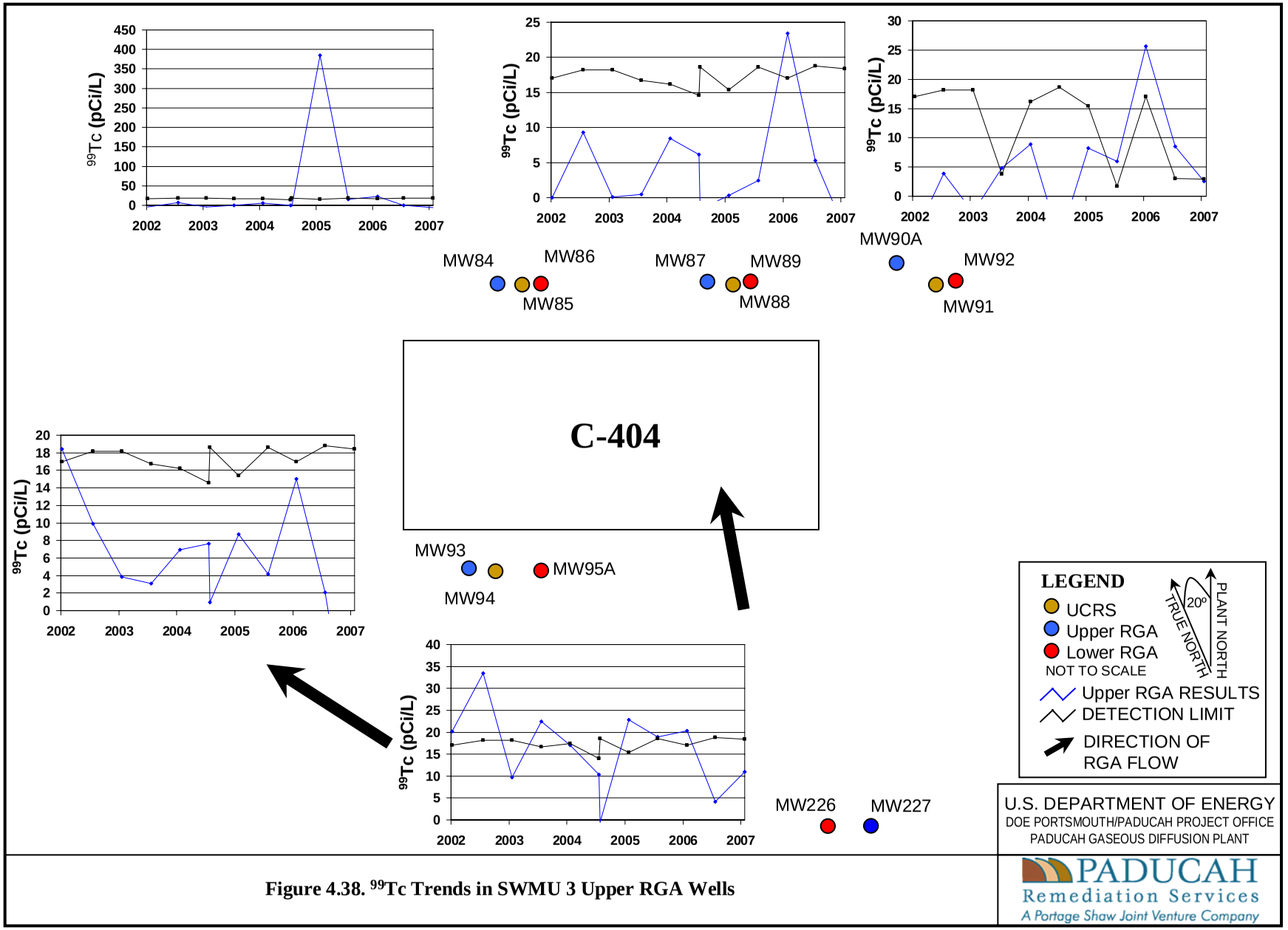

Figure 4.38. ^{99}Tc Trends in SWMU 3 Upper RGA Wells

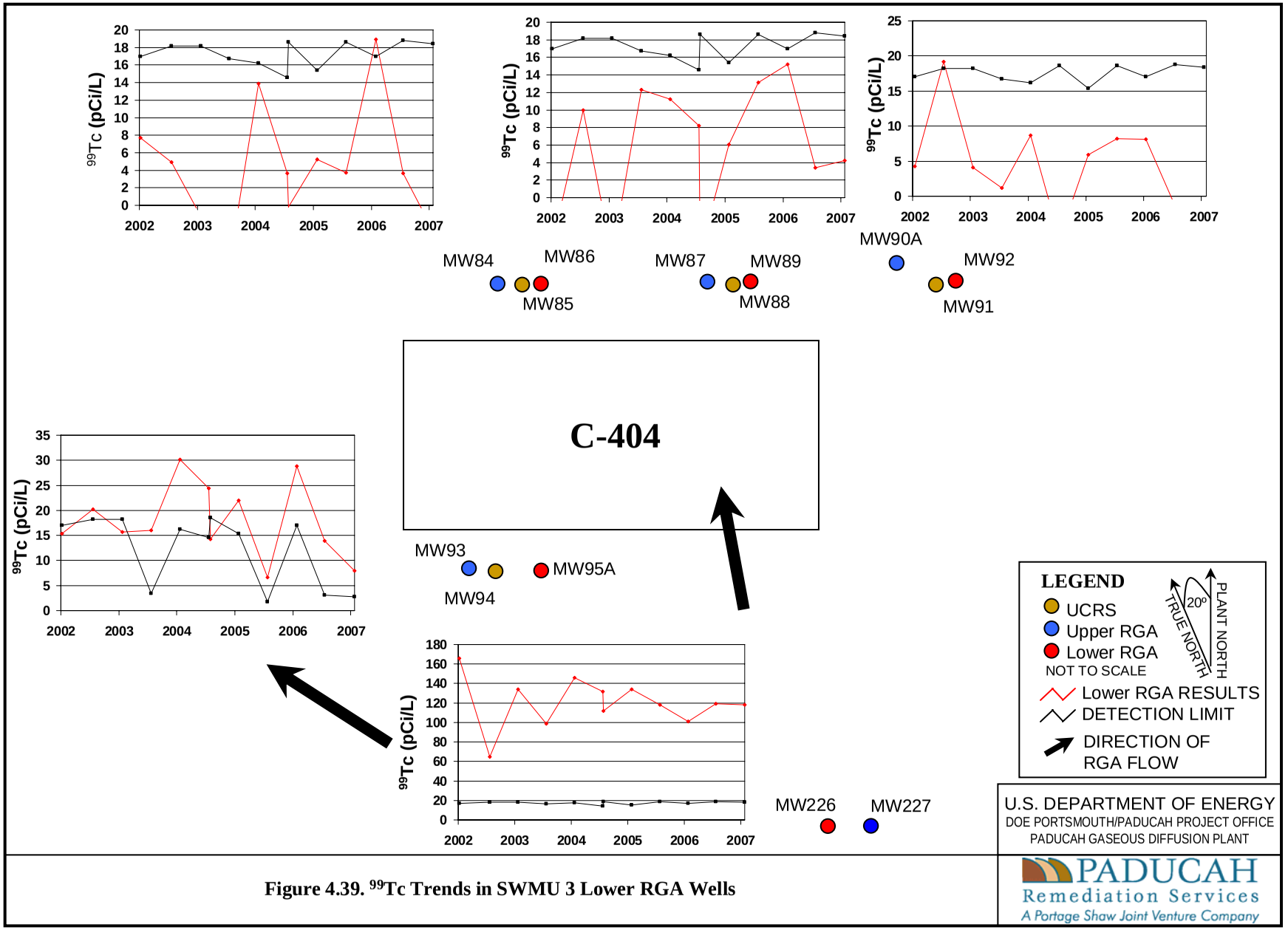

Figure 4.39. ^{99}Tc Trends in SWMU 3 Lower RGA Wells

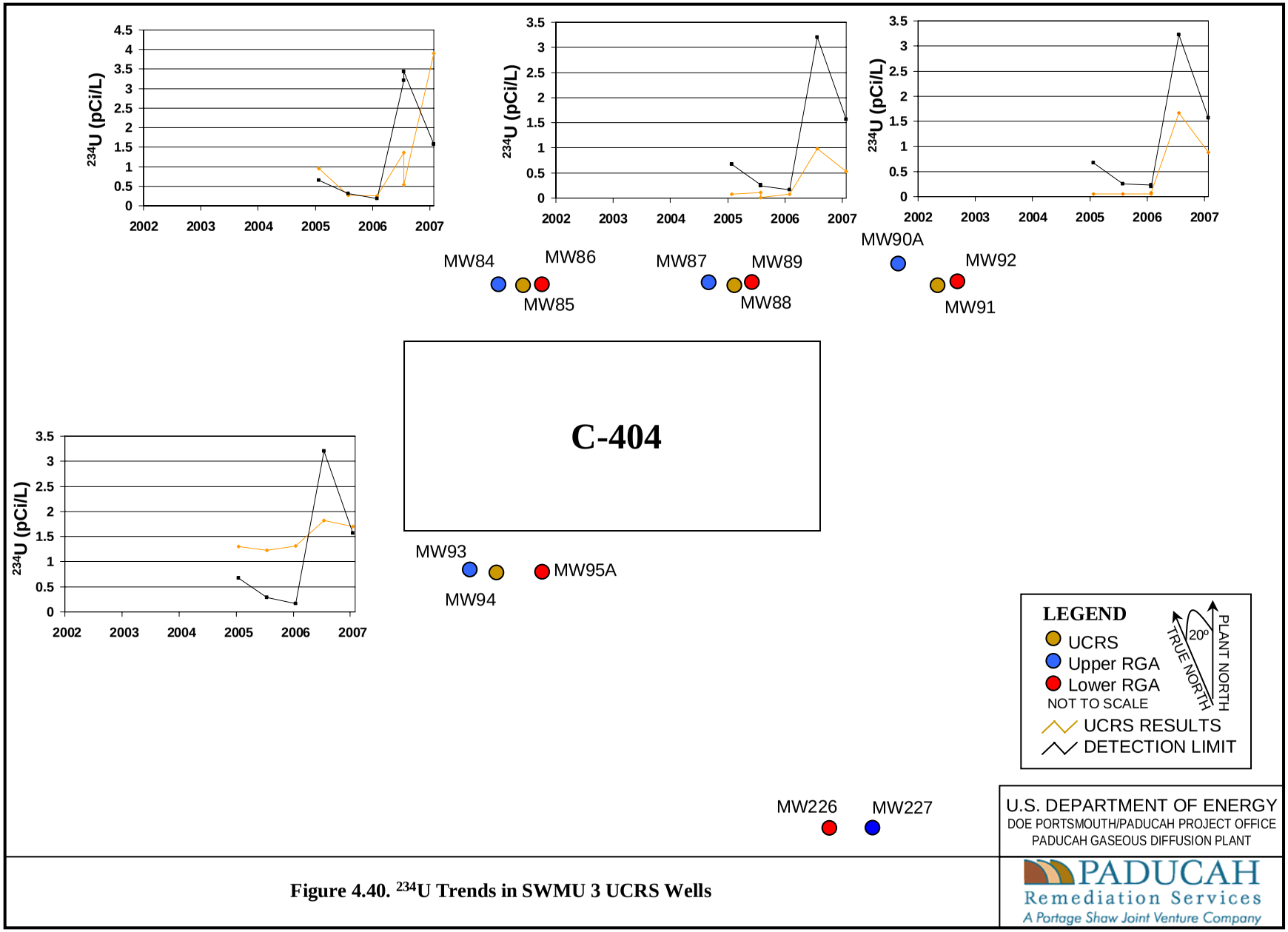

Figure 4.40. ^{234}U Trends in SWMU 3 UCRS Wells

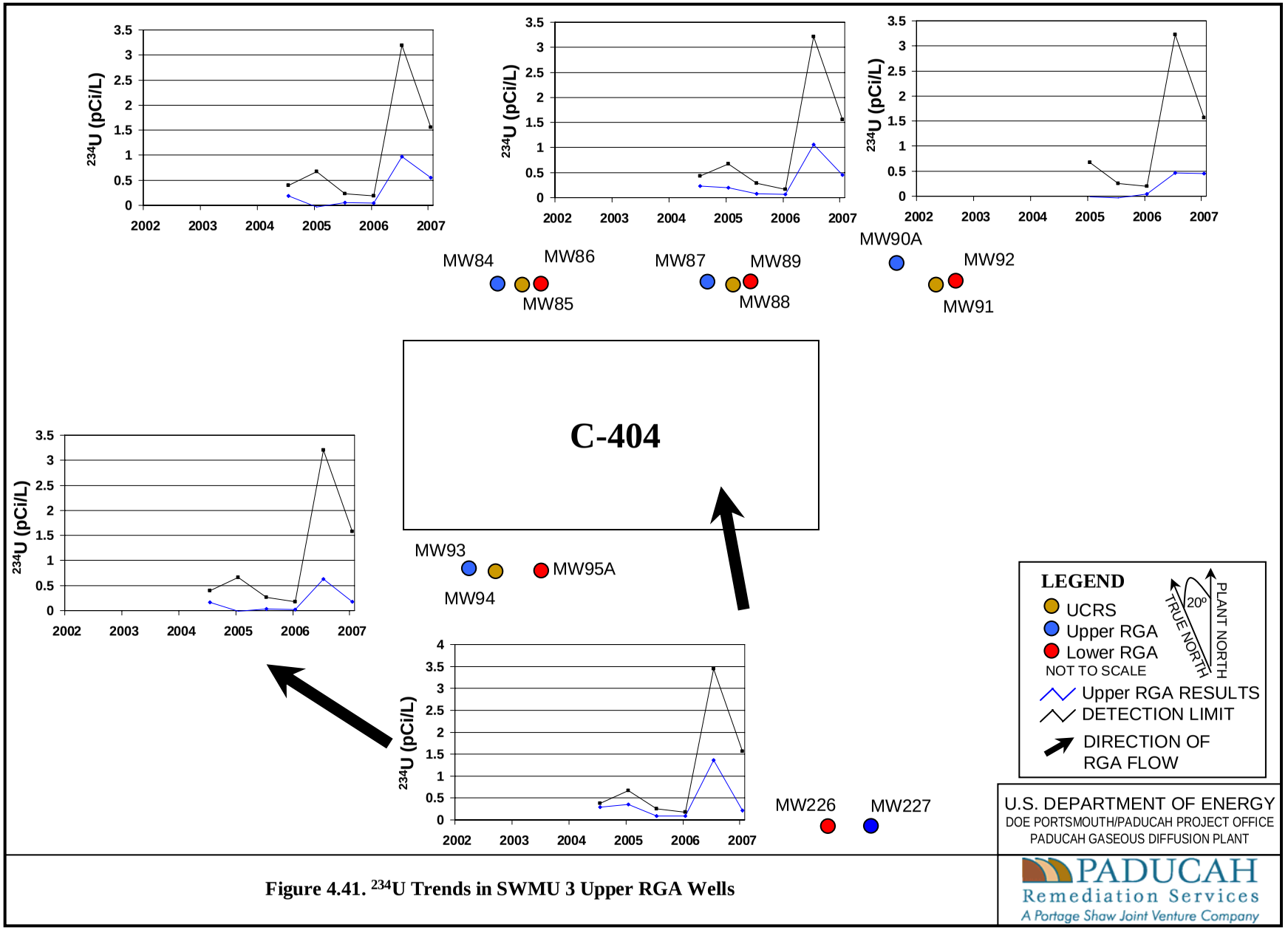

Figure 4.41. ^{234}U Trends in SWMU 3 Upper RGA Wells

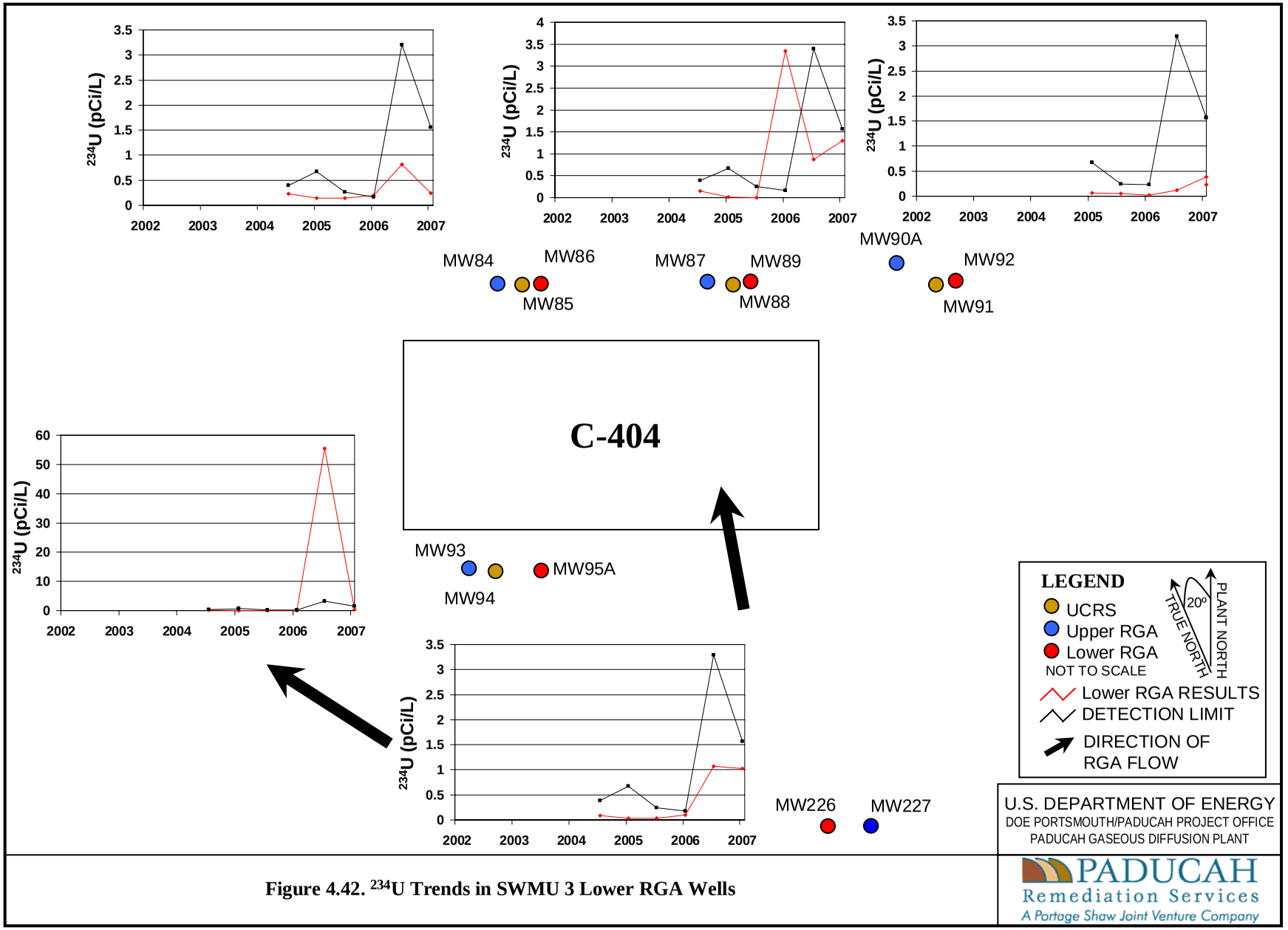

Figure 4.42. ^{234}U Trends in SWMU 3 Lower RGA Wells

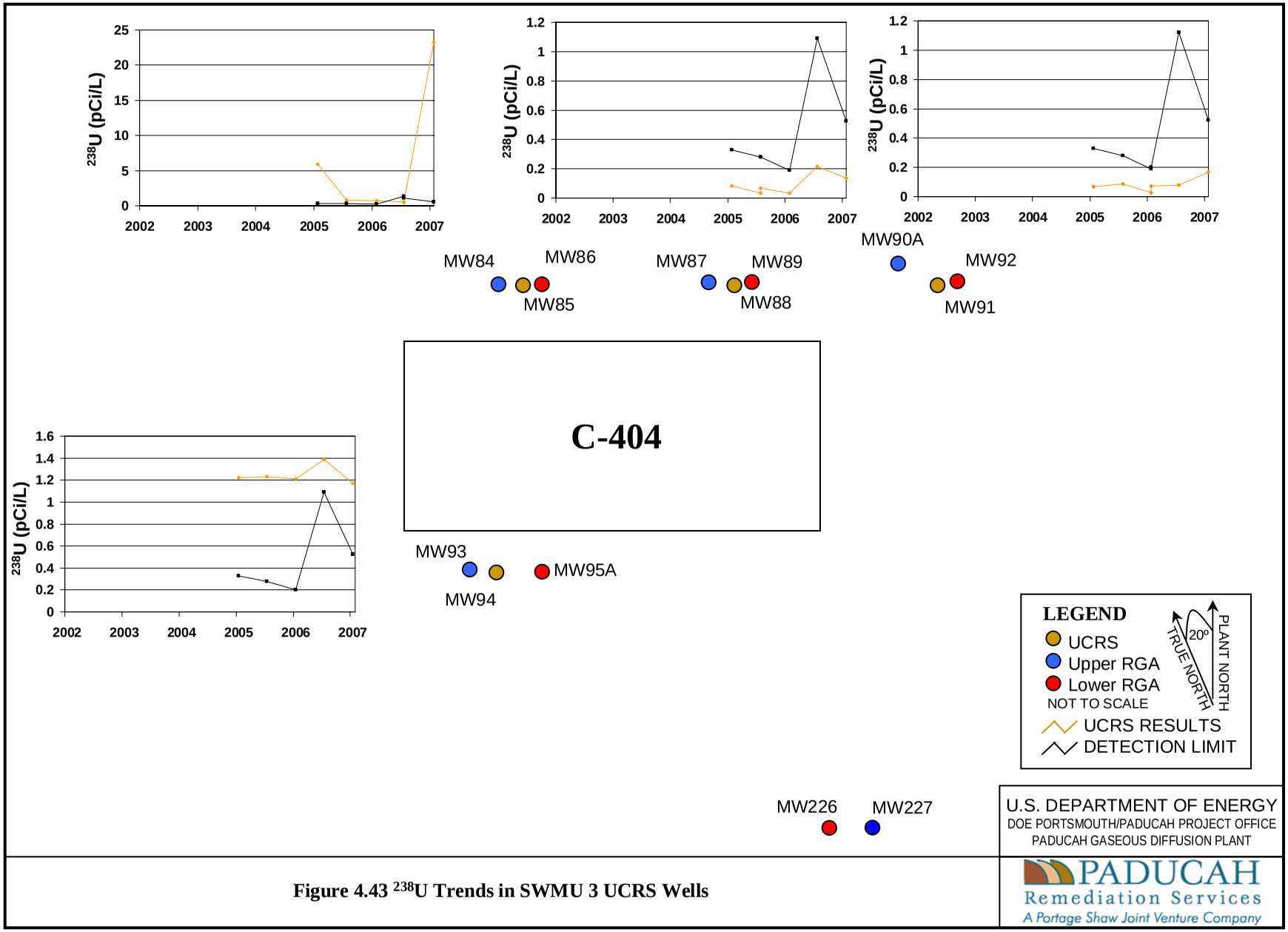

Figure 4.43 ^{238}U Trends in SWMU 3 UCRS Wells

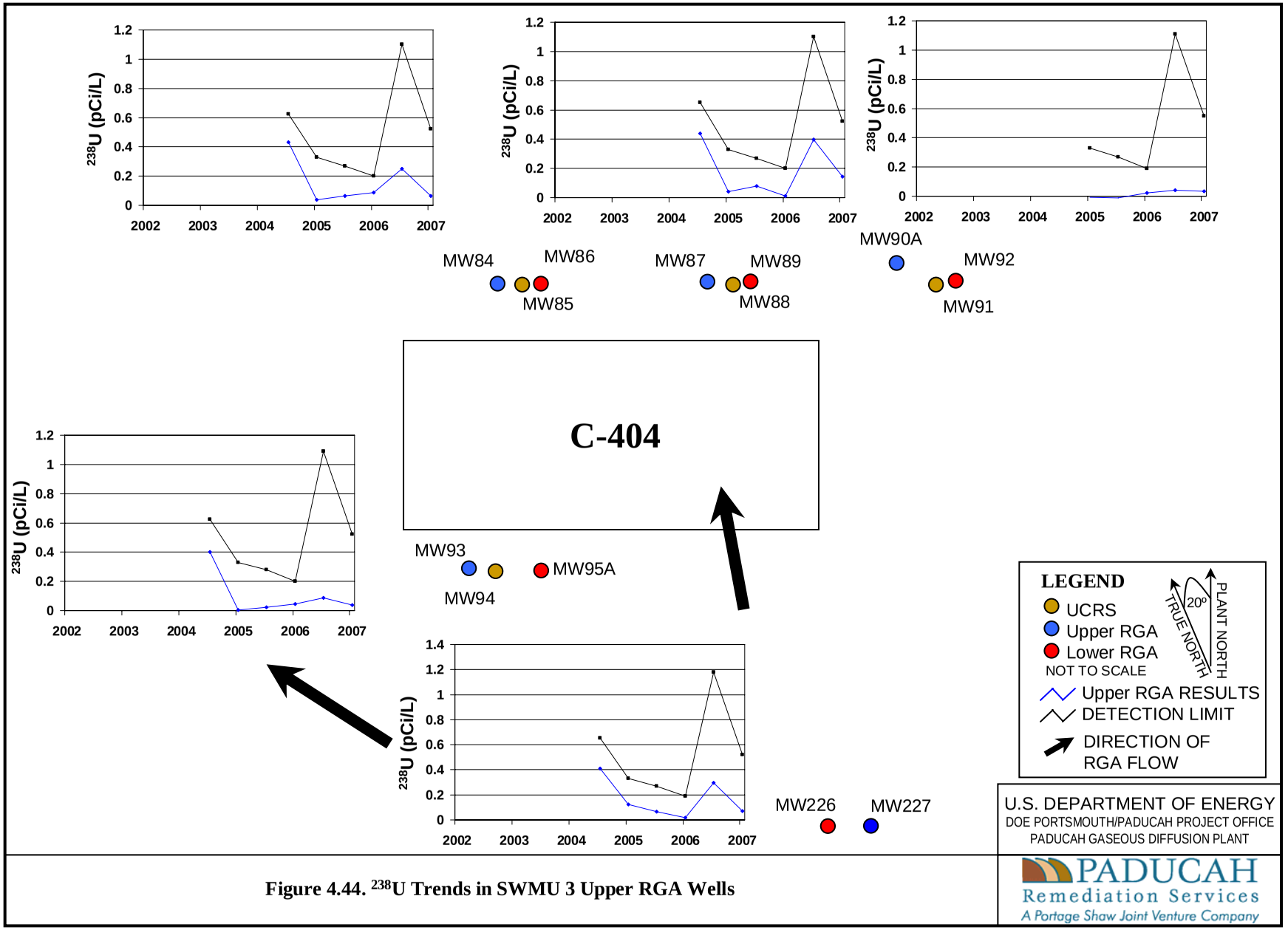

Figure 4.44. ^{238}U Trends in SWMU 3 Upper RGA Wells

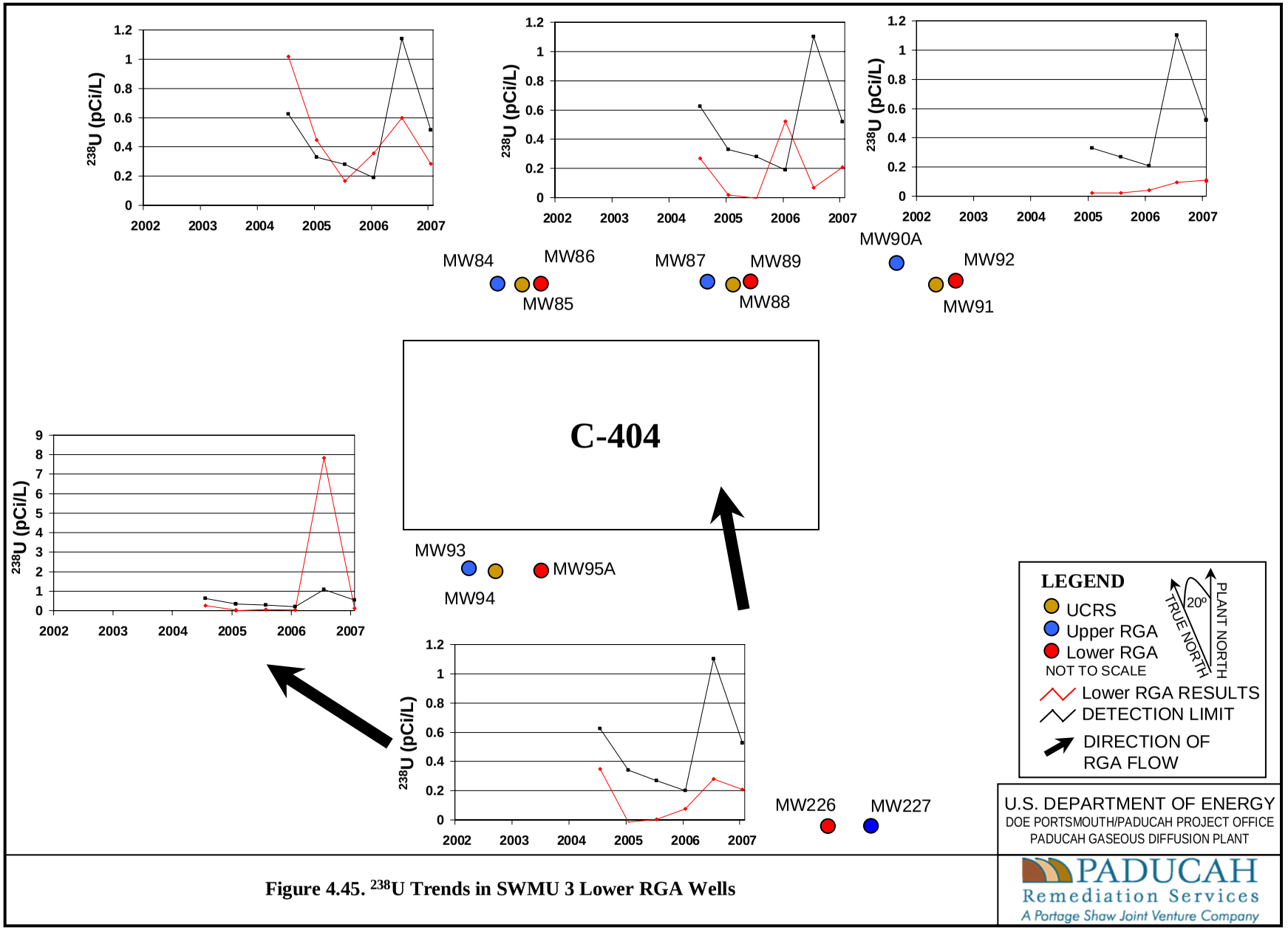

Figure 4.45. ^{238}U Trends in SWMU 3 Lower RGA Wells

4.5 SWMU 4

4.5.1 Subsurface Soils

Table 4.18 summarizes the review of SWMU 4 subsurface soil data to identify site-related contaminants. Table 4.19 shows the locations and depths of the contaminants that were detected above screening levels. During scoping for the BGOU RI/FS Work Plan, it was determined that sufficient data existed to move forward to the FS, so no additional data from SWMU 4 were collected during this RI.

SWMU 4 served as a disposal repository of radiologically contaminated and uncontaminated debris originating from the C-410 UF_6 feed plant. Beryllium is the most widely detected metal in subsurface soils above background (52 of 126 analyses), but exceeds the NAL in only 6 of 126 analyses. Figure 4.46 shows the distribution of beryllium in the subsurface soil at SWMU 4. Most of the higher concentrations (> 1 mg/kg) occur in a horizon at 40 to 55 ft bgs. Iron and vanadium are the most common metals to exceed both PGDP background (in 7 of 126 analyses for both) and the NAL (in 126 of 126 analyses of iron and 125 of 126 analyses of vanadium). Manganese exceeds PGDP background in 6 of 126 analyses and exceeds the NAL in 92 of 126 analyses. The iron and vanadium exceedances are well distributed across SWMU 4. Most of the exceedances occur at depths of 20 to 55 ft. Figure 4.47 provides the vanadium distribution in soil at the SWMU.

TCE is widely present (47 of 314 analyses) in subsurface samples from borings located within burial pits. Highest levels (up to 41 mg/kg) are commonly found in the soils below the large southern burial pit, with levels as high as 25 mg/kg at the maximum depth of the soil samples (61 ft). Figure 4.48 illustrates the distribution of TCE in soil at the unit and shows the predominant detections in the southern half of the SWMU. A potential DNAPL source is suspected in the UCRS at SWMU 4 near the southern burial pit. Subsurface soil analyses also document the TCE degradation product vinyl chloride above screening levels in 3 of 318 subsurface samples from borings within the area of the large southern burial pit (Figure 4.49). The vinyl chloride may be the result of anaerobic degradation occurring in the UCRS; however, dissolved oxygen data are not available for this SWMU and remains an uncertainty. The highest levels of PCBs cluster around the east end of the southern burial pit (in soils of 6 ft depth or less).

The most common radionuclides with activities that exceed background and the excavation worker NAL are the uranium isotopes uranium-234 and uranium-238. These detections are commonly limited to soils less than 10 ft deep and occur across the site. Figure 4.50 shows the widespread shallow uranium contamination associated with SWMU 4. Uranium levels decrease quickly below a depth of 10 ft.

Table 4.18. SWMU 4 Subsurface Soil Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection	
	Historical Data	RI Data		Above Background Value	Above Excavation Worker NAL
Inorganics (mg/kg)					
Arsenic	17.1	N/A[b]	12/125	5/125	12/125
Beryllium	2.02	N/A	85/126	52/126	6/126
Iron	34,500	N/A	126/126	7/126	126/126
Manganese	2,700	N/A	125/126	6/126	92/126
Vanadium	75.5	N/A	126/126	7/126	125/126
Organics – Volatiles (mg/kg)					
TCE	41	N/A	47/314	N/A	9/314
Vinyl chloride	0.29	N/A	7/318	N/A	3/318
Organics –PCBs (mg/kg)					
Total PCBs	4.3	N/A	10/153	N/A	10/153
PCB-1016	2.5	N/A	1/172	N/A	1/172
PCB-1248	0.8	N/A	2/172	N/A	2/172
PCB-1254	27	N/A	8/172	N/A	7/172
PCB-1260	0.5	N/A	2/172	N/A	2/172
Radionuclides (pCi/g)					
Cesium-137	1.48	N/A	2/160	2/160	2/160
Technetium-99	269	N/A	13/182	13/182	2/182
Thorium-230	68.7	N/A	2/2	2/2	1/2
Uranium	6,260	N/A	16/24	N/A	13/24
Uranium-234	69	N/A	15/23	14/23	13/23
Uranium-235	4.2	N/A	1/158	1/158	1/158
Uranium-238	126	N/A	15/23	14/23	14/23

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable since no data was collected at SWMU 4 as part of this RI.

Table 4.19. SWMU 4 Locations of Subsurface Soil Contaminants

Analysis	Depth (ft)	004-009	004-017	004-019	004-020	004-021	004-022	004-023	004-024	004-025	004-026	004-027	004-030	004-031	004-032	004-033	004-034	004-035	004-036	004-037	004-038	004-039	004-040	004-041	004-042	004-043	004-044	004-045	004-046	004-047	004-048	004-049	004-050	004-051	004-052	004-053	004-054	004-055	004-056	004-057
Inorganics (mg/kg)																																								
Arsenic	5-6	ND	8.29	ND											ND	ND	ND	ND	17.1	6.96	ND		ND	ND	ND	ND	8.24	9.22	9.45	ND	ND		ND								
	10-12						ND	ND	ND	7.28	ND							ND	ND	ND	ND		ND		ND	ND		ND		ND		ND								
	15-16	ND	ND	ND											ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND									
	20-25																	ND	ND	ND	ND		ND		ND	ND		ND		ND		ND		ND	ND					
	25-30	ND	ND	ND	ND		ND				ND				ND					ND					ND	ND														
	30-40	ND				5.75	ND	ND	ND	ND	ND	ND								ND		ND						5.56												
	40-45		ND	ND	ND	6.13	ND	ND	ND	7.7	ND	5.16			ND																			ND					
	50-55		ND	ND	ND	ND	ND	ND	ND	ND		ND	ND		ND																			ND	ND					
	60		ND	ND		ND			ND			ND			ND																									
Beryllium	5-6	ND	0.79	ND											0.58	0.77	ND	0.9	0.85	0.76	0.78		0.62	0.53	ND	ND	0.83	0.7	0.52	0.64	0.6		0.57								
	10-12						0.8	ND	ND	0.77	0.62							0.78	0.58	0.65	0.79		0.69		1.01	0.61		ND		0.87		ND									
	15-16	0.51	ND	0.55											ND	0.55	ND	0.62	0.56	0.52	ND	ND	ND	0.56	ND	0.53	ND	0.74	ND	ND	ND									
	20-25																	0.86	ND	ND	ND		0.5		ND	0.53		ND		0.57		ND		ND	ND					
	25-30	ND	0.59	0.88	0.77		ND				0.86				ND										0.69	0.95														
	30-40	ND				0.98	0.98	0.69	ND	0.78	0.72	0.61								0.76		0.58						1.07												
	40-45		ND	0.6	0.65	1.03	0.89	1.05	0.87	1.04	0.9	1.3			ND																				ND	ND					
	50-55		0.71	0.75	0.73	2.02	0.99	0.93	0.62	1.9		0.9	1.98		1.62																				0.74	0.78					
	60		0.89	0.58		0.53			ND			ND			0.64																									
Iron	5-6	6540	21200	8360											10100	22800	9260	30200	21000	23200	19600		12300	7880	9470	8800	19800	15000	14600	11300	10500		13300								
	10-12						7880	13000	12400	11100	15100							15500	22300	15600	13400		12900		21500	16600		10500		9590		6320								
	15-16	9250	9210	16000											8200	10100	6890	11700	9330	10300	5010	8230	7550	8940	11100	9250	8520	12600	7390	10000	5150									
	20-25																	27800	9300	3980	6270		10700		7170	11200		5010		13200		11900		5100	5510					
	25-30	8980	18700	20500	15500		4880				10600				8550										10300	24300														
	30-40	10300				31800	11800	21100	9570	15800	14000	9600								22900		16100						25200													
	40-45		7410	34500	8960	25800	5990	28600	22900	20000	19100	23500			5200																				3750	8210					
	50-55		16600	28000	16500	28900	11700	28900	10200	23800		12700	33400		27600																				14900	17100					
	60		11100	8780		8670			4020			7280			9420																									
Manganese	5-6	330	207	29.3											26.1	308	521	292	1140	1520	177		131	129	740	119	1200	264	510	41.6	141		267								
	10-12						58.9	426	90.8	1060	357							126	458	261	126		246		193	119		81		81.3		45.4									
	15-16	2700	229	ND											52.8	590	28.5	83.1	347	250	36.2	42.6	53.1	55.4	132	87.3	289	63.8	280	249	40.8									
	20-25																	88.4	232	141	339		492		80.9	70.3		84.2		77.9		101		21.7	197					
	25-30	123	213	42.9	199		19.6				38.1				14.9					34.4					58.6	107		278												
	30-40	84.6				42.3	69.6	132	34.8	94.5	60.8	360										48.4																		
	40-45		188	47.7	129	44.6	164	43.4	260	72	182	124			12.9																				30.4	74.2					
	50-55		240	1200	49.8	83	162	95.2	188	218		168	93.8		97.3																				24.5	101					
	60		51.4	147		37.9			38			37.8			168																									
Vanadium	5-6	15.5	26.5	18.2											14.1	31.5	16.5	30.8	33.6	29	25.9		17.5	18.9	15.4	18	25.3	23.4	18.5	25.1	15.2		21.6								
	10-12						23.7	23.7	22	21.3	22.9							26	28.9	27.8	27		18.6		33.7	26.6		19.4		11.9		13.8									
	15-16	22.8	19.3	25.5											19.1	21.1	10.8	30.9	20.5	21	13.3	17.6	21.1	24.9	22.8	20.6	19.3	26.5	16.1	22.3	13.6									
	20-25																	52.3	13.6	6.9	16.9		19.1		14.6	17.5		13.6		29.6		16.1		13.4	14.8					
	25-30	18.6	27.5	46.4	32.8		12.7				32.3				14.2					34.1					24.8	33.5		39.8												
	30-40	17.6				38.6	25.5	29.5	20.9	75.5	20.2	21.1										26.8																		
	40-45		12.3	37.9	20.3	32.5	34	48.9	21.2	26.6	27.5	24.3			13.3																				11.5	19.8					
	50-55		23.5	17.3	11.8	23.6	21.9	24.3	12.6	28.3		16.2	24.6		25.1																				11	13.9					
	60		11.9	11.6		8.3			4.26			7.25			10.9																									
Organics - Volatiles (mg/kg)																																								
TCE	3-6	ND	ND	ND											ND	0.004	ND	ND	ND	ND	ND	ND		ND	ND	ND	ND	ND		ND		ND	ND			ND	ND	ND	ND	ND
	9-12						ND	ND	0.016	ND	0.0036	ND						ND	ND	ND	ND		0.035		ND	ND		ND		ND		ND				ND	ND	ND	ND	ND
	15-16	ND	ND	ND											ND	0.079	ND	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.035	ND	ND			ND	ND	ND	ND	ND
	20-25																0.053	0.82	ND	ND	0.0064		ND	ND	ND	ND		ND		ND	ND	ND		ND	ND	ND	ND	ND	ND	ND
	25-30	ND	ND	ND	ND	ND	ND	ND			0.0072		ND		ND	ND				ND		ND	ND		ND	0.42	ND	ND	ND					ND	ND	ND		ND		ND
	30-40	0.77				0.06	41	ND	4.4	ND	0.2	0.049										ND					ND													
	40-45		ND	ND	0.049	ND	4.9	ND	8.5	ND	0.012	0.113			ND					ND															0.46	ND					
	50-55		0.015	ND	0.038	ND	6	ND	7	ND	0.12	2.86	9.2		ND																				ND	ND					
	60		0.042	ND	0.033	ND	1.1	ND	2.1	ND		13	25		ND																									

Table 4.19. SWMU 4 Locations of Subsurface Soil Contaminants (Continued)

Analysis	Depth (ft)	004-009	004-017	004-019	004-020	004-021	004-022	004-023	004-024	004-025	004-026	004-027	004-030	004-031	004-032	004-033	004-034	004-035	004-036	004-037	004-038	004-039	004-040	004-041	004-042	004-043	004-044	004-045	004-046	004-047	004-048	004-049	004-050	004-051	004-052	004-053	004-054	004-055	004-056	004-057
Vinyl	3-6	ND	ND	ND											ND	ND	ND	ND	ND	ND	ND	ND		ND	ND	ND	ND	ND		ND		ND	ND			ND	ND	ND	ND	ND
Choride	9-12						ND	ND	ND	ND	ND	ND						ND	ND	ND	ND		ND		ND	ND		ND		ND		ND				ND	ND	ND	ND	ND
	15-16	0.051	ND	ND											ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND	ND	ND	ND	ND	ND			ND	ND	ND	ND	ND
	20-25																ND	ND	ND	ND	ND		ND	ND	ND		ND		ND	ND	ND		ND	ND	ND		ND	ND	ND	ND
	25-30	ND	ND	ND	ND	ND	ND	ND			ND		ND		ND	ND						ND	ND	ND	ND	ND	ND	ND						ND	ND	ND		ND		ND
	30-40	0.29				ND	0.22	ND	ND	ND	ND	ND								ND		ND			ND		ND	ND												
	40-45		ND	ND	ND	ND	0.018	ND	ND	ND	ND	ND			ND					ND														ND	ND					
	50-55		ND	ND	ND	ND	0.011	ND	ND	ND	ND	ND	ND		ND																			ND	ND					
	60		ND	ND	ND	ND	ND	ND	ND	ND		ND	0.24		ND																									
Organics - Pesticides/PCBs (mg/kg)																																								
PCB, Total	3-6	0.424	ND	ND											ND	ND	ND	10.3	ND	ND	0.308	0.908	4.3	ND	ND	ND	ND	ND	0.8	27			ND			ND	ND	ND	4.76	0.026
	9-12						ND	ND	ND	0.5	ND							ND	ND	ND	ND		ND		ND	ND		ND		ND		ND				ND	ND	ND	ND	ND
	15-16	ND	ND	ND											ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			ND	ND	ND	ND	ND
	20-25																	ND	ND	ND	ND		ND	ND	ND	ND		ND		ND		ND				ND		ND	ND	ND
	25-30	ND	ND	ND	ND		ND				ND				ND					ND			ND		ND	ND		ND	ND							ND		ND		ND
	30-40	ND				ND	ND	ND	ND	ND	ND	ND										ND																		
	40-45		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			ND																									
	50-55		ND	ND	ND	ND	ND	ND	ND	ND		ND			ND																									
	60		ND	ND		ND		ND	ND			ND			ND																									
PCB-1016	3-6	ND	ND	ND											ND	ND	ND	ND	ND	ND	ND	ND	2.5	ND	ND	ND	ND	ND	ND	ND			ND			ND	ND	ND	ND	ND
	9-12						ND	ND	ND	ND	ND							ND	ND	ND	ND		ND		ND	ND		ND		ND		ND				ND	ND	ND	ND	ND
	15-16	ND	ND	ND											ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			ND	ND	ND	ND	ND
	20-25																	ND	ND	ND	ND		ND	ND	ND	ND		ND		ND		ND				ND		ND	ND	ND
	25-30	ND	ND	ND	ND		ND				ND				ND					ND			ND		ND	ND		ND	ND							ND		ND		ND
	30-40	ND				ND	ND	ND	ND	ND	ND	ND										ND																		
	40-45		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			ND																									
	50-55		ND	ND	ND	ND	ND	ND	ND	ND		ND			ND																									
	60		ND	ND		ND		ND	ND			ND			ND																									
PCB-1248	3-6	ND	ND	ND											ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.8	ND			ND			ND	ND	ND	ND	ND
	9-12						ND	ND	ND	0.3	ND							ND	ND	ND	ND		ND		ND	ND		ND		ND		ND				ND	ND	ND	ND	ND
	15-16	ND	ND	ND											ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			ND	ND	ND	ND	ND
	20-25																	ND	ND	ND	ND		ND	ND	ND	ND		ND		ND		ND				ND		ND	ND	ND
	25-30	ND	ND	ND	ND		ND				ND				ND					ND			ND		ND	ND		ND	ND							ND		ND		ND
	30-40	ND				ND	ND	ND	ND	ND	ND	ND										ND																		
	40-45		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			ND																									
	50-55		ND	ND	ND	ND	ND	ND	ND	ND		ND			ND																									
	60		ND	ND		ND		ND	ND			ND			ND																									
PCB-1254	3-6	ND	ND	ND											ND	ND	ND	10.3	ND	ND	0.308	0.908	1.3	ND	ND	ND	ND	ND	ND	27			ND			ND	ND	ND	4.76	0.026
	9-12						ND	ND	ND	0.2	ND							ND	ND	ND	ND		ND		ND	ND		ND		ND		ND				ND	ND	ND	ND	ND
	15-16	ND	ND	ND											ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			ND	ND	ND	ND	ND
	20-25																	ND	ND	ND	ND		ND	ND	ND	ND		ND		ND		ND				ND		ND	ND	ND
	25-30	ND	ND	ND	ND		ND				ND				ND					ND			ND		ND	ND		ND	ND							ND		ND		ND
	30-40	ND				ND	ND	ND	ND	ND	ND	ND										ND																		
	40-45		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			ND																									
	50-55		ND	ND	ND	ND	ND	ND	ND	ND		ND			ND																									
	60		ND	ND		ND		ND	ND			ND			ND																									
PCB-1260	3-6	0.424	ND	ND											ND	ND	ND	ND	ND	ND	ND	ND	0.5	ND	ND	ND	ND	ND	ND	ND			ND			ND	ND	ND	ND	ND
	9-12						ND	ND	ND	ND	ND							ND	ND	ND	ND		ND		ND	ND		ND		ND		ND				ND	ND	ND	ND	ND
	15-16	ND	ND	ND											ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			ND	ND	ND	ND	ND
	20-25																	ND	ND	ND	ND		ND	ND	ND	ND		ND		ND		ND				ND		ND	ND	ND
	25-30	ND	ND	ND	ND		ND				ND				ND					ND			ND		ND	ND		ND	ND							ND		ND		ND
	30-40	ND				ND	ND	ND	ND	ND	ND	ND			ND							ND																		
	40-45		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			ND																									
	50-55		ND	ND	ND	ND	ND	ND	ND	ND		ND			ND																									
	60		ND	ND		ND		ND	ND			ND			ND																									

Table 4.19. SWMU 4 Locations of Subsurface Soil Contaminants (Continued)

Analysis	Depth (ft)	004-009	004-017	004-019	004-020	004-021	004-022	004-023	004-024	004-025	004-026	004-027	004-030	004-031	004-032	004-033	004-034	004-035	004-036	004-037	004-038	004-039	004-040	004-041	004-042	004-043	004-044	004-045	004-046	004-047	004-048	004-049	004-050	004-051	004-052	004-053	004-054	004-055	004-056	004-057
Radionuclides (pCi/g)																																								
Cesium-137	3-6	ND	ND	ND		ND							1.48		ND	ND	ND	ND	ND	ND	ND	ND		ND	ND	ND	ND	ND		ND		ND	ND			ND	ND	ND	0.544	ND
	9-12							ND	ND									ND	ND	ND	ND		ND		ND	ND		ND		ND		ND				ND	ND	ND	ND	ND
	15-16	ND	ND	ND											ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			ND	ND	ND	ND	ND
	20-25																ND	ND	ND	ND	ND		ND	ND	ND	ND		ND		ND	ND	ND		ND	ND	ND	ND	ND	ND	ND
	25-30	ND	ND		ND			ND							ND	ND				ND		ND	ND		ND	ND	ND	ND	ND					ND	ND	ND		ND		ND
	30-40	ND				ND		ND	ND													ND					ND												
	40-45		ND	ND	ND	ND		ND	ND																									ND	ND					
	50-55		ND	ND	ND	ND		ND	ND				ND		ND																			ND	ND					
	60		ND	ND	ND	ND		ND	ND				ND		ND																									
Technetium-99	3-6	9.01	4.79	ND		ND							269	ND	ND	10.4	ND	5.7	6.37	ND	ND	ND	29.4	ND	ND	ND	ND	ND	14.6	26.1	235		ND			ND	ND	ND	8.38	ND
	9-12						ND	ND	ND	ND	ND	ND						ND	ND	ND	ND		ND		ND	ND		ND		ND		ND				ND	ND	ND	ND	ND
	15-16	ND	ND	ND											ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			ND	ND	ND	ND	ND
	20-25		ND										ND		ND			ND	ND	ND	ND	ND	ND		ND	ND		ND	ND	ND		ND		ND	ND	ND	ND	ND	ND	ND
	25-30				ND	ND	ND	ND			ND									ND					ND			ND						ND						
	30-40	ND			ND	ND	ND	ND	ND	ND	ND	ND										ND																		
	40-45		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			ND																				ND	ND					
	50-55		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND																				ND	ND					
	60			ND	ND	ND	ND	ND	ND	ND		ND	ND		ND																									
Thorium-230	6												68.7										2.06																	
Uranium	3-6	23.2			6.66								6260	51.7		57.3		114			23.8		165						183		118								84.5	
	9-12						ND			8.64																														
	25-30						ND																																	
	30-40						ND			ND		2.33																												
	40-45						ND			ND																														
	50-55									ND																														
Uranium-234	3-6	7.68			2.68									14.5		12.7		36.5			8.18		69						53.4		47.9								26.4	
	9-12						ND			3.06																														
	25-30						ND																																	
	30-40						ND			ND		1.74																												
	40-45						ND			ND																														
	50-55									ND																														
Uranium-235	3-6	ND	ND	ND		ND									ND	ND	ND	ND	ND	ND	ND	ND		ND	ND	ND	ND	ND		ND		ND	ND			ND	ND	ND	ND	ND
	9-12							ND	ND									ND	ND	ND	ND		ND		4.2	ND		ND		ND		ND				ND	ND	ND	ND	ND
	15-16	ND	ND	ND											ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			ND	ND	ND	ND	ND
	20-25																ND	ND	ND	ND	ND		ND		ND	ND		ND		ND	ND	ND		ND	ND	ND	ND	ND	ND	ND
	25-30	ND	ND		ND			ND							ND	ND				ND		ND	ND		ND	ND	ND	ND	ND					ND	ND	ND		ND		ND
	30-40	ND				ND		ND	ND													ND					ND												
	40-45		ND	ND																														ND	ND					
	50-55		ND	ND	ND	ND		ND	ND				ND		ND																			ND	ND					
	60		ND	ND	ND	ND		ND	ND				ND		ND																									
Uranium-238	3-6	15.1			3.84									36.3		43.7		75			15.1		92.7						126		67.8								56.5	
	9-12						ND			5.41																														
	15-16																																							
	20-25																																							
	25-30						ND																																	
	30-40						ND			ND		0.524																												
	40-45						ND			ND																														
	50-55									ND																														
	60																																							

ND = not detected above screening levels

Blank cells indicate interval was not sampled for the specified analysis. The maximum value is shown for each depth interval at each location.

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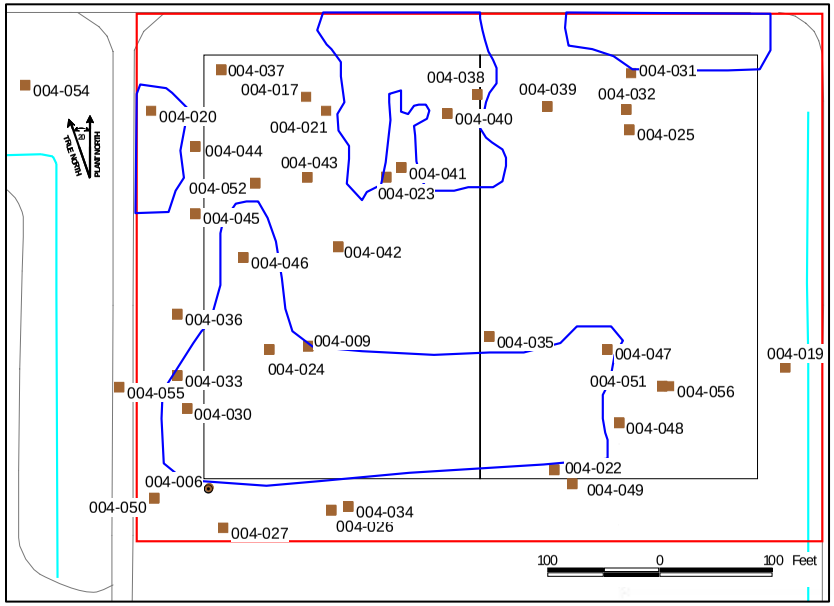

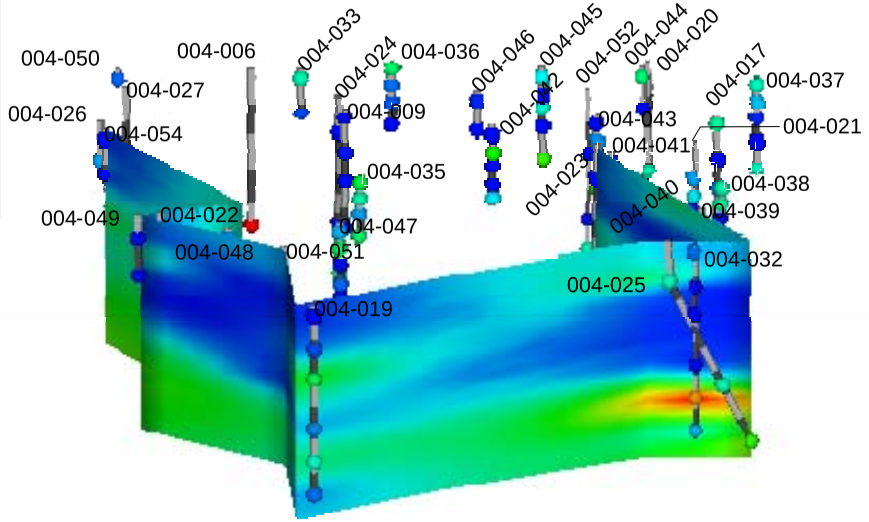

Vertical Exaggeration = 2

1 mg/kg
0.8 mg/kg
0.6 mg/kg
0.5 mg/kg

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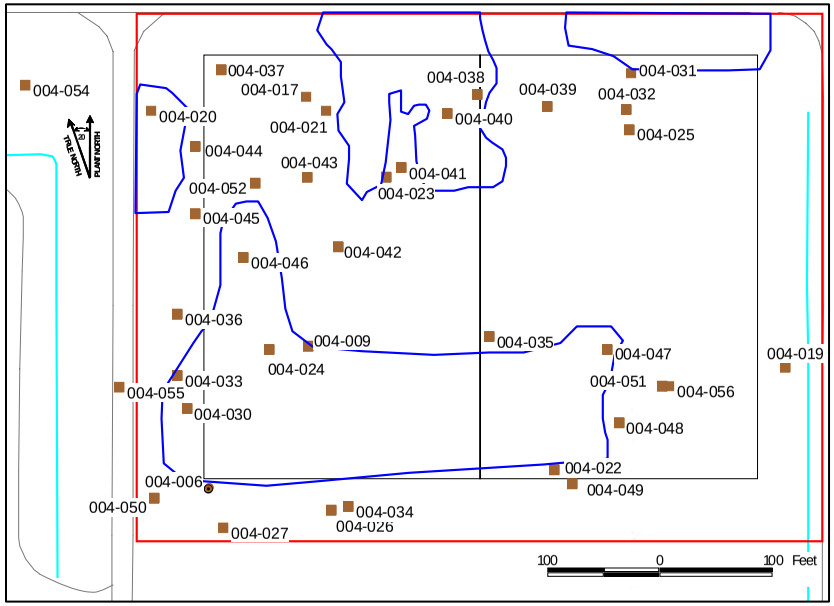
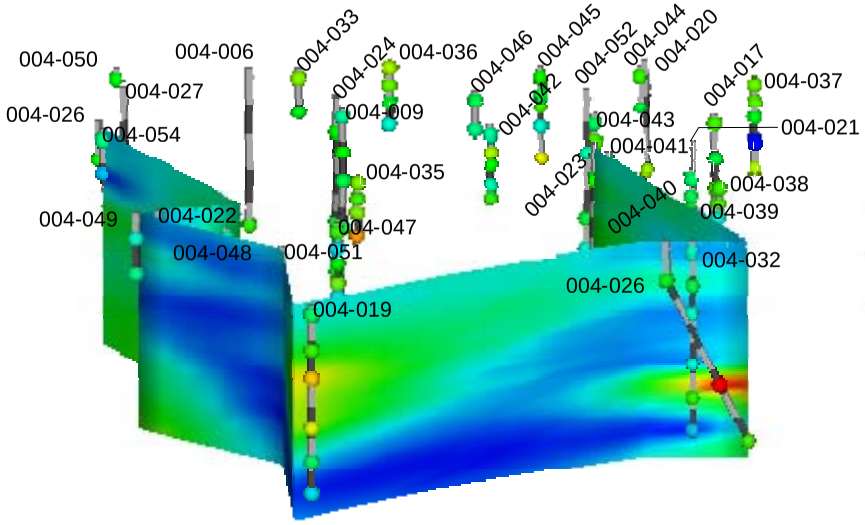
Figure 4.46. SWMU 4 Beryllium in Soil (Looking West)





Vertical Exaggeration = 2

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Figure 4.47. SWMU 4 Vanadium in Soil (Looking West)

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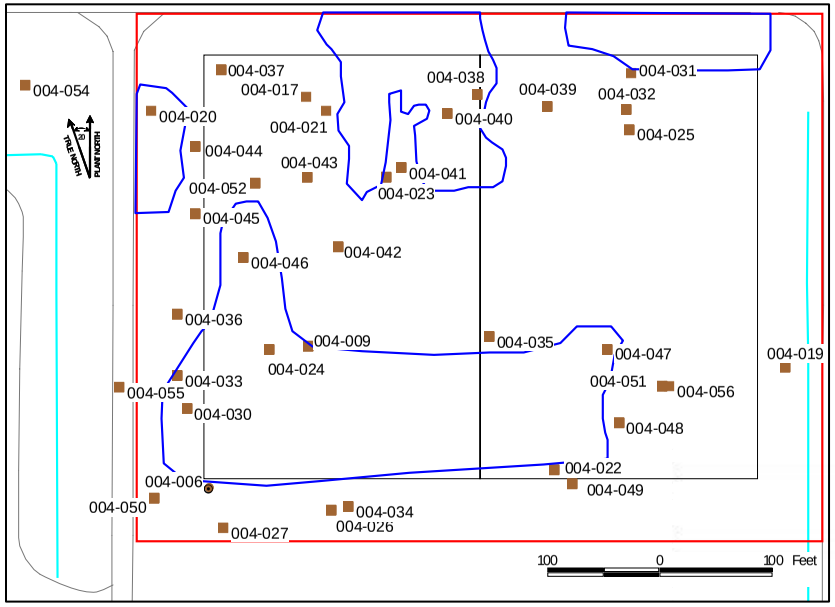

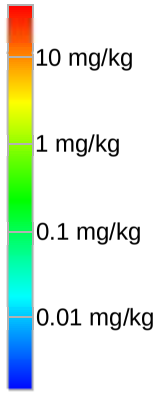

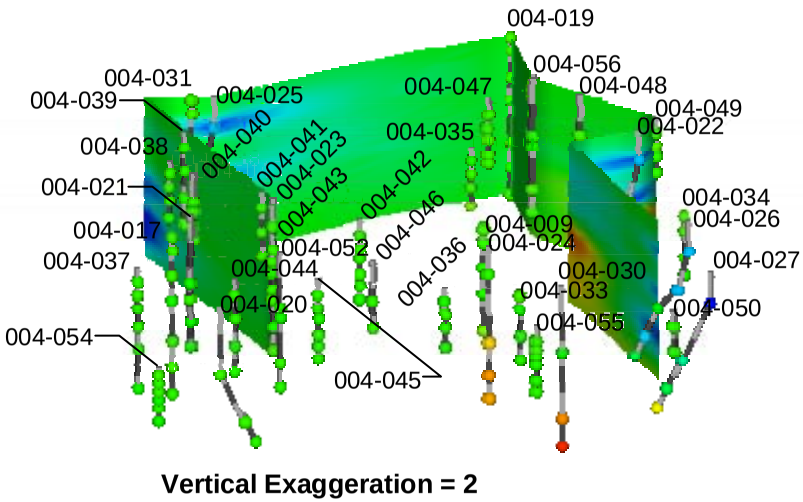

Figure 4.48. SWMU 4 TCE in Soil (Looking East)

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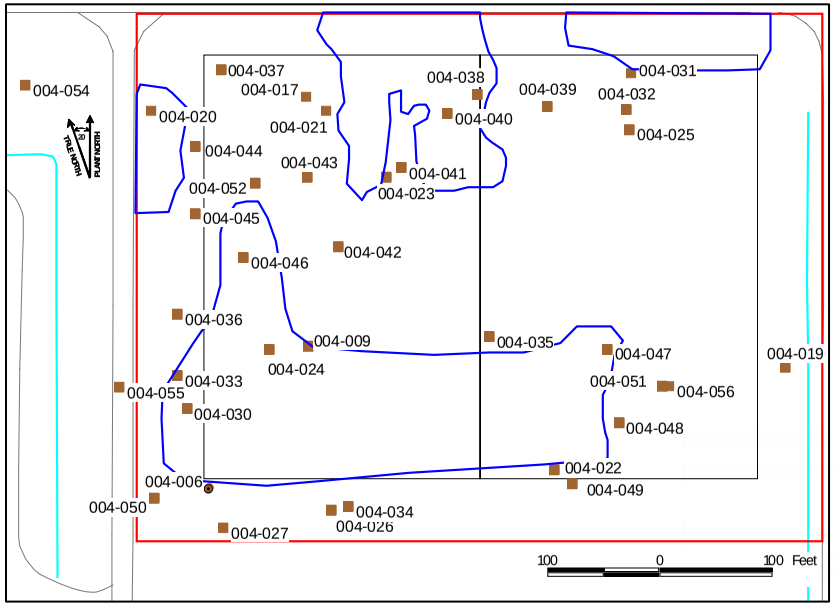

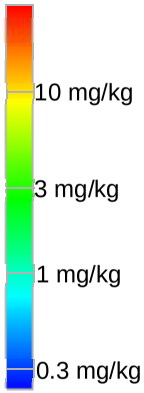

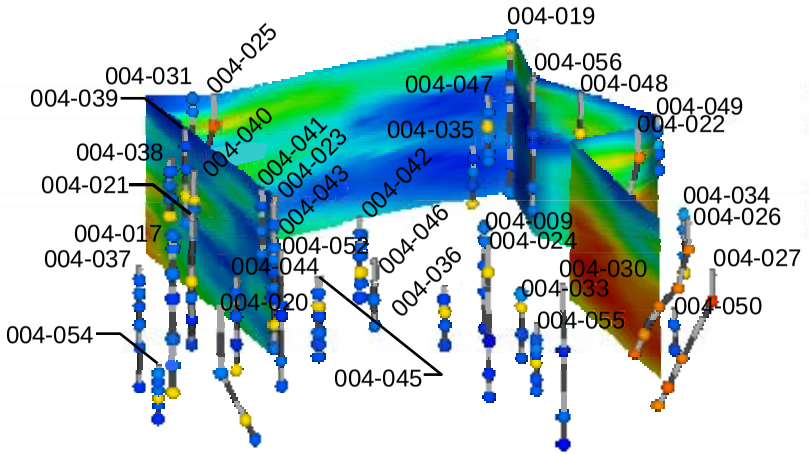

Vertical Exaggeration = 2

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Figure 4.49. SWMU 4 Vinyl Chloride in Soil (Looking East)

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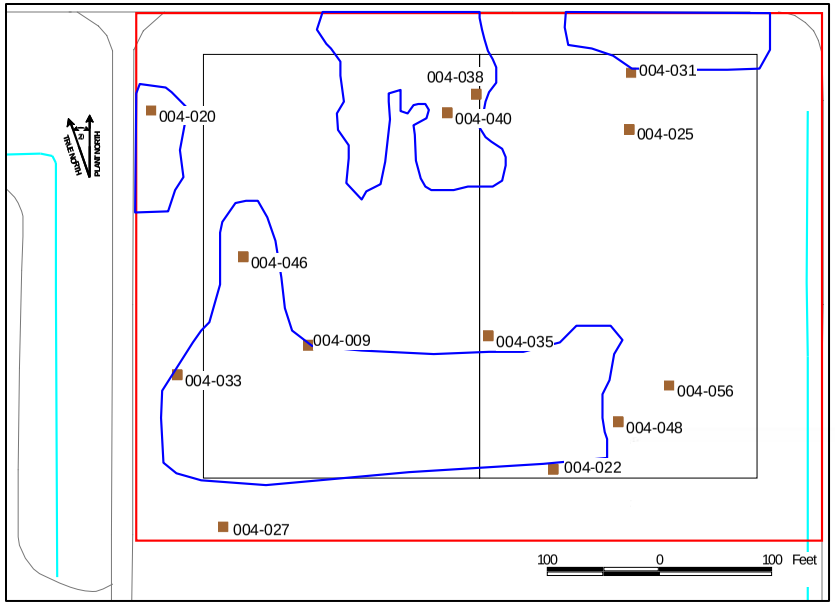

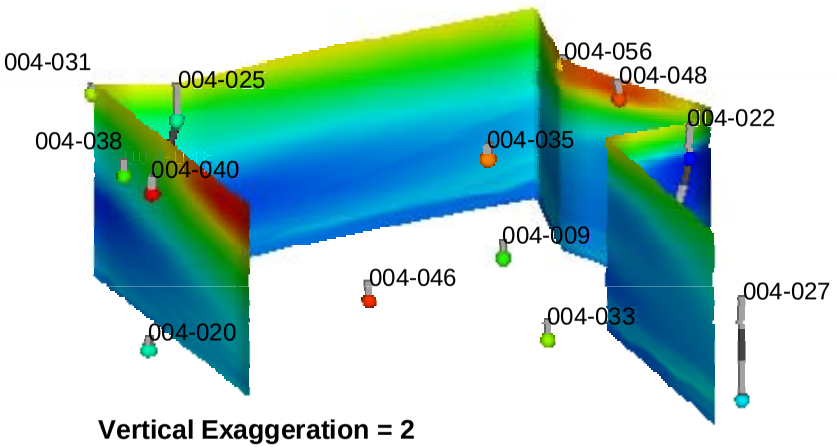

Vertical Exaggeration = 2

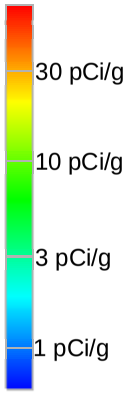

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Figure 4.50. SWMU 4 ^{234}U in Soil (Looking East)

4.5.2 SWMU 4 Groundwater

No additional sampling was conducted at SWMU 4 as part of this RI. The WAG 3 RI (DOE 2000a) provided the majority of data to characterize SWMU 4. Single temporary borings of the WAG 27 RI (DOE 1999d) and a sitewide remedial evaluation for source areas (DOE 2000b) supplied additional RGA data for the SWMU 4 area. The WAG 3 RI (DOE 2000a) provided analyses of UCRS groundwater from 26 temporary borings, shown in Figure 4.3.

Three temporary soil borings of the WAG 3 RI (004-028, 004-029, and 004-058) and single temporary soil borings from the WAG 27 RI, DG-030 (DOE 1999d) and from a sitewide remedial evaluation for source areas (DOE 2000b) provided groundwater analyses to characterize the RGA. Tables 4.20 and 4.21 summarize the review of SWMU 4 UCRS and RGA groundwater data (primarily derived from the WAG 3 RI) to identify site-related contaminants. All RGA soil borings at SWMU 4, with the exception of 720-026, also sampled the McNairy. Groundwater samples at SWMU 4 characterized groundwater down to 50 ft below the base of the RGA. The screening steps determined that the only contaminant among the McNairy groundwater samples from SWMU 4 was TCE. Table 4.22 provides detail (depth, sample location, and analytical results) for SWMU 4 groundwater samples, including nondetects and detections above screening levels.

Table 4.20. SWMU 4 UCRS Groundwater Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection	
	Historical Data	RI Data		Above MCL[a]	Above Child Resident NAL[b]
Inorganics (mg/L)					
Arsenic	0.311	N/A[b]	23/27	21/27	23/27
Beryllium	0.13	N/A	12/34	12/34	12/34
Cadmium	0.031	N/A	7/23	7/23	7/23
Chromium	5.11	N/A	15/38	15/38	6/38
Copper	1.55	N/A	14/36	1/36	14/36
Iron	2,560	N/A	33/38	N/A	31/38
Lead	1	N/A	9/9	9/9	9/9
Manganese	118	N/A	38/38	N/A	38/38
Mercury	0.004	N/A	7/31	1/31	7/31
Nickel	1.26	N/A	14/34	N/A	14/34
Vanadium	4.01	N/A	13/36	N/A	13/36
Zinc	8.2	N/A	24/38	N/A	15/38
Organics–Semivolatiles (mg/L)					
Naphthalene	0.007	N/A	1/17	N/A	1/17
Organics–Volatiles (mg/L)					
1,1-DCE	0.34	N/A	11/23	4/23	11/23
cis-1,2-DCE	12	N/A	22/33	14/33	20/33
trans-1,2-DCE	0.11	N/A	13/31	1/31	5/31
TCE	56	N/A	29/34	24/34	25/34
Vinyl chloride	0.44	N/A	12/26	9/26	12/26
Organics-Pesticides and PCBs (mg/L)					
PCB, Total	0.00091	N/A	2/5	1/5	2/5
PCB-1254	0.00091	N/A	2/5	1/5	2/5
Radionuclides (pCi/L)					
Technetium-99	1640	N/A	17/26	2/26	17/26

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

Table 4.21. SWMU 4 RGA Groundwater Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection		
	Historical Data	RI Data		Above Back-ground	Above MCL	Above Child Resident NAL
Inorganics (mg/L)						
Arsenic	0.045	N/A[b]	51/57	50/57	26/57	51/57
Beryllium	0.15	N/A	15/62	11/62	11/62	11/62
Iron	1830	N/A	86/108	41/108	N/A	72/108
Iron, Dissolved	1.22	N/A	4/4	4/4	N/A	4/4
Lead	0.328	N/A	7/8	3/8	4/8	4/8
Manganese	56.2	N/A	108/108	107/108	N/A	108/108
Manganese, Dissolved	1.59	N/A	4/4	4/4	N/A	4/4
Mercury	0.0064	N/A	4/46	3/46	2/46	2/46
Nickel	0.9	N/A	15/61	1/61	N/A	14/61
Vanadium	4.01	N/A	12/56	8/56	N/A	8/56
Zinc	3.54	N/A	22/72	21/72	N/A	7/72
Organics – Volatiles (mg/L)						
1,1-DCE	0.042	N/A	32/41	N/A	19/41	32/41
Carbon tetrachloride	0.061	N/A	3/5	N/A	2/5	3/5
Chloroform	0.055	N/A	3/4	N/A	N/A	3/4
cis-1,2-DCE	0.2	N/A	31/42	N/A	12/42	25/42
TCE	10	N/A	45/45	N/A	43/45	43/45
Vinyl chloride	0.017	N/A	20/38	N/A	3/38	20/38

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

The metals arsenic, iron, lead, and manganese frequently exceeded screening levels in both the UCRS and RGA. VOCs also were common contaminants of the UCRS and RGA associated with SWMU 4. TCE levels exceeded the MCL in 43 of 45 analyses in the RGA. TCE degradation products, notably 1,1-DCE and *cis*-1,2-DCE, also frequently exceeded MCLs. Other VOCs present at SWMU 4 include carbon tetrachloride and chloroform.

Dissolved TCE trends indicate that a potential TCE DNAPL source is present in the UCRS at SWMU 4, related to the elevated soil concentrations found in the southern burial area. A discrete DNAPL zone, less than 200 ft wide, also may be present at the base of the RGA (Figure 4.20) as evidenced by a discrete area with TCE concentrations greater than 10,000 µg/L in the lower RGA immediately downgradient of the SWMU. The evidence of the potential UCRS DNAPL presence is markedly higher dissolved TCE levels (commonly 1,000 to 4,000 µg/L) in the RGA on the west (downgradient) side of the SWMU. The area of higher TCE levels spans the entire west side of SWMU 4, suggestive of a diffuse source of DNAPL contamination in the UCRS soils underlying the burial grounds (DOE 2007b). The volume of soil potentially contaminated with TCE DNAPL at this SWMU is estimated to be approximately 31,480 yd^3. This estimate assumes a source area that is 100 ft by 100 ft with a thickness of 85 ft (depth to base of RGA, which is 100 ft minus the estimated depth to base of the waste cell of 15 ft). The volumetric extent of this DNAPL zone may be refined further for alternative evaluation in the FS.

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Table 4.22. SWMU 4 Locations of Groundwater Contaminants

Unit	Depth (ft)	Analysis	004-008	004-009	004-011	004-017	004-019	004-020	004-021	004-022	004-023	004-024	004-025	004-026	004-027	004-028	004-029	004-032	004-033	004-035	004-036	004-037	004-038	004-039	004-040	004-044	004-047	004-049	004-058	720-026	DG-030
UCRS	19-21	***Organics-Volatiles (mg/L)***																													
		1,1-DCE	ND		ND																							0.006			
		cis -1,2-DCE	ND		ND																							0.12			
		TCE	0.014		ND																							0.32			
		trans -1,2-DCE	ND		ND																							ND			
		Vinyl chloride	ND		ND																							0.29			
		Radionuclides (pCi/L)																													
		Technetium-99	1640		25																										
	23-24	***Organics-Volatiles (mg/L)***																													
		1,1-DCE																		0.0072							0.0007				
		cis -1,2-DCE																		1.5							0.1				
		TCE																		3.3							0.018				
		trans -1,2-DCE																		0.048							ND				
		Vinyl chloride																		0.34							0.12				
		Radionuclides (pCi/L)																													
		Technetium-99																		44							ND				
	25-26	***Inorganics (mg/L)***																													
		Beryllium																					ND								
		Cadmium																					ND								
		Chromium																					ND								
		Copper																					ND								
		Iron																					ND								
		Manganese																					4.47								
		Nickel																					ND								
		Vanadium																					ND								
		Zinc																					ND								
		Organics-Semivolatiles (mg/L)																													
		Naphthalene																					ND								
		Organics-Volatiles (mg/L)																													
		1,1-DCE																		0.05		0.0003		0.0015		0.002					
		cis -1,2-DCE																		0.96		0.069		0.0046		0.19					
		TCE																		23		0.35		0.09		0.73					
		trans -1,2-DCE																		ND		ND		ND		ND					
		Vinyl chloride																		0.071		0.0033		0.0016		0.001					
		Radionuclides (pCi/L)																													
		Technetium-99																		1240		390		23.6		23					
	36-40	***Organics-Semivolatiles (mg/L)***																													
		Naphthalene		ND																				ND							
		Organics-Volatiles (mg/L)																													
		1,1-DCE		ND																				0.0009		ND					
		cis -1,2-DCE		11																				ND		ND					
		TCE		19																				ND		0.002					
		trans -1,2-DCE		0.1																				ND		ND					
		Vinyl chloride		ND																				0.0002		ND					
		Radionuclides (pCi/L)																													
		Technetium-99																						44		120					

Table 4.22. SWMU 4 Locations of Groundwater Contaminants (Continued)

Unit	Depth (ft)	Analysis	004-008	004-009	004-011	004-017	004-019	004-020	004-021	004-022	004-023	004-024	004-025	004-026	004-027	004-028	004-029	004-032	004-033	004-035	004-036	004-037	004-038	004-039	004-040	004-044	004-047	004-049	004-058	720-026	DG-030
UCRS	45-48	***Inorganics (mg/L)***																													
		Arsenic															0.019														
		Beryllium														0.13	0.099					ND									
		Cadmium															0.021					ND									
		Chromium														1.34	0.3					0.19									
		Copper														0.79	0.426					ND									
		Iron														2560	1560					63.4									
		Lead															0.642														
		Manganese														42.7	118					1.2									
		Mercury														ND	0.0018					ND									
		Nickel														0.7	ND					0.083									
		Vanadium														4.01	1.22					0.125									
		Zinc														3.54	2.73					ND									
		Organics-Semivolatiles (mg/L)																													
		Naphthalene														ND	ND					ND									
		Organics-Volatiles (mg/L)																													
		1,1-DCE														ND	0.081					ND									
		cis -1,2-DCE														ND	0.13					ND									
		TCE														ND	2.2					ND									
		trans -1,2-DCE														ND	0.012					ND									
		Vinyl chloride														ND	0.012					ND									
		Radionuclides (pCi/L)																													
		Technetium-99														ND	382					194									
	50-51	***Organics-Volatiles (mg/L)***																													
		1,1-DCE									0.34																				
		cis -1,2-DCE									9																				
		TCE									48																				
		trans -1,2-DCE									0.11																				
		Vinyl chloride									0.4																				
		Radionuclides (pCi/L)																													
		Technetium-99									ND																				
	60-61	***Inorganics (mg/L)***																													
		Arsenic				ND		0.009	0.311	0.052	0.203	ND	0.014	0.02	0.086																
		Beryllium				0.037	0.005	0.103	ND	0.074	0.115	0.093	0.118	0.097	0.026																
		Cadmium				0.01	ND	0.022	0.012	ND	0.031	0.022	ND		ND																
		Chromium				0.439	0.165	1.55	0.575	1.99	2.78	1.52	2.67	5.11	2.55																
		Copper				0.243	0.103	0.942	0.131	0.691	1.05	0.62	1.03	1.55	0.722																
		Iron				705	102	1810	128	885	2540	1700	966	2090	670																
		Lead						0.757		0.312	1	0.675	0.761	0.426	0.204																
		Manganese				12.1	1.23	12.2	0.923	12.2	34.9	17.3	57.3	32.8	5.99																
		Mercury				0.0013	ND	0.0015	ND	0.0007	ND	ND	0.004	0.0015	ND																
		Nickel				0.07	0.065	0.5	0.125	0.505	ND	0.5	0.813	1.26	0.504																
		Vanadium				0.862	0.143	1.49	ND	1.13	1.95	1.52	0.99	1.98	0.376																
		Zinc				1.28	ND	3.45	2.19	3.2	8.2	4.74	5.98	6.8	2.76																
		Organics-PCBs and Pesticides(mg/L)																													
		PCB, Total								ND			0.00039	0.00091	ND																
		PCB-1254								ND			0.0002	0.00091	ND																

Table 4.22. SWMU 4 Locations of Groundwater Contaminants (Continued)

Unit	Depth (ft)	Analysis	004-008	004-009	004-011	004-017	004-019	004-020	004-021	004-022	004-023	004-024	004-025	004-026	004-027	004-028	004-029	004-032	004-033	004-035	004-036	004-037	004-038	004-039	004-040	004-044	004-047	004-049	004-058	720-026	DG-030
UCRS	60-61	***Organics-Semivolatiles (mg/L)***																													
		Naphthalene				ND	ND	ND	ND	ND	ND	0.007	ND	ND																	
		Organics-Volatiles (mg/L)																													
		1,1-DCE				0.0007	ND	ND	ND		ND							ND												
		cis -1,2-DCE				0.015	ND	0.029	ND	11	0.003	12	ND	0.56	ND			ND												
		TCE				0.26	0.016	1.7	ND	35	0.046	56	ND	0.65				ND												
		trans -1,2-DCE				ND	ND	ND	ND		ND	0.041	ND	ND	ND			ND												
		Vinyl chloride				ND	ND	ND	ND		ND			0.44	ND			ND												
		Radionuclides (pCi/L)																													
		Technetium-99				720		375	ND	ND	16.3	157	ND	ND	ND																
RGA	48	***Inorganics (mg/L)***																													
		Arsenic																													0.007
		Beryllium																													0.09
		Iron																													1110
		Lead																													0.328
		Manganese																													56.2
		Mercury																													0.0064
		Nickel																													ND
		Vanadium																													0.931
		Zinc																													1.89
		Organics-Volatiles (mg/L)																													
		1,1-DCE																													ND
		cis -1,2-DCE																													ND
		TCE																													0.006
		Vinyl chloride																													ND
	63	***Inorganics (mg/L)***																													
		Arsenic															0.022														
		Beryllium														0.15	0.022														
		Iron														1830	338														
		Lead															0.22														
		Manganese														25.8	10.3														
		Mercury														0.0022	ND														
		Nickel														0.9	ND														
		Vanadium														4.01	0.342														
		Zinc														3.54	0.812														
		Organics-Volatiles (mg/L)																													
		1,1-DCE														ND	0.0053														
		cis -1,2-DCE														ND	0.081														
		TCE														0.063	1.4														
		Vinyl chloride														ND	0.0009														
	68	***Inorganics (mg/L)***																													
		Arsenic															0.045														0.009
		Beryllium														ND	0.007												0.006		ND
		Iron														74.6	132												110		64.6
		Manganese														2.09	1.5												5.82		20.5
		Mercury														ND	ND												ND		ND
		Nickel														0.056	ND												0.067		0.113

Table 4.22. SWMU 4 Locations of Groundwater Contaminants (Continued)

Unit	Depth (ft)	Analysis	004-008	004-009	004-011	004-017	004-019	004-020	004-021	004-022	004-023	004-024	004-025	004-026	004-027	004-028	004-029	004-032	004-033	004-035	004-036	004-037	004-038	004-039	004-040	004-044	004-047	004-049	004-058	720-026	DG-030
RGA	68	***Inorganics (mg/L)***																													
		Vanadium														ND	ND												ND		ND
		Zinc														ND	0.258												0.391		0.402
		Organics-Volatiles (mg/L)																													
		1,1-DCE														0.0006	0.011												ND		0.015
		cis -1,2-DCE														0.026	0.15												ND		0.055
		TCE														1	3.8												ND		1.6
		Vinyl chloride														0.0002	0.0022												ND		0.0009
	71-73	***Inorganics (mg/L)***																													
		Arsenic															0.028														0.015
		Beryllium														ND	0.012												ND		ND
		Iron														19.8	234												50.4		29.3
		Manganese														0.487	5.54												2.59		1.75
		Mercury														ND	ND												ND		ND
		Nickel														ND	ND												ND		ND
		Vanadium														ND	0.148												ND		ND
		Zinc														ND	0.479												ND		ND
		Organics-Volatiles (mg/L)																													
		1,1-DCE														0.0003	0.0097												ND		0.0081
		cis -1,2-DCE														0.028	0.14												ND	ND	0.08
		TCE														1.5	2.1												0.006	0.1	1.5
		Vinyl chloride														0.0002	0.002												ND		0.0009
	78	***Inorganics (mg/L)***																													
		Arsenic														0.007	0.008														0.019
		Beryllium														0.006	ND												ND		ND
		Iron														165	17.6												26.7		13.2
		Manganese														5.04	0.69												1.1		1.12
		Mercury														ND	ND												ND		ND
		Nickel														0.129	ND												ND		ND
		Vanadium														ND	ND												ND		ND
		Zinc														0.549	ND												ND		ND
		Organics-Volatiles (mg/L)																													
		1,1-DCE														0.0016	0.0043												ND		0.0088
		Carbon tetrachloride														ND															0.061
		Chloroform														ND															0.055
		cis -1,2-DCE														0.065	0.02												ND		0.13
		TCE														2.1	0.4												0.018		2.5
		Vinyl chloride														ND	0.0004												ND		0.0011
	82-83	***Inorganics (mg/L)***																													
		Arsenic														0.012													0.005	ND	0.011
		Beryllium														ND	ND												ND	ND	ND
		Iron														11.5	43.1												75.5	64.3	9.15
		Iron, Dissolved																												0.803	
		Lead																												ND	
		Manganese														0.854	0.475												11.9	0.884	1.61
		Manganese, Dissolved																												0.82	

Table 4.22. SWMU 4 Locations of Groundwater Contaminants (Continued)

Unit	Depth (ft)	Analysis	004-008	004-009	004-011	004-017	004-019	004-020	004-021	004-022	004-023	004-024	004-025	004-026	004-027	004-028	004-029	004-032	004-033	004-035	004-036	004-037	004-038	004-039	004-040	004-044	004-047	004-049	004-058	720-026	DG-030
RGA	82-83	***Inorganics (mg/L)***																													
		Mercury														ND	ND												ND	ND	ND
		Nickel														ND	ND												0.362	0.0411	ND
		Vanadium														ND	ND												ND	ND	ND
		Zinc														ND	ND												0.236	0.1	ND
		Organics-Volatiles (mg/L)																													
		1,1-DCE														0.012	0.0007												ND	0.012	0.018
		Carbon tetrachloride																												0.0042	
		Chloroform																												0.0021	
		cis -1,2-DCE														0.11	ND												ND	0.0079	0.065
		TCE														3.7	0.069												0.042	0.5	1.4
		Vinyl chloride														ND	ND												ND	ND	0.0008
	87-88	***Inorganics (mg/L)***																													
		Arsenic														0.009														ND	0.007
		Beryllium														ND	ND												ND	ND	ND
		Iron														102	129												47.3	68.4	41.5
		Iron, Dissolved																												1.19	
		Lead																												ND	
		Manganese														7.89	2.52												1.99	1.88	1.98
		Manganese, Dissolved																												1.56	
		Mercury														ND	ND												ND	ND	ND
		Nickel														0.059	ND												ND	0.0532	0.064
		Vanadium														ND	ND												ND	ND	ND
		Zinc														0.237	0.258												ND	0.132	ND
		Organics-Volatiles (mg/L)																													
		1,1-DCE														0.021	0.0007												ND	0.031	0.012
		Carbon tetrachloride																												0.012	
		Chloroform																												0.0029	
		cis -1,2-DCE														0.1	ND												ND	0.011	0.038
		TCE														2	0.054												0.08	0.86	1
		Vinyl chloride														0.0008	ND												ND	0.017	0.0011
	92-93	***Inorganics (mg/L)***																													
		Arsenic														0.013														ND	0.01
		Beryllium														ND	ND												0.009	ND	ND
		Iron														33.3	108												502	13.4	67.3
		Iron, Dissolved																												1.22	
		Lead																												ND	
		Manganese														1.1	1.44												5.75	1.42	1.74
		Manganese, Dissolved																												1.59	
		Mercury														ND	ND												ND	ND	ND
		Nickel														ND	ND												ND	ND	0.059
		Vanadium														ND	ND												0.2	ND	ND
		Zinc														ND	0.25												0.609	ND	ND

Table 4.22. SWMU 4 Locations of Groundwater Contaminants (Continued)

Unit	Depth (ft)	Analysis	004-008	004-009	004-011	004-017	004-019	004-020	004-021	004-022	004-023	004-024	004-025	004-026	004-027	004-028	004-029	004-032	004-033	004-035	004-036	004-037	004-038	004-039	004-040	004-044	004-047	004-049	004-058	720-026	DG-030
RGA	92-93	***Organics-Volatiles (mg/L)***																													
		1,1-DCE														0.021	0.0009												ND	0.015	0.041
		Carbon tetrachloride																											ND		
		cis -1,2-DCE														0.17	ND												ND		0.1
		TCE														2.1	0.11												0.027	0.903	4.5
		Vinyl chloride														0.0004	ND												ND		0.0019
	98	***Inorganics (mg/L)***																													
		Arsenic																													0.023
		Beryllium														ND	ND												0.006		ND
		Iron														37.9	17.6												499		7.38
		Lead																											0.21		
		Manganese														0.943	1.07												3.1		0.187
		Mercury														ND	0.0003												ND		ND
		Nickel														ND	ND												ND		ND
		Vanadium														ND	ND												0.417		ND
		Zinc														ND	ND												0.329		ND
		Organics-Volatiles (mg/L)																													
		1,1-DCE														0.0019	0.003												ND		0.042
		cis -1,2-DCE														0.0089	0.0048												ND		0.2
		TCE														0.18	0.18												ND		10
		Vinyl chloride														ND	0.0002												ND		0.0033
	103	***Inorganics (mg/L)***																													
		Arsenic																													0.016
		Beryllium																													ND
		Iron																													133
		Manganese																													1.77
		Mercury																													ND
		Nickel																													ND
		Vanadium																													ND
		Zinc																													0.23
		Organics-Volatiles (mg/L)																													
		1,1-DCE																													0.035
		cis-1,2-DCE																													0.15
		TCE																													3.7
		Vinyl chloride																													0.0015
	108	***Inorganics (mg/L)***																													
		Beryllium																													0.021
		Iron																													1110
		Manganese																													10.1
		Mercury																													ND
		Nickel																													0.6
		Vanadium																													0.281
		Zinc																													1.32

Table 4.22. SWMU 4 Locations of Groundwater Contaminants (Continued)

Unit	Depth (ft)	Analysis	004-008	004-009	004-011	004-017	004-019	004-020	004-021	004-022	004-023	004-024	004-025	004-026	004-027	004-028	004-029	004-032	004-033	004-035	004-036	004-037	004-038	004-039	004-040	004-044	004-047	004-049	004-058	720-026	DG-030
RGA	108	***Organics-Volatiles (mg/L)***																													
		1,1-DCE																													0.006
		cis -1,2-DCE																													0.075
		TCE																													1.3
		Vinyl chloride																													ND
	113	***Inorganics (mg/L)***																													
		Beryllium																													ND
		Iron																													54.4
		Lead																													0.052
		Manganese																													2.12
		Mercury																													ND
		Nickel																													ND
		Vanadium																													0.199
		Zinc																													ND
		Organics-Volatiles (mg/L)																													
		1,1-DCE																													0.0006
		cis -1,2-DCE																													ND
		TCE																													0.037
		Vinyl chloride																													0.0005

ND = not detected above screening levels

Blank cells indicate interval was not sampled for the specified analysis. The maximum value is shown for each depth interval at each location.

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4.6 SWMU 5

4.6.1 Subsurface Soils

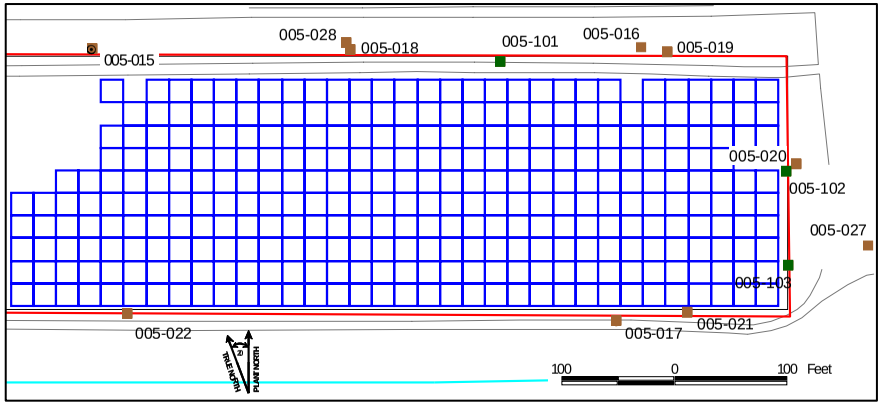
This RI collected subsurface soil samples from three angled borings at SWMU 5. Review of RI and historical data for SWMU 5 identified the contaminants listed in Table 4.23.

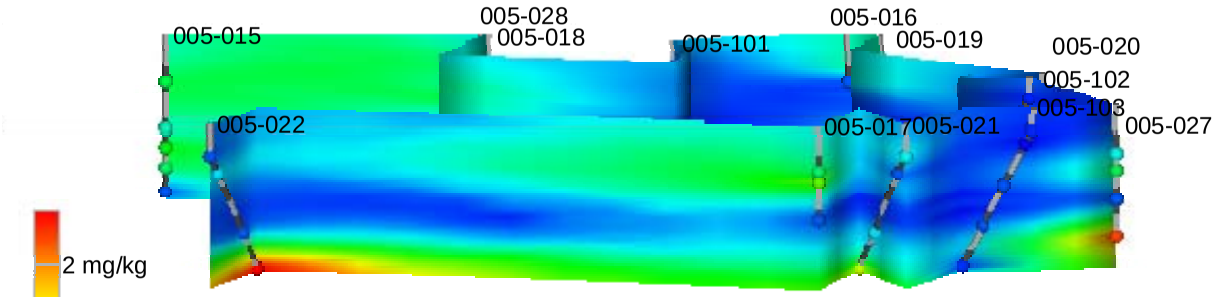
Table 4.23. SWMU 5 Subsurface Soil Contaminants

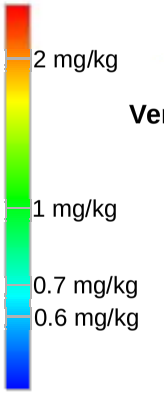
Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection	
	Historical Data	RI Data		Above Background Value	Above Excavation Worker NAL
Inorganics (mg/kg)					
Beryllium	2.59	N/A[b]	31/59	26/59	8/59
Iron	32,900	21,800	59/59	4/59	57/59
Manganese	1,750	690	59/59	2/59	44/59
Vanadium	56.9	34.3	59/59	4/59	59/59

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

The SWMU 5 burial pits were not excavated below 10 to 15 ft due to the shallow water table. Metals and radionuclides are the primary potential contaminants of interest at SWMU 5, since the majority of items believed to be buried there include some radionuclide-contaminated scrap metal and slag from PGDP nickel and aluminum smelters. The most prevalent metal detected in subsurface soils above background levels is beryllium (26 of 59 analyses), followed by iron and vanadium (4 of 59 analyses). The metals exceedances are well distributed across SWMU 5. High levels of vanadium tended to occur at moderate depths (15 to 30 ft), while beryllium exceedances mostly are at depths of 40 ft or greater. Figure 4.51 provides the distribution of beryllium at SWMU 5. The highest beryllium concentration was 2.59 mg/kg from the 40 to 45 ft sample at historical soil boring 005-022, with the next sample at 50 to 55 ft showing only 0.57 mg/kg. Figure 4.52 shows the distribution of vanadium at SWMU 5 and illustrates the horizon at 15 to 30 ft where most exceedances occur. High levels of iron range across depths of 20 to 55 ft. Table 4.24 shows the locations of detections above screening levels. The screening process did not identify any radionuclides or organic compounds as potential contaminants for SWMU 5 (in accordance with the BGOU RI Work Plan, soil and groundwater at SWMU 5 were not sampled and analyzed for VOCs).







Vertical Exaggeration = 2

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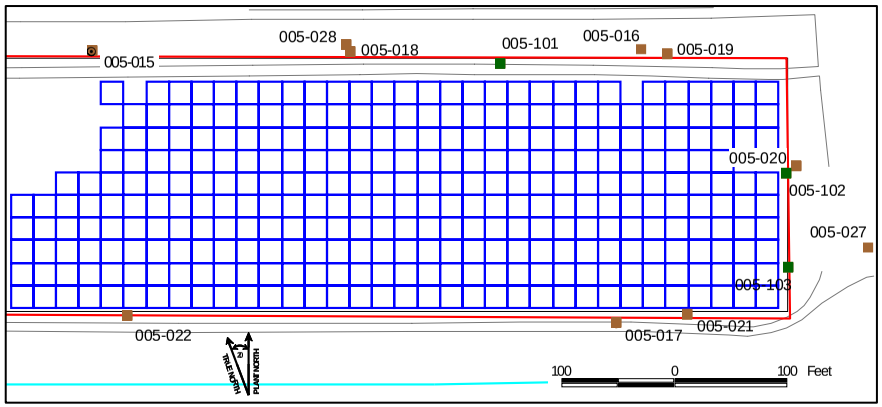
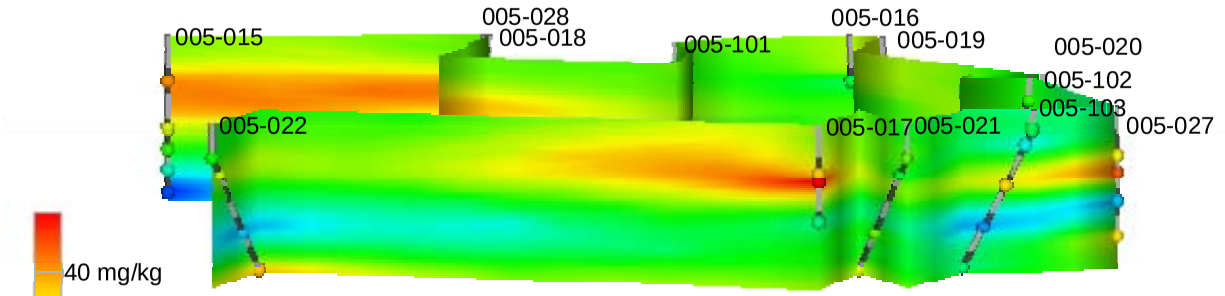
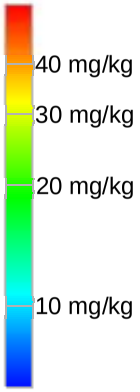
Figure 4.51. SWMU 5 Beryllium in Soil (Looking North)







Vertical Exaggeration = 2

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Figure 4.52. SWMU 5 Vanadium in Soil (Looking North)

Table 4.24. SWMU 5 Locations of Subsurface Soil Contaminants

		RI Data			Historical Data									
Analysis	**Depth (ft)**	005-101	005-102	005-103	005-015	005-016	005-017	005-018	005-019	005-020	005-021	005-022	005-027	005-028
Beryllium	10-15	ND	ND	ND				0.83	0.93	ND	0.67	ND		
	15-20	ND	ND	ND	0.92	ND	0.87				ND	0.64		
	20-25						1.23						0.69	0.74
	25-30									ND			0.91	0.96
	30-35	ND	ND	ND				ND	0.71	0.72	0.64	ND		
	35-40				0.75		ND						ND	ND
	40-45	ND	ND	ND	1.02			1.47		1.64	1.47	2.59		
	50-55				0.87			1.16		1.39	1.68	0.57	2.27	1.26
	60-65	ND	ND	ND	ND			0.84						
Iron	10-15	9,640	11,100	10,400				12,700	18,000	8,440	9,390	8,320		
	15-20	10,700	8,620	8,100	16,500	9,440	22,500				10,100	9,600		
	20-25						29,200						16,000	18,700
	25-30									9,130			16,500	32,900
	30-35	14,700	20,000	21,800				7,040	13,900	10,700	14,000	3,820		
	35-40				17,100		8,360						3,550	7,300
	40-45	1,330	1,380	9,190	17,500			17,700		24,400	24,800	29,400		
	50-55				9,940			15,500		18,000	22,700	8,720	31,900	13,800
	60-65	8,310	7,530	12,500	4,720			10,900						
Manganese	10-15	690	343	314				231	289	173	151	121		
	15-20	385	136	184	117	113	222				260	86.6		
	20-25						87.5						131	61.4
	25-30									23.2			34.8	24.6
	30-35	76.2	29.5	39.6				57	39.7	45.6	65.7	12.9		
	35-40				115		40.8						26.3	6.89
	40-45	15.5	457	37.3	827			253		68.2	84.3	144		
	50-55				1,750			304		73.3	498	149	197	236
	60-65	80.8	233	196	61.8			725						
Vanadium	10-15	20.3	20.5	15.6				27.2	33.3	18.9	22.9	19.1		
	15-20	20.6	24.6	11.3	41.4	16.5	36.1				17.3	27.8		
	20-25						56.9						33	42.4
	25-30									18.2			46.6	36.6
	30-35	27.7	31.7	34.3				13.8	22.4	22.8	23	9.65		
	35-40				29.9		14.5						9.45	21.6
	40-45	6.28	9.28	8.63	20.4			20.1		26.7	29.6	36.8		
	50-55				12.4			18.8		17.2	31.1	11.2	34	15.7
	60-65	15.1	18.4	14.6	7.23			15.5						

ND = not detected above screening levels

Blank cells indicate interval was not sampled for the specified analysis. Maximum value is shown for each depth interval.

4.6.2 SWMU 5 Groundwater

UCRS groundwater samples were collected from two of three angled borings installed at SWMU 5 as part of this RI. Samples of 10 temporary borings of the WAG 3 RI (DOE 2000a) provided historical data for the UCRS at SWMU 5. RI data were reviewed with historical data to determine the UCRS contaminants listed in Table 4.25.

The SWMU 5 disposal pits extend to a depth of 6 to 15 ft. These are underlain by the HU2 horizon of the UCRS at depths of 20 to 40 ft. The shallowest groundwater samples were from two WAG 3 RI soil borings at depths of 20-30 ft.

The remainder of the UCRS groundwater samples were from depths of 40 to 61 ft. Screening identified many metals in these UCRS groundwater samples from SWMU 5 with concentrations that exceed screening criteria. Of these, iron, lead, manganese, and molybdenum analyses had the highest frequency of exceedances. (Lead exceeded its MCL at three locations.) Locations with metals that exceed screening criteria were well distributed across the SWMU. Because it was determined during scoping meetings for the BGOU RI/FS Work Plan that SWMU 5 should not be a source for VOC contamination, organics were not analyzed during this RI; however, analyses of historical samples of UCRS groundwater documented single detections of pyrene and TCE at concentrations that exceed screening levels. TCE was detected in UCRS groundwater at a concentration of 29 µg/L in boring 005-022. No radionuclide analyses exceeded screening criteria in the UCRS groundwater samples.

This RI did not collect RGA and McNairy groundwater at SWMU 5; however, historical data were reviewed to determine the RGA groundwater contaminants listed in Table 4.26. (The screening determined that there were no McNairy groundwater contaminants.) Only locations 005-013 and 005-026 of the WAG 3 RI were sampled for metals, organics, and radionuclides in RGA and McNairy groundwater. Additionally, the location DG-002 was sampled for VOCs and radionuclides (DOE 2000b). Manganese exceeded screening criteria in all 51 RGA groundwater samples from SWMU 5. Iron was the only other metal that commonly was present at levels exceeding screening criteria. TCE concentrations exceeded screening criteria throughout the depth of the RGA. These occurrences likely are related to the Northwest Plume, which passes to the east of the SWMU 5 area. Figure 4.53 shows the relationship of the Northwest Plume in the RGA with SWMUs 5 and 6.

Table 4.25. SWMU 5 UCRS Groundwater Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection	
	Historical Data	RI Data		Above MCL	Above Child Resident NAL
Inorganics (mg/L)					
Arsenic	0.014	0.00182	3/4	1/4	3/4
Beryllium	0.144	N/A[b]	5/18	5/18	5/18
Chromium	6.47	N/A	6/20	6/20	3/20
Copper	1.81	N/A	6/20	1/20	6/20
Iron	2090	37.9	16/20	N/A	16/20
Lead	0.816	0.00208	6/6	4/6	4/6
Manganese	54.8	0.712	20/20	N/A	20/20
Mercury	0.0025	N/A	4/16	1/16	3/16
Molybdenum	N/A	0.0386	2/2	N/A	2/2
Nickel	1.37	0.0311	7/20	N/A	7/20
Vanadium	2.62	N/A	5/18	N/A	5/18
Zinc	6.77	0.064	10/18	N/A	5/18

Table 4.25. SWMU 5 UCRS Groundwater Contaminants (Continued)

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection	
	Historical Data	RI Data		Above MCL	Above Child Resident NAL
Organics – Semivolatiles (mg/L)					
Pyrene	0.023	N/A	1/6	N/A	1/6
Organics – Volatiles (mg/L)					
TCE	0.029	N/A	1/10	1/10	1/10

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

Table 4.26. SWMU 5 RGA Groundwater Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection		
	Historical Data	RI Data		Above Back-ground	Above MCL	Above Child Resident NAL
Inorganics (mg/L)						
Beryllium	0.032	N/A[b]	6/29	6/29	6/29	6/29
Cadmium	0.044	N/A	1/19	1/19	1/19	1/19
Iron	2160	N/A	41/51	19/51	N/A	35/51
Lead	0.655	N/A	1/1	1/1	1/1	1/1
Manganese	51.3	N/A	51/51	51/51	N/A	51/51
Vanadium	1.21	N/A	6/29	2/29	N/A	6/29
Zinc	0.466	N/A	6/29	6/29	N/A	1/29
Organics – Volatiles (mg/L)						
TCE	0.033	N/A	14/24	N/A	7/24	9/24

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

Table 4.27 provides detail (depth, sample location, and analytical results) for SWMU 5 groundwater samples, including nondetects and detections above screening levels.

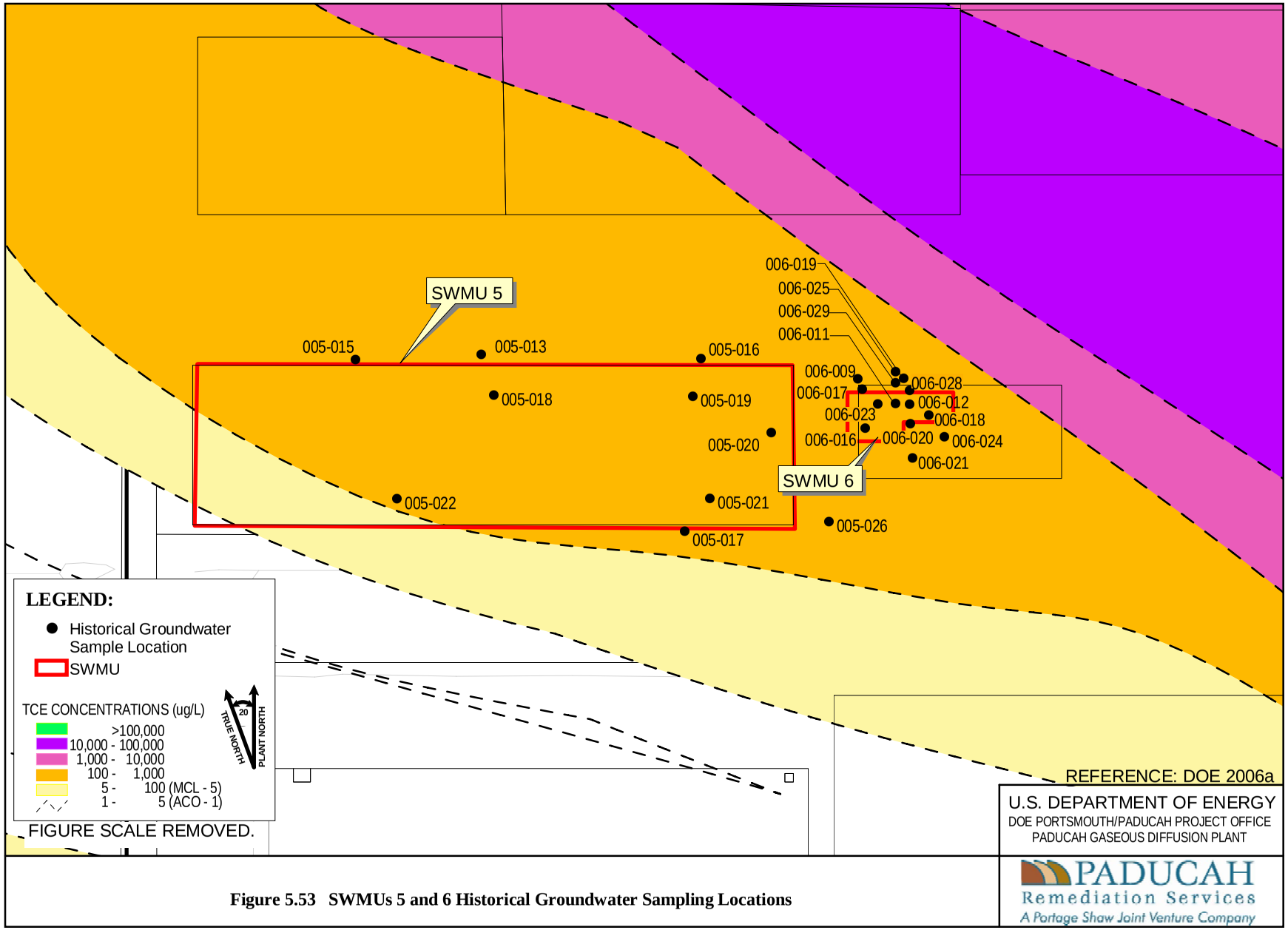

Figure 5.53 SWMUs 5 and 6 Historical Groundwater Sampling Locations

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Table 4.27. SWMU 5 Locations of Groundwater Contaminants

			Historical Data										RI Data	
Unit	Depth (ft)	Analysis	005-013	005-015	005-016	005-017	005-018	005-019	005-020	005-021	005-022	005-026	DG-002	005-101	005-102
UCRS	20-30	***Organics-Volatiles (mg/L)***													
		TCE			ND	ND									
	40-45	***Inorganics (mg/L)***													
		Arsenic												ND	0.00182
		Beryllium												ND	ND
		Chromium												ND	ND
		Copper												ND	ND
		Iron												34.7	37.9
		Lead												ND	ND
		Manganese												0.712	0.295
		Mercury												ND	ND
		Molybdenum												0.0376	0.0386
		Nickel												ND	0.0311
		Vanadium												ND	ND
		Zinc												ND	ND
	60-61	***Inorganics (mg/L)***													
		Arsenic						0.014							
		Beryllium		0.008			0.045	0.144		0.047	ND				
		Chromium		0.157			2.04	6.47		1.31	0.404				
		Copper		0.186			0.596	1.81		0.627	0.085				
		Iron		111			787	2090		631	62.6				
		Lead					0.248	0.816		0.258					
		Manganese		1.64			11.4	54.8		21	1.44				
		Mercury		ND			ND	0.0025		0.0017	ND				
		Nickel		0.1			0.482	1.37		0.54	0.129				
		Vanadium		0.159			0.765	2.62		0.756	ND				
		Zinc		0.556			2.44	6.77		2.24	ND				
		Organics-Semivolatiles (mg/L)													
		Pyrene		0.023			ND	ND		ND	ND				
		Organics-Volatiles (mg/L)													
		TCE		ND			ND	ND	ND	ND	0.029				
RGA	63	***Inorganics (mg/L)***													
		Beryllium	0.005									0.006			
		Cadmium	ND									ND			
		Iron	91.5									109			
		Manganese	1.73									7.16			

Table 4.27. SWMU 5 Locations of Groundwater Contaminants (Continued)

			Historical Data											RI Data	
Unit	Depth (ft)	Analysis	005-013	005-015	005-016	005-017	005-018	005-019	005-020	005-021	005-022	005-026	DG-002	005-101	005-102
RGA	63	***Inorganics (mg/L)***													
		Vanadium	0.105									0.108			
		Zinc	0.297									0.466			
		Organics-Volatiles (mg/L)													
		TCE	ND									ND			
	68	***Inorganics (mg/L)***													
		Beryllium	ND									0.009			
		Cadmium	ND									ND			
		Iron	14.6									172			
		Manganese	2.43									14.5			
		Vanadium	ND									0.13			
		Zinc	ND									0.407			
		Organics-Volatiles (mg/L)													
		TCE	0.006									ND			
	70-73	***Inorganics (mg/L)***													
		Beryllium	ND									ND			
		Cadmium	ND									ND			
		Iron	90.4									20.3			
		Manganese	6.52									3.53			
		Vanadium	ND									ND			
		Zinc	ND									ND			
		Organics-Volatiles (mg/L)													
		TCE	0.01									ND	ND		
	76-78	***Inorganics (mg/L)***													
		Beryllium	0.005									ND			
		Cadmium	ND									ND			
		Iron	590									41.4			
		Manganese	5.97									3.98			
		Vanadium	ND									ND			
		Zinc	ND									ND			
		Organics-Volatiles (mg/L)													
		TCE	0.033									0.008	ND		
	81-83	***Inorganics (mg/L)***													
		Beryllium										ND			
		Cadmium										ND			
		Iron										130			
		Manganese										9.93			

Table 4.27. SWMU 5 Locations of Groundwater Contaminants (Continued)

			Historical Data										RI Data	
Unit	Depth (ft)	Analysis	005-013	005-015	005-016	005-017	005-018	005-019	005-020	005-021	005-022	005-026	DG-002	005-101	005-102
RGA	81-83	***Inorganics (mg/L)***													
		Vanadium										ND			
		Zinc										ND			
		Organics-Volatiles (mg/L)													
		TCE										0.003	ND		
	86-88	***Inorganics (mg/L)***													
		Beryllium	ND									ND			
		Cadmium	ND									ND			
		Iron	120									215			
		Manganese	9.85									8.8			
		Vanadium	ND									ND			
		Zinc	ND									0.257			
		Organics-Volatiles (mg/L)													
		TCE	0.02									0.005	ND		
	90-93	***Inorganics (mg/L)***													
		Beryllium	ND									0.032			
		Cadmium	ND									0.044			
		Iron	348									2160			
		Lead										0.655			
		Manganese	7.85									51.3			
		Vanadium	ND									1.21			
		Zinc	0.23									ND			
		Organics-Volatiles (mg/L)													
		TCE	0.015									ND	ND		
	98	***Inorganics (mg/L)***													
		Beryllium	ND									0.009			
		Cadmium	ND									ND			
		Iron	54.7									312			
		Manganese	1.73									1.81			
		Vanadium	0.101									0.473			
		Zinc	ND									0.403			
		Organics-Volatiles (mg/L)													
		TCE	ND									ND			

ND = not detected above background

Blank cells indicate interval was not sampled for the specified analysis. The maximum value is shown for each depth interval at each location.

4.7 SWMU 6

4.7.1 Subsurface Soils

Subsurface soil samples were collected from four angled borings at SWMU 6 as part of this RI. The screen of RI and historical data identified the contaminants listed in Table 4.28.

Table 4.28. SWMU 6 Subsurface Soil Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection	
	Historical Data	RI Data		Above Background Value	Above Excavation Worker NAL
Inorganics (mg/kg)					
Beryllium	3.07	0.825	32/70	22/70	12/70
Iron	58,700	19,100	70/70	7/70	69/70
Manganese	1,550	315	70/70	1/70	64/70
Vanadium	79.1	38.5	69/70	10/70	69/70

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).

Each burial area within SWMU 6 received different types of waste. The contents buried within each area are summarized as follows:

- Area H—magnesium scrap
- Area I—exhaust hood blowers contaminated with perchloric acid
- Area J—contaminated aluminum scrap
- Area K—magnesium scrap
- Area L—contaminated modine cold trap

Metals analyses of subsurface soil samples from SWMU 6 rarely exceed screening criteria (both background and NALs, where applicable) for identifying contamination. Screening identified beryllium and vanadium as the most frequent metal contaminants above background (in 22 and 10 of 70 analyses, respectively). The distribution of beryllium in soil is shown in Figure 4.54. Most of the NAL exceedances of beryllium occur in a horizon at 40 to 55 ft bgs. There is uncertainty with the lower extent in the vicinity of historical soil borings 006-026 and 006-027 since no deeper samples were collected (the top of the RGA occurs at a depth of 58 to 60 ft). Figure 4.55 illustrates the vanadium distribution in soil at SWMU 6. While there appears to be some zones of higher concentration, exceedances are found at all depths of the UCRS.

Of the occurrences of aluminum detected above background levels, the majority represents samples collected beneath Area J (aluminum scrap). The SWMU 6 burial pits extended to a depth of approximately 20 ft. All five detections of aluminum above PGDP background were from a depth of 43 to 51 ft. The maximum aluminum result was 22,500 mg/kg from location 006-020 at 43 ft bgs. The screening process did not identify any radionuclides or organic compounds as potential contaminants for SWMU 6.

Table 4.29 lists the locations of the contaminant detections above screening levels.

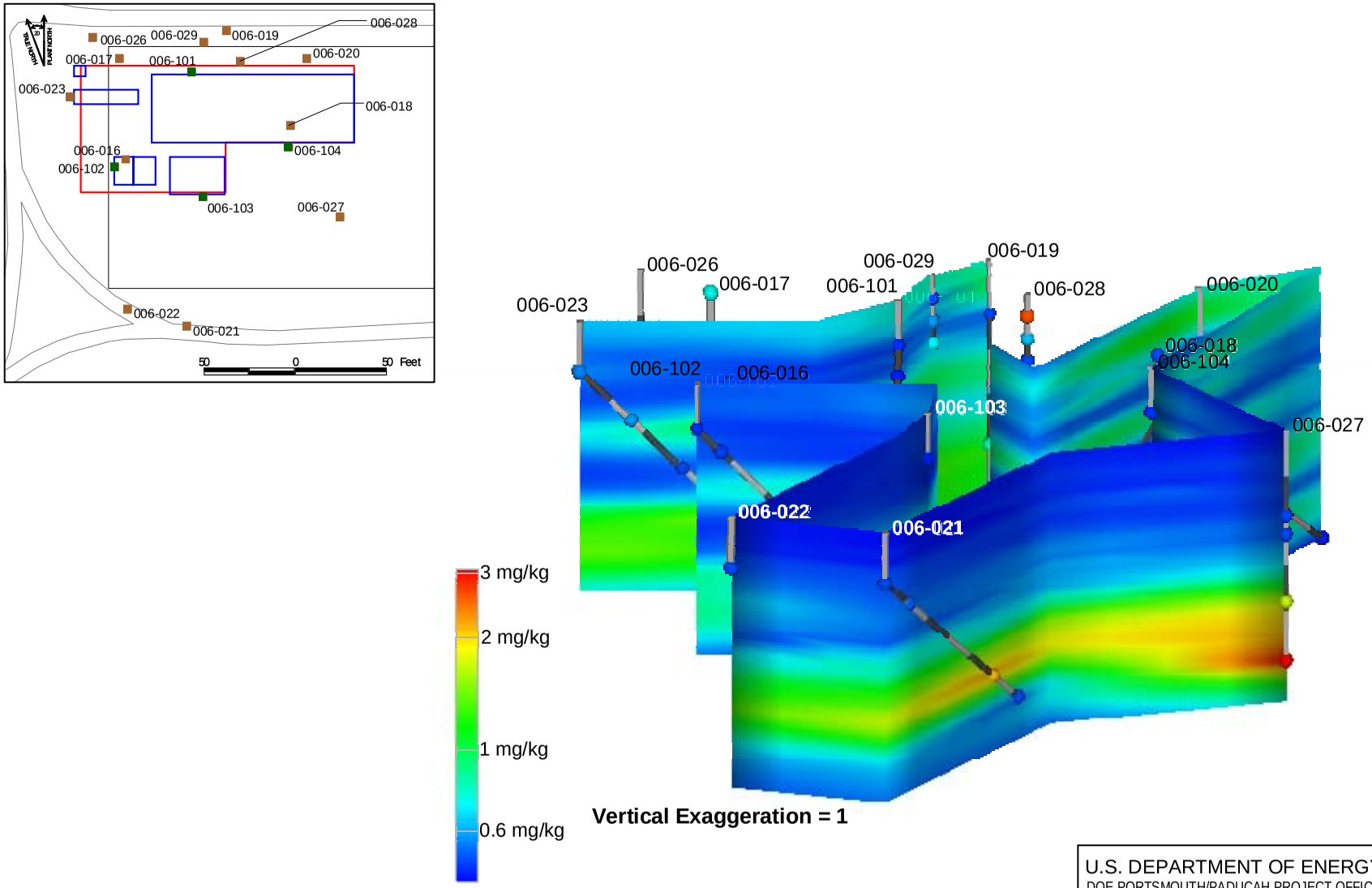

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Figure 4.54. SWMU 6 Beryllium in Soil (Looking North)

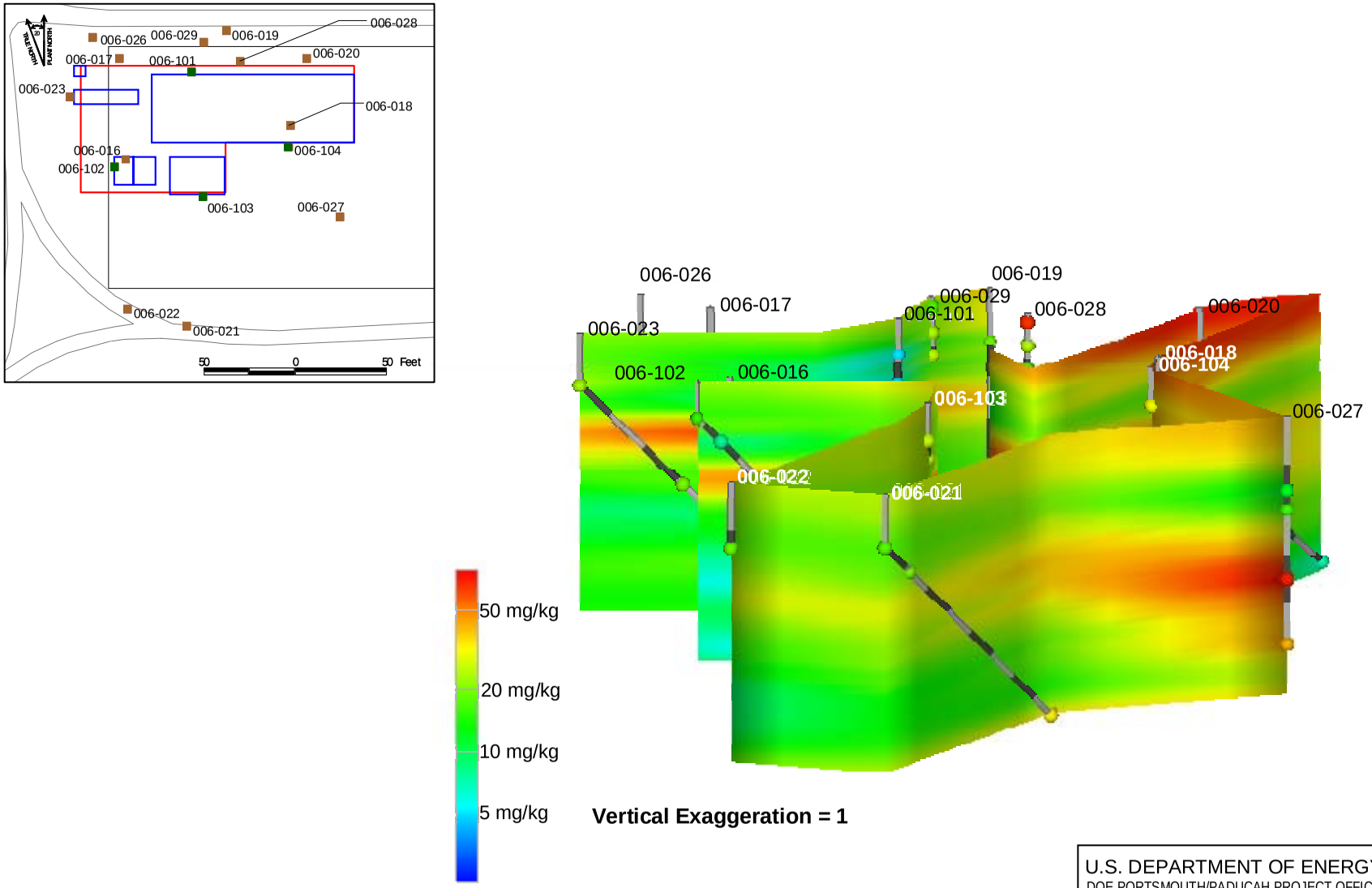

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Figure 4.55. SWMU 6 Vanadium in Soil (Looking North)

Table 4.29. SWMU 6 Locations of Subsurface Soil Contaminants

		RI Data				Historical Data											
Analysis	**Depth (ft)**	006-101	006-102	006-103	006-104	006-016	006-017	006-018	006-019	006-020	006-021	006-022	006-023	006-026	006-027	006-028	006-029
Inorganics (mg/kg)																	
Beryllium	5															2.62	ND
	10-15	ND	ND	ND	ND	ND	ND	1.32	ND	ND	ND	0.5	0.56	0.59		0.64	0.59
	15-20	ND	ND	ND	ND					ND	0.52	0.67		ND	ND	ND	0.7
	20-25					0.74	1.51	1.17					0.59	1	ND		
	30-35	ND	ND	ND	ND	ND			0.81	0.88			ND	ND	1.7	0.6	
	40-45	0.825	ND	ND	ND				1.59	1.93	2.16	1.54	1.49				
	50-55									1.66	ND		1.15	2.01	3.07		
	60	ND	ND	ND	ND						ND	0.67					
Iron	5															54,200	10,700
	10-15	8,830	14,500	9,660	10,400	10,500	9,280	35,300	10,800	10,700	9,210	9,140	9,880	10,800		10,700	11,800
	15-20	8,630	8,100	8,260	7,070					7,520	10,000	11,500		6,270	4,160	7,690	11,600
	20-25					24,800	58,700	33,700					11,500	20,200	9,200		
	30-35	11,700	14,100	17,200	19,100	3,720			18,200	17,300			7,460	5,170	22,200	16,800	
	40-45	16,900	4,850	5,910	4,260				20,800	26,700	29,900	23,000	20,100				
	50-55									22,200	5,010		17,300	32,900	36,900		
	60	ND	ND	ND	ND						5,140	1,180					
Manganese	5															353	349
	10-15	150	216	282	309	106	207	411	1,550	230	164	222	165	93.4		79.3	143
	10-15	126	288	152	151					184	100	81		92.1	108	157	174
	20-25					167	191	333					281	117	62.4		
	30-35	103	57.1	19.7	27.1				80.1	119			59.7			63.2	
	35-40					39.7								22.7	60.1		
	40-45	59.2	35.6	150	60.5				433	602	162	96	398				
	50-55									102	144		130	442	64.3		
	60	315	132	98.6	149						183	66.4					

Table 4.29. SWMU 6 Locations of Subsurface Soil Contaminants (Continued)

		RI Data				Historical Data											
Analysis	**Depth (ft)**	006-101	006-102	006-103	006-104	006-016	006-017	006-018	006-019	006-020	006-021	006-022	006-023	006-026	006-027	006-028	006-029
Vanadium	5															65.6	17.9
	10-15	5.1	16	26.5	30.9	22.5	19.1	52.7	19.8	22.6	18.1	18.9	23.8	21.6		25	24.4
	15-20	5.54	7.97	26	25.5					17.8	20.2	29.1		11.4	11.9	15.5	25
	20-25					46.6	79.1	64.7					20.1	49.1	16.6		
	30-35	11.4	13.5	35.1	33.8				33	32.9			13.9			31.6	
	35-40					10.7								10	71.1		
	40-45	5.58	6.58	26.4	19.1				23.1	42.8	33.6	23.4	19.2				
	50-55									27.3	6.26		18.8	30.6	42.5		
	60	ND	5.03	38.5	7.29						5.42	13.4					

ND = not detected above screening levels

Blank cells indicate interval was not sampled for the specified analysis. Maximum value shown for each depth interval.

4.7.2 SWMU 6 Groundwater

UCRS groundwater samples were collected from all of the four angled borings installed at SWMU 6 as part of this RI. The WAG 3 RI sampled UCRS groundwater from 15 borings at SWMU 6 (DOE 2000a). RI data were reviewed with historical data (primarily from the WAG 3 RI) to determine the contaminants listed in Table 4.30.

Table 4.30. SWMU 6 UCRS Groundwater Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection	
	Historical Data	RI Data		above MCL	above Child Resident NAL
Inorganics (mg/L)					
Arsenic	0.014	0.15	9/12	3/12	9/12
Beryllium	0.09	0.0929	6/25	6/25	6/25
Cadmium	0.039	0.0288	5/21	3/21	5/21
Chromium	3	3.32	12/39	11/39	2/39
Iron	2640	2110	35/41	N/A[b]	33/41
Iron, Dissolved	N/A	61.1	2/2	N/A	2/2
Lead	2.03	2.02	7/7	5/7	5/7
Manganese	93	170	38/41	N/A	38/41
Mercury	0.003	0.00279	7/25	2/25	4/25
Molybdenum	N/A	0.359	4/4	N/A	4/4
Nickel	0.69	0.953	12/33	N/A	12/33
Uranium	N/A	0.315	3/4	2/4	3/4
Vanadium	3.34	N/A	11/39	N/A	11/39
Zinc	4.16	10.8	17/37	N/A	11/37
Organics-Pesticides and PCBs (mg/L)					
PCB-1016	0.255	N/A	2/12	2/12	2/12
Radionuclides (pCi/L)					
Neptunium-237	219	N/A	1/14	1/14	1/14
Technetium-99	2920	310	16/18	6/18	16/18
Uranium-234	754	24	3/5	N/A	3/5
Uranium-238	1520	21.8	4/5	N/A	4/5

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

The SWMU 6 disposal pits are approximately 6 to 8 ft deep. Two temporary borings of the WAG 3 RI (006-011 and 006-012) provided groundwater samples from directly below the pits, from depths of 9–12 ft within the area of Pit J (used for contaminated aluminum scrap disposal). Metals, notably iron, and the radionuclides neptunium-237, technetium-99, uranium-234, and uranium-238 exceeded screening criteria. Samples from both borings contained PCB-1016, at levels of 0.05 to 0.26 mg/L. These were the only occurrences of organic contaminants at levels that exceed screening criteria in the UCRS groundwater samples from SWMU 6. UCRS groundwater samples from the locations 006-101, which angled beneath "Pit J," and 006-029, which sampled directly north of "Pit J," contained the highest levels of beryllium, cadmium, iron, lead, manganese, and mercury.

The HU2 interval of the UCRS occurs at approximate depths of 20 to 30 ft beneath SWMU 6. Groundwater samples from borings 006-017, 006-018, 006-025, 006-029, and 006-104 characterized contaminant levels in the HU2 interval. As discussed above, metals exceeded screening criteria with

notably elevated levels of iron. The radionuclides technetium-99, uranium-234, and uranium-238 also exceeded screening criteria. These same contaminant trends persist through the HU3 interval. Ten temporary borings sampled groundwater in the HU3 interval: 006-019, 006-020, 006-021, 006-022, 006-023, and 006-028. (See Figure 4.13 for the location of these borings.)

RGA and McNairy groundwater samples were not collected at SWMU 6 as part of this RI; however, historical data were reviewed to identify the contaminants listed in Table 4.31. (The screen of analyses of McNairy groundwater samples from SWMU 6 determined that no groundwater contaminants are present.) RGA and McNairy groundwater samples were collected from the locations 006-025, north of the SWMU, and 006-024, located to the southeast. For those metals detected above screening levels in the RGA (all but manganese) and for TCE (the lone organic contaminant), the higher contaminant levels represent samples from 006-025. Iron and manganese continued to be the most common metals to exceed screening levels. TCE levels were greater than its MCL in nearly all RGA samples. The presence of TCE is due to the Northwest Plume; the west side of the plume passes beneath SWMU 6 (Figure 4.53). Boring 006-025 is located closer to the center of the Northwest Plume than boring 006-024.

Table 4.31. SWMU 6 RGA Groundwater Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection		
	Historical Data	RI Data		Above Back-ground	Above MCL	Above Child Resident NAL
Inorganics (mg/L)						
Arsenic	0.013	N/A[b]	3/3	1/3	1/3	3/3
Beryllium	0.029	N/A	3/21	3/21	3/21	3/21
Cadmium	0.015	N/A	2/19	2/19	2/19	2/19
Iron	2210	N/A	35/42	15/42	N/A	30/42
Lead	0.788	N/A	1/1	1/1	1/1	1/1
Manganese	27.1	N/A	42/42	42/42	N/A	42/42
Vanadium	1.24	N/A	1/18	1/18	N/A	1/18
Organics – Volatiles (mg/L)						
TCE	0.74	N/A	18/18	N/A	15/18	16/18

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

Table 4.32 provides detail (depth, sample location, and analytical results) for SWMU 6 groundwater samples, including nondetects and detections above screening levels.

Table 4.32. SWMU 6 Locations of Groundwater Contaminants

			Historical Data														RI Data			
Unit	Depth (ft)	Analysis	006-009	006-011	006-012	006-016	006-017	006-018	006-019	006-020	006-021	006-022	006-023	006-024	006-025	006-028	006-029	006-101	006-102	006-103	006-104
UCRS	9-12	***Inorganics (mg/L)***																			
		Arsenic			0.005																
		Beryllium		ND	ND																
		Cadmium		ND	ND																
		Chromium		ND	ND																
		Iron		17.6	65.3																
		Manganese		0.43	1.98																
		Mercury		ND	ND																
		Nickel		ND	0.061																
		Vanadium		ND	0.137																
		Zinc		ND	ND																
		Organics-Pesticides and PCBs (mg/L)																			
		PCB-1016		0.255	0.053																
		Radionuclides (pCi/L)																			
		Neptunium-237		219	ND																
		Technetium-99		1810	2920																
		Uranium-234		754																	
		Uranium-238		1520																	
	21-22	***Inorganics (mg/L)***																			
		Arsenic															0.005				
		Beryllium					ND										0.09				
		Cadmium					ND										0.039				
		Chromium					ND										3				
		Iron					0.869										2640				
		Lead															2.03				
		Manganese					1.54										93				
		Mercury					ND										0.003				
		Nickel					ND										ND				
		Vanadium					ND										3.34				
		Zinc					ND										4.16				
		Radionuclides (pCi/L)																			
		Technetium-99	ND														16				
	27-30	***Inorganics (mg/L)***																			
		Arsenic																			
		Beryllium						0.024							0.013						0.0225
		Cadmium						0.015							ND						0.00406
		Chromium						0.678							0.277						3.32
		Iron						652							300						732
		Iron, Dissolved																			25.7
		Lead						0.417							0.204						0.427
		Manganese						14.4							8.68						20.9
		Mercury						0.002							ND						0.000755

Table 4.32. SWMU 6 Locations of Groundwater Contaminants (Continued)

			Historical Data														RI Data			
Unit	Depth (ft)	Analysis	006-009	006-011	006-012	006-016	006-017	006-018	006-019	006-020	006-021	006-022	006-023	006-024	006-025	006-028	006-029	006-101	006-102	006-103	006-104
UCRS	27-30	***Inorganics (mg/L)***																			
		Molybdenum																			0.359
		Nickel						0.05							ND						0.953
		Uranium																			0.0438
		Vanadium						1.02							0.563						ND
		Zinc						1.02							0.536						9.19
		Organics-Pesticides and PCBs (mg/L)																			
		PCB-1016																			ND
		Radionuclides (pCi/L)																			
		Neptunium-237						ND													ND
		Technetium-99						55							ND						17.3
		Uranium-234																			5.53
		Uranium-238																			5.76
	35-37	***Inorganics (mg/L)***																			
		Beryllium				ND															
		Cadmium				ND															
		Chromium				0.125															
		Iron				78.4															
		Manganese				2.02															
		Mercury				ND															
		Nickel				0.052															
		Vanadium				0.162															
		Zinc				ND															
		Radionuclides (pCi/L)																			
		Neptunium-237				ND															
		Technetium-99				690										930					
	45-46	***Inorganics (mg/L)***																			
		Arsenic																ND	ND	ND	
		Beryllium																0.0929	ND	ND	
		Cadmium																0.0288	ND	0.000837	
		Chromium																ND	ND	ND	
		Iron																2110	124	62.2	
		Iron, Dissolved																	61.1		
		Lead																2.02	ND	ND	
		Manganese																170	4.35	1.89	
		Mercury																0.00279	ND	ND	
		Molybdenum																0.0231	0.182	0.0703	
		Nickel																ND	0.14	0.0523	
		Uranium																0.315	ND	0.00275	
		Vanadium																ND	ND	ND	
		Zinc																10.8	0.812	0.497	

Table 4.32. SWMU 6 Locations of Groundwater Contaminants (Continued)

			Historical Data														RI Data			
Unit	Depth (ft)	Analysis	006-009	006-011	006-012	006-016	006-017	006-018	006-019	006-020	006-021	006-022	006-023	006-024	006-025	006-028	006-029	006-101	006-102	006-103	006-104
UCRS	45-46	***Organics-Pesticides and PCBs (mg/L)***																			
		PCB-1016																ND	ND	ND	
		Radionuclides (pCi/L)																			
		Neptunium-237																ND	ND	ND	
		Technetium-99																310	113	104	
		Uranium-234																24	ND	ND	
		Uranium-238																21.8	ND	0.558	
	60-61	***Inorganics (mg/L)***																			
		Arsenic							0.006		0.006	0.013									
		Beryllium							ND	ND	ND	0.015	ND								
		Cadmium							ND	ND	ND	ND	ND								
		Chromium							0.649	0.586	1.07	1.67	0.514								
		Iron							74.4	92.5	158	389	126								
		Manganese							2.04	1.84	1.33	9.56	1.88								
		Mercury							ND	ND	ND	ND	ND								
		Nickel							0.32	0.368	0.38	0.69	0.243								
		Vanadium							0.068	0.103	0.076	0.348	0.17								
		Zinc							ND	ND	0.611	1.14	0.463								
		Organics-Pesticides and PCBs (mg/L)																			
		PCB-1016							ND	ND	ND	ND	ND								
		Radionuclides (pCi/L)																			
		Neptunium-237							ND	ND	ND	ND	ND								
		Technetium-99							983	255	956	46.8	823								
RGA	68-68	***Inorganics (mg/L)***																			
		Beryllium												ND	0.006						
		Cadmium												ND	ND						
		Iron												63.8	88.8						
		Manganese												5.58	4.25						
		Vanadium												ND	ND						
		Organics-Volatiles (mg/L)																			
		TCE												0.006	ND						
	73-73	***Inorganics (mg/L)***																			
		Beryllium												ND	ND						
		Cadmium												ND	ND						
		Iron												78.1	14.4						
		Manganese												9.36	1.24						
		Vanadium												ND	ND						
		Organics-Volatiles (mg/L)																			
		TCE												0.005	0.01						

Table 4.32. SWMU 6 Locations of Groundwater Contaminants (Continued)

			Historical Data														RI Data			
Unit	Depth (ft)	Analysis	006-009	006-011	006-012	006-016	006-017	006-018	006-019	006-020	006-021	006-022	006-023	006-024	006-025	006-028	006-029	006-101	006-102	006-103	006-104
RGA	77-78	***Inorganics (mg/L)***																			
		Beryllium												ND	ND						
		Cadmium												ND	ND						
		Iron												9.28	144						
		Manganese												4.49	11.6						
		Vanadium												ND	ND						
		Organics-Volatiles (mg/L)																			
		TCE												0.006	0.015						
	82-83	***Inorganics (mg/L)***																			
		Arsenic													0.005						
		Beryllium												ND	ND						
		Cadmium												ND	ND						
		Iron												52.7	46.6						
		Manganese												5.58	2.72						
		Vanadium												ND	ND						
		Organics-Volatiles (mg/L)																			
		TCE												0.019	0.031						
	88-88	***Inorganics (mg/L)***																			
		Arsenic													0.005						
		Beryllium												ND	ND						
		Cadmium												ND	ND						
		Iron												139	77.8						
		Manganese												15.6	4.4						
		Vanadium												ND	ND						
		Organics-Volatiles (mg/L)																			
		TCE												0.029	0.06						
	93-93	***Inorganics (mg/L)***																			
		Beryllium												0.006	ND						
		Cadmium												0.011	ND						
		Iron												245	112						
		Manganese												27.1	11.1						
		Vanadium												ND	ND						
		Organics-Volatiles (mg/L)																			
		TCE												0.1	0.17						
	98-98	***Inorganics (mg/L)***																			
		Beryllium												ND	ND						
		Cadmium												ND	ND						
		Iron												52.4	71.9						
		Manganese												0.433	1.93						
		Vanadium												ND	ND						
		Organics-Volatiles (mg/L)																			
		TCE												0.27	0.74						

Table 4.32. SWMU 6 Locations of Groundwater Contaminants (Continued)

			Historical Data														RI Data			
Unit	Depth (ft)	Analysis	006-009	006-011	006-012	006-016	006-017	006-018	006-019	006-020	006-021	006-022	006-023	006-024	006-025	006-028	006-029	006-101	006-102	006-103	006-104
RGA	103	***Inorganics (mg/L)***																			
		Arsenic													0.013						
		Beryllium													0.029						
		Cadmium													0.015						
		Iron													2210						
		Lead													0.788						
		Manganese													14.5						
		Vanadium													1.24						
		Organics-Volatiles (mg/L)																			
		TCE													0.01						

ND = not detected above screening levels

Blank cells indicate interval was not sampled for the specified analysis. The maximum value is shown for each depth interval at each location.

4.8 SWMU 7

4.8.1 Subsurface Soils

SWMU 7 consists of six discrete burial pit areas containing uranium-contaminated concrete, uranium-contaminated scrap metal and equipment, and empty uranium and magnesium powder drums. The SWMU 7 burial pits range from 6 to 10 ft deep.

Table 4.33 summarizes the contaminants detected in the subsurface at SWMU 7.

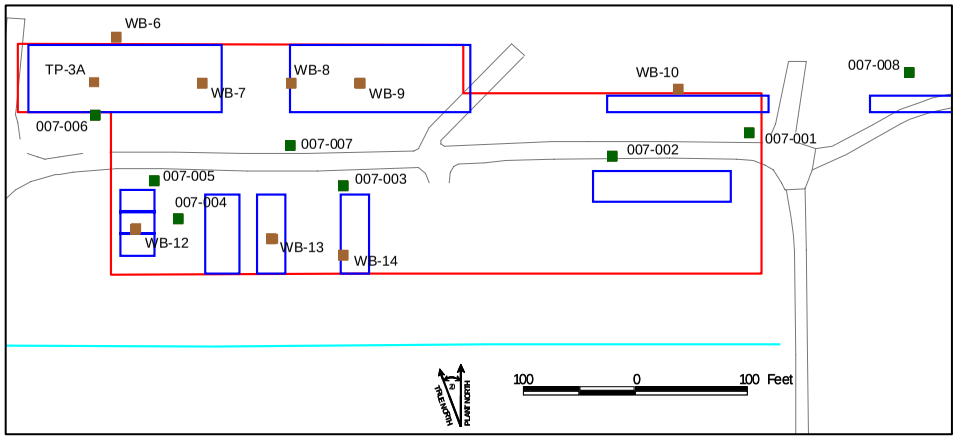
Table 4.33. SWMU 7 Subsurface Soil Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection	
	Historical Data	RI Data		Above Background Value	Above Excavation Worker NAL
Inorganics (mg/kg)					
Arsenic	N/A[b]	13.9	50/69	1/69	50/69
Beryllium	N/A	1.55	7/69	3/69	1/69
Iron	17,000	34,700	69/69	1/69	65/69
Manganese	1,200	628	69/69	1/69	44/69
Uranium	45	8.94	12/69	3/69	1/69
Organics –PCBs (mg/kg)					
Total PCBs	0.41	2.45	5/69	N/A	2/69
PCB-1248	0.41	N/A	1/69	N/A	1/69
PCB-1260	N/A	2.45	1/69	N/A	1/69
Organics – Volatiles (mg/kg)					
1,1-DCE	N/A	1.66	4/69	N/A	2/69
Vinyl chloride	N/A	0.585	5/69	N/A	1/69
Radionuclides (pCi/g)					
Thorium-230	3.7	1.34	39/67	3/67	2/67
Uranium	240	6.87	14/68	N/A	4/68
Uranium-234	115	1.34	41/76	10/76	3/76
Uranium-235/236	1.03	N/A	8/8	6/8	3/8
Uranium-238	150	5.87	35/76	22/76	18/76

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

Metals concentrations in subsurface soil samples of SWMU 7 rarely exceed background levels. Uranium metal has been detected above background levels only at three locations (WB-9, 007-009, and 007-010). These locations characterize burial pits B and C, which contained uranium-contaminated noncombustible trash. The highest concentration of uranium at these locations is 45 mg/kg. This level is greater than five times the next highest level of 8.94 mg/kg. Figure 4.56 shows the uranium distribution at SWMU 7 and indicates that the extent of contamination is limited to shallow soil depths (5 to 10 ft bgs).

The screening process identified two VOCs as contaminants at SWMU 7: vinyl chloride and 1,1-DCE. Both were detected infrequently (1 and 2 detections in 69 analyses, respectively) at levels above the excavation worker NALs. Figure 4.57 presents the vinyl chloride distribution in subsurface soils. The elevated levels of vinyl chloride occur in a small area in the central portion of SWMU 7 near burial pit C. It was detected at approximately four times the NAL screening concentration in boring 007-007 at a depth of 30 ft. Uranium-238 is the most widely detected radionuclide contaminant above PGDP background levels in subsurface soils at SWMU 7; the maximum uranium-238 result is 150 pCi/g from WBP-12A.



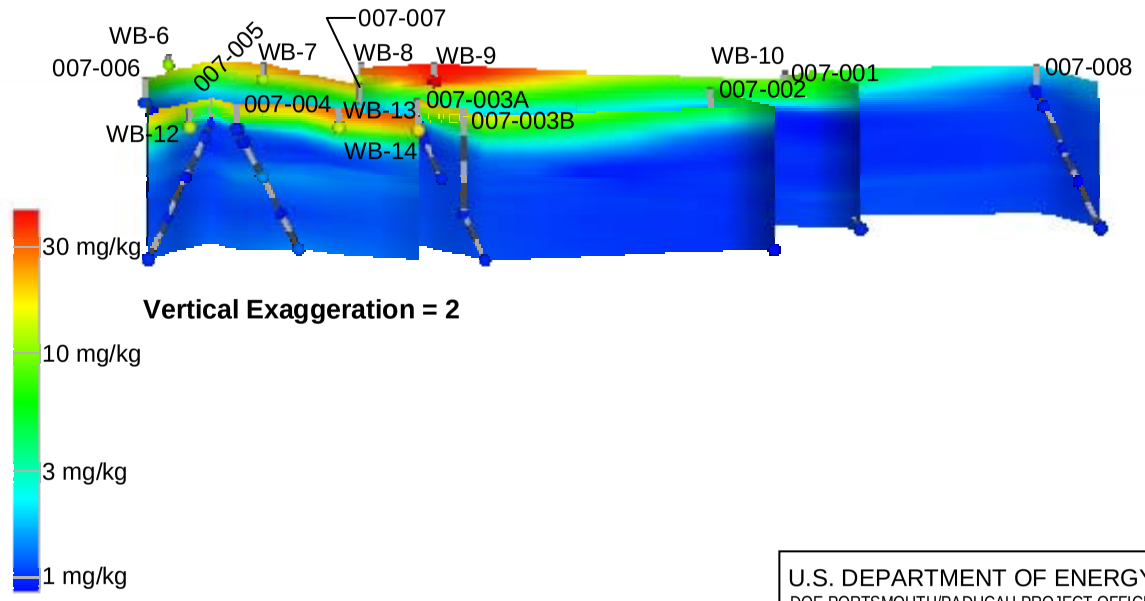


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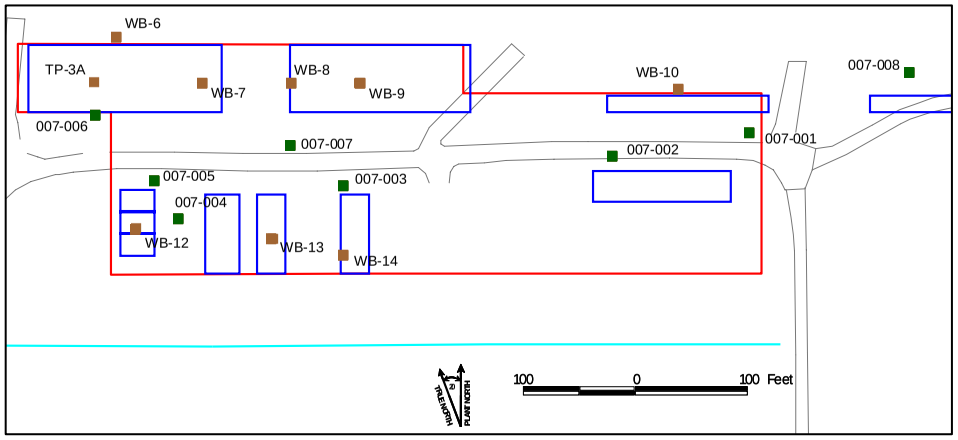
Figure 4.56. SWMU 7 Uranium in Soil (Looking North)



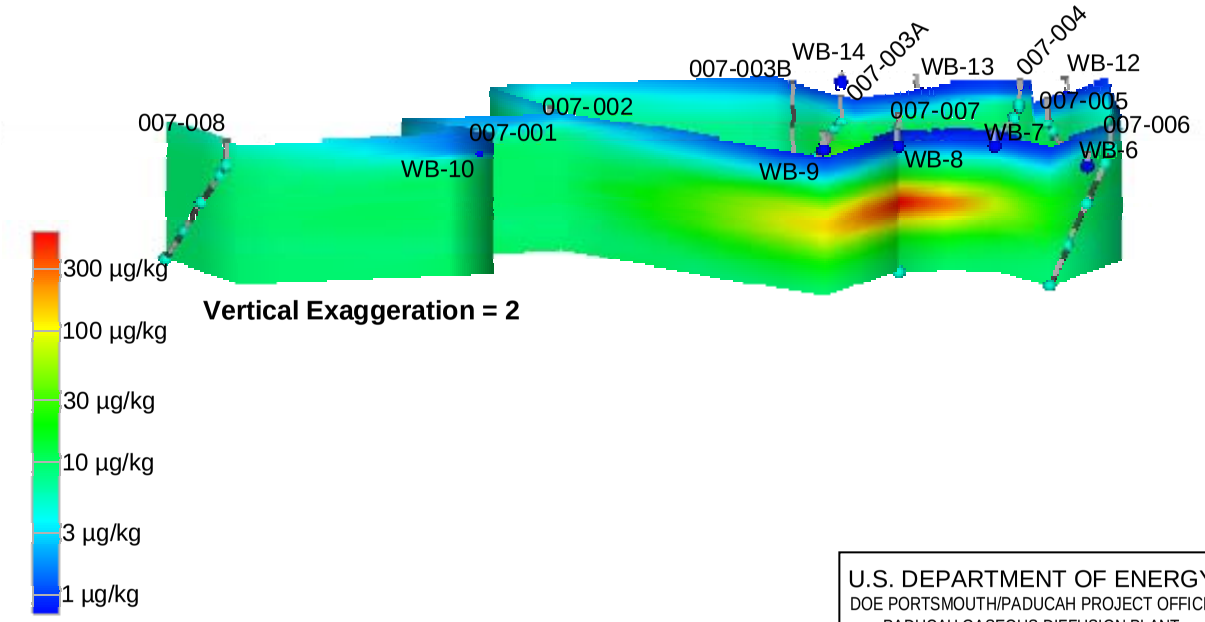


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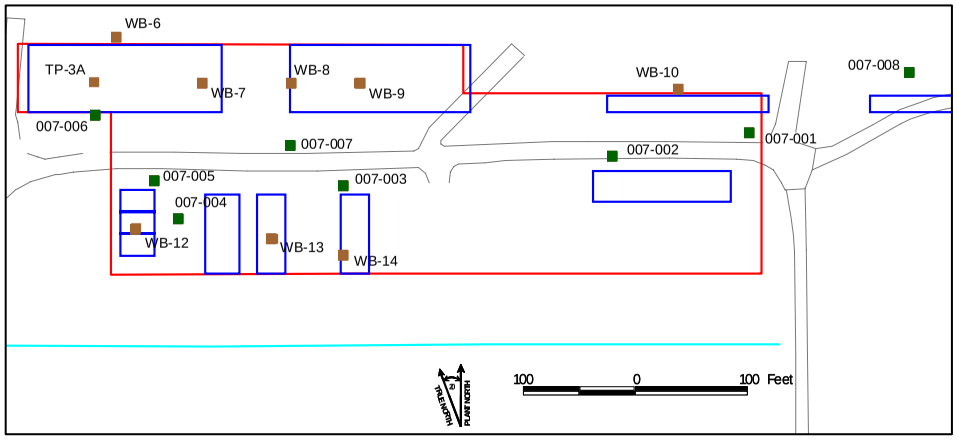
Figure 4.57. SWMU 7 Vinyl Chloride in Soil (Looking South)

Total Uranium was detected as high as 240 pCi/g from WBP-9A. Figure 4.58 provides the uranium-238 distribution in soils at SWMU 7. As expected, it is very similar to the uranium distribution presented in Figure 4.56, with most exceedances limited to depths less than 15 ft bgs. Subsurface soil samples for Pit E (located outside of the SWMU 7 boundary) at 10 ft depth contained arsenic concentrations in excess of screening levels. None of the other Pit E analyses documented metals or radionuclides above screening levels or the presence of any organic contaminants. Two test pits were excavated in SWMU 7 during the Phase II SI (CH2M HILL 1992). The excavations noted oily sheens on material being excavated and six drums were removed from one of the test pits. Samples from these pits identified many of the same inorganic, organic, and radionuclide contaminants reported in Table 4.33.

Table 4.34 presents the locations of subsurface contaminants detected above screening levels.



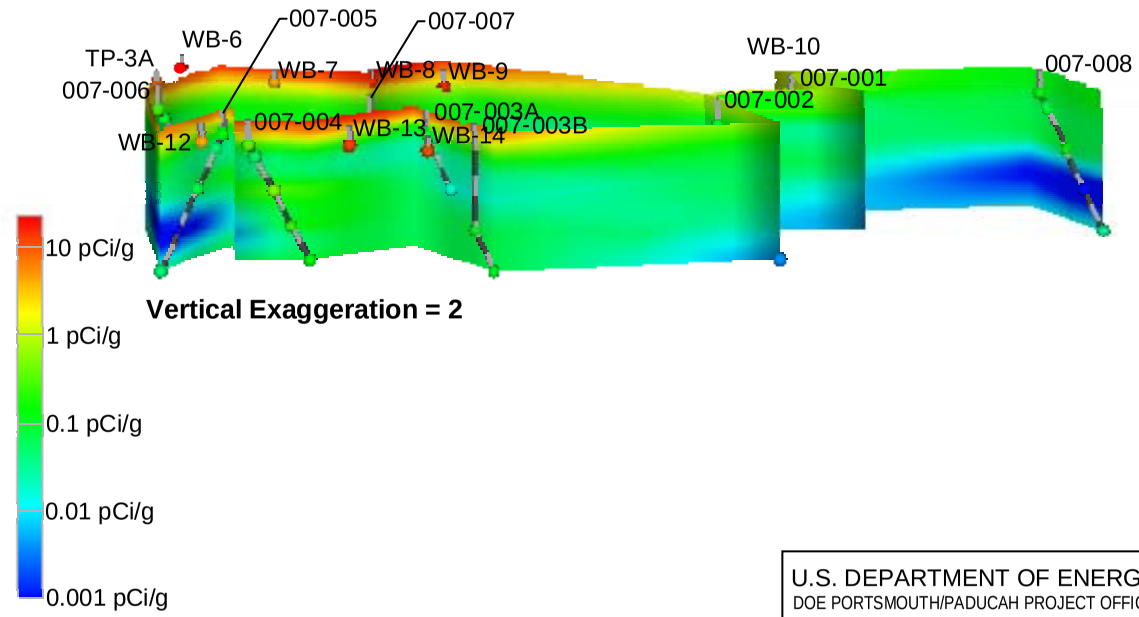


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Figure 4.58. SWMU 7 ^{238}U in Soil (Looking North)

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Table 4.34. SWMU 7 Locations of Subsurface Soil Contaminants

		RI Data												Historical Data										
Analysis	**Depth (ft)**	007-001	007-002	007-003A	007-003B	007-004	007-005	007-006	007-007	007-008	007-009	007-010	007-011	TP-3A	WB-10	WB-12	WB-13	WB-14	WB-6	WB-7	WB-8	WB-9	WBP-12A	WBP-13A	WBP-9A
Inorganics (mg/kg)																									
Arsenic	5-10										7.88	3.47	1.66		ND	ND	ND	ND	ND	ND	ND	ND			
	10	3.3	2.74	2.28		2.18	3.63	4.48	3.36	3.8	ND	1.32	2.68												
	15	1.45	6.22	1.85		1.75	1.1	2.44	1.4	ND	1.22	1.35	1.59												
	30	0.917	2.5	1.18		4.57	ND	1.62	1.1	2.76	1.41	1.66	1.37												
	45	0.973	ND		1.24	1.1	ND	ND	1.02	ND	1.06	2.99	ND												
	60	ND	13.9		5.19	2.88	1.59	1.9	1.25	ND	1.99	1.49	2.44												
Beryllium	5-10										ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND			
	10	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND												
	15	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND												
	30	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND												
	45	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND												
	60	ND	1.55		1	0.978	ND	0.588	0.512	ND	0.629	ND	0.542												
Iron	5-10										26000	8180	6580		11000	15000	14000	17000	13000	12000	14000	14000			
	10	10900	9160	9170		8440	11900	13700	12300	9130	6890	9210	12300												
	15	9090	11900	8960		8260	9020	10700	7420	5360	7270	7180	9320												
	30	4080	10500	7820		17600	3790	8440	7430	9950	7580	8890	8550												
	45	1900	1670		5650	10200	2320	3660	3950	1050	7110	20600	1440												
	60	4280	34700		20500	19600	11000	12600	13500	2500	12900	6730	17600												
Manganese	5-10										234	218	197		380	470	380	1200	390	280	630	320			
	10	371	181	292		205	172	192	327	277	104	225	192												
	15	254	256	93.7		80.2	38.1	71.4	56.1	66.9	49.1	52.4	89.2												
	30	25.6	25.8	104		212	38.6	34.7	12.2	11.1	20.7	129	152												
	45	20.4	4.88		27.2	60.7	31.2	34.7	29.5	5.53	14.2	44.1	45.9												
	60	40	237		88.2	75.6	103	628	196	15.2	107	54.8	235												
Uranium	5-10										8.94	7.56	3.86		ND	ND	ND	ND	ND	ND	ND	45			
	10	ND	ND	ND		ND	ND	1.08	2.22	ND	ND	ND	0.962												
	15	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND												
	30	ND	ND	ND		1.45	ND	ND	ND	ND	ND	1.15	ND												
	45	ND	ND		ND	ND	ND	ND	ND	ND	ND	1.3	ND												
	60	ND	ND		ND	1.23	ND	0.989	ND	ND	ND	ND	ND												
Organics –PCBs (mg/kg)																									
PCB, Total	5-10										2.45	ND	ND		ND	0.41	ND	ND	ND	0.0091	0.032	0.054			
	10	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND												
	15	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND												
	30	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND												
	45	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND												
	60	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND												
PCB-1248	5-10										ND	ND	ND		ND	0.41	ND	ND	ND	ND	ND	ND			
	10	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND												
	15	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND												
	30	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND												
	45	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND												
	60	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND												

Table 4.34. SWMU 7 Locations of Subsurface Soil Contaminants (Continued)

		RI Data												Historical Data										
Analysis	**Depth (ft)**	007-001	007-002	007-003A	007-003B	007-004	007-005	007-006	007-007	007-008	007-009	007-010	007-011	TP-3A	WB-10	WB-12	WB-13	WB-14	WB-6	WB-7	WB-8	WB-9	WBP-12A	WBP-13A	WBP-9A
PCB-1260	5-10										2.45	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND			
	10	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND												
	15	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND												
	30	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND												
	45	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND												
	60	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND												
Organics – Volatiles (mg/kg)																									
1,1-DCE	5-10										ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND			
	10	ND	1.11	ND		ND	ND	ND	ND	ND	ND	ND	ND												
	15	ND	1.66	ND		ND	ND	ND	ND	ND	ND	ND	ND												
	30	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND												
	45	ND	0.00649		ND	ND	ND	ND	ND	ND	ND	ND	ND												
	60	ND	0.00552		ND	ND	ND	ND	ND	ND	ND	ND	ND												
Vinyl chloride	5-10										ND	0.00546	ND		ND	ND	ND	ND	ND	ND	ND	ND			
	10	ND	ND	ND		ND	ND	ND	ND	ND	ND	0.0075	ND												
	15	ND	ND	ND		ND	ND	ND	ND	ND	ND	0.00699	ND												
	30	ND	ND	ND		ND	ND	ND	0.585	ND	ND	0.0351	ND												
	45	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND												
	60	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND												
Radionuclides (pCi/g)																									
Thorium-230	5-10										1.34	0.211	0.376		1.26	1.11	1.19	1.46	1.22	1.01	3.7	3.03			
	10	0.442	0.521	ND		ND	0.294	0.471	0.351	0.446	0.462	0.487	0.359												
	12-15	0.284	0.375	ND		ND	ND	ND	ND	0.369	0.232	0.33	0.299												
	30	ND	0.278	ND		ND	ND	ND	0.24	0.252	ND	0.241	0.182												
	45	ND	ND		ND	0.299	ND	0.27	ND	ND	ND	0.267	ND												
	60		ND		ND	ND	ND	0.555	ND	ND	0.239	ND	0.142												
Uranium	5-10										3.76	6.87	3.98	15									192	2.7	
	10	ND	ND	ND		ND	ND	ND	ND	ND	ND	2.21	ND	4.9											240
	12-15	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	2.6											
	30	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND												
	45	ND	ND		ND	ND	ND	0.497	ND	ND	ND	ND	ND												
	60		ND		ND	ND	ND	ND	ND	ND	ND	ND	ND												
Uranium-234	5-10										1.34	0.903	1.2	6.7	1.21	1.85	2.59	3.34	10.8	2.7	12.3	13.2	39.4	0.9	
	10	0.148	ND	0.193		0.219	ND	0.212	0.182	0.142	0.304	0.319	ND	2.3											115
	12-15	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	1.1											
	30	ND	0.14	0.18		0.258	ND	ND	0.245	0.206	ND	ND	ND												
	45	ND	ND		0.201	0.395	ND	0.239	ND	ND	ND	0.327	ND												
	60		ND		0.326	0.219	ND	0.26	ND	0.173	ND	ND	ND												
Uranium-235/236	6-7														0.07	0.12	0.34	0.35	0.86	0.17	0.88	1.03			
Uranium-238	5-10										2.36	5.87	2.66	8.4	2.02	4.07	12.3	10.8	23.2	4.01	15.4	15.2	150	1.8	
	10	0.147	ND	ND		0.335	ND	0.28	0.341	ND	0.719	1.84	0.262	2.4											119
	12-15	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	0.181	1.4											
	30	ND	ND	ND		0.499	ND	ND	0.217	ND	ND	0.251	ND												
	45	ND	ND		ND	0.225	ND	0.233	ND	ND	ND	1.34	ND												
	60		ND		ND	ND	ND	0.197	ND	ND	ND	ND	ND												

ND = not detected above screening levels

Blank cells indicate interval was not sampled for the specified analysis. The maximum value is shown for each depth interval at each location.

4.8.2 SWMU 7 Groundwater

The SWMU 7 waste pits containing various uranium-contaminated wastes are 8 to 15 ft deep. Seven temporary soil borings sampled groundwater from within and immediately below the waste pits: WB-7, WB-8, WB-9, WBP-9A, WB-12, WBP-12A, and WB-13. Several metals, the uranium isotopes, and vinyl chloride were the primary contaminants that exceeded screening levels in these samples. These same contaminants were common throughout the thickness of the UCRS.

UCRS groundwater samples were collected from six of eight angled borings and three deep vertical borings installed at SWMU 7 as part of this RI. Several sources of historical UCRS groundwater data were available for SWMU 7, as follows:

- Wells MW186 and MW187 (with a period of record for 1995 through 2007);
- Temporary borings GW-01, GW-02, GW-03, WB-7, WB-8, WB-9, WB-12, and WB-13 of the SWMUs 7 and 30 RI (DOE 1998a);
- Temporary borings WBP-9A and WBP-12A from a 1998 follow-up investigation of some SWMU 7 waste pits; and
- Temporary boring DG-005 of the sitewide remedial evaluation for source areas (DOE 2000b).

RI data were reviewed with historical data to determine the UCRS contaminants listed in Table 4.35. Screening identified nine metals in UCRS groundwater samples from SWMU 7 at levels that exceed MCLs. Arsenic, iron, uranium, and manganese were the most frequently detected metals.

Organic contaminants in UCRS groundwater at SWMU 7 consisted of five VOCs. TCE and its reductive dechlorination products, *cis*-12-DCE and vinyl chloride, were the most frequently detected organic contaminants. The radionuclide contaminants present in the SWMU 7 UCRS groundwater samples were radon-222 and the uranium isotopes uranium-234 and uranium-238.

The HU2 interval is relatively thin beneath SWMU 7, at approximate depths of 20 to 25-to-30 ft bgs. Seven temporary soil borings: 007-007, 007-010, 007-011, DG-005, GW-01, GW-02, and GW-03, and wells MW186 and MW187 provided groundwater samples from these depths. In addition to the radionuclides in the vicinity of the waste pits, significant levels of radon-222 were present. Organic contaminants from the HU2 interval included TCE, *cis*-1,2-DCE, and vinyl chloride. This corresponds to the soil contamination found in boring 007-007 near burial pit C. The relatively high level of the TCE degradation products, compared to TCE levels in this interval, is unusual at PGDP. It has been assumed, based on dissolved oxygen levels in a nearby shallow MW, that anaerobic degradation of TCE has occurred and still may occur within the UCRS. MW186, a nearby UCRS MW, has shown similar levels of TCE and *cis*-1,2-DCE. Analytical data from this well (dissolved oxygen, sulfides, total organic carbon, and TCE degradation products) indicate anaerobic degradation is likely. Because of the low connectivity of the thin HU2 sands and the high vertical hydraulic gradient, groundwater flow from this unit is primarily downward to the RGA.

As discussed in Section 3.9.4, MW66 is an upper RGA well located between burial pits A and B of SWMUs 30 and 7, respectively. The analyses of groundwater samples from MW66 reveal abrupt rises or spikes of dissolved TCE (Figure 3.29) that correlate to periods of higher hydraulic head (TCE spikes often exceed 10,000 µg/L). This spiking behavior suggests a potential UCRS DNAPL source that releases contaminant mass in response to seasonal variations (more mass being released during times of higher

Table 4.35. SWMU 7 UCRS Groundwater Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection	
	Historical Data	RI Data		Above MCL	Above Child Resident NAL
Inorganics (mg/L)					
Arsenic	0.31	0.276	20/24	16/24	20/24
Arsenic, Dissolved	0.173	0.316	14/15	7/15	6/15
Beryllium	0.039	0.0379	11/24	8/24	8/24
Cadmium	0.03	0.00695	9/24	4/24	9/24
Chromium	1.5	2.43	14/24	8/24	1/24
Copper	1.8	N/A	4/24	1/24	4/24
Iron	1200	1010	24/24	N/A[b]	22/24
Iron, Dissolved	0.41	53.4	11/15	N/A	6/15
Lead	1.1	0.694	14/17	10/17	10/17
Manganese	28	8.73	24/24	N/A	24/24
Manganese, Dissolved	0.55	2.9	15/15	N/A	6/15
Mercury	0.0028	0.00117	10/22	1/22	5/22
Molybdenum	1.4	0.429	11/17	N/A	10/17
Nickel	7.6	0.703	16/24	N/A	15/24
Nickel, Dissolved	1.2	0.0753	11/14	N/A	3/14
Uranium	83	0.239	28/117	21/117	25/117
Vanadium	1.8	1.72	8/17	N/A	7/17
Zinc	4	4.23	17/24	N/A	9/24
Organics–Semivolatiles (mg/L)					
Naphthalene	0.0042	N/A	3/16	N/A	3/16
Organics–Volatiles (mg/L)					
1,1-DCE	0.0029	0.0094	3/31	1/31	3/31
Benzene	0.0078	0.012	10/43	6/43	10/43
cis-1,2-DCE	2.9	6.5	63/101	50/101	61/101
TCE	2	12	89/100	86/100	87/100
Vinyl chloride	3.8	2.6	44/63	44/63	44/63
Radionuclides (pCi/L)					
Radon-222	801	N/A	6/7	N/A	6/7
Uranium-234	764	18.8	24/32	N/A	22/32
Uranium-238	4910	125	27/32	N/A	22/32

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

hydraulic head). If this potential DNAPL source extended deeper into the RGA, the TCE trend should not fluctuate as much as observed.

The high-TCE spikes typically are limited to years where RGA water level exceeds 324 ft amsl. In MW66, the contact of the RGA and the overlying UCRS soils occurs at an approximate elevation of 318 ft amsl. The relationship between abrupt rises in TCE levels and high RGA water levels indicates the presence of a DNAPL source zone near the boundary of SWMUs 7 and 30 at an elevation of approximately 324 ft amsl in the silt/clay horizon that overlies the RGA. The SWMUs 7 and 30 RI report (DOE 1998a) also postulated a DNAPL source near burial pit B. The volume of soil potentially contaminated with TCE DNAPL at this SWMU is estimated to be approximately 9,375 yd^3. This estimate assumes a source area that is 75 ft by 75 ft with a thickness of 45 ft (depth to top of RGA, which is 60 ft minus the estimated depth to base of waste at 15 ft). The volumetric extent of this potential DNAPL zone may be further refined for alternatives evaluation in the FS,

Five temporary soil borings of the RI: 007-001, 007-002, 007-003E, 007-008, and 007-009, sampled the HU3 interval. Metals, the uranium isotopes, and TCE and its degradation products were the primary contaminants exceeding screening levels.

RGA groundwater samples were collected from 10 ft intervals within the three deep vertical borings installed as part of this RI. Historical data for the RGA were available from MW185, MW339, MW340, and temporary soil borings DG-005, GW-01, GW-02, and GW-03. These data, together with historical data, were reviewed to identify the contaminants listed in Table 4.36.

Table 4.36. SWMU 7 RGA Groundwater Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection		
	Historical Data	RI Data		Above Back-ground	Above MCL	Above Child Resident NAL
Inorganics (mg/L)						
Arsenic	0.42	0.481	48/55	44/55	32/55	40/55
Arsenic, Dissolved	0.12	0.0436	26/30	17/30	12/30	4/30
Beryllium	0.073	0.0732	33/49	22/49	22/49	19/49
Cadmium	0.016	0.02	24/47	10/47	11/47	16/47
Chromium	2	1.46	34/47	28/47	29/47	2/47
Iron	2,200	2,460	57/57	46/57	N/A[b]	46/57
Lead	1.6	0.489	35/39	13/39	27/39	20/39
Manganese	22	72.4	57/57	43/57	N/A	43/57
Manganese, Dissolved	0.1	12.8	29/30	25/30	N/A	2/30
Molybdenum	0.33	0.0916	31/39	15/39	N/A	18/39
Nickel	1.6	1.18	37/51	9/51	N/A	28/51
Uranium	0.09	0.093	26/156	24/156	8/156	15/156
Vanadium	2.7	N/A	14/43	9/43	N/A	13/43
Zinc	9.8	4.28	33/47	32/47	N/A	18/47
Organics–Volatiles (mg/L)						
Carbon tetrachloride	0.041	N/A	7/56	N/A	5/56	7/56
Chloroform	0.012	N/A	9/54	N/A	N/A	9/54
cis-1,2-DCE	2.1	0.58	31/107	N/A	13/107	28/107
TCE	25	18	139/141	N/A	136/141	125/141
Vinyl chloride	N/A	0.3	5/66	N/A	5/66	3/66
Radionuclides (pCi/L)						
Technetium-99	5116.9	812	136/141	130/141	43/141	123/141
Uranium-234	18.6	8.71	38/69	34/69	N/A	23/69
Uranium-238	20.3	13.9	48/71	34/71	N/A	23/71

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

The data review revealed the occurrence of 12 metal contaminants in the RGA groundwater samples from SWMU 7. As in the UCRS samples, arsenic, iron, and manganese were the most frequently detected groundwater contaminants. All of the SWMU 7 RGA organic groundwater contaminants were VOCs. TCE was the dominant organic contaminant. The RGA groundwater radionuclide contaminants of SWMU 7 consist of technetium-99, uranium-234, and uranium-238. Although a potential TCE DNAPL source is believed to exist near Pit B as discussed above, the primary occurrence of VOCs and technetium-99 in the RGA is largely due to the Northwest Plume, which passes beneath SWMU 7. Figure 4.59 shows the Northwest Plume TCE that passes beneath SWMUs 7 and 30.

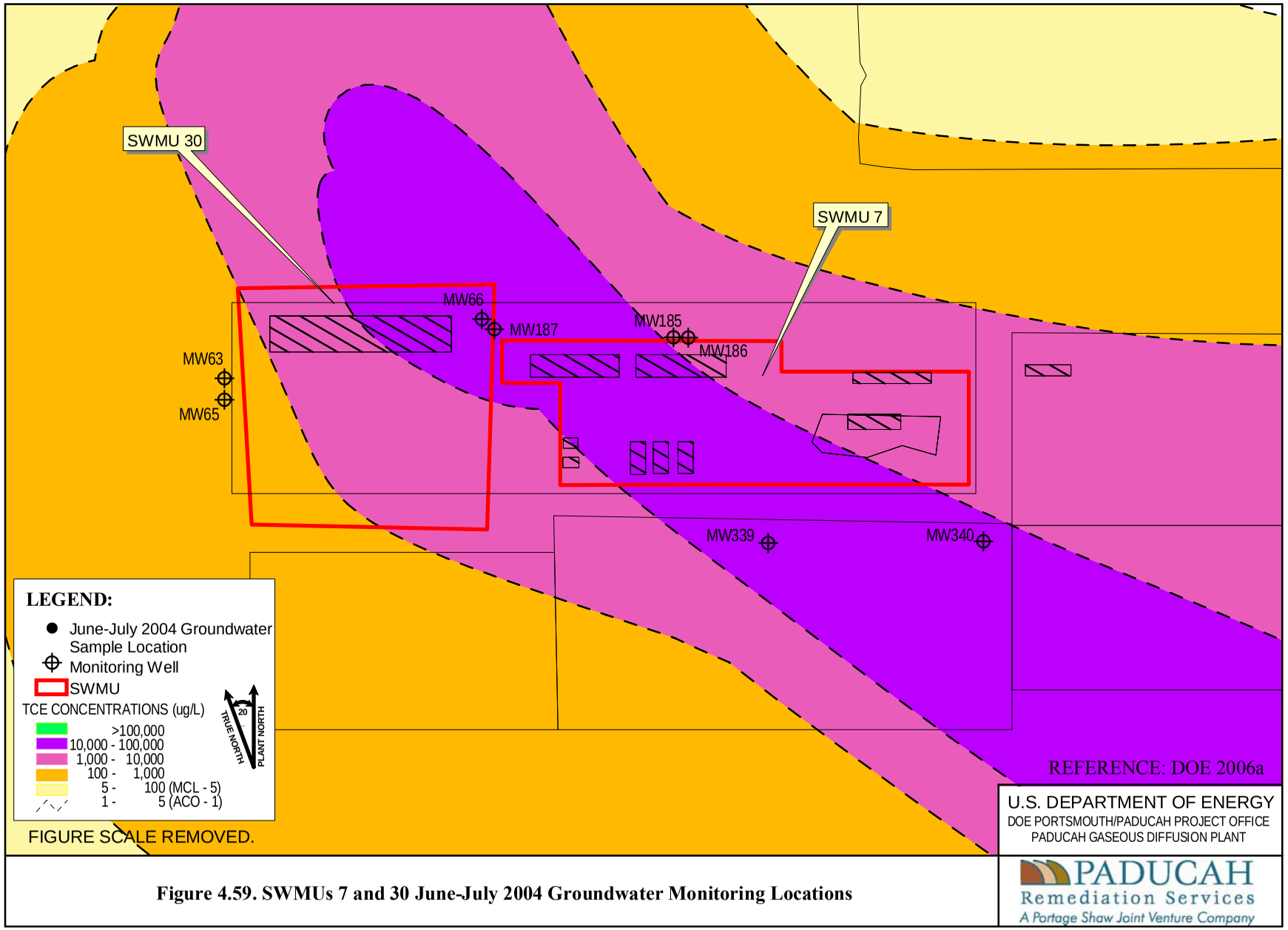

Figure 4.59. SWMUs 7 and 30 June-July 2004 Groundwater Monitoring Locations

Three locations, GWW-01, GWW-02, and GWW-03 were sampled for McNairy groundwater, close to the McNairy contact with the RGA, at SWMU 7. Table 4.37 summarizes the review of the McNairy groundwater analyses; TCE and chloroform were the only contaminants identified.

Table 4.37. SWMU 7 McNairy Groundwater Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection		
	Historical Data	RI Data		Above Back-ground	Above MCL	Above Child Resident NAL
Organics–Volatiles (mg/L)						
Chloroform	0.0038	N/A[b]	3/4	N/A	N/A	3/4
TCE	0.32	N/A	4/4	N/A	4/4	4/4

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

Table 4.38 provides detail (depth, sample location, and analytical results) for SWMU 7 groundwater samples, including nondetects and detections above screening levels.

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Table 4.38. SWMU 7 Locations of Groundwater Contaminants

			RI Data									Historical Data														
Unit	Depth (ft)	Analysis	007-001	007-002	007-003B	007-005	007-007	007-008	007-009	007-010	007-011	DG-005	GWW-01	GWW-02	GWW-03	MW185	MW186	MW187	MW339	MW340	WB-12	WB-13	WB-7	WB-8	WB-9	WBP-12A	WBP-9A
UCRS	7-9	***Inorganics (mg/L)***																									
		Arsenic																			0.0082	0.11			0.31		
		Beryllium																			ND	0.015			0.039		
		Cadmium																			ND	0.008			0.03		
		Chromium																			ND	0.6			1.5		
		Copper																			ND	0.41			1.8		
		Iron																			10	420			1200		
		Lead																			ND	0.32			0.73		
		Manganese																			0.46	12			28		
		Mercury																			ND	0.0006			0.0028		
		Molybdenum																			1.4	ND			ND		
		Nickel																			0.019	6.3			7.6		
		Uranium																			0.88	83			14	0.15	
		Vanadium																			0.022	0.7			1.8		
		Zinc																			0.075	1.6			4		
		Organics - Semivolatiles (mg/L)																									
		Naphthalene																			0.0027				ND		
		Organics - Volatiles (mg/L)																									
		1,1-DCE																			ND	ND			ND		
		Benzene																			0.0039	ND			0.00074		
		cis -1,2-DCE																			0.0022	ND			ND		
		TCE																			0.0013	ND			ND		
		Vinyl chloride																			0.011	ND			ND		
		Radionuclides(pCi/L)																									
		Uranium-234																			38.8	764			555	4.68	
		Uranium-238																			192	4910			1760	43.6	
	11-12	***Inorganics (mg/L)***																									
		Arsenic																					0.011	0.033			
		Beryllium																					ND	ND			
		Cadmium																					ND	ND			
		Chromium																					0.039	ND			
		Copper																					0.093	ND			
		Iron																					32	3.9			
		Lead																					0.027	ND			
		Manganese																					0.68	0.41			
		Mercury																					ND	ND			
		Molybdenum																					ND	0.17			
		Nickel																					0.062	0.036			
		Uranium																					ND	ND			0.11
		Vanadium																					0.057	ND			
		Zinc																					0.14	0.13			
		Organics - Semivolatiles (mg/L)																									
		Naphthalene																					0.0042	0.0037			
		Organics - Volatiles (mg/L)																									
		1,1-DCE																					ND	ND			
		Benzene																					0.0021	0.003			
		cis -1,2-DCE																					0.0036	0.0018			
		TCE																					0.00071	ND			
		Vinyl chloride																					0.018	0.0024			
		Radionuclides(pCi/L)																									
		Uranium-234																					21.6	44.9			20.2
		Uranium-238																					30.6	54.6			30.1
	22-23	***Inorganics (mg/L)***																									
		Arsenic											0.28				0.175										
		Arsenic, Dissolved															0.173										
		Beryllium											0.033				0.0002										
		Cadmium											ND				ND										

Table 4.38. SWMU 7 Locations of Groundwater Contaminants (Continued)

			RI Data									Historical Data														
Unit	Depth (ft)	Analysis	007-001	007-002	007-003B	007-005	007-007	007-008	007-009	007-010	007-011	DG-005	GWW-01	GWW-02	GWW-03	MW185	MW186	MW187	MW339	MW340	WB-12	WB-13	WB-7	WB-8	WB-9	WBP-12A	WBP-9A
UCRS	22-23	Chromium											0.91				0.063										
		Copper											0.46				ND										
		Iron											1000				1										
		Iron, Dissolved															0.41										
		Lead											1.1				ND										
		Manganese											25				0.526										
		Manganese, Dissolved															0.55										
		Mercury											0.0011				ND										
		Molybdenum											ND				ND										
		Nickel											0.53				0.046										
		Nickel, Dissolved															ND										
		Uranium											ND				0.01										
		Vanadium											1.6				ND										
		Zinc											1.4				0.034										
		Organics - Semivolatiles (mg/L)																									
		Naphthalene											ND				ND										
		Organics - Volatiles (mg/L)																									
		1,1-DCE											ND	ND	ND		0.0029										
		Benzene											ND	ND	ND		0.0078										
		cis -1,2-DCE											ND	ND	ND		2.9										
		TCE											ND	ND	ND		0.69										
		Vinyl chloride											ND	ND	ND		3.8										
		Radionuclides(pCi/L)																									
		Radon-222															247										
		Uranium-234											20.2		14.6		0.36										
		Uranium-238											26.7		22.2		0.12										
	26-32	***Inorganics (mg/L)***																									
		Arsenic				0.222	0.173			0.276	ND							0.011									
		Arsenic, Dissolved				0.0031	0.133			0.316	ND							0.01									
		Beryllium				0.034	ND			0.00595	0.0379							0.0003									
		Beryllium																									
		Cadmium				0.00525	ND			0.00204	0.00695							ND									
		Chromium				2.43	ND			0.274	ND							0.12									
		Copper				ND	ND			ND	ND							ND									
		Iron				922	75.7			142	1010							2.9									
		Iron, Dissolved				34	53.4			26.4	1.06							ND									
		Lead				0.382	0.0053			0.0597	0.694							0.0018									
		Manganese				8.73	2.13			2.61	6.6							0.14									
		Manganese, Dissolved				1.71	1.7			2.9	0.862							0.22									
		Mercury				0.00117	0.000017			0.000085	0.000769							ND									
		Molybdenum				0.429	0.0382			0.0348	0.00862							ND									
		Nickel				0.703	0.0908			0.112	ND							0.7									
		Nickel, Dissolved				0.0527	0.0753			0.053	ND							1.2									
		Uranium				0.0475	0.00109			0.239	0.0726							0.00153									
		Vanadium				1.72	ND			0.345	ND							0.0018									
		Zinc				2.93	0.769			1.17	ND							0.049									
		Organics - Semivolatiles (mg/L)																									
		Naphthalene				ND	ND			ND	ND							ND									
		Organics - Volatiles (mg/L)																									
		1,1-DCE				ND	ND			ND	ND							0.0022									
		Benzene				ND	0.011			ND	ND							ND									
		cis -1,2-DCE				ND	3.4			6.5	ND							0.24									

Table 4.38. SWMU 7 Locations of Groundwater Contaminants (Continued)

			RI Data									Historical Data														
Unit	Depth (ft)	Analysis	007-001	007-002	007-003B	007-005	007-007	007-008	007-009	007-010	007-011	DG-005	GWW-01	GWW-02	GWW-03	MW185	MW186	MW187	MW339	MW340	WB-12	WB-13	WB-7	WB-8	WB-9	WBP-12A	WBP-9A
UCRS	26-32	TCE				ND	5.6			12	ND							2									
		Vinyl chloride				ND	0.75			2.6	ND							ND									
		Radionuclides(pCi/L)																									
		Radon-222																801									
		Uranium-234				2.19	ND			18.8	8.39							0.39									
		Uranium-238				2.1	0.265			125	12							0.138									
	35	***Organics - Volatiles (mg/L)***																									
		1,1-DCE										ND															
		cis -1,2-DCE										ND															
		TCE										ND															
		Vinyl chloride										ND															
	43-45	***Inorganics (mg/L)***																									
		Arsenic	0.0106		0.119			ND																			
		Arsenic, Dissolved	0.00345		0.0986			0.00169																			
		Beryllium	0.00166		ND			ND																			
		Cadmium	ND		0.000818			0.000954																			
		Chromium	0.102		ND			ND																			
		Copper	ND		ND			ND																			
		Iron	59.7		40.2			25.2																			
		Iron, Dissolved	27.7		16.8			9.39																			
		Lead	0.0164		0.00638			0.0114																			
		Manganese	0.6		0.804			0.185																			
		Manganese, Dissolved	0.429		0.686			0.126																			
		Mercury	0.000136		0.000013			ND																			
		Molybdenum	0.054		0.0676			0.0199																			
		Nickel	0.0757		0.0603			ND																			
		Nickel, Dissolved	0.0402		0.0498			0.0158																			
		Uranium	0.00267		0.00137			0.00136																			
		Vanadium	ND		ND			ND																			
		Zinc	1.54		0.529			0.29																			
		Organics - Semivolatiles (mg/L)																									
		Naphthalene	ND		ND			ND																			
		Organics - Volatiles (mg/L)																									
		1,1-DCE	ND		ND			ND																			
		Benzene	ND		ND			ND																			
		cis -1,2-DCE	ND		ND			ND																			
		TCE	0.011		ND			0.0031																			
		Vinyl chloride	ND		ND			ND																			
	43-45	***Radionuclides(pCi/L)***																									
		Uranium-234	0.947		ND			ND																			
		Uranium-238	1.42		0.119			0.385																			
	50-53	***Inorganics (mg/L)***																									
		Arsenic		ND					ND																		
		Arsenic, Dissolved		0.00727					0.0276																		
		Beryllium		0.0214					0.00524																		
		Cadmium		0.00275					0.00136																		
		Inorganics (mg/L)																									
		Chromium		1.7					ND																		
		Copper		ND					ND																		
		Iron		490					115																		
		Iron, Dissolved		23.4					10.1																		
		Lead		0.218					0.074																		
		Manganese		3.29					1.08																		

Table 4.38. SWMU 7 Locations of Groundwater Contaminants (Continued)

			RI Data									Historical Data															
Unit	Depth (ft)	Analysis	007-001	007-002	007-003B	007-005	007-007	007-008	007-009	007-010	007-011	DG-005	GWW-01	GWW-02	GWW-03	MW185	MW186	MW187	MW339	MW340	WB-12	WB-13	WB-7	WB-8	WB-9	WBP-12A	WBP-9A
UCRS	50-53	Manganese, Dissolved		0.757					0.593																		
		Mercury		ND					0.000158																		
		Molybdenum		0.227					0.00542																		
		Nickel		ND					ND																		
		Nickel, Dissolved		0.0329					0.0211																		
		Uranium		0.039					0.0112																		
		Vanadium		ND					ND																		
		Zinc		4.23					ND																		
		Organics - Semivolatiles (mg/L)																									
		Naphthalene		ND					ND																		
		Organics - Volatiles (mg/L)																									
		1,1-DCE		0.0094					ND																		
		Benzene		ND					0.012																		
		cis -1,2-DCE		ND					0.25																		
		TCE		ND					0.059																		
		Vinyl chloride		ND					0.14																		
		Radionuclides(pCi/L)																									
		Uranium-234		4.98					4.39																		
		Uranium-238		8.51					4.28																		
RGA	60	***Inorganics (mg/L)***																									
		Arsenic								0.0327	ND																
		Arsenic, Dissolved								0.00626	ND																
		Beryllium								0.00656	0.015																
		Cadmium								0.00148	0.00237																
		Chromium								0.162	ND																
		Iron								144	255																
		Lead								0.0279	0.11																
		Manganese								3.04	2.14																
		Manganese, Dissolved								1.51	0.628																
		Molybdenum								0.0283	0.0107																
		Nickel								0.0743	ND																
		Uranium								0.0295	0.0119																
		Vanadium								ND	ND																
		Zinc								0.348	ND																
		Radionuclides(pCi/L)																									
		Technetium-99								1.28	31.1	ND															
		Uranium-234								2.25	1.82																
		Uranium-238								13.9	1.91																
		Organics - Volatiles (mg/L)																									
		Carbon tetrachloride								ND	ND																
		Chloroform								ND	ND																
		cis -1,2-DCE								0.073	ND	ND															
		TCE								0.1	0.0068	0.0014															
		Vinyl chloride								0.016	ND	ND															
	65-66	***Inorganics (mg/L)***																									
		Arsenic											0.041	0.085													
		Beryllium											0.0051	0.017													
		Cadmium											ND	0.0044													
		Chromium											0.41	0.37													
		Iron											360	400													
		Lead											0.11	0.21													

Table 4.38. SWMU 7 Locations of Groundwater Contaminants (Continued)

			RI Data									Historical Data														
Unit	Depth (ft)	Analysis	007-001	007-002	007-003B	007-005	007-007	007-008	007-009	007-010	007-011	DG-005	GWW-01	GWW-02	GWW-03	MW185	MW186	MW187	MW339	MW340	WB-12	WB-13	WB-7	WB-8	WB-9	WBP-12A	WBP-9A
RGA	65-66	Manganese											4.9	22													
		Molybdenum											0.33	ND													
		Nickel											0.35	0.44													
		Uranium											ND	ND													
		Vanadium											0.14	0.4													
		Zinc											4.2	2.1													
		Organics - Volatiles (mg/L)																									
		Carbon tetrachloride											ND	ND													
		Chloroform											ND	0.00095													
		cis -1,2-DCE										ND	ND	0.0029													
		TCE										0.021	ND	0.27													
		Vinyl chloride										ND	ND	ND													
		Radionuclides(pCi/L)																									
		Technetium-99										ND	ND	147													
		Uranium-234											1.66	2.75													
		Uranium-238											1.51	2.9													
	68-70	***Inorganics (mg/L)***																									
		Arsenic							ND	0.0348	ND	0.006			0.03												
		Arsenic, Dissolved							0.00455	0.00173	0.00476																
		Beryllium							0.00994	0.0077	0.041	ND			0.0052												
		Cadmium							0.00329	0.0018	0.0102	ND			ND												
		Chromium							ND	0.308	ND	ND			0.1												
		Iron							216	189	938	4.15			140												
		Lead							0.0935	0.0355	0.309				0.085												
		Manganese							9.31	6.75	20.5	0.1			1.9												
		Manganese, Dissolved							4.42	4.01	8.32																
		Molybdenum							0.0916	0.079	0.0459				ND												
		Nickel							ND	0.104	0.584	ND			0.12												
		Uranium							0.0118	0.03	0.031				ND												
		Vanadium							ND	ND	ND	ND			0.15												
		Zinc							ND	0.473	2.46	ND			0.99												
		Organics - Volatiles (mg/L)																									
		Carbon tetrachloride							ND	ND	ND				ND												
		Chloroform							ND	ND	ND				ND												
		cis -1,2-DCE							ND	0.0084	ND	ND			ND												
		TCE							14	0.18	0.091	0.12			ND												
		Vinyl chloride							ND	ND	ND	ND			ND												
		Radionuclides(pCi/L)																									
		Technetium-99							812	7.89	16.7	127			ND												
		Uranium-234							4.51	1.26	4.39				18.6												
		Uranium-238							6.71	7.68	4.97				2.84												
	73-78	***Inorganics (mg/L)***																									
		Arsenic											0.33	0.037	0.28	0.017											
		Arsenic, Dissolved														0.12											
		Beryllium											0.073	0.003	0.07	ND											
		Cadmium											0.011	ND	0.016	ND											
		Chromium											1.3	0.28	2	0.51											
		Iron											1700	270	2200	9.1											
		Lead											1.6	0.036	0.74	ND											
		Manganese											18	5.2	16	0.11											
		Manganese, Dissolved														0.1											

Table 4.38. SWMU 7 Locations of Groundwater Contaminants (Continued)

			RI Data									Historical Data														
Unit	Depth (ft)	Analysis	007-001	007-002	007-003B	007-005	007-007	007-008	007-009	007-010	007-011	DG-005	GWW-01	GWW-02	GWW-03	MW185	MW186	MW187	MW339	MW340	WB-12	WB-13	WB-7	WB-8	WB-9	WBP-12A	WBP-9A
RGA	73-78	Molybdenum											ND	ND	0.18	ND											
		Nickel											1.1	0.33	1.6	0.34											
		Uranium											ND	ND	ND	ND											
		Vanadium											1.6	0.097	2.7	0.0031											
		Zinc											4	4.9	9.8	0.031											
		Radionuclides(pCi/L)																									
		Technetium-99										143	1310	106	15	1260											
		Uranium-234											3.36	ND	7.95	0.52											
		Uranium-238											5.3	ND	5.46	ND											
		Organics - Volatiles (mg/L)																									
		Carbon tetrachloride											0.006	ND	ND	0.041											
		Chloroform											0.0034	0.0015	ND	0.0031											
		cis -1,2-DCE										ND	0.011	0.0039	ND	0.49											
		TCE										0.18	4.8	0.28	0.00058	4.6											
		Vinyl chloride										ND	ND	ND	ND	ND											
	80-80	***Inorganics (mg/L)***																									
		Arsenic							0.0187	0.0226	0.481	0.01															
		Arsenic, Dissolved							0.00384	0.0174	0.00561																
		Beryllium							0.0024	ND	0.063	ND															
		Cadmium							0.00108	ND	0.02	ND															
		Chromium							0.239	ND	1.08	ND															
		Iron							108	47.7	2460	29.5															
		Lead							0.0232	0.00364	0.393																
		Manganese							2.85	0.506	72.4	0.42															
		Manganese, Dissolved							1.81	0.367	12.8																
		Molybdenum							0.0842	0.0347	0.0415																
		Nickel							0.109	ND	1.15	0.06															
		Uranium							0.00392	0.00866	0.0858																
		Vanadium							ND	ND	ND	ND															
		Zinc							1.33	0.273	4.12	ND															
		Radionuclides(pCi/L)																									
		Technetium-99							530	129	45.7	138															
		Uranium-234							2.34	ND	6.79																
		Uranium-238							3.83	1.81	8.14																
		Organics - Volatiles (mg/L)																									
		Carbon tetrachloride							ND	ND	ND																
		Chloroform							ND	ND	ND																
		cis -1,2-DCE							ND	ND	ND	0.003															
		TCE							18	1.7	0.12	0.24															
		Vinyl chloride							ND	ND	ND	ND															
	85-87	***Inorganics (mg/L)***																									
		Arsenic											0.25	0.091	0.18												
		Beryllium											0.068	0.006	0.031												
		Cadmium											0.012	ND	ND												
		Chromium											1.3	0.13	0.86												
		Iron											1600	340	890												
		Lead											1.6	0.019	0.35												
		Manganese											17	4.2	14												
		Molybdenum											ND	ND	0.16												
		Nickel											1.2	0.23	0.58												
		Uranium											ND	0.063	ND												
		Vanadium											1.3	0.082	1.1												
		Zinc											6.5	2.1	3.6												

Table 4.38. SWMU 7 Locations of Groundwater Contaminants (Continued)

			RI Data									Historical Data														
Unit	Depth (ft)	Analysis	007-001	007-002	007-003B	007-005	007-007	007-008	007-009	007-010	007-011	DG-005	GWW-01	GWW-02	GWW-03	MW185	MW186	MW187	MW339	MW340	WB-12	WB-13	WB-7	WB-8	WB-9	WBP-12A	WBP-9A
RGA	85-87	***Radionuclides(pCi/L)***																									
		Technetium-99										177	633	56.9	ND												
		Uranium-234											14.5	1.25	6.98												
		Uranium-238											20.3	1.25	8												
		Organics - Volatiles (mg/L)																									
		Carbon tetrachloride											0.0016	ND	ND												
		Chloroform											0.0041	0.0032	ND												
		cis -1,2-DCE										0.003	0.01	0.0062	ND												
		TCE										0.32	2.9	0.35	0.0012												
		Vinyl chloride										ND	ND	ND	ND												
	90-91	***Inorganics (mg/L)***																									
		Arsenic							0.07	0.0292	0.22	0.01		0.2													
		Arsenic, Dissolved							0.0436	0.0157	0.00608																
		Beryllium							0.00276	0.00144	0.0732	ND		0.053													
		Cadmium							0.00131	ND	0.0197	ND		0.01													
		Chromium							0.206	0.0275	1.46	ND		2													
		Iron							162	86.7	2410	8.88		1800													
		Lead							0.0177	0.00355	0.489			0.27													
		Manganese							9.4	0.445	58.9	0.07		18													
		Manganese, Dissolved							8.95	0.338	7.24																
		Molybdenum							0.0889	0.0282	0.0239			0.17													
		Nickel							0.15	0.0441	1.18	ND		0.87													
		Uranium							0.00413	0.00197	0.093			ND													
		Vanadium							ND	ND	ND	ND		0.83													
		Zinc							1.05	0.333	4.28	ND		5.4													
		Radionuclides(pCi/L)																									
		Technetium-99							221	193	64	187		122													
		Uranium-234							1.08	1.44	8.71			10.2													
		Uranium-238							1.7	5.47	8.74			5.72													
		Organics - Volatiles (mg/L)																									
		Carbon tetrachloride							ND	ND	ND			ND													
		Chloroform							ND	ND	ND			0.0045													
		cis -1,2-DCE							0.58	ND	ND	0.003		0.0064													
		TCE							1.7	3.6	0.2	0.26		0.41													
		Vinyl chloride							0.3	ND	ND	ND		ND													
	95-96	***Inorganics (mg/L)***																									
		Arsenic											0.42						0.00337								
		Arsenic, Dissolved																	0.00149								
		Beryllium											0.062						0.0006	0.0003							
		Cadmium											0.016						ND								
		Chromium											1.3						0.0723								
		Iron											2100						24	11							
		Lead											0.65						ND								
		Manganese											20						1.9	0.22							
		Manganese, Dissolved																	0.00917								
		Molybdenum											0.17						0.00634								
		Nickel											0.98						0.0224								
		Uranium											ND						0.09	ND							
		Vanadium											1.1						0.018	0.014							
		Zinc											5.4						ND								

Table 4.38. SWMU 7 Locations of Groundwater Contaminants (Continued)

			RI Data									Historical Data														
Unit	Depth (ft)	Analysis	007-001	007-002	007-003B	007-005	007-007	007-008	007-009	007-010	007-011	DG-005	GWW-01	GWW-02	GWW-03	MW185	MW186	MW187	MW339	MW340	WB-12	WB-13	WB-7	WB-8	WB-9	WBP-12A	WBP-9A
RGA	95-96	***Radionuclides(pCi/L)***																									
		Technetium-99										118	1550						5116.9	747							
		Uranium-234											6.34						0.48	0.45							
		Uranium-238											6.27						ND	0.18							
		Organics - Volatiles (mg/L)																									
		Carbon tetrachloride											0.0047						ND	ND							
		Chloroform											0.012						ND	ND							
		cis -1,2-DCE										0.0039	0.023						2.1	0.013							
		TCE										0.42	14						25	6.5							
		Vinyl chloride										ND	ND						ND	ND							
	100	***Inorganics (mg/L)***																									
		Arsenic								ND																	
		Arsenic, Dissolved								ND																	
		Beryllium								ND																	
		Cadmium								ND																	
		Chromium								ND																	
		Iron								42.7																	
		Lead								0.00515																	
		Manganese								0.516																	
		Manganese, Dissolved								0.437																	
		Molybdenum								0.0237																	
		Nickel								ND																	
		Uranium								0.00374																	
		Vanadium								ND																	
		Zinc								0.37																	
		Organics - Volatiles (mg/L)																									
		Carbon tetrachloride								ND																	
		Chloroform								ND																	
		cis -1,2-DCE								ND																	
		TCE								0.042																	
		Vinyl chloride								ND																	
		Radionuclides(pCi/L)																									
		Technetium-99								36.6																	
		Uranium-234								1.11																	
		Uranium-238								5.94																	
McN	97	***Organics - Volatiles (mg/L)***																									
		Chloroform													0.00047												
		TCE													0.04												
	111	Chloroform											0.00084	0.0038	ND												
		TCE											0.11	0.32	0.021												

ND = not detected above screening levels

Blank cells indicate interval was not sampled for the specified analysis. The maximum value is shown for each depth interval at each location.

4.9 SWMU 30

4.9.1 Subsurface Soils

SWMU 30 was used to burn combustible trash, which may have contained uranium contamination. Ash and debris then were buried in a pit contained within the SWMU (excavated to a depth of approximately 12 ft). Table 4.39 summarizes the subsurface soil contaminants for SWMU 30 determined by the data review.

Table 4.39. SWMU 30 Subsurface Soil Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection	
	Historical Data	RI Data		Above Background Value	Above Excavation Worker NAL
Inorganics (mg/kg)					
Beryllium	N/A[b]	1.48	7/25	5/25	2/25
Iron	29,000	22,200	25/25	1/25	25/25
Manganese	1,200	486	25/25	1/25	18/25
Vanadium	40	19.3	24/25	1/25	17/25
Organics–PCBs (mg/kg)					
Total PCBs	0.18	N/A	5/26	N/A	1/26
PCB-1260	0.18	N/A	4/26	N/A	1/26
Organics–Semivolatiles (mg/kg)					
Benzo(a)pyrene	0.052	N/A	1/26	N/A	1/26
Total PAHs	0.062795	N/A	3/26	N/A	1/26
Radionuclides (pCi/g)					
Uranium	59	2.97	8/23	N/A	2/23
Uranium-234	20.6	2.46	19/28	5/28	4/28
Uranium-235/236	0.55	N/A	5/5	3/5	1/5
Uranium-238	37.4	0.77	16/28	6/28	6/28

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

As in neighboring SWMU 7, metals concentrations in subsurface soil samples of SWMU 30 rarely exceed background levels. Iron, manganese, and vanadium are the most frequent metals to be detected above the excavation worker NALs. Figure 4.60 illustrates the distribution of vanadium in subsurface soils at SWMU 30. There was only one detection above background, which occurred at boring WB-1 in the 5 to 10 ft sample. Concentrations above the excavation worker NALs extended throughout the depth of the UCRS.

Few organic compounds are present in subsurface soils at SWMU 30. The screening steps identified benzo(a)pyrene and Total PAHs as organic contaminants, at frequencies of one in 26 analyses for both. Analyses of the RI samples did not detect PCBs, but a review of historical data identified four PCB-1260 detections (locations WB-1, WB-4, WB-5, and WB-11) and one PCB-1254 detection (location WB-3), all at depths of 6 to 7 ft and distributed across the SWMU. The highest level, 0.18 mg/kg of PCB-1260, was detected in a sample from 6 ft bgs at location WB-1 from within the area of Burial Pit A. Two test pits were excavated in SWMU 30 during the Phase II SI (CH2M HILL 1992). The excavations found ash,

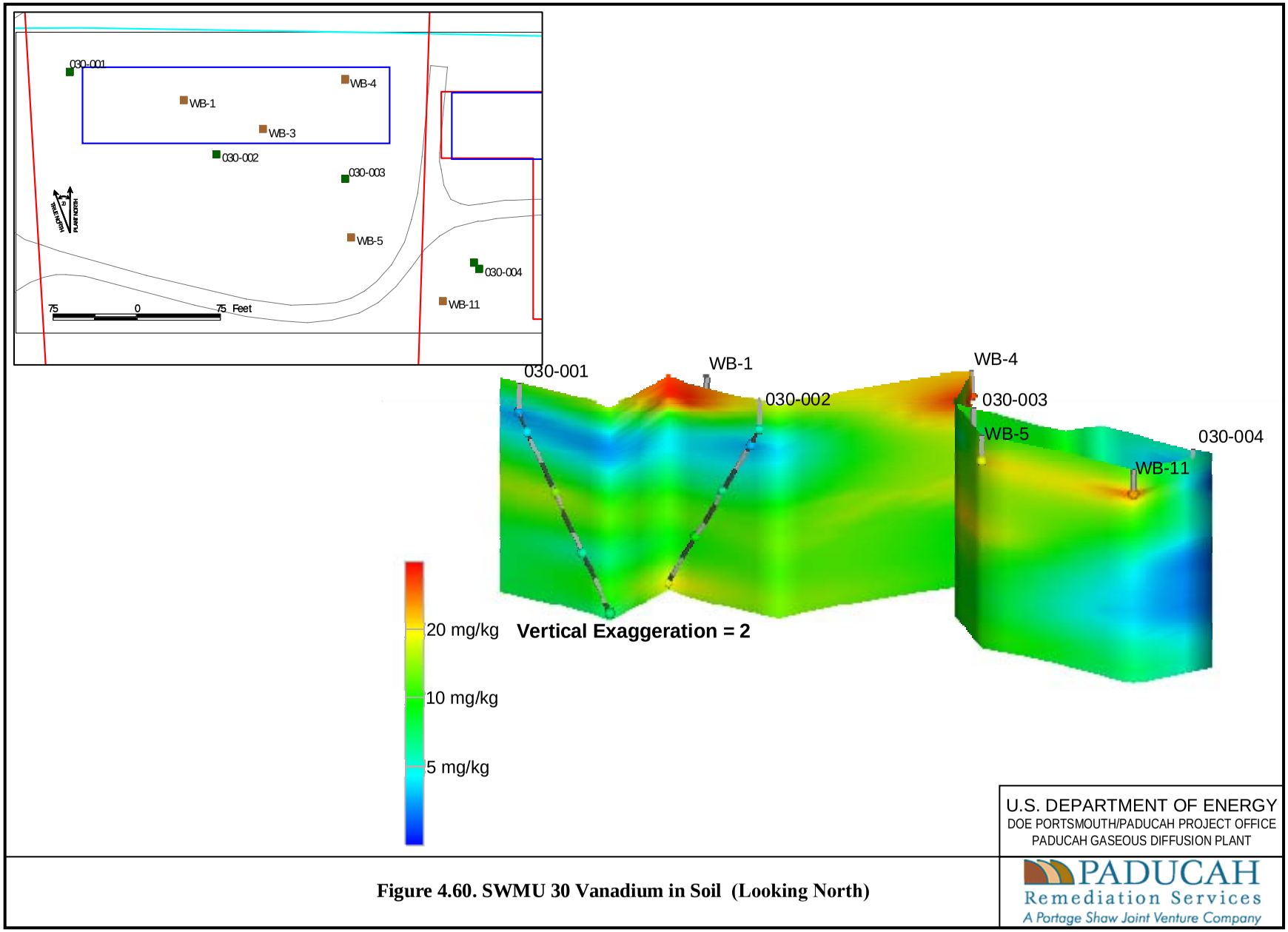

Figure 4.60. SWMU 30 Vanadium in Soil (Looking North)

bricks, and railroad rails in the test pits. Samples from these pits identified many of the same inorganic, organic, and radionuclide contaminants reported in Table 4.39.

The uranium isotopes uranium-234(maximum 20.6 pCi/g), uranium-235/236 (maximum 0.55 pCi/g), and uranium-238 (maximum 37.4 pCi/g) are the only radionuclide contaminants at depths of 10 ft or less. Figure 4.61 provides the uranium-238 distribution in soils, which indicates the limited extent of uranium contamination with all exceedances above background being less than 10 ft bgs.

Locations containing subsurface soil contaminants detected above screening levels are presented in Table 4.40.

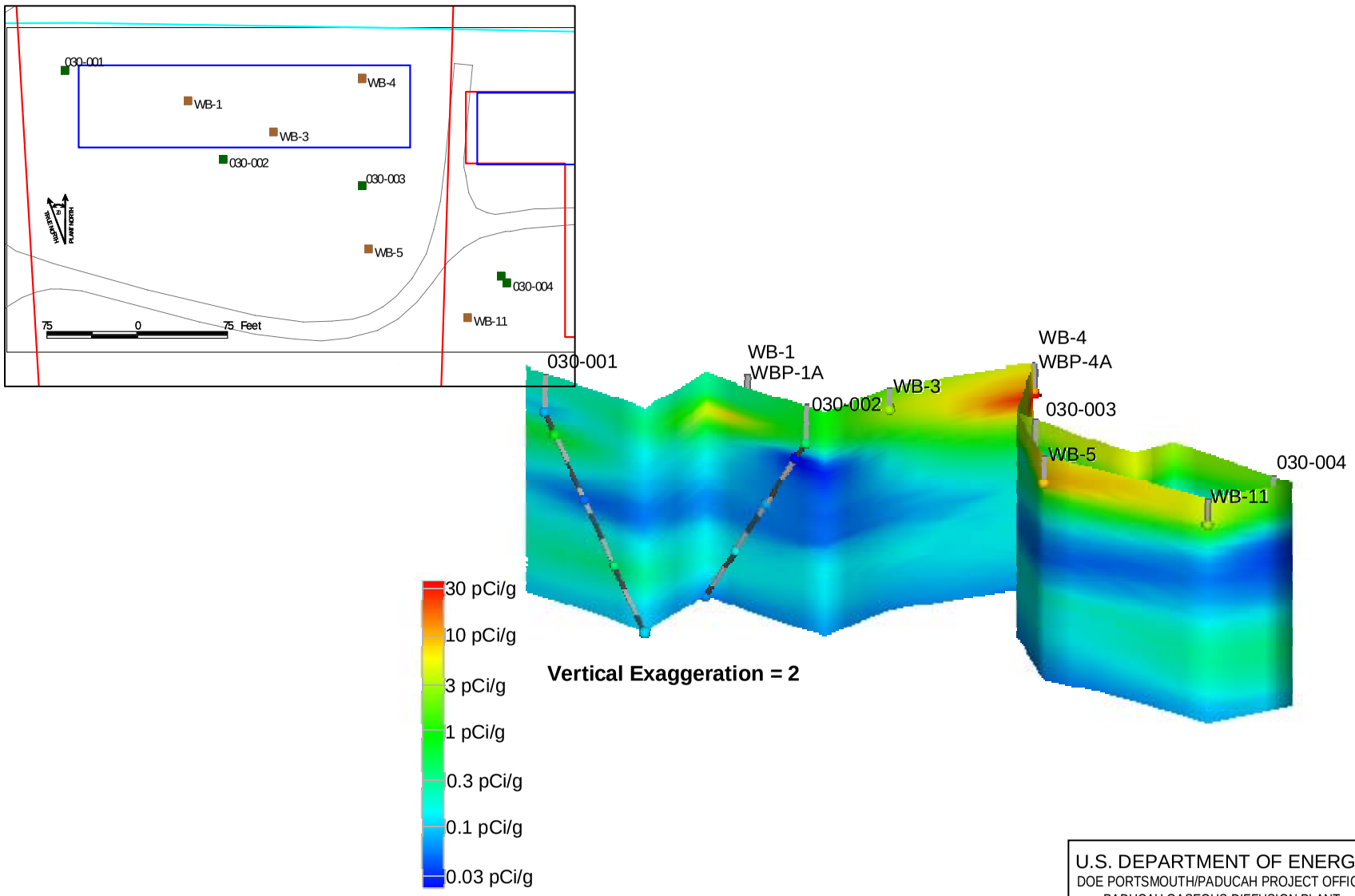

Figure 4.61. SWMU 30 ^{238}U in Soil (Looking North)

Table 4.40. SWMU 30 Locations of Subsurface Soil Contaminants

		RI Data				Historical Data						
Analysis	**Depth (ft)**	030-001	030-002	030-003	030-004	WB-1	WB-11	WB-3	WB-4	WB-5	WBP-1A	WBP-4A
Inorganics (mg/kg)												
Beryllium	5–10					ND	ND		ND	ND		
	10	ND	ND	ND	ND							
	15	ND	ND	ND	ND							
	30	ND	ND	ND	ND							
	45	0.484	0.909	ND	ND							
	60	0.806	1.48	1.41	0.61							
Iron	5–10					21000	17000		29000	14000		
	10	5,940	8,960	13,100	9,400							
	15	16,200	7,690	11,300	5,890							
	30	10,800	7,900	18,600	6,620							
	45	17,700	22,200	11,100	5,020							
	60	16,200	21,600	20,000	15,400							
Manganese	5–10					340	1200		740	230		
	10	66	69.4	188	161							
	15	92.1	62.2	92.9	36.6							
	30	24.8	15.6	26.1	15.7							
	45	70.6	73.1	30.8	22.8							
	60	163	72.3	486	171							
Vanadium	5–10					40	25		31	18		
	10	3.69	5.41	5.66	ND							
	15	4.35	3.82	10.4	4.08							
	30	13.8	6.38	19.3	3.33							
	45	5.78	9.32	7.3	3.21							
	60	6.82	17.6	8.87	3.79							
Organics–PCBs (mg/kg)												
PCB, Total	5–10					0.18	0.02	0.028	0.049	0.065		
	10	ND	ND	ND	ND							
	15	ND	ND	ND	ND							
	30	ND	ND	ND	ND							
	45	ND	ND	ND	ND							
	60	ND	ND	ND	ND							
PCB-1260	7					0.18	0.02	ND	0.049	0.065		
	10	ND	ND	ND	ND							
	15	ND	ND	ND	ND							
	30	ND	ND	ND	ND							
	45	ND	ND	ND	ND							
	60	ND	ND	ND	ND							

Table 4.40. SWMU 30 Locations of Subsurface Soil Contaminants (Continued)

		RI Data				Historical Data						
Analysis	**Depth (ft)**	030-001	030-002	030-003	030-004	WB-1	WB-11	WB-3	WB-4	WB-5	WBP-1A	WBP-4A
Organics–Semivolatiles (mg/kg)												
Benzo(a)pyrene	5–10					ND	0.052	ND	ND	ND		
	10	ND	ND	ND	ND							
	15	ND	ND	ND	ND							
	30	ND	ND	ND	ND							
	45	ND	ND	ND	ND							
	60	ND	ND	ND	ND							
Total PAH	5–10					ND	0.062795	ND	0.006725	0.001712		
	10	ND	ND	ND	ND							
	15	ND	ND	ND	ND							
	30	ND	ND	ND	ND							
	45	ND	ND	ND	ND							
	60	ND	ND	ND	ND							
Radionuclides (pCi/g)												
Uranium	5–10										34	59
	10	ND	1.02	ND	0.35							
	15	1.3	ND	2.97	ND							
	30	ND	ND	ND	ND							
	45	0.815	ND	ND	ND							
	60	0.651	ND	ND	ND							
Uranium-234	5–10					0.2	2.26	2.24	6.56	5.87	8.1	20.6
	10	ND	0.592	ND	0.15							
	15	0.5	ND	2.46	ND							
	30	ND	ND	ND	ND							
	45	0.429	0.203	0.206	0.163							
	60	0.517	ND	0.173	0.16							
Uranium-235/236	5–10					0.02	0.14	0.16	0.55	0.4		
Uranium-238	5–10					0.38	2.74	2.92	10.3	8.2	25.3	37.4
	10	ND	0.397	ND	0.181							
	15	0.77	ND	0.424	ND							
	30	ND	ND	ND	ND							
	45	0.357	0.149	0.163	0.333							
	60	ND	ND	ND	ND							

ND = not detected above screening levels
Blank cells indicate interval was not sampled for the specified analysis. Maximum value shown for each depth interval.

4.9.2 SWMU 30 Groundwater

UCRS groundwater samples were collected from one of the four angled borings installed at SWMU 30 as part of this RI (030-003). The UCRS groundwater samples in the historic data set represent MW64 (for the period of record 1995 to 2007); the SWMUs 7 and 30 RI, temporary borings WB-1, WB-4, and WB-5 (DOE 1998a); and a 1998 follow-up investigation of the main SWMU 30 waste pit, temporary boring WBP-4A. RI data were reviewed with historical data to identify the UCRS contaminants listed in Table 4.41.

Table 4.41. SWMU 30 UCRS Groundwater Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection	
	Historical Data	RI Data		above MCL	above Child Resident NAL
Inorganics (mg/L)					
Arsenic	0.067	N/A[b]	2/4	2/4	2/4
Cadmium	0.011	N/A	1/4	1/4	1/4
Iron	51	38.3	4/4	N/A	4/4
Iron, Dissolved	N/A	18.2	1/1	N/A	1/1
Lead	N/A	0.00357	3/4	2/4	2/4
Manganese	0.97	2.87	4/4	N/A	3/4
Molybdenum	0.14	0.111	2/4	N/A	2/4
Nickel	0.14	N/A	3/4	N/A	3/4
Uranium	0.17	N/A	3/6	3/6	3/6
Vanadium	0.095	N/A	2/4	N/A	2/4
Organics–Semivolatiles (mg/L)					
Naphthalene	0.00072	N/A	1/4	N/A	1/4
Organics–Volatiles (mg/L)					
Benzene	0.0054	N/A	2/5	1/5	2/5
TCE	0.45	N/A	4/6	2/6	4/6
Vinyl chloride	0.0086	N/A	2/5	2/5	2/5
Organics–Pesticides and PCBs (mg/L)					
PCB-1260	0.0029	N/A	1/3	1/3	1/3
Radionuclides (pCi/L)					
Uranium-234	2,220	9.84	5/5	N/A	5/5
Uranium-238	2,710	17.8	5/5	N/A	4/5
Uranium-238 (& daughter products)	N/A	33.9	1/1	N/A	1/1

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

Only a limited number of samples were available to characterize the UCRS groundwater at SWMU 30. Temporary borings WB-1, WB-4, WB-5, and WBP-4A sampled the depth interval of the buried waste at SWMU 30. (Pit A of SWMU 30 is approximately 12 ft deep.) MW64 and 030-003 characterize the HU2 interval of the UCRS, found at approximately 20 to 30 ft bgs at SWMU 30. The suite of contaminants was similar at the depth of the waste pits and within the HU2 interval. Screening of the sample analyses revealed nine metal contaminants: arsenic, cadmium, iron, lead, manganese, molybdenum, nickel, uranium, and vanadium. All but cadmium were detected at levels exceeding screening criteria in 50% or more of the samples. TCE was detected at three locations (MW64, WB-1, and WB-4); one location exceeded the screening level (MW64 up to 0.45 mg/L). Benzene (at location WB-4) and vinyl chloride (at

locations WB-1 and WB-4) also were detected above screening levels. The uranium isotopes uranium-234 and uranium-238 frequently exceeded screening levels in the SWMU 30 UCRS groundwater samples.

RGA and McNairy groundwater samples were not collected at SWMU 30 as part of this RI. Historical data were reviewed for RGA groundwater to determine the contaminants listed in Table 4.42. All of the SWMU 30 RGA groundwater samples were from MWs shown in Figure 4.15. MW63, MW66, and MW245 sample the upper RGA. MW65 is a lower RGA well.

Table 4.42. SWMU 30 RGA Groundwater Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection		
	Historical Data	RI Data		Above Back-ground	Above MCL	Above Child Resident NAL
Inorganics (mg/L)						
Arsenic	0.0123	N/A[b]	1/4	1/4	1/4	1/4
Iron	226	N/A	66/79	28/79	N/A	61/79
Iron, Dissolved	54.6	N/A	25/76	24/76	N/A	7/76
Lead	0.432	N/A	3/7	1/7	1/7	1/7
Manganese	39.9	N/A	64/79	56/79	N/A	58/79
Manganese, Dissolved	38.2	N/A	57/76	56/76	N/A	36/76
Uranium	0.19	N/A	4/128	2/128	2/128	4/128
Organics–Volatiles (mg/L)						
Chloroform	0.001	N/A	1/41	N/A	N/A	1/41
Tetrachloroethene	0.32	N/A	1/193	N/A	1/193	1/193
TCE	15	N/A	253/278	N/A	233/278	250/278
Radionuclides (pCi/L)						
Radon-222	632	N/A	43/44	1/44	N/A	43/44
Technetium-99	2,911	N/A	210/279	175/279	39/279	193/279
Uranium-234	448	N/A	4/11	1/11	N/A	2/11
Uranium-238	441	N/A	1/14	1/14	N/A	1/14

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

The RGA groundwater samples from SWMU 30 contained five metal contaminants: arsenic, iron, lead, manganese, and uranium. Of the organic analytes, only TCE was detected frequently above screening levels, in all four RGA groundwater MWs (Figure 4.59). Tetrachloroethene was detected at only one location, MW66, at 0.32 mg/L, which is above the screening level. Radon-222 and technetium-99 were the most frequently detected radionuclide contaminants. All technetium-99 analyses above the MCL represented samples from MW66.

No McNairy groundwater data were available.

Table 4.43 lists all SWMU 30 locations with groundwater contamination.

Table 4.43. SWMU 30 Locations of Groundwater Contaminants

			RI Data	Historical Data								
Unit	Depth (ft)	Analysis	030-003	MW245	MW63	MW64	MW65	MW66	WB-1	WB-4	WB-5	WBP-4A
UCRS	8-10	***Inorganics (mg/L)***										
		Arsenic							0.067	0.03		
		Cadmium							0.011	ND		
		Iron							10	51		
		Lead							0.23	0.084		
		Manganese							0.25	0.97		
		Molybdenum							ND	0.14		
		Nickel							0.076	0.14		
		Uranium							ND	ND		0.17
		Vanadium							0.02	0.095		
		Organics - Semivolatiles (mg/L)										
		Naphthalene							0.00072	ND		
		Organics - Volatiles (mg/L)										
		Benzene							0.0025	0.0054	ND	
		TCE							0.0022	0.0037	ND	
		Vinyl chloride							0.0086	0.0048	ND	
		Organics - Pesticides and PCBs (mg/L)										
		PCB-1260								0.0029		
		Radionuclides (pCi/L)										
		Uranium-234							2220	106		20.3
		Uranium-238							2710	247		53.6
	23	***Inorganics (mg/L)***										
		Arsenic	ND									
		Cadmium	ND									
		Iron	38.3									
		Iron, Dissolved	18.2									
		Lead	0.00357									
		Manganese	2.87									
		Molybdenum	0.111									
		Nickel	ND									
		Uranium	0.15									
		Vanadium	ND									
		Organics - Pesticides and PCBs (mg/L)										
		PCB-1260	ND									
		Organics - Semivolatiles (mg/L)										
		Naphthalene	ND									
		Organics - Volatiles (mg/L)										
		Benzene	ND									
		TCE	ND									
		Vinyl chloride	ND									
		Radionuclides (pCi/L)										
		Uranium-234	9.84									
		Uranium-238	17.8									

Table 4.43. SWMU 30 Locations of Groundwater Contaminants (Continued)

			RI Data	Historical Data								
Unit	Depth (ft)	Analysis	030-003	MW245	MW63	MW64	MW65	MW66	WB-1	WB-4	WB-5	WBP-4A
UCRS	33	***Inorganics (mg/L)***										
		Arsenic				ND						
		Cadmium				ND						
		Iron				0.74						
		Lead				ND						
		Manganese				0.017						
		Molybdenum				ND						
		Nickel				0.083						
		Uranium				ND						
		Vanadium				ND						
		Organics - Pesticides and PCBs (mg/L)										
		PCB-1260				ND						
		Organics - Semivolatiles (mg/L)										
		Naphthalene				ND						
		Organics - Volatiles (mg/L)										
		Benzene				ND						
		TCE				0.45						
		Vinyl chloride				ND						
		Radionuclides (pCi/L)										
		Uranium-238				0.44						
RGA	60-64	***Inorganics (mg/L)***										
		Arsenic			ND			ND				
		Iron			3			3.13				
		Iron, Dissolved			ND			ND				
		Lead			0.0065			ND				
		Manganese			0.041			0.037				
		Manganese, Dissolved			ND			0.04				
		Uranium			0.19			0.19				
		Organics - Volatiles (mg/L)										
		Chloroform			ND			0.001				
		TCE			0.028			15				
		Tetrachloroethene			ND			0.32				
		Radionuclides (pCi/L)										
		Radon-222			356			632				
		Technetium-99			22.5			2911				
		Uranium-234			448			0.57				
		Uranium-238			441			ND				
	75	***Inorganics (mg/L)***										
		Arsenic		0.0123								
		Arsenic, Dissolved		0.00815								
		Iron		226								
		Iron, Dissolved		54.6								
		Lead		0.432								
		Manganese		39.9								

Table 4.43. SWMU 30 Locations of Groundwater Contaminants (Continued)

			RI Data	Historical Data								
Unit	Depth (ft)	Analysis	030-003	MW245	MW63	MW64	MW65	MW66	WB-1	WB-4	WB-5	WBP-4A
RGA	75	***Inorganics (mg/L)***										
		Manganese, Dissolved		38.2								
		Uranium		ND								
		Organics - Volatiles (mg/L)										
		Chloroform		ND								
		TCE		0.21								
		Tetrachloroethene		ND								
		Radionuclides (pCi/L)										
		Radon-222		394								
		Technetium-99		63.6								
	91	***Inorganics (mg/L)***										
		Arsenic					ND					
		Iron					0.22					
		Iron, Dissolved					ND					
		Lead					ND					
		Manganese					0.0042					
		Manganese, Dissolved					ND					
		Uranium					0.00171					
		Organics - Volatiles (mg/L)										
		Chloroform					ND					
		TCE					0.096					
		Tetrachloroethene					ND					
		Radionuclides (pCi/L)										
		Radon-222					475					
		Technetium-99					37.11					
		Uranium-234					0.17					
		Uranium-238					ND					

ND = not detected above screening levels

Blank cells indicate interval was not sampled for the specified analysis. The maximum value is shown for each depth interval at each location.

4.10 SWMU 145

4.10.1 Subsurface Soils

The RI collected subsurface soil samples from seven angled borings at SWMU 145. Table 4.44 lists the contaminants identified by a review of the RI data along with historical data.

Table 4.44. SWMU 145 Subsurface Soil Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection	
	Historical Data	RI Data		Above Background Value	Above Excavation Worker NAL
Inorganics (mg/kg)					
Antimony	N/A[b]	20.2	15/45	15/45	15/45
Arsenic	21.9	7.88	39/59	4/59	39/59
Beryllium	2.08	1.24	23/59	15/59	5/59
Uranium	311	1.55	24/53	7/53	7/53
Organics–PCBs (mg/kg)					
Total PCBs	12.5	0.33	5/55	N/A	5/55
PCB-1254	1.9	0.33	3/55	N/A	3/55
PCB-1260	12.5	N/A	2/55	N/A	2/55
Radionuclides (pCi/g)					
Americium-241	1.956	N/A	2/64	N/A	1/64
Cesium-137	1.057	N/A	11/64	4/64	7/64
Technetium-99	281	1.83	12/63	11/63	5/63
Thorium-228	1.92	0.775	58/68	1/68	58/68
Thorium-230	193	0.534	52/55	6/55	12/55
Thorium-232	2.282	0.727	59/66	2/66	2/66
Uranium	593	0.795	11/50	N/A	7/50
Uranium-233/234	4.7	N/A	5/5	1/5	N/A
Uranium-234	254	0.405	36/63	13/63	12/63
Uranium-235	2.2	N/A	16/62	7/62	3/62
Uranium-238	326	0.378	43/68	18/68	18/68

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

Locations of SWMU 145 subsurface soil contaminants are listed in Table 4.45.

The metal detected predominantly above screening levels in subsurface soils at SWMU 145 is antimony. One third of the samples had an antimony level that exceeded background and the excavation worker NAL criteria. Figure 4.62 presents the antimony distribution in soil. The “hot spot” shown in the southwest corner, near historical borings DG-029 and NSD030, is the result of a false positive. As explained in Appendix D, the laboratory reporting limit was used for modeling, and in this instance, the reporting limit was 20 mg/kg. Antimony concentrations, for the most part, exceeded the background value throughout the depth of the shallow soils to the top of the RGA. The only other metal that was frequently present at concentrations above the NAL (but rarely exceeds background) was arsenic. Figure 4.63 shows the arsenic distribution in soil at SWMU 145. The arsenic background exceedances have a limited extent, as all occurred in samples collected at depths of 15 ft or less.

Of the organics in subsurface soils, PCBs were detected at levels above NAL criteria at three historical sampling locations within the former NSDD disposal trench (NST1S01, NST2S02, and A10, all at depths of 2 to 3 ft). The maximum detected PCB result was 12.5 mg/kg from A10.

Table 4.45. SWMU 145 Locations of Subsurface Soil Contaminants

		RI Data							Historical Data											
Analysis	**Depth (ft)**	145-101	145-102	145-103	145-104	145-105	145-106	145-107	A10	A2	DG-029	NSD030	NST1S01	NST1S02	NST1S03	NST2S01	NST2S02	NST2S03	NST2S04	NST2S05
Inorganics (mg/kg)																				
Antimony	2-4											ND								
	10	18.1	11.5	13.6	ND	10.9	ND	9.81												
	15	ND	ND	9.59		11	ND	ND												
	19-25										ND									
	30-34	ND	ND	ND	ND	ND	20.2	ND			ND									
	35-37						16.6				ND									
	40-45	14.7	ND	ND	ND	12.5	11.1	ND			ND									
	55-60	13.2	ND	ND	10.7	17.7		ND												
Arsenic	2-4								10.5			5.52	ND	ND		7.48	5.25			
	8-10	3.71	7.18	7.16	3.33	6.45	3.32	7.88	5.03	ND									11.5	
	15	1.19	2.87	6.67		3.57	2.04	3.25		21.9					5.76			13.7		ND
	19-25										ND									
	30-34	ND	2.01	2.36	3.39	2.16	3.68	ND			ND									
	35-37						2.46				ND									
	40-45	6.98	1.57	1.72	1.92	2.81	3.1	ND			ND									
	55-60	ND	1.49	3.16	2.63	3.92		ND												
Beryllium	2-4								ND			0.5	ND	0.66		0.75	0.62			
	8-10	ND	ND	ND	ND	ND	ND	ND	0.6	0.78									1.86	
	12-15	ND	ND	ND		ND	ND	ND		2.08					0.68			0.68		0.59
	19-25										ND									
	30-34	ND	ND	ND	ND	ND	0.812	ND			1.5									
	35-37						ND				1.88									
	40-45	ND	ND	ND	ND	0.827	0.745	ND			1.48									
	55-60	ND	ND	1.24	0.706	0.798		ND												
Uranium	2-4								20			234	150	41.4		23.1	311			
	8-10	ND	1.15	0.993	ND	ND	0.976	ND	3.8	1.9									1.9	
	12-15	ND	ND	ND		ND	ND	ND		3					2			59.3		1.65
	30	ND	ND	ND	ND	ND	1.55	ND												

Table 4.45. SWMU 145 Locations of Subsurface Soil Contaminants (Continued)

		RI Data							Historical Data											
Analysis	**Depth (ft)**	145-101	145-102	145-103	145-104	145-105	145-106	145-107	A10	A2	DG-029	NSD030	NST1S01	NST1S02	NST1S03	NST2S01	NST2S02	NST2S03	NST2S04	NST2S05
	35						1.48													
	40-45	ND	ND	ND	ND	ND	ND	1.16												
	55-60	1.16	ND	1.41	0.999	ND		ND												
Organics–PCBs (mg/kg)																				
PCB, Total	2-4								12.5			1.4	1.9	ND		ND	1.1			
	8-10	ND	ND	0.33	ND	ND	ND	ND	ND	ND									ND	
	12-15	ND	ND	ND	ND	ND	ND	ND		ND					ND			ND		ND
	19										ND									
	30	ND	ND	ND	ND	ND	ND	ND												
	35						ND													
	40-45	ND	ND	ND	ND	ND	ND	ND												
	55-60	ND	ND	ND	ND	ND		ND												
PCB-1254	2-4								ND			0.9	1.9	ND		ND	ND			
	8-10	ND	ND	0.33	ND	ND	ND	ND	ND	ND									ND	
	12-15	ND	ND	ND	ND	ND	ND	ND		ND					ND			ND		ND
	19										ND									
	30	ND	ND	ND	ND	ND	ND	ND												
	35						ND													
	40-45	ND	ND	ND	ND	ND	ND	ND												
	55-60	ND	ND	ND	ND	ND		ND												
PCB-1260	2-4								12.5			0.5	ND	ND		ND	ND			
	8-10	ND	ND	ND	ND	ND	ND	ND	ND	ND									ND	
	12-15	ND	ND	ND	ND	ND	ND	ND		ND					ND			ND		ND
	19										ND									
	30	ND	ND	ND	ND	ND	ND	ND												
	35						ND													
	40-45	ND	ND	ND	ND	ND	ND	ND												
	55-60	ND	ND	ND	ND	ND		ND												

Table 4.45. SWMU 145 Locations of Subsurface Soil Contaminants (Continued)

		RI Data							Historical Data											
Analysis	**Depth (ft)**	145-101	145-102	145-103	145-104	145-105	145-106	145-107	A10	A2	DG-029	NSD030	NST1S01	NST1S02	NST1S03	NST2S01	NST2S02	NST2S03	NST2S04	NST2S05
	55-60	ND	ND	ND	ND	ND		ND												
Radionuclides (pCi/g)																				
Americium-241	2-4								ND			0.22	ND	ND		ND	ND			
	8-10	ND	ND	ND	ND	ND	ND	ND	ND	ND									ND	
	11-15	ND	ND	ND	ND	ND	ND	ND		ND	ND				ND			1.956		ND
	19-25										ND									
	30-34	ND	ND	ND	ND	ND	ND	ND			ND									
	35-37						ND				ND									
	40-45	ND	ND	ND	ND	ND	ND	ND			ND									
	55-60	ND	ND	ND	ND	ND		ND												
Cesium-137	2-4								0.71			0.374	0.2593	0.1664		0.1243	0.5336			
	8-10	ND	ND	ND	ND	ND	ND	ND	0.086	ND									ND	
	11-15	ND	ND	ND	ND	ND	ND	ND		ND	ND				ND			1.057		ND
	19-25										ND									
	30-34	ND	ND	ND	ND	ND	ND	ND			ND									
	35-37						ND				ND									
	40-45	ND	ND	ND	ND	ND	ND	ND			ND									
	55-60	ND	ND	ND	ND	ND		ND												
Technetium-99	2-4								ND			153	65.9	82		67.6	23.6			
	8-10	ND	ND	ND	ND	ND	ND	ND	10.2	ND									ND	
	11-15	ND	ND	ND	ND	ND	ND	ND		ND	ND				12.9			281		15.6
	19-25										ND									
	30-34	ND	ND	ND	ND	ND	ND	ND			ND									
	35-37						ND				ND									
	40-45	ND	ND	ND	ND	ND	ND	ND			ND									
	55-60	ND	ND	ND	ND	1.83		ND												
Thorium-228	2-4								0.17			1.92	0.209	0.238		0.314	0.27			

Table 4.45. SWMU 145 Locations of Subsurface Soil Contaminants (Continued)

		RI Data							Historical Data											
Analysis	**Depth (ft)**	145-101	145-102	145-103	145-104	145-105	145-106	145-107	A10	A2	DG-029	NSD030	NST1S01	NST1S02	NST1S03	NST2S01	NST2S02	NST2S03	NST2S04	NST2S05
	8-10	0.248	0.388	0.376	0.382	0.459	0.4	0.339	0.359	0.461									0.269	
	11-15	0.28	0.398	0.368	0.208	0.518	0.202	0.351		0.412					0.321			0.79		0.364
	30	0.239	0.236	0.506	0.386	0.355	0.56	0.199												
	35						0.574													
	40-45	0.394	0.305	0.407	0.394	0.775	0.376	0.478												
	55-60	0.324	0.196	0.558	0.457			0.247												
Thorium-230	2-4								0.38			193	0.884	1.19		0.749	0.733			
	8-10	0.237	0.347	0.412	0.373	0.472	0.295	0.394	4.5	0.508									0.313	
	11-15	0.192	0.297	0.387	0.146	0.453	0.233	0.29		0.941					0.339			55.9		1.4
	30	ND	0.21	0.273	0.322	0.17	0.291	0.213												
	35						0.407													
	40-45	0.284	0.207	0.195	0.168	0.534	0.233	0.35												
	55-60	0.211	ND	0.353	0.225	ND		0.145												
Thorium-232	2-4								0.0935			2.16	0.1819	0.221		0.277	0.256			
	8-10	0.278	0.359	0.415	0.381	0.479	0.387	0.415	0.358	0.46									0.5376	
	11-15	0.296	0.389	0.374	ND	0.5	0.295	0.401		0.309					0.361			0.77		2.282
	30	0.254	0.299	0.357	0.359	0.36	0.482	0.318												
	35						0.537													
	40-45	0.501	0.41	0.383	0.385	0.727	0.532	0.449												
	55-60	0.356	0.182	0.522	0.421	0.1		0.276												
Uranium	2-4								10.6			5.84	77.1	33.7		12	81.2			
	8-10	ND	ND	ND	ND	ND	ND	ND	593										5.4	
	12-15	ND	ND	ND	ND	ND	ND	ND										33.9		17.9
	30	ND	ND	ND	ND	ND	ND	ND												
	35						ND													
	40-45	ND	ND	ND	ND	0.795	ND	ND												
	55-60	ND	ND	ND	ND	ND		ND												

Table 4.45. SWMU 145 Locations of Subsurface Soil Contaminants (Continued)

		RI Data							Historical Data											
Analysis	**Depth (ft)**	145-101	145-102	145-103	145-104	145-105	145-106	145-107	A10	A2	DG-029	NSD030	NST1S01	NST1S02	NST1S03	NST2S01	NST2S02	NST2S03	NST2S04	NST2S05
Uranium-233/234	2-4								4.7											
	8-10								0.81	0.66										
	11-15									1.1										
Uranium-234	2-4								4.5			2.54	10.1	6.45		3.64	33			
	8-10	ND	0.177	0.184	0.128	ND	ND	ND	254	ND									1.21	
	11-15	ND	ND	0.15	ND	0.14	ND	ND		ND					0.55			14.2		6.48
	30	ND	0.152	ND	ND	0.156	0.189	0.172												
	35						0.227													
	40-45	0.17	0.209	ND	ND	0.405	0.143	0.178												
	55-60	ND	ND	0.309	0.148	ND		ND												
Uranium-235	2-4								0.32			0.157	0.67	0.25		0.18	2.2			
	8-10	ND	ND	ND	ND	ND	ND	ND	0.047	0.049									0.045	
	11-15	ND	ND	ND	ND	ND	ND	ND		0.081	ND				0.025			0.69		0.052
	19-25										ND									
	30-34	ND	ND	ND	ND	ND	ND	ND			ND									
	35-37						ND				ND									
	40-45	ND	ND	ND	ND	ND	ND	ND			ND									
	55-60	ND	ND	ND	ND	ND		ND												
Uranium-238	2-4								6.6			3.14	65.9	29.7		8.11	104			
	8-10	ND	0.123	0.192	0.142	0.129	ND	ND	326	0.63									4.11	
	11-15	ND	ND	0.142	ND	0.176	ND	0.118		1					0.66			19.8		11.1
	30	ND	0.127	ND	ND	ND	0.153	0.16												
	35						0.23													
	40-45	ND	0.17	ND	ND	0.378	ND	0.194												
	55-60	0.125	ND	0.238	0.144	ND		ND												

ND = not detected above screening levels
Blank cells indicate interval was not sampled for the specified analysis. Maximum value is shown for each depth interval.

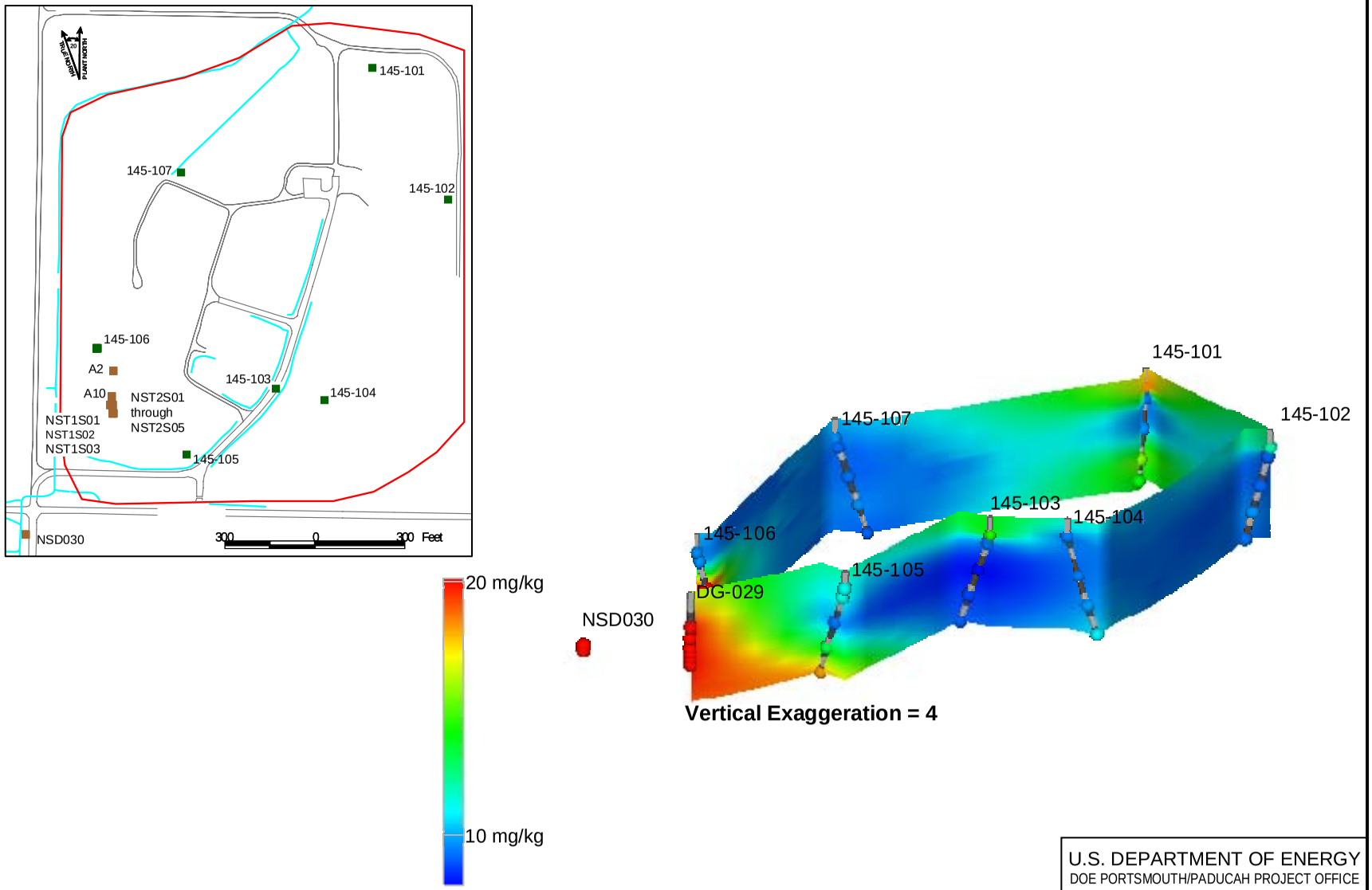

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Figure 4.62. SWMU 145 Antimony in Soil (Looking North)

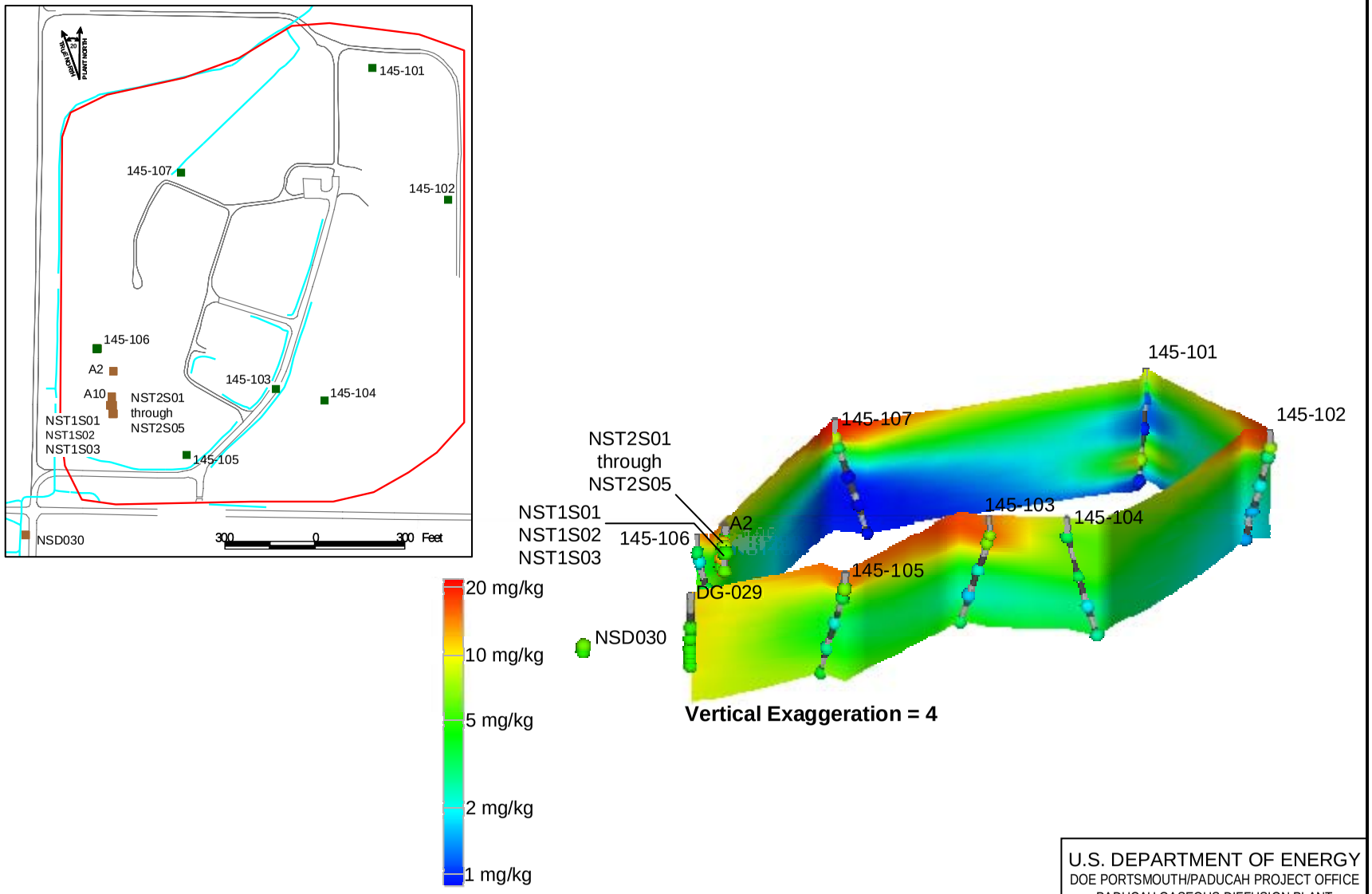

Figure 4.63. SWMU 145 Arsenic in Soil (Looking North)

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Radionuclides in subsurface soils at SWMU 145 include americium-241, cesium-137, technetium-99, thorium isotopes, and uranium isotopes. Most of these samples derive from investigation of the buried reach of the NSDD. Figure 4.64 shows the uranium distribution at SWMU 145. This figure shows the elevated concentrations of uranium in shallow samples collected near the previous location of the NSDD. Figure 4.65 presents the thorium-228 distribution in soils at SWMU 145. Thorium is widely distributed (above NALs) throughout the entire thickness of the UCRS, but localized hot spots occur near the buried reach of the NSDD. The highest detected activity encountered in this RI was from angled boring 145-105 at a depth of 40 to 45 ft bgs.

4.10.2 SWMU 145 Groundwater

The collection of UCRS groundwater samples was attempted at each of the seven angled borings installed at SWMU 145; however, sufficient groundwater was not available for sampling. Historical data from seven MWs in the area were reviewed to identify the UCRS contaminants listed in Table 4.46. The UCRS wells with groundwater data for SWMU 145 (for the period 1995 through 2006) were MW180, MW182, MW371, MW386, MW390, MW393, and MW396.

Table 4.46. SWMU 145 UCRS Groundwater Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection	
	Historical Data	RI Data		Above MCL	Above Child Resident NAL
Inorganics (mg/L)					
Arsenic	0.0189	N/A[b]	42/68	2/68	42/68
Iron	33.6	N/A	115/118	N/A	98/118
Iron, Dissolved	28.1	N/A	3/4	N/A	1/4
Manganese	4.53	N/A	96/112	N/A	79/112
Manganese, Dissolved	3.75	N/A	2/2	N/A	2/2
Nickel	0.595	N/A	23/118	N/A	10/118
Nickel, Dissolved	0.442	N/A	2/4	N/A	1/4
Uranium	0.6	N/A	58/185	27/185	58/185
Uranium, Dissolved	0.51	N/A	12/72	4/72	5/72
Vanadium	0.038	N/A	3/111	N/A	3/111
Organics – Volatiles (mg/L)					
Chloroform	0.003	N/A	2/81	N/A	2/81
Radionuclides (pCi/L)					
Radon-222	519	N/A	2/2	N/A	2/2
Uranium-234	840	N/A	3/7	N/A	3/7
Uranium-238	1,270	N/A	7/10	N/A	5/10

[a] Frequency of detection is the number of detections of an analyte per number (includes analyses of regular and duplicate samples).
[b] N/A = not applicable
MCL = maximum contaminant level NAL = no action level RI = remedial investigation

Screening of the SWMU 145 analyses determined six metals that exceed contaminant criteria in UCRS groundwater. Iron and manganese were common groundwater contaminants. Arsenic and uranium accounted for most of the other metal exceedances.

The VOC chloroform (in a sample from MW386) was the only UCRS groundwater organic contaminant to exceed screening criteria. Analyses detected TCE in samples from six locations; however, the maximum detected result (0.002 mg/L or 2 μg/L) was less than the screening level. PCB-1260 was detected at MW371 at 0.00007 mg/L (0.07 μg/L).

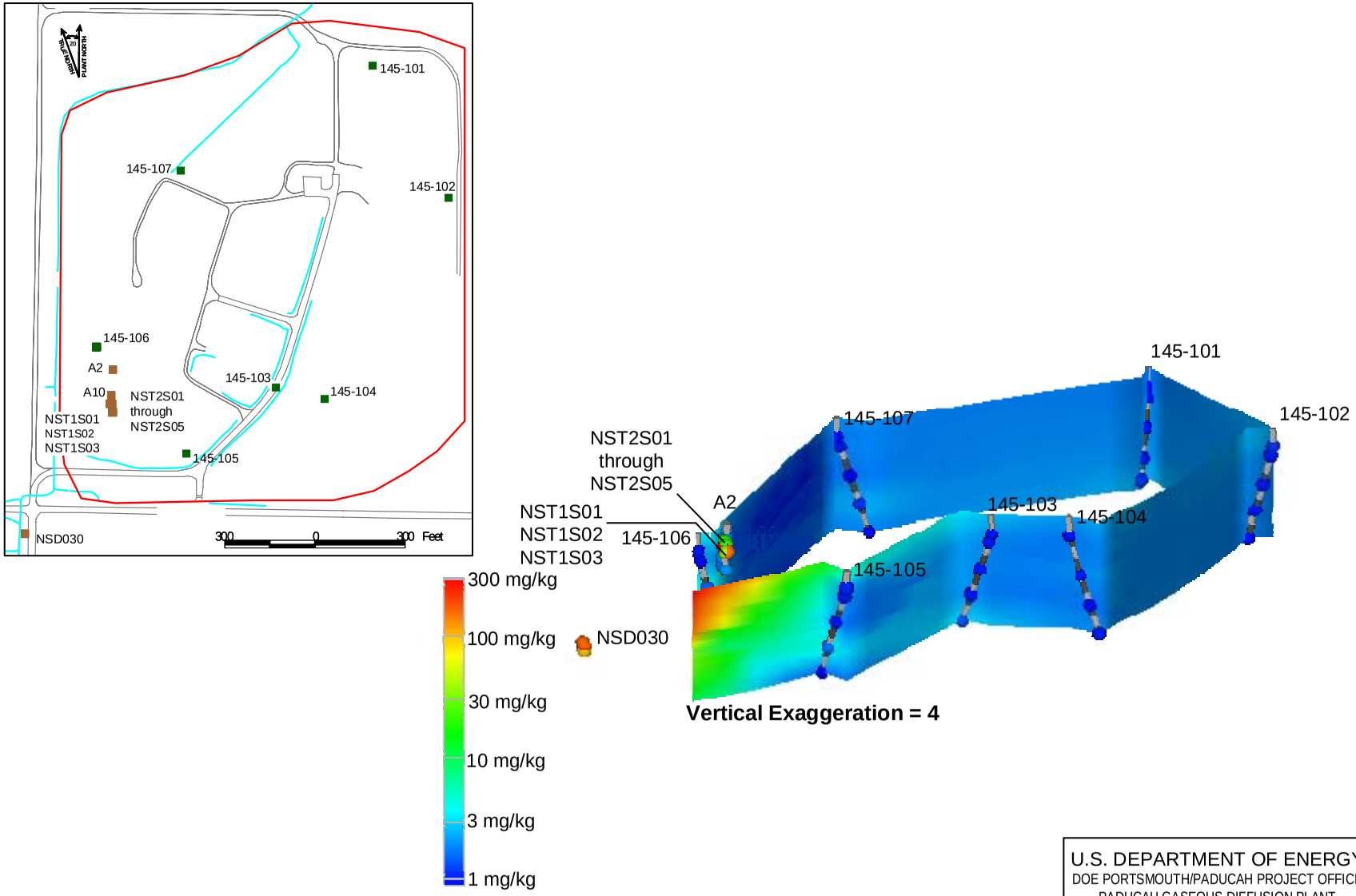

Figure 4.64. SWMU 145 Uranium in Soil (Looking North)

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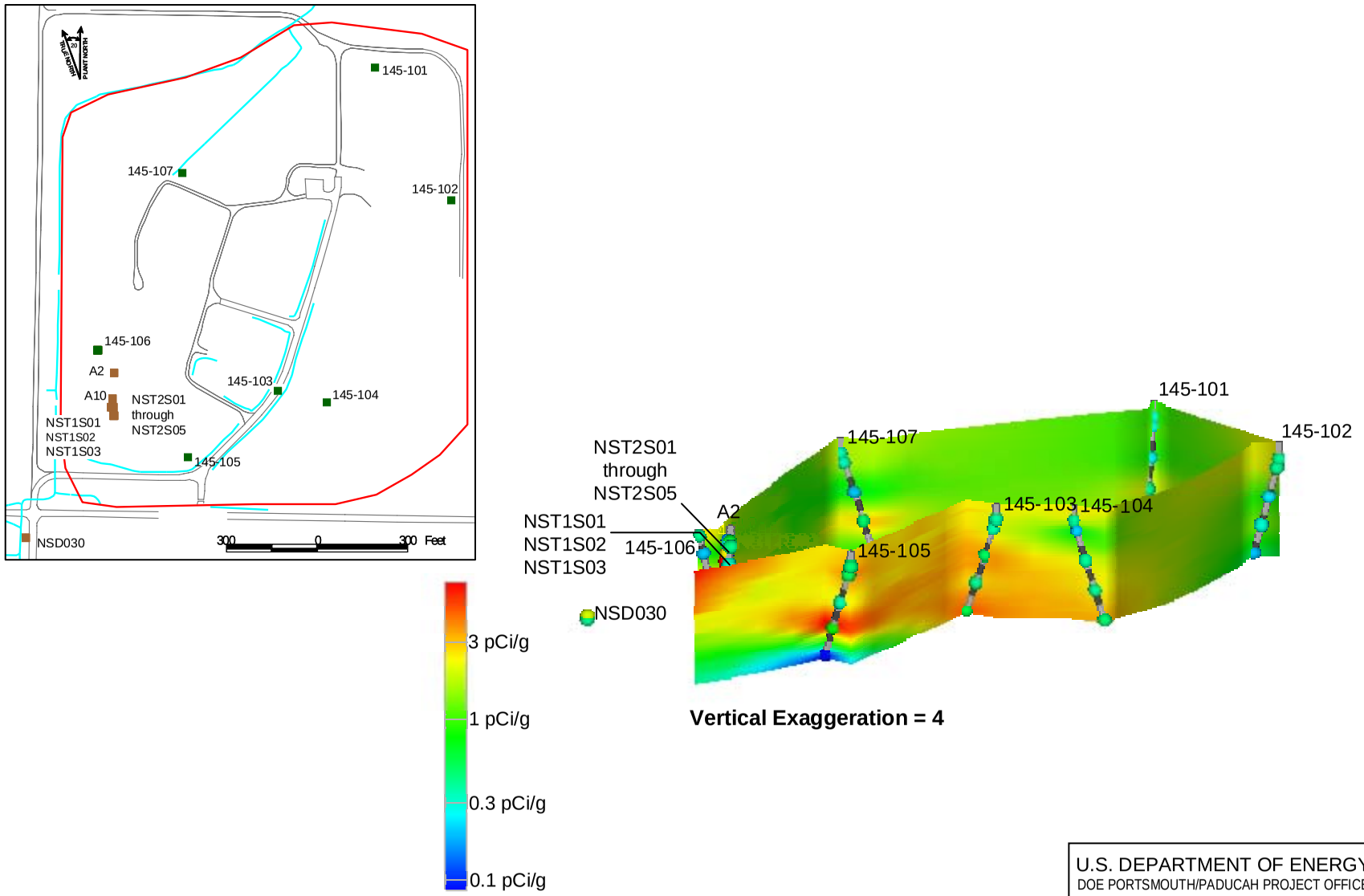

Figure 4.65. SWMU 145 ^{228}Th in Soil (Looking North)

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There is documentation of strontium and cesium at PGDP: *Study of Plutonium and Fission Products*, KYL-20, July 1995, identified cesium-137 and strontium-89; Historical Impact of Reactor Tails on the Paducah Cascade, KY/L-1239, March 1984, identified cesium-137 and strontium-90 in feed plant ash.

While the quantity of strontiuim-90 that came to Paducah from sites (Hanford, Savannah River, and others) is a trace quantity, it has been seen in samples collected from C-410 ash. It is logical to assume that wherever cesium-137 was found, strontium-90 would be found as well. Cesium-137 and strontium-90 have half-lives of 30.2 years and 28.8 years, respectively, and still are being found at the site, while other fission products with shorter half-lives have since decayed.

Uranium contamination in the UCRS groundwater was found primarily at location MW182. Samples from MW182 accounted for most of the detections of uranium-234above screening levels, as well as one of the detections of uranium-238 as a groundwater contaminant. The isotope uranium-238 also was detected above screening levels at location MW180.

RGA and McNairy groundwater samples were not collected at SWMU 145 as part of this RI. Historical data for the period 1995 through 2006 were reviewed for RGA and McNairy groundwater from 25 RGA MWs in the area and one temporary boring that sampled the McNairy Formation to identify the contaminants listed in Table 4.47.

Table 4.47. SWMU 145 RGA Groundwater Contaminants

Analysis	Maximum Result		Frequency of Detection[a]	Frequency of Detection		
	Historical Data	RI Data		Above Back-ground	Above MCL	Above Child Resident NAL
Inorganics (mg/L)						
Arsenic	0.0246	N/A[b]	173/232	34/232	16/232	173/232
Chromium	5.4	N/A	299/827	161/827	186/827	20/827
Iron	117	N/A	606/809	141/809	N/A	453/809
Manganese	36.5	N/A	374/475	180/475	N/A	265/475
Manganese, Dissolved	0.246	N/A	34/36	7/36	N/A	17/36
Molybdenum	0.117	N/A	115/450	8/450	N/A	57/450
Nickel	1.89	N/A	357/810	31/810	N/A	288/810
Nickel, Dissolved	0.5	N/A	23/52	2/52	N/A	23/52
Vanadium	0.219	N/A	81/812	3/812	N/A	74/812
Vanadium, Dissolved	0.142	N/A	43/63	2/63	N/A	43/63
Organics – Volatiles (mg/L)						
Chloroform	0.004	N/A	11/222	N/A	N/A	11/222
TCE	0.033	N/A	470/820	N/A	219/820	386/820
Organics-Pesticides and PCBs (mg/L)						
PCB, Total	0.00787	N/A	25/149	N/A	8/149	25/149
PCB-1016	0.001184	N/A	16/164	N/A	3/164	16/164
PCB-1242	0.00787	N/A	10/164	N/A	5/164	9/164
Radionuclides (pCi/L)						
Strontium-90	11.2	N/A	2/408	N/A	2/408	2/408

[a] Frequency of detection is the number of detections of an analyte per number of analyses (includes regular and duplicate samples).
[b] N/A = not applicable

Arsenic, chromium, iron, and manganese were detected above background levels in RGA groundwater at a frequency of over 10%. The presence of TCE in the RGA was the subject of a summer 2004 SI of the SWMU 145 area (DOE 2006c). This SI postulated the presence of a small UCRS TCE source in SWMU 145 (Figure 4.66). The assumed location of the source was based on TCE concentrations in the upper,

middle, and lower RGA from established MWs and temporary borings. RGA groundwater flow directions were also used to approximate the general location of a UCRS source that would result in the observed RGA TCE distribution observed in the borings and wells. Because of the low concentrations, this source is not considered to be a TCE DNAPL source. Seven RGA MWS of the C-746-S&T Landfills have produced samples with PCB contamination. The highest detected levels have been 0.001 mg/L PCB-1016 and 0.008 mg/L PCB-1242.

Table 4.48 shows the locations of all SWMU 145 groundwater contaminants.

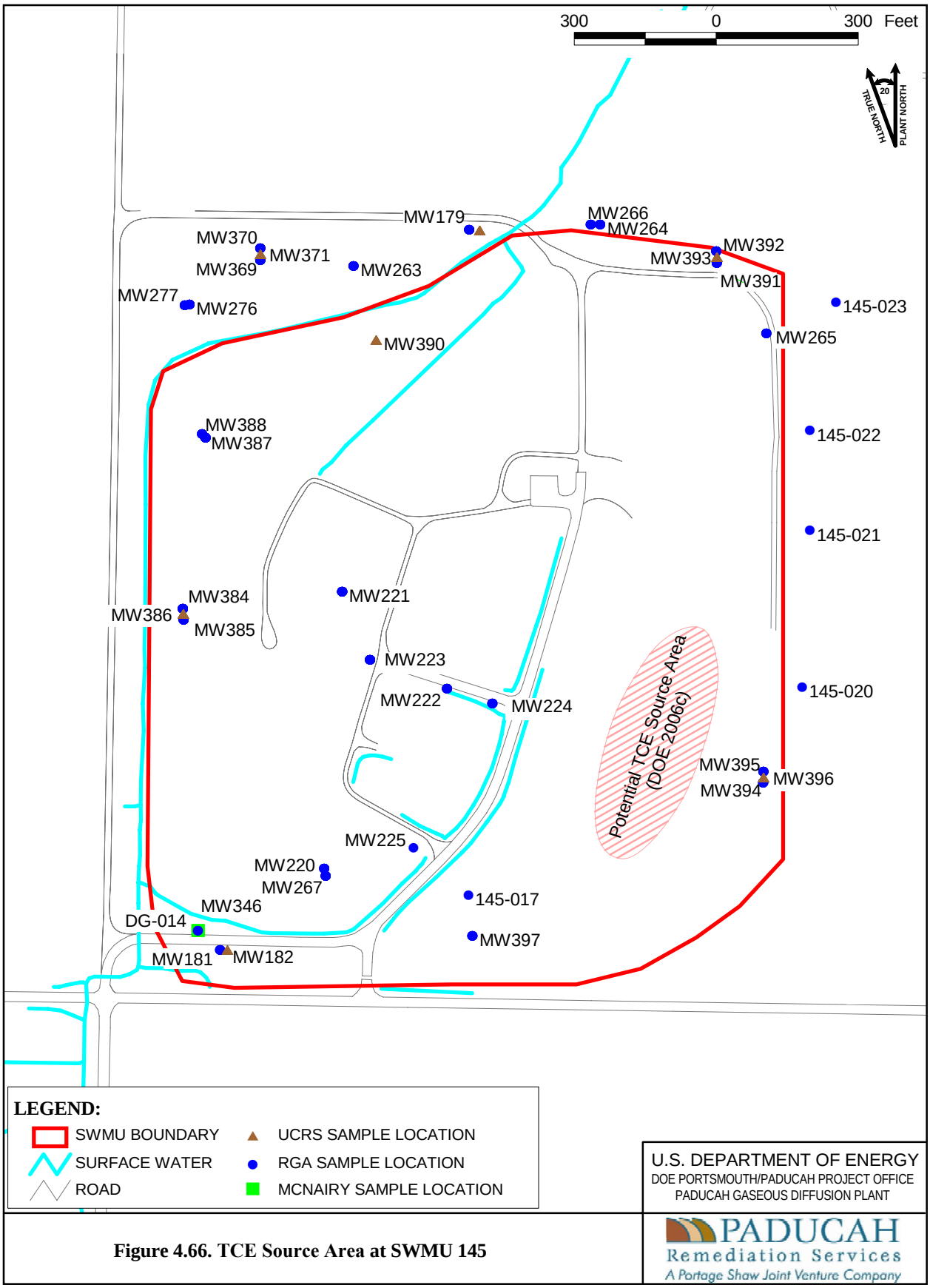

Figure 4.66. TCE Source Area at SWMU 145

Figure No. \BGOU\d2-ri swmu145.apr
DATE 1-15-09

Table 4.48. SWMU 145 Locations of Groundwater Contaminants

Unit	Depth (ft)	Analysis	MW180	MW182	MW371	MW386	MW390	MW393	MW396
UCRS	20	***Inorganics (mg/L)***							
		Arsenic		0.01					
		Iron		26.9					
		Iron, Dissolved		28.1					
		Magnesium		36.1					
		Magnesium, Dissolved		33.8					
		Manganese		4.53					
		Manganese, Dissolved		3.75					
		Nickel		0.102					
		Nickel, Dissolved		ND					
		Uranium		0.6					
		Uranium, Dissolved		0.51					
		Vanadium		0.01					
		Organics - Volatiles (mg/L)							
		Chloroform		ND					
		Radionuclides (pCi/L)							
		Radon-222		351					
		Uranium-234		840					
		Uranium-238		1270					
	27-32	***Inorganics (mg/L)***							
		Arsenic			0.00112	0.00271			
		Iron	11.3		5.81	11.6			
		Iron, Dissolved	1.29						
		Magnesium	13.5		12.9	12.4			
		Magnesium, Dissolved	12.3						
		Manganese	0.352			1.02			
		Manganese			0.074				
		Manganese, Dissolved	0.193						
		Nickel	0.595		0.0124	0.0108			
		Nickel, Dissolved	0.442						
		Uranium	0.00522		0.027	0.00127			
		Uranium, Dissolved	0.002		0.00134	ND			
		Vanadium			ND	ND			
		Organics - Volatiles (mg/L)							
		Chloroform	ND		ND	0.003			
		Radionuclides (pCi/L)							
		Radon-222	519						
		Uranium-234	1.21						
		Uranium-238	1.01						

Unit	Depth (ft)	Analysis	MW180	MW182	MW371	MW386	MW390	MW393	MW396
UCRS	37-38	***Inorganics (mg/L)***							
		Arsenic					0.0189	0.007	
		Iron					33.6	15.8	
		Manganese					1.44	0.217	
		Nickel					0.146	ND	
		Uranium					0.001	0.002	
		Uranium, Dissolved					ND	0.002	
		Vanadium					0.038	ND	
		Organics - Volatiles (mg/L)							
		Chloroform					ND	ND	
	44	***Inorganics (mg/L)***							
		Arsenic							0.00378
		Iron							11.9
		Magnesium							20.4
		Manganese							1.132
		Nickel							0.00573
		Uranium							0.002
		Uranium, Dissolved							0.003
		Vanadium							ND
		Organics - Volatiles (mg/L)							
		Chloroform							ND

Table 4.48. SWMU 145 Locations of Groundwater Contaminants (Continued)

Unit	Depth (ft)	Analysis	DG-014	MW179	MW181	MW220	MW221	MW222	MW223	MW224	MW263	MW264	MW265	MW266	MW267	MW276	MW277	MW369	MW370	MW384	MW385	MW387	MW388	MW391	MW392	MW394	MW395	MW397
RGA	45	***Organics - Volatiles (mg/L)***																										
		TCE	0.0006																									
	50-52	***Inorganics (mg/L)***																										
		Arsenic																0.0138										
		Chromium																ND										
		Iron																21.5										
		Manganese																0.867										
		Molybdenum																ND										
		Nickel																0.0168										
		Vanadium																0.027										
		Organics - Pesticides and PCBs (mg/L)																										
		PCB, Total																0.00115										
		PCB-1016																0.000605										
		PCB-1242																0.00115										
		Organics - Volatiles (mg/L)																										
		Chloroform																0.001										
		TCE	0.0005															0.016										
		Radionuclides (pCi/L)																										
		Strontium-90																ND										
	55-57	***Inorganics (mg/L)***																										
		Arsenic			0.0026																	0.00416						
		Chromium		0.06	3.18							0.03										ND						
		Iron		2.25	46.2							5.8										5.46						
		Manganese		0.009	2.97							0.268										0.72						
		Manganese, Dissolved		0.009	0.041							0.246																
		Molybdenum		0.03	0.03							0.03										0.00282						
		Nickel		0.04	1.89							0.04										ND						
		Nickel, Dissolved		0.04	0.14							0.04																
		Vanadium		0.204	0.105							0.113										ND						
		Vanadium, Dissolved		0.135	0.081							0.08																
		Organics - Pesticides and PCBs (mg/L)																										
		PCB, Total		ND								ND										ND						
		PCB-1016		ND								ND										ND						
		PCB-1242		ND								ND										ND						
		Organics - Volatiles (mg/L)																										
		Chloroform		ND	0.000076							0.000061										ND						
		TCE	0.00029	0.009	0.001							0.008										0.007						
		Radionuclides (pCi/L)																										
		Strontium-90		ND								ND										ND						
	58-60	***Inorganics (mg/L)***																										
		Arsenic														0.01				0.0246								
		Chromium									3.44					2.24				ND								
		Iron									9.12					20.2				17.3								
		Manganese									0.166					0.079				3.67								
		Manganese, Dissolved									0.16																	
		Molybdenum									0.03					0.096				ND								
		Nickel									0.14					0.359				ND								
		Nickel, Dissolved									0.04																	
		Vanadium									0.155					0.03				ND								
		Vanadium, Dissolved									0.107					ND												
		Organics - Pesticides and PCBs (mg/L)																										
		PCB, Total									ND					ND				ND								
		PCB-1016									ND					ND				ND								
		PCB-1242									ND					ND				ND								

Table 4.48. SWMU 145 Locations of Groundwater Contaminants (Continued)

Unit	Depth (ft)	Analysis	DG-014	MW179	MW181	MW220	MW221	MW222	MW223	MW224	MW263	MW264	MW265	MW266	MW267	MW276	MW277	MW369	MW370	MW384	MW385	MW387	MW388	MW391	MW392	MW394	MW395	MW397
RGA	58-60	***Organics - Volatiles (mg/L)***																										
		Chloroform									0.000063									ND								
		TCE	0.00023								0.023					0.029				0.002								
		Radionuclides (pCi/L)																										
		Strontium-90									ND					ND				11.2								
	65-68	***Inorganics (mg/L)***																										
		Arsenic																						0.00267				
		Chromium																						ND				
		Iron																						28.6				
		Manganese																						0.927				
		Molybdenum																						ND				
		Nickel																						0.00833				
		Vanadium																						ND				
		Organics - Pesticides and PCBs (mg/L)																										
		PCB, Total																						ND				
		PCB-1016																						ND				
		PCB-1242																						ND				
		Organics - Volatiles (mg/L)																										
		Chloroform																						ND				
		TCE	ND																					0.019				
		Radionuclides (pCi/L)																										
		Strontium-90																						ND				
	69-72	***Inorganics (mg/L)***																										
		Arsenic				0.00198													0.0146				0.00228					
		Chromium				0.719							1.98				2.12		ND				0.0103					
		Iron				11.1							11.9				7.89		15.8				7.29					
		Manganese				2.54							0.204				0.184		2.51				0.096					
		Manganese, Dissolved				0.052							0.19				0.05											
		Molybdenum				0.03							0.07				0.04		ND				ND					
		Nickel				1.05							0.53				1.27		0.0264				0.00568					
		Nickel, Dissolved				0.204							0.5				0.46											
		Vanadium				0.081							0.077				ND		0.035				ND					
		Vanadium, Dissolved				0.059							0.058				ND											
		Organics - Pesticides and PCBs (mg/L)																										
		PCB, Total				0.00078													0.000188				ND					
		PCB-1016				ND											ND		0.000188				ND					
		PCB-1242				0.00078											ND		ND				ND					
		Organics - Volatiles (mg/L)																										
		Chloroform				ND							0.000049				ND		ND				ND					
		TCE	ND			0.000069							0.028				0.033		0.019				0.002					
		Radionuclides (pCi/L)																										
		Strontium-90				ND													ND				ND					
	75-78	***Inorganics (mg/L)***																										
		Arsenic						0.00248													0.00249					0.00285		
		Chromium						0.144						3.04							ND					ND		
		Iron						107						17.6							5.41					1.81		
		Manganese						23.2						0.08							0.859					0.542		
		Manganese, Dissolved						0.049						0.043														
		Molybdenum						0.03						0.03							0.00272					ND		
		Nickel						0.883						0.433							0.00611					ND		
		Nickel, Dissolved						0.04						0.04														
		Inorganics (mg/L)																										
		Vanadium						0.082						0.219							ND					ND		
		Vanadium, Dissolved						0.045						0.142														

Table 4.48. SWMU 145 Locations of Groundwater Contaminants (Continued)

Unit	Depth (ft)	Analysis	DG-014	MW179	MW181	MW220	MW221	MW222	MW223	MW224	MW263	MW264	MW265	MW266	MW267	MW276	MW277	MW369	MW370	MW384	MW385	MW387	MW388	MW391	MW392	MW394	MW395	MW397
RGA	75-78	***Organics - Pesticides and PCBs (mg/L)***																										
		PCB, Total						0.0031						ND							ND					ND		
		PCB-1016						0.001167						ND							ND					ND		
		PCB-1242						0.0031						ND							ND					ND		
		Organics - Volatiles (mg/L)																										
		Chloroform						0.000073						0.000049							ND					ND		
		TCE	ND					0.00039						0.016							ND					0.021		
		Radionuclides (pCi/L)																										
		Strontium-90						ND						ND							ND					ND		
	82-85	***Inorganics (mg/L)***																										
		Arsenic					0.00218		0.00216	0.00186																	0.00257	
		Chromium					0.277		1.41	0.03					5.4												0.075	
		Iron					2.16		117	3.61					21												1.33	
		Manganese					0.818		36.5	6.32					0.056												0.629	
		Manganese, Dissolved					0.012		0.039	0.038					0.058													
		Molybdenum					0.03		0.089	0.03					0.117												0.00609	
		Nickel					0.68		1.48	0.144					0.222												0.029	
		Nickel, Dissolved					0.05		0.111	0.04					0.04													
		Vanadium					0.096		0.098	0.119					0.081												ND	
		Vanadium, Dissolved					0.072		0.059	0.072					0.058													
		Organics - Pesticides and PCBs (mg/L)																										
		PCB, Total					0.00787		0.00161	0.000359					ND												ND	
		PCB-1016					ND		0.001184	0.000359					ND												ND	
		PCB-1242					0.00787		0.00161	0.00024					ND												ND	
		Organics - Volatiles (mg/L)																										
		Chloroform					0.000073		ND	0.000058					ND												ND	
		TCE					0.007		0.001	0.006					0.000065												0.014	
		Radionuclides (pCi/L)																										
		Strontium-90					ND		ND	ND					ND												ND	
	91-95	***Inorganics (mg/L)***																										
		Arsenic																								0.00368		0.00227
		Chromium																								ND		ND
		Iron																								9.8		1.58
		Manganese																								4.59		0.466
		Molybdenum																								0.00187		ND
		Nickel																								0.0107		0.00502
		Vanadium																								ND		ND
		Organics - Pesticides and PCBs (mg/L)																										
		PCB, Total																								ND		ND
		PCB-1016																								ND		ND
		PCB-1242																								ND		ND
		Organics - Volatiles (mg/L)																										
		Chloroform																								0.004		ND
		TCE																								0.014		ND
		Radionuclides (pCi/L)																										
		Strontium-90																								ND		ND

ND = not detected above screening level

Blank cells indicate interval was not sampled for the specified analysis. The maximum value is shown for each depth interval at each location.

5. FATE AND TRANSPORT

This chapter provides an overview of the fate and transport of the primary analytes for the BGOU. (Appendix E, Section E.3 documents the methods and results of fate and transport modeling performed for the BGOU RI.) The sources modeled are SWMU 2, SWMU 3, SWMU 4, SWMU 5, SWMU 6, SWMU 7, SWMU 30, and SWMU 145. Two pathways were considered in the transport modeling analyses: (1) dissolved-phase transport through the aquifer and (2) vapor transport to a residential basement.

5.1 CONCEPTUAL MODEL

The sources of contamination to the RGA considered in this report are the waste disposal areas in the BGOU SWMUs. Releases from these SWMUs have impacted soils below or adjacent to the source zones and, through vertical infiltration in soil, these sources have the potential to contaminate the groundwater underlying these sources. Subsequently, contaminated groundwater could migrate to the points of exposure (POEs). The potential POEs for the BGOU SWMUs were identified as the SWMU boundary, plant boundary, property boundary, surface seeps at Little Bayou Creek (hereafter referred to as the Little Bayou seeps), and the Ohio River. [Modeling assessed the Little Bayou seeps and the Ohio River as the locations to assess risk to the groundwater user through a hypothetical well, consistent with the Risk Methods Document (DOE 2001). Modeling also assessed the SWMU boundary.] Not all SWMUs have transport pathways to all of the POEs. For example, SWMU 145 is located outside of the plant boundary and does not contribute to the Little Bayou seeps. SWMUs 3, 6, 7, and 30 were determined to be the only SWMUs contributing to the Little Bayou seeps POE. SWMUs 2, 4, and 5 have POEs at the plant boundary, property boundary, and the Ohio River. Figure 5.1 shows the location of the BGOU SWMUs, plant boundary, property boundary, Little Bayou seeps, Ohio River, and contaminant flow particle tracks from the SWMUs. The uncertainty in the flow paths is discussed in Section 5.5.4.

Contaminant migration could have impacted three HUs underlying the source zones at the BGOU SWMUs. These units, which control the flow of shallow groundwater and contaminant migration, are as follows, in descending depth order:

- UCRS—approximately 60 ft of silt and clay with horizons of sand and gravel;
- RGA—approximately 40 ft of gravel and sand deposits that overlie the McNairy Formation; and
- McNairy Formation—approximately 225 ft of a silty and clayey sand that forms a lower confining unit to the RGA.

Previous work has shown that groundwater flow in the UCRS is primarily vertical to the RGA and then lateral toward the Ohio River and that groundwater flow in the McNairy Formation (both vertical and lateral) is significantly slower than that in the RGA. The primary contaminant pathway for the site-related contaminants is vertical migration through the UCRS followed by lateral migration in the RGA. The RGA discharges to the Ohio River and, for a limited number of SWMUs, to the Little Bayou seeps. Section 3 provides a detailed description of the geology and hydrogeology at PGDP.

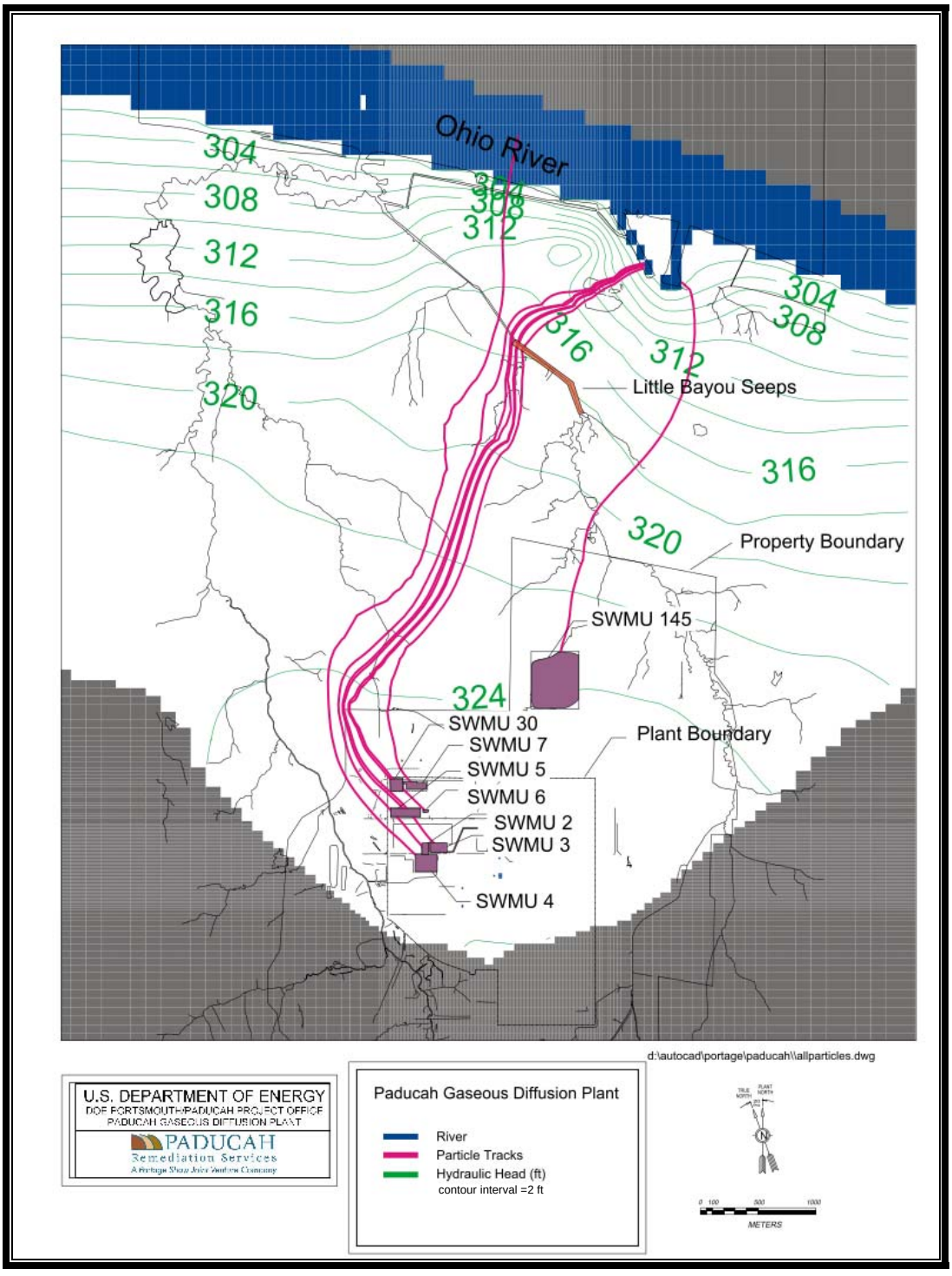

Figure 5.1. Location of the BGOU SWMUs and POEs

5.2 ANALYTE SELECTION AND CHEMICAL PROPERTIES

5.2.1 ANALYTE SELECTION

Soil results were screened prior to their use in modeling to determine groundwater analytes for source term development. The following outlines the review and screening process used prior to establishing the analytes for use in modeling:

- *Units of Reported Results.* 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.

- *Detection Status.* Each result was coded either as a detect or nondetect based on the data qualifier codes present in the database. Results assigned a "U" or "UJ" qualifier were considered nondetects. This coding subsequently was used to calculate the frequency of detection for each constituent.

- *Frequency of Detection.* Those constituents detected in less than 5% of the samples were not retained because their infrequency of detection prevents development of a usable source term.

- *Essential Nutrients.* Results for the seven essential nutrients were removed from the data sets. They are calcium, chloride, iodine, magnesium, potassium, sodium, and phosphorous.

- *Protactinium-234m, potassium-40, and thorium-234.* Results for these isotopes were not retained for source term development. Protactinium-234m was not retained because it is a short-lived daughter of uranium-238 and its presence in the source term is reflected in the uranium-238 results. Potassium-40 and thorium-234 were not retained because the former is naturally occurring and not a site-related contaminant, and the latter is a short-lived isotope not useful in source term development (DOE 2001).

Analytes retained under current conditions are presented for each SWMU in Tables E3.1 through E3.8. The maximum detected soil concentrations (surface to 60 ft bgs) are presented by analyte and by SWMU, with a comparison to the child resident soil screening levels[1] (SSLs) with a dilution attenuation factor (DAF)=1. Those analytes with a maximum concentration greater than their respective SSLs then were compared to soil/sediment child resident NALs. Constituents greater than both the SSL and NAL were retained as analytes for groundwater modeling. The screening values used may be found in Tables A.7 and A.17 of the Risk Methods Document (2001a). Exceptions to this are TCE, technetium-99, and uranium isotopes, which were retained in all SWMUs, as they are significant risk contributors or known to be part of the facility's process history.

Following this review and screening process, the analytes retained then were modeled as described below and in Appendix E of the RI Report. Modeled results were used in the BRA.

5.2.2 CHEMICAL PROPERTIES

Table 5.1 lists the analytes identified for fate and transport assessment along with the parameter values chosen to represent these contaminants in the Seasonal Soil Compartment Model (SESOIL) and Analytical Transient 1-,2-,3- Dimensional (AT123D) models.

[1] SSLs are risk-based soil concentrations considered to be protective of groundwater (DOE 2001).

Table 5.1. Burial Ground Analytes for the Groundwater Pathway and Properties

Analyte	Mol. Wt. (MW) (g/mol)	Solubility in water (mg/L)	Diffusion in air (cm^2/s)	Diffusion in water (m^2/hr)	Henry's Constant (atm.m3/mol)	Koc (L/kg)	Kd[a] (L/kg)	Half Life (years)
Acenaphthene	154	4.20E+00	4.00E-02	2.77E-06	1.60E-04	4.90E+03	3.9	Infinite
Anthracene	178.24	4.30E-02	3.20E-02	2.79E-06	5.55E-05	2.04E+04	16.3	Infinite
Antimony	121.75	1.00E+07	NA	3.60E-07	NA	NA	45	Infinite
PCB-1254	327	7.00E-02	1.56E-02	1.80E-06	3.40E-04	4.25E+04	34	Infinite
PCB-1260	375.7	2.70E-02	1.38E-02	1.56E-06	7.40E-05	2.07E+05	165.6	Infinite
Arsenic	74.92	1.00E+07	NA	3.60E-07	NA	NA	29	Infinite
Benzo(a)pyrene	252.32	1.62E-03	4.30E-02	3.24E-06	1.13E-06	9.69E+05	772	Infinite
Beryllium	9.01	1.00E+07	NA	3.60E-07	NA	NA	250	Infinite
Cadmium	112.41	1.00E+07	NA	3.60E-07	NA	NA	75	Infinite
cis-1,2-DCE	96.94	3.50E+03	7.00E-02	4.07E-06	4.08E-03	3.55E+01	0.028	Infinite
1,1-DCE	97	2.25E+03	9.00E-02	3.74E-06	2.61E-02	6.50E+01	0.013	Infinite
Dibenzo(a,h)-anthracene	278.33	2.50E-03	2.00E-02	1.86E-06	1.47E-08	1.78E+06	1,424	Infinite
Fluorathene	202.26	2.06E-01	3.00E-02	2.29E-06	1.61E-05	4.91E+04	39.3	Infinite
Fluorene	166	1.90E+00	6.10E-02	2.84E-06	7.70E-05	7.90E+03	6.3	Infinite
Manganese	54.94	1.00E+07	NA	3.60E-07	NA	NA	65	Infinite
Mercury	200.59	6.00E-02	3.07E-02	2.27E-06	2.44E-02	NA	52	Infinite
Molybdenum	95.9	1.00E+07	NA	3.60E-07	NA	NA	10	Infinite
Naphthalene	128.16	3.10E+01	5.90E-02	2.70E-06	4.83E-04	1.19E+03	0.95	Infinite
Nickel	58.69	1.00E+07	NA	3.60E-07	NA	NA	300	Infinite
Plutonium-239	239	1.00E+07	NA	3.60E-07	NA	NA	550	2.41E+04
Pyrene	202.3	1.35E-01	2.72E-02	2.61E-06	1.10E-05	6.80E+04	54.4	Infinite
Selenium	80.98	1.00E+07	NA	3.60E-07	NA	NA	5	Infinite
Technetium-99	99	1.00E+07	NA	3.60E-07	NA	NA	0.2	2.13E+05
Tetrachloroethene	165.8	2.00E+02	7.20E-02	2.95E-06	1.84E-02	2.65E+02	0.053	Infinite
TCE	131	1.10E+03	8.00E-02	3.28E-06	1.03E-02	9.40E+01	0.0752	2.66E+01[b]
Uranium-234	234	1.00E+07	NA	3.60E-07	NA	NA	66.8	2.44E+05
Uranium-235	235	1.00E+07	NA	3.60E-07	NA	NA	66.8	7.04E+08
Uranium-238	238	1.00E+07	NA	3.60E-07	NA	NA	66.8	4.47E+09
Uranium	238	1.00E+07	NA	3.60E-07	NA	NA	66.8	4.47E+09
Vanadium	50.94	1.00E+07	NA	3.60E-07	NA	NA	1,000	Infinite
Vinyl Chloride	63	2.76E+03	1.10E-01	4.43E-07	2.70E-02	1.88E+01	0.0152	Infinite
Zinc	67.41	1.00E+07	NA	3.60E-07	NA	NA	62	Infinite

[a] The Kd of an organic compound depends on the soil's organic content (foc) and compound's organic partition coefficient (Koc). Kd values presented for organic compounds are for UCRS soils (with foc value of 0.08%) only. K_ds used in AT123D are different due to the foc of 0.02% in the RGA.

[b] The 26.6 year half-life for TCE is applied to the UCRS only. The TCE half-life is still being researched by a working group and results will be utilized in the FS.

In general, all contaminants were assumed not to degrade in the environment (i.e., infinite half-life), except for radionuclides and TCE. Table 5.1 lists the half-lives assumed in the transport analyses for the analytes.

Although radionuclides behave chemically as metals, the radioactive nuclides undergo spontaneous transformations that involve the emission of particles (alpha and beta particles) and radiant energy (gamma energy). The resulting daughters (i.e., product nuclides) may be radioactive themselves (in which case they too will undergo spontaneous decay) or may be stable nuclides. Natural uranium consists of three primary isotopes: uranium-234, uranium-235, and uranium-238. The decay products of uranium isotopes also are radioactive and form decay chains.

Uranium hexafluoride is the sole raw material used in the enrichment process at PGDP. Some of the uranium feed material that was handled at PGDP has been reclaimed or recycled from reprocessed, spent reactor fuel. The chemical processes by which recycled uranium is purified leave trace amounts of

transuranic elements (neptunium and plutonium) and fission products (mainly technetium-99 and Cs-137). Technetium-99 (in the +7 oxidation state) is highly soluble in groundwater and is very mobile (its K_d is similar to that of TCE). The groundwater plumes of TCE and technetium-99 at PGDP, particularly the Northwest Plume, have similarities; however, the technetium-99 plume does not currently exhibit technetium-99 concentrations above the MCL at off-site locations, whereas the TCE plumes do not exceed MCLs off-site. Cesium-137 is not highly mobile and does not appear in PGDP plumes. Because cesium-137 has a half-life of 30 years, it is the most likely fission product (except for technetium-99) still to be present at the site.

On an activity basis, the principal radionuclides expected to pass through chemical processing and contaminate the recycled uranium are the transuranics neptunium-237, plutonium-238, plutonium-239, plutonium-240, and americium-241. Characterization studies (DOE 1999c) have shown that these radioisotopes are usually present in activities that are less than 1% of the uranium activity unless treatment processes have collected and concentrated them in sludges or trap material.

An assumption of the modeling for the BGOU RI was TCE degraded in the UCRS with a half-life of 26.6 years, but did not degrade in the RGA.[2] Although the mechanism is not well understood at PGDP, TCE and its degradation products may be degraded in the environment by various processes including hydrolysis, oxidation/reduction, photolysis, or biodegradation. TCE degradation may result in more toxic degradation products, such as vinyl chloride.

In the degradation of TCE, both aerobic and anaerobic degradation may occur. The anaerobic degradation pathway is as follows:

TCE → cis- and *trans-1,2-DCE → Vinyl Chloride → Ethene*

The anaerobic biodegradation of TCE, which initially forms *cis*-1,2-DCE, occurs under reducing conditions where sulfide- and/or methane-producing conditions exist. Such conditions occur primarily in the presence of other natural or anthropogenic carbon sources. The compounds c*is*- and *trans*-1,2-DCE are indicators of this degradation pathway because neither was used as a pure product at PGDP. The presence of c*is*- and *trans*-1,2-DCE also may have been the result of the use of industrial-grade TCE at PGDP. Both *cis*- and *trans*-1,2-DCE may further degrade anaerobically to vinyl chloride, but the rate is slower than the degradation rate of TCE, and the process may require stronger reducing conditions than those required for reduction of TCE. Low-levels of TCE intermediate dechlorination products (produced by anaerobic degradation) are found in RGA groundwater in some on-site locations. These occurrences may be related to degradation of TCE in the UCRS, where anaerobic conditions are known to occur locally.

The RGA is dominantly an aerobic environment. Aerobic biodegradation of TCE may occur under certain conditions. For example, specialized microorganisms have been identified that aerobically degrade some of these solvents in the presence of ammonia, methane, and toluene. In aerobic settings, TCE degrades to epoxides, aldehydes, chlorinated oxides, and ethanols.

Contaminant transport modeling simulates retardation during groundwater transport using indices of water solubility and adsorption to soil. In general, organic chemicals with high solubilities are more

[2] The assumption of zero degradation for TCE in the RGA is conservative. An alternative RGA degradation rate for TCE will be selected for use in the FS. The Kentucky Research Consortium for Energy and Environment, with the participation of DOE and its regulatory oversight, is researching TCE attenuation in the RGA at PGDP. PGDP modeling will incorporate these results as they become available. Recent findings (DOE 2007b) indicate the TCE half-life in the Northwest Plume of the RGA ranges from 3.2 to 11.3 years.

mobile in water than those that adsorb more strongly to soils. The following properties dictate an organic chemical's mobility within a specific medium.

- K_{oc}, the soil organic carbon partition coefficient, is a measure of the tendency for organic compounds to be adsorbed to the organic matter of soil and sediments. K_{oc} is expressed as the ratio of the amount of chemical adsorbed, per unit weight of organic carbon, to the chemical concentration in solution at equilibrium.

- K_{ow}, the octanol-water partition coefficient, is an indicator of hydrophobicity (the tendency of a chemical to avoid the aqueous phase) and is correlated with potential adsorption to soils. It also is used to estimate the potential for bioconcentration of chemicals into tissues.

- K_d, the soil/water distribution coefficient, is a measure of the tendency of a chemical to adsorb to soil or sediment particles. For organic compounds, this coefficient is calculated as the product of the K_{oc} value and the fraction of organic carbon in the soils. In general, chemicals with higher K_d values adsorb more strongly to soil/sediment particles and are less mobile than those with lower K_d values.

Release and transport mechanisms for TCE and its degradation products include vertical advective migration through unsaturated soils toward the water table, as well as gravity-driven migration as a DNAPL. The range of K_{oc} values indicates that these chlorinated VOCs are mobile through soils as dissolved constituents and tend not to partition significantly from water to soil.

Inorganic chemicals (i.e., metals) released to the unsaturated soil will be dissolved in soil moisture or absorbed onto soil particles. These dissolved metals are subject to movement with soil water. Aqueous transport mechanisms may result in metal migration through the vadose zone to groundwater. Metals, unlike organic compounds, cannot be degraded; however, metals migration can be attenuated by retardation reactions such as adsorption, surface complexation, and ion-exchange reactions with the soils which they contact. Such reactions are affected by pH, oxidation-reduction conditions, and the type and amount of organic matter, clay, and hydrous oxides present. Some metals, such as arsenic, can be transformed to other oxidation states in soil. Such transformations can affect their mobilities by affecting the way in which they react with soil particles or other solid surfaces by ion exchange, adsorption, precipitation, or complexation.

5.3 GROUNDWATER FATE AND TRANSPORT MODELING

Modeling for the BGOU RI used the Statistical Analysis and Decision Assistance (SADA), SESOIL, and AT123D models, consistent with Tier 3 of the modeling matrix in the PGDP Risk Methods Document (DOE 2001). SADA was used for the definition of the source terms, SESOIL for fate and transport modeling through the UCRS, and AT123D for fate and transport modeling through the RGA to the POEs. In addition to the models used, the MODFLOW/MODPATH models were used along with the previously developed PGDP sitewide groundwater model to establish input parameters for AT123D (i.e., distances to the POEs along flow paths (Figure 5.1), hydraulic gradient, and hydraulic conductivity). These models, along with the fixed parameter values chosen for the analyses (i.e., deterministic analysis), and model implementation are discussed in detail in Appendix E. The fate and transport modeling for the BGOU RI incorporates the sampling results of this RI and more sophisticated geospatial analysis of the source terms than those of previous models for these SWMUs; therefore, these model results differ from those of the previous models.

Modeling predicted the maximum concentration of analytes in groundwater at the boundary of each BGOU SWMU (Table 5.2). Table 5.3 presents the results of the deterministic modeling effort for the BGOU RI for the plant boundary and off-site POEs. Among the analytes, arsenic, technetium-99, and

TCE and related VOCs commonly exceeded MCLs. Table 5.4 presents the hazard quotient (HQ) and estimated lifetime cancer risk (ELCR) for each analyte based on the predicted groundwater concentrations at the plant boundary and off-site POEs. The HQs and ELCRs were calculated in accordance with the Risk Methods Document (DOE 2001). Appendix F provides a full description of the risk assessment methodology and calculations. The following discussion summarizes the results for each BGOU SWMU.

Table 5.2. Concentrations of the Analytes in Groundwater at the BGOU SWMU Boundaries Predicted in SESOIL and AT123D Modeling

Analyte	Predicted Maximum Groundwater Concentration (mg/L or pCi/L)[a]	MCL (mg/L or pCi/L)
SWMU 2		
Arsenic	***3.54E-02***	0.01
cis-1,2-DCE	***1.15E+01***	0.07
Manganese	7.16E-01	[b]
Naphthalene	9.38E-04	[b]
Technetium-99	1.02E+02	900[c]
TCE	***1.48E+00***	0.005
Uranium-234	1.58E+00	[b]
Uranium-238	1.81E+00	[b]
Uranium	9.86E-03	0.03
SWMU 3		
Arsenic	***3.29E-02***	0.01
Manganese	8.95E-01	[b]
Technetium-99	***5.560E+03***	900[c]
Uranium-238	1.59E+01	[b]
Uranium	***4.89E-02***	0.03
SWMU 4		
Arsenic	***1.77E-02***	0.01
cis-1,2-DCE	***6.68E-01***	0.07
Manganese	5.76E-01	[b]
Technetium-99	***9.008E+03***	900[c]
TCE	***1.18E+00***	0.005
Vinyl Chloride	***2.61E-02***	0.002

Table 5.2. Concentrations of the Analytes in Groundwater at the BGOU SWMU Boundaries Predicted in SESOIL and AT123D Modeling (Continued)

Analyte	Predicted Maximum Groundwater Concentration (mg/L or pCi/L)[a]	MCL (mg/L or pCi/L)
SWMU 5		
Acenaphthene	6.10E-03	[b]
Arsenic	9.25E-03	0.01
Manganese	1.01E+00	[b]
Naphthalene	5.55E-03	[b]
Technetium-99	1.27E+02	900[c]
SWMU 6		
No groundwater analytes		
SWMU 7		
1,1-DCE	***8.98E-02***	0.07
Arsenic	***1.78E-02***	0.01
cis-1,2-DCE	2.35E-02	0.07
Manganese	3.32E-01	[b]
PCB-1254	5.23E-05	[b]
Technetium-99	***9.09E+02***	900[c]
TCE	***1.09E-02***	0.005
Uranium-234	7.94E+00	[b]
Uranium-238	7.59E+00	[b]
Uranium	3.46E-03	0.03
Vinyl Chloride	***1.35E-02***	0.002
SWMU 30		
1,1-DCE	6.05E-02	0.07
Arsenic	***1.77E-02***	0.01
Manganese	3.78E-01	[b]
Selenium	1.51E-02	0.05
Technetium-99	2.87E+02	900[c]
TCE	***7.12E-01***	0.005
Uranium-234	3.99E+00	[b]
Uranium-238	5.91E+00	[b]
Uranium	8.40E-03	0.03
SWMU 145		
Antimony	***7.99E-02***	0.006
Arsenic	***6.21E-02***	0.01
PCB-1260	1.92E-03	
Technetium-99	***1.01E+04***	900[c]
Manganese	8.44E-01	[b]
Uranium-238	7.67E-02	[b]

[a] Values in bold, italic font exceed the analytes maximum contaminant level (MCL)
[b] MCLs not available for these contaminants
[c] Technetium-99 MCL based on a critical organ dose at 4 mrem/yr from drinking water consumption

Table 5.3. Concentrations of the Analytes in Groundwater Predicted in SESOIL and AT123D Modeling of the BGOU SWMUs

Analyte	Predicted Maximum Groundwater Concentration[a,b]				
	Plant Boundary (mg/L)	Property Boundary (mg/L)	Little Bayou seeps (mg/L)	Ohio River (mg/L)	MCL (mg/L or pCi/L)
	SWMU 2				
Arsenic	2.91E-03	8.35E-09	N/A	0.00E+00	0.01
cis-1,2-DCE	***1.74E+00***	***8.58E-01***	N/A	***3.38E-01***	0.07
Manganese	1.86E-05	0.00E+00	N/A	0.00E+00	[c]
Naphthalene	1.57E-04	8.27E-05	N/A	3.42E-05	[c]
Technetium-99	1.59E+01	8.06E+00	N/A	3.11E+00	900[d]
TCE	***2.17E-01***	***1.10E-01***	N/A	***4.12E-02***	0.005
Uranium-234	1.75E-05	0.00E+00	N/A	0.00E+00	[c]
Uranium-238	2.03E-05	0.00E+00	N/A	0.00E+00	[c]
Uranium	8.33E-08	0.00E+00	N/A	0.00E+00	0.03
	SWMU 3				
Arsenic	1.22E-03	0.00E+00	0.00E+00	N/A	0.01
Manganese	4.08E-10	0.00E+00	0.00E+00	N/A	[c]
Technetium-99	***1.81E+03***	***1.36E+03***	8.04E+02	N/A	900[d]
Uranium-238	1.59E+01	7.32E-11	0.00E+00	N/A	[c]
Uranium	2.27E-13	0.00E+00	0.00E+00	N/A	0.03
	SWMU 4				
Arsenic	2.70E-03	4.89E-06	N/A	0.00E+00	0.01
cis-1,2-DCE	***1.96E-01***	***8.94E-02***	N/A	3.16E-02	0.07
Manganese	5.01E-03	0.00E+00	N/A	0.00E+00	[c]
Technetium-99	***2.50E+03***	***1.20E+03***	N/A	3.79E+02	900[d]
TCE	***4.22E-01***	***2.14E-01***	N/A	***7.67E-02***	0.005
Vinyl Chloride	***5.95E-03***	***2.53E-03***	N/A	7.82E-04	0.002
	SWMU 5				
Acenaphthene	2.42E-03	1.34E-03	N/A	5.01E-04	NA
Arsenic	1.78E-03	1.27E-04	N/A	0.00E+00	0.01
Manganese	8.69E-02	2.30E-11	N/A	0.00E+00	[c]
Naphthalene	9.82E-04	3.72E-04	N/A	1.08E-04	NA
Technetium-99	4.99E+01	2.64E+01	N/A	8.72E+00	900[d]
	SWMU 6				
No groundwater analytes					
	SWMU 7				
1,1-DCE	***8.24E-02***	1.10E-02	4.02E-03	N/A	0.07
Arsenic	***1.26E-02***	2.35E-03	0.00E+00	N/A	0.01
cis-1,2-DCE	2.15E-02	3.13E-03	1.17E-03	N/A	0.07
Manganese	2.41E-01	1.05E-06	0.00E+00	N/A	[c]
PCB-1254	3.09E-05	3.05E-06	1.32E-12	N/A	[c]
Technetium-99	8.25E+02	2.70E+02	1.32E+02	N/A	900[d]
TCE	***9.87E-03***	1.42E-03	5.06E-04	N/A	0.005
Uranium-234	5.79E+00	5.84E-06	0.00E+00	N/A	[c]
Uranium-238	5.58E+00	5.85E-06	0.00E+00	N/A	[c]
Uranium	2.53E-03	2.68E-09	0.00E+00	N/A	0.03
Vinyl Chloride	***1.24E-02***	1.21E-03	4.13E-04	N/A	0.002

Table 5.3. Concentrations of the Analytes in Groundwater Predicted in SESOIL and AT123D Modeling of the BGOU SWMUs (Continued)

Analyte	Predicted Maximum Groundwater Concentration[a,b]				
	Plant Boundary (mg/L)	Property Boundary (mg/L)	Little Bayou seeps (mg/L)	Ohio River (mg/L)	MCL (mg/L or pCi/L)
SWMU 30					
1,1-DCE	5.92E-02	4.41E-03	1.32E-03	N/A	0.07
Arsenic	***1.17E-02***	2.34E-03	0.00E+00	N/A	0.01
Manganese	2.51E-01	2.85E-04	0.00E+00	N/A	[c]
Selenium	8.30E-03	9.21E-04	3.15E-04	N/A	0.05
Technetium-99	2.64E+02	7.08E+01	2.92E+01	N/A	900[d]
TCE	***6.80E-01***	***5.87E-02***	***1.96E-02***	N/A	0.005
Uranium-234	2.75E+00	1.44E-03	0.00E+00	N/A	[c]
Uranium-238	4.07E+00	1.98E-03	0.00E+00	N/A	[c]
Uranium	4.81E-03	2.41E-06	0.00E+00	N/A	0.03
SWMU 145					
Antimony	N/A	1.51E-06	N/A	0.00E+00	0.006
Arsenic	N/A	1.61E-03	N/A	0.00E+00	0.01
PCB-1260	N/A	0.00E+00	N/A	0.00E+00	[c]
Manganese	N/A	0.00E+00	N/A	0.00E+00	[c]
Technetium-99	N/A	***1.84E+03***	N/A	***9.65E+02***	900[d]
Uranium-238	N/A	0.00E+00	N/A	0.00E+00	[c]

[a] Values in bold, italic font exceed the analyte's maximum contaminant level (MCL).
[b] Radionuclide concentrations are in pCi/L.
[c] MCLs not available for these contaminants.
[d] Technetium-99 MCL based on a critical organ dose at 4 mrem/yr from drinking water consumption.
N/A = The point of exposure is not applicable to the groundwater pathway for this SWMU.

Table 5.4. Hazard and Cancer Risk Predicted from Maximum Groundwater Concentrations Derived in Modeling of BGOU SWMUs using SESOIL and AT123D[a]

Analyte	Plant Boundary		Property Boundary		Little Bayou Seeps		Near Ohio River	
	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk
SWMU 2								
Arsenic	0.9	7.7E-05	<0.1	<1.0E-06	N/A	N/A	[b]	[b]
cis-1,2-DCE	91.9	[b]	45.3	[b]	N/A	N/A	17.9	[b]
Manganese	<0.1	[b]	[b]	[b]	N/A	N/A	[b]	[b]
Naphthalene	0.1	[b]	<0.1	[b]	N/A	N/A	<0.1	[b]
Technetium-99	[b]	<1.0E-06	[b]	<1.0E-06	N/A	N/A	[b]	<1.0E-06
TCE	99.1	6.7E-03	50.3	3.4E-03	N/A	N/A	4.6	1.3E-03
Uranium-234	[b]	<1.0E-06	[b]	[b]	N/A	N/A	[b]	[b]
Uranium-238	[b]	<1.0E-06	[b]	[b]	N/A	N/A	[b]	[b]
Uranium	0.1	[b]	[b]	[b]	N/A	N/A	[b]	[b]
SWMU 3								
Arsenic	0.4	3.2E-05	[b]	[b]	[b]	[b]	N/A	N/A
Manganese	<0.1	[b]	[b]	[b]	[b]	[b]	N/A	N/A
Technetium-99	[b]	9.9E-05	[b]	7.5E-05	[b]	4.4E-05	N/A	N/A
Uranium-238	[b]	<1.0E-06	[b]	[b]	[b]	[b]	N/A	N/A
Uranium	<0.1	[b]	[b]	[b]	[b]	[b]	N/A	N/A
SWMU 4								
Arsenic	0.9	7.2E-05	<0.1	<1.0E-06	N/A	N/A	[b]	[b]
cis-1,2-DCE	10.4	[b]	4.7	[b]	N/A	N/A	0.6	[b]
Manganese	<0.1	[b]	[b]	[b]	N/A	N/A	[b]	[b]
Technetium-99	[b]	1.4E-04	[b]	6.6E-05	N/A	N/A	[b]	2.1E-05
TCE	193	2.0E-02	97.7	6.6E-03	N/A	N/A	32.7	2.4E-03
Vinyl Chloride	0.3	1.9E-04	0.1	7.4E-05	N/A	N/A	<0.1	2.3E-05
SWMU 5								
Arsenic	0.6	4.7E-05	<0.1	3.4E-06	N/A	N/A	[b]	[b]
Manganese	0.2	[b]	<0.1	[b]	N/A	N/A	[b]	[b]
Naphthalene	0.5	[b]	0.2	[b]	N/A	N/A	<0.1	[b]
Technetium-99	[b]	2.7E-06	[b]	1.4E-06	N/A	N/A	[b]	<1.0E-06
SWMU 6								
No groundwater analytes								

Table 5.4. Hazard and Cancer Risk Predicted from Maximum Groundwater Concentrations Derived in Modeling of BGOU SWMUs using SESOIL and AT123D[a] (Continued)

Analyte	Plant Boundary		Property Boundary		Little Bayou Seeps		Near Ohio River	
	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk
SWMU 7								
1,1-DCE	0.8	1.9E-03	0.1	2.5E-04	<0.1	9.3E-05	N/A	N/A
Arsenic	4.0	3.3E-04	0.8	6.2E-05	[b]	[b]	N/A	N/A
cis-1,2-DCE	1.1	[b]	0.2	[b]	<0.1	[b]	N/A	N/A
Manganese	0.5	[b]	<0.1	[b]	[b]	[b]	N/A	N/A
PCB-1254	2.5	4.8E-06	0.2	<1.0E-06	<0.1	<1.0E-06	N/A	N/A
Technetium-99	[b]	4.5E-05	[b]	1.5E-05	[b]	7.3E-06	N/A	N/A
TCE	4.5	3.1E-04	0.6	4.4E-05	0.2	1.6E-05	N/A	N/A
Uranium-234	[b]	8.2E-06	[b]	<1.0E-06	[b]	[b]	N/A	N/A
Uranium-238	[b]	9.7E-06	[b]	<1.0E-06	[b]	[b]	N/A	N/A
Uranium	0.4	[b]	<0.1	[b]	[b]	[b]	N/A	N/A
Vinyl Chloride	0.6	3.6E-04	<0.1	3.6E-05	<0.1	1.2E-05	N/A	N/A
SWMU 30								
1,1-DCE	0.6	1.4E-03	<0.1	1.0E-04	<0.1	3.0E-05	N/A	N/A
Arsenic	3.8	3.1E-04	0.8	6.2E-05	[b]	[b]	N/A	N/A
Manganese	0.5	[b]	<0.1	[b]	[b]	[b]	N/A	N/A
Selenium	0.2	[b]	<0.1	[b]	<0.1	[b]	N/A	N/A
Technetium-99	[b]	1.4E-05	[b]	3.9E-06	[b]	1.6E-06	N/A	N/A
TCE	311	2.1E-02	26.8	1.8E-03	9.0	6.1E-04	N/A	N/A
Uranium-234	[b]	3.9E-06	[b]	<1.0E-06	[b]	[b]	N/A	N/A
Uranium-238	[b]	7.1E-06	[b]	<1.0E-06	[b]	[b]	N/A	N/A
Uranium	0.8	[b]	<0.1	[b]	[b]	[b]	N/A	N/A
SWMU 145								
Antimony	N/A	N/A	<0.1	[b]	N/A	N/A	[b]	[b]
Arsenic	N/A	N/A	0.5	4.3E-05	N/A	N/A	[b]	[b]
Technetium-99	N/A	N/A	[b]	1.0E-04	N/A	N/A	[b]	5.3E-05

[a] Contaminants with an HQ greater than 0.1 or a cancer risk greater than 1.00E-06 are considered analytes – all values are rounded to one decimal place.

[b] Value not calculated since the groundwater concentrations were predicted as zero at this point of exposure (POE) by AT123D, or the contaminant did not have a reported cancer slope factor or chemical toxicity reference dose (RfD).

N/A = The point of exposure is not applicable to the groundwater pathway for this SWMU

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5.3.1 SWMU 2

Analytes retained after the screening process described in Section 5.2.1 are presented for SWMU 2 in Table E3.1. Each analyte was modeled and the resulting peak groundwater concentrations below SWMU 2 shown in Table 5.5 then were compared to the child resident NALs from Table A.18 of the 2001 Risk Methods Document and the provisional groundwater backgrounds shown in the 2001 Risk Method Document in Table A.13. Those analytes with groundwater concentrations below SWMU 2 that exceeded the NALs or background values then were carried through the toxicity and exposure assessments and cancer risk and hazards were calculated for the Rural Resident Groundwater User. Mercury, nickel, and vanadium were modeled and found not to reach the RGA during the 1,000 year modeling period.

Table 5.5. Screening of Modeled Peak Concentrations in Groundwater for SWMU 2

Analyte	Time (years)	Peak Conc. Below SWMU 2 (mg/L)[a]	Background Groundwater Concentration (mg/L)[a]	Groundwater Child Resident No Action Level (mg/L)[a]	Retain?
Arsenic	9.95E+02	3.54E-02	5.00E-03	3.50E-05	Y
cis-1,2-DCE	1.50E+01	1.15E+01	NA	2.73E-03	Y
Manganese	9.90E+02	7.16E-01	1.19E-01	3.50E-02	Y
Naphthalene	1.40E+02	9.38E-04	NA	2.85E-04	Y
TCE	2.00E+01	1.48E+00	NA	1.60E-03	Y
Uranium	1.00E+03	9.86E-03	2.00E-03	9.06E-04	Y
Zinc	9.90E+02	9.83E-03	4.90E-02	4.50E-01	N
Technetium-99	4.00E+01	1.02E+02	2.23E+01	1.40E+01	Y
Uranium-234	9.85E+02	1.58E+00	7.00E-01	5.46E-01	Y
Uranium-238	9.90E+02	1.81E+00	7.00E-01	4.43E-01	Y

[a] Units for radionuclides are pCi/L.
NA = not applicable N = No Y = Yes

The groundwater results presented in Table 5.3 for SWMU 2 show that the predicted groundwater concentrations of *cis*-1,2-DCE and TCE exceed their respective MCLs at the plant boundary, property boundary, and Ohio River POEs. All the remaining SWMU 2 analytes are not predicted to exceed their respective MCLs at the POEs. The following summarizes those analytes that exceeded ELCR and HQ risk criteria of 1.0E-06 and 0.1, respectively.

		Plant Boundary	Property Boundary	Ohio River
Arsenic	**ELCR**	7.7E-05	--	--
	HQ	0.9	--	--
***cis*-1,2-DCE**	**ELCR**	--	--	--
	HQ	91.9	45.3	17.9
TCE	**ELCR**	6.7E-03	3.4E-03	1.3E-03
	HQ	99.1	50.3	4.6

-- = does not exceed

All remaining analytes exhibited HQ values less than 0.1 and ELCR values less than 1.0E-06 at all POEs. Figures 5.2 through 5.4 present the predicted concentrations over time of SWMU 2 analytes that exceed a HQ of 0.1 and/or an ELCR of 1.0E-06 (Table 5.4). As shown in these figures, arsenic is predicted to continue rising in concentration at 1,000 years at the plant boundary, will not reach the property boundary or Ohio River in the 1,000 year period. Both *cis*-1,2-DCE and TCE are predicted to exceed their MCLs at all POEs within approximately 100 years and then decline in concentration below the MCLs.

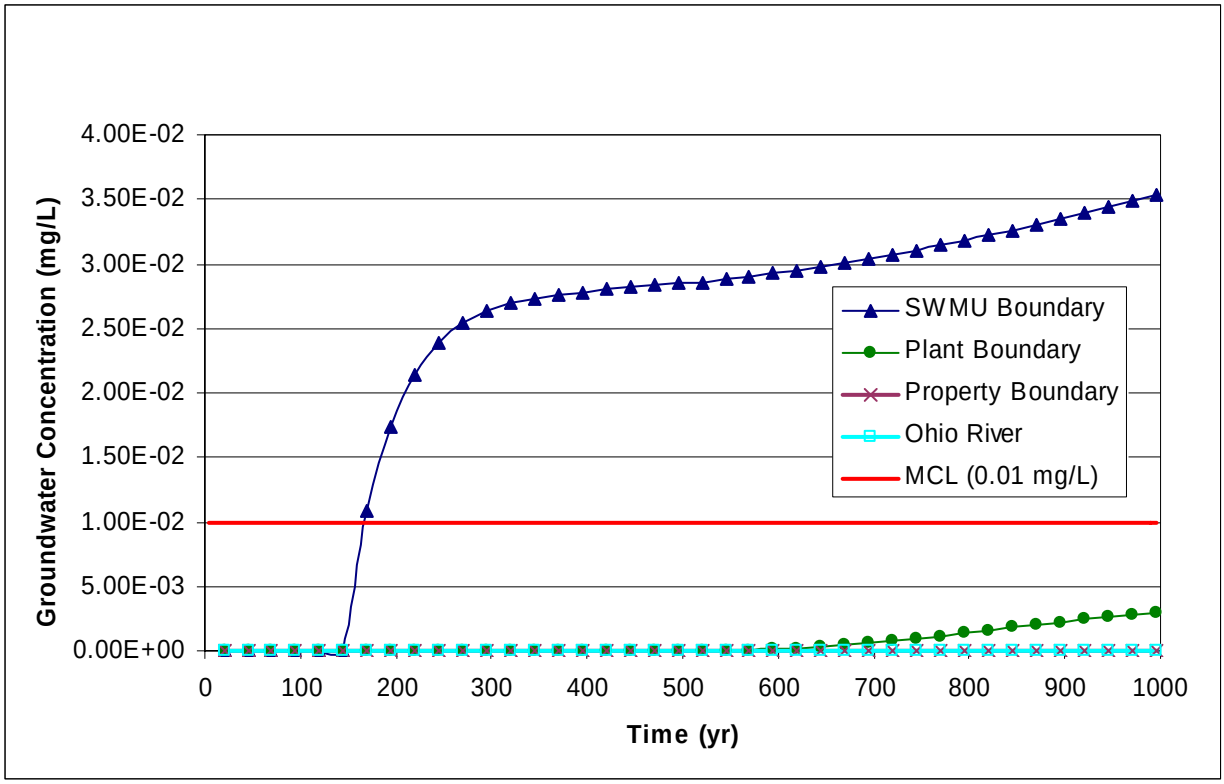

Figure 5.2. Predicted Arsenic Concentration in Groundwater at the POEs Based on Contaminant Leaching from SWMU 2

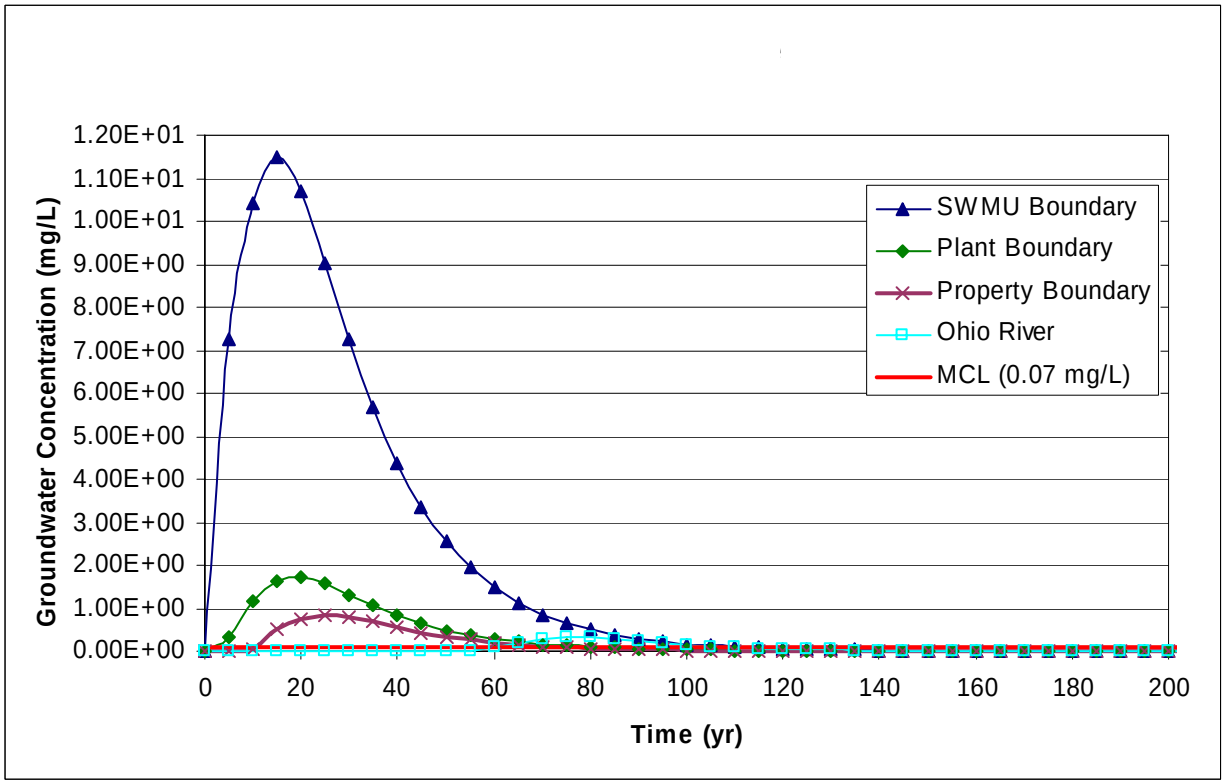

Figure 5.3. Predicted *cis*-1,2-DCE Concentration in Groundwater at the POEs Based on Contaminant Leaching from SWMU 2

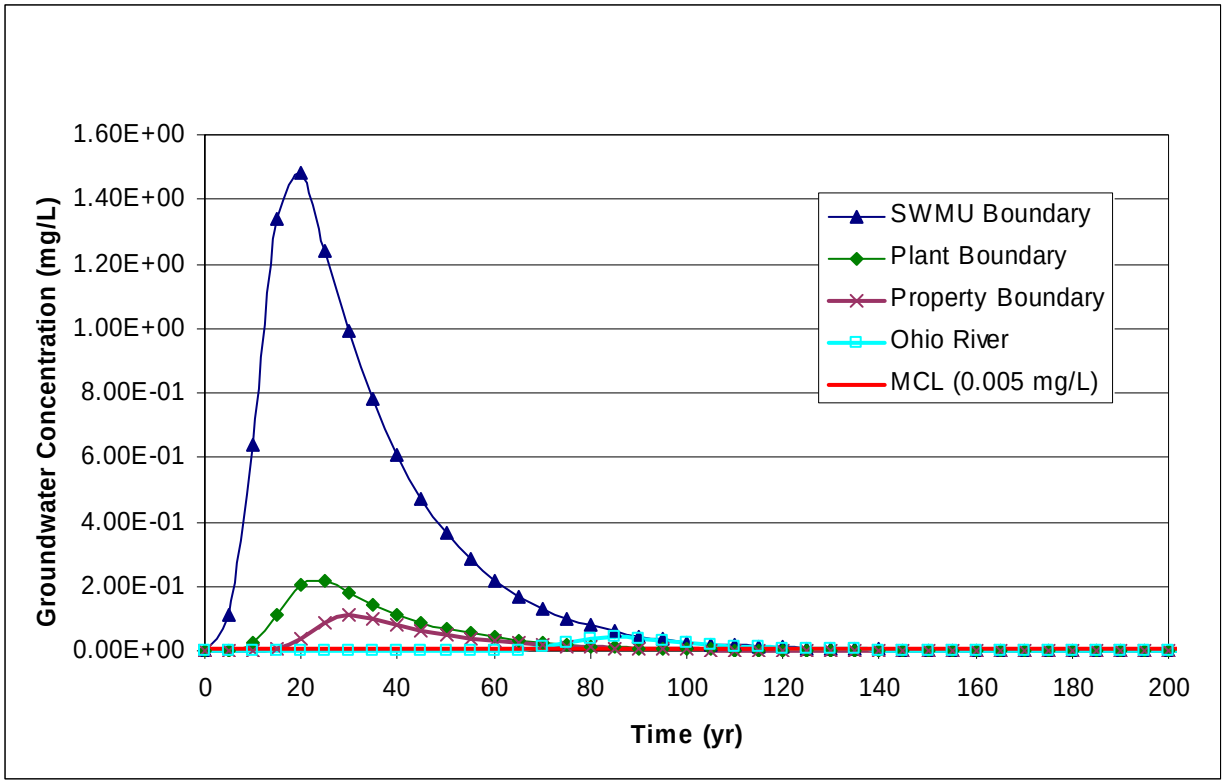

Figure 5.4. Predicted TCE Concentration in Groundwater at the POEs Based on Contaminant Leaching from SWMU 2

5.3.2 SWMU 3

Analytes retained after the screening process described in Section 5.2.1 are presented for SWMU 3 in Table E3.2. Each analyte was modeled and the resulting peak groundwater concentrations below SWMU 3 shown in Table 5.6 then were compared to the child resident NALs from Table A.18 of the 2001 Risk Methods Document and the provisional groundwater backgrounds shown in the 2001 Risk Method Document in Table A.13. Those analytes with groundwater concentrations below SWMU 3 that exceeded the NALs or background values then were carried through the toxicity and exposure assessments and cancer risk and hazards were calculated for the Rural Resident Groundwater User. Nickel and vanadium were modeled and found not to reach the RGA during the 1,000 year modeling period.

Table 5.6. Screening of Modeled Peak Concentrations in Groundwater for SWMU 3

Analyte	Time (years)	Peak Conc. Below SWMU 3 (mg/L)[a]	Background Groundwater Concentration (mg/L)[a]	Groundwater Child Resident No Action Level (mg/L)[a]	Retain?
Arsenic	9.80E+02	3.29E-02	5.00E-03	3.50E-05	Y
Manganese	9.70E+02	8.95E-01	1.19E-01	3.50E-02	Y
Mercury	9.80E+02	9.29E-05	2.00E-04	4.44E-04	N
TCE	3.50E+01	3.45E-04	NA	1.60E-03	N
Uranium	8.75E+02	4.89E-02	2.00E-03	9.06E-04	Y
Zinc	9.55E+02	9.30E-02	4.90E-02	4.50E-01	N
Technetium-99	4.50E+01	5.56E+03	2.23E+01	1.40E+01	Y
Uranium-238	9.90E+02	1.59E+01	7.00E-01	4.43E-01	Y

[a] Units for radionuclides are pCi/L; NA = not applicable; N = No; Y = Yes

Screening identified arsenic, manganese, technetium-99, and uranium as analytes for SWMU 3. Fate and transport modeling predicts that technetium-99 will exceed the MCL at the plant and property boundary POEs. The following summarizes those analytes that exceeded ELCR or HQ risk criteria of 1.0E-06 and 0.1, respectively.

		Plant Boundary	Property Boundary	Little Bayou Seeps
Arsenic	**ELCR**	3.2E-05	--	--
	HQ	0.4	--	--
Technetium-99	**ELCR**	9.9E-05	7.5E-05	4.4E-05
	HQ	--	--	--

-- = does not exceed

All remaining analytes exhibited HQ values less than 0.1 and ELCR values less than 1.0E-06 at the POEs. Figures 5.5 and 5.6 illustrate the predicted concentrations through time of SWMU 3 analytes that exceed a HQ of 0.1 and/or an ELCR of 1.0E-06 (Table 5.4). As shown in these figures, arsenic is predicted to continue rising in concentration at 1,000 years at the plant boundary at groundwater concentrations less than the MCL, but will not reach the property boundary or Little Bayou Seeps in the 1,000 year period. Technetium-99 is predicted to peak at all POEs within 200 years and at dissolved levels greater than the MCL at the plant and property POEs.

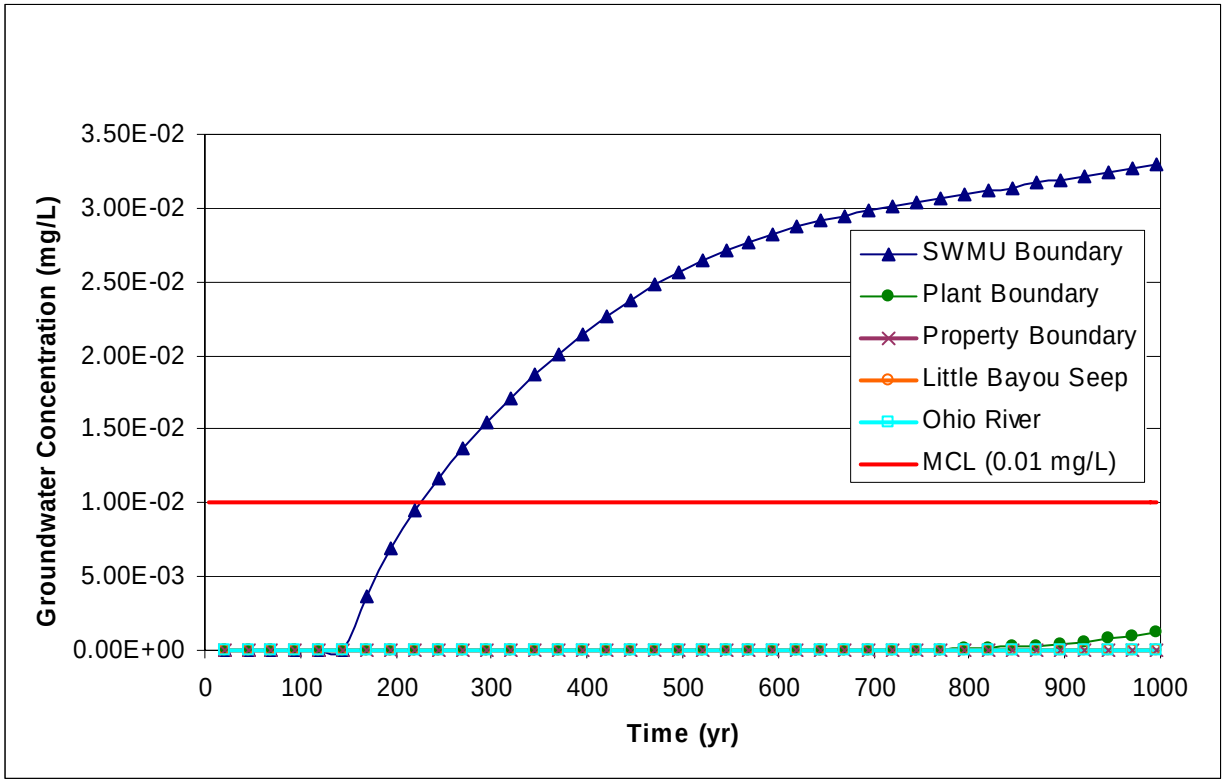

Figure 5.5. Predicted Arsenic Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 3

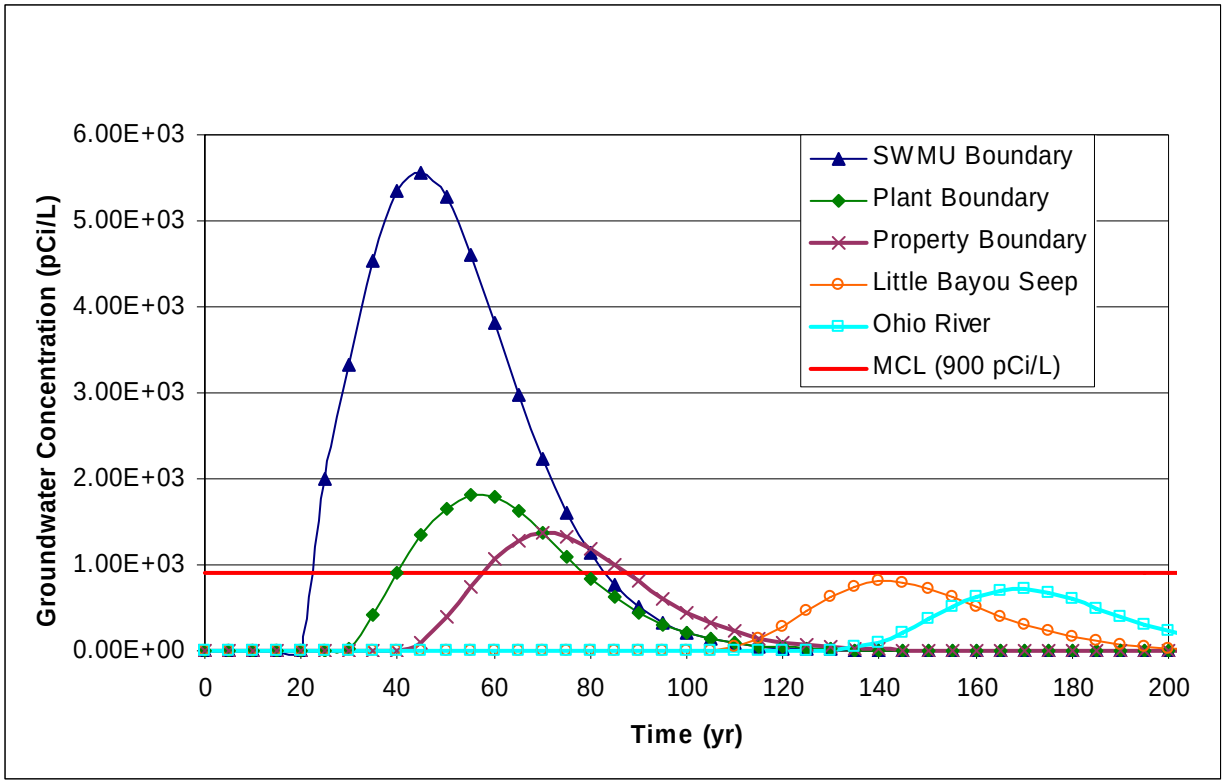

Figure 5.6. Predicted ^{99}Tc Activities in Groundwater at the POEs Based on Contaminant Leaching from SWMU 3

5.3.3 SWMU 4

Analytes retained after the screening process described in Section 5.2.1 are presented for SWMU 4 in Table E3.3. Each analyte was modeled and the resulting peak groundwater concentrations below SWMU 4 shown in Table 5.7 then were compared to the child resident NALs from Table A.18 of the 2001 Risk Methods Document and the provisional groundwater backgrounds shown in the 2001 Risk Method Document in Table A.13. Those analytes with groundwater concentrations below SWMU 4 that exceeded the NALs or background values then were carried through the toxicity and exposure assessments and cancer risk and hazards were calculated for the Rural Resident Groundwater User. Nickel, uranium, vanadium, plutonium-239, and zinc were modeled and found not to reach the RGA during the 1,000 year modeling period.

Table 5.7. Screening of Modeled Peak Concentrations in Groundwater for SWMU 4

Analyte	Time (years)	Peak Conc. Below SWMU 4 (mg/L)[a]	Background Groundwater Concentration (mg/L)[a]	Groundwater Child Resident No Action Level (mg/L)[a]	Retain?
Arsenic	9.90E+02	1.77E-02	5.00E-03	3.50E-05	Y
cis-1,2-DCE	1.50E+01	6.68E-01	NA	2.73E-03	Y
Manganese	1.00E+03	5.76E-01	1.19E-01	3.50E-02	Y
TCE	5.00E+00	1.18E+00	NA	1.60E-03	Y
Zinc	1.00E+03	1.57E-09	4.90E-02	4.50E-01	N
Vinyl Chloride	5.00E+00	2.61E-02	NA	3.50E-05	Y
Technetium-99	5.00E+01	9.00E+03	2.23E+01	1.40E+01	Y

[a] Units for radionuclides are pCi/L. NA = not applicable N = No Y = Yes

The groundwater results presented in Table 5.3 for SWMU 4 show that the predicted groundwater concentrations of *cis*-1,2-DCE; technetium-99; TCE, and vinyl chloride will exceed their respective MCLs at the plant boundary and property boundary. TCE also is predicted to exceed the MCL at the Ohio River. The following summarizes those analytes that exceeded ELCR or HQ risk criteria of 1.0E-06 and 0.1, respectively.

		Plant Boundary	Property Boundary	Ohio River
Arsenic	**ELCR**	7.2E-05	--	--
	HQ	0.9	--	--
***cis*-1,2-DCE**	**ELCR**	--		--
	HQ	10.4	4.7	0.6
Technetium-99	**ELCR**	1.4E-04	6.6E-05	2.1E-05
	HQ	--	--	--
TCE	**ELCR**	2.0E-02	6.6E-03	2.4E-03
	HQ	193	97.7	32.7
Vinyl chloride	**ELCR**	1.9E-04	7.4E-05	2.3E-05
	HQ	0.3	0.1	--

-- = does not exceed

All remaining analytes exhibited HQ values less than 0.1 and ELCR values less than 1.0E-06 at all POEs. Figures 5.7 through 5.11 portray the modeled concentrations over time of SWMU 4 analytes that exceed a HQ of 0.1 and/or an ELCR of 1.0E-06 (Table 5.4). As shown in these figures, the dissolved arsenic concentration is predicted to continue rising at 1,000 years at the plant boundary, but will not reach the property boundary or Ohio River in the 1,000 year period. The chemicals c*is*-1,2-DCE; TCE; vinyl chloride, and technetium-99 are predicted to exceed the MCL at the plant and property boundaries within 100 years. Modeling predicts TCE also will exceed the MCL at the Ohio River within 100 years.

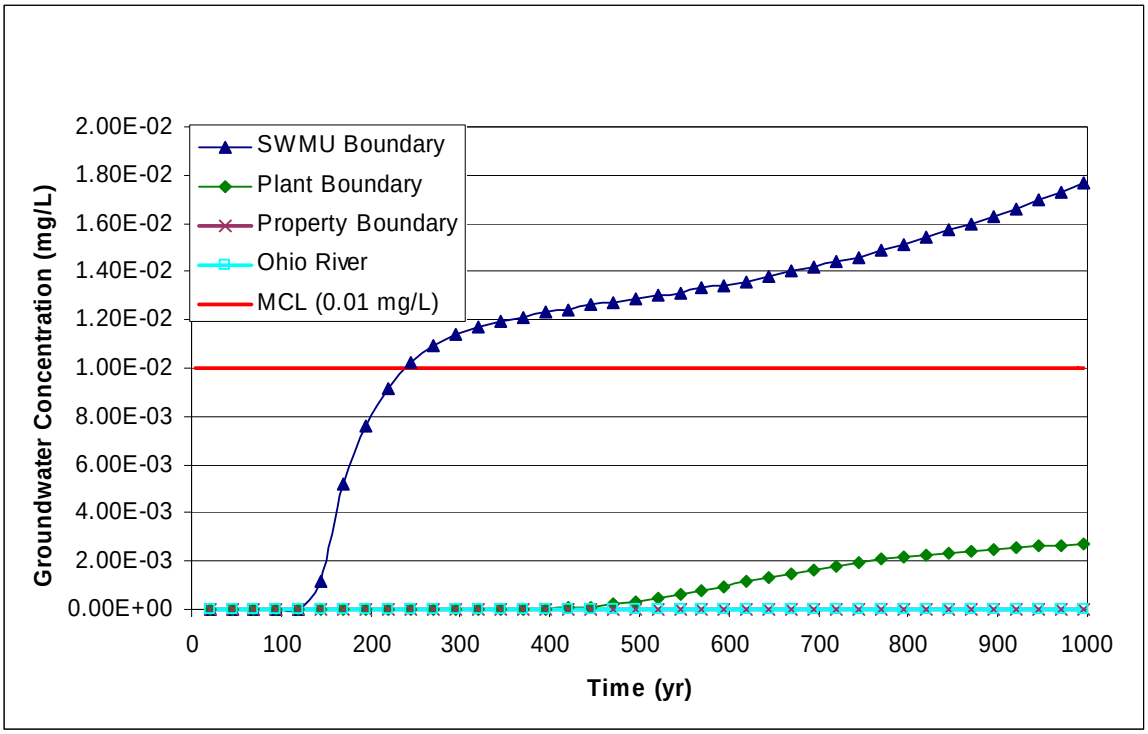

Figure 5.7. Predicted Arsenic Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 4

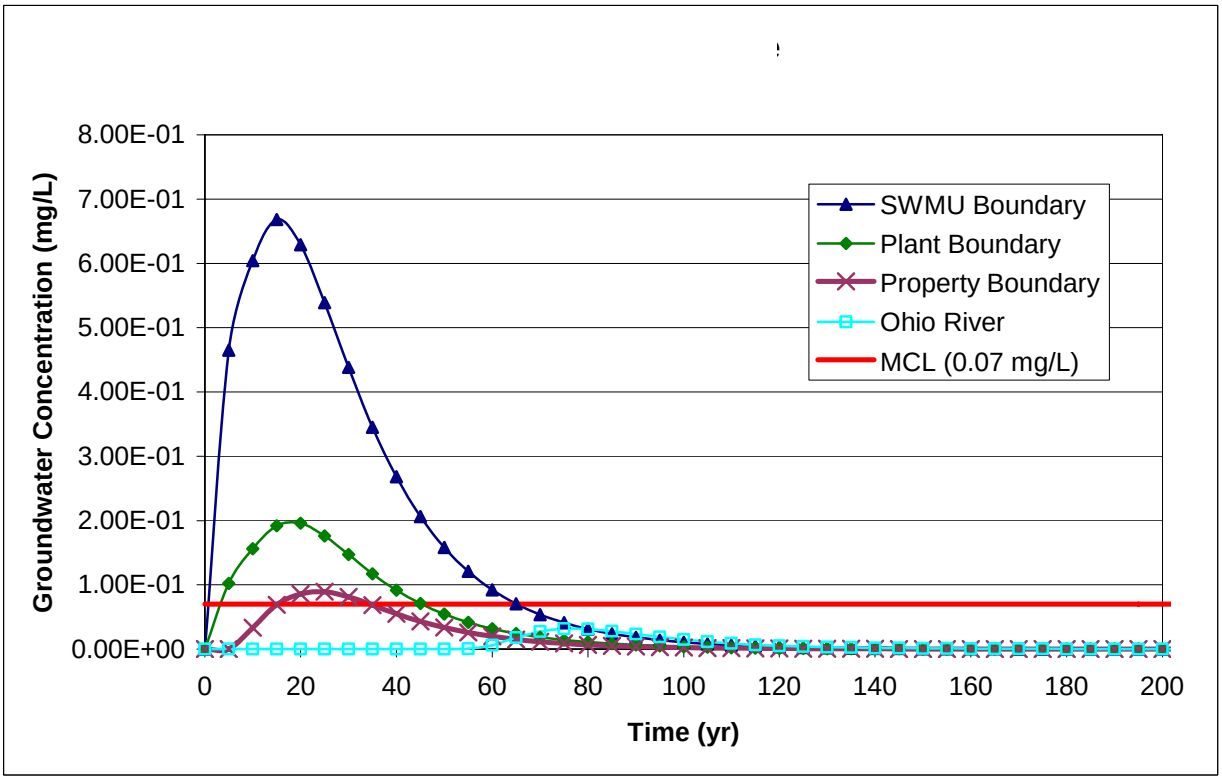

Figure 5.8. Predicted *cis*-1,2-DCE Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 4

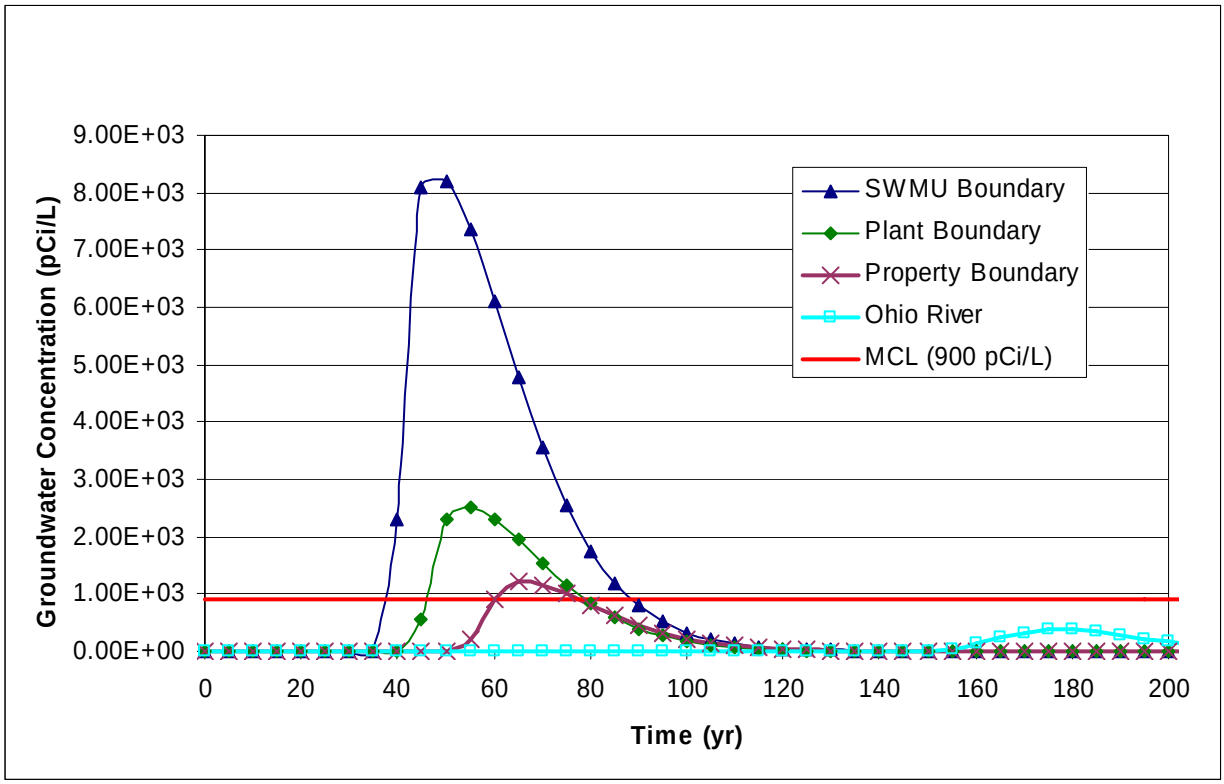

Figure 5.9. Predicted ^{99}Tc Activities in Groundwater at the POEs Based on Contaminant Leaching from SWMU 4

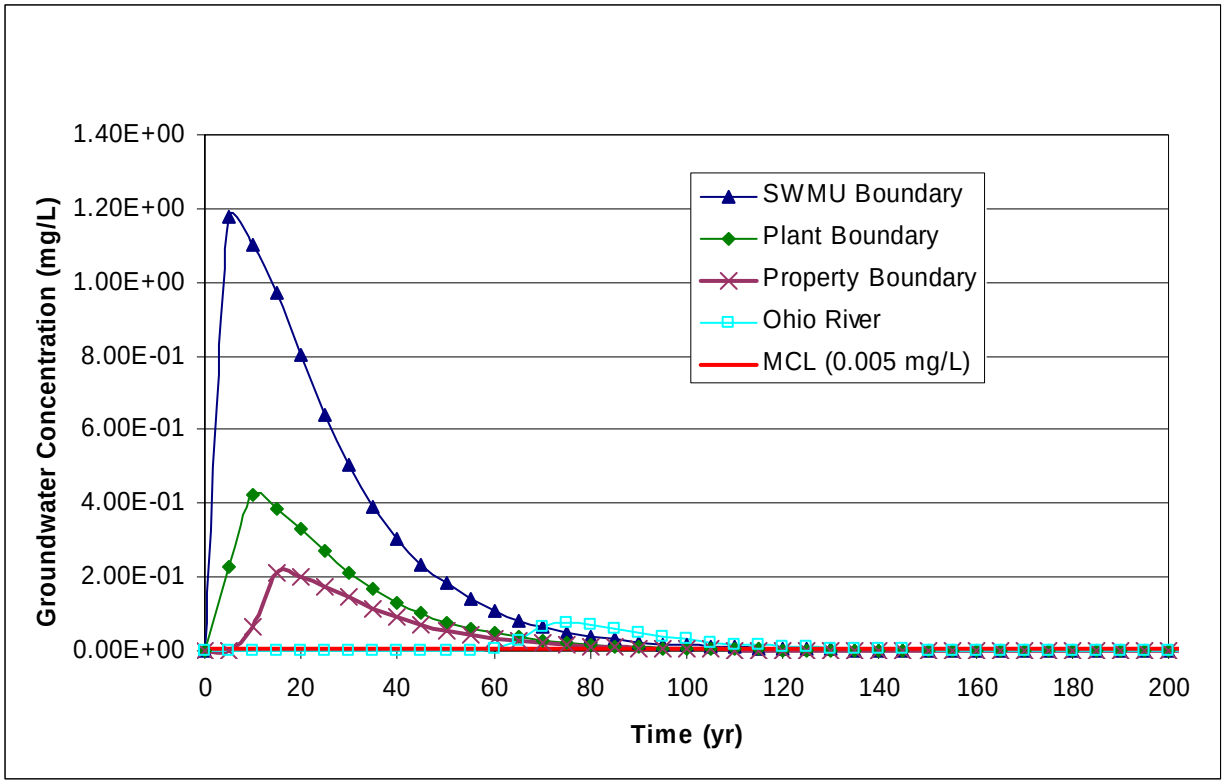

Figure 5.10. Predicted TCE Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 4

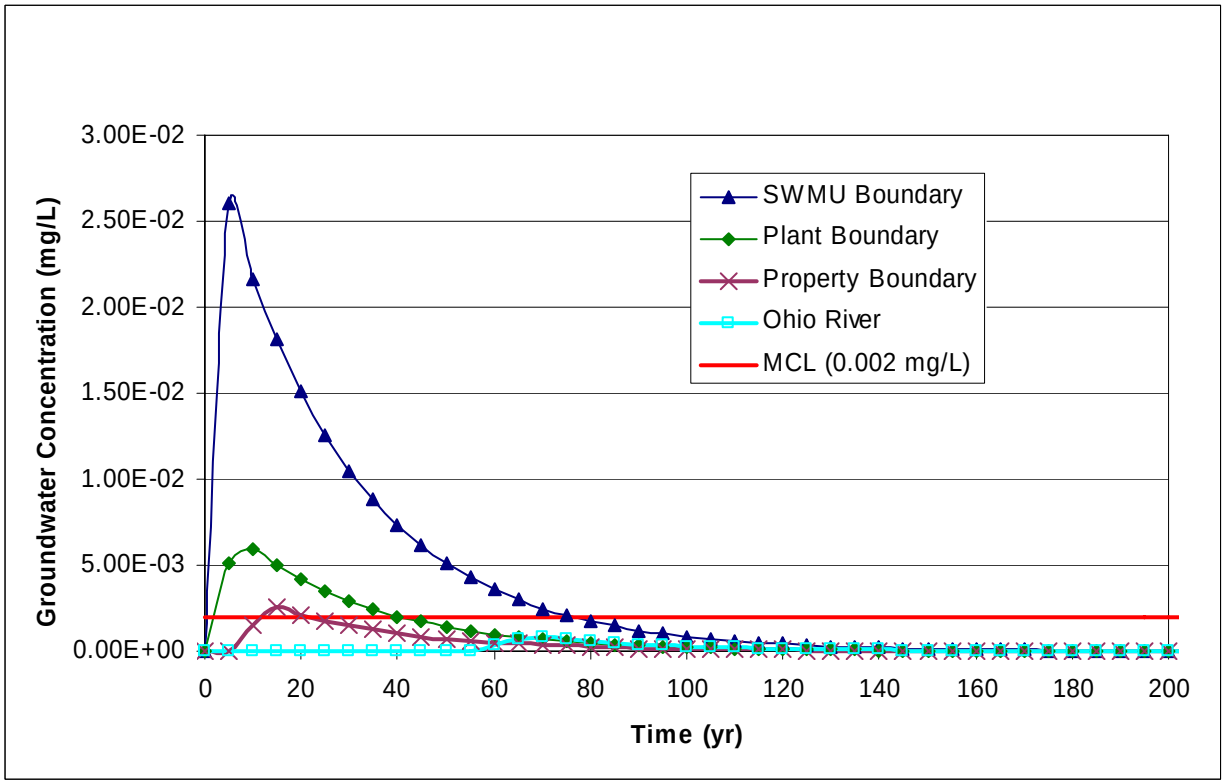

Figure 5.11. Predicted Vinyl Chloride Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 4

5.3.4 SWMU 5

Analytes retained after the screening process described in Section 5.2.1 are presented for SWMU 5 in Table E3.4. Each analyte was modeled and the resulting peak groundwater concentrations below SWMU 5 shown in Table 5.8 then were compared to the child resident NALs from Table A.18 of the 2001 Risk Methods Document and the provisional groundwater backgrounds shown in the 2001 Risk Method Document in Table A.13. Those analytes with groundwater concentrations below SWMU 5 that exceeded the NALs or background values then were carried through the toxicity and exposure assessments and cancer risk and hazards were calculated for the Rural Resident Groundwater User. Vanadium, benzo(a)pyrene, and dibenz(a,h,)anthracene were modeled and found not to reach the RGA during the 1,000 year modeling period.

Table 5.8. Screening of Modeled Peak Concentrations in Groundwater for SWMU 5

Analyte	Time (years)	Peak Conc. Below SWMU 5 (mg/L)[a]	Background Groundwater Concentration (mg/L)[a]	Groundwater Child Resident No Action Level (mg/L)[a]	Retain?
Acenaphthene	4.60E+02	6.10E-03	NA	1.36E-02	N
Anthracene	1.25E+02	8.06E-03	NA	7.66E-02	N
Arsenic	1.00E+03	9.25E-03	5.00E-03	3.50E-05	Y
Fluorene	7.20E+02	3.63E-03	NA	9.72E-03	N
Manganese	9.45E+02	1.01E+00	1.19E-01	3.50E-02	Y
Naphthalene	1.30E+02	5.55E-03	NA	2.85E-04	Y
Nickel	1.00E+03	2.01E-03	3.05E-01	3.01E-02	N
Selenium	5.70E+02	1.27E-03	5.00E-03	7.54E-03	N
TCE	1.00E+01	9.91E-04	NA	1.60E-03	N
Zinc	9.40E+02	1.58E-01	4.90E-02	4.50E-01	N
Technetium-99	5.00E+00	1.27E+02	2.23E+01	1.40E+01	Y

[a] Units for radionuclides are pCi/L.
NA = not applicable N = No Y = Yes

All SWMU 5 analytes are predicted to be less than their respective MCLs at all POEs. The following summarizes those analytes that exceeded ELCR or HQ risk criteria of 1.0E-06 and 0.1, respectively.

		Plant Boundary	Property Boundary	Ohio River
Arsenic	**ELCR**	4.7E-05	3.4E-06	--
	HQ	0.6	--	--
Manganese	**ELCR**	--	--	--
	HQ	0.2	--	--
Napthalene	**ELCR**	--	--	--
	HQ	0.5	0.2	--
Technetium-99	**ELCR**	2.7E-06	1.4E-06	--
	HQ	--	--	--

-- = does not exceed

All remaining analytes exhibited HQ values less than 0.1 and ELCR values less than 1.0E-06 at all POEs. Figures 5.12 through 5.15 illustrate the future predicted concentrations of SWMU 5 analytes that exceed a HQ of 0.1 and/or an ELCR of 1.0E-06 (Table 5.4). As shown in these figures, the dissolved arsenic and manganese concentrations are predicted to continue rising at 1,000 years at the plant boundary. Manganese will not reach the property boundary or Ohio River in the 1,000 year period. Arsenic begins to increase in concentration at the plant boundary at 1,000 years; however, the concentrations are less than the MCL. Technetium-99 is not predicted to exceed the MCL at the POEs.

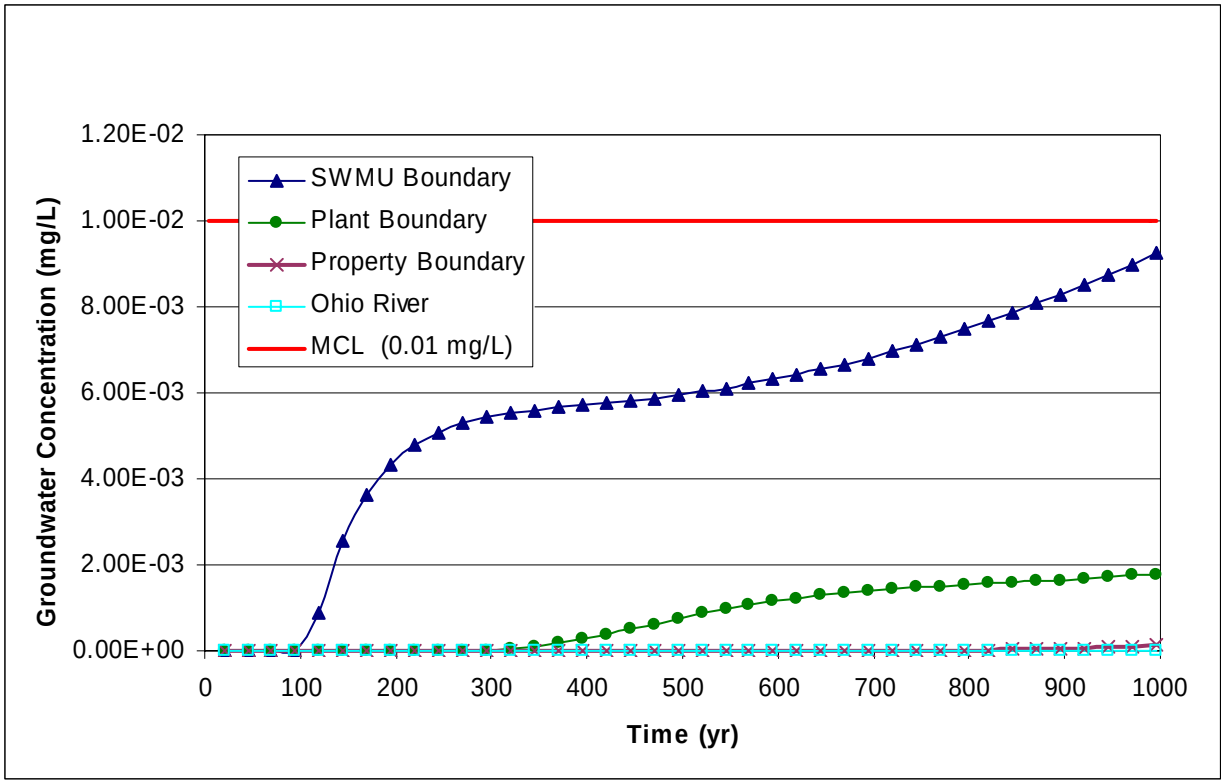

Figure 5.12. Predicted Arsenic Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 5

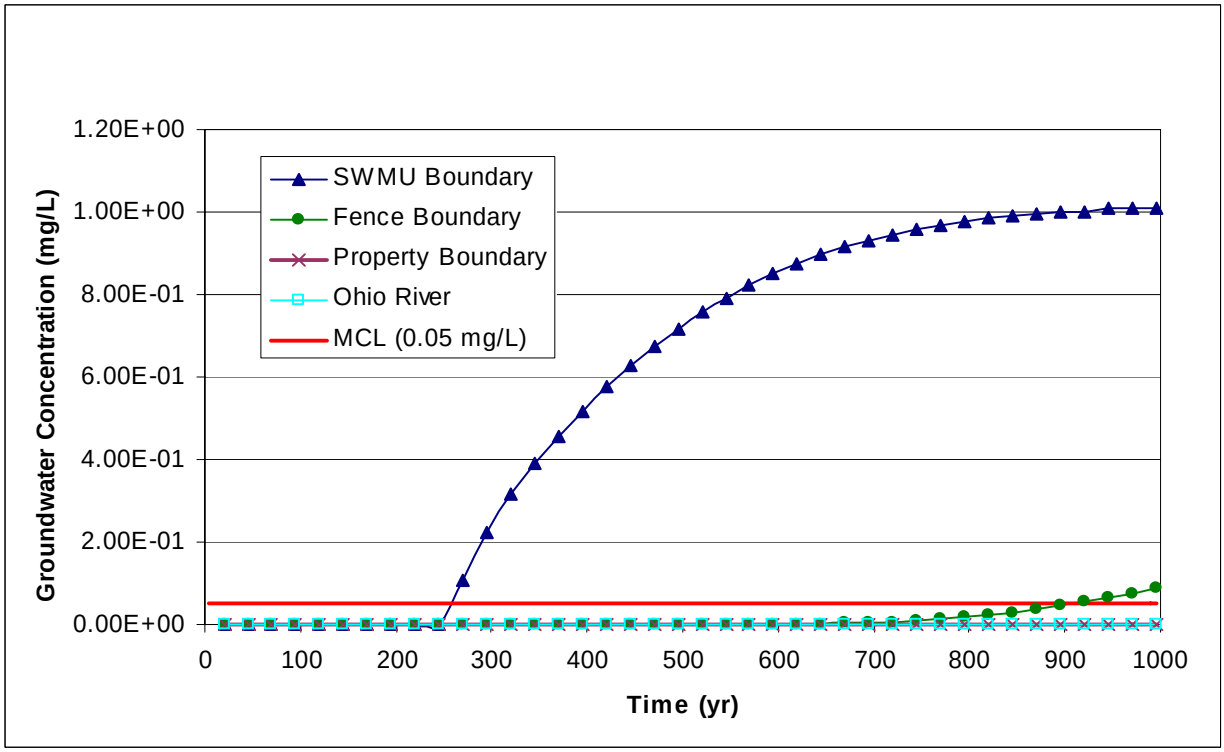

Figure 5.13. Predicted Manganese Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 5

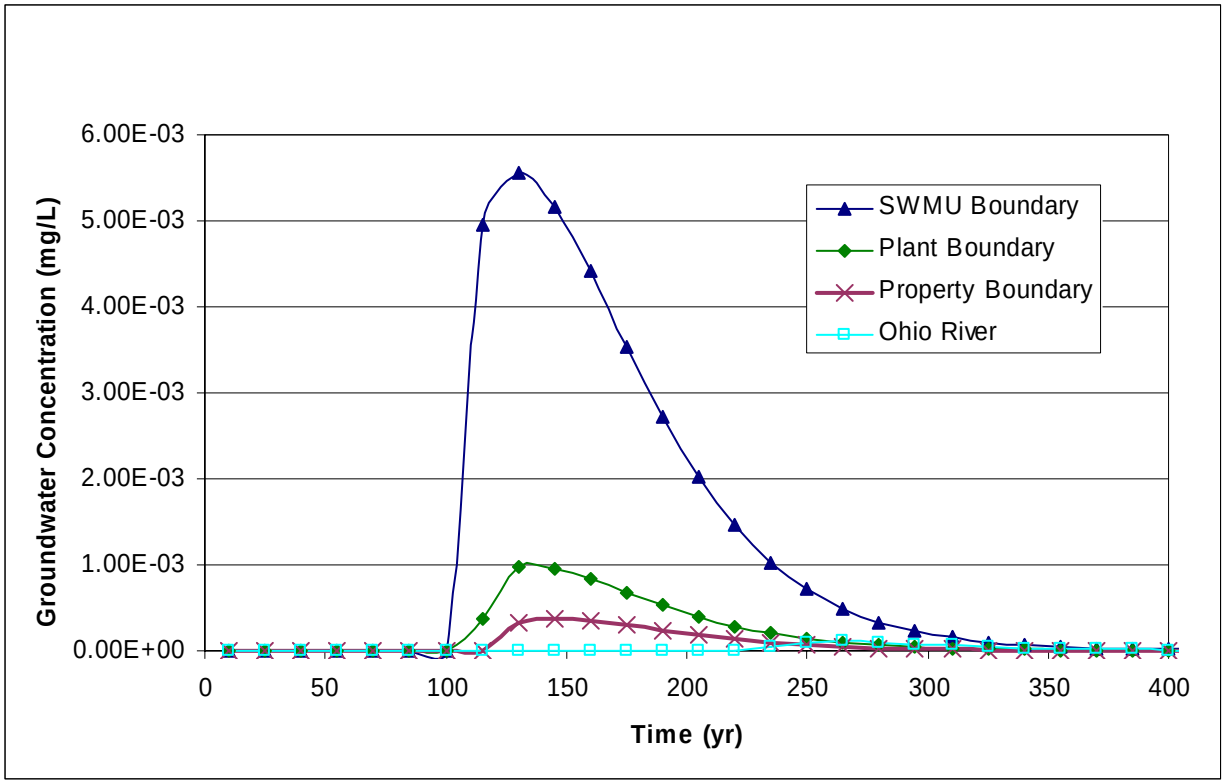

Figure 5.14. Predicted Naphthalene Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 5

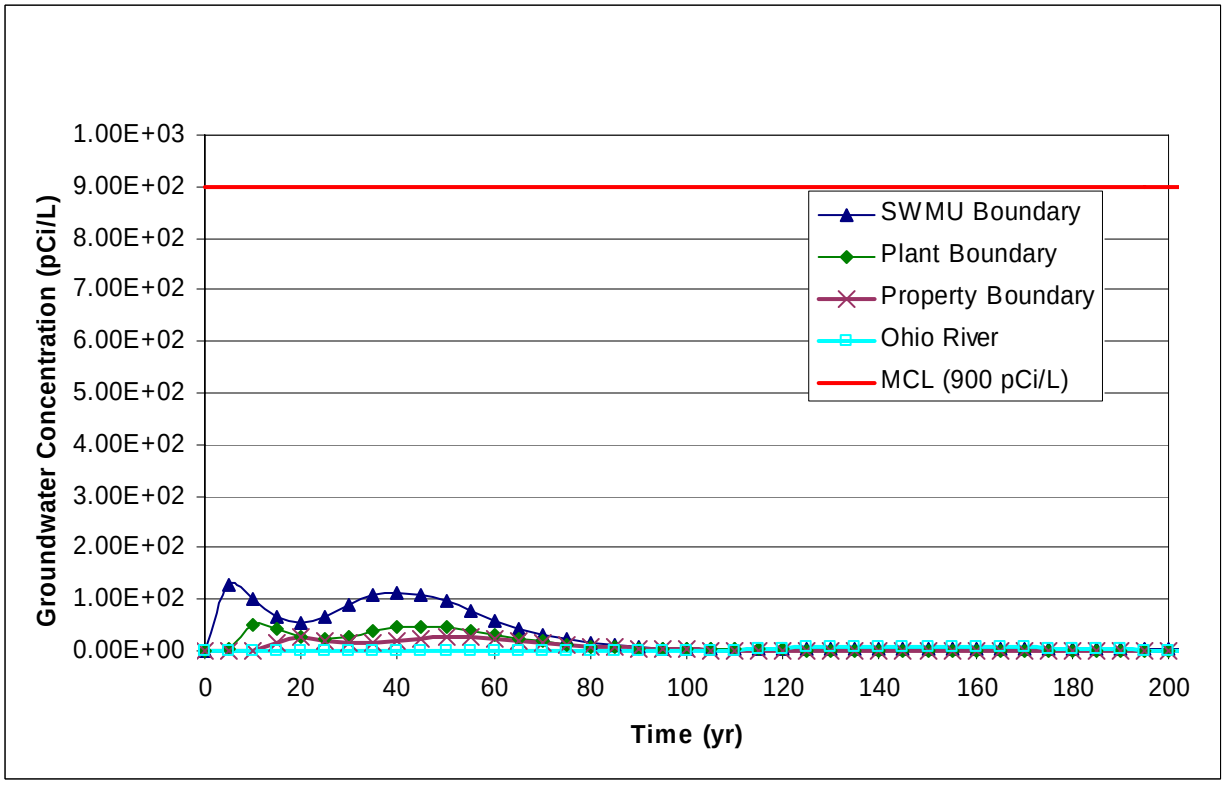

Figure 5.15. Predicted ^{99}Tc Activities in Groundwater at the POEs Based on Contaminant Leaching from SWMU 5

5.3.5 SWMU 6

Analytes retained after the screening process described in Section 5.2.1 are presented for SWMU 6 in Table E3.5. Each analyte was modeled and the resulting peak groundwater concentrations below SWMU 6 shown in Table 5.9 then were compared to the child resident NALs from Table A.18 of the 2001 Risk Methods Document and the provisional groundwater backgrounds shown in the 2001 Risk Method Document in Table A.13. Those analytes with groundwater concentrations below SWMU 6 that exceeded the NALs or background values then were carried through the toxicity and exposure assessments and cancer risk and hazards were calculated for the Rural Resident Groundwater User. Beryllium, nickel, vanadium, and benzo(a)pyrene were modeled and found not to reach the RGA during the 1,000 year modeling period.

Table 5.9. Screening of Modeled Peak Concentrations in Groundwater for SWMU 6

Analyte	Time (years)	Peak Conc. Below SWMU 6 (mg/L)[a]	Background Groundwater Concentration (mg/L)[a]	Groundwater Child Resident No Action Level (mg/L)[a]	Retain?
Arsenic	9.90E+02	1.92E-03	5.00E-03	3.50E-05	N
TCE	1.10E+01	3.19E-05	NA	1.60E-03	N
Uranium	4.10E+02	1.91E-04	2.00E-03	9.06E-04	N
Zinc	4.45E+02	3.63E-02	4.90E-02	4.50E-01	N

[a] Units for radionuclides are pCi/L.
NA = not applicable N = No

All of the analytes modeled for SWMU 6 that were identified by the initial SSL screening for groundwater did not reach the water table in 1,000 years or exhibited groundwater concentrations that were less than the groundwater background or the groundwater child NALs (see Appendix F); therefore, there were no groundwater analytes for SWMU 6.

5.3.6 SWMU 7

Analytes retained after the screening process described in Section 5.2.1 are presented for SWMU 7 in Table E3.6. Each analyte was modeled and the resulting groundwater concentrations below SWMU 7 shown in Table 5.10 then were compared to the child resident NALs from Table A.18 of the 2001 Risk Methods Document and the provisional groundwater backgrounds shown in the 2001 Risk Method Document in Table A.13. Those analytes with groundwater concentrations below SWMU 7 that exceeded the NALs or background values then were carried through the toxicity and exposure assessments and cancer risk and hazards were calculated for the Rural Resident Groundwater User. Vanadium, PCB-1260, benzo(a)pyrene, and fluoranthene were modeled and found not to reach the RGA during the 1,000 year modeling period.

Table 5.10. Screening of Modeled Peak Concentrations in Groundwater for SWMU 7

Analyte	Time (years)	Peak Conc. Below SWMU 7 (mg/L)[a]	Background Groundwater Concentration (mg/L)[a]	Groundwater Child Resident No Action Level (mg/L)[a]	Retain?
1,1-DCE	9.00E+00	8.98E-02	NA	4.70E-05	Y
Arsenic	1.00E+02	1.78E-02	5.00E-03	3.50E-05	Y
Cadmium	8.55E+02	1.96E-05	1.00E-02	6.61E-04	N
cis-1,2,-DCE	1.00E+01	2.35E-02	NA	2.73E-03	Y

Table 5.10. Screening of Modeled Peak Concentrations in Groundwater for SWMU 7 (Continued)

Analyte	Time (years)	Peak Conc. Below the SWMU (mg/L)[a]	Background Groundwater Concentration (mg/L)[a]	Groundwater Child Resident No Action Level (mg/L)[a]	Retain as Analyte?
Manganese	8.25E+02	3.32E-01	1.19E-01	3.50E-02	Y
Mercury	9.45E+02	1.01E-05	2.00E-04	4.44E-04	N
PCB-1254	1.00E+03	5.23E-05	NA	1.94E-05	Y
Pyrene	1.00E+03	3.48E-06	NA	1.82E-02	N
Selenium	4.00E+02	1.12E-02	5.00E-03	3.01E-02	N
Tetrachloroethene	1.80E+01	1.40E-04	NA	5.82E-04	N
TCE	4.00E+00	1.09E-02	NA	1.60E-03	Y
Uranium	9.80E+02	3.46E-03	2.00E-03	9.06E-04	Y
Vinyl Chloride	3.00E+00	1.35E-02	NA	3.50E-05	Y
Zinc	7.25E+02	6.73E-02	4.90E-02	4.50E-01	N
Technetium-99	4.00E+01	9.09E+02	2.23E+01	1.40E+01	Y
Uranium-234	9.80E+02	7.94E+00	7.00E-01	5.46E-01	Y
Uranium-235	6.95E+02	8.10E-02	3.00E-01	5.38E-01	N
Uranium-238	9.75E+02	7.59E+00	7.00E-01	4.43E-01	Y

[a] Units for radionuclides are pCi/L.
NA = not applicable N = No Y = Yes

The groundwater results presented in Table 5.3 for SWMU 7 show the predicted groundwater concentrations of 1,1-DCE, arsenic, TCE, and vinyl chloride will exceed their respective MCLs at the plant boundary. All SWMU 7 analytes are modeled to be less than their respective MCLs at the property boundary and Little Bayou seeps. The following summarizes those analytes that exceeded ELCR or HQ risk criteria of 1.0E-06 and 0.1, respectively.

		Plant Boundary	Property Boundary	Little Bayou Seeps
1,1-DCE	**ELCR**	1.9E-03	2.5E-04	9.3E-05
	HQ	0.8	0.1	--
Arsenic	**ELCR**	3.3E-04	6.2E-05	--
	HQ	4.0	0.8	--
***cis*-1,2-DCE**	**ELCR**	--	--	--
	HQ	1.1	0.2	--
Manganese	**ELCR**	--	--	--
	HQ	0.5	--	--
PCB-1254	**ELCR**	4.8E-06	--	--
	HQ	2.5	0.2	--
Technetium-99	**ELCR**	4.5E-05	1.5E-05	7.3E-06
	HQ	--	--	--
TCE	**ELCR**	3.1E-04	4.4E-05	1.6E-05
	HQ	4.5	0.6	0.2
Uranium	**ELCR**	--	--	--
	HQ	0.4	--	--
Uranium-234	**ELCR**	8.2E-06	--	--
	HQ	--	--	--
Uranium-238	**ELCR**	9.6E-06	--	--
	HQ	--	--	--
Vinyl chloride	**ELCR**	3.6E-04	3.6E-05	1.2E-05
	HQ	0.6	--	--

-- = does not exceed

All remaining analytes exhibited HQ values less than 0.1 and ELCR values less than 1.0E-06 at all POEs. Figures 5.16 through 5.26 portray the predicted concentrations of SWMU 7 analytes that exceed a HQ of 0.1 and/or an ELCR of 1.0E-06 (Table 5.4). Arsenic was modeled and found not to reach the Little Bayou seeps in the 1,000 year modeling period.

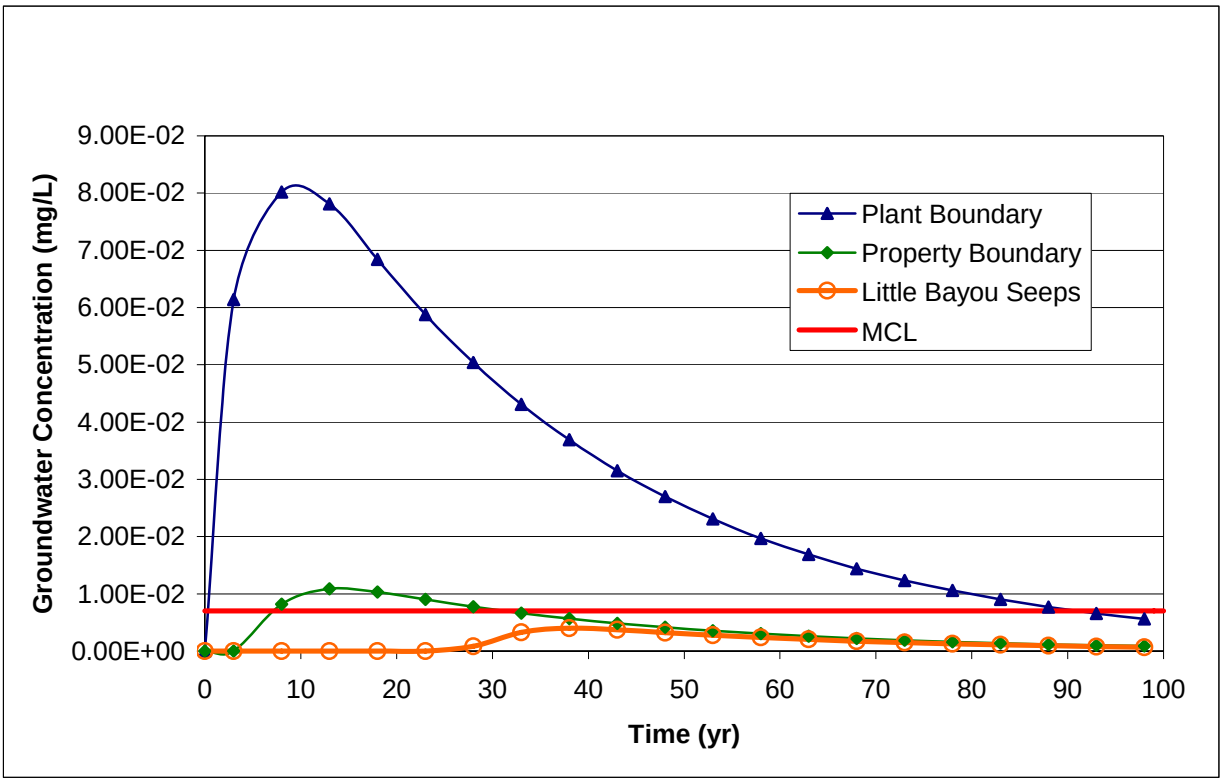

Figure 5.16. Predicted 1,1-DCE Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 7

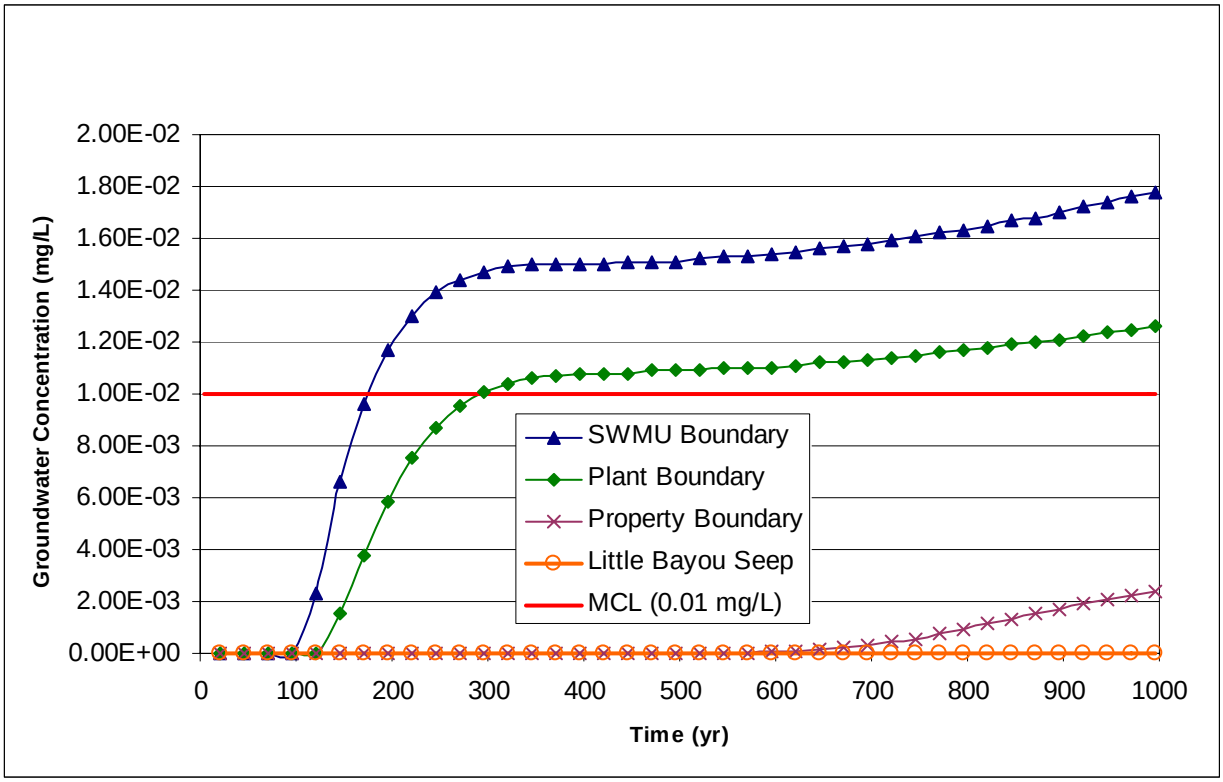

Figure 5.17. Predicted Arsenic Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 7

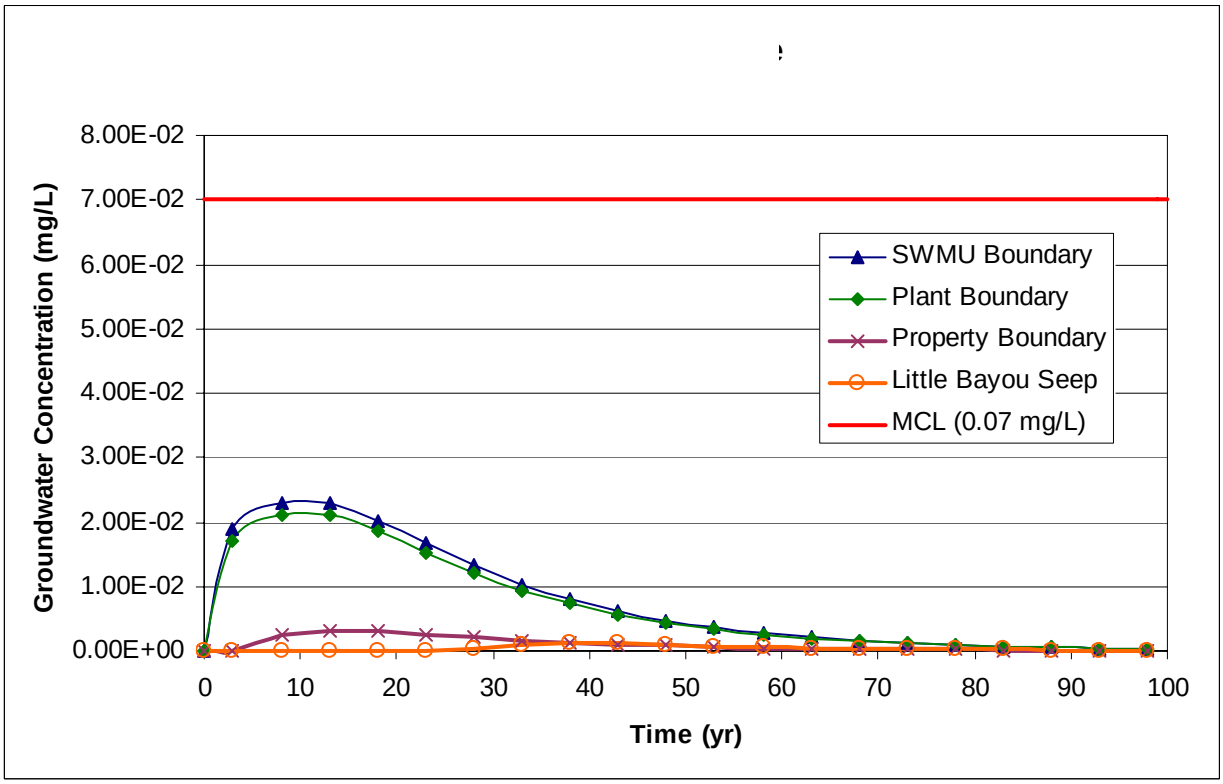

Figure 5.18. Predicted *cis*-1,2-DCE Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 7

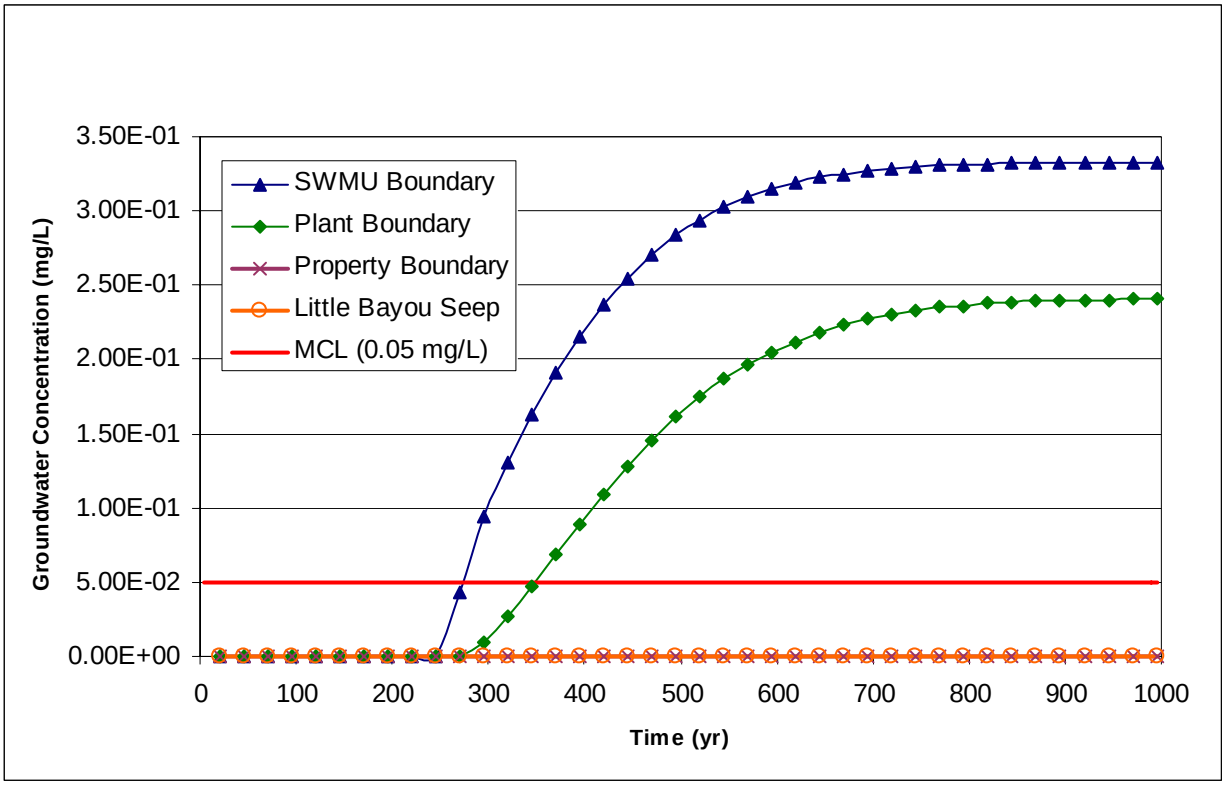

Figure 5.19. Predicted Manganese Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 7

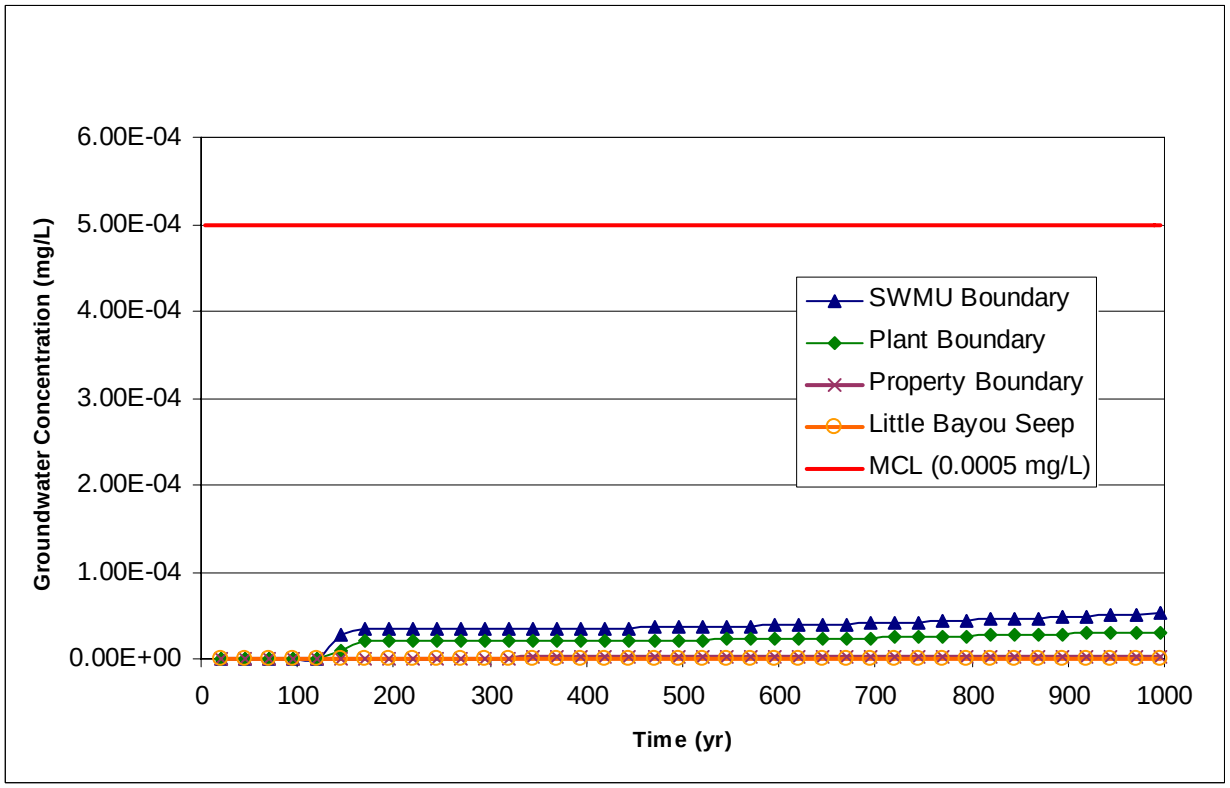

Figure 5.20. Predicted PCB-1254 Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 7

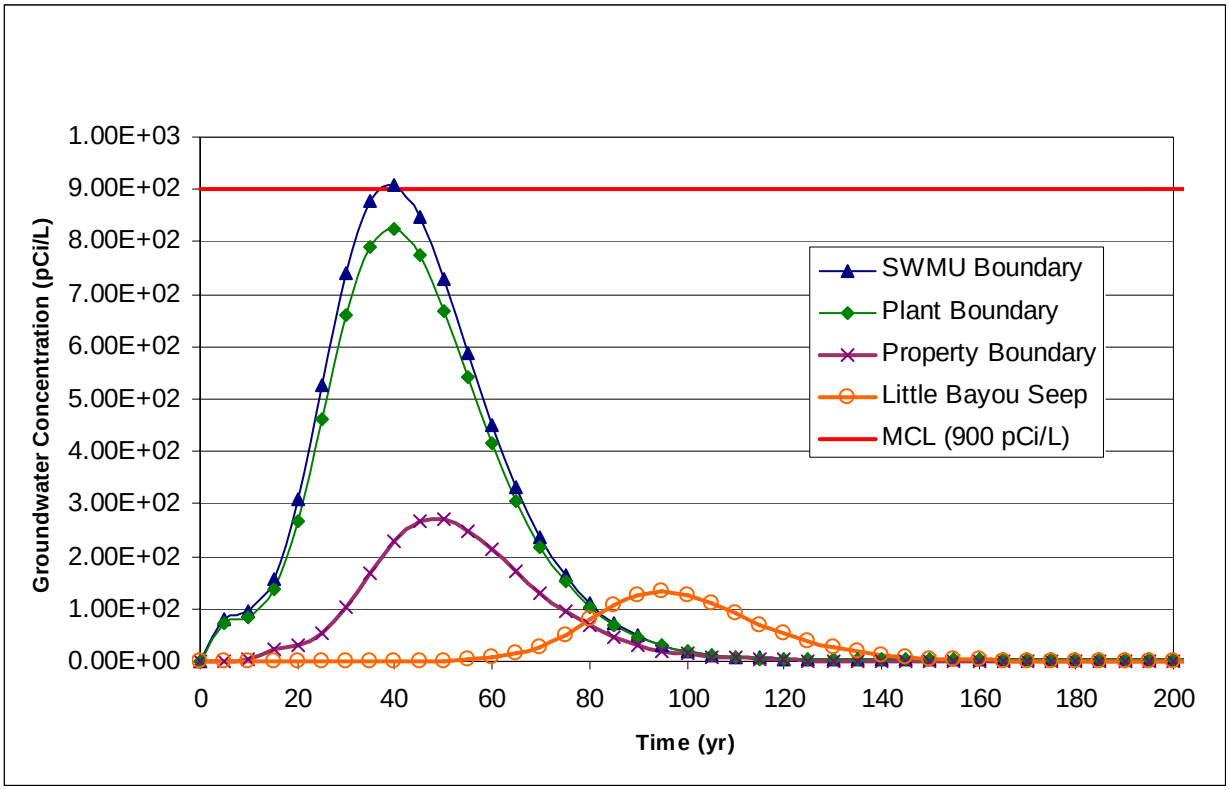

Figure 5.21. Predicted ^{99}Tc Activities in Groundwater at the POEs Based on Contaminant Leaching from SWMU 7

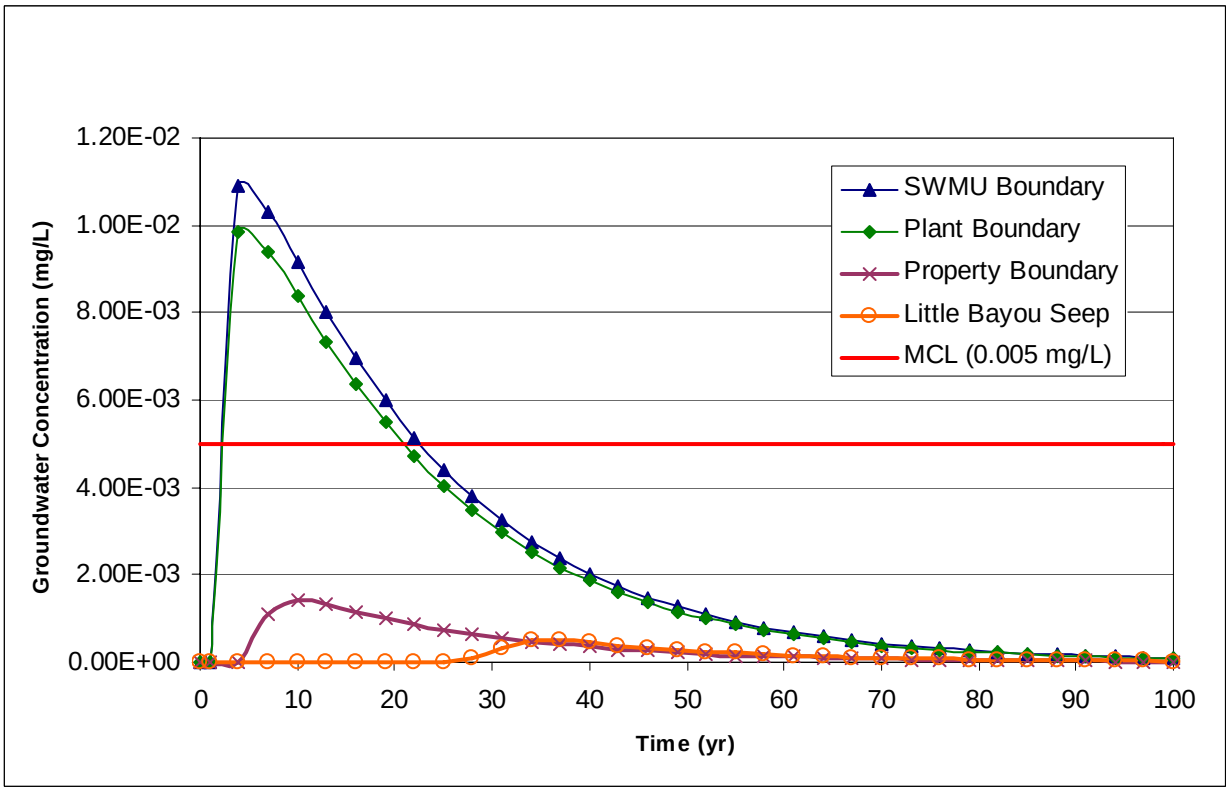

Figure 5.22. Predicted TCE Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 7

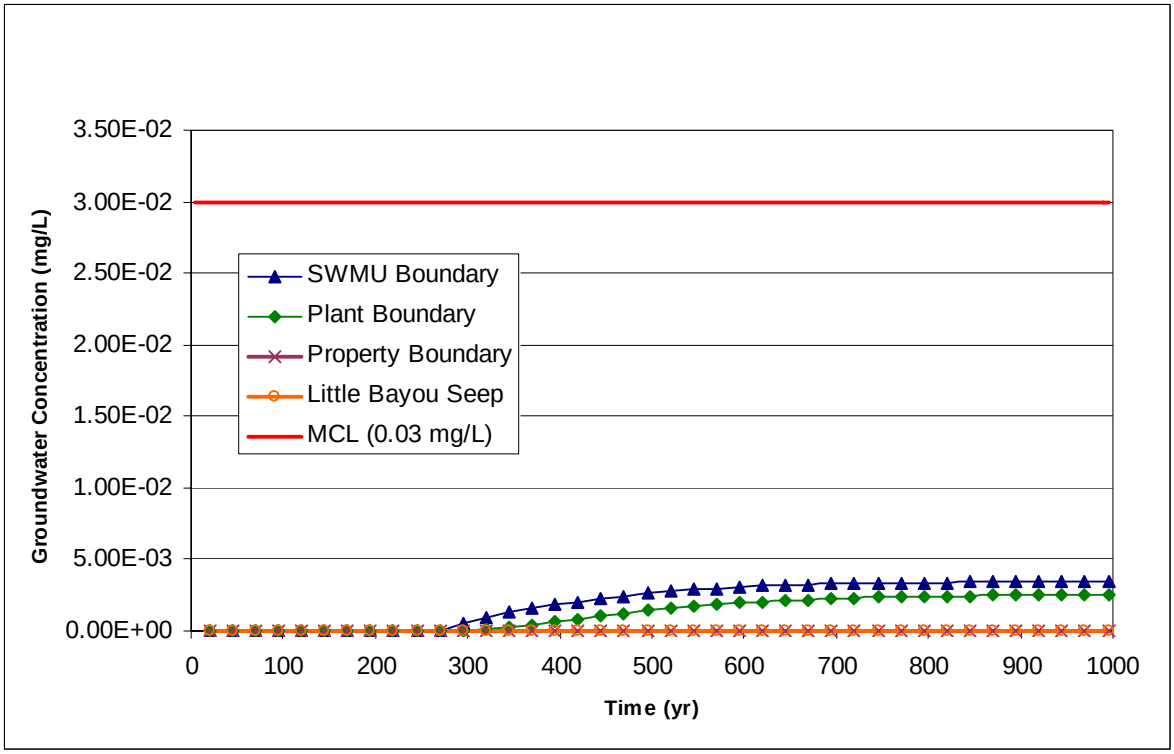

Figure 5.23. Predicted Uranium Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 7

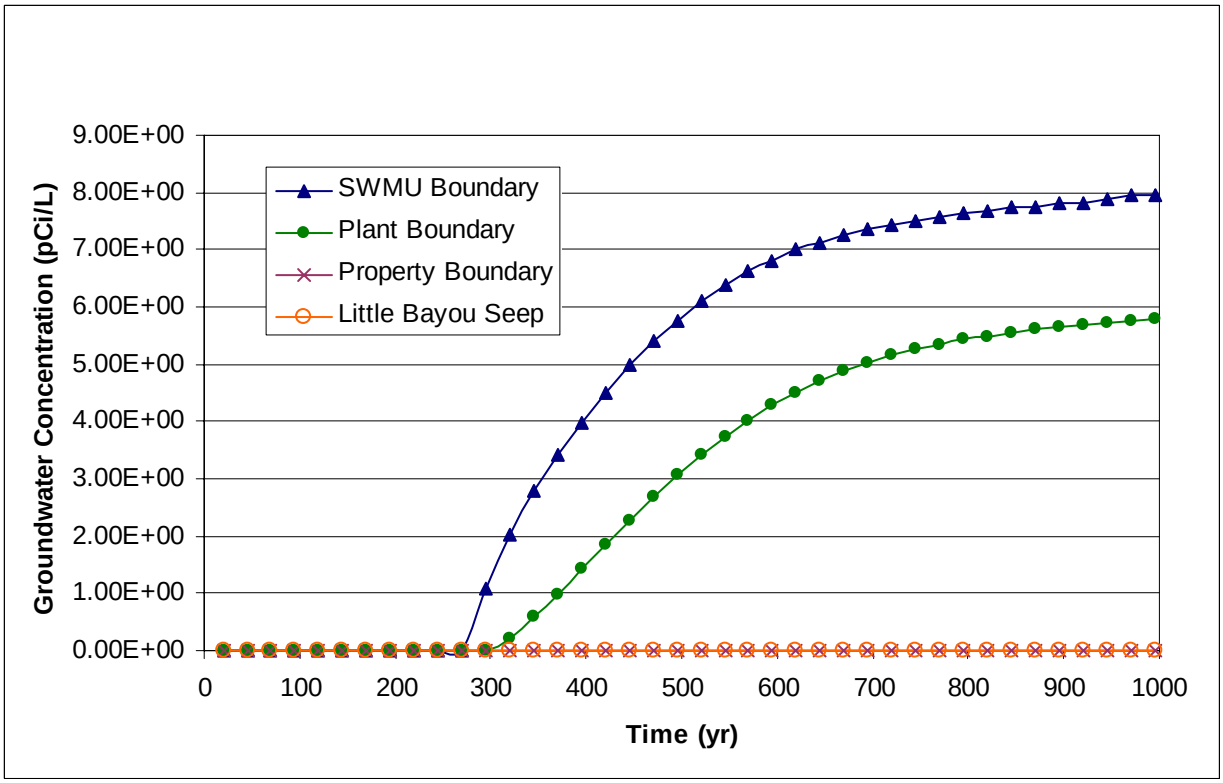

Figure 5.24. Predicted ^{234}U Activities in Groundwater at the POEs Based on Contaminant Leaching from SWMU 7

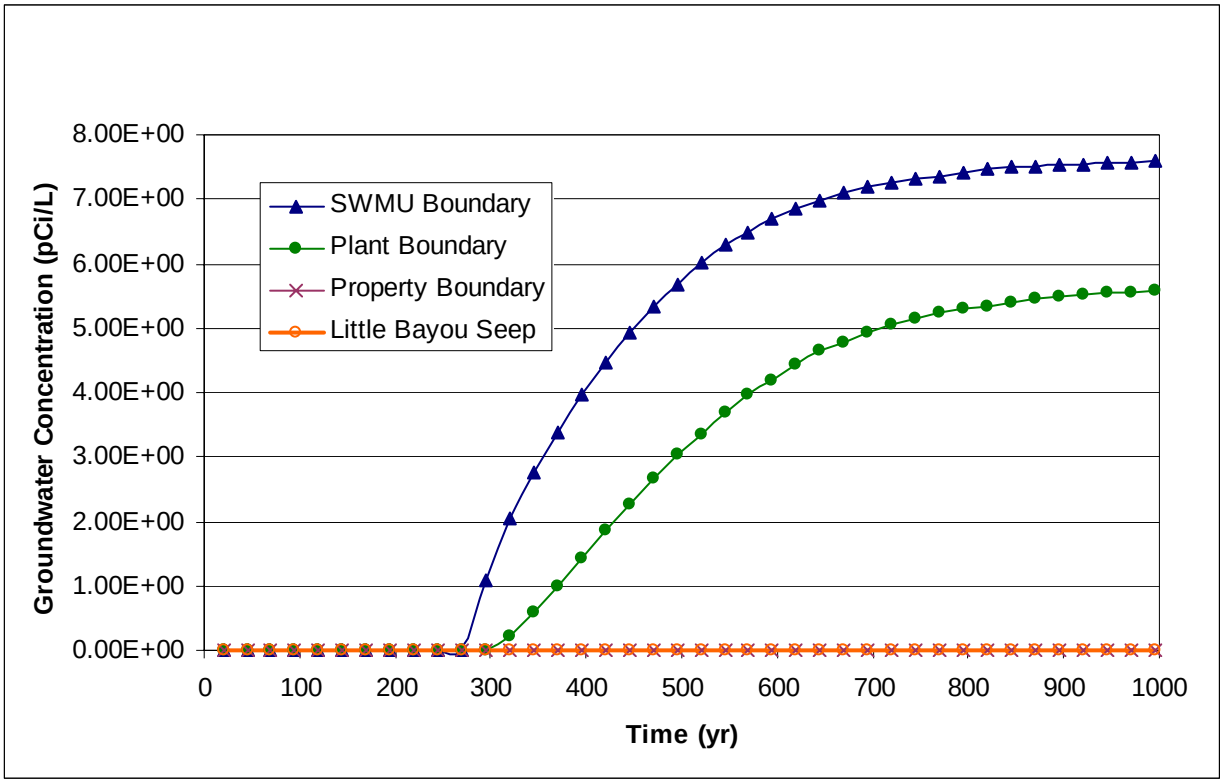

Figure 5.25. Predicted ^{238}U Activities in Groundwater at the POEs Based on Contaminant Leaching from SWMU 7

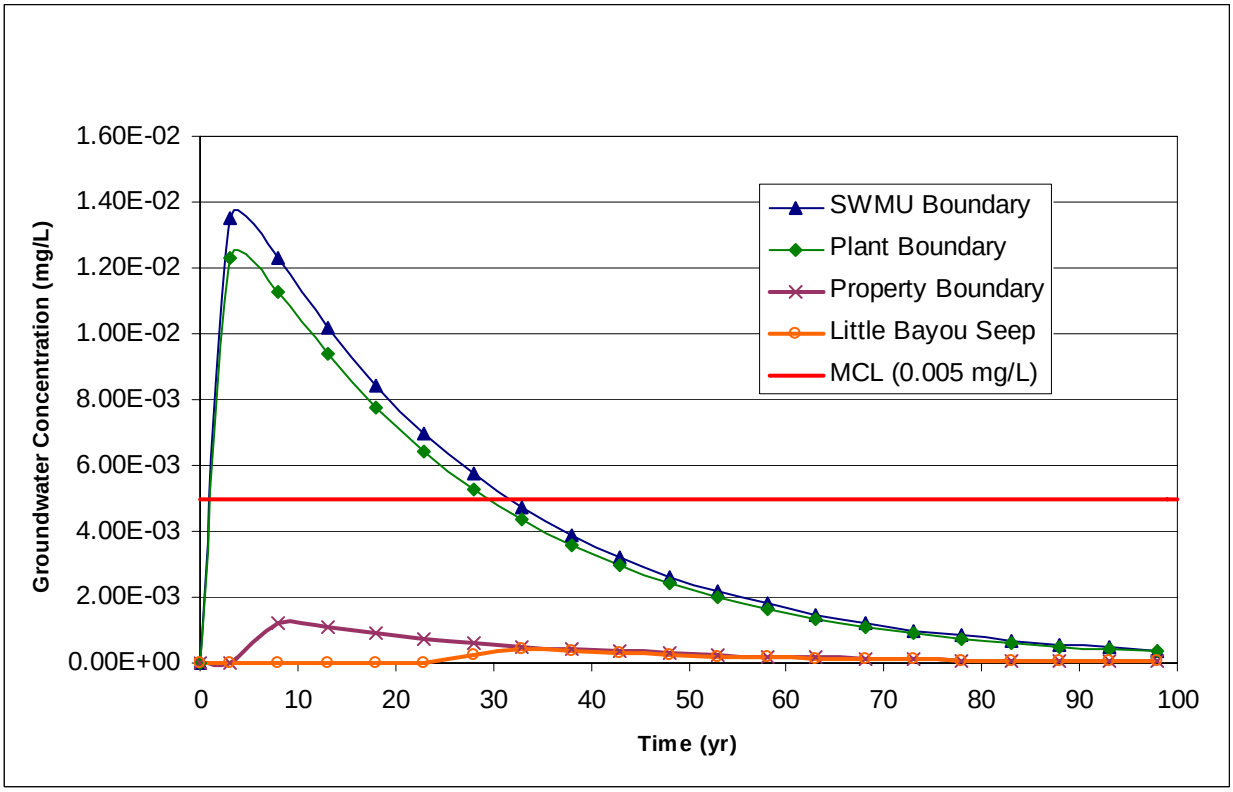

Figure 5.26. Predicted Vinyl Chloride Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 7

5.3.7 SWMU 30

Analytes retained after the screening process described in Section 5.2.1 are presented for SWMU 30 in Table E3.7. Each analyte was modeled and the resulting peak groundwater concentrations below SWMU 30 shown in Table 5.11 then were compared to the child resident NALs from Table A.18 of the 2001 Risk Methods Document and the provisional groundwater backgrounds shown in the 2001 Risk Method Document in Table A.13. Those analytes with groundwater concentrations below SWMU 30 that exceeded the NALs or background values then were carried through the toxicity and exposure assessments and cancer risk and hazards were calculated for the Rural Resident Groundwater User. Cadmium, nickel, vanadium, benzo(a)pyrene, and dibenz(a,h)anthracene were modeled and found not to reach the RGA during the 1,000 year modeling period.

Table 5.11. Screening of Modeled Peak Concentrations in Groundwater for SWMU 30

Analyte	Time (years)	Peak Conc. Below SWMU 30 (mg/L)[a]	Background Groundwater Concentration (mg/L)[a]	Groundwater Child Resident No Action Level (mg/L)[a]	Retain?
1,1-DCE	2.00E+00	6.05E-02	NA	4.70E-05	Y
Acenaphthene	3.90E+02	2.02E-04	NA	1.36E-02	N
Arsenic	9.90E+02	1.77E-02	5.00E-03	3.50E-05	Y
Fluorene	7.20E+02	1.26E-04	NA	9.72E-03	N
Manganese	7.90E+02	3.78E-01	1.19E-01	3.50E-02	Y
Mercury	1.00E+03	4.41E-06	2.00E-04	4.44E-04	N
Naphthalene	1.35E+02	1.81E-04	NA	2.85E-04	N
PCB-1254	1.00E+03	1.30E-05	NA	1.94E-05	N
PCB-1260	1.00E+03	5.42E-06	NA	1.94E-05	N
Pyrene	3.30E+02	1.82E-05	NA	1.82E-02	N
Selenium	3.60E+02	1.51E-02	5.00E-03	7.45E-03	Y
TCE	1.30E+01	7.12E-01	NA	5.82E-04	Y
Uranium	5.40E+02	8.40E-03	2.00E-03	9.06E-04	Y
Zinc	9.90E+02	7.77E-02	4.90E-02	4.50E-01	N
Technetium-99	3.70E+01	2.87E+02	2.23E+01	1.40E+01	Y
Uranium-234	7.05E+02	3.99E+00	7.00E-01	5.46E-01	Y
Uranium-235	6.15E+02	1.38E-01	3.00E-01	5.38E-01	N
Uranium-238	6.90E+02	5.91E+00	7.00E-01	4.43E-01	Y

[a] Units for radionuclides are pCi/L.
NA = not applicable N = No Y = Yes

The modeled groundwater concentrations of arsenic and TCE exceed their respective MCLs at the plant boundary (Table 5.3). Predicted TCE concentrations also exceed the MCL at the property boundary, and Little Bayou seeps. The following summarizes those analytes that exceeded ELCR or HQ risk criteria of 1.0E-06 and 0.1, respectively.

		Plant Boundary	Property Boundary	Little Bayou Seeps
1,1-DCE	**ELCR**	1.4E-03	1.0E-04	3.0E-05
	HQ	0.6	--	--
Arsenic	**ELCR**	3.1E-04	6.2E-05	--
	HQ	3.8	0.8	--
Manganese	**ELCR**	--	--	--
	HQ	0.5	--	--
Selenium	**ELCR**	--	--	--
	HQ	0.2	--	--

Technetium-99	**ELCR**	1.4E-05	3.9E-06	1.6E-06
	HQ	--	--	--
TCE	**ELCR**	2.1E-02	1.8E-03	6.1E-04
	HQ	311	26.8	9.0
Uranium	**ELCR**	--	--	--
	HQ	0.8	--	--
Uranium-234	**ELCR**	3.9E-06	--	--
	HQ	--	--	--
Uranium-238	**ELCR**	7.1E-06	--	--
	HQ	--	--	--

-- = does not exceed

All remaining analytes exhibited HQ values less than 0.1 and ELCR values less than 1.0E-06 at all POEs. Figures 5.27 through 5.35 display the modeled concentrations of SWMU 30 analytes that exceed a HQ of 0.1 and/or an ELCR of 1.0E-06 (Table 5.4). As shown in these figures, the dissolved arsenic and manganese concentrations are predicted to continue rising at 1,000 years at the plant boundary, with arsenic exceeding its MCL. Dissolved arsenic concentrations were less than the MCL at the property boundary, but dissolved manganese levels have not reached the property boundary or Little Bayou Seeps in the 1,000-year period.

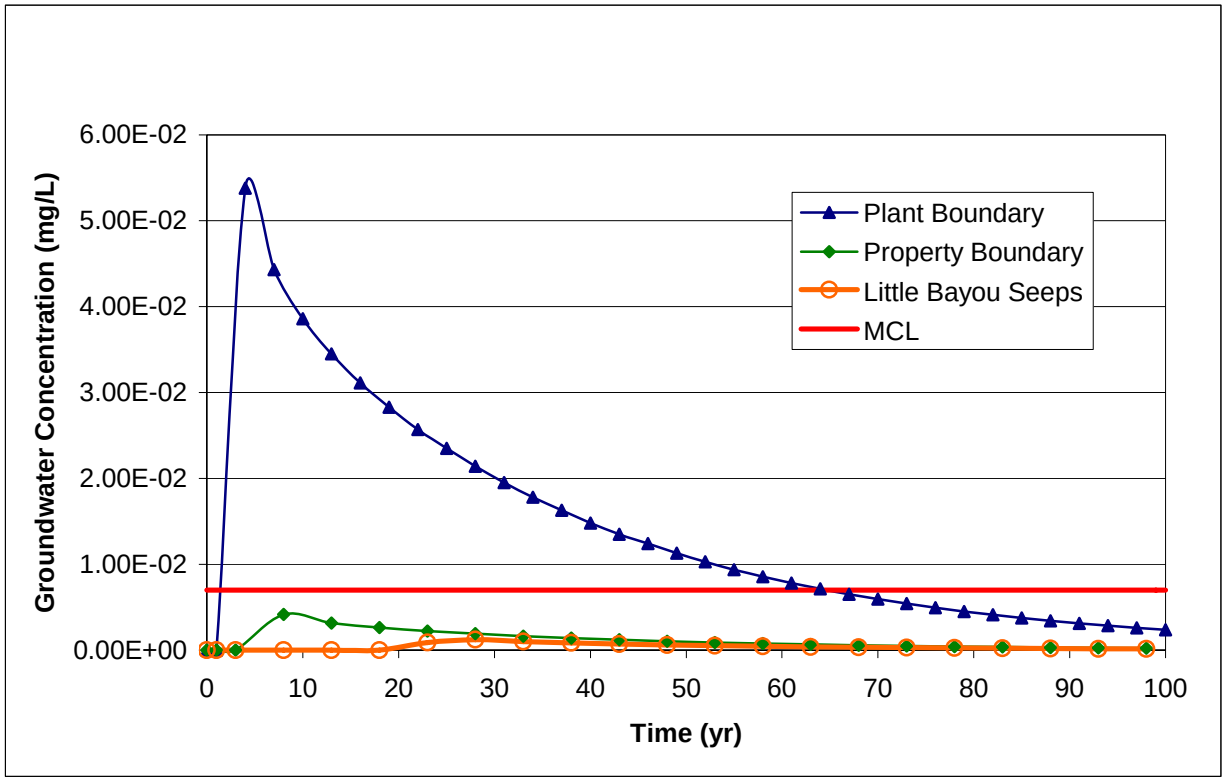

Figure 5.27. Predicted 1,1-DCE Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 30

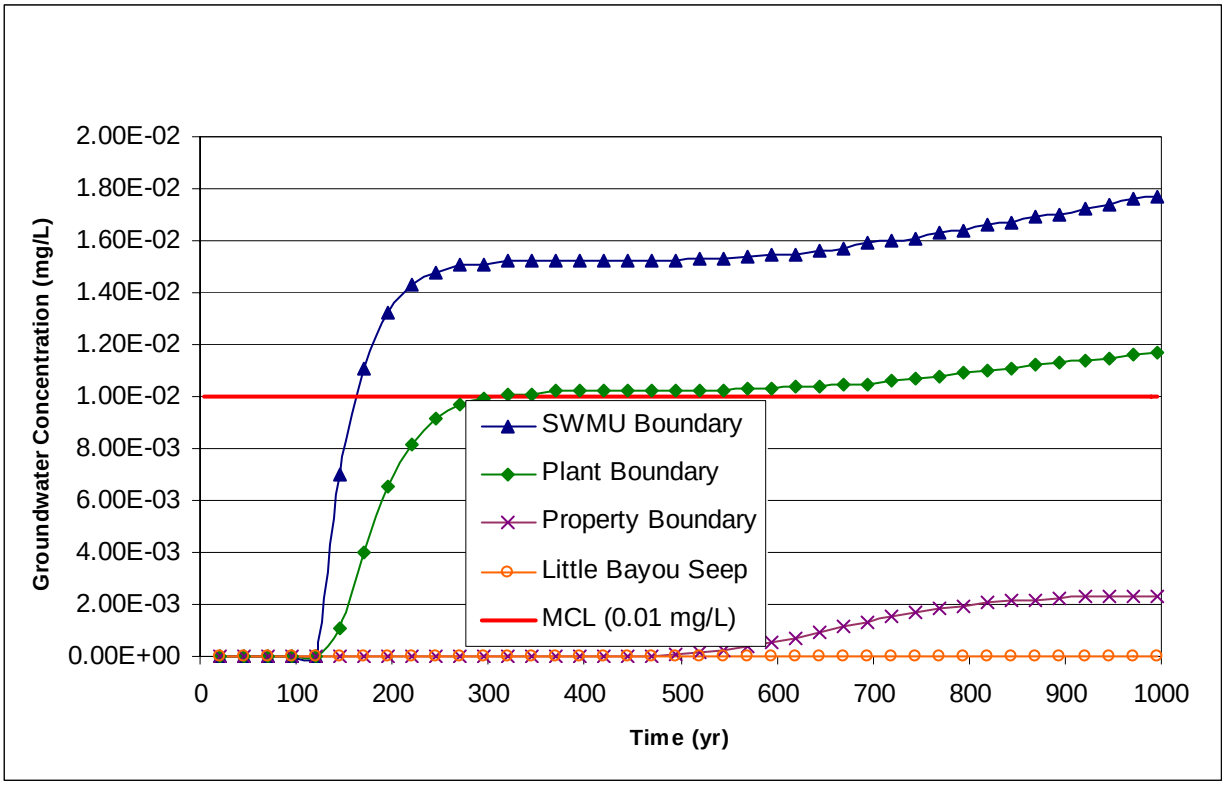

Figure 5.28. Predicted Arsenic Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 30

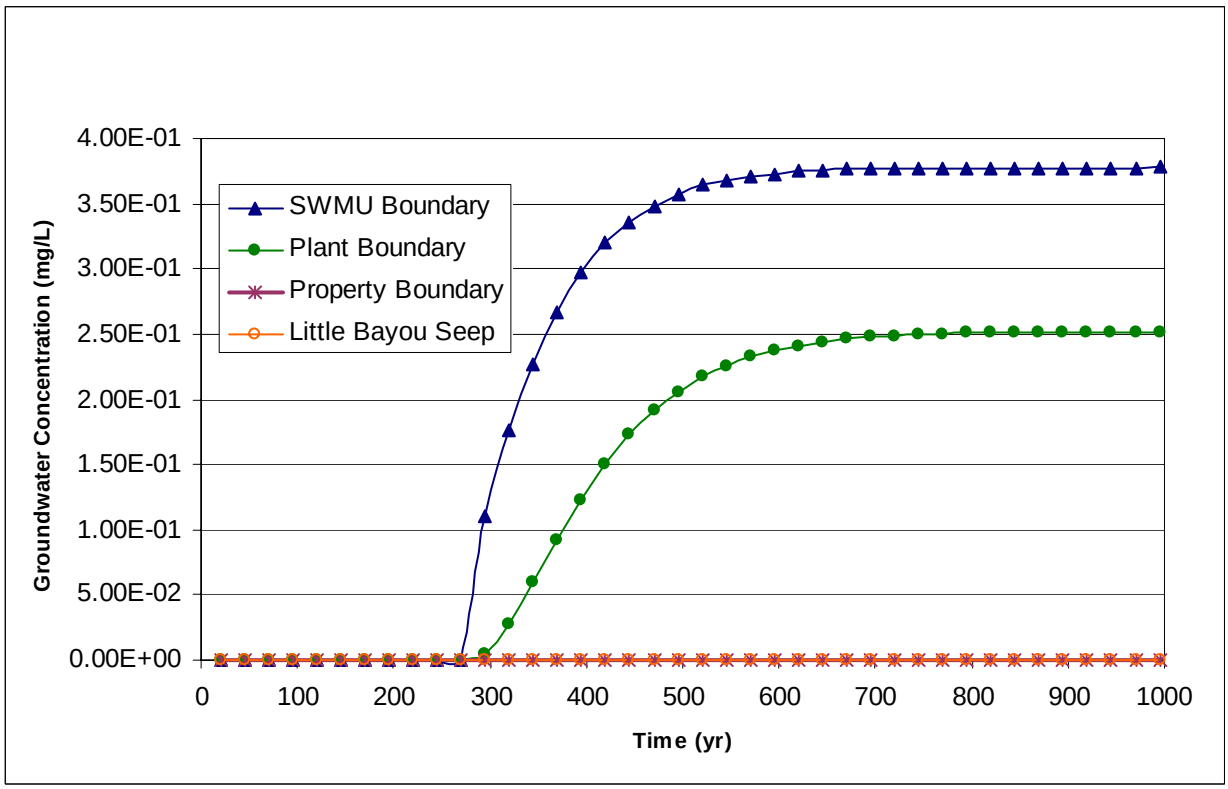

Figure 5.29. Predicted Manganese Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 30

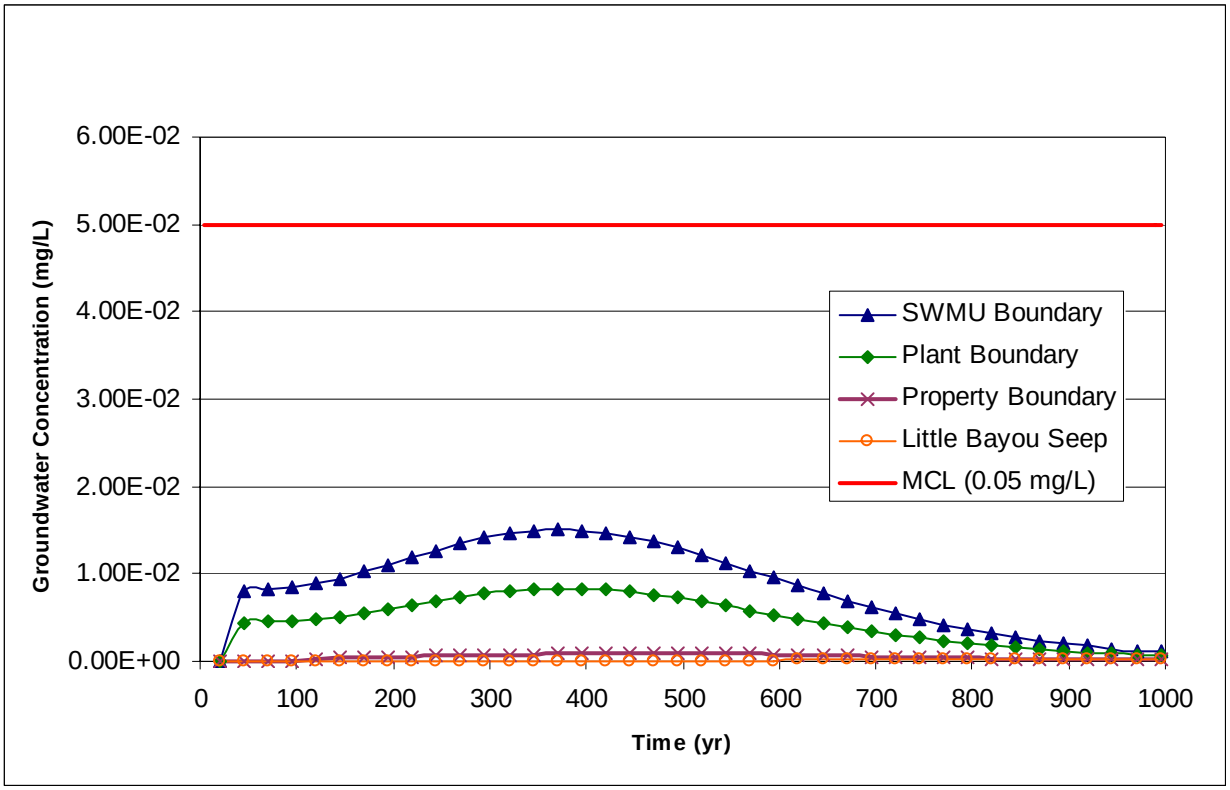

Figure 5.30. Predicted Selenium Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 30

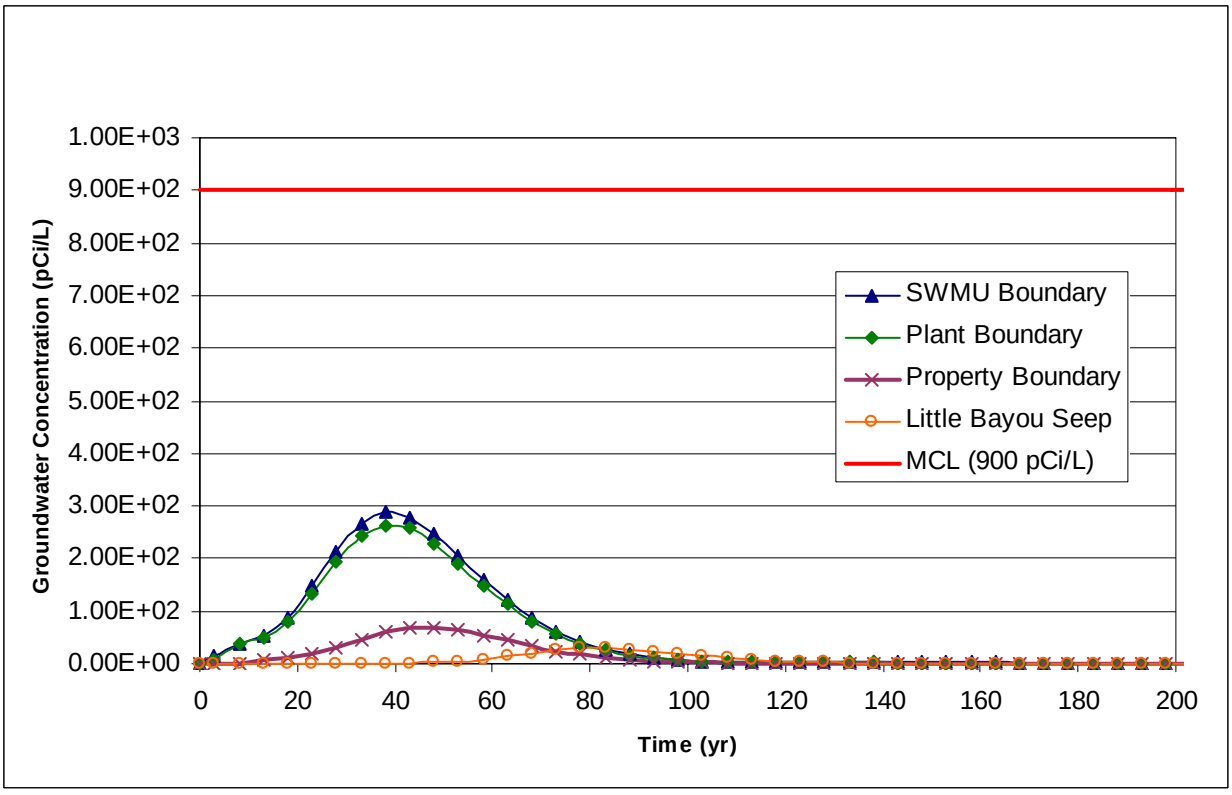

Figure 5.31. Predicted ^{99}Tc Activities in Groundwater at the POEs Based on Contaminant Leaching from SWMU 30

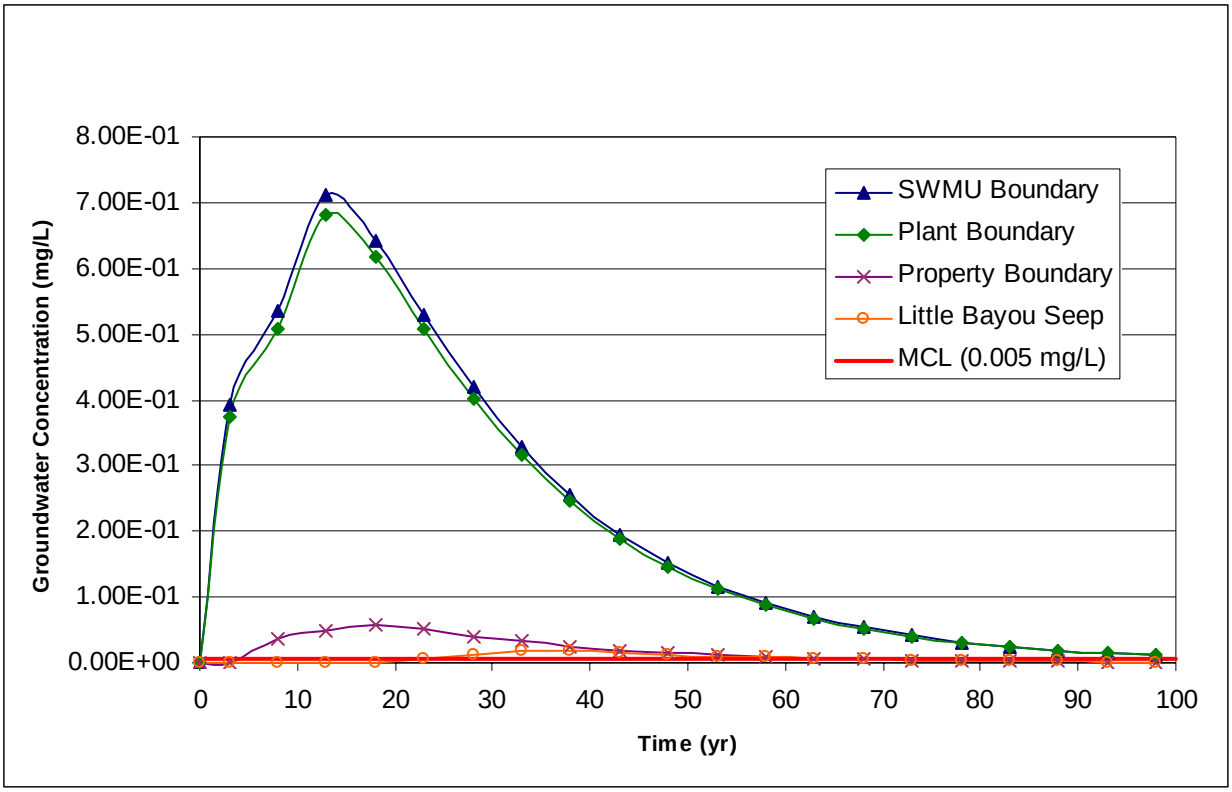

Figure 5.32. Predicted TCE Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 30

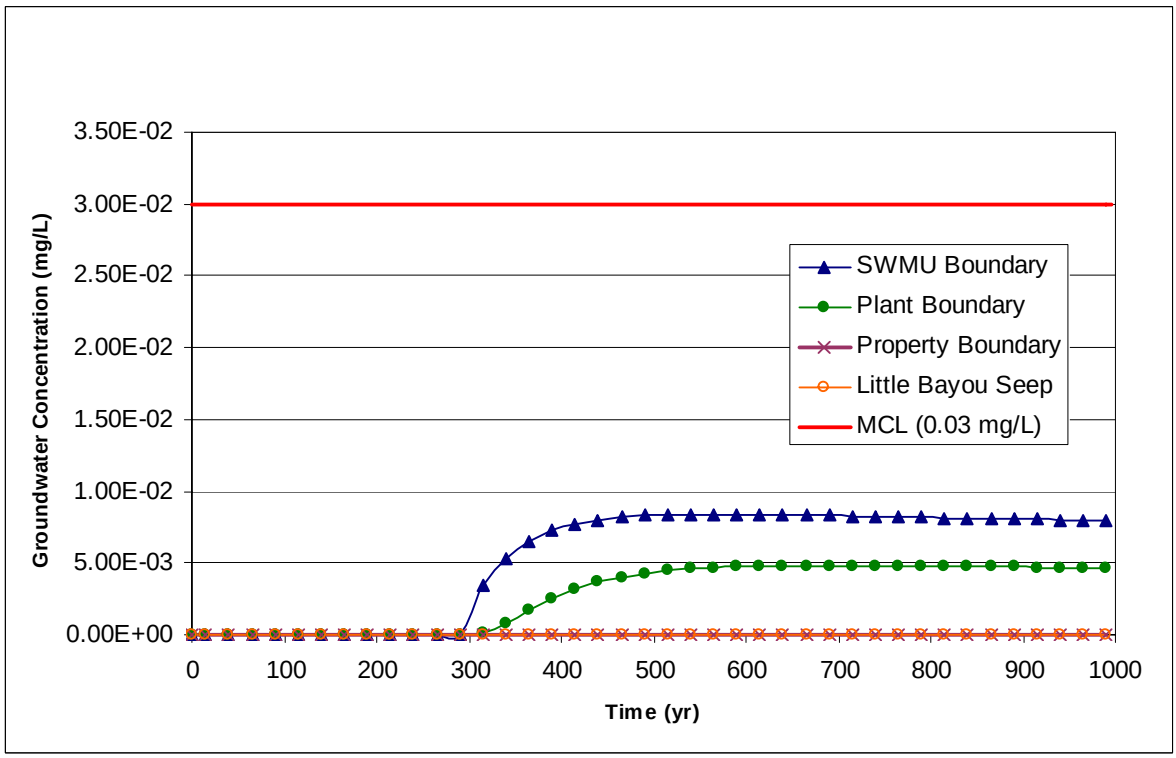

Figure 5.33. Predicted Uranium Concentration in Groundwater at the POEs Based on Contaminant Leaching from SWMU 30

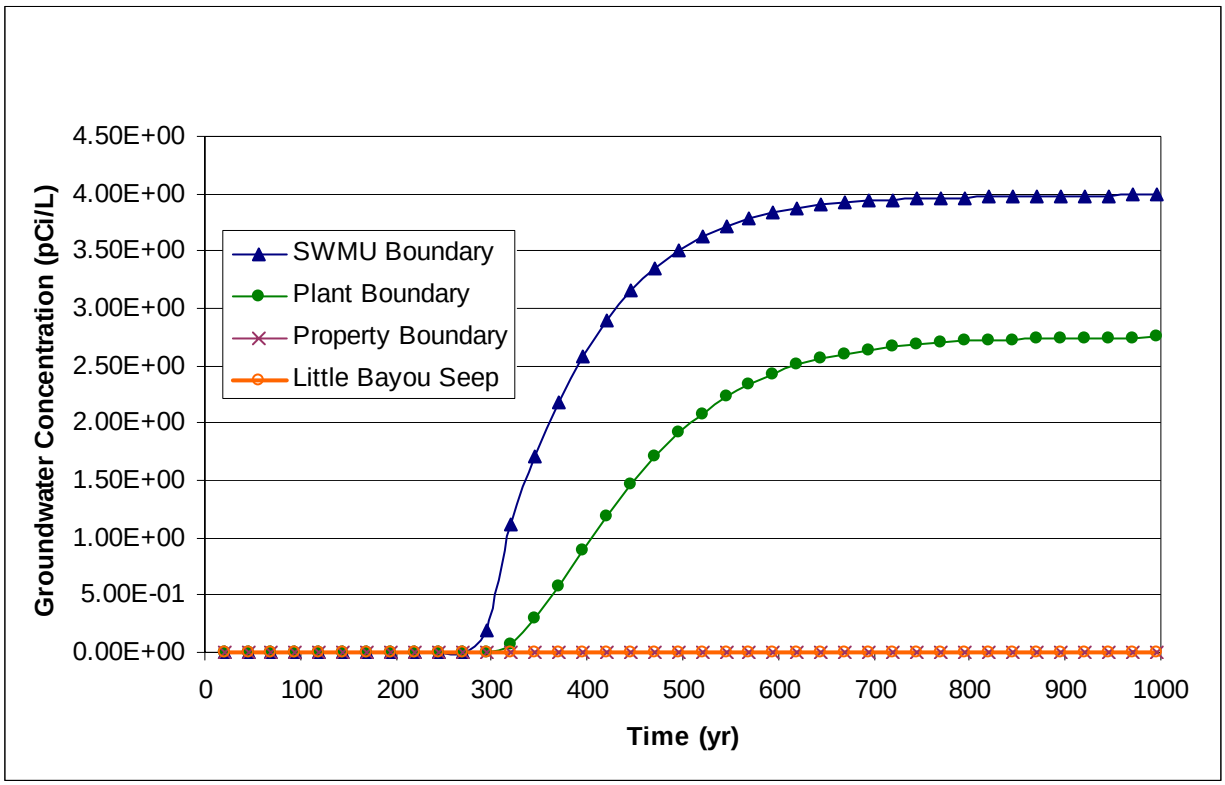

Figure 5.34. Predicted ^{234}U Activities in Groundwater at the POEs Based on Contaminant Leaching from SWMU 30

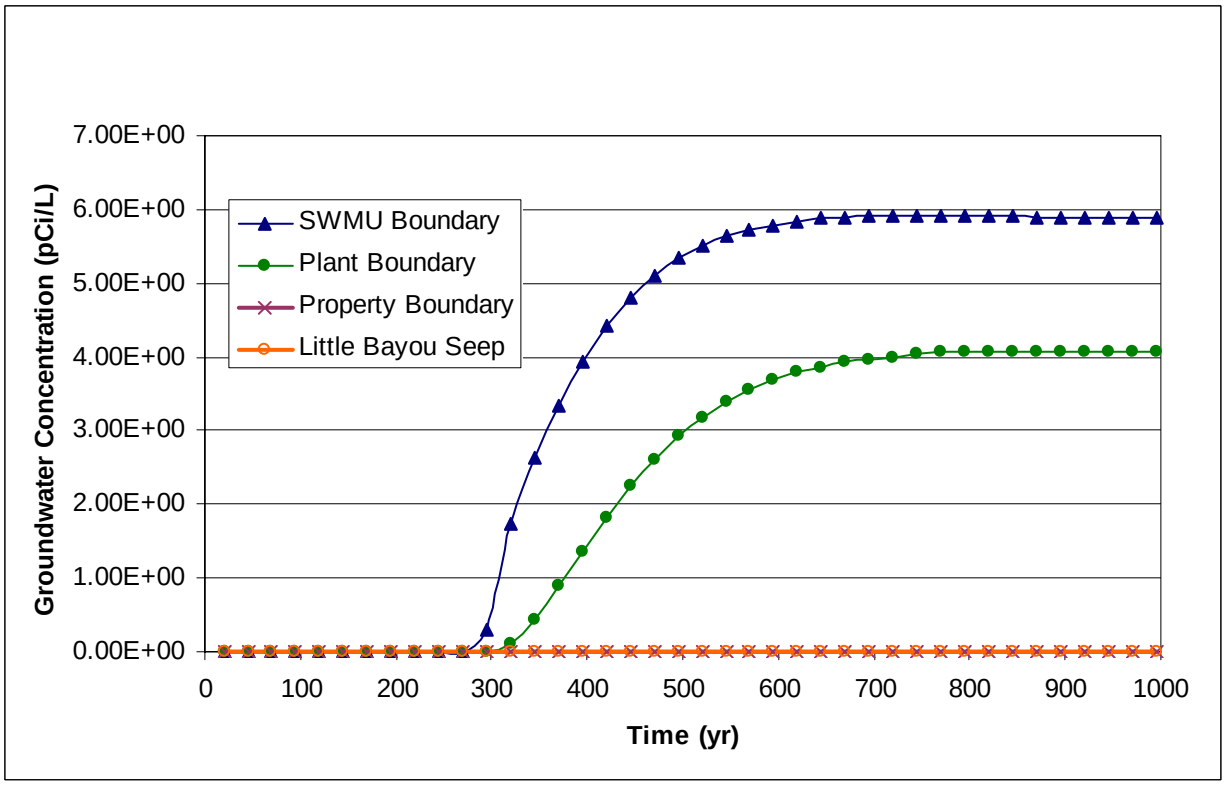

Figure 5.35. Predicted ^{238}U Activities in Groundwater at the POEs Based on Contaminant Leaching from SWMU 30

5.3.8 SWMU 145

Analytes retained after the screening process described in Section 5.2.1 are presented for SWMU 145 in Table E3.8. Each analyte was modeled and the resulting peak groundwater concentrations below SWMU 145 shown in Table 5.12 then were compared to the child resident NALs from Table A.18 of the 2001 Risk Methods Document and the provisional groundwater backgrounds shown in the 2001 Risk Method Document in Table A.13. Those analytes with groundwater concentrations below SWMU 145 that exceeded the NALs or background values then were carried through the toxicity and exposure assessments and cancer risk and hazards were calculated for the Rural Resident Groundwater User. Vanadium, benzo(a)pyrene, plutonium-239, and uranium-234 were modeled and found not to reach the RGA during the 1,000 year modeling period.

Table 5.12. Screening of Modeled Peak Concentrations in Groundwater for SWMU 145

Analyte	Time (years)	Peak Conc. Below SWMU 145 (mg/L)[a]	Background Groundwater Concentration (mg/L)[a]	Groundwater Child Resident No Action Level (mg/L)[a]	Retain?
Antimony	1,000	7.99E-02	6.00E-02	5.64E-04	Y
PCB-1260	805	1.92E-03	NA	4.28E-05	Y
Arsenic	1,000	6.21E-02	5.00E-03	3.50E-05	Y
Cadmium	1,000	4.10E-03	1.00E-02	6.61E-04	N
Manganese	1,000	8.44E-01	1.19E-01	3.50E-02	Y
Mercury	850	2.59E-04	2.00E-04	4.44E-04	N
Nickel	1,000	4.14E-03	3.05E-01	3.01E-02	N
Technetium-99	30	1.0106E+04	2.23E+01	1.40E+01	Y
Uranium-238	1,000	2.58E+01	7.00E-01	4.43E-01	Y

[a] Units for radionuclides are pCi/L; NA = not applicable; N = No; Y = Yes

The groundwater results presented in Table 5.3 for SWMU 145 show the predicted groundwater concentration of technetium-99 will exceed the MCL at the property boundary and Ohio River. Modeled levels of all remaining SWMU 145 analytes are less than their respective MCLs at the POEs. The following summarizes those analytes that exceeded ELCR or HQ risk criteria of 1.0E-06 and 0.1, respectively.

		Property Boundary	Ohio River
Arsenic	**ELCR**	4.3E-05	--
	HQ	0.5	--
Technetium-99	**ELCR**	1.0E-04	5.3E-05
	HQ	--	--

-- = does not exceed

All remaining analytes exhibited HQ values less than 0.1 and ELCR values less than 1.0E-06 at all POEs. Predicted concentrations of SWMU 145 analytes that exceed a HQ of 0.1 and/or an ELCR of 1.0E-06 (Table 5.4) are illustrated in Figures 5.36 and 5.37. As shown in these figures, arsenic is increasing in concentration at the plant boundary at 1,000 years; however, the concentrations are less than the MCL. technetium-99 was predicted to exceed the MCL at the POEs.

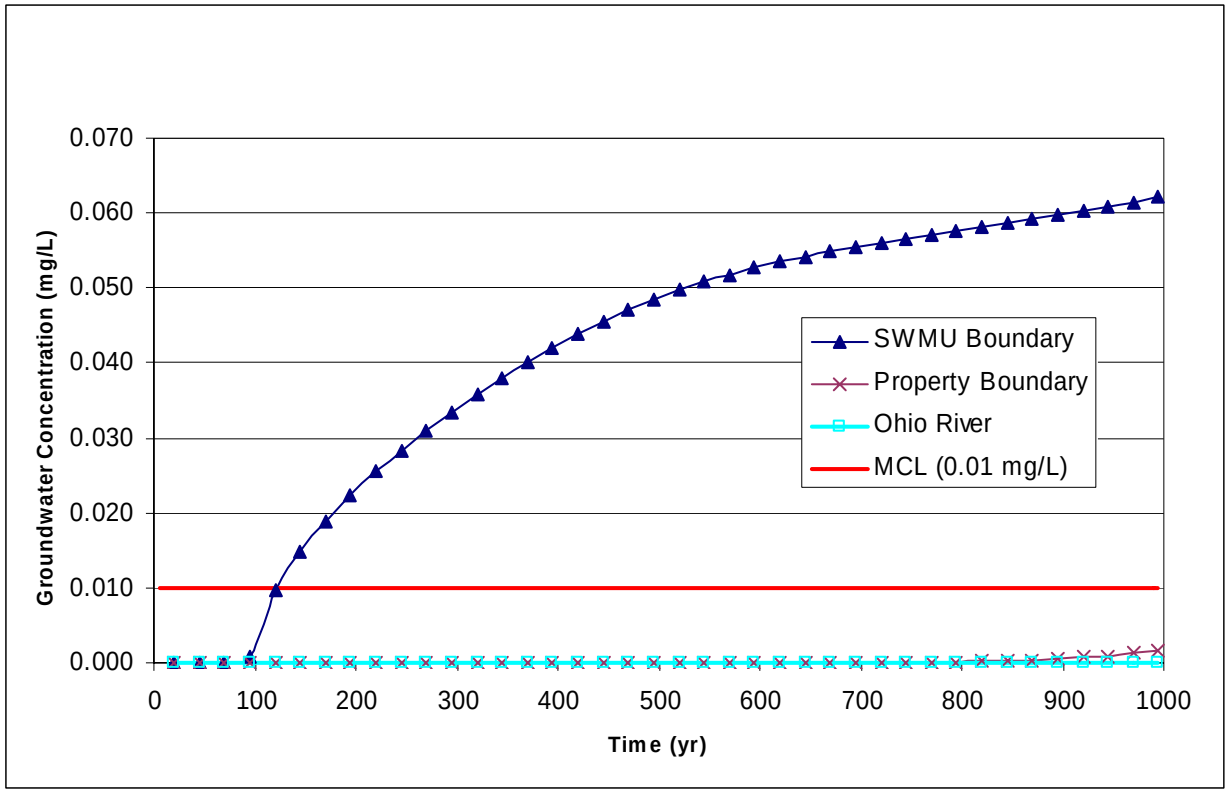

Figure 5.36. Predicted Arsenic Concentrations in Groundwater at the POEs Based on Contaminant Leaching from SWMU 145

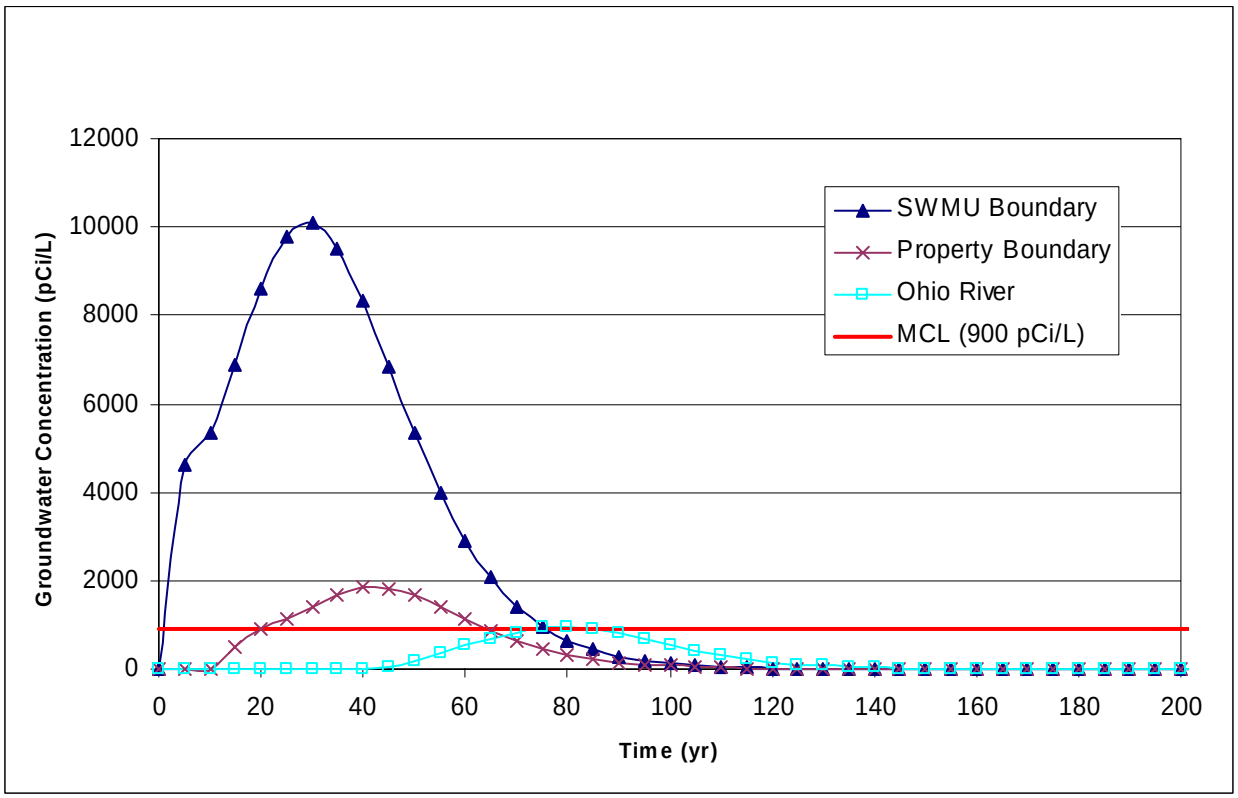

Figure 5.37. Predicted ^{99}Tc Activity in Groundwater at the POEs Based on Contaminant Leaching from SWMU 145

5.4 VAPOR TRANSPORT MODELING

The BGOU RI includes vapor transport modeling to evaluate the potential air concentrations in a residential basement for soil and groundwater contamination at the BGOU SWMUs and POEs. Modelers used the Johnson and Ettinger model (1991), coded into spreadsheets by EPA (2004), to assess the potential migration of VOCs into a residential basement (see Appendix E for details of the analysis).

Table 5.13 presents the resulting basement air concentrations, predicted by the model. Table 5.14 summarizes the health and cancer risks calculated in accordance with Appendix A of the Risk Methods Document. The vapor transport modeling for mercury was conservatively based on the metallic form, which has a Henry's Law Constant of 1.07E-02 atm-m^3/mol. Metallic mercury, with its uniquely high vapor pressure relative to other metals, can enter the atmosphere from the groundwater environment as several different gaseous compounds. The rate of vaporization of mercury and certain of its inorganic compounds decrease in the sequence Hg > Hg_2Cl_2 > $HgCl_2$ > HgS > HgO. The Henry's Law Constant decreases dramatically down the sequence (for example, $HgCl_2$ has a value of 7.09E-10 atm-m^3/mol).

The results of the vapor transport modeling (Table 5.14) show that TCE is predicted to have HQ values above 0.1 and/or ELCRs exceeding 1.0E-06 for a residential basement exposure above SWMUs 2, 3, 4, 7, and 30. Additional analytes that were found to exceed the HQ value of 0.1 and/or an ELCR value of 1.0E-06 within the SWMUs included *cis*-1,2-DCE (SWMUs 2 and 4); vinyl chloride (SWMUs 4 and 7); 1,1-DCE (SWMUs 7 and 30); and mercury (SWMUs 3, 7, 30, and 145).

Derived ELCR values exceeded 1.0E-06 for modeled TCE concentrations from groundwater transport at the plant boundary (SWMUs 2, 4, and 30) and property boundary (SWMUs 2, 4, and 30). Modeled vinyl chloride (SWMU 4) and 1,1-DCE (SWMUs 7 and 30) concentrations also equate to ELCR values greater than 1.0E-06 from groundwater transport at the plant boundary.

Table 5.13. Basement Air Concentrations Based on Vapor Transport Modeling Results for Each BGOU SWMU

		Air concentration (mg/m^3)		
Source Area	**Contaminant**	**SWMU Boundary**	**Plant Boundary**	**Property Boundary**
SWMU 2	TCE	2.81E-02	1.09E-04	5.55E-05
	cis-1,2-DCE	1.95E-01	7.82E-04	3.89E-04
	Naphthalene	2.70E-07	1.56E-08	8.43E-09
SWMU 3	TCE	1.62E-05	8.52E-10	4.47E-10
	Mercury	7.22E-06	1.12E-14	0.00E+00
SWMU 4	TCE	4.90E-03	2.12E-04	1.08E-04
	cis-1,2-DCE	5.76E-03	8.80E-05	4.05E-05
	Vinyl chloride	6.7E-03	1.98E-04	2.55E-06
SWMU 5	TCE	5.41E-06	1.98E-07	9.13E-08
	Acenaphthene	2.04E-07	7.47E-08	4.30E-08
	Fluorene	5.16E-08	2.37E-08	1.27E-08
	Naphthalene	3.80E-06	9.75E-08	3.79E-08
	Pyrene	2.28E-09	NA	NA
SWMU 6	TCE	9.34E-06	3.88E-09	1.92E-09
SWMU 7	TCE	8.63E-05	4.96E-06	7.16E-07
	cis-1,2-DCE	2.13E-04	9.66E-06	1.42E-06
	Vinyl chloride	1.23E-02	1.25E-05	1.22E-06
	1,1-DCE	1.03E-02	6.70E-05	9.03E-06
	Mercury	9.99E-06	2.22E-09	2.41E-12
	Pyrene	7.68E-09	4.93E-12	1.31E-12
	Tetrachloroethene	2.00E-05	6.40E-08	4.70E-09
SWMU 30	TCE	6.75E-02	3.42E-04	2.96E-05
	1,1-DCE	3.36E-02	4.85E-05	3.62E-06
	Acenaphthene	2.77E-08	4.96E-09	9.22E-10
	Fluorene	3.92E-09	NA	NA
	Mercury	1.66E-05	8.91E-1	2.23E-11
	Pyrene	6.56E-10	2.47E-11	6.54E-12
	Naphthalene	3.10E-07	1.90E-08	1.85E-09
SWMU 145	Mercury	1.42E-05	7.95E-08	2.60E-14

Table 5.14. Vapor Hazard Quotients and Risk Based on Vapor Transport Modeling Results for Each BGOU SWMU

Source Area	Contaminant	On-Site		Plant Boundary		Property Boundary	
		HQ	ELCR	HQ	ELCR	HQ	ELCR
SWMU 2	TCE	**3.15E+00**	**1.84E-03**	1.22E-02	**7.14E-06**	6.22E-03	**3.64E-06**
	cis-1,2-DCE	**2.50E+01**	0.00E+00	1.00E-01	0.00E+00	4.99E-02	0.00E+00
	Naphthalene	4.03E-04	0.00E+00	4.99E-06	0.00E+00	1.26E-05	0.00E+00
SWMU 3	TCE	1.82E-03	**1.06E-06**	9.63E-08	5.68E-11	5.01E-08	2.93E-11
	Mercury	1.08E-01	0.00E+00	1.67E-10	0.00E+00	0.00E+00	0.00E+00
SWMU 4	TCE	**5.54E-01**	**3.23E-04**	2.38E-02	**1.39E-05**	1.21E-02	**7.07E-06**
	cis-1,2-DCE	**7.38E-01**	0.00E+00	1.13E-02	0.00E+00	5.19E-03	0.00E+00
	Vinyl Chloride	**2.99E-01**	**4.19E-05**	8.85E-03	**1.24E-06**	1.14E-04	1.60E-08
SWMU 5	TCE	6.06E-04	3.54E-07	2.22E-05	1.30E-08	1.02E-05	5.98E-09
	Acenaphthene	4.37E-06	0.00E+00	1.60E-06	0.00E+00	9.21E-07	0.00E+00
	Fluorene	1.65E-06	0.00E+00	7.57E-07	0.00E+00	4.06E-07	0.00E+00
	Naphthalene	5.67E-03	0.00E+00	1.45E-03	0.00E+00	5.65E-04	0.00E+00
	Pyrene	9.71E-08	0.00E+00	NA	NA	NA	NA
SWMU 6	TCE	1.05E-03	6.12E-07	4.35E-07	2.54E-10	2.15E-07	1.26E-10
SWMU 7	TCE	9.68E-03	**5.65E-06**	5.56E-04	3.25E-07	8.03E-05	4.69E-08
	cis-1,2-DCE	2.73E-02	0.00E+00	1.24E-03	0.00E+00	1.82E-04	0.00E+00
	Vinyl Chloride	**5.48E-01**	**7.68E-05**	5.59E-04	7.83E-08	5.45E-05	7.64E-09
	1,1-DCE	**2.30E-01**	**3.66E-04**	1.50E-03	**2.39E-06**	2.02E-04	3.21E-07
	Mercury	1.49E-01	0.00E+00	3.31E-05	0.00E+00	3.59E-08	0.00E+00
	Pyrene	3.27E-07	0.00E+00	2.10E-10	0.00E+00	5.58E-11	0.00E+00
	Tetrachloroethene	1.49E-04	8.13E-09	4.78E-07	2.60E-11	3.51E-08	1.91E-12
SWMU 30	TCE	**7.57E+00**	**4.42E-03**	3.83E-02	**2.24E-05**	3.32E-03	**1.94E-06**
	1,1-DCE	**7.52E-01**	**1.20E-03**	1.09E-03	**1.73E-06**	8.10E-05	1.29E-07
	Acenaphthene	5.93E-07	0.00E+00	1.06E-07	0.00E+00	1.97E-08	0.00E+00
	Fluorene	1.25E-07	0.00E+00	NA	NA	NA	NA
	Mercury	2.47E-01	0.00E+00	1.33E-05	0.00E+00	3.33E-07	0.00E+00
	Naphthalene	4.62E-04	0.00E+00	2.83E-05	0.00E+00	2.76E-06	0.00E+00
	Pyrene	2.80E-08	0.00E+00	1.05E-09	0.00E+00	2.79E-10	0.00E+00
SWMU 145	Mercury	2.12E-01	0.00E+00	1.19E-03	0.00E+00	3.88E-10	0.00E+00

5.5 FATE AND TRANSPORT UNCERTAINTY

The source inventory, unsaturated zone transport, and saturated zone transport were modeled using the SADA, SESOIL, and AT123D computer codes. The use of these computer codes in the analyses resulted in the use of simplifying assumptions. These assumptions resulted in modeling uncertainties. This section lists the modeling uncertainties and discusses their impacts upon the modeling results. A detailed discussion of the uncertainty in the modeling analyses is provided in Appendix E.

5.5.1 Source Term Development

The source term was developed using sampling results, geospatial analyses in SADA, and consideration of SESOIL limitations. While the sampling results are appropriate for source identification, SESOIL requires input of the soil concentrations for each layer of interest in the UCRS. Additionally, due to SESOIL's requirement to use the same constant area for each layer, the analyte concentrations of all layers needed to be normalized against the area of the layer with the maximum estimated analyte mass. Geospatial interpolation was used based on the SADA nearest neighbor algorithm to estimate the total mass in each UCRS layer based upon the sampling results.

The techniques in SADA that can be used for source term development are nearest neighbor, inverse distance, and ordinary kriging. The nearest neighbor technique was selected for source zone refinement because it yielded results that were most compatible with the conceptual site model of contaminant release, as described in Attachment 2 to Appendix E.

Each potential analyte source area was discretized using rows and columns with a uniform spacing. Multiple domains with varying depths were used to characterize the analyte source areas vertically in relation to the existing aquifers; therefore, the domain was further discretized into horizontal layers. Analyte results for each domain were compiled, and analyte concentrations in each cell of the domain were predicted using geospatial interpolation (see Appendix E Attachment 2 for details).

The SADA estimated uranium mass in relation to other metals (i.e., vanadium and manganese) appears to be underestimated. The mass of metals, such as vanadium and manganese, also appear to be overestimated using SADA. The SADA interpolation estimates the mass between sample points. This results in an estimated mass of vanadium and manganese in the waste volume based on sample points located outside the waste zone, since these metals tend to be ubiquitous throughout the soils. Likewise, the sample points for uranium outside the waste zone are used to interpolate the mass in the waste zone; however, the transport of uranium from the waste into the surrounding soils is limited due to the sorption of this metal. Since the waste was not sampled, the uranium mass estimates for the waste areas in the SADA model likely are underestimated due to the limited migration of uranium. The uncertainty in the mass of uranium present in waste will be addressed further during remedial alternatives screening in the feasibility study.

5.5.2 SESOIL and AT123D Transport Uncertainties

SESOIL requires that the same constant area for each layer represented in the model, thus requiring that the analyte concentrations of all layers predicted using SADA be normalized against the area of the layer with the maximum estimated analyte mass. The impact of this normalization was investigated and found that the normalization process has a minor impact on the results (see Appendix E for a detailed discussion).

An additional source of uncertainty in the AT123D modeling runs involves the use of a single hydraulic conductivity and hydraulic gradient. The hydraulic conductivity and gradient are variable from the SWMU locations to the various POEs. The MODPATH model was run to establish the steady-state head distribution in the RGA. MODPATH was used to track flowpaths of particles released from the SWMU location by using the steady-state, head distribution generated by MODFLOW. The distances from the SWMU to the POEs were taken along the flowpaths to determine the distance from the SWMU to the POEs. The hydraulic gradient from the SWMU to the property boundary was estimated using the head difference divided by the distance from the release point to the property boundary POE. The conductivity along the flowpath also was estimated for use in the AT123D model.

Additional uncertainties in the fate and transport analyses include (1) selection of the sorption coefficients (K_d) for uranium in the UCRS, (2) SWMUs on the western side of the plant that may exhibit waste that is below the water table in the UCRS, and (3) the fact that SESOIL and AT123D do not consider contaminant transformation such as that for radioactive decay. These uncertainties are discussed in detail in Appendix E, Section E.3.3.

5.5.3 Potential Interaction of Sources

The simulations presented in this report for the BGOU SWMUs are based on individual simulations of each SWMU. There is a potential that source plumes from the SWMUs could interact at the POEs. According to the flow paths presented in Figure 5.1, the contaminant plumes from a few of the BGOU SWMUs would interact. The contaminant flow paths from SWMU 6 and SWMU 30 will interact, however, as noted previously, SWMU 6 did not have any groundwater analytes. The contaminant plumes from SWMU 3 and SWMU 5 will interact, and SWMU 2 will interact with a portion of the SWMU 5 contaminant plume. The interaction of the plumes could not be assessed using the SESOIL/AT123D model, since only one SWMU can be discretized in the model for each run.

An evaluation was conducted to ensure that analytes were not eliminated from the groundwater analyses from combined source contributions in the groundwater. The screening evaluation was conducted for the potential interaction of SWMUs 2, 3, and 5. The analysis was based on the conservative summation of the maximum groundwater concentrations below each SWMU provided in Tables 5.5, 5.6, and 5.8. These combined contaminant concentrations are provided in Table E.3.38. These combined groundwater concentrations then were compared to the child resident NALs from Table A.18 of the 2001 Risk Methods Document and the provisional groundwater backgrounds shown in the 2001 Risk Method Document in Table A.13. The results of the conservative analysis indicate that the selection of analytes evaluated for risk and hazard would not change based on the combination of the source contributions to groundwater from SWMU 2, 3, and 5.

5.5.4 Location of POEs

The POEs used in the modeling were placed at locations below the SWMU, at the plant boundary, property boundary, Little Bayou seeps, and Ohio River where the greatest contaminant concentrations are expected in the future. By picking locations on the centerline of predicted contaminant plumes as the POEs, the modeling assumed that the hypothetical future resident would pick, by chance, the worst possible location to install a water supply well.

Based on particle tracks taken from the calibrated sitewide numerical flow model developed in MODFLOW for PGDP, SWMUs 2, 4, 5, and 145 were shown not to impact the Little Bayou seeps. If the SWMUs were to impact the seeps, it has been shown that SWMUs 2, 4, and 145 have modeled groundwater concentrations at the Ohio River that exceed MCLs for several analytes; therefore, the modeled groundwater concentrations at the Little Bayou seeps also would exceed the MCLs for these

analytes. Modeling results for SWMU 5 show that the groundwater concentrations at the property boundary do not exceed the MCLs for any analytes modeled; therefore, the groundwater concentrations at the Little Bayou seeps also would be less than the MCLs for each analyte.

Table 5.15. Evaluation of Combined Plume Interactions on Selection of Analytes

Analyte	Background Groundwater Concentration (mg/L)[a]	Groundwater Child Resident No Action Level (mg/L)[a]	Peak Conc. Below SWMU 2 (mg/L)[a]	Peak Conc. Below SWMU 3 (mg/L)[a]	Peak Conc. Below SWMU 5 (mg/L)[a]	Sum of Peak Conc. Below SWMUs (mg/L)[a]	Retain as Analyte			
							SWMU 2	SWMU 3	SWMU 5	SUM SWMUs
Acenaphthene	NA	1.36E-02			6.10E-03	6.10E-03			N	N
Anthracene	NA	7.66E-02			8.06E-03	8.06E-03			N	N
Arsenic	5.00E-03	3.50E-05	3.54E-02	3.29E-02	9.25E-03	7.76E-02	Y	Y	Y	Y
Uranium-234	7.00E-01	5.46E-01	1.58E+00			1.58E+00	Y			Y
Uranium-238	7.00E-01	4.43E-01	1.81E+00	1.59E+01		1.77E+01	Y	Y		Y
Technetium-99	2.23E+01	1.40E+01	1.02E+02	5.56E+03	1.27E+02	5.79E+03	Y	Y	Y	Y
cis-1,2-DCE	NA	2.73E-03	1.15E+01			1.15E+01	Y			Y
Manganese	1.19E-01	3.50E-02	7.16E-01	8.95E-01	1.01E+00	2.62E+00	Y	Y	Y	Y
Mercury	2.00E-04	4.44E-04		9.29E-05		9.29E-05		N		N
Fluorene	NA	9.72E-03			3.63E-03	3.63E-03			N	N
Naphthalene	NA	2.85E-04	9.38E-04		5.55E-03	6.49E-03	Y		Y	Y
Nickel	3.05E-01	3.01E-02			2.01E-03	2.01E-03			N	N
Selenium	5.00E-03	7.54E-03			1.27E-03	1.27E-03			N	N
TCE	NA	1.60E-03	1.48E+00	3.45E-04	9.91E-04	1.48E+00	Y	N	N	Y
Uranium	2.00E-03	9.06E-04	9.86E-03	4.89E-02		5.88E-02	Y	Y		Y
Zinc	4.90E-02	4.50E-01	9.83E-03	9.30E-02	1.58E-01	2.61E-01	N	N	N	N

SWMU = solid waste management unit

5.5.5 Future Environmental Changes

Several future environmental changes at the PGDP could impact the accuracy of the modeling predictions. These changes include plant shutdown and dam operation on the Ohio River. In a previous modeling effort for a landfill at PGDP, several sensitivity analyses were performed (DOE 2003) to examine the impacts those changes may have on groundwater flow and contaminant transport. The sensitivity analysis of the groundwater travel time due to plant shutdown was studied by varying the recharge over a range of values. The results of the analysis indicated that a decrease in the recharge rate resulted in a monotonic increase in the travel time to the receptor. Thus, chemicals that have short degradation half-lives would show a decrease in concentration due to plant shutdown.

The Olmstead Dam operation is expected to increase the stage (water level) of the Ohio River; therefore, a sensitivity analysis was conducted (DOE 2003) to assess changes in groundwater travel time in relation to dam operation by increasing the river stage between 304.44 ft amsl and 310.04 ft amsl (the baseline river stage is 300.04 ft amsl). The results of the analysis indicated that the travel times in the aquifer changed very little in relation to the Ohio River stage; therefore, the dam operation would have little impact on the results shown in this report.

5.5.6 Burial Cell Waste

Sample data around and beneath the BGOU SWMUs were used to develop a source inventory of contaminants. The premise of this source inventory development is based on the inherent assumption that the contaminants around and beneath the BGOU SWMUs represent the release mass from the Burial Ground disposal cells. The groundwater transport analyses do not model potential future releases directly from the SWMU burial cells.

Waste at several SWMUs was containerized in drums before disposal. Previous inspections of buried drums at PGDP have indicated that the drums were highly corroded. It is considered unlikely that a significant portion of the drummed waste still is containerized at the BGOU SWMUs due to the length of time the drums have been buried and, thus, susceptible to a corrosive environment. The drums were not modeled in this RI report due to the overall objectives of the RI analyses and uncertainty in the degradation process. Due to the uncertainty in the degradation of the drummed waste, real measured sample data surrounding the SWMUs were used to evaluate the potential risk from the SWMU waste. This methodology resulted in the SWMUs with drummed waste exhibiting risk and hazard values that exceeded acceptable levels; therefore, the overall objectives of the RI analysis were met without requiring a detailed analysis of the degradation of drums.

5.5.7 SWMU 4 RGA TCE Source

The TCE source in SWMU 4 was assessed in this RI based on soil sample results. As discussed in Section 4.5.2, a potential DNAPL zone, less than 200 ft wide, also may be present at the base of the RGA as evidenced by a discrete area with TCE concentrations greater than 10,000 µg/L in the lower RGA immediately downgradient of the SWMU. The volume of soil potentially contaminated with TCE DNAPL at this SWMU is estimated to be approximately 31,480 yd^3. This estimate assumes a source area that is 100 ft by 100 ft with a thickness of 85 ft (depth to base of RGA, which is 100 ft minus the estimated depth to base of the waste cell of 15 ft). The DNAPL source term for TCE in the RGA at SWMU 4 was not evaluated in the RI modeling analyses since the RGA concentrations in the lower RGA currently exceed the MCL. The UCRS TCE source concentrations were sufficient to indicate that actions

should be taken for SWMU 4. The uncertainties related to source term size and location will be better defined in a remedial design investigation prior to the design and implementation of a remedy.

5.5.8 SWMU 3 UCRS Groundwater Contamination

The groundwater analyses conducted for this RI are based on soil samples obtained from soils surrounding the SWMUs and their subsequent release to the RGA and transport through the RGA. In some instances, water samples from wells in the UCRS indicated additional contaminant concentrations that were not accounted for in the analyses. For example, UCRS wells MW85, MW88, MW91, and MW94 at SWMU 3 indicated elevated levels of TCE. The water data were added to the SWMU 3 TCE soil concentrations and a SADA nearest neighbor interpolation was assessed. The resulting transport analyses indicated that the TCE concentrations were below the MCL.

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6. BASELINE RISK ASSESSMENT

This BRA utilizes information collected during the recently completed RI of the BGOU SWMUs, in addition to information collected during previous investigations listed here:

- *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1895/V1-V4&D1, U.S. Department of Energy, Paducah, KY (DOE 2000a).

- *Remedial Investigation Report for Solid Waste Management Units 7 and 30 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1604/V1&D2, U.S. Department of Energy, Paducah, KY (DOE 1998c).

- *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds Solid Waste Management Units 2 and 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1141&D2, U.S. Department of Energy, Paducah, KY (DOE 1994).

- *Data Summary and Interpretation Report for Interim Remedial Design at Solid Waste Management Unit 2 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1549&D1, U.S. Department of Energy, Paducah, KY (DOE 1997a).

The purpose of this BRA is to characterize the baseline risks posed to human health from contact with contaminants in soil and water at these SWMUs and at locations to which contaminants may migrate. A summary of the data used is presented in Attachment F1 to Appendix F.

Part of Goal 2 for the BGOU RI, as presented in the BGOU Work Plan (DOE 2006a), was to determine if contaminants at the BGOU units are contributing to groundwater contamination; this risk assessment supports that goal by using modeled concentrations of contaminants to the RGA to support the refinement of an assessment of risks to human health and the environment through groundwater. The Work Plan also specified that the RI should include a risk assessment for residential, industrial, and recreational receptors. Risk assessments for each of those scenarios are presented here. The information collected during the RI, the earlier historical data, and the results of this BRA will be used to determine if sufficient data are available to evaluate risk and to determine if response actions to reduce risks are needed and, if needed, to screen among response action alternatives.

The methods and presentations used in this BRA are consistent with those presented in the Risk Methods Document (DOE 2001). The Risk Methods Document integrates the human health risk assessment guidance from the EPA and the Kentucky Department for Environmental Protection (KDEP) and incorporates instructions contained in regulatory agency comments on earlier risk assessments performed for PGDP.

6.1 DATA COLLECTION AND EVALUATION

The four previous reports listed above contain risk assessment results for one or more of the burial grounds considered in this RI. The results of these assessments are summarized here, as well as in Section F.1 of Appendix F and the BGOU Work Plan, and are presented in more detail in Attachment F2 to Appendix F. Risks and hazards for soil exposure presented in this BRA are taken from these four previous assessments. For groundwater, these previous assessments were based on measured groundwater

concentrations, while this risk assessment used modeled concentrations. Differences can be found in COCs, risk, or hazard level among these previous assessments based on measured concentrations and those resulting from the modeled concentrations presented in this risk assessment. These differences may result from factors such as overestimation by the model or of the source term in the model, or the differences may represent contributions from background or other sources to the measured concentrations in the wells.

6.1.1 Identification of COPCs

Soil COPCs previously were determined in the investigations listed and as outlined in Appendix F, Section F.2. This subsection describes the process used to determine the list of groundwater COPCs used in this BRA, including the sources of data and the procedures used to screen the data.

Soil data used to model groundwater concentrations in the BRA describing current contaminant concentrations in groundwater at SWMU 2, SWMU 3, SWMU 4, SWMU 5, SWMU 6, SWMU 7, SWMU 30, and SWMU 145 were derived from the recently completed BGOU RI sampling, as well as historical data acquired from the PGDP OREIS database. Methods used to collect and analyze subsurface soil samples used for groundwater modeling as well as the soil data itself 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 of the BGOU RI and those selected from the Paducah OREIS database were collected using appropriate methods that were consistent with each project's work plan.

Soil results were screened against a number of criteria prior to their use in groundwater modeling to determine groundwater COPCs for use in the BRA. Soil results were used for samples collected from the ground surface to approximately 60 ft bgs. The following outlines the review and screening process used prior to establishing the COPCs for use in modeling:

- *Units of Reported Results.* 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.

- *Detection Status.* Each result was coded either as a detect or nondetect based on the data qualifier codes present in the database. Results assigned a "U" or "UJ" qualifier were considered nondetects. This coding subsequently was used to calculate the frequency of detection for each constituent.

- *Frequency of Detection.* Those constituents detected in less than 5% of the samples were not considered a COPC.

- *Essential Nutrients.* Results for the seven essential nutrients were removed from the data sets. They are: calcium, chloride, iodine, magnesium, potassium, sodium and phosphorous.

- *Protactinium-234m, potassium-40, and thorium-234.* All results for protactinium-234 were removed from consideration in the BRA. Because the uranium-238 toxicity value incorporates the contribution to cancer risk from protactinium-234 and other short-lived progeny, its inclusion would result in a double-counting of the cancer risk had it been retained. Thorium-234 has a half-life so short (24.1 days) that exposure to it is not relevant on the timescale of a risk assessment. Potassium-40 was eliminated because it is ubiquitous.

Analytes retained as COPCs under current conditions are presented for each SWMU in the tables in Appendix F, Section F.2.3.2. The maximum detected soil concentrations (surface to 60 ft bgs) are presented by analyte and by SWMU, with a comparison to the child resident SSLs[1] with a DAF=1. Those analytes with a maximum concentration greater than their respective SSLs were then compared to soil/sediment child resident NALs. Those constituents greater than both the SSL and NAL were retained as COPCs for groundwater modeling. The screening values used may be found in Tables A.7 and A.17 of the Risk Methods Document (DOE 2001). Exceptions to this screening are TCE, technetium-99 and uranium isotopes, which were retained in all SWMUs, as they are significant risk contributors or known to be part of the facility's process history.

Following this review and screening process, the COPCs retained then were modeled as described in Section 5 and Appendix E of the RI Report. Modeled results exceeding both the child resident NALs from Table A.18 and the provisional groundwater backgrounds shown in Table A.13 of the 2001 Risk Method Document then were carried through the toxicity and exposure assessments, and cancer risk and hazards indices were calculated for the Rural Resident Groundwater User.

6.1.2 Points of Exposure for Groundwater COPCs

Groundwater concentrations used in the assessment were modeled to several locations for examination of potential Rural Resident exposure. These were as follows:

- SWMU boundary
- Plant boundary
- Property boundary
- Little Bayou seeps (when particle modeling showed a contribution to the seep), and
- Monitoring well located near the Ohio River

This risk assessment uses the modeled groundwater concentrations at all POEs. A screening of measured concentrations in the groundwater against NALs and action levels is presented in Appendix E of the BGOU Work Plan as ancillary information only. A list of COCs from that screening of measured groundwater is reproduced in Appendix F, Section F.1.5.

6.2 EXPOSURE ASSESSMENT

This section describes the exposure assessment used to determine the pathways of exposure that were considered for the surface and subsurface soil and groundwater at the source units that are part of the BGOU RI. Specifically, the exposure settings of the BGOU are described, the routes of exposure are outlined, and the daily intakes and doses are presented.

6.2.1 Characterization of Exposure Setting

As shown in the physical descriptions presented in Appendix F, Section F.3.2, current land use of all sources investigated during the BGOU RI is industrial. Under current use, because of access restrictions, only plant workers and authorized visitors are allowed access to the source areas. As discussed in the PGDP Site Management Plan (DOE 2007a), foreseeable future land use of the area is expected to be industrial as well.

[1] SSLs are risk-based soil concentrations considered to be protective of groundwater (DOE 2001).

At present, both recreational and residential land uses occur in areas surrounding PGDP. Recreational use occurs in the WKWMA. The WKWMA is used primarily for hunting and fishing, but other activities include horseback riding, field trials, hiking, and bird watching. An estimated 5,000 fishermen visit the area annually, according to the Kentucky Department of Fish and Wildlife Resources manager of the WKWMA. Residential use near the plant and in areas to which the groundwater from the BGOU may migrate is rural residential and includes agricultural activities. However, current response actions have eliminated exposure to contaminated groundwater by these rural residents; as part of the WAG 26 Groundwater Removal Action completed August 30, 1994, DOE extended municipal water lines to residences affected by off-site groundwater contamination. More urban residential use occurs in the villages of Heath, Grahamville, and Kevil, which are within 3 miles of DOE property boundaries, but outside of the area projected to be potentially impacted by the BGOU. The closest major urban area is the municipality of Paducah, Kentucky, which has a population of approximately 26,000 and is approximately 10 miles east of PGDP. Other municipalities in the region near PGDP are Cape Girardeau, Missouri, which is approximately 40 miles west of the plant; and the cities of Metropolis and Joppa, Illinois, which are across the Ohio River from PGDP. Total population within a 50-mile radius of the plant is approximately 732,000 people, with about 88,500 people living within 10 miles. The population of McCracken County, in which PGDP lies, is estimated at 65,000 people.

In the area near PGDP and in western Kentucky, in general, the economy historically has been agricultural based; however, industry has increased in recent years. PGDP is a major employer, with approximately 1,400 workers. Another major employer near PGDP is the TVA Shawnee Steam Plant, which employs approximately 260 individuals.

6.2.2 Identification of Exposure Pathways

The following discussions focus on points of potential human contact, types of receptors, and exposure routes that are relevant to exposure to contaminated groundwater and soil evaluated in this and previous BRAs.

6.2.2.1 Points of Human Contact – Land Use Considerations

The potential BGOU sources are located within a large industrial facility; therefore, the current land use is industrial. Per KDEP and EPA agreement (Risk Methods Document), industrial land use limits the current exposure scenario to an industrial worker (with exposure to the first ft of surface soil) and an excavation worker (with potential exposure to soil in the 0-10 ft bgs depth). The current scenarios do not include any current use of groundwater drawn from the RGA at the sources.

The current land use can be expected to continue in the foreseeable future, and the most plausible future land use of the BGOU sites also is industrial. In the future, the expected exposure frequencies and durations may be higher than duration and frequency of the current exposure. Additionally, use of groundwater drawn from the RGA at the BGOU sources 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, however unlikely. In addition, consideration of a range of land uses is consistent with the approved BGOU RI Work Plan (DOE 2006a). The BRA reports the hazards and risks for current and several hypothetical future uses, consistent with regulatory guidance and the approved BGOU RI Work Plan (DOE 2006a). PGDP is an industrial facility and future land use is expected to remain industrial. The future on-site rural resident is not a likely land-use scenario. These factors should be considered in examination of risk information provided in this report. The following future land uses are included in the BRA:

- **Future on-site industrial use—**direct contact with surface soil (0 to 1 ft bgs).

- **Future on-site excavation worker**—direct contact with surface and subsurface soil (0 to 10 ft bgs).

- **Future on-site recreational user**—direct contact with surface soils and consumption of game exposed to contaminated surface soil.

- **Future on-site rural resident—**direct contact with surface soil and use of modeled groundwater concentrations from the RGA at source areas, as well as vapor intrusion into a residential basement located above the source.

- **Future off-site rural resident**—use in the home of groundwater drawn from the RGA as well as vapor intrusion into basements at the DOE plant boundary, the DOE property boundary, at Little Bayou seeps (when appropriate) and at the Ohio River.

6.2.2.2 Potential Receptor Populations

The reasonably expected potential receptor population under current and future conditions at the source units are the industrial worker and the excavation worker. Potential receptor populations under future conditions in BGOU areas also include hypothetical recreational and residential exposures. The receptor populations for these scenarios contain age cohorts. For the recreational users, the cohorts include the child (aged 1 to 7), teen (aged 8 to 20), and the adult (older than 21). For rural residents, the cohorts include children (aged 1 to 7) and older individuals (termed adults in this and previous BRAs). Finally, this and earlier assessments assume that the recreational user is a rural resident who has repeated access to the study area. Recreational users not residing in the study area are not considered separately because nearby residents were determined to be the individuals most likely to take part in recreational activities at PGDP on a continual basis. In addition, the exposure assessment determined that little information useful in remedy selection would be obtained by including a separate visiting recreational user in the assessment.

6.2.2.3 Exposure Points and Exposure Routes

Human health risks are assessed by determining 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 reasons for selecting or not selecting each exposure route for each of the potentially exposed populations are presented in this BRA. The exposure routes that were quantitatively assessed in this and previous BRAs are listed below. The exposure routes that were quantitatively assessed in this BRA using modeled groundwater are highlighted with an asterisk (*). Further discussion of the rationale behind including these exposure routes in the BRAs can be found in Appendix F, Section F.3.3.3.

- Ingestion of groundwater as a drinking water source*
- Inhalation of volatile constituents emitted while using groundwater*
- Dermal contact with groundwater while showering*
- Inhalation of vapors released from groundwater into home basements*
- Vapor intrusion into a basement of a residence*
- 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
- External exposure to ionizing radiation emitted from contaminated soil
- Consumption of game contaminated by consumption of vegetation grown in contaminated soil
- Ingestion of produce

6.2.2.4 Calculation of Exposure Point Concentrations

Groundwater exposure point concentrations (EPCs) used to determine potential future risks for residential use of groundwater at four POEs (i.e., unit boundary, plant boundary, property boundary, and either Ohio River or Little Bayou seeps) were developed from soil data through groundwater modeling. The modeled concentrations in groundwater over time at the four POEs are provided in the figures in Section 5.

6.2.2.5 Calculation of Chronic Daily Intakes

Chronic daily intakes (CDIs), which are calculated for inorganic and organic constituents, and radionuclide intakes, calculated for radionuclides, represent the exposure to a COPC as mass contacted per unit body weight per unit time for the applicable receptor (EPA 1991). CDIs and radionuclide intakes are calculated using the values presented in Tables F.1 through F. 4 of Appendix F and are from the 2001 approved version of the Risk Methods Document, except where a footnote indicates that the value is from the draft 2008 revision of the Risk Methods Document. Values in these tables marked as "chemical-specific" were obtained from tables in Appendix B and Appendix D of the draft 2008 Risk Methods Document.

These CDIs derived are presented in Tables F. 6 through F. 29 of Appendix F. In this presentation, the CDIs used to estimate hazard indices (HIs) (i.e., noncarcinogenic effects) are presented first, and then followed by the values used to estimate ELCRs.

6.3 TOXICITY ASSESSMENT

Many of the toxicological summaries included in Appendix F, section F.4 were obtained from the *Risk Assessment Information System* (RAIS) prepared by the Toxicology and Risk Analysis Section of Oak Ridge National Laboratory for DOE (DOE 2004b). This site also lists toxicity values taken from the EPA's Integrated Risk Information System (IRIS) database (EPA 2004), 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 Appendix F. For those chemicals not profiled in RAIS, a brief summary of information drawn from Agency for Toxic Substances and Disease Registry (ATSDR) or other library research sources is included in this section. The last paragraph of each profile contains the toxicity values used in this BRA. These values also are summarized in Tables 6.1 through 6.4 for groundwater COPCs.

The slope factor for chemicals is defined as a plausible upperbound estimate of the probability of a response (i.e., development of cancer) per unit intake of a chemical over a lifetime (EPA 1989). Slope factors are specific for each chemical and route of exposure.

Toxicity values used in risk calculations also include the chronic RfD, 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 also are specific to the chemical and route of exposure.

Table 6.1. Toxicity Values For Chronic Exposure to Carcinogens via the Ingestion and Inhalation Exposure Routes

COPC[a]	Class	Oral Slope Factor[b]	Oral Slope Factor Source[c]	Oral Unit Risk[d]	Inhalation Slope Factor[e]	Inhalation Slope Factor Source[c]	Inhalation Unit Risk[f]	Types of Cancers
Inorganic Chemicals (Metals)								
Arsenic	A	1.50E+00	a	5.00E-02	1.51E+01	a	4.30E-03	Respiratory system tumors
Organic Compounds								
1,1-DCE	C	6.00E-01	a	1.70E-02	1.75E-01	a	5.00E-05	Kidney, adenocarcinoma
Aroclor-1254	B2	4.00E-01	b		3.50E-01	b		Liver
Aroclor-1260	B2	2.00E+00	b		2.00E+00	b		Liver
TCE[h]	C-B2	3.22E-01	c		3.22E-01	c	1.10E-01	Liver and lung cancer
Vinyl Chloride	A	1.50E+00	a	4.20E-02	3.08E-02	a	8.80E-06	Liver, lung, digestive track, and brain tumors
Radionuclides								
	ICRP[g] Lung Class							
Technetium-99	M	2.75E-12	a		1.41E-11	a		Various
Uranium-234	M	7.07E-11	a					Various
Uranium-238	M	7.18-11	a					Various

Note: Blank cells indicate that data are not available or are not appropriate.

[a] All COPCs are listed.

[b] The units for the oral slope factors are $(mg/kg \times day)^{-1}$ for nonradionuclides and risk/pCi for radionuclides.

[c] Source codes are defined as follows:
a: Risk Assessment Information System
b: 2008 Risk Methods Document (DOE 2008b)
c: KDEP

[d] The units for the oral unit risks are $(mg/L)^{-1}$.

[e] The units for the inhalation slope factors are $(mg/kg \times day)^{-1}$ for nonradionuclides and risk/pCi for radionuclides.

[f] The units for inhalation unit risks are $m^3/\mu g$.

[g] ICRP Publication 72 is referenced in the HEAST user's guide (ICRP 1996). Lung class absorption types are defined as follows:
S = slow (particulate)
M = medium (particulate)
F = fast (particulate)

[h] Value used is from KDEP (2004) review of TCE slope factors. The slope factors used in previous assessments were 0.052 for the oral slope factor and 0.002 for the inhalation slope factor. This issue is discussed further in the uncertainty section.

Table 6.2. Toxicity Values for Chronic Exposure to Noncarcinogens Via the Ingestion and Inhalation Exposure Routes

COPC[a]	Oral Reference Dose[b]	Oral Reference Dose Source[c]	Inhalation Reference Dose[d]	Inhalation Reference Concentration[e]	Inhalation Reference Concentration Source[c]	RfD basis (vehicle)[f]	Target Organ Critical Effect	Confidence Level[f]	Uncertainty Factor/Modifying Factor[f]
Inorganic Chemicals (Metals)									
Antimony	4.00E-04	a				(O)LOAEL	GI	(O)Low	(O)UF=1,000 (O)MF=1
Arsenic	3.00E-04	a				(O)NOAEL /LOAEL	Skin	Medium	(O)UF=3 (O)MF=1
Manganese	4.60E-02	c	1.43E-05	5.00E-05	c	(I)LOAEL (O)NOAEL	CNS	(I)Medium (O)Medium	(I)UF=1,000 (I)MF=1 (O)UF=1 (O)MF=1
Selenium	5.00E-03	a				NOAEL/ LOAEL	Lungs (selenosis)	High	(O)UF=3 (O)MF=1
Uranium	6.00E-04	a,e				LOAEL	Kidney	NA	(O)UF=100 (O)MF=1
Organic Compounds									
1,1-DCE	5.00E-02	a	5.71E-02	2.00E-01	ex	LOAEL	Liver	Medium	(O)UF=1,000 (O)MF=1
1,2-DCE, *cis*-	1.00E-02	a	9.97E-03	3.49E-02	ex	NOAEL	Blood	Low	(O)UF=3,000 (O)MF=1
Aroclor-1254	2.00E-05	c	1.99E-05		c	(O)LOAEL	Endocrine System	Medium	(O)UF=300 (O)MF=1
TCE	3.00E-04	v	1.14E-02	4.00-02	ex	NA	Liver, kidney, CNS	NA	NA
Vinyl Chloride	3.00E-03	a	2.86E-02	1.00E-01	a	(I)NOAEL/ LOAEL (O)NOAEL /LOAEL	Liver, kidney, CNS	Medium	(I)UF=30 (I)MF=1 (O)UF=3 (I)MF=1
Naphthalene	2.00E-02	a	8.57E-04	3.00E-03	a	(O)NOAEL (I)LOAEL	Decreased body weight Respira-tory	(O)Low (I)Medium	(O)UF=3,000 (O)MF=1 (I)UF=3,000 (I)MF=1

Notes: Blank cells indicate that data are not available or are not appropriate. NA=information not readily available at this time; GI=gastrointestinal; CNS=central nervous system

[a] All COPCs are listed.

[b] The units for the oral reference doses are mg/(kg × day).

[c] Source codes are defined as follows:

a: *Integrated Risk Information System* (IRIS) (EPA 2004)

b: *Health Effects Assessment Summary Tables* (HEAST) (EPA 1998)

c: 2008 *Risk Methods Document* (DOE 2008b)

e: Also see Soil Screening Guidance for Radionuclides: User's Guide.

ex: Value is extrapolated from the oral reference dose.

u: The inhalation slope factor was calculated from inhalation unit risk as described in *RAGS: Region 4 Bulletins, Human Health Risk Assessment (Interim Guidance)* (November 1995).

v: A provisional value provided to DOE's Oak Ridge Operations by EPA's Superfund Health Risk Technical Support Center.

w: This value was withdrawn from IRIS or HEAST but is used in the assessment per guidance in the Risk Methods Document.

x: A provisional value from EPA National Center for Environmental Assessment (NCEA).

[d] The units for the inhalation reference doses are mg/(kg × day).

[e] The units for the inhalation reference concentrations are mg/m^3.

[f] O=oral; I=inhalation; UF=uncertainty factor; MF=modifying factor; NA=not available.

Table 6.3. Toxicity Values for Chronic Dermal Contact Exposure to Carcinogens

COPC[a]	Dermal Slope Factor[b]	Dermal Slope Factor Source[c]	GI ABS Factor[d]
Inorganic Chemicals (Metals)			
Arsenic	3.66E+00	a	0.41
Organic Compounds			
1,1-DCE	6.00E-01	b	0.1
Aroclor-1254	4.44E-01	b	0.9
Aroclor-1260	2.22E+00	b	0.9
TCE	2.67E+00	a	0. 15
Vinyl Chloride	1.50E+00	a	1

Note: Blank cells indicate that data are not available or are not appropriate.
[a] All groundwater COPCs are listed.
[b] The units for these dermal dose slope factors are $(mg/kg \times d)^{-1}$ for nonradionuclides. Absorbed cancer slope factors are calculated by dividing the administered cancer slope factor by GI absorption factor; this value is used in the BRA to calculate contribution to cancer risk from dermal exposure.
[c] Sources for dermal slope factor:
a: Risk assessment information system (RAIS)
b: 2008 Risk Methods Document (DOE 2008b)
[d] All GI ABS factors from 2008 Risk Methods Document (DOE 2008b).

Table 6.4. Toxicity Values for Chronic Exposure to Noncarcinogens Via the Dermal Contact Exposure Route

COPC[a]	Dermal Reference Dose[b]	Administered Reference Dose[c]	GI ABS[d]
Inorganic Chemicals (Metals)			
Antimony	8.00E-06	4.00E-04	0.02
Arsenic	1.23E-04	3.00E-04	0.41
Manganese	1.84E-03	2.40E-02	0.04
Selenium	2.20E-03	5.00E-03	0.44
Uranium[e]	5.10E-04	6.00E-04	0.85
Organic Compounds			
1,1-DCE	5.00E-02	9.00E-03	1
1,2-DCE, *cis*-	1.00E-02	1.00E-02	1
Aroclor-1254	1.80E-05	2.00E-05	0.9
Naphthalene	1.60E-02	2.00E-02	0.8
TCE	4.50E-05	6.00E-03	0.15
Vinyl Chloride	3.00E-03	3.00E-03	1

Note: Blank cells indicate that data are not available or are not appropriate.
[a] All COPCs are listed.
[b] The units for the absorbed doses are mg/(kg × day). All dermal reference dose were obtained from the 2008 Risk Methods Document (DOE 2008b).
[c] Administered reference doses are equivalent to the oral reference dose and were used to calculate all dermal reference doses listed in the 2008 Risk Methods Document (DOE 2008b). The units are mg/(kg x day).
[d] GI absorption factors are from the 2008 Risk Methods Document (DOE 2008b) and are unitless.
[e] Uranium Source: 40 *CFR* Part 141 (2000).

6.4 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. Equations used in the BRAs to determine the HIs and ELCRs are presented in Section F.6 of Appendix F. These results are summarized in Tables 6.5 through 6.12, as well as in Appendix F, Section F.5.

6.4.1 Risk Characterization for Soil

Results from previous risk assessments were used for the soil risk characterization. Results of previous risk assessments are available for SWMUs 2, 3, 4, 5, 6, 7, and 30 (DOE 1994; DOE 1998c; DOE 2000a). The results for systemic toxicity (HI) and ELCR for soil exposure are discussed below. The percent contribution listed for each soil COC is listed with the same accuracy (i.e., 2% or 2.0%) as the original document from which the value was taken.

6.4.1.1 Future Industrial Worker

Cumulative HIs for the industrial worker were greater than 1 at SWMUs 4, 7, and 30 based on soil exposure.

- At SWMU 4, chromium, iron, and vanadium were the primary drivers contributing 45%, 24%, and 24% to the HI, respectively.

- At SWMU 7, beryllium, chromium, iron, manganese, uranium, and vanadium were the major drivers (> 5%) contributing 9.6%, 13.6%, 20.6%, 10.7%, 13.7%, and 17.7% to the HI, respectively.

- At SWMU 30, aluminum, beryllium, chromium, iron, manganese, uranium, and vanadium were the major drivers contributing 5.1%, 10.8%, 13.5%, 19.8%, 11.3%, 9.0%, and 17.6% to the HI, respectively.

Cumulative ELCRs exceeded 1E-04 for all SWMUs and were greater than 1E-03 at SWMU 7 and SWMU 30 for exposure to soil (SWMU 145 was not evaluated for this scenario). The following summarizes the cumulative risk estimates and major contributors (> 5%) to the ELCR for these SWMUs.

- SWMU 2 cumulative ELCR 1.20E-04; drivers are uranium-235+daughters at 83.9% and uranium-238+daughters at 10.7%.

- SWMU 3 cumulative ELCR 1.20E-04; drivers are uranium-235+daughters at 83.9% and uranium-238+daughters at 10.7%.

- SWMU 4 cumulative ELCR 5.40E-04; the primary driver is beryllium at 97%.

- SWMU 5 cumulative ELCR 4.10E-04; drivers are arsenic at 6%, beryllium at 49%, and Total PAH at 45%.

- SWMU 6 cumulative ELCR 2.40E-04; drivers are beryllium at 90% and Total PAH at 10%.

- SWMU 7 cumulative ELCR 3.90E-03; the primary driver is beryllium at 96%.

- SWMU 30 cumulative ELCR 3.80E-03; the primary driver is beryllium at 96.2%.

6.4.1.2 Future Excavation Worker

Cumulative HIs for the future excavation worker were greater than 1 for SWMUs 4, 5, 6, 7, and 30 based on soil exposure. This exposure scenario was not evaluated for SWMU 2, SWMU 3, and SWMU 145. The following summarizes the cumulative HIs and major contributors to elevated hazards at these SWMUs.

- SWMU 4 cumulative HI 2.61; drivers are aluminum at 8%, chromium at 24%, iron at 24%, manganese 14%, and vanadium 20%.

- SWMU 5 cumulative HI 2.16; drivers are aluminum at 9%, arsenic at 7%, chromium at 18%, iron at 38%, and manganese at 22%.

- SWMU 6 cumulative HI 2.44; drivers are aluminum at 8%, chromium at 15%, iron at 32%, manganese at 15%, and vanadium at 26%.

- SWMU 7 cumulative HI 5.40; drivers are antimony at 11.3%, chromium at 17.6%, iron at 21.3%, manganese at 11%, uranium at 7.5%, and vanadium at 10.9%.

- SWMU 30 cumulative HI 4.50; drivers are antimony at 6.3%, chromium at 10.2%, copper at 7.6%, iron at 19.8%, manganese at 14.3%, uranium at 12.2%, and vanadium at 12.7%.

Cumulative ELCRs exceeded 1E-04 for all SWMUs (except SWMUs 2 and 3) and were greater than 1E-03 at SWMU 4, SWMU 7, and SWMU 30 for exposure to soil. The following summarizes the cumulative risk estimates and major contributors to the ELCR for these SWMUs.

- SWMU 4 cumulative ELCR 2.70E-03; drivers are beryllium at 7% and Total Uranium at 83%.

- SWMU 5 cumulative ELCR 2.90E-04; drivers are arsenic at 8%, beryllium at 62%, and Total PAH at 28%.

- SWMU 6 cumulative ELCR 2.30E-04; drivers are beryllium at 90% and Total PAH at 9%.

- SWMU 7 cumulative ELCR 1.60E-03; drivers are beryllium at 42.2%, uranium-235 at 9.1%, and uranium-238 at 41.3%.

- SWMU 30 cumulative ELCR 1.20E-03; driver is beryllium at 93.7%.

6.4.1.3 Future Recreational Users

Cumulative HIs for the child, teen, and adult recreational users were less than 1 for SWMUs 4, 5, 6, 7, and 30 based on soil exposure. Cumulative ELCRs exceeded 1E-06 for future adult recreational users only at SWMUs 5, 7, and 30 based on consumption of game. This exposure scenario was not evaluated at SWMUs 2, 3, and 145. The following summarizes the cumulative risk estimates and major contributors to the ELCR for these SWMUs.

- SWMU 5 cumulative ELCR 1.0E-05; driver is Total PAH at 96%.

- SWMU 7 cumulative ELCR 1.1E-05; drivers are Aroclor-1260 at 18.6%, benzo(a)pyrene at 9.5%, dibenzo(a,h)anthracene at 42.5%, and uranium-238 at 15.7%.

- SWMU 30 cumulative ELCR 1.5E-05; drivers are Aroclor-1260 at 48.2%, benzo(a)pyrene at 12.9% and dibenzo(a,h)anthracene at 20.8%.

6.4.1.4 Future On-Site Rural Residents

The following summarizes the cumulative HIs and ELCRs observed for each resident cohort.

Hazards—Future Child Residential Exposure to Soil. Cumulative HIs based on direct contact with soil for the child rural resident were greater than 1 for SWMUs 4, 5, 6, 7, and 30. This exposure scenario was not evaluated for SWMUs 2, 3, and 145. The major contributors to elevated hazards are as follows:

- SWMU 4 cumulative HI 98.2: chromium at 24%, iron at 60%, and vanadium at 9%.
- SWMU 5 cumulative HI 46.2: aluminum at 24%, arsenic at 53%, and chromium at 17%.
- SWMU 6 cumulative HI 9.38: beryllium at 8%, chromium at 72%, and nickel at 15%.
- SWMU 7 cumulative HI 370: arsenic at 6.2%, iron at 19.7%, and uranium at 58.4%.
- SWMU 30 cumulative HI 260: arsenic at 7.5%, iron at 22.6%, and uranium at 46.8%.

Hazard—Future Adult Resident Exposure to Soil. Cumulative HIs for the future on-site adult resident were greater than 1 for SWMUs 4, 5, 6, 7, and 30. This exposure scenario was not evaluated for SWMUs 2, 3, and 145. The major contributors to elevated hazards are as follows:

- SWMU 4 cumulative HI 28.4: chromium at 22%, iron at 63%, and vanadium at 8%.
- SWMU 5 cumulative HI 13.9: aluminum at 24%, arsenic at 55%, and chromium at 15%.
- SWMU 6 cumulative HI 2.57: beryllium at 7%, chromium at 70%, nickel at 17%, and zinc at 6%.
- SWMU 7 cumulative HI 110: arsenic at 6.5%, iron at 19.8%, and uranium at 59.5%.
- SWMU 30 cumulative HI 79: arsenic at 7.9%, iron at 22.8%, and uranium at 47.5%.

Risks—Future Adult Residential Exposure to Soil. Cumulative ELCRs exceeding 1E-03 from direct contact with soil was observed for SWMUs 4, 5, 6, 7, and 30. This exposure scenario was not evaluated for SWMUs 2, 3, and 145. Cumulative ELCRs greater than 1E-02 were identified for SWMUs 5, 7, and 30. The major contributors to elevated risks are as follows:

- SWMU 4 cumulative ELCR 4.3E-03: beryllium at 72%, total PCBs at 5%, uranium-234 at 6%, and uranium-238 at 17%.

- SWMU 5 cumulative ELCR 1.0E-02: arsenic at 21%, beryllium at 9%, and Total PAH at 68%.

- SWMU 6 cumulative ELCR 2.4E-03: beryllium at 54% and Total PAH at 46%.

- SWMU 7 cumulative ELCR 3.4E-02: arsenic at 7.3%, beryllium at 65.4%, and uranium-238 at 17.6%.

- SWMU 30 cumulative ELCR 3.2E-02: arsenic at 6.8%, beryllium at 66.7%, and uranium-238 at 11.5%.

6.4.2 Risk Characterization of Vapor Intrusion into Basements from Soil

Characterization of risks from vapor intrusion into basements from soil was conducted as part of the current risk assessment.[2] To examine potential risks and hazards, vapor intrusion modeling was completed and examined for three POEs: the property boundary, the plant boundary, and at the SWMU. The HQs and ELCRs for the modeled vapor concentrations are presented in Table E.3.34 of Appendix E. Modeled concentrations for the on-site POE showed an HQ greater than 0.1 for vapor intrusion from TCE, *cis*-1,2-DCE, 1,1-DCE, vinyl chloride, or mercury intrusion for the following:

- SWMU 2: TCE, and *cis*-1,2-DCE.
- SWMU 3: mercury.
- SWMU 4: TCE, *cis*-1,2-DCE; and vinyl chloride.
- SWMU 7: 1,1-DCE, mercury; and vinyl chloride.
- SWMU 30: mercury, 1,1-DCE; and TCE.
- SWMU 145: mercury.

ELCRs for the on-site POE were greater than 1E-06 for several SWMUs based on modeled contaminant concentrations. The following summarizes those SWMUs exhibiting elevated risks based on modeled soil concentrations:

- SWMUs 2: TCE.
- SWMU 3: TCE.
- SWUM 4: TCE and vinyl chloride.
- SWMU 7: TCE; vinyl chloride; and 1,1-DCE.
- SWMU 30: TCE and 1,1-DCE.

Vapor intrusion into basements also was modeled at the plant boundary and property boundary. At the plant boundary all HIs were below 0.1. ELCRs were below 1E-06 for all SWMUs except for SWMUs 2, 4, 7, and 30. The following lists the risk driver for each SWMU:

- SWMU 2: TCE.
- SWMU 4: TCE and vinyl chloride.
- SWMU 7: 1,1-DCE.
- SWMU 30: TCE and 1,1-DCE.

At the property boundary all HIs were below 0.1. The ELCR for TCE exceeded 1E-06 risk at the property boundary for TCE at SWMUs 2, 4, and 30. All other risks/hazards were below 1E-06 or an HI of 1 at the property boundary. The quantitative assessment of potential risks and hazards due to exposure to vapor intrusion is summarized in Table 5.14. Table F.73 in Appendix F includes which SWMUs exceeded *de minimis* risk and hazard thresholds for vapor intrusion modeling for the on-site receptor and the receptor at the property boundary.

[2] The vapor transport modeling for mercury was conservatively based on the metallic form, which has a Henry's Law Constant of 1.07E-02 atm-m^3/mol. The rate of vaporization of mercury and certain of its inorganic compounds decrease in the sequence Hg > Hg_2Cl_2 > $HgCl_2$ > HgS > HgO. The Henry's Law Constant decreases dramatically down the sequence (for example, $HgCl_2$ has a value of 7.09E-10 atm-m^3/mol).

6.4.3 Risk Characterization for Residential Use of Groundwater Drawn from the RGA

Risks for residential groundwater use were calculated based on modeled concentrations in the RGA groundwater. The HIs and ELCRs also are presented for each SWMU in Tables F. 34 through F. 57 in Appendix F. Tables F.58 through F.60 show the HIs and ELCRs for the predicted maximum (peak) concentrations for individual contaminants over the 1,000 year time frame of the model. Different contaminants migrate at different rates; therefore, the total HI or ELCR in groundwater at a given time may be less than the sum of the risks of individual peaks. Figures F.2 to F.15 in Appendix F show the total hazard and total risks from the predicted concentrations of all COCs at each time step in the model for each SWMU except SWMU 6 (which had no modeled COCs). These hazards and risks are calculated using the residential NALs (DOE 2001) for residential use of groundwater

6.4.3.1 Hazards—Future Resident Exposure to Groundwater at the SWMU Boundary

Cumulative HIs based on exposure to groundwater for the future on-site rural resident were greater than 1 for all of the SWMUs evaluated (SWMU 6 was not evaluated). The following lists those constituents that contributed to elevated HIs. The major contaminants driving the hazard were ingestion of uranium metal and iron and ingestion and inhalation of TCE and *cis*-1,2 DCE.

The following lists those constituents that contributed to elevated HIs by SWMU for the Child Resident:

- SWMU 2: TCE at 52% and *cis*-1,2-DCE at 47%.
- SWMU 3: arsenic at 48%, uranium at 36%, and manganese at 17%.
- SWMU 4: TCE at 93% and *cis*-1,2-DCE at 6%.
- SWMU 5: arsenic at 38%, naphthalene at 35%, and manganese at 27%.
- SWMU 7: arsenic at 30%, TCE at 26%, Total PCBs at 22%, and *cis*-1,2-DCE at 7%.
- SWMU 30: TCE at 97%.
- SWMU 145: antimony at 48% and arsenic at 48%.

6.4.3.2 Risks—Future Residential Exposure to Groundwater at the SWMU Boundary

Cumulative ELCRs exceeding 1E-06 from direct exposure to groundwater was observed for all of the SWMUs evaluated (SWMU 6 was not evaluated). Cumulative ELCR greater than 1E-04 were identified for all of the SWMUs evaluated. The major contaminants (> 5%) driving risk were ingestion of arsenic and TCE.

- SWMU 2: TCE at 98%.
- SWMU 3: arsenic at 72%; technetium-99 at 25%.
- SWMU 4: TCE at 68%; vinyl chloride at 31%.
- SWMU 5: arsenic at 97%.
- SWMU 7: arsenic at 15%; 1,1-DCE at 66%; and vinyl chloride at 12%.
- SWMU 30: 1,1-DCE at 6%;TCE at 92%.
- SWMU 145: arsenic at 5%; Aroclor-1260 at 93%.

6.4.4 Risk Characterization for Residential Use of Groundwater at Future Modeled Concentrations on Boundary and River POEs

Risk and hazard estimates for future off-site residential use based on modeled groundwater concentrations were calculated for this BRA. The following summarizes the results of the quantitative assessment at the

plant boundary, property boundary, and outside the property boundary at either the Little Bayou seeps (applicable to SWMUs 3, 7, and 30) or Ohio River (applicable to SWMUs 2, 4, 5 and 145).

6.4.4.1 Future Residential Exposure to Groundwater–Plant Boundary

SWMU 6 was not evaluated for groundwater exposure, and SWMU 145 lies outside the plant boundary. Cumulative HIs based on exposure to groundwater at the DOE plant boundary were greater than one for SWMU 2, SWMU 4, SWMU 5, SWMU 7, and SWMU 30. The major contaminants contributing to hazard were TCE, *cis*-1,2-DCE, arsenic, manganese, naphthalene, and Total PCBs.

The cumulative ELCR was greater than 1E-06 for SWMU 2, SWMU 3, SWMU 4, SWMU 5, SWMU 7, and SWMU 30. The cumulative ELCR was greater than 1E-04 for SWMU 2, SWMU 3, SWMU 4, SWMU 7, and SWMU 30. The major contaminants contributing to risk were TCE, 1,1-DCE, vinyl chloride, technetium-99, and arsenic.

6.4.4.2 Future Residential Exposure to Groundwater – Property Boundary

Cumulative HIs based on exposure to groundwater at the DOE property boundary were greater than 1 for SWMU 2, SWMU 4, and SWMU 7, and SWMU 30. The major contaminants driving hazard were ingestion of arsenic, TCE, *cis*-1,2-DCE, and Total PCBs.

Cumulative ELCR exceeded 1E-06 for groundwater exposure for all of the SWMUs, except SWMU 6. Cumulative ELCRs greater than 1E-04 from groundwater use were identified for SWMUs 2, 4, 7, 30, and 145. The major contaminants driving risk were ingestion of arsenic, TCE, 1,1-DCE, vinyl chloride, and technetium-99.

6.4.4.3 Future Residential Exposure to Groundwater–Outside the Property Boundary (Little Bayou seeps or the Ohio River)

Cumulative HIs based on exposure to groundwater for the future off-site rural resident were greater than 1 at the Little Bayou seeps for SWMU 30 and at the Ohio River for SWMUs 2 and 4. The major contaminants driving hazard were ingestion of TCE and *cis*-1,2-DCE.

Cumulative ELCRs of 1E-06 from groundwater exposure were observed at the Little Bayou seeps for SWMUs 3, 7, and 30, and at the Ohio River for SWMUs 2, 4, and 145. Cumulative ELCRs greater than 1E-04 from groundwater use were identified for SWMU 2, 4, 7, and 30. The contaminants driving risk were ingestion of TCE, 1,1-DCE, vinyl chloride, and technetium-99.

6.4.5 Identification of Land Use Scenarios, Pathways, Media and COCs

This subsection outlines land use scenarios, exposure pathways, media, and COCs for each source area. The results of the previous risk assessments for SWMUs 2, 3, 4, 5, 6, 7, and 30 are used for the risk characterization for soil and are presented in Attachment F2 of this document. Section 6.6 presents the RGOs for each location and land use scenario.

6.4.5.1 Land Use Scenarios of Concern

To determine whether a land use scenario is 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 a) 1 for HI and b) 1×10^{-6} for ELCR. Land use scenarios with total HIs exceeding the benchmark of 1 are deemed land use scenarios of concern for non-cancer hazard. Land use scenarios with

a total ELCR exceeding the benchmark of 1×10^{-6} are deemed land use scenarios of concern for cancer risk. These criteria were used in the previous risk assessments for SWMUs 4, 5, 6, 7, and 30 as well (DOE 1998c; DOE 2000). For the risk characterization of soil for SWMUs 2 and 3, land use scenarios of concern were determined by using EPA guidance and policy in effect at the time of the risk assessment (DOE 1994). The following are land uses of concern for BGOU at the SWMUs indicated:

- Industrial: SWMUs 2, 3, 4, 5, 6, 7, and 30.
- Excavation: SWMUs 4, 5, 6, 7, and 30.
- Recreational: SWMUs 5, 7, and 30.
- On-Site Residential: SWMUs 2, 3, 4, 5, 6, 7, 30, and 145.
- Off-Site Residential: SWMUs 2, 3, 4, 5, 7, 30, and 145.

Table F. 63 in Appendix F outlines all land use scenarios for all SWMUs that exceed *de minimis* risk or hazard levels.

6.4.5.2 Contaminants of Concern (Soil)

To make a determination about whether contaminants are of concern in soil, quantitative risk and hazard results over all pathways from the previous risk assessments for SWMUs 2, 3, 4, 5, 6, 7, and 30 (DOE 1994; DOE 1998c; DOE 2000a) were compared to risk and hazard benchmarks for land use scenarios of concern. The benchmarks used for this comparison were a) 0.1 for HI and b) 1×10^{-6} for ELCR.

Contaminants with chemical-specific HIs or ELCRs exceeding these benchmarks are deemed COCs. A priority COC is a contaminant whose chemical-specific HI is greater than 1 or whose ELCR is greater than 1×10^{-4} for one or more scenarios (DOE 2008b). The following are priority COCs found in soil at individual SWMUs:

- SWMU 2–none.

- SWMU 3–none.

- SWMU 4–barium, beryllium, cadmium, chromium, iron, nickel, uranium, vanadium, Total dioxins/furans, Total PCBs, uranium-234, and uranium-238.

- SWMU 5–aluminum, arsenic, beryllium, chromium, nickel, Total PAHs, and Total PCBs.

- SWMU 6–beryllium, chromium, nickel, and Total PAHs.

- SWMU 7–aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, manganese, nickel, uranium, vanadium, benzo(a)pyrene, dibenzo(a,h)anthracene, Aroclor-1254, Aroclor-1260, plutonium-239, uranium-234, uranium-235, uranium-235/236, and uranium-238.

- SWMU 30–aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, manganese, mercury, nickel, uranium, vanadium, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, Aroclor-1254, Aroclor-1260, uranium-234, uranium-235, uranium-235/236, and uranium-238.

6.4.5.3 Contaminants of Concern (Groundwater–Modeled from Soil)

Similarly for groundwater, to determine 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 a) 0.1 for HI and b) 1×10^{-6} for ELCR.

Contaminants with chemical-specific HIs or ELCRs exceeding these benchmarks were deemed COCs. Priority COCs are contaminants whose chemical-specific HI is greater than 1 or whose ELCR is greater than 1×10^{-4} for one or more scenarios (DOE 2008b). The following presents priority COCs found in groundwater at individual SWMUs:

- SWMU 2–arsenic; manganese; uranium; *cis*-1,2-DCE; and TCE.
- SWMU 3–arsenic; manganese; uranium; and technetium-99.
- SWMU 4–arsenic; manganese; *cis*-1,2-DCE; TCE; vinyl chloride; and technetium-99.
- SWMU 5–arsenic; manganese; and naphthalene.
- SWMU 6–none.
- SWMU 7–arsenic; 1,1-DCE; *cis*-1,2-DCE; Total PCBs; TCE; vinyl chloride.
- SWMU 30–arsenic; 1,1-DCE; TCE.
- SWMU 145–antimony; arsenic; manganese; Total PCB; and technetium-99.

"Priority COCs" are identified in this section as an aid to risk managers during decision making. Table F.74 in Appendix F summarizes the COCs for both soil and groundwater.

6.4.6 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 a) 0.1 for HI and b) 1×10^{-6} for ELCR. For soil, the quantitative risk and hazard results from the previous risk assessments for SWMUs 2, 3, 4, 5, 6, 7, and 30 (DOE 1994; DOE 1998c; DOE 2000a) were used in the comparison. Exposure routes with HIs and ELCRs exceeding these benchmarks are considered pathways of concern (POCs). These POCs are shown by SWMU in Table F.73 of Appendix F. Each of the pathways included in the BRA is a POC for at least one SWMU.

6.4.7 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 and RGA groundwater are media of concern for all eight SWMUs. Table F.74 in Appendix F provides specific information concerning how each media contributes to risks and hazards for BGOU.

6.4.8 Summary of Risk Characterization

Tables 6.5 through 6.12 present summaries of the risk characterization by location considered in the BRA. 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.
- Percent contribution each COC contributes to the total risk.

Table 6.5 Summary of Risk Characterization for SWMU 2

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker/intruder at current concentrations (soil) (from WAG 22 RI Addendum[b])	1.2E-05	^{235}U + daughters ^{238}U + daughters	83.8 10.7	External exposure	94.7	6.8E-03	*No COCs		*No COCs	
Future industrial worker at current concentrations (soil) (from WAG 22 RI Addendum[b])	1.2E-04	Arsenic ^{235}U + daughters ^{238}U + daughters	2.8 83.9 10.7	Ingestion External exposure	4.7 94.7	7.0E-02	*No COCs		*No COCs	
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	1.30E+03	Arsenic Manganese Uranium *cis*-1,2-DCE Naphthalene TCE	0.9 0.1 0.1 46.8 0.0 52.1	Ingestion Dermal Shower inhalation Household inhalation	46.0 11.7 4.8 37.5

Table 6.5. Summary of Risk Characterization for SWMU 2 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future adult rural resident at current concentrations (RGA groundwater only)	4.69E-02	Arsenic TCE ^{99}Tc ^{234}U ^{238}U	2.0 98.0 0.0 0.0 0.0	Ingestion Dermal Shower inhalation Household inhalation	19.9 11.0 7.8 61.3	3.79E+02	Arsenic Manganese Uranium *cis*-1,2-DCE Naphthalene TCE	0.9 0.1 0.1 36.8 0.0 62.1	Ingestion Dermal Shower inhalation Household inhalation	45.0 23.9 3.5 27.5
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	1.92E+02	Arsenic *cis*-1,2-DCE Naphthalene TCE	0.5 48 0.1 52	Ingestion Dermal Shower inhalation Household inhalation	45 12.4 5.4 38
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	6.82E-03	Arsenic TCE	1.1 98.9	Ingestion Dermal Shower inhalation Household inhalation	19.2 11.1 7.9 61.8	5.08E+01	Arsenic *cis*-1,2-DCE Naphthalene TCE	0.5 31.5 0.1 67.9	Ingestion Dermal Shower inhalation Household inhalation	62 27 1.2 10
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA	9.56E+01	*cis*-1,2-DCE TCE	47.4 52.6	Ingestion Dermal Shower inhalation Household inhalation	45.4 11.8 4.9 38.0
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	3.42E-03	TCE	100	Ingestion Dermal Shower inhalation Household inhalation	18.3 11.2 8.0 62.5	2.79E+01	*cis*-1,2-DCE TCE	37.3 62.7	Ingestion Dermal Shower inhalation Household inhalation	44.4 24.1 3.6 27.9
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	NA	NA	NA	NA	NA	2.25E+01	*cis*-1,2-DCE TCE	79.4 20.5	Ingestion Dermal Shower inhalation Household inhalation	16.2 18.8 7.4 57.7
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	1.28E-03	TCE	100	Ingestion Dermal Shower inhalation Household inhalation	18.3 11.2 8.0 62.5	6.7E+00	*cis*-1,2-DCE TCE	61.2 38.7	Ingestion Dermal Shower inhalation Household inhalation	15.5 37.7 5.3 41.5

ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern

Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.

. *No COCs = there are no COCs or POCs at this SWMU for this endpoint (may apply to ELCR or HI)

[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.

[b] *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1141&D2, September 1994 (DOE 1994). Attachment 2-1 through 2-6. This risk assessment combined SWMU 2 and 3.

Table 6.6. Summary of Risk Characterization for SWMU 3

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker/intruder at current concentrations (soil) (from WAG 22 RI Addendum[b])	1.2E-05	^{235}U + daughters ^{238}U + daughters	83.8 10.7	External exposure	94.7	6.8E-03	*No COCs		*No COCs	NE
Future industrial worker at current concentrations (soil) (from WAG 22 RI Addendum[b])	1.2E-04	Arsenic ^{235}U + daughters ^{238}U + daughters	2.8 83.9 10.7	Ingestion External exposure	4.7 94.7	7.0E-02	*No COCs		*No COCs	NE
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	2.20E+01	Arsenic Manganese Uranium	47.9 16.6 35.5	Ingestion Dermal	99.5 0.5
Future adult rural resident at current concentrations (RGA groundwater only)	1.20E-03	Arsenic ^{99}Tc ^{238}U	72.4 25.3 2.3	Ingestion Dermal	99.8 0.2	6.32E+00	Arsenic Manganese Uranium	47.7 16.9 35.4	Ingestion	99.0
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	3.98E-01	Arsenic	100	Ingestion	97.9
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	1.32E-04	Arsenic ^{99}Tc	24.6 75.4	Ingestion	99.9	1.12E-01	Arsenic	100	Ingestion	99.6
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA		*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	7.46E-05	^{99}Tc	100	Ingestion	100		*No COCs		*No COCs	

Table 6.6. Summary of Risk Characterization for SWMU 3 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child rural resident at modeled concentrations (RGA groundwater drawn at Little Bayou seeps)	NA	NA	NA	NA	NA		*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Little Bayou seeps)	4.41E-05	^{99}Tc	100.0	**Ingestion**	**100**		*No COCs		*No COCs	
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		Not a POE for groundwater from this SWMU.								
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		Not a POE for groundwater from this SWMU.								

ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern

Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.

*No COCs = there are no COCs or POCs.

[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.

[b] *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1141&D2, September 1994 (DOE 1994). Attachment 2-1 through 2-6. This risk assessment combined SWMU 2 and 3.

Table 6.7. Summary of Risk Characterization for SWMU 4

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil) (WAG 3 RI[b])	5.4E-04	Beryllium ^{238}U	97 2	Dermal External exposure	97 2	3.62E+00	 Beryllium Chromium Iron Vanadium Barium	 5 45 24 24 2	Dermal	99
Future industrial worker at current concentrations (soil) (WAG 3 RI[b])	5.4E-04	Beryllium ^{238}U	97 2	Dermal External exposure	97 2	3.62E+00	Beryllium Chromium Iron Vanadium Barium	5 45 24 24 2	Dermal	99
Future child rural resident at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	9.82E+01	Barium Beryllium Cadmium Chromium Iron Nickel Vanadium	2 2 2 24 60 2 9	Ingestion Dermal Ingestion of vegetables	1 21 78
Future adult rural resident at current concentrations (soil) (WAG 3 RI[b])	4.3E-03	Beryllium Total PCB ^{234}U ^{238}U	72 5 6 17	Dermal External exposure Ingestion of vegetables	36 2 61	2.84E+01	Barium Beryllium Cadmium Chromium Iron Nickel Vanadium	2 2 2 22 63 2 8	Dermal Ingestion of vegetables	14 85
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	5.82E+02	Arsenic Manganese *cis*-1,2-DCE TCE Vinyl Chloride	1.0 0.2 6.1 92.5 0.2	Ingestion Dermal Shower inhalation Household inhalation	67.2 20.2 1.4 11.2
Future adult rural resident at current concentrations (RGA groundwater only)	5.41E-02	Arsenic TCE Vinyl chloride ^{99}Tc	0.9 67.7 30.5 0.9	Ingestion Dermal Shower inhalation Household inhalation	15.4 36.7 5.4 42.4	1.98E+02	Arsenic Manganese *cis*-1,2-DCE TCE Vinyl chloride	0.8 0.2 4.1 94.7 0.2	Ingestion Dermal Shower inhalation Household inhalation	56.5 35.6 0.9 7.0
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	2.04E+02	Arsenic *cis*-1,2-DCE TCE Vinyl chloride	0.4 4.6 94.4 0.1	Ingestion Dermal Shower inhalation Household inhalation	67.5 20.6 1.4 10.6

Table 6.7. Summary of Risk Characterization for SWMU 4 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	2.03E-02	Arsenic TCE Vinyl chloride ^{99}Tc	0.4 98.0 0.9 0.7	Ingestion Dermal Shower inhalation Household inhalation	13.6 7.2 5.2 74.0	6.97E+01	Arsenic *cis*-1,2-DCE TCE	0.4 3.0 96.6	Ingestion Dermal Shower inhalation Household inhalation	56.5 36.1 0.8 6.6
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA	1.03E+02	*cis*-1,2-DCE TCE Vinyl chloride	4.6 95.3 0.1	Ingestion Dermal Shower inhalation Household inhalation	67.6 20.8 1.3 10.3
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	6.79E-03	TCE Vinyl chloride ^{99}Tc	97.9 1.1 1.0	Ingestion Dermal Shower inhalation Household inhalation	19.8 11.0 7.8 61.3	3.51E+01	*cis*-1,2-DCE TCE	3.1 96.8	Ingestion Dermal Shower inhalation Household inhalation	56.4 36.3 0.8 6.4
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	NA	NA	NA	NA	NA	3.33E+01	*cis*-1,2-DCE TCE	1.7 98.2	Ingestion Dermal Shower inhalation Household inhalation	74.6 22.9 1.4 1.0
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	2.43E-03	TCE Vinyl chloride ^{99}Tc	98.2 0.9 0.9	Ingestion Dermal Shower inhalation Household inhalation	19.6 11.0 7.9 61.5	1.26E+01	*cis*-1,2-DCE TCE	3.0 96.9	Ingestion Dermal Shower inhalation Household inhalation	56.4 36.3 0.8 6.4
Future child recreational user at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	< 1	*No COCs		*No COCs	
Future teen recreational user at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	< 1	*No COCs		*No COCs	
Future adult recreational user at current concentrations (soil) (WAG 3 RI[b])	< 1.0E-06	*No COCs		*No COCs		< 1	*No COCs		*No COCs	
Future excavation worker at current concentrations (soil and waste) (WAG 3 RI[b])	2.7E-03	Arsenic Beryllium Total dioxins/furans Total PCB ^{226}Ra Total uranium ^{238}U	1 7 4 2 2 83 1	Ingestion Dermal External exposure	37 10 54	2.61E+00	Aluminum Arsenic Barium Beryllium Cadmium Chromium Iron Manganese Vanadium	8 4 2 2 1 24 24 14 20	Ingestion Dermal	13 87

ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern

Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.

*No COCs = There are no COCs or POCs.

[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.

[b] *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, DOE/OR/07-1895&D1*, September 2000 (DOE 2000a), Table 1.55. In this table, lead has been excluded as a COC.

Table 6.8. Summary of Risk Characterization for SWMU 5

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil) (WAG 3 RI[b])	4.1E-04	Arsenic Beryllium Total PAH	6 49 45	Ingestion Dermal	2 98	< 1	*No COCs		*No COCs	
Future industrial worker at current concentrations (soil) (WAG 3 RI[b])	4.1E-04	Arsenic Beryllium Total PAH	6 49 45	Ingestion Dermal	2 98	< 1	*No COCs		*No COCs	
Future child rural resident at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	4.62E+01	Aluminum Arsenic Beryllium Chromium Nickel Zinc	24 53 1 17 3 1	Ingestion Dermal Ingestion of vegetables	1 12 87
Future adult rural resident at current concentrations (soil) (WAG 3 RI[b])	>1.0E-02*	Arsenic Beryllium Total PAH Total PCB	21 9 68 2	Dermal Ingestion of vegetables	9 90	1.39E+01	Aluminum Arsenic Beryllium Chromium Nickel Zinc	24 55 1 15 3 1	Dermal Ingestion of vegetables	8 92
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	7.91E+00	Arsenic Manganese Naphthalene	37.5 27.2 35.4	Ingestion Shower inhalation Household inhalation	64.3 4.0 31.0
Future adult rural resident at current concentrations (RGA groundwater only)	2.52E-04	Arsenic ^{99}Tc	97.2 2.8	Ingestion	99.7	2.08E+00	Arsenic Manganese Naphthalene	40.8 30.2 29.0	Ingestion Household inhalation	69.8 25.3
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	1.25E+00	Arsenic Manganese Naphthalene	45.6 14.8 39.6	Ingestion Household inhalation	60.4 34.7
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	4.99E-05	Arsenic ^{99}Tc	94.5 5.5	Ingestion	99.7	3.24E-01	Arsenic Naphthalene	50.3 33.0	Ingestion	66.5

Table 6.8. Summary of Risk Characterization for SWMU 5 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA	2.28E-01	Naphthalene	82.2	Household inhalation	72.0
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	4.81E-06	Arsenic ^{99}Tc	69.9 30.1	Ingestion	99.8	<0.1	*No COCs		*No COCs	
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	NA	NA	NA	NA	NA		*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		*No COCs		*No COCs			*No COCs		*No COCs	
Future child recreational user at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	< 1	*No COCs		*No COCs	
Future teen recreational user at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	< 1	*No COCs		*No COCs	
Future adult recreational user at current concentrations (soil) (WAG 3 RI[b])	1.0E-05	Arsenic Total PAH Total PCB	2 96 2	Ingestion of venison Ingestion of rabbit Ingestion of quail	16 63 21	< 1	*No COCs		*No COCs	
Future excavation worker at current concentrations (soil and waste) (WAG 3 RI[b])	2.9E-04	Arsenic Beryllium Total PAH Total PCB	8 62 28 1	Ingestion Dermal	13 87	2.16E+00	Aluminum Arsenic Barium Beryllium Chromium Iron Manganese	9 7 2 3 18 38 22	Ingestion Dermal	18 82

ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern

Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.

*No COCs = There are no COCs or POCs.

* = The ELCR is approximate because the linearized multistage model returns imprecise values at risks > 1.0E-02.

[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.

[b] *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, DOE/OR/07-1895&D1*, September 2000 (DOE 2000a), Table 1.56. In this table, lead has been excluded as a COC.

Table 6.9. Summary of Risk Characterization for SWMU 6

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil) (WAG 3 RI[b])	2.4E-04	Beryllium Total PAH	90 10	Dermal	99	< 1	*No COCs		*No COCs	
Future industrial worker at current concentrations (soil) (WAG 3 RI[b])	2.4E-04	Beryllium Total PAH	90 10	Dermal	99	< 1	*No COCs		*No COCs	
Future child rural resident at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	9.38E+00	Beryllium Chromium Nickel Zinc	8 72 15 5	Dermal Ingestion of vegetables	34 65
Future adult rural resident at current concentrations (soil) (WAG 3 RI[b])	2.4E-03	Beryllium Total PAH	54 46	Dermal Ingestion of vegetables	30 69	2.57E+00	Beryllium Chromium Nickel Zinc	7 70 17 6	Dermal Ingestion of vegetables	24 75
Future child rural resident at current concentrations (RGA groundwater only)		*No COCs		*No COCs			*No COCs		*No COCs	
Future adult rural resident at current concentrations (RGA groundwater only)		*No COCs		*No COCs			*No COCs		*No COCs	
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)		*No COCs		*No COCs			*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)		*No COCs		*No COCs			*No COCs		*No COCs	
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)		*No COCs		*No COCs			*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)		*No COCs		*No COCs			*No COCs		*No COCs	
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		*No COCs		*No COCs			*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		*No COCs		*No COCs			*No COCs		*No COCs	

Table 6.9. Summary of Risk Characterization for SWMU 6 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child recreational user at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	< 1	*No COCs		*No COCs	
Future teen recreational user at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	< 1	*No COCs		*No COCs	
Future adult recreational user at current concentrations (soil) (WAG 3 RI[b])	< 1.0E-06	*No COCs		*No COCs		< 1	*No COCs		*No COCs	
Future excavation worker at current concentrations (soil and waste) WAG 3 RI[b])	2.3E-04	Beryllium Total PAH	90 9	Ingestion Dermal	5 95	2.44E+00	Aluminum Barium Beryllium Chromium Iron Manganese Vanadium	8 2 3 15 32 15 26	Ingestion Dermal	12 88

ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern

Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.

– = There are no COCs or POCs.

[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.

[b] *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, DOE/OR/07-1895&D1*, September 2000 (DOE 2000a), Table 1.57. In this table, lead has been excluded as a COC.

Table 6.10. Summary of Risk Characterization for SWMU 7

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil) (from WAG 22 RI[b])	3.8E-03	Arsenic Beryllium Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{234}U ^{235}U $^{235/236}U$ ^{238}U	0.6 97.6 <0.1 0.3 <0.1 0.4 0.1 <0.1 <0.1 0.2 0.3 2.1	Ingestion Dermal External exposure	0.5 97.4 2.5	5.0E+00	Aluminum Antimony Arsenic Beryllium Chromium Iron Manganese Uranium Vanadium	4.1 4.4 2.6 9.6 13.6 20.6 10.7 13.7 17.7	Ingestion Dermal	3.6 96.4
Future industrial worker at current concentrations (soil) (from WAG 22 RI[b])	3.9E-03	Arsenic Beryllium Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{234}U ^{235}U $^{235/236}U$ ^{238}U	0.6 96.0 <0.1 0.3 <0.1 0.4 0.1 <0.1 <0.1 0.2 0.3 2.1	Ingestion Dermal External exposure	0.5 97.1 2.4	5.0E+00	Aluminum Antimony Arsenic Beryllium Chromium Iron Manganese Uranium Vanadium	4.1 4.4 2.6 9.6 13.6 20.6 10.7 13.7 17.7	Ingestion Dermal	3.6 96.4
Future child rural resident at current concentrations (soil) (from WAG 22 RI[b])	NA	NA	NA	NA	NA	3.7E+02	Aluminum Antimony Arsenic Barium Beryllium Cadmium Chromium Cobalt Copper Iron Manganese Nickel Uranium Vanadium Zinc Aroclor-1254	2.7 0.9 6.2 0.3 1.3 0.8 2.7 0.1 0.3 19.7 1.9 0.4 58.4 2.4 0.2 1.7	Ingestion Dermal Ingestion of vegetables from soil	1.4 7.7 90.9

Table 6.10. Summary of Risk Characterization for SWMU 7 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future adult rural resident at current concentrations (soil) (from WAG 22 RI[b])	3.4E-02	Arsenic Beryllium Aroclor-1254 Aroclor-1260 Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{239}Pu ^{234}U ^{235}U $^{235/236}$U ^{238}U	7.3 65.4 0.2 0.4 0.2 1.7 0.2 <0.1 1.9 0.3 0.2 0.4 3.3 0.3 0.5 17.6	Ingestion Dermal External exposure Ingestion of vegetables from soil	0.5 33.0 1.9 64.6	1.1E+02	Aluminum Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Iron Manganese Nickel Uranium Vanadium Zinc Aroclor-1254	2.7 0.8 6.5 0.3 1.1 0.8 2.3 0.3 19.8 1.6 0.4 59.5 2.0 0.2 1.7	Ingestion Dermal Ingestion of vegetables from soil	0.5 5.0 94.6
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	1.89E+01	Arsenic Manganese Uranium 1,1-DCE *cis*-1,2-DCE Total PCBs TCE Vinyl chloride	30.2 3.7 2.9 4.5 6.6 22.3 26.4 3.4	Ingestion Dermal contact Inhalation while showering Inhalation household use	60.9 21.0 2.0 16.0
Future adult rural resident at current concentrations (RGA groundwater only)	3.13E-03	Arsenic 1,1-DCE Total PCBs TCE Vinyl chloride ^{99}Tc ^{234}U ^{238}U	15.1 66.4 0.2 4.1 11.9 1.6 0.4 0.4	Ingestion Dermal contact Inhalation while showering Inhalation during household use	61.2 3.7 4.9 30.3	6.39E+00	Arsenic Manganese Uranium 1,1-DCE *cis*-1,2-DCE Total PCBs TCE Vinyl chloride	25.5 3.2 2.5 3.1 4.5 31.4 27.1 2.7	Ingestion Dermal contact Inhalation household use	51.4 37.2 10.1

Table 6.10. Summary of Risk Characterization for SWMU 7 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	1.45E+01	Arsenic Manganese Uranium 1,1-DCE *cis*-1,2-DCE Total PCBs TCE Vinyl chloride	27.9 3.6 2.8 5.4 7.9 17.2 31.2 4.1	Ingestion Dermal contact Inhalation while showering Inhalation household use	62.3 18.7 2.2 16.9
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	2.98E-03	Arsenic 1,1-DCE Total PCBs TCE Vinyl chloride ^{99}Tc ^{234}U ^{238}U	11.2 63.9 0.2 10.3 12.3 1.5 0.3 0.3	Ingestion Dermal contact Inhalation while showering Inhalation during household use	55.4 3.4 4.7 36.5	4.78E+00	Arsenic Manganese Uranium 1,1-DCE *cis*-1,2-DCE Total PCBs TCE Vinyl chloride	24.2 3.1 2.4 3.8 5.5 24.8 32.9 3.3	Ingestion of groundwater Dermal contact Inhalation household use	53.8 33.8 11.0
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA	1.97E+00	Arsenic 1,1-DCE *cis*-1,2-DCE Total PCBs TCE	38.1 5.3 8.4 12.4 32.9	Ingestion Dermal contact Inhalation household use	66.3 15.8 15.9
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	4.11E-04	Arsenic 1,1-DCE TCE Vinyl chloride ^{99}Tc	15.1 61.8 10.7 8.7 3.6	Ingestion Dermal contact Inhalation while showering Inhalation during household use	56.7 3.2 4.5 35.5	6.36E-01	Arsenic Total PCBs TCE	33.9 18.4 35.5	Ingestion Dermal contact	58.8 29.3
Future child rural resident at modeled concentrations (RGA groundwater drawn at Little Bayou seeps)	NA	NA	NA	NA	NA	3.373E-01	TCE	61.0	Ingestion Inhalation household use	52.5 30.0
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Little Bayou seeps)	1.28E-04	1,1-DCE TCE Vinyl chloride ^{99}Tc	72.6 12.3 9.5 5.7	Ingestion Dermal contact Inhalation while showering Inhalation during household use	49.6 3.6 5.3 41.4	1.15E-01	*No COCs		*No COCs	

Table 6.10. Summary of Risk Characterization for SWMU 7 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		Not a POE for groundwater from this SWMU.								
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		Not a POE for groundwater from this SWMU.								
Future child recreational user at current concentrations (from WAG 22 RI[b])	NA	NA	NA	NA	NA	7.3E-02	*No COCs		*No COCs	
Future teen recreational user at current concentrations (from WAG 22 RI[b])	NA	NA	NA	NA	NA	6.4E-02	*No COCs		*No COCs	
Future adult recreational user at current concentrations (from WAG 22 RI[b])	1.1E-05	Aroclor-1260 Benzo(a)pyrene Dibenzo(a,h)anthracene ^{238}U	18.6 9.5 42.5 15.7	Ingestion of deer Ingestion of rabbit Ingestion of quail	10.0 70.9 21.8	7.5E-02	*No COCs		*No COCs	
Future excavation worker at current concentrations (soil) (from WAG 22 RI[b])	1.6E-03	Arsenic Beryllium Benzo(a)pyrene Dibenzo(a,h)anthracene ^{237}Np ^{239}Pu ^{234}U ^{235}U $^{235/236}U$ ^{238}U	1.8 42.2 0.1 1.7 0.4 0.5 3.4 9.1 0.4 41.3	Ingestion Dermal External exposure	25.6 43.8 32.5	5.4E+00	Aluminum Antimony Arsenic Chromium Copper Iron Manganese Nickel Uranium Vanadium	5.0 11.3 3.4 17.6 2.9 21.3 11.0 3.9 7.5 10.9	Ingestion Dermal	18.4 81.5

ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern

Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.

*No COCs = There are no COCs or POCs.

[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.

[b] *Remedial Investigation Report for Solid Waste Management Units 7 and 30 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1604/V1&D2, January 1998 (DOE 1998a), Tables 1.59 through 1.68, excluding lead as a COC.

Table 6.11. Summary of Risk Characterization for SWMU 30

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil) (from WAG 22 RI[b])	3.7E-03	Arsenic Beryllium Aroclor-1260 Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{234}U ^{235}U $^{235/236}$U ^{238}U	0.5 97.5 0.1 0.1 0.8 0.1 0.3 0.1 <0.1 <0.1 0.2 0.3 1.4	Ingestion Dermal External exposure	0.5 97.3 1.7	4.4E+00	Aluminum Antimony Arsenic Beryllium Cadmium Chromium Iron Manganese Uranium Vanadium	5.1 3.7 2.7 10.8 3.5 13.5 19.8 11.3 9.0 17.6	Ingestion Dermal	2.9 97.1
Future industrial worker at current concentrations (soil) (from WAG 22 RI[b])	3.8E-03	Arsenic Beryllium Aroclor-1260 Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{34}U ^{35}U $^{235/236}$U ^{238}U	0.5 96.2 0.1 0.1 0.8 0.1 0.3 0.1 <0.1 <0.1 0.2 0.3 1.4	Ingestion Dermal External exposure	0.5 97.8 1.7	4.4E+00	Aluminum Antimony Arsenic Beryllium Cadmium Chromium Iron Manganese Uranium Vanadium	5.1 3.7 2.7 10.8 3.5 13.5 19.8 11.3 9.0 17.6	Ingestion Dermal	2.9 97.1
Future child rural resident at current concentrations (soil) (from WAG 22 RI[b])	NA	NA	NA	NA	NA	2.6E+02	Aluminum Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Iron Manganese Mercury Nickel Uranium Vanadium Zinc Aroclor-1254	4.1 0.9 7.5 0.6 1.8 2.2 3.2 0.6 22.6 2.5 0.7 0.8 46.8 3.0 0.2 2.6	Ingestion Dermal Ingestion of vegetables from soil	1.3 9.4 89.3

Table 6.11. Summary of Risk Characterization for SWMU 30 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future adult rural resident at current concentrations (soil) (from WAG 22 RI[b])	3.2E-02	Arsenic Beryllium Aroclor-1254 Aroclor-1260 Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene bis(2-ethylhexyl)phthalate Chrysene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{234}U ^{235}U $^{235/236}$U ^{238}U	6.8 66.7 0.2 1.8 0.4 4.4 0.5 <0.1 <0.1 <0.1 1.7 0.4 0.2 4.5 0.3 0.6 11.5	Ingestion Dermal External exposure Ingestion of vegetables from soil	0.5 35.4 1.3 62.8	7.9E+01	Aluminum Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Iron Manganese Mercury Nickel Uranium Vanadium Zinc Aroclor-1254	4.1 0.8 7.9 0.6 1.5 2.2 2.9 0.6 22.8 2.1 0.7 0.9 47.5 2.4 0.2 2.7	Ingestion Dermal Ingestion of vegetables from soil	0.5 6.1 93.4
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	3.34E+02	Arsenic Manganese Selenium Uranium 1,1-DCE TCE	1.7 0.2 0.1 0.4 0.2 97.4	Ingestion Dermal contact Inhalation while showering Inhalation household use	70.6 21.3 0.9 7.2
Future adult rural resident at current concentrations (RGA groundwater only)	2.40E-02	Arsenic 1,1-DCE TCE ^{99}Tc ^{234}U ^{238}U	2.0 5.8 92.1 0.1 0.0 0.0	Ingestion Dermal contact Inhalation while showering Inhalation household use	21.6 10.5 7.7 60.2	1.17E+02	Arsenic Manganese Uranium 1,1-DCE TCE	1.4 0.2 0.3 1.3 96.7	Ingestion Dermal contact Inhalation while showering Inhalation household use	57.9 36.5 0.9 4.7
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	3.16E+02	Arsenic Manganese Selenium Uranium 1,1-DCE TCE	1.2 0.2 0.1 0.2 0.2 98.2	Ingestion of groundwater Dermal contact Inhalation while showering Inhalation household use	70.4 21.4 0.9 7.3
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	2.28E-02	Arsenic 1,1-DCE TCE ^{99}Tc ^{234}U ^{238}U	1.4 6.0 92.5 0.1 0.0 0.0	Ingestion Dermal contact Inhalation while showering Inhalation household use	21.1 10.6 7.8 60.6	1.10E+02	Arsenic Manganese Uranium 1,1-DCE TCE	1.0 0.1 0.2 0.1 98.5	Ingestion Dermal contact Inhalation while showering Inhalation household use	58.0 37.0 0.6 4.5

Table 6.11. Summary of Risk Characterization for SWMU 30 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA	2.76E+01	Arsenic TCE	2.7 97.1	Ingestion Dermal contact Inhalation while showering Inhalation household use	70.7 21.2 0.9 7.2
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	1.99E-03	Arsenic 1,1-DCE TCE Technetium-99	3.1 5.1 91.6 0.2	Ingestion Dermal contact Inhalation while showering Inhalation household use	22.3 10.4 7.6 59.7	9.56E+00	Arsenic TCE	2.2 97.6	Ingestion Dermal contact Inhalation household use	58.4 36.6 4.4
Future child rural resident at modeled concentrations (RGA groundwater drawn at Little Bayou seeps)	NA	NA	NA	NA	NA	8.97E+00	TCE	99.8	Ingestion Dermal contact Inhalation household use	69.9 21.8 7.4
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Little Bayou seeps)	6.41E-04	1,1-DCE TCE ^{99}Tc	4.8 95.0 0.2	Ingestion Dermal contact Inhalation while showering Inhalation household use	19.8 10.8 7.9 61.6	3.12E+00	TCE	99.9	Ingestion Dermal contact Inhalation household use	57.4 37.5 4.5
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		Not a POE for groundwater from this SWMU								
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		Not a POE for groundwater from this SWMU								
Future child recreational user at current concentrations (from WAG 22 RI[b])	NA	NA	NA	NA	NA	4.2E-02	*No COCs		*No COCs	
Future teen recreational user at current concentrations (from WAG 22 RI[b])	NA	NA	NA	NA	NA	3.8E-02	*No COCs		*No COCs	

Table 6.11. Summary of Risk Characterization for SWMU 30 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future adult recreational user at current concentrations (from WAG 22 RI[b])	1.5E-05	Aroclor-1260 Benzo(a)pyrene Dibenzo(a,h)anthracene	48.2 12.9 20.8	Ingestion of deer Ingestion of rabbit Ingestion of quail	8.7 80.0 11.3	4.3E-02	*No COCs		*No COCs	
Future excavation worker at current concentrations (soil) (from WAG 22 RI[b])	1.2E-03	Arsenic Beryllium Aroclor-1248 Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{239}Pu ^{234}U ^{235}U $^{235/236}$U ^{238}U	1.9 93.7 0.1 0.1 0.8 0.1 0.4 0.1 0.3 0.2 0.8 0.1 0.8 0.6	Ingestion Dermal External exposure	6.3 91.7 3.3	4.5E+00	Aluminum Antimony Arsenic Beryllium Cadmium Chromium Copper Iron Manganese Uranium Vanadium	4.6 6.3 3.3 3.8 3.0 10.2 7.6 19.8 14.3 12.2 12.7	Ingestion Dermal	26.4 73.5

ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern

Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.

[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.

[b] *Remedial Investigation Report for Solid Waste Management Units 7 and 30 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1604/V1&D2, January 1998 (DOE 1998a), Tables 1.59 through 1.68, excluding lead as a COC.

Table 6.12. Summary of Risk Characterization for SWMU 145

Receptor	Total ELCRa	COCs	% Total ELCR	POCs	% Total ELCR	Total HIa	COCs	% Total HI	POCs	% Total HI
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	4.17E+01	Antimony Arsenic Manganese	48.0 47.7 4.3	Ingestion Dermal contact	97.8 2.2
Future adult rural resident at current concentrations (RGA groundwater only)	3.27E-02	Arsenic ^{99}Tc Aroclor-1260	5.1% 1.7% 93.2	Ingestion Dermal contact	99.8 0.2	1.22E+01	Antimony Arsenic Manganese	49.0 46.7 4.3	Ingestion Dermal contact	6.9 93.1
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA	5.16E-01	Arsenic	99.9	Ingestion	99.8
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	1.44E-04	Arsenic ^{99}Tc	29.7 70.3	Ingestion	99.9	1.48E-01	Arsenic	99.9	Ingestion	99.6
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	NA	NA	NA	NA	NA		*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	5.29E-05	^{99}Tc	100.0	Ingestion	100		*No COCs		*No COCs	
Future child recreational user at current concentrations (soil)	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

Table 6.12. Summary of Risk Characterization for SWMU 145 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future teen recreational user at current concentrations (soil)	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Future adult recreational user at current concentrations (soil)	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Future excavation worker at current concentrations	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern

Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.

NE = not evaluated: land use scenario was not assessed because surface soil was not assessed for this SWMU.

[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.

6.4.9 Uncertainty in the Risk Assessment

Risk and hazard estimates could vary if different assumptions were used in deriving the risk estimates or if better information were available for some parameters. No uncertainties were estimated to have a large effect on the risk characterization, and only the following were estimated to have a moderate effect:

- Exclusion of some potential biota (produce and fish) for future receptors,
- Migration of groundwater to off-site receptors,
- Calculation of toxicity values for chemicals (particularly TCE), and
- Updates to toxicity values.

Uncertainty on toxicity factors plays a major role in this risk assessment. Because the RfD for lead was in question even when the previous soil assessments were written, the results were calculated without lead in those previous documents, and those results were summarized in this assessment. At the time the WAG 22 and WAG 3 RI reports were developed, beryllium still was evaluated as a carcinogen. The cancer slope factor for beryllium has been withdrawn from IRIS, and there has been an agreement not to use this withdrawn value for risk assessments at PGDP. At several SWMUs, beryllium was a significant contributor to the total cancer risk from soil exposure; generally, beryllium accounted for greater than 90% of the risk to the industrial worker and greater than 65% of the risk to the resident. When beryllium is removed from consideration as a carcinogen, the total ELCR becomes much lower at those SWMUs for which it is a COC.

- SWMU 4: 1.6E-05 for future industrial worker and 1.2E-03 for the resident
- SWMU 5: 2.1E-04 for future industrial worker; no significant change for the resident value
- SWMU 6: 2.4E-05 for future industrial worker and 1.1E-03 for the resident
- SWMU 7: 1.6E-04 for future industrial worker and 1.2E-02 for the resident
- SWMU 30: 1.4E-04 for future industrial worker and 1.1E-02 for the resident

For SWMUs 4 and 6, removal of the contribution of beryllium to the ELCR reduces the total ELCR to within the EPA risk range for the industrial worker scenario.

6.5 BRA OBSERVATIONS AND CONCLUSIONS

This section summarizes the results of this and previous BRAs and draws conclusions from the results. This section also includes a series of observations in which the results of the BRAs are combined with the uncertainties in the risk assessment.

Appendix F provides observations regarding the results and uncertainties of this and previous risk assessments in detail. This section provides a summary of the results of those observations. The discussion focuses on the individual exposure scenarios examined for the assessment.

6.5.1 Future Industrial Worker

SWMUs 4, 7, and 30 hazard levels exceed 1 for industrial worker exposure to soil, with chromium, iron, and vanadium serving as the primary hazard drivers for elevated HIs. All SWMUs (SWMU 145 was not evaluated for this scenario) exceed risk levels of 1E-04 for industrial worker exposure to soil, with uranium-235+daughters, uranium-238+daughters, and beryllium serving as the primary risk drivers. Other COCs contributing to elevated risks include Total PAH and arsenic. SWMUs 2, 3, 5, 7, and 30 exceed risk levels of 1E-04 for industrial worker exposure to soil, if beryllium is not included in the cumulative ELCR for each of the SWMUs.

6.5.2 Future Excavation Worker

SWMUs 4, 5, 6, 7, and 30 exceed a hazard level of 1 for excavation worker exposure to soil (SWMUs 4, 5 and 6 were evaluated for exposure to soil and waste), with aluminum, antimony, chromium, iron, manganese, uranium, and vanadium serving as the primary hazard driver for elevated HIs. Other COCs contributing to hazards include arsenic and copper. SWMUs 4, 5, 6, 7, and 30 exceed the risk level of 1E-04 for excavation worker exposure to soil, with beryllium, uranium, Total PAH, and uranium-238 serving as the primary risk drivers. Other COCs contributing to elevated risks include arsenic and uranium-235. SWMUs 4, 5, 7, and 145 exceed the risk level of 1E-04 for excavation worker exposure to soil when beryllium is not included in the cumulative ELCR. SWMUs 4, 5 and 6 included exposure to soil and waste which was included in this BHHRA but referred to as one media type, soil.

6.5.3 Future On-Site Residents (Groundwater)

For residential groundwater use at the SWMU boundary, ELCR was greater than 1E-04 and HI was greater than 1 for all SWMUs except SWMU 6. The primary risk drivers are TCE, arsenic, vinyl chloride, 1,1-DCE, and technetium-99.

6.5.4 Future Off-Site Residents (Groundwater)

SWMUs 2, 4, 5, 7, and 30 exceed a hazard level of 1 for off-site residential exposure to groundwater at the PGDP plant boundary. SWMUs 2, 4, 7, and 30 exceed a hazard level of 1 at the property boundary. SWMUs 2, 4, and 30 exceed a hazard level of 1 at the Ohio River (or seeps). The primary drivers for hazard are arsenic, TCE, *cis*-1,2-DCE, and 1,1-DCE. SWMUs 2, 3, 4, 7, and 30 at the plant boundary, SWMUs 2, 4, 7, 30, and 145 at the property boundary, and SWMUs 2, 4, 7, and 30 at the Ohio River (or seeps) exceed a risk level of 1E-04 for off-site residential exposure to groundwater. The primary risk drivers are TCE, 1,1-DCE, and technetium-99.

6.6 REMEDIAL GOAL OPTIONS

RGOs are presented in Table 6.13 for soil for the industrial worker, excavation worker, and residential user scenarios and in Table 6.14 for the residential groundwater user. RGOs were calculated for each COC from the modeled groundwater concentrations considering residential use of groundwater at each source and at the property boundary POE. When calculating the HI-based RGOs, the more conservative child-based values are reported. In addition, for comparison to the RGOs, the MCL for each COC is presented. Note, MCLs are not clean-up criteria, though they may be ARARs. The National Contingency Plan (NCP) notes that clean-up criteria different from MCLs may be required if multiple contaminants are present or if contaminants may reach a receptor through exposure routes different from those considered in the development of MCLs. Risks for use of contaminated groundwater must be presented in addition to a simple screen against MCLs so that risk managers can make appropriate decisions. The calculation used to derive groundwater RGOs can be found in section 8.1 of Appendix F. The soil RGOs were calculated from the NALs (DOE 2008b) for all COCs from the previous risk assessments for SWMUs 2, 3, 4, 5, 6, 7, and 30 (DOE 1994; DOE 1998a; DOE 2000a).

Table 6.13. RGOs for Soil COCs of the BGOU SWMUs

COC[A]	Cancer NAL	Noncancer NAL	RGO[B] at HI=0.1	RGO at HI=1	RGO at HI=3	RGO at ELCR= 1×10^{-6}	RGO at ELCR= 1×10^{-5}	RGO at ELCR= 1×10^{-4}	Units
Residential User Soil Exposure									
Aluminum		9.69E+02	9.69E+01	9.69E+02	2.91E+03				mg/kg
Antimony		8.69E-02	8.69E-03	8.69E-02	2.61E-01				mg/kg
Arsenic	1.44E-01	1.16E+00	1.16E-01	1.16E+00	3.48E+00	1.44E-01	1.44E+00	1.44E+01	mg/kg
Barium		1.40E+02	1.40E+01	1.40E+02	4.20E+02				mg/kg
Beryllium and compounds	1.19E-03	2.20E-01	2.20E-02	2.20E-01	6.60E-01	1.19E-03	1.19E-02	1.19E-01	mg/kg
Cadmium	2.00E+00	3.26E+00	3.26E-01	3.26E+00	9.78E+00	2.00E+00	2.00E+01	2.00E+02	mg/kg
Chromium	1.10E+02	8.32E+01	8.32E+00	8.32E+01	2.50E+02	1.10E+02	1.10E+03	1.10E+04	mg/kg
Cobalt	4.69E+02	6.95E+01	6.95E+00	6.95E+01	2.09E+02	4.69E+02	4.69E+03	4.69E+04	mg/kg
Copper		9.39E+01	9.39E+00	9.39E+01	2.82E+02				mg/kg
Iron		4.14E+02	4.14E+01	4.14E+02	1.24E+03				mg/kg
Manganese		5.60E+01	5.60E+00	5.60E+01	1.68E+02				mg/kg
Nickel	5.06E+03	4.35E+01	4.35E+00	4.35E+01	1.31E+02	5.06E+03	5.06E+04	5.06E+05	mg/kg
Uranium		2.57E+00	2.57E-01	2.57E+00	7.71E+00				mg/kg
Vanadium		7.71E-01	7.71E-02	7.71E-01	2.31E+00				mg/kg
Zinc		5.21E+02	5.21E+01	5.21E+02	1.56E+03				mg/kg
Aroclor 1260	6.08E-02					6.08E-02	6.08E-01	6.08E+00	mg/kg
Benz[a]anthracene	7.48E-02					7.48E-02	7.48E-01	7.48E+00	mg/kg
Benzo[a]pyrene	7.48E-03					7.48E-03	7.48E-02	7.48E-01	mg/kg
Benzo[b]fluoranthene	7.48E-02					7.48E-02	7.48E-01	7.48E+00	mg/kg
Dibenz[a,h]anthracene	7.48E-03					7.48E-03	7.48E-02	7.48E-01	mg/kg
Total Dioxins/Furans	6.78E-07					6.78E-07	6.78E-06	6.78E-05	mg/kg
Indeno[1,2,3-cd]pyrene	7.48E-02					7.48E-02	7.48E-01	7.48E+00	mg/kg
Total PCBs	5.78E-02					5.78E-02	5.78E-01	5.78E+00	mg/kg
Total PAHs	7.48E-03					7.48E-03	7.48E-02	7.48E-01	mg/kg
Neptunium-237+D	8.39E-02					8.39E-02	8.39E-01	8.39E+00	pCi/g
Plutonium-239*	3.15E+00					3.15E+00	3.15E+01	3.15E+02	pCi/g
Radium-226+D	7.94E-03					7.94E-03	7.94E-02	7.94E-01	pCi/g
Uranium-234	5.47E+00					5.47E+00	5.47E+01	5.47E+02	pCi/g
Uranium-235+D	1.22E-01					1.22E-01	1.22E+00	1.22E+01	pCi/g
Uranium-238+D	5.17E-01					5.17E-01	5.17E+00	5.17E+01	pCi/g

Table 6.13. RGOs for Soil COCs of the BGOU SWMUs (continued)

COC	Cancer NAL	Noncancer NAL	RGO at HI=0.1	RGO at HI=1	RGO at HI=3	RGO at ELCR= 1×10^{-6}	RGO at ELCR= 1×10^{-5}	RGO at ELCR= 1×10^{-4}	Units
Industrial Worker Soil Exposure									
Aluminum		4.22E+03	4.22E+02	4.22E+03	1.27E+04				mg/kg
Antimony		3.46E-01	3.46E-02	3.46E-01	1.04E+00				mg/kg
Arsenic	4.84E-01	7.78E+00	7.78E-01	7.78E+00	2.33E+01	4.84E-01	4.84E+00	4.84E+01	mg/kg
Barium		5.92E+02	5.92E+01	5.92E+02	1.78E+03				mg/kg
Beryllium and compounds	2.83E-03	8.68E-01	8.68E-02	8.68E-01	2.60E+00	2.83E-03	2.83E-02	2.83E-01	mg/kg
Cadmium	1.49E+01	1.97E+01	1.97E+00	1.97E+01	5.91E+01	1.49E+01	1.49E+02	1.49E+03	mg/kg
Chromium	2.11E+02	3.26E+02	3.26E+01	3.26E+02	9.78E+02	2.11E+02	2.11E+03	2.11E+04	mg/kg
Cobalt	9.05E+02	4.48E+02	4.48E+01	4.48E+02	1.34E+03	9.05E+02	9.05E+03	9.05E+04	mg/kg
Copper		4.91E+02	4.91E+01	4.91E+02	1.47E+03				mg/kg
Iron		1.90E+03	1.90E+02	1.90E+03	5.70E+03				mg/kg
Manganese		2.29E+02	2.29E+01	2.29E+02	6.87E+02				mg/kg
Nickel	9.75E+03	2.22E+02	2.22E+01	2.22E+02	6.66E+02	9.75E+03	9.75E+04	9.75E+05	mg/kg
Uranium		1.88E+01	1.88E+00	1.88E+01	5.64E+01				mg/kg
Vanadium		3.04E+00	3.04E-01	3.04E+00	9.12E+00				mg/kg
Zinc		2.50E+03	2.50E+02	2.50E+03	7.50E+03				mg/kg
Aroclor 1260	1.75E-01					1.75E-01	1.75E+00	1.75E+01	mg/kg
Benz[a]anthracene	1.94E-01					1.94E-01	1.94E+00	1.94E+01	mg/kg
Benzo[a]pyrene	1.94E-02					1.94E-02	1.94E-01	1.94E+00	mg/kg
Benzo[b]fluoranthene	1.94E-01					1.94E-01	1.94E+00	1.94E+01	mg/kg
Dibenz[a,h]anthracene	1.94E-02					1.94E-02	1.94E-01	1.94E+00	mg/kg
Total Dioxins/Furans	1.89E-06					1.89E-06	1.89E-05	1.89E-04	mg/kg
Indeno[1,2,3-cd]pyrene	1.94E-01					1.94E-01	1.94E+00	1.94E+01	mg/kg
Total PCBs	1.63E-01					1.63E-01	1.63E+00	1.63E+01	mg/kg
Total PAHs	1.94E-02					1.94E-02	1.94E-01	1.94E+00	mg/kg
Neptunium-237+D	2.71E-01					2.71E-01	2.71E+00	2.71E+01	pCi/g
Plutonium-239*	1.07E+01					1.07E+01	1.07E+02	1.07E+03	pCi/g
Radium-226+D	2.56E-02					2.56E-02	2.56E-01	2.56E+00	pCi/g
Uranium-234	1.89E+01					1.89E+01	1.89E+02	1.89E+03	pCi/g
Uranium-235+D	3.95E-01					3.95E-01	3.95E+00	3.95E+01	pCi/g
Uranium-238+D	1.70E+00					1.70E+00	1.70E+01	1.70E+02	pCi/g

Table 6.13. RGOs for Soil COCs of the BGOU SWMUs (continued)

COC	Cancer NAL	Noncancer NAL	RGO at HI=0.1	RGO at HI=1	RGO at HI=3	RGO at ELCR= 1×10^{-6}	RGO at ELCR= 1×10^{-5}	RGO at ELCR= 1×10^{-4}	Units
Excavation Worker Soil Exposure									
Aluminum		4.84E+03	4.84E+02	4.84E+03	1.45E+04				mg/kg
Antimony		4.52E-01	4.52E-02	4.52E-01	1.36E+00				mg/kg
Arsenic	3.13E-01	5.03E+00	5.03E-01	5.03E+00	1.51E+01	3.13E-01	3.13E+00	3.13E+01	mg/kg
Barium		7.11E+02	7.11E+01	7.11E+02	2.13E+03				mg/kg
Beryllium and compounds	3.83E-03	1.15E+00	1.15E-01	1.15E+00	3.45E+00	3.83E-03	3.83E-02	3.83E-01	mg/kg
Cadmium	2.12E+00	1.45E+01	1.45E+00	1.45E+01	4.35E+01	2.12E+00	2.12E+01	2.12E+02	mg/kg
Chromium	2.85E+02	4.36E+02	4.36E+01	4.36E+02	1.31E+03	2.85E+02	2.85E+03	2.85E+04	mg/kg
Cobalt	1.22E+03	3.11E+02	3.11E+01	3.11E+02	9.33E+02	1.22E+03	1.22E+04	1.22E+05	mg/kg
Copper		4.37E+02	4.37E+01	4.37E+02	1.31E+03				mg/kg
Iron		2.02E+03	2.02E+02	2.02E+03	6.06E+03				mg/kg
Manganese		2.90E+02	2.90E+01	2.90E+02	8.70E+02				mg/kg
Nickel	1.32E+04	2.05E+02	2.05E+01	2.05E+02	6.15E+02	1.32E+04	1.32E+05	1.32E+06	mg/kg
Uranium		1.10E+01	1.10E+00	1.10E+01	3.30E+01				mg/kg
Vanadium		4.03E+00	4.03E-01	4.03E+00	1.21E+01				mg/kg
Zinc		2.50E+03	2.50E+02	2.50E+03	7.50E+03				mg/kg
Aroclor 1260	1.55E-01					1.55E-01	1.55E+00	1.55E+01	mg/kg
Benz[a]anthracene	2.16E-01					2.16E-01	2.16E+00	2.16E+01	mg/kg
Benzo[a]pyrene	2.16E-02					2.16E-02	2.16E-01	2.16E+00	mg/kg
Benzo[b]fluoranthene	2.16E-01					2.16E-01	2.16E+00	2.16E+01	mg/kg
Dibenz[a,h]anthracene	2.16E-02					2.16E-02	2.16E-01	2.16E+00	mg/kg
Total Dioxins/Furans	1.79E-06					1.79E-06	1.79E-05	1.79E-04	mg/kg
Indeno[1,2,3-cd]pyrene	2.16E-01					2.16E-01	2.16E+00	2.16E+01	mg/kg
Total PCBs	1.48E-01					1.48E-01	1.48E+00	1.48E+01	mg/kg
Total PAHs	2.16E-02					2.16E-02	2.16E-01	2.16E+00	mg/kg
Neptunium-237+D	3.27E-01					3.27E-01	3.27E+00	3.27E+01	pCi/g
Plutonium-239*	1.62E+00					1.62E+00	1.62E+01	1.62E+02	pCi/g
Radium-226+D	3.30E-02					3.30E-02	3.30E-01	3.30E+00	pCi/g
Uranium-234	2.83E+00					2.83E+00	2.83E+01	2.83E+02	pCi/g
Uranium-235+D	4.55E-01					4.55E-01	4.55E+00	4.55E+01	pCi/g
Uranium-238+D	1.17E+00					1.17E+00	1.17E+01	1.17E+02	pCi/g

[A] COC = contaminant of concern
[B] RGO = remedial goal option. RGOs for soil for both HI and ELCR are calculated from the 2008 draft NALs (DOE 2008)

Table 6.14 RGOs for Groundwater COCs of the BGOU SWMUs

Residential User Groundwater Exposure COC[A]	EPC[B]	SWMU[C]	ELCR at EPC	HI at EPC	RGO[D] at HI=0.1	RGO at HI=1	RGO at HI=3	RGO at ELCR= 1 x 10^{-6}	RGO at ELCR= 1 x 10^{-5}	RGO at ELCR= 1 x 10^{-4}	MCL	
												mg/L
Antimony	7.99E-02	145		5.97E+00	1.34E-03	1.34E-02	1.34E-01				0.006	mg/L
Arsenic	6.21E-02	145	1.65E-03	1.99E+01	3.12E-04	3.12E-03	9.36E-03	3.76E-05	3.76E-04	3.76E-03	0.010	mg/L
Manganese	1.01E+00	5		2.15E+00	4.70E-02	4.70E-01	1.41E+00				---	
Selenium	1.51E-02	30		2.90E-01	5.21E-03	5.21E-02	1.56E-01				0.05	mg/L
Uranium	4.89E-02	3		7.82E+00	604	603	1.88E-02				0.03	
Total PCBs	5.23E-05	7	7.09E-06	4.20E+00	1.25E-06	1.25E-05	3.74E-05	7.38E-06	7.38E-05	7.38E-04	0.0005	mg/L
1,1-DCE	8.98E-02	7	2.08E-03	8.51E-01	1.06E-02	1.06E-01	3.17E-01	4.32E-05	4.32E-04	4.32E-03	---	mg/L
cis-1,2-DCE	1.15E+01	2		6.07E+02	1.89E-03	1.89E-02	5.68E-02				0.07	mg/L
Naphthalene	5.55E-03	5		2.80E+00	1.98E-04	1.98E-03	5.95E-03				---	mg/L
TCE	1.18E+00	4	3.67E-02	5.39E+02	2.19E-04	2.19E-03	6.57E-03	3.22E-05	3.22E-04	3.22E-03	0.005	mg/L
Vinyl Chloride	2.61E-02	4	1.65E-02	1.21E+00	2.16E-03	2.16E-02	6.47E-02	1.58E-06	1.58E-05	1.58E-04	0.002	mg/L
Technetium-99	1.01E+04	145	5.54E-04					1.82E+01	1.82E+02	1.82E+03	900[E]	pCi/L
Uranium-234	7.94E+00	7	1.11E-05					7.12E-01	7.12E+00	7.12E+01	20[F]	pCi/L
Uranium-238	1.59E+01	3	2.76E-05					5.76E-01	5.76E+00	5.76E+01	20[F]	pCi/L

[A] COC = contaminant of concern
[B] EPC = exposure point concentration; represents maximum EPC value for all SWMUs where constituent was a COC for the applicable scenario
[C] SWMU = the SWMU associated with the maximum EPC value
[D] RGO = remedial goal option
[E] converted from MCL of 4 mrem/yr dose (DOE 2001)
[F] converted from MCL for total uranium of 0.03 mg/L (DOE 2001)

6.7 SCREENING ECOLOGICAL RISK ASSESSMENT

Appendix G provides summaries of the results of ecological risk assessments (ERAs) previously completed for SWMUs 2, 4, 5, 6, 7, and 30 within the BGOU of PGDP (Figure G.1). SWMUs 3 and 145 are not included because SWMU 3 is covered by a RCRA cap and SWMU 145 is sited on 44 acres that now lie beneath the C-746-S&T Landfills. For most of the SWMUs, no new surface data have been collected since the previous risk assessments were performed. In addition, the soils at these units are outside the scope of the BGOU RI as defined in the approved work plan (DOE 2006a); therefore, a new quantitative risk assessment was not performed for soils. A summary of the results of the comparison in previous assessments of the site data to the ecological screening levels is provided in Table 6.15. This table lists the number of COPCs in each suite retained for each site and the medium for further consideration. This table shows that a number of inorganic analytes detected above background values and detected organic analytes were retained. Radionuclides were eliminated as COPCs for all sites except for SWMUs 7 and 30.

Table 6.15. Summary of Suite of COPCs Retained in Surface Soil

Area	Media	Metal	Rad	Pesticide/PCB	SVOC	VOC
SWMU 2	Soil	6	----	----	----	----
SWMU 3	Soil	NE	NE	NE	NE	NE
SWMU 4	Soil	5	----	1	----	----
SWMU 5	Soil	5	----	1	3	----
SWMU 6	Soil	2	----	----	1	----
SWMU 7	Soil	19	Total*	1	----	----
SWMU 30	Soil	17	Total*	1	----	----
SWMU 145	Soil	NE	NE	NE	NE	NE

----: no COPCs
NE: SWMU did not undergo an ecological evaluation.
*Radionuclide risk was assessed based on a total dose benchmark for all radionuclides.
SVOC=semivolatile organic compound
VOC=volatile organic compound

Each of the sites evaluated in the ERAs summarized in this section retained a number of COPCs as COPCs. Some metals at concentrations above background were retained as COPCs for ecological risk at each SWMU. Total PCBs were retained as COPCs for all SWMUs except SWMU 6. This is based on direct risk from soil as well as risks to some wildlife receptors from bioaccumulation through the food chain. The only other COPCs retained are three SVOCs (fluorene, phenanthrene, and di-n-butyl phthalate) at SWMU 5 and di-n-butyl phthalate at SWMU 6.

The current plan is to conduct further ecological risk assessment in future activities. In the absence of these activities, the benchmarks used in the screenings presented here and in the no further action (NFA) levels the PGDP Ecological Risk Methods Document (DOE 2001) and the 2008 draft revision of the same document will be used to develop ecologically-based RGOs.

7. SUMMARY AND CONCLUSIONS

This chapter summarizes and presents conclusions about the nature and extent of contamination, fate and transport, and risk assessment at the eight burial grounds evaluated during this RI. The conclusions are drawn from known site conditions, historical knowledge of the burial grounds, and geological and environmental sampling data collected from the burial areas.

7.1 OVERVIEW

The PGDP SMP (DOE 2007a) focuses environmental restoration activities into five strategic initiatives, as follows:

- BGOU Strategic Initiative,
- Decontamination and Decommissioning (D&D) OU Strategic Initiative,
- Groundwater OU Strategic Initiative,
- Soils OU Strategic Initiative, and
- Surface Water OU Strategic Initiative.

These initiatives include a series of prioritized response actions, ongoing site characterization activities to support future response action decisions, and D&D of the operating gaseous diffusion plant once it ceases operation. After completion of these activities, the Comprehensive Site OU evaluation will be conducted, with implementation of additional actions, as needed, to ensure long-term protectiveness.

7.2 RECOMMENDED REMEDIAL ACTION OBJECTIVES

General site cleanup objectives have been developed that serve as guiding principles for creating more detailed remedial action objectives (RAOs) to focus OUs on site-specific problems. A primary objective for the BGOU is to contribute to the protection of off-site residents by addressing sources of groundwater contamination. Based on the current and reasonably anticipated future land use, on-site industrial workers, recreational users, and off-site residents are the primary human receptors having the greatest potential for exposure to site contamination originating from PGDP. The primary pathways of exposure are (1) the groundwater pathway for off-site residents; (2) the surface water pathway (i.e., surface water and sediments) for recreational users (assumed to be primarily local residents); and (3) direct contact with waste, soil, and sediment for industrial workers. The following are the preliminary BGOU RAOs.

- Contribute to protection of current and future residential receptors from exposure to contaminated groundwater by addressing sources of groundwater contamination.

- Protect industrial workers from exposure to waste and contaminated soils.

- Treat or remove principal threat wastes wherever practicable, consistent with 40 *CFR* § 300.430 (a)(iii)(A).

The selected response actions for each OU must meet the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) threshold criteria: 1) be protective of human health and the environment and 2) attain Applicable or Relevant and Appropriate Requirements (ARARs) [or provide grounds for invoking a waiver under CERCLA 121(d)(4)]. The NCP defines protectiveness in terms of risk-based levels and states that acceptable health-based exposure levels for known or suspected

carcinogens are concentration levels that represent an excess upper-bound lifetime cancer risk between 10^{-4} to 10^{-6}. The NCP requires the 10^{-6} risk level be used as the point of departure for determining remediation goals for alternatives when ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants at a site or multiple pathways of exposure. For systemic toxicants, EPA guidance defines a HI less than 1 as an acceptable health-based exposure level.

A summary of potential location-specific ARARs that have been identified for the BGOU is included as Appendix H of this document.

7.3 REMEDIAL INVESTIGATION SCOPE

The scope of the BGOU Strategic Initiative includes an RI, BRA, FS, remedy selection, and implementation of actions, as necessary, for protection of human health and the environment. This BGOU RI addresses eight SWMUs containing burial grounds and landfills at PGDP: seven (SWMUs 2, 3, 4, 5, 6, 7, and 30) are located within the main PGDP secure area; and one (SWMU 145) is located within a controlled access area to the north. Two other SWMUs in the BGOU are the C-746-S and C-746-T Landfills, which are closed landfills that were not included in this RI.

SWMU	Facility
2	C-749 Uranium Burial Ground
3	C-404 Low-Level Radioactive Waste Burial Ground
4	C-747 Contaminated Burial Yard and C-748-B Burial Area
5	C-746-F Burial Yard
6	C-747-B Burial Ground
7	C-747-A Burial Ground
30	C-747-A Burn Area
145	Area P

Ditches essentially bound each of the BGOU SWMUs to facilitate surface drainage. The nature and extent of contamination within these ditches is within the scope of the Surface Water OU Strategic Initiative and the Comprehensive Site OU evaluation.

The BGOU RI/FS Work Plan identified four primary goals for this RI and for the follow-up FS (DOE 2006a). Table 7.1 summarizes these goals and references sections of the RI report (where applicable) that address these goals. Both the historical data and new data collected during this RI were of sufficient quality to address the data needs identified during the DQO process.

The potential areas of buried metal within the C-746-P and C-746-P1 Scrap Yards (SWMU 13) identified during this BGOU RI field investigation will be characterized with a Field Sampling Plan addendum to the BGOU RI/FS Work Plan and follow-on field investigation. The results will be discussed with the FFA parties and, if further action is necessary, a path forward will be determined.

Table 7.1. Goals Identified for the BGOU RI

GOAL 1:	**CHARACTERIZE NATURE OF SOURCE ZONE**
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?
1-5:	What are the chemical and physical properties of associated material at the source areas?
GOAL 2:	**DEFINE EXTENT OF SOURCE ZONE AND CONTAMINATION IN SOIL AND OTHER SECONDARY SOURCES AT ALL UNITS**
2-1:	What are the past, current, and potential future migratory paths?
2-2:	What are the past, current, and potential future release mechanisms?
2-3:	What are the contaminant concentrations or activity gradients?
2-4:	What is the vertical and lateral extent of contamination?
2-5:	What is the relationship of the UCRS gradient to the source, to surface water bodies, and to the RGA?
GOAL 3:	**DETERMINE SURFACE AND SUBSURFACE TRANSPORT MECHANISMS AND PATHWAYS**
3-1:	What are the contaminant migration trends?
3-2:	To what area is the dissolved-phase plume migrating?
3-3:	What are the effects of underground utilities and plant operations on migration pathways including ditches?
3-4:	What is the role of the UCRS in contaminant transport?
3-5:	What are the physical and chemical properties of the formations and subsurface matrices?
GOAL 4:	**SUPPORT EVALUATION OF REMEDIAL ALTERNATIVES**
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 or secondary contamination source)?
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 or secondary contamination sources?

Table 7.1. Goals Identified for the BGOU RI (Continued)

GOAL 1: Characterize Nature of Source Zone

		SWMU	Location in Text
1-1 & 1-3	What are the suspected contaminants? What are the concentrations and activities at the source?	SWMU 2	Section 4.3
		SWMU 3	Section 4.4
		SWMU 4	Section 4.5
		SWMU 5	Section 4.6
		SWMU 6	Section 4.7
		SWMU 7	Section 4.8
		SWMU 30	Section 4.9
		SWMU 145	Section 4.10
1-2 & 1-5	What are the plant processes that could have contributed to the contamination? When and over what duration did releases occur? What are the chemical and physical properties of associated material at the source areas?	SWMU 2	Section 1.3.1.2
		SWMU 3	Section 1.3.2.2
		SWMU 4	Section 1.3.3.2
		SWMU 5	Section 1.3.4.2
		SWMU 6	Section 1.3.5.2
		SWMU 7	Section 1.3.6.2
		SWMU 30	Section 1.3.7.2
		SWMU 145	Section 1.3.8.2
1-4	What is the area and volume of the source zone?	SWMU 2	Section 1.3.1.1 and Appendix E, Table E.3.3
		SWMU 3	Section 1.3.2.1 and Appendix E, Table E.3.7
		SWMU 4	Section 1.3.3.1 and Appendix E, Table E.3.11
		SWMU 5	Section 1.3.4.1 and Appendix E, Table E.3.15
		SWMU 6	Section 1.3.5.1 and Appendix E, Table E.3.19
		SWMU 7	Section 1.3.6.1 and Appendix E, Table E.3.21
		SWMU 30	Section 1.3.7.1 and Appendix E, Table E.3.25
		SWMU 145	Section 1.3.8.1 and Appendix E, Table E.3.29

Table 7.1. Goals Identified for the BGOU RI (Continued)

GOAL 2: Define Extent of Source Zone and Contamination in Soil and Other Secondary Sources at All Units

		SWMU	Location in Text
2-1	What are the past, current, and potential future migratory paths?	All SWMUs	Section 5.1 and Figure 5.1
2-2	What are the past, current, and potential future release mechanisms?	All SWMUs	Section 4
2-3	What are the contaminant concentrations or activity gradients?	SWMU 2	Section 4.3
		SWMU 3	Section 4.4
		SWMU 4	Section 4.5
		SWMU 5	Section 4.6
		SWMU 6	Section 4.7
		SWMU 7	Section 4.8
		SWMU 30	Section 4.9
		SWMU 145	Section 4.10
2-4	What is the vertical and lateral extent of contamination?	SWMU 2	Table 4.7, Appendix D, SWMU 2
		SWMU 3	Table 4.13, Appendix D, SWMU 3
		SWMU 4	Table 4.19, Appendix D, SWMU 4
		SWMU 5	Table 4.24, Appendix D, SWMU 5
		SWMU 6	Table 4.29, Appendix D, SWMU 6
		SWMU 7	Table 4.34, Appendix D, SWMU 7
		SWMU 30	Table 4.40, Appendix D, SWMU 30
		SWMU 145	Table 4.45, Appendix D, SWMU 145
2-5	What is the relationship of the UCRS gradient to the source, to surface water bodies, and to the RGA?	SWMU 2	Section 3.9.3.1
		SWMU 3	Section 3.9.3.1
		SWMU 4	Section 3.9.3.2
		SWMU 5	Section 3.9.3.3
		SWMU 6	Section 3.9.3.3
		SWMU 7	Section 3.9.3.4
		SWMU 30	Section 3.9.3.4
		SWMU 145	Section 3.9.3.5

Table 7.1. Goals Identified for the BGOU RI (Continued)

GOAL 3: Determine Surface and Subsurface Transport Mechanisms and Pathways

		SWMU	Location in Text
3-1 & 3-2	What are the contaminant migration trends? To what area is the dissolved-phase plume migrating?	SWMU 2	Section 5.3.1
		SWMU 3	Section 5.3.2
		SWMU 4	Section 5.3.3
		SWMU 5	Section 5.3.4
		SWMU 6	Section 5.3.5
		SWMU 7	Section 5.3.6
		SWMU 30	Section 5.3.7
		SWMU 145	Section 5.3.8
3-3	What are the effects of underground utilities and plant operations on migration pathways including ditches?	All SWMUs	Section 3.9.2
3-4	What is the role of the UCRS in contaminant transport?	SWMU 2	Section 4.3.2
		SWMU 3	Section 4.4.2
		SWMU 4	Section 4.5.2
		SWMU 5	Section 4.6.2
		SWMU 6	Section 4.7.2
		SWMU 7	Section 4.8.2
		SWMU 30	Section 4.9.2
		SWMU 145	Section 4.10.2
3-5	What are the physical and chemical properties of the formations and subsurface matrices?	All SWMUs	Section 3.9.3

Table 7.1. Goals Identified for the BGOU RI (Continued)

GOAL 4: Support Evaluation of Remedial Alternatives

		SWMU	Location in Text
4-1	What are the possible remedial technologies applicable for this unit?	All SWMUs	Tables 7.10 and 7.11, To be evaluated in FS
4-2	What are the physical and chemical properties of media to be remediated?	All SWMUs	Sections 1.3 and 3.9.3
4-3	Are cultural impediments present?	All SWMUs	Section 3.9.1. To be further evaluated in FS
4-4	What is the extent of contamination (geologic limitations presented by the source zone or secondary contamination source)?	SWMU 2	Section 3.9.3.1
		SWMU 3	Section 3.9.3.1
		SWMU 4	Section 3.9.3.2
		SWMU 5	Section 3.9.3.3
		SWMU 6	Section 3.9.3.3
		SWMU 7	Section 3.9.3.4
		SWMU 30	Section 3.9.3.4
		SWMU 145	Section 3.9.3.5
4-5	What would be the impact of action on and by other sources?	All SWMUs	To be evaluated in FS
4-6	What would the impact of an action at the source on the integrator units?	All SWMUs	To be evaluated in FS
4-7	What are stakeholders' perceptions of contamination at or migrating from source zone or secondary contamination sources?	All SWMUs	To be evaluated in FS

7.4 NATURE AND EXTENT OF CONTAMINATION

Materials that were disposed of in each of the SWMUs of the BGOU contained hazardous substances. The conceptual model applicable to all of the BGOU SWMUs is that releases from these SWMUs have impacted soils below or adjacent to the source zones and, through vertical infiltration in the soil, have the potential to contaminate the groundwater underlying these sources. Analysis of soil and groundwater from the area of each SWMU documents the presence of metals, organic compounds, and radionuclides above screening levels. Section 4 summarizes the characterization of the area of these SWMUs, as part of the BGOU RI and previous investigation efforts.

Principal threat waste (PTW) is defined by EPA as "source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human

health or the environment should exposure occur" (EPA 1991). EPA also recognizes that "although no threshold level of risk has been established to identify principal threat waste, a general rule of thumb is to consider as a principal threat those source materials with toxicity and mobility characteristics that combine to pose a potential risk several orders of magnitude greater than the risk level that is acceptable for the current or reasonably anticipated future land use, given realistic exposure scenarios" (EPA 1997).

For the BGOU SWMUs, the TCE DNAPL at SWMUs 4, 7, and 30 and uranium at SWMUs 2 and 3 potentially are PTW. Dissolved contaminant trends in the RGA indicate that SWMU 4 and the adjoining areas of SWMUs 7 and 30 could contain TCE sources as DNAPL. The mobility and toxicity of DNAPLs make them PTW.

The uranium at SWMU 2 presents risk greater than 1E-03 under some hypothetical exposure scenarios. Some forms of the buried uranium could be considered potential PTW where toxicity and mobility combine to pose such a risk to human health. These hypothetical exposure scenarios assume a direct contact exposure to buried waste (DOE 1997a). The uranium metal present at SWMUs 2 and 3 likely is not mobile due to its insolubility in water. The Data Summary and Interpretation Report (DOE 1997a) concluded that only some forms of uranium present may be mobile (e.g., uranyl fluoride at SWMU 2). Uncertainties concerning the risks associated with the toxicity and mobility of the uranium will be considered further during alternative evaluation in the FS.

Iron and manganese are frequently detected contaminants in subsurface soils in six of the SWMUs (Table 7.2). Arsenic and vanadium were other metals that were a frequently detected contaminant in the subsurface soils of the BGOU.

Table 7.2. Subsurface Soil Analytes Frequently Detected Above Background or Soil Screening Level

Source Areas	Metals	Organic Compounds[a]	Radionuclides
SWMU 2	Arsenic, Iron, Manganese, Vanadium	--	--
SWMU 3	Arsenic	--	--
SWMU 4	Iron, Manganese, Vanadium	--	^{230}Th, U, ^{234}U, ^{238}U
SWMU 5	Iron, Manganese, Vanadium	--	--
SWMU 6	Iron, Manganese, Vanadium	--	--
SWMU 7	Arsenic, Iron, Manganese	--	$^{235/236}$U
SWMU 30	Iron, Manganese, Vanadium	--	$^{235/236}$U
SWMU 145	Arsenic	--	^{228}Th

[a] While no organic compounds exceeded the 50% criterion for this table, elevated TCE levels exist in a few soil and groundwater samples that are indicative of a TCE DNAPL source at SWMU 4 and SWMUs 7 and 30.

-- = none U = uranium ^{238}U = uranium-238

^{228}Th = thorium-228 ^{234}U = uranium-234

^{230}Th = thorium-230 $^{233/236}$U = uranium-235/236

Metals are the most common of the frequently detected contaminants in both UCRS and RGA groundwater samples (Tables 7.3 and 7.4). Iron and manganese are the predominant contaminants in the UCRS. Iron is less prevalent in the RGA.

Table 7.3. UCRS Groundwater Analytes Frequently Detected Above Screening Level

Source Area	Metals	Organic Compounds	Radionuclides
SWMU 2	Beryllium, Iron, Manganese, Uranium, Vanadium	1,1-DCE; TCE	^{234}U, ^{238}U
SWMU 3	Arsenic, Iron, Manganese, Molybdenum	TCE	^{99}Tc
SWMU 4	Arsenic, Iron, Lead, Manganese	*cis*-1,2-DCE; TCE	^{99}Tc
SWMU 5	Arsenic, Iron, Lead, Manganese, Molybdenum	--	--
SWMU 6	Arsenic, Iron, Lead, Manganese, Molybdenum, Uranium	--	^{99}Tc, ^{234}U, ^{238}U
SWMU 7	Arsenic, Iron, Lead, Manganese, Molybdenum, Nickel	*cis*-1,2-DCE; TCE; Vinyl chloride	^{222}Rn, ^{234}U, ^{238}U
SWMU 30	Arsenic, Iron, Lead, Manganese, Molybdenum, Nickel, Uranium, Vanadium	TCE	^{234}U, ^{238}U
SWMU 145	Arsenic, Iron, Manganese	--	^{222}Rn, ^{238}U

-- = none
DCE = dichloroethene
^{222}Rn = radon-222
TCE = trichloroethene
^{99} Tc = technetium-99
^{234}U = uranium-234
^{238}U = uranium-238

Table 7.4. RGA Groundwater Analytes Frequently Detected Above Screening Level

Source Areas	Metals	Organic Compounds	Radionuclides
SWMU 2	Arsenic, Beryllium, Iron, Manganese, Vanadium	1,1-DCE; TCE	^{234}U, ^{238}U
SWMU 3	Manganese	TCE	--
SWMU 4	Arsenic, Manganese, Iron, Lead	1,1-DCE; Carbon Tetrachloride; Chloroform; *cis*-1,2-DCE; TCE; Vinyl Chloride	--
SWMU 5	Iron, Lead, Manganese	--	--
SWMU 6	Arsenic, Iron, Lead, Manganese	TCE	--
SWMU 7	Arsenic, Iron, Lead, Manganese, Nickel	TCE	^{99}Tc
SWMU 30	Iron, Manganese	TCE	^{222}Rn, ^{99}Tc
SWMU 145	Arsenic, Iron, Manganese	--	--

-- = none
DCE = dichloroethene
^{222}Rn = radon-222
TCE = trichloroethene
^{99} Tc = technetium-99
^{234}U = uranium-234
^{238}U = uranium-238

7.5 FATE AND TRANSPORT

Modeling assessed fate and transport of contaminants for two pathways: (1) dissolved-phase transport through the aquifer and (2) vapor transport to a residential basement. Section 5 and Appendix E document the fate and transport modeling applied to the BGOU RI.

Previous work has shown that the primary pathway for groundwater flow and the site-related contaminants is predominantly vertical migration through the UCRS, followed by lateral migration in the RGA. Contaminated groundwater could migrate to the POEs. The POEs evaluated were at the SWMU, at the plant boundary, at the property boundary, and near the Ohio River (either at the Little Bayou Creek seeps or at the Ohio River, depending on modeled groundwater flow paths beginning at each SWMU). Not all SWMUs have transport pathways to all of the POEs. For example, SWMU 145 is located outside of the plant boundary and does not contribute to the Little Bayou seeps. SWMUs 3, 6, 7, and 30 were determined to be the only SWMUs contributing to the Little Bayou seeps POE. While there is some uncertainty related to modeling in predicting whether a SWMU would contribute to the Little Bayou seeps, this uncertainty should not affect or drive remedial decisions. Table 7.5 identifies analytes that were modeled to exceed MCLs at the POEs.

Table 7.5. Analytes Predicted to Exceed Maximum Contaminant Levels at the Points of Exposure

Source Area	Contaminant	SWMU Boundary	Plant Boundary	Property Boundary	Little Bayou seeps	Ohio River
SWMU 2	Arsenic	**Yes**[a]	No[b]	No	N/A[c]	No
	cis-1,2-DCE	**Yes**	**Yes**	**Yes**	N/A	**Yes**
	TCE	**Yes**	**Yes**	**Yes**	N/A	**Yes**
SWMU 3	Arsenic	**Yes**	No	No	No	N/A
	^{99}Tc	**Yes**	**Yes**	**Yes**	No	N/A
	Uranium	**Yes**	No	No	No	N/A
SWMU 4	Arsenic	**Yes**	No	No	N/A	No
	cis-1,2-DCE	**Yes**	**Yes**	**Yes**	N/A	No
	^{99}Tc	**Yes**	**Yes**	**Yes**	N/A	No
	TCE	**Yes**	**Yes**	**Yes**	N/A	**Yes**
	Vinyl Chloride	**Yes**	**Yes**	**Yes**	N/A	No
SWMU 5	No analytes predicted to exceed MCLs at POEs					
SWMU 6	No analytes predicted to exceed MCLs at POEs					
SWMU 7	1,1-DCE	**Yes**	**Yes**	No	No	N/A
	Arsenic	**Yes**	**Yes**	No	No	N/A
	^{99}Tc	**Yes**	No	No	No	N/A
	TCE	**Yes**	**Yes**	No	No	N/A
	Vinyl Chloride	**Yes**	**Yes**	No	No	N/A
SWMU 30	Arsenic	**Yes**	**Yes**	No	No	N/A
	TCE	**Yes**	**Yes**	**Yes**	**Yes**	N/A
SWMU 145	Antimony	**Yes**	N/A	No	N/A	No
	Arsenic	**Yes**	N/A	No	N/A	No
	^{99}Tc	**Yes**	N/A	**Yes**	N/A	**Yes**

[a] Yes = The modeled analyte concentration exceeds its MCL
[b] No = The modeled analyte concentration does not exceed its MCL
[c] N/A = The POE does not apply to the SWMU
DCE = dichloroethene
MCL = maximum contaminant level
POE = point of exposure
SWMU = solid waste management unit
TCE = trichloroethene
^{99}Tc = technetium-99

Vapor transport modeling assessed contaminant concentrations in a hypothetical residential basement at the SWMU and in hypothetical residential basements at the POEs. (Appendix E, Section E.3.2 documents the vapor transport modeling performed for the BGOU RI.) Table 7.6 summarizes the results of vapor transport modeling. At some POEs, the excess lifetime cancer risk (ELCR) or hazard posed by hypothetical exposure to the modeled air concentration exceeded 1E-06 or 0.1, respectively. Currently there are no buildings, or pipelines connected to buildings, located over the contaminated material at the BGOU SWMUs. The existing buildings at PGDP are slated to be decontaminated and demolished after the plant closes; therefore, the on-site industrial worker scenario was not evaluated.

Table 7.6. Analytes with Basement Air Concentrations of Concern Based on Vapor Transport Modeling Results at the Points of Exposure

Source Area	Contaminant	SWMU Boundary	Plant Boundary	Property Boundary
SWMU 2	TCE	**Yes**[a]	**Yes**	**Yes**
	cis-1,2-DCE	**Yes**	No[b]	No
SWMU 3	TCE	**Yes**	No	No
	Mercury[c]	Yes	No	No
SWMU 4	TCE	**Yes**	**Yes**	**Yes**
	Vinyl Chloride	**Yes**	**Yes**	No
	cis-1,2-DCE	**Yes**	No	No
SWMU 5	No analytes with air concentrations of concern			
SWMU 6	No analytes with air concentrations of concern			
SWMU 7	TCE	**Yes**	No	No
	Vinyl Chloride	**Yes**	No	No
	1,1-DCE	**Yes**	**Yes**	No
	Mercury	Yes	No	No
SWMU 30	TCE	**Yes**	**Yes**	**Yes**
	1,1-DCE	**Yes**	**Yes**	No
	Mercury	Yes	No	No
SWMU 145	Mercury	Yes	No	No

DCE = dichloroethene SWMU = solid waste management unit TCE = trichloroethene

[a] Yes = Modeled air concentration equals or exceeds 1.0E-06 excess lifetime cancer risk (ELCR) or 0.1 hazard quotient (HQ)

[b] No = Modeled air concentration is less than 1.0E-06 ELCR or 0.1 HQ

[c] The vapor transport modeling for mercury was conservatively based on the metallic form, which has a Henry's Law Constant of 1.07E-02 atm-m^3/mol. The rate of vaporization of mercury and certain of its inorganic compounds decrease in the sequence $Hg > Hg_2Cl_2 > HgCl_2 > HgS > HgO$. The Henry's Law Constant decreases dramatically down the sequence (for example, $HgCl_2$ has a value of 7.09E-10 atm-m^3/mol).

7.6 RISK ASSESSMENT

PGDP is an industrial facility. The reasonably anticipated future use of the area within the current plant boundary is expected to remain industrial. This expectation should be considered when using the risk information provided in the report to support risk management decision making.

For soil, results from previous risk assessments were used. The BGOU Work Plan did not call for additional surface (0-1 ft bgs) or subsurface (0-10 ft bgs) soil sampling at most SWMUs. The risk for the on-site resident for soil exceeds 1E-04 and the HI is greater than 1 at all SWMUs except for SWMU 2, 3, and SWMU 145 (which were not evaluated for soil exposure for this scenario). The contaminants that are risk drivers for soil are aluminum, arsenic, beryllium, chromium, iron, nickel, Total PAHs, uranium (as a metal), uranium-234, uranium-238, vanadium, and zinc.

Residential use of groundwater was evaluated at the SWMU boundary, plant boundary, property boundary, and Ohio River (or seeps) for all SWMUs except SWMU 6 (SWMU 6 had no groundwater COPCs) and SWMU 145 (SWMU 145 was not evaluated at the plant boundary since it lies outside that boundary). At the SWMU boundary, risks and hazards from groundwater use for all evaluated SWMUs exceeded 1E-04 risk and exceeded an HI of 1. The major contaminants driving the groundwater risks and hazards at SWMU boundary point of exposure are arsenic (at SWMUs 3, 5, 7, and 145); antimony (at SWMU 145); Aroclor-1260 (at SWMU 145); *cis*-1,2-DCE (at SWMUs 2 and 7); 1-1-DCE (at SWMUs 7 and 30); manganese (at SWMUs 3 and 5); naphthalene (at SWMU 5); Total PCBs (at SWMU 7); TCE (at SWMUs 2, 4, 7, and 30); technetium-99 (at SWMU 3); uranium (at SWMU 3); and vinyl chloride (at SWMUs 4 and 7). At the plant boundary, risks and hazards from groundwater for SWMUs 2, 3, 4, 5, 7,

and 30 exceeded 1E-04 risk or exceeded an HI of 1. At the property boundary, risks and hazards from groundwater for SWMUs 2, 4, 7, 30, and 145 exceeded 1E-04 risk or exceeded an HI of 1. At the Ohio River (or seeps), risks and hazards from groundwater for SWMUs 2, 4, 7, and 30 exceeded 1E-04 risk or exceeded an HI of 1. The major contaminants driving the groundwater risks and hazards at the property boundary and Ohio River (or Little Bayou Creek seeps) POEs are arsenic, *cis*-1,2-DCE, 1,1-DCE, TCE, technetium-99, and vinyl chloride. While the migration of contamination from the potential TCE DNAPL zones at SWMU 4 and SWMUs 7 and 30 were not modeled due to uncertainties in source term development, a qualitative analysis completed considering results from previous studies done for the PGDP (e.g., C-400 DNAPL source) indicates that TCE migration from these sources would have resulted in potential risks exceeding 1E-04 at all POEs.

For exposure to soil, at least one of the on-site receptor scenarios (industrial worker, excavation worker, or recreational user), all SWMUs (except SWMU 145 where these scenarios were not assessed) have an ELCR $\geq$ 1.0E-06. For at least one of these scenarios, SWMUs 4, 5, 6, 7, and 30 have HIs > 1. Soil exposures to industrial or excavation workers are more relevant to the potential future uses of the site.

For the excavation worker who is exposed to both surface soil and subsurface soil (soil from 0 to 10 ft bgs), HIs were greater than one at SWMUs 4, 5, 6, 7, and 30. Risks for the excavation worker exceeded 1E-04 at SWMUs 4, 5, 6, 7, and 30. The risk/hazard drivers for the excavation worker scenario were arsenic, beryllium, Total PAHs, uranium, uranium-235, and uranium-238.

Given the reasonably anticipated future industrial use of the areas within the plant boundary, the most likely future and current scenario is the industrial worker. The ELCR for the future industrial worker scenario exceeded 1E-04 at SWMUs 2, 3, 4, 5, 6, 7, and 30 primarily due to risk from arsenic, beryllium, Total PAHs, uranium-235, and uranium-238. The HI exceeds 1 for the industrial worker at SWMUs 4, 7, and 30; aluminum, beryllium, chromium, iron, manganese, uranium, and vanadium are the hazard drivers. Risks for the current industrial worker (at 16 days per year of exposure) were less than those for the future industrial worker; risks for the current industrial worker exceeded 1E-04 at SWMUs 4, 5, 6, 7, and 30.

Table 7.7 presents a summary of the dominant exposure pathways and COCs for each SWMU for exposure to subsurface soil and groundwater.

The inclusion of beryllium as a risk driver is a result of incorporating the historical risk assessments. At the time those risk assessments were developed, beryllium still was evaluated as a carcinogen. Since then, the oral cancer slope factor for beryllium has been withdrawn and no longer is used for PGDP risk assessments. As a result, the total ELCR becomes much lower at those SWMUs where beryllium is a contaminant of concern. For SWMUs 4 and 6, removal of the contribution of beryllium to the ELCR reduces the total ELCR to within the EPA risk range for the industrial worker scenario.

Table 7.7. Exposure Routes and Exposure Pathways and COCs Associated with Dominant Risk for Each SWMU

Source Area	HI	ELCR
SWMU 2	• Ingestion of groundwater and household inhalation of vapors (TCE; *cis*-1,2-DCE)	• Household inhalation of vapors (TCE) • Ingestion of groundwater (TCE) • External exposure to subsurface soil (uranium-235, uranium-238)
SWMU 3	• Ingestion of groundwater (arsenic, uranium)	• Ingestion of groundwater (arsenic, technetium-99) • External exposure to subsurface soil (uranium-235, uranium-238)
SWMU 4	• Ingestion of groundwater (TCE) • Dermal exposure to soil (chromium, iron)	• Household inhalation of vapors and dermal exposure (TCE, vinyl chloride) • Dermal exposure to subsurface soil (beryllium)
SWMU 5	• Ingestion of RGA groundwater (arsenic, naphthalene) • Ingestion of vegetables (arsenic, aluminum)	• Ingestion of RGA groundwater (arsenic)
SWMU 6	• Ingestion of subsurface soil (chromium) • Dermal exposure to soil (chromium)	• Dermal exposure to subsurface soil (PAHs, beryllium) • Ingestion of vegetables (PAHs, beryllium)
SWMU 7	• Ingestion of RGA groundwater (TCE, arsenic, Total PCBs) • Ingestion of vegetables (iron, uranium) • Dermal exposure to soil (vanadium, iron, uranium)	• Household inhalation of vapors and ingestion of RGA groundwater (1,1-DCE) • Dermal exposure and ingestion of vegetables (beryllium, uranium-238)
SWMU 30	• Ingestion of RGA groundwater (TCE) • Ingestion of subsurface soil (uranium) • Dermal exposure to soil (vanadium, iron)	• Household inhalation of vapors (TCE) • Ingestion of vegetables (beryllium, uranium-238)
SWMU 145	• Ingestion of RGA groundwater (antimony, arsenic)	• Ingestion of RGA groundwater (Total PCBs)

DCE = dichloroethene
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
RGA = Regional Gravel Aquifer
TCE = trichloroethene

The BGOU RI includes a summary of previous ecological risk assessments for SWMUs 2, 4, 5, 6, 7, and 30. Neither SWMU 3 nor SWMU 145 has been assessed for ecological risk. SWMU 3 is covered by a RCRA cap, and SWMU 145 is located beneath the C-746-S & –T Landfills, which also are covered by caps. Comparison of site characterization data against NFA screening levels determined that all of the SWMUs have metals and organic compounds (in surface soil) that are COPCs for ecological risk to the environment, while SWMUs 7 and 30 have a radionuclide COPC (in surface soil).

7.7 UNCERTAINTIES/ASSUMPTIONS

The BGOU Work Plan identified data gaps on a SWMU-by-SWMU basis that were necessary to be filled in order to move forward with the FS. The Work Plan was 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 and subsurface transport mechanisms, and to support evaluation of remedial technologies in the FS.

Nature of the Source Zone

A key project assumption for the upcoming FS is that the available historical documentation and soil and groundwater characterization data is sufficient relative to waste characteristics, to chemical and physical properties, and to waste volume estimates to evaluate general response actions, to screen technology types, and to conduct detailed alternative analysis for the BGOU. The potential impact of source zone uncertainties on alternatives analysis will be further documented and analyzed in the FS. While the BGOU RI field investigation sampled directly beneath the waste units using angled borings, it remains possible that the buried waste contains hazards or constituents that current sample results do not characterize (historical disposal records and waste manifests are incomplete for some SWMUS). A related uncertainty is that the field investigation was unable to sample to the middle of a few of the larger SWMUs (SWMUs 5 and 145, particularly); therefore, there are some uncertainties in the nature and extent of the contaminant source that will need to be managed during the decision-making process.

Many of the SWMUs have been investigated previously. The BGOU RI uses a combination of historical and current sample results of soil and groundwater from the area of each SWMU. The results of previous investigations and RI sampling document and confirm the presence of metals, organic compounds, and radionuclides in the BGOU burial grounds. The associated samples were collected and analyzed over several previous and continuing investigations, as well as the BGOU RI, using several methods. QA/QC practices at PGDP, now and previously, limit the uncertainty associated with the sampling and analysis process. To minimize the potential for “age” to bias the analysis of the data, the historical sample analyses used in the BGOU RI are limited to groundwater samples collected in January 1995 and later and soil samples collected in June 1996 and later. This criterion, which was established during scoping for the BGOU RI and is documented in Section 5 of the BGOU RI Work Plan, maximizes the number of historical sample analyses available to the RI, while providing a reasonable assurance of the comparability of the data. There are limited monitoring wells in close proximity to some SWMUs, but temporary borings provide a snapshot of the conditions where groundwater samples could be obtained.

The potential for acidic leachate at each SWMU is uncertain due to the lack of disposal records. SWMUs with the greatest potential for acidic leachate are SWMU 6 (exhaust fans with perchloric acid) and SWMU 4 (records of chemicals buried are incomplete). It should be noted that angled borings beneath SWMU 6 found no evidence of acidic leachate. The potential for acid leaching at the SWMUs will be evaluated further relative to the importance of acid leaching in screening, and detailed analysis of alternatives in the FS.

Because all drummed waste was assumed to have been released to the environment during disposal or through degradation, samples from soils surrounding the buried wastes were used to evaluate potential contaminant migration and risks associated with the SWMUs. This approach resulted in the inclusion of SWMUs with drummed waste exhibiting risk and hazard values that exceeded acceptable levels; therefore, though the integrity of buried drums is an uncertainty, the overall objectives of the RI analysis were met. The risk assessment concluded that these uncertainties, related to the source zone, were not estimated to have a large effect on the risk characterization and do not affect future decision making.

The BGOU FS may identify the need for remedial design support or additional source delineation after final selection of media-specific remedial goals and remedial alternatives. In addition, monitoring of the source zones will be evaluated in the FS.

Extent of the source zone and secondary sources

Secondary sources of groundwater contamination that are derived from the BGOU burial grounds, such as the potential DNAPL source zone beneath SWMU 4, are within the scope of the BGOU for ecvaluation and remedial action. The evidence for UCRS DNAPL presence is documented in previous investigations (DOE 2007b) and discussed in the RI. Collection of UCRS groundwater samples was attempted from 32 angled borings in order to detect releases or secondary sources that may be related to the SWMUs. Of the 32 attempts, 17 boring locations provided enough groundwater to collect a sample. Assessment of the secondary source in the UCRS at SWMUs 7 and 30 was based on both historical and newly generated data, while the assessment of the secondary source in both the UCRS and RGA at SWMU 4 is based primarily on historical data. Because the UCRS water samples supplement only the characterization of the BGOU SWMUs (the analysis of subsurface soil samples is the primary measure that supports the assessment of nature and extent and risk) and secondary sources, the lack of UCRS water samples from all soil borings does not limit the planned assessment of the SWMUs. The volumetric extent of secondary source contamination has been approximated and constitutes a project assumption for evaluation of the alternatives. The impact of source volume or DNAPL uncertainties will be evaluated and further discussed in the FS.

Surface and subsurface transport mechanisms

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. Contaminated groundwater could migrate to the POEs identified for the BGOU SWMUs as the plant boundary, property boundary, surface seeps at Little Bayou Creek, and near the Ohio River. Not all SWMUs have transport pathways to all of the POEs. For example, SWMU 145 is located outside of the plant boundary and does not contribute to the Little Bayou seeps. SWMUs 3, 6, 7, and 30 were determined to be the only SWMUs contributing to the Little Bayou seeps POE. While there is some uncertainty related to modeling in predicting whether a SWMU would contribute to the Little Bayou seeps, this uncertainty should not affect or drive remedial decisions.

The location of the water table varies in burial ground SWMUs. Most of the buried waste at SWMU 2 is saturated. The westward slope of the water table below SWMU 2 indicates that the water table must be equally shallow beneath SWMU 3. Because SWMU 3 is an aboveground facility with a RCRA multi-layered cap, all but the base of the landfill wastes likely are unsaturated. The stratigraphy of SWMU 4 is comparable to that of SWMUs 2 and 3. It appears that the hydrogeologic setting is similar, and the water table likely extends up into the waste burial pits. At SWMUs 5 and 6, even the shallowest wastes (with top near 365 ft amsl), likely are buried below the water table (at an elevation of approximately 367 ft amsl on the north side of SWMU 5). The SWMUs 7 and 30 RI (DOE 1998a) determined that a shallow water table exists approximately 5 ft bgs (Figure 3.22) and within the burial cells. UCRS piezometer and well measurements documented a strong downward gradient within the area. The elevation of the water table remains poorly documented at SWMU 145. Some buried waste at SWMU 145 likely is saturated.

Uncertainty does exist with regard to the dissolved oxygen in the UCRS at SWMUs 4 and 6 due to a lack of data. The majority of dissolved oxygen measurements from UCRS wells range from near zero to four mg/L and oxidation/reduction potential commonly ranges from -100 to 300 microVolts, with the majority of measurements greater than zero. Line plots in Figure 3.9 of the RI further demonstrate trends of dissolved oxygen (517 measurements) and oxidation/reduction potential (136 measurements) in the

UCRS at the BGOU SWMUs. Due to the relative abundance of measurements for most SWMUs that demonstrate that the cumulative trend is likely to be representative of conditions at each SWMU, the oxidation/reduction potential in the UCRS at SWMUs 4 and 6 will be assumed to be similar to that in the UCRS at other BGOU SWMUs. The impact of this assumption will be evaluated further in the FS. If determined necessary to support implementation of a remedial alternative, dissolved oxygen could be measured as part of a remedial design support investigation for SWMUs 4 and 6.

7.8 CONCLUSIONS

Table 7.8 summarizes the decision rules of the BGOU Strategic Initiative (DOE 2006a). For each SWMU of the BGOU, risk levels associated with contamination at the SWMUs and associated with groundwater contamination derived from all of the SWMUs meet the criteria of the decision rules to progress to evaluate actions that will mitigate risk and to achieve ARARs; to seek an ARAR waiver in accordance with EPA guidance; or to propose alternative standards.

The following are the major contaminant distribution findings for sources investigated in the BGOU RI.

- Environmental media, specifically subsurface soil and groundwater, have been impacted by releases of contaminants at all of the BGOU SWMUs.

- TCE trends in the RGA indicate that TCE DNAPL potentially is present at SWMU 4 and in the vicinity of the shared border between SWMUs 7 and 30. (See Sections 3.9.4, 4.5.2, and 4.8.2.) Concentrations of TCE at SWMU 4 suggest this potential TCE DNAPL may be present both in the waste cells and underlying soils of the UCRS and in the matrix of the RGA. TCE trends at SWMUs 7 and 30 indicate that the potential TCE DNAPL source is likely constrained to the UCRS soils.

- The BRA completed as part of the BGOU RI indicates that ELCRs greater than the upper end of EPA's acceptable risk range (i.e., 1E-04) and HIs greater than 1 exist at all SWMUs; therefore, an FS is appropriate for impacted media at each SWMU. The metals arsenic, beryllium, and uranium; the organic compounds Total PAHs and Total PCBs; and the radionuclides uranium-235 and uranium-238 are common contaminants that present the dominant risks from exposure to surface and subsurface soil. The major contaminants driving the groundwater risks at the on-site POEs are arsenic, Aroclor-1260, 1,1-DCE, TCE, technetium-99, and vinyl chloride.

- Migration of contaminants through groundwater from all but SWMU 6 to locations at the SWMU boundary, the plant boundary, property boundary, and near the Ohio River, also posed greater than *de minimis* risks to a hypothetical residential groundwater user. Arsenic, TCE, 1,1-DCE, technetium-99, and vinyl chloride are the primary risk drivers.

- The Screening Ecological Risk Assessment retained a number of COPCs, primarily metals, at each of the sites. Each SWMU requires further ecological evaluation.

Table 7.8. Decision Rules for the BGOU Strategic Initiative

GOAL	DECISION RULE		
		***If* statement**	***Then* statement**
Nature of Contamination	1a	If the concentration of analytes found in the source zone could result in a cumulative excess lifetime cancer risk greater than 1×10^{-6} or a cumulative Hazard Index greater than 1 through contact with contaminated media, **or** if the concentration of analytes in the source zone could result in detrimental impacts to nonhuman receptors through contact with contaminated media as indicated by exceeding ecological screening criteria, **and** if the concentrations of analytes in the source zone are greater than those expected to occur naturally in the environment,	then evaluate actions that will mitigate risk; otherwise pursue a "no further action" decision (see D1b and D1c)
	1b	If concentrations of analytes found in the source zone exceed ARARs,	then evaluate actions that will bring contamination within the source zone into compliance with ARARs; seek an ARAR waiver (such as technical impracticability, inconsistent application of state standards, interim measure, greater risk to human health and the environment, equivalent standard of performance) in accordance with EPA guidance; or propose/obtain alternative standards
	1c	If contaminants found at the site are known to transform or degrade into chemicals that could lead to increased risks to human health or the environment or into chemicals for which there are ARARs, **and** if the concentrations of these contaminants could result in risks greater than those defined in D1a or concentrations greater than ARARs,	then evaluate actions that will mitigate potential future risk or obtain compliance with ARARs; seek an ARAR waiver (such as technical impracticability, inconsistent application of state standards, interim measure, greater risk to human health and the environment, equivalent standard of performance) in accordance with EPA guidance; or propose/obtain alternative standards
Extent of Contamination	2a	If secondary contamination sources are found, **and** if the concentration of analytes within the secondary contamination source is found to potentially result in a cumulative excess lifetime cancer risk greater than 1×10^{-6} or a cumulative Hazard Index greater than 1 through contact with contaminated media at the unit, **and** if the concentrations of analytes are greater than those expected to occur naturally in the environment,	then evaluate actions that will mitigate risk; otherwise, do not consider secondary contamination sources when making remedial decisions for the unit

Table 7.8. Decision Rules for the BGOU Strategic Initiative (Continued)

GOAL	DECISION RULE		
		***If* statement**	***Then* statement**
Fate and Transport	3a	If contaminants are found in the source zone, **or** if secondary contamination sources are found, **and** if these contaminants are found to be migrating or may migrate from the source zone or from secondary contamination sources at concentrations that may potentially result in a cumulative excess lifetime cancer risk greater than 1×10^{-6} or a cumulative Hazard Index greater than 1 through use of contaminated media at downgradient points of exposure, **and** the concentrations of analytes are greater than those expected to occur naturally in the environment,	then evaluate actions that will mitigate risk; otherwise, do not consider risk posed by migratory pathways when evaluating remedial alternatives for the unit (see D3b)
	3b	If contaminants are found in the source zone, **or** if secondary contamination sources are found, **and** if these contaminants are found to be migrating or may migrate from the source zone or from the secondary contamination source at concentrations that exceed ARARs,	then evaluate actions that will bring migratory concentrations into compliance with ARARs; seek an ARAR waiver (such as technical impracticability, inconsistent application of state standards, interim measure, greater risk to human health and the environment, equivalent standard of performance) in accordance with EPA guidance; or propose/obtain alternative standards; otherwise, do not consider ARARs when examining migratory pathways during the evaluation of remedial actions (see D3a)
Risk Assessment	4a	If Decision D1a, D1b, D1c, D2a, D3a, or D3b indicate that response actions are needed,	then evaluate response actions to mitigate risk in the source zone

7.8.1 Recommendations for Future Work

Based on results in this RI Report, an FS will be conducted for each of the SWMUs in the BGOU. A listing of potential process options is detailed in Tables 7.9 and 7.10 and is consistent with data collection objectives in the work plan.

Table 7.9. Potential Process Options for Primary Sources (Waste and Vadose Soils)

Soil	
Institutional Controls	• Land-use restrictions
	• Environmental media monitoring
Containment	• Low-permeability capping
	• Constructed barriers
	• Dust and vapor suppression
	• Erosion control
	• Retro-fitted liners
	• Surface water control
Recovery or Removal	• Excavation/storage
	• Excavation/disposal
Treatment	• *In situ* grouting
	• Freezing

Table 7.10. Potential Process Options for Secondary Sources (DNAPL)

Groundwater	
Institutional Controls	• Land-use restrictions
	• Environmental media monitoring
Containment	• Constructed barriers
	• Hydraulic containment
	• Retro-fitted liners
	• Subsurface drainage
Recovery or Removal	• Extraction/storage
	• Extraction/disposal
Ex Situ Treatment	• Coagulation/flocculation
	• Freeze crystallization
	• Gravity separation
	• Media filtration
	• Membrane separation
	• Neutralization
In Situ Treatment	• *In situ* neutralization
	• Reactive walls
	• Phytoremediation

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APPENDIX A

TECHNICAL MEMORANDUM FOR FIELD ACTIVITIES

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CONTENTS

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ACRONYMS

AOC	area of contamination
BGOU	Burial Grounds Operable Unit
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
DPT	direct push technology
EM	electromagnetometer
EPA	U.S. Environmental Protection Agency
ES&H	Environment, Safety, and Health
HSA	hollow-stem auger
NSDD	North-South Diversion Ditch
Paducah OREIS	Paducah Oak Ridge Environmental Information System
PCB	polychlorinated biphenyl
PEMS	Project Environmental Measurements System
PGDP	Paducah Gaseous Diffusion Plant
pH	negative logarithm of the hydrogen-ion concentration
PPE	personal protective equipment
QC	quality control
RCRA	Resource Conservation and Recovery Act
RGA	Regional Gravel Aquifer
RI	remedial investigation
SWMU	solid waste management unit
UCRS	Upper Continental Recharge System
VOC	volatile organic compound
WAG	Waste Area Group

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A.1. INTRODUCTION

The purpose of this memorandum is to provide certain technical details regarding field activities pertaining to the Burial Grounds Operable Unit (BGOU) Remedial Investigation (RI). A brief summary of project objectives is provided below; a more thorough discussion is contained in the body of the report.

The BGOU is one of six operable units located within the Paducah Gaseous Diffusion Plant (PGDP). This operable unit consists of contamination associated with PGDP's landfills and burial grounds. Burial grounds addressed by this RI include the following solid waste management units (SWMUs):

SWMU 2	C-749 Uranium Burial Ground
SWMU 3	C-404 Low-Level Radioactive Waste Burial Ground
SWMU 4	C-747 Contaminated Burial Yard and C-748-B Burial Area
SWMU 5	C-746-F Burial Yard
SWMU 6	C-747-B Burial Ground
SWMUs 7 and 30	C-747-A Burial Ground and Burn Area
SWMU 145	C-746-P Construction/Demolition Debris Disposal and Spoils Area (including the residential/inert borrow area and old North-South Diversion Ditch (NSDD) disposal trench)

The primary focus of this RI was to collect field and analytical data necessary to determine the nature and extent of any soil and groundwater contamination originating from, and immediately under, the burial cells; support the completion of a baseline human health risk assessment and a screening-level ecological risk assessment; and evaluate appropriate remedial alternatives (if necessary) at each of the SWMUs. The RI had the following four specific objectives:

- Characterize Nature of Source Zone—Characterize the nature of contaminant source materials by using existing data and, if required, by collecting additional data;

- Define Extent of Source Zone and Contamination in Soil and Other Secondary Sources at All Units—Define the nature, extent (vertical and lateral), and magnitude of contamination in soils, sediments, surface water, and groundwater by using existing data and, if required, by collecting additional data; determine the presence, general location (if practicable), and magnitude of any dense nonaqueous-phase liquid zones;

- Determine Surface and Subsurface Transport Mechanisms and Pathways—Gather existing quality data and, if necessary, collect additional adequate-quality data to analyze contaminant transport mechanisms, evaluate risk, and support a Feasibility Study; and

- Support Evaluation of Remedial Technologies—Determine if the existing data are sufficient to evaluate alternatives that will reduce risk to human health and the environment and/or control the migration of contaminants off-site.

The following table presents various procedures and work instructions that were used to complete the fieldwork conducted as part of the BGOU RI.

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

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 Measurement Procedures: pH, Temperature, and Conductivity, and Dissolved Oxygen
Field Quality Control
Filter Pack and Screen Selection for Wells and Piezometers
Groundwater Sampling Procedures: Water Level Measurements
Identification and Management of Waste Not From a Radioactive Material Management Area
Labeling, Packaging, and Shipping of Environmental Field Samples
Lithologic Logging
Monitoring Well Development
Monitoring Well Installation
Monitoring Well Purging and Groundwater Sampling
Off-Site Decontamination Pad Operating Procedures
On-Site Handling and Disposal of Waste Materials
Opening Containerized Waste
Paducah Contractor Records Management Program
Pumping Liquid Wastes Into Tankers
Quality Assured Data
Sampling of Containerized Wastes
Use of Field Logbooks
Well and Temporary Boring Abandonment

The existing data for SWMU 4 was determined to be sufficient to evaluate the nature and extent of contamination and provide data from under the burial cells; therefore, no additional samples were collected for this SWMU. Borings were collected from under some of the burial cells for SWMUs 5 and 6 in a previous investigation; however, not all cells were evaluated. For SWMU 5, additional borings were collected from cells not previously targeted. For SWMU 6, physical constraints limited access to the area during previous investigations. Equipment had been removed subsequent to the Waste Area Group (WAG) 3 RI from the area, and it was possible to collect samples and evaluate those cells during this RI.

Activities addressed in this technical memorandum (Appendix A) are discussed in the following chapters:

- Chapter 2—Sampling Strategy
- Chapter 3—Surveying
- Chapter 4—Sampling Procedures
- Chapter 5—Field Decontamination
- Chapter 6—Waste Management
- Chapter 7—Environment, Safety, and Health
- Chapter 8—Fieldwork Documentation
- Chapter 9—Deviation from Planned Sample Locations

A.2. SAMPLING STRATEGY

The field sampling strategy used for the RI consisted of intrusive media sampling (surface and subsurface soil, and groundwater). The investigation activities used standard industry practices that were consistent with U.S. Environmental Protection Agency (EPA) procedures and protocols. Sampling activities at the burial grounds focused on the soils and groundwater beneath the burial pits down to a depth of 60 ft bgs (below ground surface). Surface and subsurface soils adjacent to but not beneath the burial pits were not part of this investigation. These will be evaluated through the Soils Operable Unit. Likewise, the Regional Gravel Aquifer (RGA) was not part of this investigation. It will be evaluated through the Groundwater Operable Unit. Borings adjacent to the NSDD were advanced to a depth of 15 ft bgs to evaluate impacts from the pipeline that once discharged leachate from SWMU 3 into the NSDD.

A.2.1 SOIL/SEDIMENT SAMPLING

The drilling technology for the angled borings and the six shallow vertical borings was a track-mounted rig capable of both direct push technology (DPT) and hollow-stem auger (HSA) 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, auger flights then were drilled over the push rods to advance the borings to the sample depth. The deep vertical borings were completed with a larger HSA drill rig capable of reaching a depth of 100 ft bgs. For the deeper samples, drillers advanced the hollow stem augers to near the sample depth and then pushed the DPT sample tube through the hollow-stem augers to the sample depth to collect the soil samples.

The BGOU RI Work Plan directed the use of angled borings to sample from beneath the burial cells. Per the RI Work Plan, the field crew did not collect soil samples at or near the surface in the angled borings because these borings were begun at a specified distance away from the burial cells, outside the influence of the buried waste. Table A.2 summarizes the common soil sample depths.

Table A.2. BGOU RI Soil Sample Depths

Target Vertical Depth (ft)*			Actual Drilled Length (ft) at 45° Angle			Actual Vertical Depth (ft)	
Top	Bottom		Top	Bottom		Top	Bottom
8	10		10	15		7	11
13	15		15	20		11	14
28	30		40	45		28	32
43	45		60	65		42	46
58	60		80	85		57	60

*Specified in the BGOU RI Work Plan

Drilling and sampling difficulties necessitated slight adjustments to sampling depths in some instances. Collection of duplicate samples, likewise, required a longer sample interval to accommodate the increased sample volume. In addition, the sampling depths of the two lower intervals in boreholes 145-106 and 145-107 were adjusted to accommodate a locally thinner Upper Continental Recharge System (UCRS). Cross sections and tables in Section 4 and the boring logs in Appendix B document the depth of each soil sample.

The BGOU RI included sampling from both shallow and deep vertical borings. Ten shallow borings were installed along a former drainage ditch that connected the C-404 Landfill and the NSDD. The field crew collected samples from these borings at the surface and from 1 to 5 ft, 5 to 10 ft, and 10 to 15 ft. Three deep borings were installed within SWMU 7. With the exception of the surface soil sample in boring 007-011, the field crew collected soil samples in these borings from depths of 0 to 1 ft, 3 to 5 ft, 8 to 10 ft, 13 to 15 ft, 28 to 30 ft, 43 to 45 ft, and 58 to 60 ft. (The 0-1 ft depth interval in boring 007-011 consisted of gravel road base which was not amenable to laboratory analysis).

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 Region 4, November 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 officer and radiation control officer 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 officer and radiation control officer scanned the sample for contamination. The field scans of the acetate liner and soil core rarely identified contamination. When contamination was found, the health and safety officer and radiation control officer directed the field crew in any additional personal protective equipment (PPE) requirements and appropriate handling precautions.

Immediately upon approval from the health and safety officer and radiation control officer for the field crew to sample the soil core, the field crew collected the samples for volatile organic compound (VOC) analysis by filling two 2 ounce, wide-mouth, sample bottles with soil, ensuring that no air space was present, and securely sealing the filled bottles. At the same time, the project geologist examined soil core samples for lithologic description. After the collection of the VOC samples and the description of the lithology were complete, the remaining soil was placed in a clean bowl and mixed thoroughly. Samplers placed the resulting soil mixture in the appropriate sample jars for analysis.

A.2.2 GROUNDWATER SAMPLING

Groundwater samples were collected from multiple discrete depths within the UCRS and RGA using temporary borings at various locations. The RI field crew collected water samples in the UCRS where the temporary soil borings intersected water-producing zones. Water sampling in the RGA began at the top of the RGA (approximately 60 ft bgs) and continued at 10 ft intervals to the base of the RGA (approximately 100 ft bgs). This strategy resulted in a total of up to six water samples collected from the borings, depending on the presence of water-bearing zones in the UCRS and the thickness of the RGA at a boring's location. The drilling and sampling process allowed collection of discrete-depth water samples with minimum vertical cross-contamination.

A.3. SURVEYING

Two types of surveying were performed for the BGOU RI. They were civil surveying to locate sampling points and geophysical surveying to locate areas of potential burial.

A.3.1 CIVIL SURVEYING

As the field crew performed the BGOU RI sampling, they marked the boring locations using flagging and wooden stakes. Entries in project logbooks and on field maps further documented the sample locations. Brass markers were incorporated as part of pad installation for any monitoring wells. The BGOU RI included surveying of sampling locations upon completion of the RI field 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 (PEMS), and the coordinate locations were transferred with the station's ready-to-load file to the Paducah Oak Ridge Environmental Information System (Paducah OREIS).

A.3.2 GEOPHYSICAL SURVEYING

The BGOU RI performed nonintrusive data collection (surface geophysics) for several of the SWMUs in order to better delineate areas of subsurface burial. Because these SWMUs consist of one or more burial pits of various depths that are filled with a heterogeneous collection of wastes and backfill soils, the BGOU represented a difficult target for geophysical characterization. Magnetic properties of the metal drums and buried metal scrap offered the best contrast with the native soils for imaging.

A Geonics electromagnetometer (EM)-61 Metal Locator pulled on a trailer was used to perform the geophysics. The EM-61 detects buried metal with very good resolution utilizing time-domain electromagnetic phenomena to detect buried metal up to 16 ft below the surface (http://www.geologyuk.com/geophysics/tech_summary/07_Technical%20summary%20sheet_EM61.pdf). Generally, readings from the EM-61 were taken along continuous lines spaced 5 ft apart in both north-south and east-west orientations (see Figure A.1). Locations of anomalies were pin flagged in the field and recorded on a PC600 Data Logger. The pin-flagged locations were mapped and transferred to digital maps. Depths of the anomalies were taken from the data recorded and also transferred to the maps.

Geophysical surveys of SWMUs 7 and 30 and 145 delineated the burial pits exact location and burial extent prior to sampling activities. The survey grid covered an area that extended at least 10 ft beyond the currently identified burial pit edges. The survey grid for SWMU 145 was set to 5 ft by 10 ft (5-ft line spacing in the east-west direction and 10-ft line spacing in the north-south direction, see Figure A.2) due to the size of the SWMU.

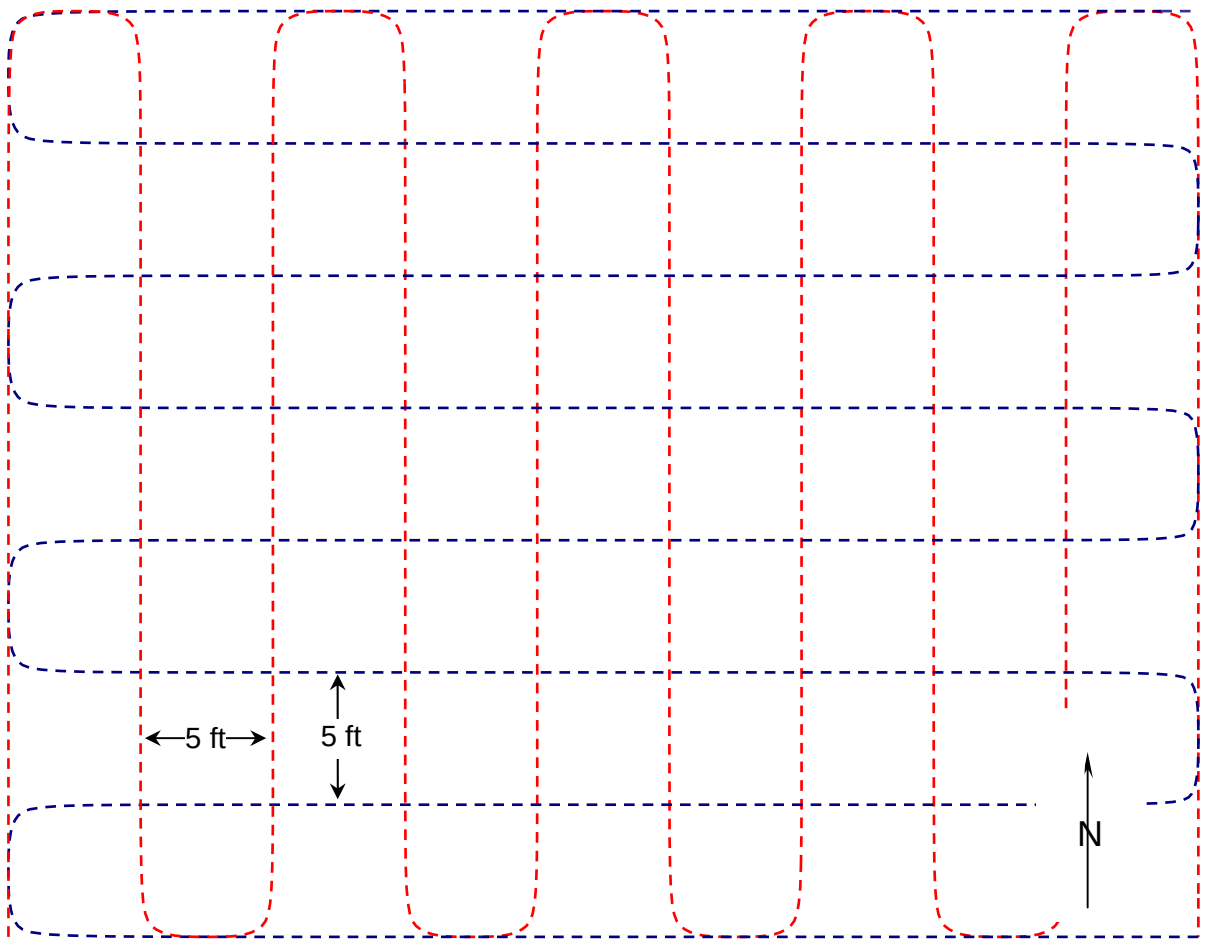

Figure A.1. Example EM-61 Survey Grid for BGOU RI

Portions of SWMUs 2, 3, 5, and 6 were surveyed to delineate accurately burial pits prior to drilling. For these SWMUs, grid spacing was not consistent along continuous lines since the results of these surveys were specifically targeted to aid in placement of the planned drilling. Additionally, geophysical surveys were used at SWMU 2 to delineate the exact location of a buried electrical conduit within the burial yard. A portion of SWMU 5 was surveyed to delineate the location of an abandoned waterline at the north of the burial yard.

Following an employee interview, geophysical surveys were performed in three areas within SWMU 13 utilizing the same methodology that was applied for SWMUs 7 and 30 and 145 (i.e., trailer-mounted EM-61 pulled along a grid of continuous lines spaced 5 ft apart). The EM-61 survey identified metal throughout the three areas of interest beginning at a depth of 2 ft bgs. This metal likely is small scrap material related to previous activities that followed removal of the scrap piles (spreading and covering small amounts of metal as part of yard cleanup). The EM-61 survey detected an anomaly in the third area at the western end of the SWMU, beginning at approximately 4 to 8 ft in depth.

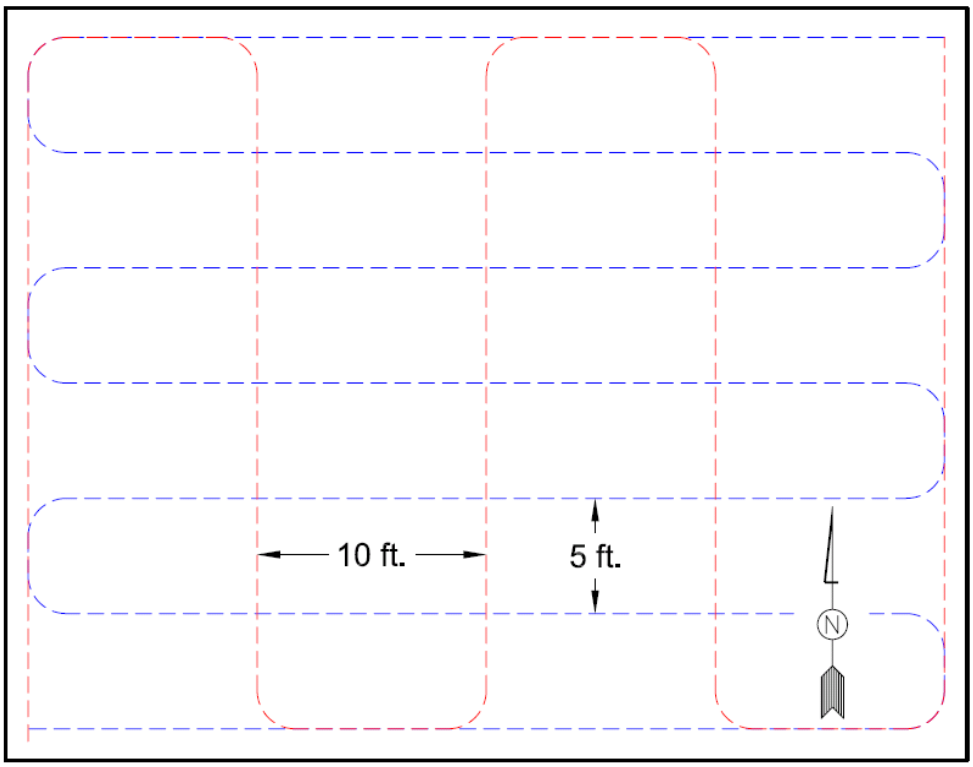

Figure A.2. Example EM-61 Survey Grid for BGOU RI at SWMU 145

A.4. SAMPLING PROCEDURES

During the sampling event, three types of samples—soil/sediment, groundwater, and field quality control (QC)—were collected and submitted for analysis. The sampling team varied between two and three members. Prior to initiation of field sampling, all sample team members completed general and project-specific 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. 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), and
- 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/SEDIMENT SAMPLES

The field crew sampled the soil borings in accordance with DOE Prime Contractor-approved procedures, consistent with *Environmental Investigation Standard Operating Procedures and Quality Assurance Manual*, EPA Region 4, November 2001, collecting soil for VOC analysis, followed by samples for lithologic description as soon as the acetate sleeve was cut open. After the description of the lithology was complete, the remaining 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. Since round bowls were used for sample preparation, adequate mixing was achieved by stirring the material in a circular fashion, reversing direction, and occasionally turning the material over.

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

A.4.2 GROUNDWATER SAMPLES

Where the temporary soil borings intersected water-bearing units, the BGOU RI collected a groundwater sample from the UCRS and multiple discrete depths in the RGA. This RI (fieldwork performed in 2007) resulted in a total of 30 groundwater samples. The first step in collecting both UCRS and RGA groundwater sample was to purge the drill pipe and the disturbed soil in the vicinity of the open pipe. The field crew used bladder pumps to purge the boring and to collect the water samples.

Since sampling took place immediately after drilling ceased, there was no stagnant water to remove from the boring and, therefore, no predetermined minimum purge volume. The sample crew collected the water sample in both the UCRS and RGA only after the measure of select geochemical parameters [i.e., acidity as reported as the negative logarithm of the hydrogen-ion concentration (pH), specific conductivity, and temperature] stabilized within the purge water (signifying that the discharging water was representative of groundwater quality). The geochemical parameters were considered stabilized when the following criteria were met:

- At least three measurements taken three minutes apart have consistent readings for temperature, conductivity, and pH;
- Temperature measurements agree within 1 °C;
- Conductivity measurements agree within 10%; and
- pH measurements agree within 0.5 units.

When the geochemical parameters stabilized, the sampling crew adjusted the flow rate of the pump for sampling. Groundwater samples were collected in accordance with SWMU-specific sampling plans (*Work Plan for the Burial Grounds Operable Unit Remedial Investigation/Feasibility Study at Paducah Gaseous Diffusion Plant, Paducah, KY*, DOE/OR/07-2179&D2/R1, August). (The sampling plans were specific as to the analytes for each SWMU and the horizons, UCRS and RGA, to be sampled.) All samples required multiple analyses. With the exception of a duplicate groundwater sample in boring 007-007, each groundwater interval that was sampled yielded sufficient volume to fill sample bottles for all analyses. The sampling crew collected the field parameters of groundwater temperature, pH, and specific conductance during each sampling event.

After sampling was completed, the sample crew removed the tubing and pump from the boring. The pump and tubing was decontaminated in accordance with DOE Prime Contractor-approved procedures prior to its next use.

A.4.3 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:

- Trip Blanks—Analysis of trip blanks documented the occurrence of cross contamination by VOCs during sample handling and shipping. The sample crew prepared trip blanks by filling VOC vials with deionized water before collection of the field samples. These trip blanks accompanied the filled sample bottles in ice chests in the field and during shipment and through interim storage in secured refrigerators until laboratory analysis. The trip blanks were analyzed for VOCs only.

- 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 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. The BGOU RI required field blanks at a frequency of one in 20 samples (5%) for each sample matrix.

- Field Duplicate Samples—Field duplicate samples determined the sampling variance. The sampling crew collected one duplicate for every ten samples (10%), per matrix. The field duplicate was analyzed for the same set of analytical parameters as the sample it duplicated.

- Equipment Blanks or Rinsate Samples—Equipment blanks provided a measure of the decontamination process effectiveness and were used as reagent blanks, as needed. These equipment blanks were required only when nondisposable equipment was being used. The equipment blanks consisted of deionized water passed through or over decontaminated sampling equipment and analyzed for the same parameters as the samples collected with the equipment. Equipment blanks were collected at a frequency of one for every 20 samples (5%).

In addition to the QC samples that were collected for laboratory analysis, temperature blanks accompanied the soil and groundwater samples in the transport coolers to document proper preservation of the samples. All transport coolers contained temperature blanks.

A.5. FIELD DECONTAMINATION

The field decontamination procedure, *Decontamination of Sampling Equipment and Devices,* (PRS-ENM-2702) determined the decontamination activities for the stainless steel spoons and bowls used in soil sampling and the pumps and tubing used for groundwater 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 towelett.
- The inside of the pump and tubing was cleaned by purging soap water, followed by tap water and analyte-free water, through the pump and tubing.
- 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, PRS-FCD-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. Because of its remote location, the BGOU RI drill crew constructed a temporary decontamination pad at SWMU 145 that was used in cleaning the drill rig and tooling. The on-site decontamination facility, C-416, supported cleaning activities for the drill rig and associated tooling during sampling at all other (on-site) BGOU RI locations.

A.6. WASTE MANAGEMENT

The RI work plan 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 area of contamination (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 RCRA 90-Day storage standards; the 90-Day storage restriction and the requirement to label hazardous waste was not applied to the storage areas.

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.

Decontamination water that included small quantities of soil sediments/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 Outfall 001 after final characterization documented that the stored water met release criteria in the Kentucky Pollutant Discharge Elimination System 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 is being decanted and placed in an approved container. Drummed soils and other solid wastes have been 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, 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 (PCB) waste,
- Transuranic waste,
- Low-level waste,
- Mixed waste, or
- Nonhazardous waste.

Waste minimization requirements were implemented, as appropriate, and included those established by the 1984 Hazardous and Solid Waste Amendments of RCRA; DOE Orders 5400.1, 5400.3, 435.1; and DOE Prime Contractor's 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 in the approved work plan and was used to provide instruction regarding safety and health of workers, the public, and the environment. 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 BGOU 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 was 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 (i.e., 24-hour) clock for the time.

- Zeroes were recorded with a slash (/) to distinguish them from letter Os.

- 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; and
— 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. DEVIATION FROM PLANNED SAMPLE LOCATIONS

A.9.1 INTRODUCTION

A Geographic Information System provided sample coordinates from maps of the intended sample locations in the BGOU RI Work Plan. Some of these locations were later adjusted to address additional data regarding the placement of waste. Once these locations were agreed upon, conventional survey methods located the sample coordinates at each SWMU. Table A.3 lists originally planned sample location coordinates and the final sample location coordinates.

A.9.1 DISCUSSION OF DEVIATION FROM COORDINATE LOCATIONS

During the survey and location of the sample boreholes, there were some boreholes that could not be located at the planned coordinates due to steep topography and surface structures, the presence of buried shock sensitive (explosive) waste, and High Radiation Areas. When obstructions or conditions prevented location of a sample at the planned location, the samples locations were offset close to the intended site. This section presents a summary of the samples that were relocated and provides the distance that the samples were offset from the intended coordinates.

At SWMU 5, it was discovered at the time of installation that an angled boring (005-103) at the southeast corner was being drilled in a diagonal orientation to the waste cells and not in a perpendicular orientation, as stated in the text of the work plan. The error was confirmed and the installation was stopped. A new boring was started a few ft away with a perpendicular orientation. The 10 ft and the 15 ft samples collected from the diagonally-oriented boring were discarded. The 30 ft sample was submitted for analysis along with the full set of samples from the new boring oriented perpendicular to the waste cells. Data from the initial boring are included with the summaries in the RI Report with the other data from boring 005-103. This data is available individually within the dataset and is identified by the sample number ‘005103SA030-2’.

Table A.3. BGOU RI Sample Locations

Sample Location	Planned Easting	Planned Northing	Final Easting	Final Northing	Displacement (ft)
			SWMU 2		
002-001	-6,312.96	-924.80	-6,275.65	-1,030.25	111.9
002-002	-6,228.85	-824.49	-6,285.73	-813.89	57.9
			SWMU 3		
003-001	-6,071.13	-826.20	-6,072.45	-814.33	11.9
003-002	-5,901.41	-824.49	-5,904.5	-808.99	15.8
003-003	-5,751.48	-823.53	-5,755.25	-802.32	21.5
003-004	-5,654.54	-908.49	-5,634.54	-910.43	20.1
003-005	-5,361.38	-899.92	-5,372.98	-899.56	11.6
003-006	-5,292.80	-725.05	-5,296.92	-723.92	4.3
003-007	-5,212.22	-533.04	-5,210.8	-533.49	1.5
003-008	-5,133.36	-363.32	-5,132.26	-363.78	1.2
003-009	-4,968.78	-363.32	-4,968.32	-363.17	0.5
003-010	-4,804.20	-361.60	-4,804.22	-361.38	0.2
			SWMU 5		
005-101	-6,676.72	200.58	-6,615.28	194.07	61.8
005-102	-6,545.21	199.28	-6,352.97	86.61	222.8
005-103	-6,345.99	19.59	-6,350.41	3.87	16.3
			SWMU 6		
006-101	-6,253.46	121.60	-6,224.07	156.46	45.6
006-102	-6,288.55	97.72	-6,275.76	95.12	13.1
006-103	-6,234.47	75.00	-6,217.78	68.71	17.8
006-104	-6,180.98	104.34	-6,178.21	93.91	10.8
			SWMU 7		
007-001	-6,270.86	913.50	-6,271.04	913	0.5
007-002	-6,342.41	807.58	-6,328.25	859.9	54.2
007-003	-6,557.62	784.20	-6,566.19	834.02	50.6
(offset)			-6,561.94	834.35	50.3
007-004	-6,682.69	788.71	-6,711.86	794.3	29.7
007-005	-6,745.51	759.69	-6,713.91	838.26	84.7
007-006	-6,751.14	884.76	-6,786.05	876.72	35.8
007-007	-6,588.89	883.64	-6,602.83	849.08	37.3
007-008	-6,061.29	924.76	-6,064.71	934.28	10.1
007-009	-6,830.86	990.12	-6,785.37	964.98	52.0
007-010	-6,590.86	988.99	-6,543.57	957.99	56.5
007-011	-6,260.72	810.96	-6,282.4	869.1	62.1
			SWMU 30		
030-001	-7,114.24	994.91	-7,187.03	976.62	75.1
030-002	-6,954.24	922.79	-7,035.76	883.46	90.5
030-003	-6,926.07	883.36	-6,939.76	881.58	13.8
030-004	-6,814.52	793.22	-6,800.23	781.03	18.8
			SWMU 145		
145-101	-1,832.30	4,329.28	-2,156.26	4,493.87	363.4
145-102	-1,821.86	3,790.02	-1,895.42	4,042.42	262.9
145-103	-2,413.30	3,748.28	-2,465.84	3,406.88	345.4
145-104	-2,618.56	3,716.96	-2,333.16	3,381.42	440.5
145-105	-2,917.76	4,367.55	-2,765.27	3,183.99	1,193.3
145-106	-2,343.72	4,565.85	-3,088.28	3,545.83	1,262.9
145-107	-2,044.52	4,510.19	-2,809.44	4,138.49	850.4

APPENDIX B

LITHOLOGIC LOGS AND WELL CONSTRUCTION DIAGRAMS, GROUNDWATER STABILIZATION LOGS, AND WELL DEVELOPMENT LOGS

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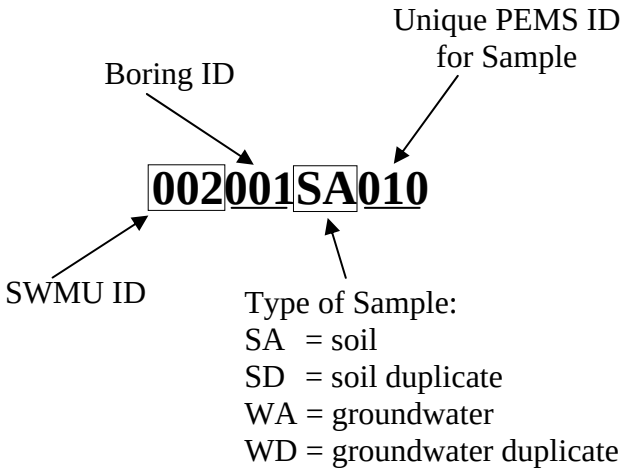
SAMPLE ID LEGEND



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SWMU 2

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LITHOLOGIC LOG	*BORING/WELL ID 002-001-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 002
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 14:30/4-4-07	End Time/Date: 11:15/4-5-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -6275.65 N -1030.259	Direction (plant grid): North

Depth (ft)	SAMPLE INTERVAL	SAMPLE ID	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5					
	7-11	002001SA010	CLAY, light brown, 7.5YR 6/4, firm, moist, with orange streaks	~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~	14:44
10	11-14	002001SA015	CLAY, gray, 7.5YR 6/1, firm, moist, mottled, with gray streaks	~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~	14:52
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25	28-32	002001SA030	CLAY, brown, 7.5YR 4/2, soft, moist, mottled, with black streaks: 5% chert fragments ⅛" across	~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~	16:30 Additional sample was required. Collected a second sample liner.
30	32-42	N/A	Core not retrieved	N/A	N/A
35					
40	42-46	002001SA045	SAND, medium to coarse grained, poorly sorted with angular to rounded chert approximately ⅛" to ½" across	---------- ---------- ----------	10:36
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55	57-60	002001SA060	SAND, fine to coarse grained, poorly sorted	---------- ---------- ----------	11:15

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY	~~~~~~~~~~ ~~~~~~~~~~ ~~~~~~~~~~
SAND	---------- ---------- ----------

LITHOLOGIC LOG	*BORING/WELL ID 002-002-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 002
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 14:38/4-3-07	End Time/Date: 10:40/4-4-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -6285.732 N -813.893	Direction (plant grid): South

Depth (ft)	SAMPLE INTERVAL	SAMPLE ID	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	002002SA010	CLAY, light brown, 7.5YR 6/4, firm, moist, with gray and orange streaks	~~~~~~~~~~	14:44
10	11-14	002002SA015	CLAY, brown, 7.5YR 5/4, firm, moist, mottled, with gray and orange streaks	~~~~~~~~~~	14:49
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25					
30	28-32	002002SA030 002002SD030	CLAY, strong brown, 7.5YR 5/6, firm, moist, with gray streaks: 5% sand	~~~~~~~~~~	15:19
35	32-42	N/A	Core not retrieved	N/A	N/A
40	42-46	002002SA045	CLAY, strong brown, 7.5YR 5/8, hard, dry, mottled with black streaks	~~~~~~~~~~	9:00 / 4/4/07
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55	57-60	002002SA060	SAND, medium grained, dark red: 10% clay	----------	10:40

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY ~~~~~~~~~~
SAND ----------

SWMU 3

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LITHOLOGIC LOG	*BORING/WELL ID 003-001-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 003
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 9:30/4-9-07	End Time/Date: 15:30/4-9-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -6072.453 N -814.337	Direction (plant grid): Southeast

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	003001SA010	CLAY, brown, 7.5YR 6/4, firm, moist, with gray and black streaks		9:40
10	11-14	003001SA015	CLAY, brown, 7.5YR 5/2, firm, moist, mottled, with gray and orange streaks		9:47
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25					
	28-30	003001SA030	CLAY, light gray, 7.5YR 7/1, soft, moist, with orange streaks		13:02
30	30-32		CLAY, strong brown, 7.5YR 5/8, firm, dry, with gray streaks: 5% sand		
35	32-42	N/A	Core not retrieved	N/A	N/A
40	42-46	003001SA045	CLAY, strong brown, 7.5YR 5/6, firm, moist, with gray and orange streaks		14:15
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55					
	57-60	003001SA060	CLAY, brown, 7.5YR 5/4, firm moist, mottled, with black streaks		15:30

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY
SAND

LITHOLOGIC LOG	*BORING/WELL ID* *003-002-ASB*	Page 1 of 1
Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 003	
Project: BGOU RI	Client: USDOE/PRS	
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield	
Start Time/Date: 10:30/4-10-07	End Time/Date: 16:22/4-10-07	
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers	
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT	
Total Depth (Vertical): 60 feet	Angle: 45°	
Logged By: Mark Gartner	Protective Level: Modified Level D	
Coordinates: E -5904.505 N -808.997	Direction (plant grid): Southwest:	

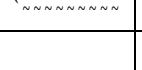
Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	003002SA010	CLAY, gray, 7.5YR 5/1, hard, dry, mottled, roots, with orange streaks		10:37
10	11-14	003002SA015	CLAY, brown, 7.5YR 5/4, soft, moist, with gray and orange streaks		10:42
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25	28-32	003002SA030	CLAY, gray, 7.5YR 5/1, firm, moist: sand (10%)		14:37
30	32-42	N/A	Core not retrieved	N/A	N/A
35					
40	42-46	003002SA045	CLAY, strong brown, 7.5YR 4/6, firm, moist: sand (5%) gray		15:47
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55	57-60	003002SA060	CLAY, white, 7.5YR 8/1, hard, moist, with orange streaks: sand (5%)		16:22

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

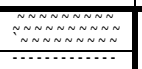
LEGEND: CLAY
SAND

LITHOLOGIC LOG	*BORING/WELL ID 003-003-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 003
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 13:29/4-12-07	End Time/Date: 10:22/4-16-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -5755.259 N -802.323	Direction (plant grid):

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	003003SA010	CLAY, brown, 7.5YR 5/4, firm, moist, with gray and orange streaks		13:38
10	11-14	003003SA015	CLAY, light gray, 7.5YR 7/1, firm, moist, with orange streaks		13:42
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25	28-32	003003SA030 003003WA060	CLAY, white, 7.5YR 8/1, soft, dry, with brown streaks		16:52
30					
35	32-42	N/A	Core not retrieved	N/A	N/A
40	42-46	003003SA045	CLAY, gray, 7.5YR 6/1, very soft, wet, with orange streaks: sand (20%)		9:05 / 4-13-07 Duplicate
			CLAY, gray, 7.5YR 6/1, very soft, wet, with orange streaks: sand (20%)		9:20
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55	57-60	003003SD060	CLAY, brown, 7.5YR 5/4, hard, moist, with orange, gray and black streaks		10:12 / Duplicate
		003003SA060			10:22

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY 

SAND 

LITHOLOGIC LOG	*BORING/WELL ID 003-004-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 003
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 15:10/4-16-07	End Time/Date: 13:41/4-17-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -5634.547 N -910.438	Direction (plant grid): West

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	003004SA010	CLAY, gray, 7.5YR 6/1, firm, moist, with brown and orange streaks	~~~~~~~~~~	15:25
10	11-14	003004SA015	CLAY, strong brown, 7.5YR 5/6, firm, moist, with gray and orange streaks	~~~~~~~~~~	15:30
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25					
30	28-32	003004SA030 003004WA060	SAND, reddish brown, fine grained, well sorted, with gray streaks	~~~~~~~~~~	16:07
35	32-42	N/A	Core not retrieved	N/A	N/A
40					
45	42-46	003004SA045	CLAY, brown, 7.5YR 5/4, firm, moist, with gray streaks	~~~~~~~~~~	12:55 / 4-17-07
50	46-57	N/A	Core not retrieved	N/A	N/A
55					
	57-60	003004SA060	CLAY, brown, 7.5YR 4/4, hard, moist, with gray streaks	~~~~~~~~~~	13:41

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY ~~~~~~~~~~

SAND ----------

LITHOLOGIC LOG	*BORING/WELL ID* *003-005-VSB*	Page 1 of 1
Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 003	
Project: BGOU RI	Client: USDOE/PRS	
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield	
Start Time/Date: 12:54 / 2-7-07	End Time/Date: 13:54 / 2-7-07	
Borehole Diameter: 2.25"	Drilling Method: Direct Push	
Sampling Method: DT-21 Dual Tube	Drill Rig: Geoprobe® 6620DT	
Total Depth (Vertical): 15 feet	Angle: Vertical	
Logged By: Mark Gartner	Protective Level: Modified Level D	
Coordinates: E -5372.989 N -899.566	Direction (plant grid): N/A	

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-1	003005SA001	CLAY, gray, 7.5YR 6/1, soft, moist, mottled with orange streaks		13:22
	1-5	003005SA005	CLAY, light gray, 7.5YR 7/1, soft, moist with orange streaks		13:30
5	5-10	003005SA010 003005SD010	CLAY, light brown, 7.5YR 6/3, firm, moist with orange and gray streaks		13:36 Duplicate sample was collected.
10	10-15	003005SA015	CLAY, light gray, 7.5YR 7/1, firm, moist with orange streaks		13:54
	Total Depth is 15 feet.		LEGEND: CLAY		
			SAND		

LITHOLOGIC LOG	*BORING/WELL ID* *003-006-VSB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 003
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 10:05 / 2-7-07	End Time/Date: 11:10 / 2-7-07
Borehole Diameter: 2.25"	Drilling Method: Direct Push
Sampling Method: DT-21 Dual Tube	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 15 feet	Angle: Vertical
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -5296.92 N -723.924	Direction (plant grid): N/A

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-1	003006SA001	CLAY, brown, 7.5YR 5/3, firm, moist, mottled with gray and orange streaks: Chert (40%)		10:36
	1-5	003006SA005	CLAY, strong brown, 7.5YR 5/6 soft, moist: Sand (30%) and Chert (30%)		10:48
5	5-10	003006SA010	CLAY, brown, 7.5YR 5/4, soft, moist with few orange and gray streaks		11:04
10	10-15	003006SA015	CLAY, light brown, 7.5YR 6/4, soft, moist with orange streaks		11:10
	Total Depth is 15 feet.		LEGEND: CLAY		
			SAND		

LITHOLOGIC LOG	*BORING/WELL ID 003-007-VSB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 003
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 8:51 / 2-7-07	End Time/Date: 9:20 / 2-7-07
Borehole Diameter: 2.25"	Drilling Method: Direct Push
Sampling Method: DT-21 Dual Tube	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 15 feet	Angle: Vertical
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -5210.803 N -533.498	Direction (plant grid): N/A

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-1	003007SA001	CLAY, brown, 7.5YR 5/3, hard, moist, mottled with gray and orange streaks		8:51
	1-5	003007SA005	CLAY, brown, 7.5YR 5/4, firm, moist, with orange streaks		9:00
5	5-10	003007SA010	CLAY, light brown, 7.5YR 6/3, firm, moist with few black streaks		9:09
10	10-15	003007SA015	CLAY, light brown, 7.5YR 6/4, firm, moist with orange streaks		9:28

Total Depth is 15 feet.

LEGEND: CLAY

SAND

LITHOLOGIC LOG	*BORING/WELL ID* *003-008-VSB*	Page 1 of 1
Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 003	
Project: BGOU RI	Client: USDOE/PRS	
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield	
Start Time/Date: 13:24 / 2-6-07	End Time/Date: 13:47 / 2-6-07	
Borehole Diameter: 2.25"	Drilling Method: Direct Push	
Sampling Method: DT-21 Dual Tube	Drill Rig: Geoprobe® 6620DT	
Total Depth (Vertical): 15 feet	Angle: Vertical	
Logged By: Mark Gartner	Protective Level: Modified Level D	
Coordinates: E -5132.269 N -363.783	Direction (plant grid): N/A	

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-1	003008SA001	CLAY, light brown, 7.5YR 6/3, firm, moist, mottled, roots with gray and orange streaks		13:24
	1-5	003008SA005	CLAY, reddish yellow, 7.5YR 6/6, soft, moist, with black, white, and orange streaks		13:30
5	5-10	003008SA010	CLAY, reddish yellow, 7.5YR 6/8, firm, moist with gray, white, and black streaks		13:39
10	10-15	003008SA015	CLAY, light brown, 7.5YR 6/4, soft, moist with gray and orange streaks		13:47

Total Depth is 15 feet.

LEGEND: CLAY

SAND

LITHOLOGIC LOG	*BORING/WELL ID* *003-009-VSB*	Page 1 of 1
Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 003	
Project: BGOU RI	Client: USDOE/PRS	
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield	
Start Time/Date: 11:48 / 2-6-07	End Time/Date: 12:27 / 2-6-07	
Borehole Diameter: 2.25"	Drilling Method: Direct Push	
Sampling Method: DT-21 Dual Tube	Drill Rig: Geoprobe® 6620DT	
Total Depth (Vertical): 15 feet	Angle: Vertical	
Logged By: Mark Gartner	Protective Level: Modified Level D	
Coordinates: E -4938.326 N -363.171	Direction (plant grid): N/A	

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-1	003009SA001	CLAY, brown, 7.5YR 5/3, firm, moist, mottled, roots with a few gray and orange streaks	~~~~~~~~~~	11:48
	1-5	003009SA005	CLAY, brown, 7.5YR 4/3, firm, moist, with a few gray and orange streaks	~~~~~~~~~~	12:07
5	5-10	003009SA010	CLAY, light brown, 7.5YR 6/3, firm, moist, mottled with gray and orange streaks	~~~~~~~~~~	12:17
10	10-15	003009SA015	CLAY, brown, 7.5YR 5/4, soft, moist with gray streaks	~~~~~~~~~~	12:27

Total Depth is 15 feet.

LEGEND: CLAY ~~~~~~~~~~

SAND ----------

LITHOLOGIC LOG	*BORING/WELL ID* *003-010-VSB*	Page 1 of 1
Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 003	
Project: BGOU RI	Client: USDOE/PRS	
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield	
Start Time/Date: 9:26 / 2-6-07	End Time/Date: 10:05 / 2-6-07	
Borehole Diameter: 2.25"	Drilling Method: Direct Push	
Sampling Method: DT-21 Dual Tube	Drill Rig: Geoprobe® 6620DT	
Total Depth (Vertical): 15 feet	Angle: Vertical	
Logged By: Mark Gartner	Protective Level: Modified Level D	
Coordinates: E -4804.221 N -361.385	Direction (plant grid): N/D	

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-1	003010SA001	CLAY, brown, 7.5YR 5/3, hard, moist with a few gray and black streaks		9:26
	1-5	003010SA005	CLAY, brown, 7.5YR 5/4, soft, moist, with gray and orange streaks		9:45
5	5-10	003010SA010	CLAY, brown, 7.5YR 5/4, soft, moist, mottled with gray, black and orange streaks		9:55
10	10-15	003010SA015	CLAY, brown, 7.5YR 5/3, very soft, moist with orange streaks		10:05

Total Depth is 15 feet.

LEGEND: CLAY

SAND

SWMU 5

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LITHOLOGIC LOG	*BORING/WELL ID 005-101-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 005
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Ryan Kulik
Start Time/Date: 11:42/5-17-07	End Time/Date: 8:45/5-18-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 40°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -6615.283 N 194.077	Direction (plant grid): South

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	005101SA010	CLAY, light brown, 7.5YR 6/4, soft, moist with gray and orange streaks	~~~~~~~~~~	12:01
10	11-14	005101SA015	CLAY, light brown, 7.5YR 6/4, soft, moist, with gray and orange streaks	~~~~~~~~~~	12:10
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25					
30	28-32	005101SA030	CLAY, brown, 7.5YR 5/4, firm, moist with gray, black and orange streaks	~~~~~~~~~~	13:39
35	32-42	N/A	Core not retrieved	N/A	N/A
40	42-46	005101SA45 005101WA060	SAND, tan, medium grained, well sorted	----------	15:00
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55	57-60	005101SA060	SAND, reddish brown, fine grained, well sorted	----------	8:45 / 5-18-07

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY ~~~~~~~~~~
SAND ----------

LITHOLOGIC LOG	*BORING/WELL ID 005-102-ASB*	Page 1 of 1
Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 005	
Project: BGOU RI	Client: USDOE/PRS	
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield	
Start Time/Date: 8:50/4-21-07	End Time/Date: 14:50/4-21-07	
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers	
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT	
Total Depth (Vertical): 60 feet	Angle: 45°	
Logged By: Mark Gartner	Protective Level: Modified Level D	
Coordinates: E -6352.979 N 86.614	Direction (plant grid): West	

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	005102SA010	CLAY, brown, 7.5YR 5/4, soft, moist, with black organic layers and gray streaks	~~~~~~~~~~	9:05
10	11-14	005102SA015	CLAY, light gray, 7.5YR 7/1, soft, moist, with orange streaks	~~~~~~~~~~	9:12
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25					
30	28-32	005102SA030	CLAY, strong brown, 7.5YR 5/4, firm, moist with gray streaks	~~~~~~~~~~	10:04
35	32-40	N/A	Core not retrieved	N/A	N/A
40	40-41	005102WA060	Core not retrieved	N/A	N/A
	41-42	N/A	Core not retrieved	N/A	N/A
	42-46	005102SA045	SAND, light gray, fine grained: Clay (30%), black layers	----------	12:06
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55					
	57-60	005102SA060	CLAY, brown, 7.5YR 5/4, soft, moist: sand (25%)	~~~~~~~~~~	14:50

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY ~~~~~~~~~~

SAND ----------

LITHOLOGIC LOG	*BORING/WELL ID 005-103-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 005
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 15:18/4-18-07	End Time/Date: 4-19-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -6350.415 N 3.873	Direction (plant grid): West

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	005103SA010	CLAY, brown, 7.5YR 5/4, soft, moist, with gray and orange streaks	~~~~~	15:30
10	11-14	005103SA015	CLAY, brown, 7.5YR 5/4, firm, dry, with gray streaks	~~~~~	15:32
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25	28-32	005103SA030	Sand, fine grained with gray streaks: Clay (35%)	-----	16:33
30	32-42	N/A	Core not retrieved	N/A	N/A
35					
40	42-46	005103SA045	CLAY, brown, 7.5YR 5/4, firm, dry, with gray streaks	~~~~~	4-19-07
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55	57-60	005103SA060 005103SD060	CLAY, brown, 7.5YR 5/4, firm, dry, with gray streaks	~~~~~	Duplicate
			SAND, medium grained and wet	-----	

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY	~~~~~
SAND	-----

LITHOLOGIC LOG	*BORING/WELL ID 005-103B-ASB*	Page 1 of 1
Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 005	
Project: BGOU RI	Client: USDOE/PRS	
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield	
Start Time/Date: 11:49/4-18-07	End Time/Date: 13:35 / 4-18-07	
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers	
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT	
Total Depth (Vertical): 60 feet	Angle: 45°	
Logged By: Mark Gartner	Protective Level: Modified Level D	
Coordinates: E N	Direction (plant grid): Southwest	

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	005-103B-8-10 ft	CLAY, reddish yellow, 7.5YR 6/6, firm, moist, with gray and black streaks		12:00 Sample not submitted to lab*
10	11-14	005-103B-13-15 ft	CLAY, brown, 7.5YR 5/4, hard, moist, with gray and black streaks		12:04 Sample not submitted to lab*
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25					
	28-32	005-103B-28-30 ft	CLAY, strong brown, 7.5YR 5/6, firm, moist, with gray and orange streaks: Sand (10%)		13:35

Total Vertical Depth is 30 feet.
Total Linear Depth is 45 feet.

LEGEND: CLAY
SAND

* Angled boring 005-103B was drilled in the wrong direction. Samples 005-103B-8-10 ft and 005-103B-13-15 ft were discarded because the samples were not collected from below buried waste in SWMU 5.

SWMU 6

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LITHOLOGIC LOG	*BORING/WELL ID 006-101-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 006
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 15:45/2-26-07	End Time/Date: 9:46/2-28-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -6224.07 N 156.469	Direction (plant grid): South

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	006101SA010	CLAY, brown, 7.5YR 5/3, firm, moist, with gray and orange streaks	~~~~~~~~~~	16:00
10	11-14	006101SA015	CLAY, light brown, 7.5YR 6/4, firm, moist, mottled, with orange streaks	~~~~~~~~~~	16:12
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25					
30	28-32	006101SA030 006101SD030	CLAY, reddish yellow, 7.5YR 6/6, firm, moist, mottled, with gray and orange streaks	~~~~~~~~~~	8:30 / 2-27-07
35	32-42	N/A	Core not retrieved	N/A	N/A
40	42-46	006101SA045 006101WA060	CLAY, brown, 7.5YR 4/4, hard, moist, with gray streaks	~~~~~~~~~~	9:44
45					
50	46-57	N/A	Core not retrieved	N/A	N/A
55					
	57-60	006101SA060	SAND, fine to medium grained, poorly sorted	----------	9:46 / 2-28-07

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY ~~~~~~~~~~
SAND ----------

LITHOLOGIC LOG	*BORING/WELL ID* *006-102-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 006
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 9:25/2-22-07	End Time/Date: 2-26-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -6275.763 N 95.128	Direction (plant grid): East

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	006102SA010	CLAY, brown, 7.5YR 4/4, firm, moist, mottled, with gray and orange streaks	~~~~~~~~~~	9:34
10	11-14	006102SA015 006102SD015	CLAY, brown, 7.5YR 5/4, hard, moist, mottled, with gray and orange streaks	~~~~~~~~~~	9:39
15	14-18	N/A	Core not retrieved	N/A	N/A
	18-19	006102WA060	Core not retrieved	N/A	N/A
20	19-28	N/A	Core not retrieved	N/A	N/A
25	28-32	006102SA030	CLAY, strong brown, 7.5YR 5/6, hard, moist, mottled, with gray and orange streaks	~~~~~~~~~~	11:00
30	32-42	N/A	Core not retrieved	N/A	N/A
35					
40	42-46	006102SA045	SAND, fine to coarse grained, poorly sorted	----------	14:15 1" of Recovery
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55	57-60	006102SA060	SAND, fine to medium grained, poorly sorted	----------	2-26-07

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY ~~~~~~~~~~
SAND ----------

LITHOLOGIC LOG	*BORING/WELL ID* *006-103-ASB*	Page 1 of 1
Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 006	
Project: BGOU RI	Client: USDOE/PRS	
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield	
Start Time/Date: 11:40/2-8-07	End Time/Date: 10:11/2-14-07	
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers	
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT	
Total Depth (Vertical): 60 feet	Angle: 45°	
Logged By: Mark Gartner	Protective Level: Modified Level D	
Coordinates: E -6217.781 N 68.719	Direction (plant grid): North	

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	006103SA010	CLAY, light brown, 7.5YR 6/4, firm, moist, with gray, black, and orange streaks	~~~~~~~~~~	12:02
10	11-14	006103SA015	CLAY, light brown, 7.5YR 6/4, firm, moist, with gray, black, and orange streaks	~~~~~~~~~~	12:08
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25	28-32	006103SA030	CLAY, brown, 7.5YR 5/4, firm, moist, with gray streaks: Sand (5%)	~~~~~~~~~~	13:37
30	32-42	N/A	Core not retrieved	N/A	N/A
35					
40	42-46	006103SA045	CLAY, strong brown, 7.5YR 5/6, hard, moist, with gray and orange streaks	~~~~~~~~~~	14:04 / 2-9-07
45	46-50	N/A	Core not retrieved	N/A	N/A
50	50-51	006103WA060	Core not retrieved	N/A	N/A
	46-57	N/A	Core not retrieved	N/A	N/A
55	57-60	006103SA060	CLAY, strong brown, 7.5YR 5/6, firm, moist: sand (10%), white, fine grained	----------	10:11 / 2-14-07

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY ~~~~~~~~~~
SAND ----------

LITHOLOGIC LOG	*BORING/WELL ID 006-104-ASB*	Page 1 of 1
Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 006	
Project: BGOU RI	Client: USDOE/PRS	
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield	
Start Time/Date: 9:50/2-19-07	End Time/Date: 14:05/2-21-07	
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers	
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT	
Total Depth (Vertical): 60 feet	Angle: 45°	
Logged By: Mark Gartner / Todd Mills	Protective Level: Modified Level D	
Coordinates: E -6178.211 N 93.911	Direction (plant grid): Northeast	

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	006104SA010	CLAY, brown, 7.5YR 5/4, firm, moist, with gray streaks	~~~~~~~~~~	10:11
10	11-14	006104SA015	CLAY, brown, 7.5YR 5/3, hard, moist, with gray streaks	~~~~~~~~~~	
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25	28-32	006104SA030	CLAY, strong brown, 7.5YR 4/6, hard, dry, with sand streaks	~~~~~~~~~~	13:41
30					
35	32-42	N/A	Core not retrieved	N/A	N/A
40	42-46	006104SA045 006104WA060	CLAY, pinkish gray, 7.5YR 7/2, very stiff, moist, from 43 to 45 feet	~~~~~~~~~~	
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55	57-60	N/A	Core not retrieved	N/A	13:09 Attempt failed 57-60' sample
60	60-63	N/A	Core not retrieved	N/A	13:50 Attempt failed 64-66' sample
	63-65	006104SA060	SAND, fine grained, reddish brown, well sorted, black streaks	----------	14:05

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY ~~~~~~~~~~
SAND ----------

SWMU 7

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LITHOLOGIC LOG	*BORING/WELL ID* *007-001-ASB*	Page 1 of 1
Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 007	
Project: BGOU RI	Client: USDOE/PRS	
Drilling Contractor: Chase Environmental, LLC	Driller: Ryan Kulik	
Start Time/Date: 09:54/3-28-07	End Time/Date: 09:41/3-29-07	
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers	
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT	
Total Depth (Vertical): 60 feet	Angle: 45°	
Logged By: Mark Gartner	Protective Level: Modified Level D	
Coordinates: E -6271.047 N 913.003	Direction (plant grid): Southeast	

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5					
	7-11	007001SD010	CLAY, strong brown, 7.5YR 5/8, hard, moist, mottled, with gray and orange streaks	~~~~~~~~~~	10:14 Duplicate
10		007001SA010	CLAY, brown, 7.5YR 5/3, firm, moist, mottled, with black and orange streaks	~~~~~~~~~~	10:17
	11-14	007001SA015	CLAY, brown, 7.5YR 5/3, firm, moist, mottled, with black and orange streaks	~~~~~~~~~~	10:24
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25					
	28-32	007001SA030	CLAY, gray, 7.5YR 6/1, firm, moist, with orange streaks: Sand (5%)	~~~~~~~~~~	12:45
30	32-42	N/A	Core not retrieved	N/A	N/A
35					
40					
	42-46	007001SA045 007001WA060	SAND, gray, medium grained, poorly sorted: Chert (10%) angular to subangular, ranging from ¼ to ½ inch across	----------	13:44
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55					
	57-60	007001SA060	SAND, gray, medium grained, poorly sorted: Chert (4 inch seam), angular, ½ to ¾ inch across	----------	9:22 / 3-29-07 Min. sample recovered.
60	60-62.5		SAND, gray, medium grained, poorly sorted: Chert (4 inch seam), angular, ½ to ¾ inch across		9:41: Additional sample required.
	62.5-65	N/A	Core not retrieved	N/A	N/A

Total Vertical Depth is 62.5 feet.
Total Linear Depth is 87.5 feet.

LEGEND: CLAY ~~~~~~~~~~
SAND ----------

LITHOLOGIC LOG	*BORING/WELL ID 007-002-ASB*	Page 1 of 1
Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 007	
Project: BGOU RI	Client: USDOE/PRS	
Drilling Contractor: Chase Environmental, LLC	Driller: Ryan Kulik	
Start Time/Date: 12:04/3-27-07	End Time/Date: 16:42/3-27-07	
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers	
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT	
Total Depth (Vertical): 60 feet	Angle: 45°	
Logged By: Mark Gartner	Protective Level: Modified Level D	
Coordinates: E -6328.252 N 859.906	Direction (plant grid): Southeast	

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	007002SA010	CLAY, gray, 7.5YR 6/1, firm, moist, mottled, with gray streaks	~~~~~~~~~~	12:25
10	11-14	007002SA015	CLAY, light brown, 7.5YR 6/4, firm, moist, mottled, with gray and orange streaks	~~~~~~~~~~	12:39
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25					
30	28-32	007002SA030	CLAY, strong brown, 7.5YR 5/6, firm, moist, mottled with gray and orange streaks: Sand (5%)	~~~~~~~~~~	14:38
35	32-42	N/A	Core not retrieved	N/A	N/A
40					
45	42-46	007002SA045	SAND, gray, medium grained, well sorted, moist	----------	15:38
50	46-50	N/A	Core not retrieved	N/A	N/A
	50-51	007002WA060			
	51-57	N/A			
55	57-60	007002SA060	CLAY, light brown, 7.5YR 6/3, soft, moist with gray and orange streaks: Sand (15%) fine grained	~~~~~~~~~~	16:42

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY ~~~~~~~~~~
SAND ----------

LITHOLOGIC LOG	*BORING/WELL ID 007-003-ASB*	Page 1 of 1
Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 007	
Project: BGOU RI	Client: USDOE/PRS	
Drilling Contractor: Chase Environmental, LLC	Driller: Ryan Kulik	
Start Time/Date: 8:35/3-19-07	End Time/Date: 11:08/3-21-07	
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers	
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT	
Total Depth (Vertical): 60 feet	Angle: 45°	
Logged By: Mark Gartner	Protective Level: Modified Level D	
Coordinates: E N	Direction (plant grid): Southeast	

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5					
	7-11	007003SA010	CLAY, brown, 7.5YR 5/2, soft, moist, with few orange streaks	~~~~~~~~~~	8:40
10	11-14	007003SA015	CLAY, pinkish gray, 7.5YR 6/2, firm, moist, mottled with gray and orange streaks	~~~~~~~~~~	8:47
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25					
	28-32	007003SA030	CLAY, strong brown, 7.5YR 5/6, soft, moist, mottled with gray and orange streaks	~~~~~~~~~~	9:28
30	32-42	N/A	Core not retrieved	N/A	N/A
35					
40					
	42-46	007003SA045 007003WA060	SAND, fine to medium grained, poorly sorted, water with angular chert up to ¼ across	----------	13:48 / 3-20-07
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55					
	57-60	007003SA060	CLAY, reddish yellow, 7.5YR 6/8, hard, moist with gray streaks	~~~~~~~~~~	11:08 / 3-21-07

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY ~~~~~~~~~~

SAND ----------

LITHOLOGIC LOG	*BORING/WELL ID* *007-004-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 007
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Ryan Kulik
Start Time/Date: 8:56/3-26-07	End Time/Date: 15:30/3-26-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -6711.864 N 794.304	Direction (plant grid): East

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	007004SA010	CLAY, gray, 7.5YR 6/1, firm, moist, with few orange streaks	~~~~~~~~~~	9:12
10	11-14	007004SA015	CLAY, gray, 7.5YR 5/1, soft, moist with orange streaks	~~~~~~~~~~	9:18 40% recovery
15	14-18		CLAY, gray, 7.5YR 5/1, soft, moist with orange streaks	~~~~~~~~~~	Additional sample
20	18-28	N/A	Core not retrieved	N/A	N/A
25	28-32	007004SA030	SAND, medium to coarse grained, poorly sorted: Chert (25%), angular, up to ½ inch across	----------	12:12
30	32-42	N/A	Core not retrieved	N/A	N/A
35	42-46	007004SA045	CLAY, light brown, 7.5YR6/3, soft, moist, with gray streaks	----------	13:30
40	46-57	N/A	Core not retrieved	N/A	N/A
45	57-60	007004SA060	CLAY, brown, 7.5YR 5/3, hard, moist, mottled with black streaks	~~~~~~~~~~	15:30
50					
55					

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY ~~~~~~~~~~
SAND ----------

LITHOLOGIC LOG	*BORING/WELL ID 007-005-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 007
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 15:24/3-12-07	End Time/Date: 3-13-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -6713.919 N 838.269	Direction (plant grid): Southwest

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	007005SA010	CLAY, light gray, 7.5YR 7/1, firm, moist, mottled with orange streaks	~~~~~~~~~~	15:37
10	11-14	007005SA015	GRAVEL	----------	Gravel collapsed the sample liner – no recovery
15	14-18		CLAY, light brown, 7.5YR 6/4, firm, moist, mottled with gray streaks	~~~~~~~~~~	16:20
20	18-28	N/A	Core not retrieved	N/A	N/A
25	28-32	007005SA030	CLAY, gray, 7.5YR 6/1, soft, moist, mottled with orange streaks	~~~~~~~~~~	9:04 / 3-13-07
30	32-42	N/A	Core not retrieved	N/A	N/A
35	42-46	007005SA045 007005WA060	SAND, fine to coarse grained, poorly sorted, wet, iron stained: Chert (5%), subangular	----------	9:54
40	46-57	N/A	Core not retrieved	N/A	N/A
45					
50					
55	57-60	007005SA060	CLAY, strong brown, 7.5YR 5/6, firm, moist, mottled with gray streaks with sand seams	~~~~~~~~~~	

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND : GRAVEL ---------- CLAY ~~~~~~~~~~ SAND ----------

LITHOLOGIC LOG	*BORING/WELL ID 007-006-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 007
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Ryan Kulik
Start Time/Date: 15:42/3-21-07	End Time/Date: 15:15 / 3-23-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -6786.053 N 876.721	Direction (plant grid): Northeast

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5					
	7-11	007006SA010	CLAY, brown, 7.5YR 5/4, hard, moist with gray and orange streaks		16:21
10	11-14	007006SA015	CLAY, light brown, 7.5YR 6/4, firm, moist with gray streaks		16:45
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25					
	28-32	007006SA030	CLAY, reddish yellow, 7.5YR 6/6, hard, moist with gray and orange streaks: Sand (5%)		9:22 / 3-22-07
30	32-42	N/A	Core not retrieved	N/A	N/A
35					
40					
	42-46	N/A	N/A	N/A	No recovery
45	46-51	007006SA045	Clay, brown, 7.5YR 5/3, hard, mist, mottled, with orange and gray streaks		13:00 / 3-23-07
50	51-57	N/A	Core not retrieved	N/A	N/A
55					
	57-60	007006SA060	Clay, brown, 7.5YR 5/3, hard, mist, mottled, with orange and gray streaks		15:15

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY

SAND

LITHOLOGIC LOG	*BORING/WELL ID 007-007-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 007
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 13:56/3-14-07	End Time/Date: 10:10 / 3-16-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -6602.836 N 849.08	Direction (plant grid): North

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	007007SA010	CLAY, gray, 7.5YR 6/1, soft, moist	~~~~~~~~~~	14:38
10	11-14	007007SA015	CLAY, light brown, 7.5YR 6/4, firm, moist with gray and orange streaks	~~~~~~~~~~	14:42
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25	28-32	007007SA030	CLAY, reddish yellow, 7.5YR 6/6, firm, moist with gray and orange streaks: Sand (5%)	~~~~~~~~~~	16:32
30	32-42	N/A	Core not retrieved	N/A	N/A
35					
40	42-46	007007SA045 007007SD045 007007WA060 007007WD060	SAND, fine grained up to ½" across, poorly sorted, water	----------	13:26 / 3-15-07
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55	57-60	007007SA060	SAND , fine to medium grained with 5% clay	----------	10:10 / 3-16-07

Total Vertical Depth is 60 feet.
Total Linear Depth is 83 feet.

LEGEND: CLAY ~~~~~~~~~~
SAND ----------

LITHOLOGIC LOG	*BORING/WELL ID 007-008-ASB*	Page 1 of 1
Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 007	
Project: BGOU RI	Client: USDOE/PRS	
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield	
Start Time/Date: 9:20/4-2-07	End Time/Date: 16:41 / 4-2-07	
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers	
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT	
Total Depth (Vertical): 60 feet	Angle: 45°	
Logged By: Mark Gartner	Protective Level: Modified Level D	
Coordinates: E -6064.711 N 934.282	Direction (plant grid): Southeast	

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	007008SA010	CLAY, gray, 7.5YR 6/1, soft, moist, with orange streaks	~~~~~~~~~~	9:30
10	11-14	007008SA015	CLAY, light gray, 7.5YR 7/1, firm, moist, mottled, with orange streaks	~~~~~~~~~~	9:35
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25	28-32	007008SA030	CLAY, strong brown, 7.5YR 5/6, firm, moist, mottled with gray streaks	~~~~~~~~~~	10:34
30	32-42	N/A	Core not retrieved	N/A	N/A
35					
40	42-46	007008SA045 007008WA060	SAND, medium grained, wet: Chert (5%) angular, ⅛" across	----------	12:42
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55	57-60	007008SA060	SAND , medium grained with 10% clay: Chert (few), angular up to ½" across	----------	16:41

Total Vertical Depth is 60 feet.
Total Linear Depth is 83 feet.

LEGEND: CLAY ~~~~~~~~~~
SAND ----------

LITHOLOGIC LOG	*BORING/WELL ID 007-009-VSB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 007
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 12:05/4-30-07	End Time/Date: 5-8-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: CME High Torque 55 and Geoprobe® 6620DT
Total Depth (Vertical): 96 feet	Angle: Vertical
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -6785.376 N 964.982	Direction (plant grid): N/A

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-1	007009SA001	CLAY, light brown, 7.5YR 6/3, hard, dry with black and orange streaks		12:15: Pused two additional liners
	1-5	007009SA005	CLAY, light brown, 7.5YR 6/3, firm, moist with gray and orange streaks		12:19
5	5-10	007009SA010	CLAY, light brown, 7.5YR 6/3, firm, moist with gray and orange streaks		12:24
10	10-15	007009SA015	CLAY, light brown, 7.5YR 6/4, soft, moist with orange streaks		12:27
15 20	15-25	N/A	Core not retrieved	N/A	N/A
25	25-30	007009SA030	CLAY, light brown, 7.5YR 6/3, firm, moist, mottled with gray and orange streaks		12:49
30 35	30-40	N/A	Core not retrieved	N/A	N/A
40	40-45	007009SA045	CLAY, light brown, 7.5YR 4/3, very hard, moist, with gray streaks		13:37
45 50	45-55	007009WA030	Core not retrieved	N/A	N/A
55	55-60	007009SA60	CLAY, brown, 7.5YR 4/4, firm, moist, with gray streaks		10:29 / 5-1-07

Total Vertical Depth is 96 feet.
Water samples collected at the following depths: 69, 80, 90, 90D ft.

LEGEND: CLAY
SAND

LITHOLOGIC LOG	*BORING/WELL ID 007-010-VSB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 007
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 8:45/5-10-07	End Time/Date: 5-15-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig:CME High Torque 55 and Geoprobe® 6620DT
Total Depth (Vertical): 100 feet	Angle: Vertical
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -6543.575 N 957.997	Direction (plant grid): N/A

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-1	007010SA001	Gravel – fill material		8:45: Pushed 4 liners. 780,00 dpm
	1-5	007010SA005	CLAY, white, 7.5YR 8/1, soft, moist		8:50
5	5-10	007010SA010	CLAY, white, 7.5YR 8/1, firm, moist, mottled with orange streaks		9:20
10	10-15	007010SA015	CLAY, pinkish white, 7.5YR 6/4, soft, moist with gray streaks		12:19
15	15-25	N/A	Core not retrieved	N/A	N/A
20					
25	25-30	007010SA030	CLAY, brown, 7.5YR 5/4, hard, moist, mottled with gray and orange streaks		12:35
30	30-40	N/A	Core not retrieved	N/A	N/A
35					
40	40-45	0070110SA045 007010WA030	CLAY, brown, 7.5YR 5/4, firm, moist, with orange streaks: Sand (10%)		9:30 / 5-11-07
45	45-55	N/A	Core not retrieved	N/A	N/A
50					
55	55-60	007010SA060 007010WA060	SAND, fine grained reddish brown with black streaks: Silt (10%)		15:45

Total Vertical Depth is 100 ft
Water samples collected at the following depths: 66, 80, 90, 100 ft

LEGEND: GRAVEL, CLAY, SAND

LITHOLOGIC LOG	*BORING/WELL ID 007-011-VSB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 007
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 14:21/4-24-07	End Time/Date: 4-26-07
Borehole Diameter: 8.25"	Drilling Method: 4.25" ID Augers
Sampling Method: Split Spoons	Drill Rig: CME High Torque 55
Total Depth (Vertical): 100 feet	Angle: Vertical
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -6282.4 N 869.1	Direction (plant grid): N/A

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-1	N/A	Sample not Collected – Soil all rock and Gravel	--- ---	15:09
	1-5	007011SA005	CLAY, gray, 7.5YR 6/1, firm, moist, mottled with orange streaks	~~~ ~~~ ~~~	15:20
5	5-10	007010SA010	CLAY, white, 7.5YR 8/1, firm, moist, mottled with orange streaks	~~~ ~~~ ~~~	15:30
10	10-15	007010SA015	CLAY, light gray, 7.5YR 7/1, soft, moist, variegated gray and orange	~~~ ~~~ ~~~	15:53
15 20	15-25	N/A	Core not retrieved	N/A	N/A
25	25-30	007011SA030 007011SD030	CLAY, light gray, 7.5YR 7/1, soft, moist, variegated gray and orange	~~~ ~~~ ~~~	16:04
30 35	30-40	N/A	Core not retrieved	N/A	N/A
40	40-45	007011SA045 007011WA030	SAND, fine grained, gray: Chert (15%) sub angular, ⅛" to ½" across	--- --- ---	8:20 / 4-25-07
45 50	45-55	N/A	Core not retrieved	N/A	N/A
55	55-60	007011SA060 007011WA060	SAND, medium grained, gray: Chert (5%), angular, ⅛" to 3" across	--- --- ---	13:35

Total Vertical Depth is100 feet. Water samples collected at the following depths: 70, 80, 90 ft.

LEGEND: GRAVEL --- --- CLAY ~~~ ~~~ ~~~

SAND --- --- ---

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SWMU 30

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LITHOLOGIC LOG	*BORING/WELL ID 030-001-ASB*	Page 1 of 1
Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 030	
Project: BGOU RI	Client: USDOE/PRS	
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield	
Start Time/Date: 8:34/3-5-07	End Time/Date: 14:40/3-5-07	
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers	
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT	
Total Depth (Vertical): 60 feet	Angle: 45°	
Logged By: Mark Gartner	Protective Level: Modified Level D	
Coordinates: E -7187.038 N 976.622	Direction (plant grid): Southeast	

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	030001SA010	CLAY, light brown, 7.5YR 6/4, firm, moist, mottled, with gray and orange streaks	~~~~~~~~~~	8:52
10	11-14	030001SA015	CLAY, light brown, 7.5YR 6/4, firm, moist, mottled, with gray and orange streaks	~~~~~~~~~~	8:56
15	14-18		CLAY, light brown, 7.5YR 6/4, firm, moist, mottled, with gray and orange streaks		9:04 Additional sample was required
20	18-28	N/A	Core not retrieved	N/A	N/A
25	28-32	030001SA030	SAND, iron stained, fine grained, well sorted, slight moisture	----------	9:31
30	32-42	N/A	Core not retrieved	N/A	N/A
35	42-46	030001SA045	CLAY, light brown, 7.5YR 6/3, hard, moist, with red and black streaks	~~~~~~~~~~	10:20
40	46-57	N/A	Core not retrieved	N/A	N/A
45	57-60	030001SA060	CLAY, light brown, 7.5YR 6/4, soft, moist, with gray and orange streaks: Sand from 84 to 85', fine to medium grained , poorly sorted	~~~~~~~~~~	14:40
50					
55					

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY ~~~~~~~~~~
SAND ----------

LITHOLOGIC LOG	*BORING/WELL ID 030-002-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 030
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 8:30/3-6-07	End Time/Date: 13:31/3-6-07
Borehole Diameter: 2.25"	Drilling Method: Direct Push
Sampling Method: DT-21 Dual Tube	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -7035.76 N 883.462	Direction (plant grid): Northwest

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	030002SA010	CLAY, reddish yellow, 7.5YR 6/6, hard, moist, mottled, with gray and orange streaks		8:48
10	11-14	030002SA015	CLAY, reddish yellow, 7.5YR 6/6, firm, moist, mottled, with gray and orange streaks		8:54
15	14-18		CLAY, light brown, 7.5YR 6/3, firm, moist, with gray and orange streaks		8:56 Additional sample required
20	18-28	N/A	Core not retrieved	N/A	N/A
25	28-32	030002SA030	CLAY, light brown, 7.5YR 6/4, hard, moist, with gray and orange streaks: Sand from 40 to 41', medium to coarse grained, poorly sorted, iron stained		9:19
30	32-42	N/A	Core not retrieved	N/A	N/A
35	42-46	030002SA045	CLAY, brown, 7.5YR 5/3, hard, moist, mottled, with gray and orange streaks		10:41
40	46-50	030002SD045	CLAY, brown, 7.5YR 5/3, hard, moist, mottled, with gray and orange streaks		Duplicate
45	50-57	N/A	Core not retrieved	N/A	N/A
50	57-60	030002SA060	CLAY, light gray, 7.5YR 7/1, hard, moist, with orange streaks: Sand (5%)		13:31 / 3-6-07
55					

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY

SAND

LITHOLOGIC LOG	*BORING/WELL ID 030-003-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 030
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 8:30/3-7-07	End Time/Date: 13:11/3-8-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -6939.763 N 881.58	Direction (plant grid): Southeast

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5					
	7-11	030003SA010	CLAY, brown, 7.5YR 4/4, firm, moist, with gray streaks		8:35
10	11-14	030003SA015	CLAY, brown, 7.5YR 5/3, firm, moist, with orange streaks		8:48
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25					
	28-32	030003SA030	CLAY, reddish yellow, 7.5YR 6/6,very hard, moist, with gray streak		14:56
30	32-42	N/A	Core not retrieved	N/A	N/A
35					
40					
	42-46	030003SA045	CLAY, strong brown, 7.5YR 5/6, hard, moist, with gray and orange streaks		10:33 / 3-8-07
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55					
	57-60	030003SA060 030003WA060	CLAY, strong brown, 7.5YR 5/6, hard, moist, mottled, with gray streaks		13:11

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY

SAND

LITHOLOGIC LOG	*BORING/WELL ID 030-004-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 030
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 3-6-07	End Time/Date: 3-6-07
Borehole Diameter: 2.75"	Drilling Method: Direct Push
Sampling Method: DT-21 Dual Tube	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -6800.238 N 781.032	Direction (plant grid): Northwest

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5					
	7-11	030004SA010	CLAY, white, 7.5YR 8/1, hard, moist, with orange streaks		
10					
	11-14	030004SA015	CLAY, white, 7.5YR 8/1, hard, moist, with orange streaks		
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25					
	28-32	030004SA030	CLAY, white, 7.5YR 8/1, hard, moist, with a few orange streaks		
30					
35	32-42	N/A	Core not retrieved	N/A	N/A
40					
	42-46	030004SA045	CLAY, white, 7.5YR 8/1, hard, moist, with a few orange streaks		
45					
50	46-57	N/A	Core not retrieved	N/A	N/A
55					
	57-60	030004SA060	CLAY, brown, 7.5YR 4/4, very hard, dry, with gray streaks		14:32

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY

SAND

SWMU 145

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LITHOLOGIC LOG	***BORING/WELL ID*** *145-101-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 145
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 14:15/1-24-07	End Time/Date: 12:35 / 1-24-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Todd Mills / Mark Gartner	Protective Level: Modified Level D
Coordinates: E -2156.26 N 4493.87	Direction (plant grid): South

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	145101SA010	CLAY, brown, 7.5YR 4/3, medium firm, slightly moist, with gray streaks		14:22
10	11-14	145101SA015	CLAY, gray, 7.5YR 6/1, medium firm, moist with light gray streaks		14:31
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25	28-32	145101SA030	CLAY, gray, 7.5YR 6/1, firm, slightly moist with gray streaks		15:15
30	32-42	N/A	Core not retrieved	N/A	N/A
35					
40	42-46	145101SA045	CLAY, brown, 7.5YR 4/4, very firm, slightly moist, with black streaks		10:15 / 1-25-07
45	46-50	N/A	Core not retrieved	N/A	N/A
50	50-53	145101SA060	CLAY, light brown, 7.5YR 6/4, hard, moist, gray and orange streaks with a 3" sand seam, white, fine grained to ¼" across, poorly sorted		12:35

Total Vertical Depth is 53 feet.
Total Linear Depth is 75 feet.

LEGEND: CLAY

SAND

LITHOLOGIC LOG	*BORING/WELL ID 145-102-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 145
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 8:40/1-16-07	End Time/Date: 16:42/1-18-07
Borehole Diameter: 2.75"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -1895.42 N 4042.42	Direction (plant grid): West

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	145102SA010	CLAY, brown, 7.5YR 7/1, firm, dry, black organic material, with orange streaks		9:42
10	11-14	145102SA015	CLAY, gray, 7.5YR 7/1, firm, dry, crumbly		
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25	28-32	145102SA030 145102SD030	CLAY, brown, 7.5YR 4/4, hard, moist, with orange and gray streaks		10:28
30	32-42	N/A	Core not retrieved	N/A	N/A
35					
40	42-46	145102SA045	CLAY, reddish yellow, 7.5YR 6/6, firm, moist, gray and orange streaks		13:07
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55	57-60	145102SA060	CLAY (from 80 to 81.5'), strong brown, 7.5 YR 4/6, hard, moist, with black streaks SAND (from 81.5 to 83'), light gray fine grained, well sorted		16:42

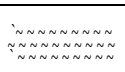
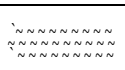
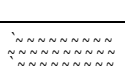
Total Vertical Depth is 60 feet.
Total Linear Depth is 83 feet.

LEGEND: CLAY

SAND

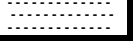
LITHOLOGIC LOG	*BORING/WELL ID 145-103-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 145
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 11:47 / 1-9-07	End Time/Date: 15:19/1-9-07
Borehole Diameter: 2.75"	Drilling Method: Direct Push
Sampling Method: DT-21 Dual Tube	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -2465.84 N 3406.88	Direction (plant grid): Northwest

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	145103SA010	CLAY, dark gray, 7.5YR 4/1, soft, moist, rock fragments		12:02
10	11-14	145103SA015	CLAY, gray, 7.5YR 6/1, firm, dry		12:12
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25	28-32	145103SA030	CLAY, brown, 7.5YR 5/3, firm, moist, with gray streaks		12:52
30	32-42	N/A	Core not retrieved	N/A	N/A
35					
40	42-46	145103SA045	CLAY, brown, 7.5YR 5/4, firm, moist, gray streaks: Sand (10%)		13:49
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55	57-60	145103SA060	CLAY, strong brown, 7.5 YR 5/6, hard, moist with black and gray streaks: Sand (10%)		15:19

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY 

SAND 

LITHOLOGIC LOG	*BORING/WELL ID 145-104-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 145
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 14:34 / 1-10-07	End Time/Date: 12:42/1-22-07
Borehole Diameter: 2.75"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -2333.16 N 3381.42	Direction (plant grid): East

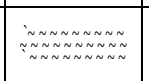
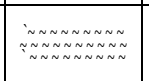
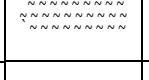
Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	145104SA010	CLAY, greenish gray, GLEY1 6/10Y, soft, dry, wood fragments		14:57
10	11-14	145104SA015	CLAY, greenish gray, GLEY1 6/10Y, soft, dry, wood fragments		15:16 Stop drilling activities due to High LEL readings.
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25					
30	28-32	145104SA030	CLAY, brown, 7.5YR 4/4, firm, moist with orange streaks		9:45
35	32-42	N/A	Core not retrieved	N/A	N/A
40	42-46	145104SA045	CLAY, brown, 7.5YR 5/4, hard, moist with gray and orange streaks		10:26
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55	57-60	145104SA060	CLAY, strong brown, 7.5 YR 5/8, hard, dry, with 1" sand seam, white, fine grained, dry		12:42

Total Vertical Depth is 60 feet.
Total Linear Depth is 82.5 feet.

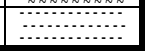
LEGEND: CLAY
SAND

LITHOLOGIC LOG	*BORING/WELL ID 145-105-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 145
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 12:38 / 1-8-07	End Time/Date: 13:41/1-23-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner / Todd Mills	Protective Level: Modified Level D
Coordinates: E -2765.27 N 3183.99	Direction (plant grid): Northwest

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5					
	7-11	145105SA010	CLAY, brown, 7.5YR 5/3, soft, moist, mottles with gray and red streaks		12:52
10	11-14	145105SA015	CLAY, brown, 7.5YR 4/3, firm, moist, dark orange streaks		13:02
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25					
	28-32	145105SA030	CLAY, reddish yellow, 7.5YR 6/6, firm, dry, with gray streaks: Sand seam (1'), fine grained, with a few angular chert fragments		14:26
30	32-42	N/A	Core not retrieved	N/A	N/A
35					
40					
	42-46	145105SA045	CLAY, light brown, 7.5YR 6/4, hard, dry, gray streaks:		15:49
45	46-57	N/A	Core not retrieved	N/A	N/A
50					
55					
	57-60	145105SA060	SILTY CLAYEY, strong brown, 7.5YR 5/6, sand and gravel		14:10 / 1-23-07

Total Vertical Depth is 60 feet.
Total Linear Depth is 85 feet.

LEGEND: CLAY	
SAND	

LITHOLOGIC LOG	*BORING/WELL ID 145-106-ASB*	Page 1 of 1
Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 145	
Project: BGOU RI	Client: USDOE/PRS	
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield	
Start Time/Date: 9:20/1-26-07	End Time/Date: 14:49/1-26-07	
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers	
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT	
Total Depth (Vertical): 43 feet	Angle: 45°	
Logged By: Todd Mills	Protective Level: Modified Level D	
Coordinates: E -3088.28 N 3545.83	Direction (plant grid): East	

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	145106SA010	CLAY, very pale brown, 10YR 7/3, firm, slightly moist, with iron staining		Duplicate sample
		145106SD010	CLAY, very pale brown, 10YR 7/3, firm, slightly moist, with iron staining		10:13
10	11-14	145106SA015	CLAY, gray, 7.5YR 7/1, firm, dry		10:25
15	14-28	N/A	Core not retrieved	N/A	N/A
20					
25	28-30	145106SA030	CLAY, brown, 7.5YR 4/3, very firm, moist, with black streaks		11:39
30	30-33	N/A	Core not retrieved	N/A	N/A
35	33-35	145106SA045	CLAY, brown, 7.5YR 4/4, very firm, moist		13:59
	38-40	145106SA060	CLAY, brown, 7.5YR 4/4, very firm, slightly moist, black streaks		15:00
40	40-43	N/A	Core not retrieved	N/A	N/A

Total Vertical Depth is 43 feet.
Total Linear Depth is 60 feet.

LEGEND: CLAY
SAND

LITHOLOGIC LOG	*BORING/WELL ID 145-107-ASB*	Page 1 of 1

Facility: Paducah Gaseous Diffusion Plant, Paducah, KY	Site: SWMU- 145
Project: BGOU RI	Client: USDOE/PRS
Drilling Contractor: Chase Environmental, LLC	Driller: Jeff Brownfield
Start Time/Date: 13:50 / 1-29-07	End Time/Date: 11:24/1-31-07
Borehole Diameter: 6.25"	Drilling Method: Direct Push Through Augers
Sampling Method: DT-21 Dual Tube / 2.25" ID Augers	Drill Rig: Geoprobe® 6620DT
Total Depth (Vertical): 60 feet	Angle: 45°
Logged By: Mark Gartner	Protective Level: Modified Level D
Coordinates: E -2809.44 N 4138.49	Direction (plant grid): South

Depth (ft)	SAMPLE INTERVAL	SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	COMMENTS
0	0-7	N/A	Core not retrieved	N/A	N/A
5	7-11	145107SA010	CLAY, brown, 7.5YR 4/2, firm, moist with gray and orange streaks: Quartz (5%), ⅛" to ¼" across, rounded to subangular		14:02
10	11-14	145107SA015	CLAY, dark gray, 7.5YR 4/1, soft, moist		14:10
15	14-18		CLAY, dark gray, 7.5YR 4/1, soft, moist		Additional sample was required.
20	18-28	N/A	Core not retrieved	N/A	N/A
25	28-32	145107SA030	CLAY, brown, 7.5YR 4/4, firm, moist, gray streaks with 10% sand: Sand seam (2.5'), fine grained to medium grained, poorly sorted with 10% clay		15:11
30	32-42	N/A	Core not retrieved	N/A	N/A
35	42-46	145107SA045	CLAY, light gray, 7.5YR 7/1, very hard, dry with orange streaks		15:44 / 1-30-07
40	46-57	N/A	Core not retrieved	N/A	N/A
45	57-60	145107SA060	SAND, white, fine grained, dry with iron staining		11:24 / 1-31-07
50					
55					

Total Vertical Depth is 60 feet.
Total Linear Depth is 83 feet.

LEGEND: CLAY
SAND

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APPENDIX C

ANALYTICAL DATA AND QA/QC EVALUATION RESULTS

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APPENDIX C

ANALYTICAL DATA AND QA/QC EVALUATION RESULTS

APPENDIX D

THREE DIMENSIONAL VISUALIZATION FIGURES

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APPENDIX D

THREE DIMENSIONAL VISUALIZATION FIGURES

APPENDIX E

CONTAMINANT FATE AND TRANSPORT MODELING RESULTS FOR THE BGOU

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CONTENTS

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FIGURES

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TABLES

ACRONYMS

AT123D	Analytical Transient 1-, 2-, 3-Dimensional Model
BGOU	Burial Grounds Operable Unit
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
COC	contaminant of concern
COPC	chemical of potential concern
DAF	diluation/attenuation factor
DCE	dichloroethene
DNAPL	dense nonaqueous-phase liquid
DQO	Data Quality Objective
ELCR	excess lifetime cancer risk
EPA	U. S. Environmental Protection Agency
f_{oc}	soil organic carbon fraction
HQ	hazard quotient
HU	hydrogeologic unit
K_d	distribution coefficient
K_{oc}	organic carbon partition coefficient
MCL	Maximum Contaminant Level
MEPAS	Multimedia Environmental Pollutant Assessment System
Paducah OREIS	Paducah Oak Ridge Environmental Information System
PCB	polychlorinated biphenyl
PGDP	Paducah Gaseous Diffusion Plant
POE	point of exposure
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RESRAD	RESidual RADioactive Materials
RfD	reference dose
RGA	Regional Gravel Aquifer
RGO	remedial goal option
RI	Remedial Investigation
SADA	Statistical Analysis and Decision Assistance Model
SESOIL	Seasonal Soil Compartment Model
SQL	sample quantitation limit
SSL	soil screening level
SVOC	semivolatile organic compound
SWMU	solid waste management unit
^{99}Tc	technetium-99
TCE	trichloroethene
UCL	upper confidence limit
UCRS	Upper Continental Recharge System
VOC	volatile organic compound

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E.1. INTRODUCTION

This appendix presents the methods and results of the fate and transport modeling performed for the Burial Grounds Operable Unit (BGOU) Remedial Investigation (RI), consisting of [Solid Waste Management Unit (SWMU) 2, SWMU3, SWMU 4, SWMU 5, SWMU 6, SWMU 7, SWMU 30, and SWMU 145].

The fate and transport modeling of the BGOU RI is consistent with the Tiers 1, 2 and 3 of the modeling matrix included in the Paducah Gaseous Diffusion Plant (PGDP) Risk Methods Document (DOE 2001). This modeling matrix is consistent with the 2007 revision to the Risk Methods Document, since the methodologies are the same for fate and transport modeling. As indicated by this matrix (Table E.1.1), Tier 1 consists of simple screens using soil screening levels (SSLs) to identify those contaminants that may migrate from source areas to undefined downgradient points of exposure (POEs); Tier 2 consists of source delineation and transport modeling using input parameters that are unlikely to underestimate the potential for contaminant transport to undefined downgradient POEs (i.e., are conservative estimates of contaminant transport); and Tier 3 consists of source delimitation and transport modeling using input parameters that result in more accurate estimates of future contaminant concentrations at POEs beneath the SWMUs, at the PGDP plant boundary, PGDP property boundary, Little Bayou seeps, and the Ohio River.

Section 5 summarizes the modeling results documented by this appendix.

Table E.1.1. Modeling Matrix for Groundwater[a]

	Values for Soil to Protect Groundwater	Model	Point of Exposure	Notes
INVESTIGATION DOCUMENTS	Tier 1 Initial analysis used to identify COPCs that might migrate from source areas and require further fate and transport analysis.	Concentrations in source term are the maximum detected concentrations of contaminants in the source. Contaminant concentrations compared to site screening levels and groundwater protection values in Appendix A of the PGDP Methods Document.	At source unit.	Use dilution/attenuation factor (DAF) of 1 for site screening levels unless site-specific values are available. Groundwater Protection value based on residential use and targets of 1E-6, 0.1, and 1 for risk, hazard, and dose, respectively. If site-specific DAF values are used, then the groundwater protection value should be justified. The depth to groundwater will be considered in the calculation.
	Tier 2 Analysis is used to refine the list of COPCs that might migrate from source areas. Depending on the DQOs for the project, additional fate and transport analysis of selected COPCs might be completed.	Concentrations in source term for all contaminants are the lesser of the maximum and UCL95 concentration of the appropriate distribution. Fate and transport modeling completed using SESOIL and/or RESRAD.	At source unit.	Includes source delimitation. The analysis will recognize SESOIL limitations when modeling inorganic COPCs-refine K_ds.
DECISION DOCUMENTS	Tier 3 Analysis is used for COCs identified from Tier 2 modeling. Includes consideration of COC concentrations at downgradient locations. The results of this analysis may be used to develop clean-up levels for some COCs.	Source term developed using SADA. Fate and transport completed using SESOIL and RESRAD with AT123D.	At source unit and at downgradient exposure points. Exposure points are at the plant boundary, the property boundary, Little Bayou seeps, and the Ohio River.	Uses source delimitation and refined K_ds from previous tiers. Contaminant migration paths will be derived using the sitewide groundwater model. On the Terrace (southern portion of PGDP), different points of exposure will apply and be determined using the sitewide groundwater model.
	Tier 4 Analysis is used for the COCs presenting the greatest risk at downgradient exposure points. The results of this analysis may be used to develop clean-up levels for some COCs.	Source modeling and MODFLOW T	Down-gradient points Exposure points are at the plant boundary, the property boundary, Little Bayou Creek, and the Ohio River.	To be used to refine clean-up goals (if needed). On the Terrace (southern portion of PGDP), different points of exposure will apply and be determined using the sitewide groundwater model.

[a] Adapted from Table 3.2 of the PGDP Risk Methods Document (DOE/OR/07-1506&D2).

AT123D = Analytical Transient 1-, 2-, 3-Dimensional
COC = contaminant of concern
COPC = chemical of potential concern
DAF = dilution/attenuation factor
DQO = Data Quality Objective
K_d = distribution coefficient
RESRAD = Residual Radioactive Materials
SADA = Statistical Analysis and Decision Assistance
SESOIL = Seasonal Soil Compartment Model
UCL = upper confidence level

E.2. RESULTS FROM PREVIOUS MODELING EFFORTS

E.2.1 SUMMARY

Transport modeling results contained in previous investigations and risk assessments were examined to determine the types of models completed previously and the results of those modeling activities. All reports considered were from work completed between 1990 and 2004.

As part of this summary, previously completed transport models were categorized into one of the four modeling tiers described in Table 3.2 in the Risk Methods Document (DOE 2001). These tiers and their descriptions are as follows:

- Tier 1: Results are derived using simple comparisons between sampling results and soil screening levels for groundwater protection. No source-term calculations are performed. Results are used for scoping investigation activities. The POE considered is at the source unit.

- Tier 2: Results are derived using analytical models such as the Multimedia Environmental Pollutant Assessment System (MEPAS), Residual Radioactive Materials (RESRAD), SESOIL, and AT123D. Source-terms are conservatively derived by assuming that the source-term volume consists of all areas with a detected result and that the source-term concentration is equal to the maximum detected concentration over all samples. Results are used to determine if a response action should be considered for the source. The POE considered is at the source unit.

- Tier 3: Results are derived using analytical models such as MEPAS, RESRAD, SESOIL, and AT123D. Source-terms are less conservatively derived than under Tier 2 by using three-dimensional plots and/or computer programs that can perform geospatial modeling (e.g., SADA). The source concentration is assumed to be the average concentration over all detected concentrations within the source volume. Results are used in decision documents to select among possible response actions and to derive cleanup levels. The POEs considered are at the source unit and at downgradient points (e.g., the PGDP boundary, property boundary, and either Little Bayou Creek or the Ohio River).

- Tier 4: Results are derived using numerical models, such as MODFLOW T. Similar to Tier 3, source-terms are derived using three-dimensional plots and/or computer programs that can perform geospatial modeling. The source concentration is assumed to be the average concentration over all detected concentrations within the source volume. Results are used in decision documents to design a selected response action, such as in refining cleanup levels and selecting monitoring points. The POEs considered are at the source unit and at downgradient points (e.g., the PGDP boundary, property boundary, and either Little Bayou Creek or the Ohio River).

Generally, all previous modeling that has been performed for the burial grounds falls within Tier 2; however, in most cases, modeling to downgradient POEs (i.e., the PGDP boundary and/or property boundary) was included. Modeling to the downgradient points is similar to the Tier 3 requirement. No modeling to Little Bayou Creek or the Ohio River has been completed previously for the burial grounds.

Table E.2.1 and the following text summarizes previous modeling performed for each burial ground. No previous modeling has been performed for SWMU 145. All risk and hazard estimates presented are for hypothetical residential use of groundwater obtained from the Regional Gravel Aquifer (RGA) at locations such as the plant boundary and property boundary.

Table E.2.1. Summary of Previous Modeling Performed for Burial Grounds at PGDP

Unit	Tier/Model Used	Report	PGDP Boundary		Property Boundary		River/Little Bayou Creek Seeps	
			Total risk/hazard	COCs	Total risk/hazard	COCs	Total risk/hazard	COCs
SWMU 2	Tier 1—None	*Results of the Public Health and Ecological Assessment, Phase II, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* KY/SUB/13B-97777C P-03/1991/1, December 1991.	Not calculated; qualitative determination	TCE, ^{99}Tc, Beryllium, Chromium, Lead	Not calculated	NA	Not calculated	NA
	Tier 1—None	*Solid Waste Landfill Subsurface Investigation Report,* KY/ERWM-12, February 1994.	Not calculated; qualitative determination	^{99}Tc, Uranium, metals	Not calculated	NA	Not calculated	NA
	Tier 2—MEPAS	*Data Summary and Interpretation Report for Interim Remedial Design at Solid Waste Management Unit 2 of Waste Area Grouping 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-1549&D1, February 1997b.	VOCs Risk = 3E-05 Hazard = <1 Dose = NA Based on predicted maximum concentration at PGDP boundary at 35 years from present	TCE	Risk = 2E-05 Hazard = <1 Dose = NA Based on predicted maximum concentration at PGDP boundary 35 years from present	TCE	Not calculated	NA
			Metals Risk = 1E-05 Hazard = <1 Dose = NA Based on predicted maximum concentration at PGDP boundary at 1,505 years from present	Arsenic	Risk = 1E-05 Hazard = <1 Dose = NA Based on predicted maximum concentration at boundary at more than 1,000 years from present	Arsenic	Not calculated	NA
	Tier 2—SESOIL/ AT123D	*Sitewide Risk Assessment Model and Environmental Baseline for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-2104&D0, September 2003.	Not calculated	NA	Risk = 6E-03 Hazard = 1,000 Dose = <1 mrem/year	Risk: TCE, vinyl chloride, ^{99}Tc Hazard: *cis*-1,2-DCE; TCE	Not calculated	NA
SWMU 3	Tier 1—None	*Results of the Public Health and Ecological Assessment, Phase II, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* KY/SUB/13B-97777C P-03/1991 /1, December 1991.	Not calculated; qualitative determination	TCE, ^{99}Tc, Beryllium, Chromium, Lead	Not calculated	NA	Not calculated	NA

Table E.2.1 Summary of Previous Modeling Performed for Burial Grounds at PGDP (Continued)

Unit	Tier/Model Used	Report	PGDP Boundary		Property Boundary		River/Little Bayou Creek Seeps	
			Total risk/hazard	COCs	Total risk/hazard	COCs	Total risk/hazard	COCs
SWMU 3	Tier 2—SESOIL/AT123D	*Sitewide Risk Assessment Model and Environmental Baseline for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2104&D0, September 2003.	Not calculated	NA	Risk = 7E-06 Hazard = 2 Dose = <1 mrem/year	Risk: ^{99}Tc Hazard: naphthalene	Not calculated	NA
SWMU 4	Tier 2—MEPAS	*Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1895&D1, September 2000.	TCE and solvents Risk = 6E-02 Hazard = 2,000 (Assumed 100 years from present)	Risk: 1,1-DCE; TCE; vinyl chloride; carbon tetrachloride Hazard: 1,1-DCE; TCE	Not calculated; however, a comparison of concentrations indicates that risks and hazards would be about one order of magnitude less than those calculated for the PGDP boundary.	Assumed the same as PGDP boundary COCs	Not calculated	NA
			Metals and radionuclides Risk = 6E-03 Hazard = 400 (Assumed at >1,000 years from present)	Risk: Arsenic, ^{237}Np, ^{239}Pu, ^{99}Tc, ^{234}U, ^{235}U, ^{238}U Hazard: Arsenic, Cobalt, Copper, Iron, Manganese				
			Dose = Not calculated	NA				
	Tier 2—SESOIL/AT123D	*Sitewide Risk Assessment Model and Environmental Baseline for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2104&D0, September 2003.	Not calculated	NA	Risk = >1 Hazard = 2,000,000 Dose = 2 mrem/year	Risk: carbon tetrachloride; chloroform; 1,1-DCE; TCE; vinyl chloride; ^{99}Tc Hazard: carbon tetrachloride; chloroform; *cis*-1,2-DCE; *trans*-1,2-DCE; 1,1-DCE; TCE; vinyl chloride Dose: ^{99}Tc	Not calculated	NA

Table E.2.1 Summary of Previous Modeling Performed for Burial Grounds at PGDP (Continued)

Unit	Tier/Model Used	Report	PGDP Boundary		Property Boundary		River/Little Bayou Creek Seeps	
			Total risk/hazard	COCs	Total risk/hazard	COCs	Total risk/hazard	COCs
SWMU 5	Tier 2—MEPAS	*Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1895&D1, September 2000.	TCE and solvents Risk = <1E-06 Hazard = <1	Risk: none Hazard: none	Not calculated; however, a comparison of concentrations indicates that risks and hazards would be about one order of magnitude less than those calculated for the PGDP boundary.	Assumed the same as PGDP boundary COCs	Not calculated	NA
			Metals and radionuclides Risk = <1E-06 Hazard = 100 (Assumed at >1,000 years from present)	Risk: none Hazard: Iron, Manganese				
			Dose = Not calculated	NA				
	Tier 2—SESOIL/ AT123D	*Sitewide Risk Assessment Model and Environmental Baseline for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2104&D0, September 2003.	Not calculated	NA	Risk = 5E-03 Hazard = 100 Dose = <1 mrem/year	Risk: 1,1-DCE and ^{99}Tc Hazard: naphthalene Dose: None	Not calculated	NA
SWMU 6	Tier 2—MEPAS	*Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1895&D1, September 2000.	TCE and solvents Risk = <1E-06 Hazard = <1	Risk: none Hazard: none	Not calculated; however, a comparison of concentrations indicates that risks and hazards would be about one order of magnitude less than those calculated for the PGDP boundary.	Assumed the same as PGDP boundary COCs	Not calculated	NA
			Metals and radionuclides Risk = <1E-06 Hazard = 20 (Assumed at >1,000 years from present)	Risk: none Hazard: Iron				
			Dose = Not calculated	NA				
	Tier 2—SESOIL/ AT123D	*Sitewide Risk Assessment Model and Environmental Baseline for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2104&D0, September 2003.	Not calculated	NA	Risk = 3E-05 Hazard = <1 Dose = <1 mrem/year	Risk: ^{99}Tc Hazard: none Dose: none	Not calculated	NA
SWMU 7	Tier 1—None	*Results of the Public Health and Ecological Assessment, Phase II, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, KY/SUB/13B-97777C P-03/1991/1.	Not calculated; qualitative determination	TCE; 1,2-DCE; vinyl chloride; ^{99}Tc; Arsenic; Chromium; Nickel	Not calculated	NA	Not calculated	NA

Table E.2.1 Summary of Previous Modeling Performed for Burial Grounds at PGDP (Continued)

Unit	Tier/Model Used	Report	PGDP Boundary		Property Boundary		River/Little Bayou Creek Seeps	
			Total risk/hazard	COCs	Total risk/hazard	COCs	Total risk/hazard	COCs
SWMU 7	Tier 2—SESOIL/AT123D	*Remedial Investigation Report for Solid Waste Management Units 7 and 30 of Waste Area Grouping 22 at Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-1604&D2, January 1998.	Not calculated	NA	Risk = 2E-04 Hazard = <1 Dose = Not calculated (Results are for sources at both SWMUs 7 and 30 and are for 100 years from present.)	Risk: vinyl chloride, ^{99}Tc Hazard: none Dose: NA	Not calculated	NA
	Tier 3—SESOIL/AT123D	*Technetium-99 Transport Modeling Results for Sources at SWMUs 7 and 30 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* KY/EM-266, March 1998.	Risk = Not calculated Hazard = NA Dose = Not calculated [Results are maximum contribution from the incinerator area (Area Z) in SWMU 7]	Maximum concentration of ^{99}Tc was 63 pCi/L at 20 years from present	Risk = Not calculated Hazard = NA Dose = Not calculated [Results are maximum from the incinerator area (Area Z) in SWMU 7]	Maximum concentration of ^{99}Tc was 11 pCi/L at 25 years from present	Not calculated	NA
	Tier 2—SESOIL/AT123D	*Sitewide Risk Assessment Model and Environmental Baseline for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-2104&D0, September 2003.	Not calculated	NA	Risk = 8E-04 Hazard = 30 Dose = 11 mrem/year	Risk: benzene, chloroform, ethylbenzene, ^{99}Tc Hazard: Copper, benzene, naphthalene Dose: ^{99}Tc	Not calculated	NA
SWMU 30	Tier 1—None	*Results of the Public Health and Ecological Assessment, Phase II, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* KY/SUB/13B-97777C P-03/1991/1.	Not calculated; qualitative determination	TCE; 1,2-DCE; vinyl chloride; ^{99}Tc; Arsenic; Chromium; Nickel	Not calculated	NA	Not calculated	NA
	Tier 2—SESOIL/AT123D	*Remedial Investigation Report for Solid Waste Management Units 7 and 30 of Waste Area Grouping 22 at Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-1604&D2, January 1998.	Not calculated	NA	Risk = 2E-04 Hazard = <1 Dose = Not calculated (Results are for sources at both SWMUs 7 and 30 and are for 100 years from present.)	Risk: vinyl chloride, ^{99}Tc Hazard: none Dose: NA	Not calculated	NA

Table E.2.1. Summary of Previous Modeling Performed for Burial Grounds at PGDP (Continued)

Unit	Tier/Model Used	Report	PGDP Boundary		Property Boundary		River/Little Bayou Creek Seeps	
			Total risk/hazard	COCs	Total risk/hazard	COCs	Total risk/hazard	COCs
SWMU 30	Tier 3—SESOIL/AT123D	*Technetium-99 Transport Modeling Results for Sources at SWMUs 7 and 30 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, KY/EM-266, March 1998.	Risk = Not calculated Hazard = NA Dose = Not calculated (Results are maximum contribution from Pits B/C in SWMU 30.)	Maximum concentration of ^{99}Tc was 122 pCi/L at 20 years from present	Risk = Not calculated Hazard = NA Dose = Not calculated (Results are maximum contribution from Pits B/C in SWMU 30.)	Maximum concentration of ^{99}Tc was 21 pCi/L at 25 years from present	Not calculated	NA
	Tier 2—SESOIL/AT123D	*Sitewide Risk Assessment Model and Environmental Baseline for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2104&D0, September 2003.	Not calculated	NA	Risk = 3E-04 Hazard = 8 Dose = 5 mrem/year	Risk: ^{99}Tc Hazard: naphthalene Dose: ^{99}Tc	Not calculated	NA

COC = contaminant of concern
DCE = dichloroethene
MEPAS = Multimedia Environmental Pollutant Assessment System
mrem = millirem
NA = Not applicable
^{237}Np = neptunium-237
^{239}Pu = Plutonium-239
SESOIL = Seasonal Soil Compartment Model
^{99}Tc = technetium-99
TCE = trichloroethene
^{234}U = uranium-234
^{235}U = uranium-235
^{238}U = uranium-238
VOC = volatile organic compound

More modeling results are available for SWMU 2 than other BGOU SWMUs; however, no modeling has extended to Tier 3. Tier 2 modeling results, which have included modeling to the PGDP boundary and property boundary POEs, have concluded that this unit may be a potential contributor of trichloroethene (TCE) and other volatile organic compounds (VOCs) to groundwater. In addition, this unit may be a contributor of technetium-99 (^{99}Tc), but the risks due to ^{99}Tc levels are two orders of magnitude less (i.e., equal to 3E-05) than those from solvents (5E-03). It is unlikely that this unit is a contributor of metals to groundwater, and an extensive analysis in *Data Summary and Interpretation Report for Interim Remedial Design at Solid Waste Management 2 of Waste Area Grouping 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1549&D1, (DOE 1997) determined that the uranium metal present in the burial ground is unlikely to contribute to groundwater contamination.

SWMU 3 may contribute contaminants to groundwater; however, no modeling has extended to Tier 3. Tier 2 modeling results, at the property boundary POE, have concluded that this unit is a minor contributor of ^{99}Tc to groundwater (Risk = 7E-06). Naphthalene also has been identified as a contaminant of concern (COC) (for hazard), but this result is suspect due to conservative source-term development. This unit has not been shown to be a contributor of metals to groundwater.

SWMU 4 previous modeling identified a risk over 1 and hazard over 2,000,000 at the property boundary POE using Tier 2 modeling. The maximum risks are predicted to be from chloroform (> 1), 1,1-DCE (3.98E-01), carbon tetrachloride (1.22E-01), TCE (2.37E-02), and vinyl chloride (1.46E-02). The maximum hazards are predicted to be from chloroform (1,710,000), *cis*-1,2-DCE (789,000), *trans*-1,2-DCE (16,900), and carbon tetrachloride (11,600) (DOE 2003a). COCs include VOCs [TCE; 1,1-dichloroethene (DCE); vinyl chloride; 1,2-DCE; carbon tetrachloride, and chloroform], metals (arsenic, cobalt, copper, iron, and manganese), and radionuclides [neptunium-237 (^{237}Np), plutonium-239 (^{239}Pu), ^{99}Tc, uranium-234 (^{234}U), uranium-235 (^{235}U), and uranium-238 (^{238}U)]. Although Tier 2 modeling derived elevated risk and hazard, these results are highly uncertain because of the conservative source term used in the modeling.

SWMU 5 previous modeling identified COCs for risk as 1,1-DCE and ^{99}Tc and identified COCs for hazard as naphthalene, Mn, and Fe. Although Tier 2 modeling derived an elevated risk (5E-05) and hazard (100), these results are highly uncertain due to the conservative Tier 2 source-term used in the modeling.

SWMU 6 Tier 2 modeling derived elevated risk from ^{99}Tc (3E-05) and hazard from iron (20); however, these results are highly uncertain due to the conservative source-term used in the modeling.

SWMU 7 may contribute contaminants to groundwater; however, Tiers 2 and 3 modeling results indicate that the contamination contributed is probably not significant. While early Tier 2 modeling identified SWMU 7 as a potential source of ^{99}Tc and vinyl chloride, later Tier 3 modeling determined that the level of ^{99}Tc that might reach a receptor at the PGDP boundary or property boundary (maximum of 63 and 11 pCi/L) is well below the Maximum Contaminant Level (MCL) (900 pCi/L). Later Tier 2 modeling (i.e., that from the sitewide risk model) did identify additional COCs; however, this result is highly uncertain given the conservative source-term used.

SWMU 30 may contribute contaminants to groundwater; however, Tiers 2 and 3 modeling results indicate that the contamination contributed probably is not significant. While early Tier 2 modeling identified SWMU 30 as a potential source of ^{99}Tc and vinyl chloride; later Tier 3 modeling determined that the level of ^{99}Tc that might reach a receptor at the PGDP boundary or property boundary (maximum of 122 and 21 pCi/L) is well below the MCL (900 pCi/L). Later Tier 2 modeling (i.e., that from the sitewide risk model) did identify ^{99}Tc as an important COC; however, this result is highly uncertain given the conservative source-term used.

Attachment E.1 provides more detailed summaries and excerpts of reports of previous modeling for the BGOU RI SWMUs.

E.3. MODELING COMPLETED AS PART OF BGOU RI

E.3.1 GROUNDWATER MODELING

The BGOU RI performed fate and transport modeling using the SADA, SESOIL, MODFLOW/MODPATH, and AT123D models. In general, the selected POEs where groundwater concentrations of the analytes were estimated were below the SWMU, at the plant boundary, at the property boundary, at the Little Bayou seeps, and the Ohio River; however, not all SWMUs have transport pathways to all of the POEs. For example, SWMU 145 is located outside of the plant boundary and does not contribute to the Little Bayou seeps.

Modelers used the following approach to evaluate the migration of the selected analytes from the BGOU SWMUs to groundwater and subsequently to the POEs.

1. Develop a conceptual model of each SWMU including estimated depths to the RGA and the derived flow paths and distances to the POEs using MODFLOW/MODPATH and the PGDP sitewide groundwater model.

2. Refine the source zones for each analyte in a SWMU using the SADA model.

3. Perform leachate modeling using SESOIL to estimate the rate of contaminant loading over time from each source area in a SWMU.

4. Perform saturated flow and transport modeling with AT123D using contaminant loading information from SESOIL.

Contaminant migration may have impacted three hydrogeologic units underlying the source areas at the SWMUs comprising the BGOU. These units, which control the flow of groundwater and contaminant migration at these SWMU source areas, are as follows (in descending order):

1. Upper Continental Recharge System (UCRS)–approximately 60 ft of silt and clay with horizons of sand and gravel;

2. RGA–approximately 40 ft of gravel, sand, and silt deposits that overlie the McNairy Formation; and

3. McNairy Formation–approximately 225 ft of sand and silt with some clay.

Previous work has shown that groundwater flow in the UCRS is primarily vertical and that the lateral groundwater flow in the McNairy is significantly slower than that in the RGA. The primary contaminant pathway considered in the fate and transport modeling is vertical migration through the UCRS followed by lateral migration in the RGA to the POEs.

SADA. Spatial Analysis and Decision Assistance model (UT 2005) was used to estimate the source volumes of analytes from the sample results through geospatial interpolation techniques. (See Attachment E.1 for additional information on source delineation). Surface and subsurface sampling results were taken from the Paducah Oak Ridge Environmental Information System (Paducah OREIS). The limitations of

this data include the lack of sampling results for the waste, which may exhibit higher concentrations than the surrounding soil samples. In addition, a portion of the waste is contained in drums at several SWMUs which was not modeled in this report. The limitations of the data used in the analyses are presented in detail in Section E.3.3. Information for each result included the sample and station identifier, the date of sample collection, the location and depth at which the sample was taken, whether the analyte was detected or not detected at the sample quantitation limit (SQL), and the result. The results initially were screened against the risk-based SSLs for protection of RGA groundwater for significant analytes at PGDP contained in the Risk Methods Document (DOE 2001) (see Appendix F).

Modelers divided each analyte source area into rows and columns with a uniform spacing of 20 ft for SWMUs 2, 3, 4, 5, 6, 7, and 30 and a uniform spacing of 100 ft for SWMU 145. Multiple domains with varying depths were used to characterize the analyte source areas vertically in relation to the existing aquifers; therefore, the domain was further discretized into horizontal layers. analyte results for each domain were compiled, and analyte concentrations in each cell of the domain were predicted using geospatial interpolation (see Appendix E Attachment 2 for details).

The techniques in SADA that can be used for source term development in a three-dimensional system are nearest neighbor, inverse distance, and kriging. The nearest neighbor technique was selected for source zone refinement because it yielded results that were most compatible with the conceptual site model of contaminant release, as described in Attachment 2 to Appendix E.

As shown in the source term tables of following sections, the size of sources varied between the layers. The SESOIL input parameter for contaminant sources allows only one value for the source area; therefore, for each contaminant, the area of the SADA layer with the highest contaminant mass was used as the SESOIL input for source zone area. The analyte concentrations in the other layers were normalized to the area of the layer with the maximum mass.

SESOIL. Seasonal Soil Compartment Model (Bonazountas and Wagner 1984) was used for leachate modeling. SESOIL estimates contaminant concentrations in the soil profile following introduction via direct application and/or interaction with other media. The model defines the soil compartment as a soil column extending from the ground surface through the unsaturated zone to the top of the saturated soil zone/water table. Processes simulated in SESOIL are categorized in three cycles—the hydrologic cycle, sediment cycle, and pollutant cycle. Each cycle is a separate submodule in the SESOIL code. The hydrologic cycle includes rainfall, surface runoff, infiltration, soil-water content, evapotranspiration, and groundwater recharge. The sediment cycle includes sediment washload as a result of rainstorms (i.e., soil erosion that results from surface runoff). The pollutant cycle includes convective transport, volatilization, adsorption/desorption, and degradation/decay. A contaminant in SESOIL can partition in up to four phases (liquid, adsorbed, air, and pure). Output of the SESOIL model includes contaminant concentrations at various soil depths and contaminant loss from the unsaturated soil zone in terms of surface runoff, percolation to groundwater, volatilization, and degradation. SESOIL predicts the monthly contaminant load to the water table from the area of concern that can be directly input into the AT123D model for contaminant migration in the saturated zone to selected downgradient POEs.

The hydrologic modeling parameter values used in the SESOIL modeling were based on representative conditions at the PGDP and site specific values for the individual SWMU (Table E.3.1). The modeling parameters were selected so that they could account for expected variability in the hydraulic system and would be unlikely to underestimate contaminant release and transport. However, SESOIL does have limitations in regard to modeling waste that may potentially be located in the water table in the UCRS and contaminant transformations such as that resulting from radionuclide decay. These issues and their contribution to the uncertainty in the analyses are addressed in Section E.3.3.

Table E.3.1. Soil Parameters Used in SESOIL Modeling for the BGOU RI

Input Parameter	Value	Source
Soil type	Silty clay	PGDP site-specific
Bulk density (g/cm3)	1.46	Laboratory analysis
Percolation rate (cm/year)	11	PGDP calibrated model
Intrinsic permeability (cm2)	1.6E-10	Calibrated
Disconnectedness index	10	Calibrated
Porosity	0.45	Laboratory analysis
Depth to water table (m)		Site specific (to RGA) based on field observation
SWMU 2	19.5	
SWMU 3	19.8	
SWMU 4	19.2	
SWMU 5	18.3	
SWMU 6	19.2	
SWMU 7	18.3	
SWMU 30	18.6	
SWMU 145	17.7	
Fraction of organic carbon (%)	0.08	Laboratory analysis
Frendlich equation exponent	1	SESOIL default value

The chemical-specific parameters used in the SESOIL modeling included each analyte's solubility in water, organic carbon partition coefficient (K_{oc}), Henry's Law constant, distribution coefficient (K_d), diffusion coefficients in air and water, and, for TCE and radionuclides, degradation rate constant. The chemical-specific parameters are presented for each SWMU analyte in Sections E.3.1.1 through E.3.1.8. The K_d values for organic compounds were derived using the following relationship.

$$K_d = K_{oc} \times f_{oc}$$

where: K_d is the distribution coefficient,

K_{oc} is the organic carbon partition coefficient, and

f_{oc} is the fraction of organic carbon for source area soils.

The f_{oc} used for the unsaturated zone at PGDP was 0.08 (DOE 1998a).

AT123D. AT123D Simulation of Waste Transport in the Aquifer System (Yeh 1981) was used for saturated flow and contaminant transport modeling. AT123D computes the spatial-temporal concentration distribution of chemicals in the aquifer system and predicts the transient spread of a chemical plume through a groundwater aquifer. The fate and transport processes accounted for in AT123D are advection, dispersion, adsorption/retardation, and decay. This model can be used as a tool for estimating the dissolved concentration of a chemical in three dimensions in the groundwater resulting from a mass release (either continuous or instant or depleting source) from a source. In the present modeling, the time varying mass loading was transferred from the SESOIL output file, and the concentrations of analytes were estimated at the selected POEs. The chemical-specific parameters match those used in SESOIL modeling, except no degradation of TCE was assumed in the RGA. The chemical-specific parameters are presented for each SWMU analyte in Sections E.3.1.1 through E.3.1.8. Excluding the distance to the POEs, Table E.3.2 presents the hydrogeologic parameters used for saturated flow and contaminant transport modeling for the BGOU RI. The AT123D flow model was abstracted from the calibrated flow model of the site developed in MODFLOW by using the flow parameters for hydraulic gradients and hydraulic conductivities of the RGA from the numerical model as described below.

Table E.3.2. Hydrogeologic Parameters Used in AT123D Modeling for the BGOU RI

Input Parameter	Value	Source
Bulk density (kg/m3)	1,670	Laboratory analysis
Effective porosity	0.3	PGDP sitewide model calibrated value
Hydraulic conductivity (m/hour)		PGDP sitewide model calibrated value
SWMUs 2, 3, 4, 5, 6, 7, and 30	19.05	
SWMU 145	6.35	
Hydraulic gradient (m/m)		PGDP sitewide model calibrated value
SWMUs 2 and 3	0.0002	
SWMU 4	0.0002	
SWMU 5	0.0002	
SWMUs 6 and 145	0.0008	
SWMU 7	0.0003	
SWMU 30	0.00036	
Aquifer thickness	9.14 m 30 ft	Site average
Longitudinal dispersivity (m)	15	Approximate values used in the past
Density of water (kg/m3)	1,000	Default
Fraction of organic carbon (%)	0.02[a]	Laboratory analysis
Source Area	Variable	These dimensions were derived from the SADA analysis for each analyte.

[a] UCRS soils were assigned an f_{oc} value of 0.08% while the RGA was assigned an f_{oc} value of 0.02%

MODFLOW/MODPATH. The U.S. Geological Survey's Modular Three-Dimensional Finite-Difference Ground-Water Model/A Particle-Tracking Postprocessor Model for MODFLOW (USGS 2005) computer codes were used to evaluate the particle tracks from selected BGOU SWMUs and to determine the distances to the POEs, hydraulic gradients, and hydraulic conductivities of the RGA for input into the AT123D model. Figure E.3.1 shows MODPATH particle tracks for all of the BGOU SWMUs.

E.3.1.1 SWMU 2

The C-749 Uranium Burial Ground (SWMU 2) is located within the west-central section of the plant. SWMU 2 was used from 1951 to 1977 for the disposal of uranium and uranium-contaminated wastes. Disposal records for SWMU 2 indicate that 270 tons of uranium, 59,000 gal of oils, and 450 gal of TCE were disposed of in the unit (DOE 1999a).

E.3.1.1.1 Conceptual model for source areas at SWMU 2

SWMU 2 occupies an area of approximately 32,000 ft^2 (0.73 acres); with approximate dimensions of 160 ft by 200 ft. The thickness of the UCRS is estimated to be 64 ft (depth to the top of the RGA). The primary waste at SWMU 2 consists of uranium and uranium alloys, placed in pits that were excavated to depths of 7 to 17 ft. Other wastes at the unit consist of uranyl fluoride and TCE.

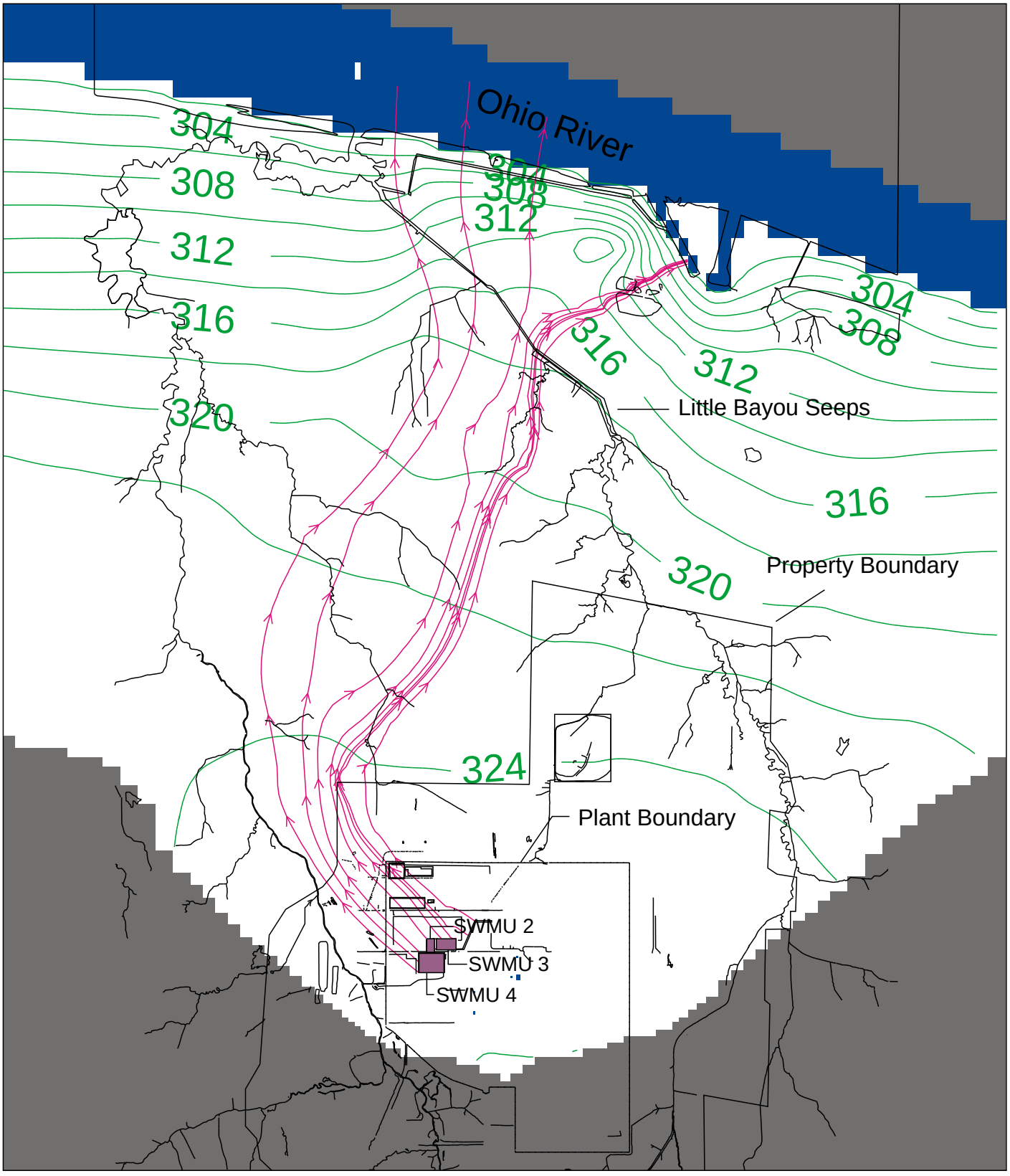


Figure E.3.1. Particle Tracking Results for SWMUss 2, 3, and 4

The uranium buried at PGDP most likely is in the metallic state or is coated with uranium (IV) oxide. Neither of these forms of uranium is very susceptible to leaching. The kinetics of dissolution of the buried metal and uranium (IV) oxide is controlled by the amount of oxygen and carbon dioxide that leaches through the waste. Site records show that much of the metal was coated with oil. Petroleum-based oils are resistant to chemical and biological degradation and from leaching by percolating waters. In addition, oils consume oxygen as they slowly degrade, which lowers the oxidation-reduction potential. Under such conditions, uranium dissolution is negligible (ORNL 1998).

The conceptual model for SWMU 2 is that contaminants in the disposal site directly impacted soils below and adjacent to the areas where the material was buried and, through vertical infiltration in soil, potentially may impact the groundwater underlying these sources. The infiltrating groundwater migrates vertically through the UCRS and laterally in the RGA, which could transport the contaminants to the POEs.

E.3.1.1.2 Contaminant transport modeling for SWMU 2 using SESOIL and AT123D

SESOIL allows for the input of 4 soil layers with up to 10 sublayers within each soil layer for contaminant source input. For this modeling effort, the soil zones were arranged in four layers. The first soil layer represented the SADA surface soil data from 0 to 1 ft deep. The second soil layer was 9 ft thick representing SADA layer 2 from 1 to 9 ft in depth, the third layer was subdivided into 4 sublayers of equal thickness (10 ft each) representing SADA layers 3 through 6. SESOIL soil layer 4 was subdivided into 4 sublayers of equal thickness (3.5 ft each) to represent the total thickness of SADA layer 7 from 50 ft to 64 ft in depth. Figure E.3.2 provides an illustration of the SADA and SESOIL contaminant loading layers. Table E.3.3 presents the analytes remaining after the screening process and the source terms for each analyte source zone at SWMU 2. Table E.3.4 lists the chemical-specific parameters applicable to the SESOIL model of SWMU 2. The distances to the POEs used in the AT123D model for SWMU 2 are 1,528 ft to the plant boundary, 3,753 ft to the property boundary, and 21,126 ft to the Ohio River. SWMU 2 particle tracks do not travel to the Little Bayou seeps.

E.3.1.1.3 Groundwater modeling results for SWMU 2

Table E.3.5 summarizes the predicted maximum groundwater concentrations at the POEs for the analytes modeled at SWMU 2. These contaminants were predicted by SESOIL to reach the water table within the 1,000 year period in concentrations that were greater then the groundwater background or greater than the groundwater child no action levels. Several contaminants that originally passed the screening for groundwater did not reach the water table in 1,000 years [i.e., antimony, benzo(a)pyrene, mercury, nickel, ^{235}U, and vanadium] or exhibited groundwater concentrations that were less than the groundwater background or the groundwater child no action levels (i.e., zinc) (see Section 5.4 of the main text). PCB-1254 was detected at SWMU 2 in five samples; however it did not pass the initial screening for analytes.

As shown in Table E.3.5, the predicted maximum groundwater concentrations of *cis*-1,2-DCE and TCE at the plant boundary, property boundary, and Ohio River are predicted to exceed the MCL in the future. None of the other analytes are expected to attain concentrations that exceed their respective MCLs at any of the POEs.

SESOIL LAYER	SESOIL SUB LAYER	SADA LAYER
1 (0-1 ft)	1 (1 ft)	L1
2 (1-10 ft)	1 (9 ft)	L2
3 (10-50 ft)	1 (10 ft)	L3
	2 (10 ft)	L4
	3 (10 ft)	L5
	4 (10 ft)	L6
4 (50-64 ft)	1 (3.5 ft)	L7
	2 (3.5 ft)	
	3 (3.5 ft)	
	4 (3.5 ft)	

Figure E.3.2. Conceptualization of the SADA and SESOIL Layers for Contaminant Loading

Table E.3.3. Summary of Source Term Characteristics Developed by SADA for SWMU 2

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Antimony			
L1	0-1	11.60	1.77E+05	1.77E+05	8.48E+04	1.15	13.28
L2	01-10	10.05	1.54E+05	1.54E+06	6.41E+05	1.00	10.05
L3	10-20	0.00	0.00	0.00	0.00	0.00	0.00
L4	20-30	0.00	0.00	0.00	0.00	0.00	0.00
L5	30-40	0.00	0.00	0.00	0.00	0.00	0.00
L6	40-50	0.00	0.00	0.00	0.00	0.00	0.00
L7	50-64	0.00	0.00	0.00	0.00	0.00	0.00
			Total Mass		7.26E+05		
				Arsenic			
L1	0-1	22.10	4.80E+04	4.80E+04	4.39E+04	1.21	26.79
L2	01-10	8.36	3.96E+04	3.96E+05	1.37E+05	1.00	8.36
L3	10-20	6.85	3.96E+04	4.36E+05	1.23E+05	1.00	6.85
L4	20-30	5.77	3.96E+04	4.36E+05	1.04E+05	1.00	5.77
L5	30-40	6.47	3.96E+04	4.36E+05	1.16E+05	1.00	6.47
L6	40-50	5.87	3.96E+04	4.36E+05	1.06E+05	1.00	5.87
L7	50-64	4.92	3.96E+04	3.56E+05	7.26E+04	1.00	4.92
			Total Mass		7.03E+05		
				Benzo(a)pyrene			
L1	0-1	0.14	1.88E+04	1.88E+04	1.09E+02	1.00	0.14
L2	01-10	0.00	0.00	0.00	0.00	0.00	0.00
L3	10-20	0.00	0.00	0.00	0.00	0.00	0.00
L4	20-30	0.00	0.00	0.00	0.00	0.00	0.00
L5	30-40	0.00	0.00	0.00	0.00	0.00	0.00
L6	40-50	0.00	0.00	0.00	0.00	0.00	0.00
L7	50-64	0.00	0.00	0.00	0.00	0.00	0.00
			Total Mass		1.09E+02		
				***cis*-1,2-DCE**			
L1	0-1	0.00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
L2	01-10	1.06	1.64E+04	1.64E+05	7.17E+03	2.41	2.55
L3	10-20	114.72	6.80E+03	7.48E+04	3.55E+05	1.00	114.72
L4	20-30	70.45	9.60E+03	1.06E+05	3.08E+05	1.41	99.46
L5	30-40	80.50	8.40E+03	9.24E+04	3.08E+05	1.24	99.44
L6	40-50	44.87	1.16E+04	1.28E+05	2.37E+05	1.71	76.54
L7	50-64	37.17	1.12E+04	1.01E+05	1.55E+05	1.65	61.22
			Total Mass		1.37E+06		
				Manganese			
L1	0-1	372.83	4.80E+04	4.80E+04	7.40E+05	1.21	451.92
L2	01-10	369.68	3.96E+04	3.96E+05	6.05E+06	1.00	369.68
L3	10-20	386.99	3.96E+04	4.36E+05	6.97E+06	1.00	386.99
L4	20-30	378.32	3.96E+04	4.36E+05	6.81E+06	1.00	378.32
L5	30-40	377.03	3.96E+04	4.36E+05	6.79E+06	1.00	377.03
L6	40-50	316.18	3.96E+04	4.36E+05	5.69E+06	1.00	316.18
L7	50-64	277.65	3.96E+04	3.56E+05	4.09E+06	1.00	277.65
			Total Mass		3.71E+07		

Table E.3.3. Summary of Source Term Characteristics Developed by SADA for SWMU 2 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Mercury			
L1	0-1	0.29	3.72E+04	3.72E+04	4.41E+02	1.00	0.29
L2	01-10	0.02	1.60E+03	1.60E+04	1.19E+01	0.04	0.0008
L3	10-20	0.02	8.00E+02	8.80E+03	6.18E+00	0.02	0.0004
L4	20-30	0.02	8.00E+02	8.80E+03	6.18E+00	0.02	0.0004
L5	30-40	0.00	0.00	0.00	0.00	0.00	0.00
L6	40-50	0.00	0.00	0.00	0.00	0.00	0.00
L7	50-64	0.00	0.00	0.00	0.00	0.00	0.00
			Total Mass		4.65E+02		
				Napthalene			
L1	0-1	0.27	3.72E+04	3.72E+04	4.17E+02	1.00	0.27
L2	01-10	0.00	0.00	0.00	0.00	0.00	0.00
L3	10-20	0.00	0.00	0.00	0.00	0.00	0.00
L4	20-30	0.00	0.00	0.00	0.00	0.00	0.00
L5	30-40	0.00	0.00	0.00	0.00	0.00	0.00
L6	40-50	0.00	0.00	0.00	0.00	0.00	0.00
L7	50-64	0.00	0.00	0.00	0.00	0.00	0.00
			Total Mass		4.17E+02		
				Nickel			
L1	0-1	29.10	4.80E+04	4.80E+04	5.77E+04	1.32	38.37
L2	01-10	11.31	3.56E+04	3.56E+05	1.66E+05	0.98	11.06
L3	10-20	11.97	3.64E+04	4.00E+05	1.98E+05	1.00	11.97
L4	20-30	10.76	3.20E+04	3.52E+05	1.57E+05	0.88	9.46
L5	30-40	10.88	3.28E+04	3.61E+05	1.62E+05	0.90	9.81
L6	40-50	10.95	2.92E+04	3.21E+05	1.45E+05	0.80	8.78
L7	50-64	10.04	2.88E+04	2.59E+05	1.08E+05	0.79	7.94
			Total Mass		9.94E+05		
				^{99}Tc			
L1	0-1	1.82	5.20E+04	5.20E+04	3.92E+09	1.67	3.04
L2	01-10	0.58	3.12E+04	3.12E+05	7.44E+09	1.00	0.58
L3	10-20	0.32	1.96E+04	2.16E+05	2.86E+09	0.63	0.20
L4	20-30	0.10	1.68E+04	1.85E+05	7.80E+08	0.54	0.06
L5	30-40	0.16	1.20E+04	1.32E+05	8.59E+08	0.38	0.06
L6	40-50	0.07	1.72E+04	1.89E+05	5.42E+08	0.55	0.04
L7	50-64	0.07	1.32E+04	1.19E+05	3.27E+08	0.42	0.03
			Total Mass		1.67E+10		
				TCE			
L1	0-1	0.00	0.00E+00	0.00E+00	0.00E+00		
L2	01-10	0.13	9.60E+03	9.60E+04	5.11E+02	1.04	0.13
L3	10-20	42.65	9.20E+03	1.01E+05	1.78E+05	1.00	42.65
L4	20-30	24.28	1.16E+04	1.28E+05	1.28E+05	1.26	30.61
L5	30-40	14.58	1.16E+04	1.28E+05	7.69E+04	1.26	18.39
L6	40-50	8.94	1.28E+04	1.41E+05	5.20E+04	1.39	12.44
L7	50-64	0.20	1.08E+04	9.72E+04	8.06E+02	1.17	0.24
			Total Mass		4.37E+05		

Table E.3.3. Summary of Source Term Characteristics Developed by SADA for SWMU 2 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				^{234}U			
L1	0-1	16.01	5.20E+04	5.20E+04	3.44E+10	1.25	20.01
L2	01-10	14.33	4.16E+04	4.16E+05	2.46E+11	1.00	14.33
L3	10-20	0.81	4.28E+04	4.71E+05	1.57E+10	1.03	0.83
L4	20-30	0.76	4.04E+04	4.44E+05	1.39E+10	0.97	0.73
L5	30-40	0.83	4.12E+04	4.53E+05	1.56E+10	0.99	0.82
L6	40-50	0.72	4.08E+04	4.49E+05	1.34E+10	0.98	0.71
L7	50-64	0.64	4.20E+04	3.78E+05	9.92E+09	1.01	0.64
			Total Mass		3.49E+11		
				^{235}U			
L1	0-1	2.73	5.20E+04	5.20E+04	5.86E+09	1.30	3.55
L2	01-10	3.43	4.00E+04	4.00E+05	5.67E+10	1.00	3.43
L3	10-20	0.09	4.00E+04	4.40E+05	1.72E+09	1.00	0.09
L4	20-30	0.08	4.00E+04	4.40E+05	1.48E+09	1.00	0.08
L5	30-40	0.07	4.00E+04	4.40E+05	1.34E+09	1.00	0.07
L6	40-50	0.07	4.00E+04	4.40E+05	1.27E+09	1.00	0.07
L7	50-64	0.00	0.00	0.00	0.00E+00	0.00	0.00
			Total Mass		6.83E+10		
				^{238}U			
L1	0-1	88.34	5.20E+04	5.20E+04	1.90E+11	1.25	110.43
L2	01-10	83.85	4.16E+04	4.16E+05	1.44E+12	1.00	83.85
L3	10-20	1.49	4.28E+04	4.71E+05	2.90E+10	1.03	1.53
L4	20-30	1.10	4.04E+04	4.44E+05	2.02E+10	0.97	1.07
L5	30-40	1.02	4.12E+04	4.53E+05	1.92E+10	0.99	1.01
L6	40-50	0.88	4.08E+04	4.49E+05	1.64E+10	0.98	0.87
L7	50-64	0.71	4.20E+04	3.78E+05	1.11E+10	1.01	0.71
			Total Mass		1.73E+12		
				Uranium			
L1	0-1	167.67	4.80E+04	4.80E+04	3.33E+05	7.06	1,183.53
L2	01-10	798.80	6.80E+03	6.80E+04	2.25E+06	1.00	798.80
L3	10-20	14.51	8.80E+03	9.68E+04	5.81E+04	1.29	18.78
L4	20-30	18.13	1.44E+04	1.58E+05	1.19E+05	2.12	38.39
L5	30-40	13.60	1.12E+04	1.23E+05	6.93E+04	1.65	22.40
L6	40-50	12.45	8.00E+03	8.80E+04	4.53E+04	1.18	14.65
L7	50-64	5.79	9.20E+03	8.28E+04	1.98E+04	1.35	7.84
			Total Mass		2.89E+06		
				Vanadium			
L1	0-1	28.55	4.80E+04	4.80E+04	5.67E+04	1.26	36.06
L2	01-10	19.14	3.80E+04	3.80E+05	3.01E+05	1.00	19.14
L3	10-20	20.37	3.80E+04	4.18E+05	3.52E+05	1.00	20.37
L4	20-30	17.44	3.80E+04	4.18E+05	3.01E+05	1.00	17.44
L5	30-40	17.44	3.96E+04	4.36E+05	3.14E+05	1.04	18.17
L6	40-50	16.62	3.96E+04	4.36E+05	2.99E+05	1.04	17.32
L7	50-64	15.05	3.96E+04	3.56E+05	2.22E+05	1.04	15.68
			Total Mass		1.85E+06		

Table E.3.3. Summary of Source Term Characteristics Developed by SADA for SWMU 2 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Zinc			
L1	0-1	104.88	4.80E+04	4.80E+04	2.08E+05	1.00	104.88
L2	01-10	32.00	3.20E+03	3.20E+04	4.23E+04	0.07	2.13
L3	10-20	35.78	4.00E+03	4.40E+04	6.51E+04	0.08	2.98
L4	20-30	34.70	3.20E+03	3.52E+04	5.05E+04	0.07	2.31
L5	30-40	35.30	4.80E+03	5.28E+04	7.71E+04	0.10	3.53
L6	40-50	35.72	4.80E+03	5.28E+04	7.80E+04	0.10	3.57
L7	50-64	34.10	4.80E+03	4.32E+04	6.09E+04	0.10	3.41
			Total Mass		5.82E+05		

[a] Radionuclides are in units of pCi/g for concentrations and pCi for mass.

Table E.3.4. Chemical-Specific Parameters of the Analytes Used in SESOIL Modeling of SWMU 2

Analyte	Mol. Wt. (MW) (g/mol)	Solubility in water (mg/L)	Diffusion in air (cm^2/s)	Diffusion in water (m^2/hr)	Henry's Constant (atm.m3/mol)	Koc (L/kg)	Kd[a] (L/kg)	Half Life (years)
Antimony	121.75	1.00E+07	NA	3.60E-07	NA	NA	45	infinite
Arsenic	74.92	1.00E+07	NA	3.60E-07	NA	NA	29	infinite
Benzo(a)pyrene	252.32	1.62E-03	4.3E-02	3.24E-06	1.13E-06	9.69E+05	772	infinite
cis-1,2-DCE	96.94	3.50E+03	0.07	4.07E-06	4.08E-03	35.5	0.028	infinite
Manganese	54.94	1.00E+07	NA	1.29E-07	NA	NA	65	infinite
Mercury	200.59	6.00E-02	3.07E-02	2.27E-06	2.44E-02	NA	52	infinite
Naphthalene	128.16	31.0	0.059	2.70E-06	4.83E-04	1.19E+03	0.95	infinite
Nickel	58.69	1.00E+07	NA	3.60E-07	NA	NA	300	infinite
^{99}Tc	99	1.00E+07	NA	3.60E-07	NA	NA	0.2	2.13E+05
TCE	131	1,100	0.08	3.28E-06	0.0103	94	0.0752	26.6
^{234}U	234	1.00E+07	NA	3.60E-07	NA	NA	66.8	2.44E+05
^{235}U	235	1.00E+07	NA	3.60E-07	NA	NA	66.8	7.04E+08
^{238}U	238	1.00E+07	NA	3.60E-07	NA	NA	66.8	4.47E+09
Uranium	238	1.00E+07	NA	3.60E-07	NA	NA	66.8	4.47E+09
Vanadium	50.94	1.00E+07	NA	3.60E-07	NA	NA	1,000	infinite
Zinc	67.41	1.00E+07	NA	3.60E-07	NA	NA	62	infinite

[a] The soil/water distribution coefficient (Kd) of an organic compound depends on the soil's organic content (f_{oc}) and compound's organic partition coefficient (Koc). Kd values presented for organic compounds are for UCRS soils (with f_{oc} value of 0.08%) only. Kds used in AT123D are different due to the f_{oc} of 0.02% in the RGA.

Table E.3.5. Concentrations of the Analytes in Groundwater Predicted in SESOIL and AT123D Modeling of SWMU 2

Analyte	Predicted Maximum Groundwater Concentration[a,b]				
	SWMU (mg/L)	Plant Boundary (mg/L)	Property Boundary (mg/L)	Ohio River (mg/L)	MCL (mg/L)
Arsenic	***3.54E-02***	2.91E-03	8.35E-09	0	0.01
cis-1,2-DCE	***1.15E+01***	***1.74E+00***	***8.58E-01***	***3.38E-01***	0.07
Manganese	***7.16E-01***	1.86E-05	0	0	[d]
Naphthalene	9.38E-04	1.57E-04	8.27E-05	3.42E-05	[d]
^{99}Tc	1.02E+02	1.59E+01	8.06E+00	3.11E+00	900[c]
TCE	***1.48E+00***	***2.17E-01***	***1.10E-01***	***4.12E-02***	0.005
^{234}U	1.58E+00	1.75E-05	0	0	[d]
^{238}U	1.81E+00	2.03E-05	0	0	[d]
Uranium	9.86E-03	8.33E-08	0	0	0.03

[a] Values in bold, italic font exceed the analyte's MCL
[b] Radionuclide concentrations are in pCi/L
[c] ^{99}Tc MCL based on a critical organ dose at 4 mrem/yr from drinking water consumption
[d] MCLs not available for these contaminants

The hazard quotients (HQs) and excess lifetime cancer risks (ELCRs) calculated in accordance with the Risk Methods Document (DOE 2001) are presented in Table E.3.6. (Appendix F provides a full description of the risk assessment methodology and calculations.) The predicted TCE concentrations result in the greatest HQs and cancer risks; therefore, TCE is the most important analyte for contaminant migration at SWMU 2, while *cis*-1,2-DCE also provides (HQs) greater than 1. Arsenic also provides a cancer risk greater than 10^{-5}.

Table E.3.6. Hazard and Cancer Risk Predicted from Maximum Groundwater Concentrations Derived in Modeling of SWMU 2 Using SESOIL and AT123D[a]

Analyte	SWMU		Plant Boundary		Property Boundary		Ohio River	
	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk
Arsenic	11.3	9.38E-04	0.9	7.7E-05	<0.1	<1.0E-06	[b]	[b]
cis-1,2-DCE	607	[b]	91.9	[b]	45.3	[b]	17.9	[b]
Manganese	1.52	[b]	<0.1	[b]	[b]	[b]	[b]	[b]
Naphthalene	0.47	[b]	0.1	[b]	<0.1	[b]	<0.1	[b]
^{99}Tc	[b]	5.60E-06	[b]	<1.0E-06	[b]	<1.0E-06	[b]	<1.0E-06
TCE	676	3.09E-02	99.1	6.7E-03	50.3	3.4E-03	4.6	1.3E-03
^{234}U	[b]	2.23E-06	[b]	<1.0E-06	[b]	[b]	[b]	[b]
^{238}U	[b]	2.68E-06	[b]	<1.0E-06	[b]	[b]	[b]	[b]
Uranium	1.58	[b]	0.1	[b]	[b]	[b]	[b]	[b]

[a] Contaminants with a HQ greater than 0.1 or a cancer risk greater than 1.00E-06 are considered analytes.
[b] Value not calculated since the groundwater concentrations was reported as zero at this POE by AT123D, or the contaminant did not have a reported cancer slope factor or chemical toxicity RfD.

Figures 5.2 through 5.4 in Section 5 of the main text, show the predicted concentrations over time at each POE for analytes with a HQ greater than 0.1 and/or a risk greater than 1.0E-06. As shown in these figures, arsenic is predicted to continue rising in concentration at 1,000 years at the plant boundary, but has not reached the property boundary or Ohio River in the 1,000 year period. Both *cis*-1,2-DCE and TCE are predicted to exceed the their MCLs at all POEs within approximately 100 years and then decline in concentration below the MCLs.

E.3.1.2 SWMU 3

The C-404 Low-Level Radioactive Waste Burial Ground (SWMU 3) is located in the west-central section of PGDP. PGDP operated SWMU 3 as a surface impoundment from approximately 1952 until early 1957. During this time, all influents to the impoundment originated from C-400. In 1957, the C-404 surface impoundment was converted to a solid waste disposal facility for solid uranium-contaminated wastes. Approximately 6,615,000 lb of uranium-contaminated wastes were disposed of at SWMU 3. The total volume is approximately 260,000 ft^3. Some uranium-contaminated waste also is contaminated with TCE, radionuclides, and metals. In 1986, the disposal of all waste at C-404 Landfill was halted, and a portion of the disposed waste was found to be Resource Conservation and Recovery Act (RCRA)-hazardous. The landfill was covered with a RCRA multilayered cap and certified closed in 1987 (DOE 1987; DOE 1989).

E.3.1.2.1 Conceptual model for source areas at SWMU 3

SWMU 3 occupies an area of approximately 53,200 ft^2 (1.2 acres), with approximate dimensions of 140 by 380 ft. The thickness of the UCRS is estimated to be 65 ft (depth to the top of the RGA). The primary wastes at SWMU 3 consist of uranium precipitated from aqueous solutions, uranium tetrafluoride, uranium metal, uranium oxides, and radioactively contaminated trash. There are no records documenting the cleanout of sludges and sediments from the pond when it was converted to a landfill. A partial clay cap was installed on the eastern end of the landfill in 1982 (DOE 1987).

The conceptual model for SWMU 3 is that contaminants in the disposal site directly impacted soils below and adjacent to the areas where the material was landfilled and, through vertical infiltration in soil, may potentially impact the groundwater underlying these sources. The infiltrating groundwater migrates vertically through the UCRS and laterally in the RGA, which could transport the contaminants to the POEs.

E.3.1.2.2 Contaminant transport modeling for SWMU 3 using SESOIL and AT123D

For this modeling effort, the soil zones were arranged in four layers. Although SWMU 3 waste is contained in a mounded area, the mounding was not modeled in SESOIL. Instead the waste was assumed to be located at grade. The first soil layer represented the SADA surface soil data from 0 to 1 ft deep. The second soil layer was 9 ft thick representing SADA layer 2 from 1 to 9 ft in depth, the third layer was subdivided into 4 sublayers of equal thickness (10 ft each) representing SADA layers 3 through 6. SESOIL soil layer 4 was subdivided into 4 sublayers of equal thickness (3.75 ft each) to represent the total thickness of SADA layer 7 from 50 ft to 65 ft in depth. Table E.3.7 presents the analytes remaining after the screening process and the source terms for each analyte. Table E.3.8 lists the chemical-specific parameters applicable to the SESOIL model of SWMU 3. The distances to the POEs used in the AT123D model for SWMU 3 are 2,049 ft to the plant boundary, 4,455 ft to the property boundary, and 16,598 ft to the Little Bayou seeps.

Table E.3.7. Summary of Source Term Characteristics Developed by SADA for SWMU 3

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Arsenic			
L1	0-1	4.97	4.20E+05	4.20E+05	8.62E+04	0.51	2.54
L2	01-10	3.89	8.20E+05	8.20E+06	1.32E+06	1.00	3.89
L3	10-20	2.42	7.70E+05	8.47E+06	8.49E+05	0.94	2.28
L4	20-30	2.50	7.70E+05	8.47E+06	8.75E+05	0.94	2.35
L5	30-40	2.44	7.70E+05	8.47E+06	8.53E+05	0.94	2.29
L6	40-50	2.44	7.70E+05	8.47E+06	8.53E+05	0.94	2.29
L7	50-65	2.28	7.60E+05	6.84E+06	6.44E+05	0.93	2.11
			Total Mass		5.48E+06		
				Manganese			
L1	0-1	359.57	4.20E+05	4.20E+05	6.24E+06	0.50	179.79
L2	01-10	276.44	8.40E+05	8.40E+06	9.60E+07	1.00	276.44
L3	10-20	177.46	8.40E+05	9.24E+06	6.78E+07	1.00	177.46
L4	20-30	184.17	8.40E+05	9.24E+06	7.04E+07	1.00	184.17
L5	30-40	185.80	8.40E+05	9.24E+06	7.10E+07	1.00	185.80
L6	40-50	184.36	8.40E+05	9.24E+06	7.04E+07	1.00	184.36
L7	50-65	178.20	8.40E+05	7.56E+06	5.57E+07	1.00	178.20
			Total Mass		4.37E+08		
				Mercury			
L1	0-1	0.02	1.40E+05	1.40E+05	1.34E+02	1.08	0.02
L2	01-10	0.02	1.20E+05	1.20E+06	9.92E+02	0.92	0.02
L3	10-20	0.02	1.20E+05	1.32E+06	1.09E+03	0.92	0.02
L4	20-30	0.02	1.30E+05	1.43E+06	1.18E+03	1.00	0.02
L5	30-40	0.02	1.30E+05	1.43E+06	1.18E+03	1.00	0.02
L6	40-50	0.02	1.30E+05	1.43E+06	1.16E+03	1.00	0.02
L7	50-65	0.02	1.40E+05	1.26E+06	1.04E+03	1.08	0.02
			Total Mass		6.77E+03		
				Molybdenum			
L1	0-1	4.35	2.80E+05	2.80E+05	5.03E+04	1.87	8.12
L2	01-10	3.78	1.50E+05	1.50E+06	2.34E+05	1.00	3.78
L3	10-20	0.00	0.00	0.00	0.00	0.00	0.00
L4	20-30	0.00	0.00	0.00	0.00	0.00	0.00
L5	30-40	0.00	0.00	0.00	0.00	0.00	0.00
L6	40-50	0.00	0.00	0.00	0.00	0.00	0.00
L7	50-65	0.00	0.00	0.00	0.00	0.00	0.00
			Total Mass		2.85E+05		
				Nickel			
L1	0-1	7.90	4.20E+05	4.20E+05	1.37E+05	0.51	4.05
L2	01-10	9.89	7.20E+05	7.20E+06	2.94E+06	0.88	8.69
L3	10-20	8.20	8.20E+05	9.02E+06	3.06E+06	1.00	8.20
L4	20-30	8.17	8.10E+05	8.91E+06	3.01E+06	0.99	8.07
L5	30-40	8.11	8.10E+05	8.91E+06	2.99E+06	0.99	8.01
L6	40-50	8.04	8.30E+05	9.13E+06	3.03E+06	1.01	8.14
L7	50-65	8.04	8.20E+05	7.38E+06	2.45E+06	1.00	8.04
			Total Mass		1.76E+07		

Table E.3.7. Summary of Source Term Characteristics Developed by SADA for SWMU 3 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				^{99}Tc			
L1	0-1	12.58	2.60E+05	2.60E+05	1.35E+11	0.74	9.34
L2	01-10	26.86	3.50E+05	3.50E+06	3.89E+12	1.00	26.86
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
L4	20-30	2.40	1.00E+04	1.10E+05	1.09E+10	0.03	0.07
L5	30-40	2.40	1.00E+04	1.10E+05	1.09E+10	0.03	0.07
L6	40-50	2.40	1.00E+04	1.10E+05	1.09E+10	0.03	0.07
L7	50-65	0.00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
			Total Mass		4.05E+12		
				TCE			
L1	0-1	0.0063	3.00E+04	3.00E+04	7.85E+00	3.00	0.02
L2	01-10	0.0152	1.00E+04	1.00E+05	6.28E+01	1.00	0.02
L3	10-20	0.0152	1.00E+04	1.10E+05	6.91E+01	1.00	0.02
L4	20-30	0.0000	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
L5	30-40	0.0000	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
L6	40-50	0.0000	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
L7	50-65	0.0000	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
			Total Mass		1.40E+02		
				^{238}U			
L1	0-1	1.29	4.20E+05	4.20E+05	2.24E+10	0.70	0.90
L2	01-10	6.67	6.00E+05	6.00E+06	1.65E+12	1.00	6.67
L3	10-20	12.63	1.90E+05	2.09E+06	1.09E+12	0.32	4.00
L4	20-30	12.63	1.90E+05	2.09E+06	1.09E+12	0.32	4.00
L5	30-40	12.26	1.90E+05	2.09E+06	1.06E+12	0.32	3.88
L6	40-50	12.26	1.90E+05	2.09E+06	1.06E+12	0.32	3.88
L7	50-65	10.53	2.00E+05	1.80E+06	7.84E+11	0.33	3.51
			Total Mass		6.76E+12		
				Uranium			
L1	0-1	15.97	2.90E+05	2.90E+05	1.92E+05	0.52	8.27
L2	01-10	20.56	5.60E+05	5.60E+06	4.76E+06	1.00	20.56
L3	10-20	40.45	1.80E+05	1.98E+06	3.31E+06	0.32	13.00
L4	20-30	38.59	1.90E+05	2.09E+06	3.33E+06	0.34	13.09
L5	30-40	36.09	1.80E+05	1.98E+06	2.95E+06	0.32	11.60
L6	40-50	36.09	1.80E+05	1.98E+06	2.95E+06	0.32	11.60
L7	50-65	40.62	1.50E+05	1.35E+06	2.27E+06	0.27	10.88
			Total Mass		1.98E+07		
				Vanadium			
L1	0-1	25.30	4.20E+05	4.20E+05	4.39E+05	0.50	12.65
L2	01-10	19.01	8.40E+05	8.40E+06	6.60E+06	1.00	19.01
L3	10-20	17.04	8.40E+05	9.24E+06	6.51E+06	1.00	17.04
L4	20-30	17.24	8.40E+05	9.24E+06	6.58E+06	1.00	17.24
L5	30-40	17.17	8.40E+05	9.24E+06	6.56E+06	1.00	17.17
L6	40-50	17.23	8.40E+05	9.24E+06	6.58E+06	1.00	17.23
L7	50-65	16.99	8.40E+05	7.56E+06	5.31E+06	1.00	16.99
			Total Mass		3.86E+07		

Table E.3.7. Summary of Source Term Characteristics Developed by SADA for SWMU 3 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Zinc			
L1	0-1	25.73	3.90E+05	3.90E+05	4.15E+05	0.60	15.44
L2	01-10	31.35	6.50E+05	6.50E+06	8.42E+06	1.00	31.35
L3	10-20	30.78	3.80E+05	4.18E+06	5.32E+06	0.58	17.99
L4	20-30	32.05	3.60E+05	3.96E+06	5.25E+06	0.55	17.75
L5	30-40	31.78	3.50E+05	3.85E+06	5.06E+06	0.54	17.11
L6	40-50	31.78	3.50E+05	3.85E+06	5.06E+06	0.54	17.11
L7	50-65	32.27	3.50E+05	3.15E+06	4.20E+06	0.54	17.38
			Total Mass		3.37E+07		

[a] Radionuclides are in units of pCi/g for concentrations and pCi for mass.

Table E.3.8. Chemical-Specific Parameters of the Analytes Used in SESOIL Modeling of SWMU 3

Analyte	Mol. Wt. (MW) (g/mol)	Solubility in water (mg/L)	Diffusion in air (cm^2/s)	Diffusion in water (m^2/hr)	Henry's Constant (atm.m3/mol)	Koc (L/kg)	Kd[a] (L/kg)	Half Life (years)
Arsenic	74.92	1.00E+07	NA	3.60E-07	NA	NA	29	infinite
Manganese	54.94	1.00E+07	NA	1.29E-07	NA	NA	65	infinite
Mercury	200.59	6.00E-02	3.07E-02	2.27E-06	2.44E-02	NA	52	infinite
Molybdenum	95.9	1.00E+07	NA	3.60E-07	NA	NA	10	infinite
Nickel	58.69	1.00E+07	NA	3.60E-07	NA	NA	300	infinite
^{99}Tc	99	1.00E+07	NA	3.60E-07	NA	NA	0.2	2.13E+05
TCE	131	1,100	0.08	3.28E-06	0.0103	94	0.0752	26.6
^{238}U	238	1.00E+07	NA	3.60E-07	NA	NA	66.8	4.47E+09
Uranium	238	1.00E+07	NA	3.60E-07	NA	NA	66.8	4.47E+09
Vanadium	50.94	1.00E+07	NA	3.60E-07	NA	NA	1000	infinite
Zinc	67.41	1.00E+07	NA	3.60E-07	NA	NA	62	infinite

[a] The soil/water distribution coefficient (Kd) of an organic compound depends on the soil's organic content (f_{oc}) and compound's organic partition coefficient (Koc). Kd values presented for organic compounds are for UCRS soils (with f_{oc} value of 0.08%) only. Kds used in AT123D are different due to the f_{oc} of 0.02% in the RGA.

E.3.1.2.3 Groundwater modeling results for SWMU 3

Table E.3.9 summarizes the predicted maximum groundwater concentrations at the POEs for the analytes modeled at SWMU 3. These contaminants were predicted by SESOIL to reach the water table within the 1,000 year period in concentrations that were greater then the groundwater background or greater than the groundwater child no action levels. Several contaminants that originally passed the screening for groundwater did not reach the water table in 1,000 years (i.e., molybdenum, nickel, and vanadium) or exhibited groundwater concentrations that were less than the groundwater background or the groundwater child no action levels (i.e., mercury, TCE, and zinc) (see Section 5.4 of the main text).

Table E.3.9. Concentrations of the Analytes in Groundwater Predicted in SESOIL and AT123D Modeling of SWMU 3

	Predicted Maximum Groundwater Concentration[a,b]				
Analyte	**SWMU (mg/L)**	**Plant Boundary (mg/L)**	**Property Boundary (mg/L)**	**Little Bayou seeps (mg/L)**	**MCL (mg/L)**
Arsenic	***3.29E-02***	1.22E-03	0	0	0.01
Manganese	***8.95E-01***	4.08E-10	0	0	
^{99}Tc	***5.560E+03***	1.81E+03	1.36E+03	8.04E+02	900[c]
^{238}U	1.59E+01	7.32E-11	0	0	[d]
Uranium	***4.89E-02***	2.27E-13	0	0	0.03

[a] Values in bold, italic font exceed the analyte's MCL
[b] Radionuclide concentrations are in pCi/L
[c] ^{99}Tc MCL based on a critical organ dose at 4 mrem/yr from drinking water consumption
[d] MCLs not available for these contaminants

As shown in Table E.3.9, the predicted maximum groundwater concentrations for all analytes except ^{99}Tc are less than the MCLs for the contaminants at the POEs. The HQs and cancer risks calculated in accordance with the Risk Methods Document (DOE 2001) are presented in Table E.3.10. The predicted ^{99}Tc concentrations result in the greatest cancer risks; therefore, ^{99}Tc is the most important analyte for contaminant migration at SWMU 3, while arsenic also provides an elevated cancer risk.

Table E.3.10. Hazard and Cancer Risk Predicted from Maximum Groundwater Concentrations Derived in Modeling of SWMU 3 Using SESOIL and AT123D[a]

	SWMU		**Plant Boundary**		**Property Boundary**		**Little Bayou seeps**	
Analyte	**Hazard Quotient**	**Cancer Risk**	**Hazard Quotient**	**Cancer Risk**	**Hazard Quotient**	**Cancer Risk**	**Hazard Quotient**	**Cancer Risk**
Arsenic	10.5	8.72E-04	0.4	3.2E-05	[b]	[b]	[b]	[b]
Manganese	3.65	[b]	<0.1	[b]	[b]	[b]	[b]	[b]
^{99}Tc	[b]	3.05E-04	[b]	9.9E-05	[b]	7.5E-05	[b]	4.4E-05
^{238}U	[b]	<1.0E-06	[b]		[b]		[b]	
Uranium	7.82	[b]	<0.1	[b]	[b]	[b]	[b]	[b]

[a] Contaminants with a HQ greater than 0.1 or a cancer risk greater than 1.00E-06 are considered analytes.
[b] Value not calculated since the groundwater concentrations was reported as zero at this POE by AT123D, or the contaminant did not have a reported cancer slope factor or chemical toxicity RfD.

Figures 5.5 and 5.6 in Section 5 of the main text, show the predicted concentrations over time at each POE for analytes with a HQ greater than 0.1 and/or a risk greater than 1.0E-06 (Table E.3.10 and Table 5.4). As shown in these figures, arsenic is predicted to continue rising in concentration at 1,000 years at the plant boundary, but has not reached the property boundary or Little Bayou seeps in the 1,000 year period. ^{99}Tc is predicted to exceed the MCL within 200 years and then decline in concentration at the plant and property POEs.

E.3.1.3 SWMU 4

The C-747 Contaminated Burial Yard and the C-748-B Burial Area (SWMU 4) is located in the western section of the plant area. PGDP used the C-747 Burial Yard from 1951 to 1958 for the disposal of radiologically contaminated and uncontaminated debris originating from the C-410 uranium hexafluoride feed plant. The area consists of two pits covering an area of approximately 8,300 ft^2 (50 ft by 15 ft and 50 ft by 150 ft) (Union Carbide 1978) of the total 92,000 ft^2. The C-748-B Burial Area is listed in the 1973 Union Carbide document on waste disposal as a Proposed Chemical Landfill Site and is located on the west side of C-747. SWMU 4 also may have received sludges designated for disposal at the C-404 Burial Grounds. These sludges potentially included uranium-contaminated solid waste and ^{99}Tc contaminated

magnesium fluoride. Potential contaminants associated with this SWMU include uranium, ^{99}Tc, metals, and TCE (DOE 1998b).

E.3.1.3.1 Conceptual model for source areas at SWMU 4

SWMU 4 occupies an area of approximately 286,700 ft^2 (6.6 acres). The thickness of the UCRS is estimated to be 63 ft (depth to the top of the RGA). The conceptual model for SWMU 4 is that potentially contaminated trash and scrap was buried in waste pits at SWMU 4. Subsequently, contaminants in the disposed material directly impacted soils below or adjacent to the areas where material was buried and, through vertical infiltration in soil, contaminated the groundwater underlying these sources. The infiltrating groundwater migrates vertically through the UCRS and laterally in the RGA, which could transport the contaminants to the POEs. Previous work on the Southwest Plume discusses a secondary TCE DNAPL source in the RGA below SWMU 4. This source was not modeled, however, further discussion is provided in Section E.3.3.7.

E.3.1.3.2 Contaminant transport modeling for SWMU 4 using SESOIL and AT123D

For this modeling effort, the soil zones were arranged in four layers. The first soil layer represented the SADA surface soil data from 0 to 1 ft deep. The second soil layer was 9 ft thick representing SADA layer 2 from 1 to 9 ft in depth, the third layer was subdivided into 4 sublayers of equal thickness (10 ft each) representing SADA layers 3 through 6. SESOIL soil layer 4 was subdivided into 4 sublayers of equal thickness (3.25 ft each) to represent the total thickness of SADA layer 7 from 50 ft to 63 ft in depth, the four sublayer division of this layer allowed for better numerical solution of the final flux to the RGA. Table E.3.11 presents the analytes remaining after the screening process and the source terms for each analyte. Table E.3.12 lists the chemical-specific parameters applicable to the SESOIL model of SWMU 4. The distances to the POEs used in the AT123D model for SWMU 4 are 984 ft to the plant boundary, 3,000 ft to the property boundary, and 22,967 ft to the Ohio River. SWMU 4 particle tracks do not travel to the Little Bayou seeps.

Table E.3.11. Summary of Source Term Characteristics Developed by SADA for SWMU 4

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Arsenic			
L1	0-1	8.87	1.14E+05	1.14E+05	4.16E+04	2.12	18.79
L2	01-10	8.48	5.36E+04	5.36E+05	1.88E+05	1.00	8.48
L3	10-20	6.76	2.88E+04	3.17E+05	8.85E+04	0.54	3.63
L4	20-30	6.70	3.24E+04	3.56E+05	9.87E+04	0.60	4.05
L5	30-40	6.43	2.96E+04	3.26E+05	8.65E+04	0.55	3.55
L6	40-50	6.37	2.48E+04	2.73E+05	7.18E+04	0.46	2.95
L7	50-63	5.81	1.76E+04	1.06E+05	2.53E+04	0.33	1.91
			Total Mass		6.00E+05		
				***cis*-1,2-DCE**			
L1	0-1	0.00	0.00E+00	0.00E+00	0.00E+00		
L2	01-10	3.84	1.32E+04	1.32E+05	2.10E+04	0.31	1.20
L3	10-20	1.64	3.48E+04	3.83E+05	2.60E+04	0.82	1.35
L4	20-30	1.54	4.24E+04	4.66E+05	2.97E+04	1.00	1.54
L5	30-40	1.11	4.92E+04	5.41E+05	2.49E+04	1.16	1.29
L6	40-50	0.88	4.76E+04	5.24E+05	1.90E+04	1.12	0.98
L7	50-63	0.98	4.96E+04	2.98E+05	1.21E+04	1.17	1.15
			Total Mass		1.33E+05		

Table E.3.11. Summary of Source Term Characteristics Developed by SADA for SWMU 4 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Manganese			
L1	0-1	475.31	3.47E+05	3.47E+05	6.82E+06	1.50	711.33
L2	01-10	327.05	2.32E+05	2.32E+06	3.14E+07	1.00	327.05
L3	10-20	320.36	2.32E+05	2.55E+06	3.38E+07	1.00	320.36
L4	20-30	193.55	2.32E+05	2.55E+06	2.04E+07	1.00	193.55
L5	30-40	178.70	2.32E+05	2.55E+06	1.89E+07	1.00	178.70
L6	40-50	234.60	2.32E+05	2.55E+06	2.48E+07	1.00	234.60
L7	50-63	133.92	2.32E+05	1.39E+06	7.71E+06	1.00	133.92
			Total Mass		1.44E+08		
				Nickel			
L1	0-1	21.47	2.72E+05	2.72E+05	2.41E+05	1.36	29.10
L2	01-10	16.79	2.00E+05	2.00E+06	1.39E+06	1.00	16.79
L3	10-20	12.83	1.93E+05	2.12E+06	1.12E+06	0.96	12.34
L4	20-30	14.05	1.22E+05	1.35E+06	7.82E+05	0.61	8.58
L5	30-40	15.75	1.06E+05	1.17E+06	7.59E+05	0.53	8.33
L6	40-50	13.23	1.21E+05	1.33E+06	7.29E+05	0.60	8.00
L7	50-63	10.99	1.14E+05	6.84E+05	3.11E+05	0.57	6.25
			Total Mass		5.34E+06		
				^{99}Tc			
L1	0-1	39.00	1.36E+04	1.36E+04	2.19E+10	0.17	6.53
L2	01-10	49.65	8.12E+04	8.12E+05	1.67E+12	1.00	49.65
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
L7	50-63	0.00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
			Total Mass		1.69E+12		
				TCE			
L1	0-1	0.00	0.00E+00	0.00E+00	0.00E+00		
L2	01-10	2.39	8.24E+04	8.24E+05	8.16E+04	0.86	2.06
L3	10-20	2.85	6.60E+04	7.26E+05	8.55E+04	0.69	1.96
L4	20-30	3.02	7.24E+04	7.96E+05	9.93E+04	0.75	2.28
L5	30-40	2.56	9.60E+04	1.06E+06	1.12E+05	1.00	2.56
L6	40-50	2.45	9.84E+04	1.08E+06	1.10E+05	1.03	2.51
L7	50-63	3.15	9.96E+04	5.98E+05	7.77E+04	1.04	3.26
			Total Mass		5.65E+05		
				^{234}U			
L1	0-1	15.57	3.47E+05	3.47E+05	2.24E+11	2.03	31.66
L2	01-10	27.69	1.75E+05	1.75E+06	2.01E+12	1.03	28.40
L3	10-20	27.59	1.71E+05	1.88E+06	2.14E+12	1.00	27.59
L4	20-30	28.03	1.67E+05	1.83E+06	2.13E+12	0.98	27.38
L5	30-40	28.26	1.62E+05	1.78E+06	2.08E+12	0.95	26.74
L6	40-50	28.76	1.58E+05	1.73E+06	2.06E+12	0.92	26.53
L7	50-63	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
			Total Mass		1.06E+13		

Table E.3.11. Summary of Source Term Characteristics Developed by SADA for SWMU 4 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				^{238}U			
L1	0-1	30.55	3.47E+05	3.47E+05	4.39E+11	2.03	62.10
L2	01-10	52.13	1.75E+05	1.75E+06	3.78E+12	1.03	53.48
L3	10-20	51.72	1.71E+05	1.88E+06	4.02E+12	1.00	51.72
L4	20-30	52.47	1.67E+05	1.83E+06	3.98E+12	0.98	51.25
L5	30-40	52.77	1.62E+05	1.78E+06	3.88E+12	0.95	49.93
L6	40-50	53.71	1.58E+05	1.73E+06	3.85E+12	0.92	49.56
L7	50-63	0.00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
			Total Mass		1.99E+13		
				Uranium			
L1	0-1	118.94	3.47E+05	3.47E+05	1.71E+06	2.03	241.79
L2	01-10	884.57	1.75E+05	1.75E+06	6.41E+07	1.03	907.36
L3	10-20	827.57	1.71E+05	1.88E+06	6.43E+07	1.00	827.57
L4	20-30	807.78	1.67E+05	1.83E+06	6.13E+07	0.98	788.86
L5	30-40	789.77	1.62E+05	1.78E+06	5.80E+07	0.95	747.23
L6	40-50	768.17	1.58E+05	1.73E+06	5.51E+07	0.92	708.80
L7	50-63	0.00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
			Total Mass		3.04E+08		
				Vanadium			
L1	0-1	25.21	3.47E+05	3.47E+05	3.62E+05	1.50	37.73
L2	01-10	21.69	2.32E+05	2.32E+06	2.08E+06	1.00	21.69
L3	10-20	22.83	2.32E+05	2.55E+06	2.41E+06	1.00	22.83
L4	20-30	26.28	2.32E+05	2.55E+06	2.77E+06	1.00	26.28
L5	30-40	25.06	2.32E+05	2.55E+06	2.64E+06	1.00	25.06
L6	40-50	22.81	2.32E+05	2.55E+06	2.41E+06	1.00	22.81
L7	50-63	20.40	2.32E+05	1.39E+06	1.17E+06	1.00	20.40
			Total Mass		1.38E+07		
				Vinyl Chloride			
L1	0-1	0.00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
L2	01-10	0.16	6.40E+03	6.40E+04	4.15E+02	0.37	0.06
L3	10-20	0.08	1.64E+04	1.80E+05	6.05E+02	0.95	0.08
L4	20-30	0.09	9.20E+03	1.01E+05	3.95E+02	0.53	0.05
L5	30-40	0.19	1.72E+04	1.89E+05	1.49E+03	1.00	0.19
L6	40-50	0.18	1.76E+04	1.94E+05	1.43E+03	1.02	0.18
L7	50-63	0.20	2.08E+04	1.25E+05	1.04E+03	1.21	0.24
			Total Mass		5.37E+03		
				Zinc			
L1	0-1	40.73	3.26E+05	3.26E+05	5.50E+05	1.00	40.73
L2	01-10	8.48	5.36E+04	5.36E+05	1.88E+05	0.16	1.39
L3	10-20	6.76	2.88E+04	3.17E+05	8.85E+04	0.09	0.60
L4	20-30	6.70	3.24E+04	3.56E+05	9.87E+04	0.10	0.67
L5	30-40	6.43	2.96E+04	3.26E+05	8.65E+04	0.09	0.58
L6	40-50	6.37	2.48E+04	2.73E+05	7.18E+04	0.08	0.48
L7	50-63	5.81	1.76E+04	1.06E+05	2.53E+04	0.05	0.31
			Total Mass		1.11E+06		

[a] Radionuclides are in units of pCi/g for concentrations and pCi for mass.

Table E.3.12. Chemical-Specific Parameters of the Analytes Used in SESOIL Modeling of SWMU 4

Analyte	Mol. Wt. (MW) (g/mol)	Solubility in water (mg/L)	Diffusion in air (cm^2/s)	Diffusion in water (m^2/hr)	Henry's Constant (atm.m3/mol)	Koc (L/kg)	Kd[a] (L/kg)	Half Life (years)
Arsenic	74.92	1.00E+07	NA	3.60E-07	NA	NA	29	infinite
cis-1,2-DCE	96.94	3.50E+03	0.07	4.07E-06	4.08E-03	35.5	0.028	infinite
Manganese	54.94	1.00E+07	NA	1.29E-07	NA	NA	65	infinite
Nickel	58.69	1.00E+07	NA	3.60E-07	NA	NA	300	infinite
^{99}Tc	99	1.00E+07	NA	3.60E-07	NA	NA	0.2	2.13E+05
TCE	131	1,100	0.08	3.28E-06	0.0103	94	0.0752	26.6
^{234}U	234	1.00E+07	NA	3.60E-07	NA	NA	66.8	2.44E+05
^{238}U	238	1.00E+07	NA	3.60E-07	NA	NA	66.8	4.47E+09
Uranium	238	1.00E+07	NA	3.60E-07	NA	NA	66.8	4.47E+09
Vanadium	50.94	1.00E+07	NA	3.60E-07	NA	NA	1000	infinite
Zinc	67.41	1.00E+07	NA	3.60E-07	NA	NA	62	infinite
Vinyl Chloride	63	2,760	0.11	4.43E-07	0.0270	18.8	0.0152	26.6

[a] The soil/water distribution coefficient (Kd) of an organic compound depends on the soil's organic content (f_{oc}) and compound's organic partition coefficient (Koc). Kd values presented for organic compounds are for UCRS soils (with f_{oc} value of 0.08%) only. Kds used in AT123D are different due to the f_{oc} of 0.02% in the RGA.

E.3.1.3.3 Groundwater modeling results for SWMU 4

Table E.3.13 summarizes the predicted maximum groundwater concentrations at the POEs for the analytes modeled at SWMU 4. These contaminants were predicted by SESOIL to reach the water table within the 1,000 year period in concentrations that were greater then the groundwater background or greater than the groundwater child no action levels. Several contaminants that originally passed the screening for groundwater did not reach the water table in 1,000 years (i.e., arsenic, antimony, nickel, ^{234}U, ^{238}U, and vanadium) or exhibited groundwater concentrations that were less than the groundwater background or the groundwater child no action levels (i.e., zinc) (see Section 5.4 of the main text).

Table E.3.13. Concentrations of the Analytes in Groundwater Predicted in SESOIL and AT123D Modeling of SWMU 4

Analyte	Predicted Maximum Groundwater Concentration[a,b]				
	SWMU (mg/L)	Plant Boundary (mg/L)	Property Boundary (mg/L)	Ohio River (mg/L)	MCL (mg/L)
Arsenic	***1.77E-02***	2.70E-03	4.89E-06	0	0.01
cis-1,2-DCE	***6.68E-01***	***1.96E-01***	***8.94E-02***	3.16E-02	0.07
Manganese	***5.76E-01***	5.01E-03	0	0	[d]
^{99}Tc	***9.008E+03***	***2.50E+03***	***1.20E+03***	3.79E+02	900[c]
TCE	***1.18E+00***	***4.22E-01***	***2.14E-01***	***7.67E-02***	0.005
Vinyl Chloride	***2.61E-02***	***5.95E-03***	***2.53E-03***	7.82E-04	0.002

[a] Values in bold, italic font exceed the analyte's MCL
[b] Radionuclide concentrations are in pCi/L
[c] ^{99}Tc MCL based on a critical organ dose at 4 mrem/yr from drinking water consumption
[d] MCLs not available for these contaminants

As shown in Table E.3.13, the predicted maximum groundwater concentrations for *cis*-1,2-DCE, ^{99}Tc, TCE and vinyl chloride exceed the MCLs at the plant and property boundary. TCE also is predicted to exceed the MCL at the Ohio River. The HQs and cancer risks calculated in accordance with the Risk Methods Document (DOE 2001) are presented in Table E.3.14. The predicted TCE, vinyl chloride, and ^{99}Tc concentrations result in the greatest cancer risks; with TCE being the most important analyte for contaminant migration at SWMU 4. TCE also exhibits the highest HQ for SWMU 4.

Table E.3.14. Hazard and Cancer Risk Predicted from Maximum Groundwater Concentrations Derived in Modeling of SWMU 4 Using SESOIL and AT123D[a]

Analyte	SWMU		Plant Boundary		Property Boundary		Ohio River	
	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk
Arsenic	5.67	4.69E-04	0.9	7.2E-05	<0.1	<1.0E-06	[b]	[b]
cis-1,2-DCE	35.3	[b]	10.4	[b]	4.7	[b]	0.6	[b]
Manganese	1.23	[b]	<0.1	[b]	[b]	[b]	[b]	[b]
^{99}Tc	[b]	4.94E-04	[b]	1.4E-04	[b]	6.6E-05	[b]	2.1E-05
TCE	539	3.67E-02	193	2.0E-02	97.7	6.6E-03	32.7	2.4E-03
Vinyl Chloride	1.21	1.65E-02	0.3	1.9E-04	0.1	7.4E-05	<0.1	2.3E-05

[a] Contaminants with a HQ greater than 0.1 or a cancer risk greater than 1.00E-06 are considered analytes.
[b] Value not calculated since the groundwater concentrations was reported as zero at this POE by AT123D, or the contaminant did not have a reported cancer slope factor or chemical toxicity RfD.

Figures 5.7 through 5.11 in Section 5 of the main text, show the predicted concentrations over time at each POE for analytes with a HQ greater than 0.1 and/or a risk greater than 1.0E-06 for contaminants migrating from SWMU 4. As shown in these figures, manganese is predicted to continue rising in concentration at 1,000 years at the plant boundary, but has not reached the property boundary or Ohio River in the 1,000 year period. *Cis*-1,2-DCE; ^{99}Tc; TCE; and vinyl chloride are predicted to exceed the MCL at the plant and property boundaries within 100 years. TCE also is predicted to exceed the MCL at the Ohio River within 100 years.

E.3.1.4 SWMU 5

The C-746-F Burial Yard is located in the northwestern section of the PGDP secured area, adjacent to SWMU 6 to the east. Disposal pits were located on a grid system. Documentation of the size of these grids ranges from 10 ft by 10 ft cells to 20 ft by 20 ft cells excavated to a depth of 6 to 15 ft bgs. SWMU 5 was in operation from 1965 to 1987. The burial pits were used for the burial of components from the "Work for Others" activities, some radionuclide-contaminated scrap metal, and slag from the nickel and aluminum smelters. Metals and radioisotopes are the primary potential contaminants of interest at this SWMU.

E.3.1.4.1 Conceptual model for source areas at SWMU 5

SWMU 5 occupies an area of approximately 197,400 ft^2 (4.5 acres). The thickness of the UCRS is estimated to be 60 ft (depth to the top of the RGA). Metals and radionuclides were buried in pits at SWMU 5. The conceptual model for SWMU 5 is that contaminants in disposed material directly impacted soils below or adjacent to the areas where material was buried and, through vertical infiltration in soil, contaminated the groundwater underlying these sources. The infiltrating groundwater migrates vertically through the UCRS and laterally in the RGA, which could transport the contaminants to the POEs.

E.3.1.4.2 Contaminant transport modeling for SWMU 5 using SESOIL and AT123D

For this modeling effort, the soil zones were arranged in four layers. The first soil layer represented the SADA surface soil data from 0 to 1 ft deep. The second soil layer was 9 ft thick representing SADA layer 2 from 1 to 9 ft in depth, the third layer was subdivided into 4 sublayers of equal thickness (10 ft each) representing SADA layers 3 through 6. SESOIL soil layer 4 was subdivided into 4 sublayers of equal thickness (2.5 ft each) to represent the total thickness of SADA layer 7 from 50 ft to 60 ft in depth. Table E.3.15 presents the analytes remaining after the screening process and the source terms for each analyte.

Table E.3.15. Summary of Source Term Characteristics Developed by SADA for SWMU 5

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
Acenaphthene							
L1	0-1	2.71	1.54E+05	1.54E+05	1.73E+04	1.00E+00	2.71
L2	01-10	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L7	50-60	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
			Total Mass		1.73E+04		
Anthracene							
L1	0-1	3.51	1.80E+05	1.80E+05	2.61E+04	1.00E+00	3.51
L2	01-10	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L7	50-60	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
			Total Mass		2.61E+04		
Arsenic							
L1	0-1	8.78	1.04E+05	1.04E+05	3.79E+04	1.76E+00	15.49
L2	01-10	2.51	4.52E+04	4.07E+05	4.22E+04	7.64E-01	1.91
L3	10-20	2.31	4.12E+04	4.12E+05	3.94E+04	6.96E-01	1.61
L4	20-30	3.47	5.92E+04	5.92E+05	8.49E+04	1.00E+00	3.47
L5	30-40	1.65	3.48E+04	3.48E+05	2.38E+04	5.88E-01	0.97
L6	40-50	1.79	3.72E+04	3.72E+05	2.75E+04	6.28E-01	1.12
L7	50-60	1.50	3.48E+04	3.48E+05	2.16E+04	5.88E-01	0.88
			Total Mass		2.77E+05		
Benzo(a)pyrene							
L1	0-1	6.14	2.52E+05	2.52E+05	6.40E+04	1.00E+00	6.14
L2	01-10	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L7	50-60	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
			Total Mass		6.40E+04		
Dibenz(a,h)anthracene							
L1	0-1	0.44	2.96E+04	2.96E+04	5.40E+02	1.00E+00	0.44
L2	01-10	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L7	50-60	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
			Total Mass		5.40E+02		

Table E.3.15. Summary of Source Term Characteristics Developed by SADA for SWMU 5 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Fluoranthene			
L1	0-1	14.25	1.79E+05	1.79E+05	1.06E+05	1.00E+00	14.25
L2	01-10	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L7	50-60	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
			Total Mass		1.06E+05		
				Fluorene			
L1	0-1	3.29	1.32E+05	1.32E+05	1.80E+04	1.00E+00	3.29
L2	01-10	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L7	50-60	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
			Total Mass		1.80E+04		
				Manganese			
L1	0-1	3.82E+02	4.03E+05	4.03E+05	6.36E+06	2.21E+00	845.91
L2	01-10	1.79E+02	1.82E+05	1.64E+06	1.21E+07	1.00E+00	179.07
L3	10-20	1.85E+02	1.82E+05	1.82E+06	1.39E+07	1.00E+00	185.24
L4	20-30	1.56E+02	1.82E+05	1.82E+06	1.17E+07	1.00E+00	155.86
L5	30-40	1.54E+02	1.82E+05	1.82E+06	1.16E+07	1.00E+00	154.05
L6	40-50	2.00E+02	1.82E+05	1.82E+06	1.50E+07	1.00E+00	199.52
L7	50-60	2.58E+02	1.82E+05	1.82E+06	1.94E+07	1.00E+00	258.26
			Total Mass		9.02E+07		
				Naphthalene			
L1	0-1	3.80	8.00E+03	8.00E+03	1.26E+03	1.00E+00	3.80
L2	01-10	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L7	50-60	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
			Total Mass		1.26E+03		
				Nickel			
L1	0-1	2.79E+01	3.88E+05	3.88E+05	4.47E+05	2.44E+00	68.15
L2	01-10	1.03E+01	1.43E+05	1.29E+06	5.50E+05	9.02E-01	9.32
L3	10-20	1.04E+01	1.42E+05	1.42E+06	6.14E+05	8.97E-01	9.36
L4	20-30	1.12E+01	1.59E+05	1.59E+06	7.33E+05	1.00E+00	11.16
L5	30-40	9.20E+00	1.39E+05	1.39E+06	5.28E+05	8.74E-01	8.04
L6	40-50	1.01E+01	1.50E+05	1.50E+06	6.29E+05	9.47E-01	9.58
L7	50-60	9.87E+00	1.54E+05	1.54E+06	6.29E+05	9.70E-01	9.58
			Total Mass		4.13E+06		

Table E.3.15. Summary of Source Term Characteristics Developed by SADA for SWMU 5 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				PCB-1260			
L1	0-1	0.15	1.34E+05	1.34E+05	8.23E+02	1.00E+00	0.15
L2	01-10	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L7	50-60	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
			Total Mass		8.23E+02		
				Pyrene			
L1	0-1	8.29	2.82E+05	2.82E+05	9.68E+04	1.00E+00	8.29
L2	01-10	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L7	50-60	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
			Total Mass		9.68E+04		
				Selenium			
L1	0-1	1.17	2.56E+04	2.56E+04	1.23E+03	1.00E+00	1.17
L2	01-10	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L7	50-60	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
			Total Mass		1.23E+03		
				TCE			
L1	0-1	0.0000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L2	01-10	0.0028	5.92E+04	5.33E+05	6.26E+01	1.00E+00	0.0028
L3	10-20	0.0029	6.04E+04	6.04E+05	7.34E+01	1.02E+00	0.0030
L4	20-30	0.0030	5.96E+04	5.96E+05	7.35E+01	1.01E+00	0.0030
L5	30-40	0.0030	5.92E+04	5.92E+05	7.43E+01	1.00E+00	0.0030
L6	40-50	0.0031	5.64E+04	5.64E+05	7.33E+01	9.53E-01	0.0030
L7	50-60	0.0032	5.44E+04	5.44E+05	7.28E+01	9.19E-01	0.0030
			Total Mass		4.30E+02		
				Vanadium			
L1	0-1	20.65	4.03E+05	4.03E+05	3.44E+05	2.21	45.71
L2	01-10	23.18	1.82E+05	1.64E+06	1.57E+06	1.00	23.18
L3	10-20	22.14	1.82E+05	1.82E+06	1.67E+06	1.00	22.14
L4	20-30	24.70	1.82E+05	1.82E+06	1.86E+06	1.00	24.70
L5	30-40	18.45	1.82E+05	1.82E+06	1.39E+06	1.00	18.45
L6	40-50	19.13	1.82E+05	1.82E+06	1.44E+06	1.00	19.13
L7	50-60	18.00	1.82E+05	1.82E+06	1.35E+06	1.00	18.00
			Total Mass		9.62E+06		

Table E.3.15. Summary of Source Term Characteristics Developed by SADA for SWMU 5 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Zinc			
L1	0-1	70.69	3.21E+05	3.21E+05	9.38E+05	2.37	167.74
L2	01-10	32.20	1.30E+05	1.17E+06	1.56E+06	0.96	30.96
L3	10-20	32.87	1.33E+05	1.33E+06	1.81E+06	0.99	32.38
L4	20-30	34.66	1.27E+05	1.27E+06	1.82E+06	0.94	32.51
L5	30-40	37.01	1.15E+05	1.15E+06	1.76E+06	0.85	31.53
L6	40-50	42.44	1.28E+05	1.28E+06	2.25E+06	0.95	40.30
L7	50-60	40.94	1.35E+05	1.35E+06	2.29E+06	1.00	40.94
			Total Mass		1.24E+07		
				^{99}Tc			
L1	0-1	7.16	1.42E+05	1.42E+05	4.22E+10	1.00	7.16
L2	01-10	0.00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00
L7	50-60	3.89	9.60E+03	9.60E+04	1.54E+10	0.07	0.26
			Total Mass		5.76E+10		

[a] Radionuclides are in units of pCi/g for concentrations and pCi for mass.

Table E.3.16 lists the chemical-specific parameters applicable to the SESOIL model of SWMU 5. Figure E.3.3 shows the particle tracks that were modeled for SWMUs 5 and 6. The distances to the POEs used in the AT123D model for SWMU 5 are 778 ft to the plant boundary, 2,293 ft to the property boundary, and 19,844 ft to the Ohio River. SWMU 5 particle tracks do not travel to the Little Bayou seeps.

Table E.3.16. Chemical-Specific Parameters of the Analytes Used in SESOIL Modeling of SWMU 5

Analyte	Mol. Wt. (MW) (g/mol)	Solubility in water (mg/L)	Diffusion in air (cm^2/s)	Diffusion in water (m^2/hr)	Henry's Constant (atm.m3/mol)	Koc (L/kg)	Kd[a] (L/kg)	Half Life (years)
Anthracene	178.24	0.043	0.032	2.79E-06	5.55E-05	2.04E+04	16.3	infinite
Arsenic	74.92	1.00E+07	NA	3.60E-07	NA	NA	29	infinite
Benzo(a)pyrene	252.32	1.62E-03	4.3E-02	3.24E-06	1.13E-06	9.69E+05	772	infinite
Dibenzo(a,h)anthracene	278.33	0.0025	0.020	1.86E-06	1.47E-08	1.78E+06	1,424	infinite
Fluorathene	202.26	0.206	0.030	2.29E-06	1.61E-05	4.91E+04	39.3	infinite
Fluorene	166.0	1.90	0.061	2.84E-06	7.7E-05	7.9E+03	6.3	infinite
Manganese	54.94	1.00E+07	NA	1.29E-07	NA	NA	65	infinite
Naphthalene	128.16	31.0	0.059	2.70E-06	4.83E-04	1.19E+03	0.95	infinite
Nickel	58.69	1.00E+07	NA	3.60E-07	NA	NA	300	infinite
PCB-1260	375.70	0.027	0.014	4.32E-06	7.40E-05	2.07E+05	165.6	infinite
Pyrene	202.3	0.135	0.0272	2.61E-06	1.1E-05	6.8E+04	54.4	infinite
Selenium	80.98	1.00E+07	NA	3.60E-07	NA	NA	5	infinite
^{99}Tc	99	1.00E+07	NA	3.60E-07	NA	NA	0.2	2.13E+05
TCE	131	1,100	0.08	3.28E-06	0.0103	94	0.0752	26.6
Vanadium	50.94	1.00E+07	NA	3.60E-07	NA	NA	1,000	infinite
Zinc	67.41	1.00E+07	NA	3.60E-07	NA	NA	62	infinite

[a] The soil/water distribution coefficient (Kd) of an organic compound depends on the soil's organic content (f_{oc}) and compound's organic partition coefficient (Koc). Kd values presented for organic compounds are for UCRS soils (with f_{oc} value of 0.08%) only. Kds used in AT123D are different due to the f_{oc} of 0.02% in the RGA.

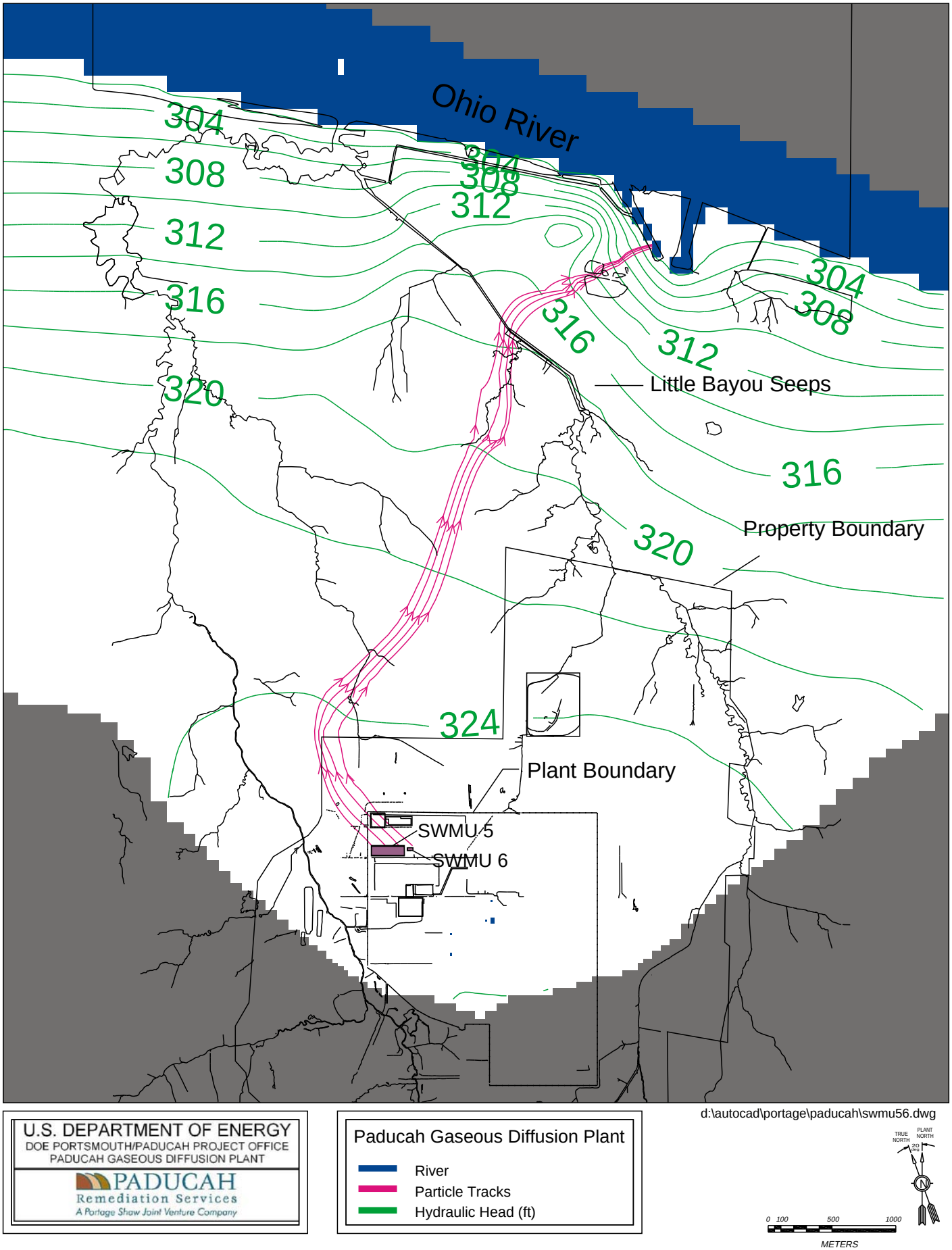


Figure E.3.3. Particle Tracks for SWMUs 5 and 6

E.3.1.4.3 Groundwater modeling results for SWMU 5

Table E.3.17 summarizes the predicted maximum groundwater concentrations at the POEs for the analytes modeled at SWMU 5. These contaminants were predicted by SESOIL to reach the water table within the 1,000 year period in concentrations that were greater then the groundwater background or greater than the groundwater child no action levels. Several contaminants that originally passed the screening for groundwater did not reach the water table in 1,000 years [i.e., benzo(a)pyrene, dibenzo(a,h)anthracene, fluoranthene, PCB-1260, pyrene, and vanadium] or exhibited groundwater concentrations that were less than the groundwater background or the groundwater child no action levels (i.e., acenaphthene, anthracene, fluorine, nickel, selenium, TCE, and zinc) (see Section 5.4 of the main text).

Table E.3.17. Concentrations of the Analytes in Groundwater Predicted in SESOIL and AT123D Modeling of SWMU 5

Analyte	Predicted Maximum Groundwater Concentration[a,b]				
	SWMU (mg/L)	Plant Boundary (mg/L)	Property Boundary (mg/L)	Ohio River (mg/L)	MCL (mg/L)
Arsenic	9.25E-03	1.78E-03	1.27E-04	0	0.01
Manganese	***1.01E+00***	***8.69E-02***	2.30E-11	0	[d]
Naphthalene	5.55E-03	9.82E-04	3.72E-04	1.08E-04	na
^{99}Tc	1.27E+02	4.99E+01	2.64E+01	8.72E+00	900[c]

[a] Values in bold, italic font exceed the analyte's MCL
[b] Radionuclide concentrations are in pCi/L
[c] ^{99}Tc MCL based on a critical organ dose at 4 mrem/yr from drinking water consumption
[d] MCLs not available for these contaminants

All analytes are less than their MCL (note acenaphthene, manganese, and naphthalene do not have MCLs). The HQs and cancer risks calculated in accordance with the Risk Methods Document (DOE 2001) are presented in Table E.3.18. The predicted arsenic concentration at the plant boundary results in the greatest HQ, with naphthalene and manganese also exhibiting a HQ above 0.1. Arsenic presents the highest cancer risk followed by ^{99}Tc.

Table E.3.18. Hazard and Cancer Risk Predicted from Maximum Groundwater Concentrations Derived in Modeling of SWMU 5 Using SESOIL and AT123D[a]

Analyte	SWMU		Plant Boundary		Property Boundary		Ohio River	
	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk
Arsenic	2.96	2.45E-04	0.6	4.7E-05	<0.1	3.4E-06	[b]	[b]
Manganese	2.15	[b]	0.2	[b]	<0.1	[b]	[b]	[b]
Naphthalene	2.80	[b]	0.5	[b]	0.2	[b]	<0.1	[b]
^{99}Tc	[b]	6.97E-06	[b]	2.7E-06	[b]	1.4E-06	[b]	<1.0E-06

[a] Contaminants with a HQ greater than 1 or a cancer risk greater than 1.00E-06 are considered analytes.
[b] Value not calculated since the groundwater concentrations was reported as zero at this POE by AT123D, or the contaminant did not have a reported cancer slope factor or chemical toxicity RfD.

Figures 5.12 through 5.15 in Section 5 of the main text, show the predicted concentrations over time at each POE for analytes with a HQ greater than 0.1 and/or a risk greater than 1.0E-06 (see Table E.3.18) for contaminants migrating from SWMU 5. As shown in these figures, manganese is predicted to continue rising in concentration at 1,000 years at the plant boundary, but has not reached the property boundary or Ohio River in the 1,000 year period. Arsenic also is increasing in concentration at the plant boundary at 1,000 years; however, the concentrations are less than the MCL. ^{99}Tc is not predicted to exceed the MCL at the POEs.

E.3.1.5 SWMU 6

The C-747-B Burial Ground is located in the northwest section of the plant area east of SWMU5. PGDP buried waste at SWMU 6 in five separate burial cells between 1960 and 1976. The contents of each cell are as follows (DOE 2000):

- Area H—Magnesium Scrap Burial Area. The scrap buried at this location is magnesium, in various shapes generated in the machine shop.

- Area I—Exhaust Fan Burial Area. Eight exhaust hood blowers removed from C-710 were discarded in this pit. These blowers, which were about 15 inches in diameter and weighed about 100 lb each, were discarded in 1966 because of contamination with perchloric acid. Each blower was spaced about 4 ft apart in the hole. Area I-2 is a 6 ft by 6 ft pit just north of the main Area I pit that was used in 1976 for the disposal of additional exhaust fans.

- Area J—Contaminated Aluminum Burial Area. The contaminated scrap buried in this hole involved aluminum scrap in the form of nuts, bolts, plates, trimmings, etc., that were generated in the converter and compressor shop. This scrap was buried about 1960 or 1962.

- Area K—Magnesium Scrap Burial Area. The scrap buried at this location is magnesium in various shapes generated in the machine shop.

- Area L—Modine Trap Burial Area. A single contaminated modine trap was buried in this area. The cold trap was about 4 ft in diameter, approximately 15 ft long, and weighed about 5,000 lb.

Approximately 50% of the surface area of SWMU 6 formerly has been used to store radioactively-contaminated equipment and materials. These items include industrial forklifts and transport carts, flatbed trailers, generators, concrete pipes, and other miscellaneous items (DOE 2000).

E.3.1.5.1 Conceptual model for source areas at SWMU 6

SWMU 6 occupies an area of approximately 13,500 ft^2 (0.31 acres). The thickness of the UCRS is estimated to be 63 ft (depth to the top of the RGA). The conceptual model for SWMU 6 is that the waste cells contain potentially contaminated materials. Subsequently, contaminants in the disposed material directly impacted soils below or adjacent to the areas where material was buried and, through vertical infiltration in soil, contaminated the groundwater underlying these sources. The infiltrating groundwater migrates vertically through the UCRS and laterally in the RGA, which could transport the contaminants to the POEs.

E.3.1.5.2 Contaminant transport modeling for SWMU 6 using SESOIL and AT123D

For this modeling effort, the soil zones were arranged in four layers. The first soil layer represented the SADA surface soil data from 0 to 1 ft deep. The second soil layer was 9 ft thick representing SADA layer 2 from 1 to 9 ft in depth, the third layer was subdivided into 4 sublayers of equal thickness (10 ft each) representing SADA layers 3 through 6. SESOIL soil layer 4 was subdivided into 4 sublayers of equal thickness (3.25 ft each) to represent the total thickness of SADA layer 7 from 50 ft to 63 ft in depth. Table E.3.19 presents the analytes remaining after the screening process and the source terms for each analyte. Table E.3.20 lists the chemical-specific parameters applicable to the SESOIL model of SWMU 6. Figure E.3.3 presents the head distribution and flowpaths of several particles released from the SWMU. The distances to the POEs used in the AT123D model for SWMU 6 are 1,328 ft to the plant boundary, 3,561 ft to the property boundary, 15,138 ft to the Little Bayou seeps, and 19,424 ft to the Ohio River.

Table E.3.19. Summary of Source Term Characteristics Developed by SADA for SWMU 6

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Arsenic			
L1	0-1	5.63	2.50E+03	2.50E+03	5.82E+02	0.22	1.22
L2	01-10	3.16	9.90E+03	9.90E+04	1.29E+04	0.86	2.72
L3	10-20	2.83	9.70E+03	1.07E+05	1.25E+04	0.84	2.39
L4	20-30	3.99	1.15E+04	1.27E+05	2.08E+04	1.00	3.99
L5	30-40	2.68	3.60E+03	3.96E+04	4.38E+03	0.31	0.84
L6	40-50	3.58	5.80E+03	6.38E+04	9.44E+03	0.50	1.80
L7	50-63	3.50	6.10E+03	4.88E+04	7.06E+03	0.53	1.86
			Total Mass		6.77E+04		
				Beryllium			
L1	0-1	0.58	1.88E+04	1.88E+04	4.54E+02	0.56	0.33
L2	01-10	0.93	8.90E+03	8.90E+04	3.43E+03	0.27	0.25
L3	10-20	0.87	9.30E+03	1.02E+05	3.67E+03	0.28	0.24
L4	20-30	1.06	1.37E+04	1.51E+05	6.60E+03	0.41	0.43
L5	30-40	1.32	1.65E+04	1.82E+05	9.87E+03	0.49	0.65
L6	40-50	1.62	1.79E+04	1.97E+05	1.32E+04	0.53	0.87
L7	50-63	1.69	3.35E+04	2.68E+05	1.87E+04	1.00	1.69
			Total Mass		5.60E+04		
				Nickel			
L1	0-1	13.03	2.27E+04	2.27E+04	1.22E+04	0.64	8.28
L2	01-10	10.26	1.76E+04	1.76E+05	7.46E+04	0.49	5.06
L3	10-20	10.09	1.51E+04	1.66E+05	6.93E+04	0.42	4.27
L4	20-30	13.02	1.40E+04	1.54E+05	8.29E+04	0.39	5.11
L5	30-40	20.85	1.08E+04	1.19E+05	1.02E+05	0.30	6.31
L6	40-50	16.36	1.36E+04	1.50E+05	1.01E+05	0.38	6.23
L7	50-63	15.26	3.57E+04	2.86E+05	1.80E+05	1.00	15.26
			Total Mass		6.23E+05		
				TCE			
L1	0-1	0.0000	0.00E+00	0.00E+00	0.00E+00	0.00	0.0000
L2	01-10	0.0033	4.30E+03	4.30E+04	5.80E+00	1.00	0.0033
L3	10-20	0.0045	4.30E+03	4.73E+04	8.75E+00	1.00	0.0045
L4	20-30	0.0052	4.30E+03	4.73E+04	1.01E+01	1.00	0.0052
L5	30-40	0.0056	3.90E+03	4.29E+04	9.97E+00	0.91	0.0051
L6	40-50	0.0062	3.10E+03	3.41E+04	8.80E+00	0.72	0.0045
L7	50-63	0.0066	2.10E+03	1.68E+04	4.61E+00	0.49	0.0032
			Total Mass		4.81E+01		
				Uranium			
L1	0-1	114.00	5.90E+03	5.90E+03	2.78E+04	1.00	114.00
L2	01-10	1.06	3.00E+03	3.00E+04	1.31E+03	0.51	0.54
L3	10-20	1.06	2.80E+03	3.08E+04	1.35E+03	0.47	0.50
L4	20-30	1.05	2.90E+03	3.19E+04	1.39E+03	0.49	0.52
L5	30-40	1.06	4.30E+03	4.73E+04	2.06E+03	0.73	0.77
L6	40-50	1.06	5.30E+03	5.83E+04	2.56E+03	0.90	0.95
L7	50-63	1.09	3.70E+03	2.96E+04	1.33E+03	0.63	0.68
			Total Mass		3.78E+04		

Table E.3.19. Summary of Source Term Characteristics Developed by SADA for SWMU 6 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Vanadium			
L1	0-1	17.71	2.88E+04	2.88E+04	2.11E+04	0.54	9.61
L2	01-10	23.24	2.72E+04	2.72E+05	2.61E+05	0.51	11.91
L3	10-20	21.39	2.72E+04	2.99E+05	2.65E+05	0.51	10.96
L4	20-30	27.18	2.72E+04	2.99E+05	3.36E+05	0.51	13.92
L5	30-40	30.16	2.72E+04	2.99E+05	3.73E+05	0.51	15.45
L6	40-50	23.99	2.72E+04	2.99E+05	2.97E+05	0.51	12.29
L7	50-63	22.81	5.31E+04	4.25E+05	4.01E+05	1.00	22.81
			Total Mass		1.95E+06		
				Zinc			
L1	0-1	56.69	2.17E+04	2.17E+04	5.09E+04	0.57	32.46
L2	01-10	31.37	1.90E+04	1.90E+05	2.46E+05	0.50	15.73
L3	10-20	34.49	1.42E+04	1.56E+05	2.23E+05	0.37	12.92
L4	20-30	34.84	1.47E+04	1.62E+05	2.33E+05	0.39	13.51
L5	30-40	44.67	1.25E+04	1.38E+05	2.54E+05	0.33	14.73
L6	40-50	55.70	1.60E+04	1.76E+05	4.05E+05	0.42	23.52
L7	50-63	54.62	3.79E+04	3.03E+05	6.85E+05	1.00	54.62
			Total Mass		2.10E+06		
				^{99}Tc			
L1	0-1	1.45E+01	6.40E+03	6.40E+03	3.84E+09	1.00	14.5
L2	01-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.0
L3	10-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.0
L4	20-30	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.0
L5	30-40	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.0
L6	40-50	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.0
L7	50-63	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.0
			Total Mass		3.84E+09		

[a] Radionuclides are in units of pCi/g for concentrations and pCi for mass.

Table E.3.20. Chemical-Specific Parameters of the Analytes Used in SESOIL Modeling of SWMU 6

Analyte	Mol. Wt. (MW) (g/mol)	Solubility in water (mg/L)	Diffusion in air (cm^2/s)	Diffusion in water (m^2/hr)	Henry's Constant (atm.m3/mol)	Koc (L/kg)	Kd[a] (L/kg)	Half Life (years)
Arsenic	74.92	1.00E+07	NA	3.60E-07	NA	NA	29	infinite
Beryllium	9.01	1.00E+07	NA	3.60E-07	NA	NA	250	infinite
Nickel	58.69	1.00E+07	NA	3.60E-07	NA	NA	300	infinite
TCE	131	1,100	0.08	3.28E-06	0.0103	94	0.0752	26.6
^{99}Tc	99	1.00E+07	NA	3.60E-07	NA	NA	0.2	2.13E+05
Uranium	238	1.00E+07	NA	3.60E-07	NA	NA	66.8	4.47E+09
Vanadium	50.94	1.00E+07	NA	3.60E-07	NA	NA	1,000	infinite
Zinc	67.41	1.00E+07	NA	3.60E-07	NA	NA	62	infinite

[a] The soil/water distribution coefficient (Kd) of an organic compound depends on the soil's organic content (f_{oc}) and compound's organic partition coefficient (Koc). Kd values presented for organic compounds are for UCRS soils (with f_{oc} value of 0.08%) only. Kds used in AT123D are different due to the f_{oc} of 0.02% in the RGA.

E.3.1.5.3 Groundwater modeling results for SWMU 6

All of the analytes modeled at SWMU 6 that originally passed the screening steps for groundwater did not reach the water table in 1,000 years (i.e., beryllium, nickel, vanadium, and ^{99}Tc) or exhibited groundwater concentrations that were less than the groundwater background or the groundwater child no action levels (i.e., arsenic, TCE, uranium, and zinc) (see Section 5.4 of the main text),; therefore, there are no groundwater analytes for SWMU6.

E.3.1.6 SWMU 7

The C-747-A area is located in the northwest corner of the PGDP secured area and comprises the eastern two-thirds of C-747-A. SWMU 7 includes five discrete burial pit areas (DOE 1998c) used for the disposal of wastes from 1957 to 1979. The following summarizes what is known about the size and disposed waste in the burial pits.

- Pit B—This pit measures approximately 60 ft by 172 ft in area. Buried material includes noncombustible trash and contaminated and noncombustible material and equipment. According to the Phase II PGDP Site Investigation geophysical survey (CH2M HILL 1992), the actual excavation extends beyond the designated boundaries and may connect with the adjacent burial pit (Pit C). A geophysical survey conducted for this RI interprets B and C as separate pits.

- Pit C—This pit is approximately the same size as Pit B. Historic records indicate that both Pit B and C received the same material.

- Pit D—This pit underlies an area of approximately 15 ft by 99 ft. Documented buried material consists of uranium-contaminated concrete pieces of reactor tray bases from C-410, used during the fluorination process of uranium tetrafluoride to uranium hexafluoride.

- Pit E (outside the eastern boundary of SWMU 7 , within an adjacent scrap yard)—This pit measures approximately 15 ft by 143 ft. Documented buried material consists of uranium-contaminated concrete pieces of reactor tray bases.

- Pits F1-F5—These five pits are all small (average size of each pit is approximately 20 ft by 80 ft). Engineering drawings indicate a sixth “F” pit that was not labeled. Documented buried material consists of uranium-contaminated scrap metal and equipment and empty uranium and magnesium powder.

- Pit G—This pit extends approximately 27 ft by 122 ft in area. Documented buried material consists of noncombustible trash and contaminated and noncombustible material and equipment.

E.3.1.6.1 Conceptual model for source areas at SWMU 7

SWMU 7 occupies an area of approximately 240,900 ft^2 (5.5 acres). The thickness of the UCRS was estimated to be 60 ft (depth to the top of the RGA). The conceptual model for SWMU 7 is that potentially contaminated materials were buried in waste pits at SWMU 7. Subsequently, contaminants in the disposed material directly impacted soils below or adjacent to the areas where material was buried and, through vertical infiltration in soil, contaminated the groundwater underlying these sources. The infiltrating groundwater migrates vertically through the UCRS and laterally in the RGA, which could transport the contaminants to the POEs.

E.3.1.6.2 Contaminant transport modeling for SWMU 7 using SESOIL and AT123D

For this modeling effort, the soil zones were arranged in four layers. The first soil layer represented the SADA surface soil data from 0 to 1 ft deep. The second soil layer was 9 ft thick representing SADA layer 2 from 1 to 9 ft in depth, the third layer was subdivided into 4 sublayers of equal thickness (10 ft each) representing SADA layers 3 through 6. SESOIL soil layer 4 was subdivided into 4 sublayers of equal thickness (2.5 ft each) to represent the total thickness of SADA layer 7 from 50 ft to 60 ft in depth, the four sublayer division of this layer allowed for better numerical solution of the final flux to the RGA. Table E.3.21 presents the analytes remaining after the screening process and the source terms for each analyte. Table E.3.22 lists the chemical-specific parameters applicable to the SESOIL model of SWMU 7. Figure E.3.4 presents the head distribution and flowpaths of several particles released from the SWMU. The distances to the POEs used in the AT123D model for SWMU 7 are 97 ft to the plant boundary, 2,367 ft to the property boundary, and 14,283 ft to the Little Bayou seeps.

Table E.3.21. Summary of Source Term Characteristics Developed by SADA for SWMU 7

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
			1,1-DCE				
L1	0-1	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L2	01-10	0.87	2.80E+04	2.52E+05	9.01E+03	1.00E+00	0.87
L3	10-20	0.77	2.76E+04	2.76E+05	8.74E+03	9.86E-01	0.75
L4	20-30	0.80	2.68E+04	2.68E+05	8.83E+03	9.57E-01	0.76
L5	30-40	0.67	2.60E+04	2.60E+05	7.18E+03	9.29E-01	0.62
L6	40-50	0.68	2.48E+04	2.48E+05	7.00E+03	8.86E-01	0.60
L7	50-60	0.53	2.32E+04	2.32E+05	5.08E+03	8.29E-01	0.44
			Total Mass		4.58E+04		
			Arsenic				
L1	0-1	6.17	2.38E+05	2.38E+05	6.08E+04	1.59E+00	9.80
L2	01-10	3.60	1.50E+05	1.35E+06	2.01E+05	1.00E+00	3.60
L3	10-20	3.35	1.42E+05	1.42E+06	1.97E+05	9.49E-01	3.18
L4	20-30	3.43	1.41E+05	1.41E+06	2.00E+05	9.39E-01	3.22
L5	30-40	3.20	1.34E+05	1.34E+06	1.78E+05	8.96E-01	2.86
L6	40-50	3.43	1.26E+05	1.26E+06	1.78E+05	8.40E-01	2.88
L7	50-60	3.14	1.29E+05	1.29E+06	1.67E+05	8.59E-01	2.69
			Total Mass		1.18E+06		
			Benzo(a)pyrene				
L1	0-1	1.13	1.42E+05	1.42E+05	6.64E+03	1.00E+00	1.13
L2	01-10	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	.0.00
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L7	50-60	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
			Total Mass		6.64E+03		
			Cadmium				
L1	0-1	0.56	1.22E+05	1.22E+05	2.80E+03	1.00E+00	0.558
L2	01-10	0.15	1.76E+04	1.58E+05	9.81E+02	1.45E-01	0.022
L3	10-20	0.15	1.68E+04	1.68E+05	1.03E+03	1.38E-01	0.020
L4	20-30	0.15	1.60E+04	1.60E+05	9.82E+02	1.32E-01	0.020
L5	30-40	0.15	1.48E+04	1.48E+05	9.28E+02	1.22E-01	0.018
L6	40-50	0.16	9.60E+03	9.60E+04	6.22E+02	7.89E-02	0.012
L7	50-60	0.16	7.60E+03	7.60E+04	4.96E+02	6.25E-02	0.010
			Total Mass		7.84E+03		

Table E.3.21. Summary of Source Term Characteristics Developed by SADA for SWMU 7 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				***cis*-1,2-DCE**			
L1	0-1	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
L2	01-10	0.01	3.56E+04	3.20E+05	1.37E+02	1.02E+00	0.011
L3	10-20	0.05	3.36E+04	3.36E+05	6.98E+02	9.66E-01	0.049
L4	20-30	0.06	3.64E+04	3.64E+05	8.72E+02	1.05E+00	0.061
L5	30-40	0.10	3.48E+04	3.48E+05	1.45E+03	1.00E+00	0.101
L6	40-50	0.07	3.88E+04	3.88E+05	1.09E+03	1.11E+00	0.076
L7	50-60	0.11	2.48E+04	2.48E+05	1.09E+03	7.13E-01	0.075
			Total Mass		5.33E+03		
				Fluoranthene			
L1	0-1	1.79	1.68E+05	1.68E+05	1.25E+04	1.00E+00	1.79
L2	01-10	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L7	50-60	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
			Total Mass		1.25E+04		
				Manganese			
L1	0-1	286.91	2.38E+05	2.38E+05	2.82E+06	1.35E+00	387.98
L2	01-10	210.86	1.76E+05	1.58E+06	1.38E+07	1.00E+00	210.86
L3	10-20	180.78	1.76E+05	1.76E+06	1.32E+07	1.00E+00	180.78
L4	20-30	168.55	1.76E+05	1.76E+06	1.23E+07	1.00E+00	168.55
L5	30-40	150.16	1.76E+05	1.76E+06	1.09E+07	1.00E+00	150.16
L6	40-50	123.56	1.76E+05	1.76E+06	8.99E+06	1.00E+00	123.56
L7	50-60	127.42	1.76E+05	1.76E+06	9.27E+06	1.00E+00	127.42
			Total Mass		7.12E+07		
				Mercury			
L1	0-1	0.058	1.54E+05	1.54E+05	3.72E+02	1.00E+00	0.058
L2	01-10	0.023	3.68E+04	3.31E+05	3.19E+02	2.38E-01	0.006
L3	10-20	0.022	3.64E+04	3.64E+05	3.38E+02	2.36E-01	0.005
L4	20-30	0.021	2.92E+04	2.92E+05	2.53E+02	1.89E-01	0.004
L5	30-40	0.021	3.00E+04	3.00E+05	2.58E+02	1.94E-01	0.004
L6	40-50	0.023	2.08E+04	2.08E+05	2.01E+02	1.35E-01	0.003
L7	50-60	0.024	2.00E+04	2.00E+05	1.95E+02	1.30E-01	0.003
			Total Mass		1.94E+03		
				Nickel			
L1	0-1	25.94	2.38E+05	2.38E+05	2.55E+05	1.99E+00	51.62
L2	01-10	12.64	1.27E+05	1.14E+06	5.96E+05	1.06E+00	13.40
L3	10-20	12.52	1.20E+05	1.20E+06	6.19E+05	1.00E+00	12.52
L4	20-30	13.51	9.64E+04	9.64E+05	5.38E+05	8.06E-01	10.89
L5	30-40	13.51	9.00E+04	9.00E+05	5.03E+05	7.53E-01	10.17
L6	40-50	12.56	8.84E+04	8.84E+05	4.59E+05	7.39E-01	9.29
L7	50-60	12.84	8.72E+04	8.72E+05	4.63E+05	7.29E-01	9.36
			Total Mass		3.43E+06		

Table E.3.21. Summary of Source Term Characteristics Developed by SADA for SWMU 7 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				PCB-1254			
L1	0-1	0.130	1.88E+04	1.88E+04	1.01E+02	8.87E-01	0.115
L2	01-10	0.034	2.20E+04	1.98E+05	2.79E+02	1.04E+00	0.035
L3	10-20	0.033	2.12E+04	2.12E+05	2.92E+02	1.00E+00	0.033
L4	20-30	0.033	1.92E+04	1.92E+05	2.66E+02	9.06E-01	0.030
L5	30-40	0.035	1.68E+04	1.68E+05	2.45E+02	7.92E-01	0.028
L6	40-50	0.039	9.60E+03	9.60E+04	1.55E+02	4.53E-01	0.018
L7	50-60	0.040	7.60E+03	7.60E+04	1.25E+02	3.58E-01	0.014
			Total Mass		1.46E+03		
				PCB-1260			
L1	0-1	0.63	1.80E+05	1.80E+05	4.71E+03	1.00E+00	0.63
L2	01-10	2.45	8.00E+02	7.20E+03	7.29E+02	4.43E-03	0.01
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L7	50-60	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
			Total Mass		5.44E+03		
				Pyrene			
L1	0-1	2.07	1.68E+05	1.68E+05	1.44E+04	1.00E+00	2.07
L2	01-10	0.03	1.00E+04	9.00E+04	1.23E+02	5.95E-02	0.002
L3	10-20	0.03	9.20E+03	9.20E+04	1.26E+02	5.48E-02	0.002
L4	20-30	0.03	8.80E+03	8.80E+04	1.20E+02	5.24E-02	0.002
L5	30-40	0.03	8.80E+03	8.80E+04	1.20E+02	5.24E-02	0.002
L6	40-50	0.03	6.40E+03	6.40E+04	8.73E+01	3.81E-02	0.001
L7	50-60	0.03	5.20E+03	5.20E+04	7.09E+01	3.10E-02	0.001
			Total Mass		1.50E+04		
				Selenium			
L1	0-1	0.66	1.00E+05	1.00E+05	2.73E+03	3.85E+00	2.54
L2	01-10	0.55	2.60E+04	2.34E+05	5.29E+03	1.00E+00	0.55
L3	10-20	0.54	2.12E+04	2.12E+05	4.69E+03	8.15E-01	0.44
L4	20-30	0.53	1.84E+04	1.84E+05	4.06E+03	7.08E-01	0.38
L5	30-40	0.52	1.64E+04	1.64E+05	3.51E+03	6.31E-01	0.33
L6	40-50	0.52	1.12E+04	1.12E+05	2.41E+03	4.31E-01	0.22
L7	50-60	0.49	8.00E+03	8.00E+04	1.62E+03	3.08E-01	0.15
			Total Mass		2.43E+04		
				^{99}Tc			
L1	0-1	54.05	2.65E+05	2.65E+05	5.93E+11	1.00	54.05
L2	01-10	2.17	4.84E+04	4.36E+05	3.91E+10	0.18	0.40
L3	10-20	2.22	4.88E+04	4.88E+05	4.48E+10	0.18	0.41
L4	20-30	2.21	4.12E+04	4.12E+05	3.77E+10	0.16	0.34
L5	30-40	2.22	3.80E+04	3.80E+05	3.49E+10	0.14	0.32
L6	40-50	1.94	2.64E+04	2.64E+05	2.12E+10	0.10	0.19
L7	50-60	2.05	2.60E+04	2.60E+05	2.21E+10	0.10	0.20
			Total Mass		7.92E+11		

Table E.3.21. Summary of Source Term Characteristics Developed by SADA for SWMU 7 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Tetrachloroethene			
L1	0-1	0.0000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.0000
L2	01-10	0.0062	3.60E+03	3.24E+04	8.30E+00	9.00E-01	0.0056
L3	10-20	0.0062	2.00E+03	2.00E+04	5.13E+00	5.00E-01	0.0031
L4	20-30	0.0062	4.00E+03	4.00E+04	1.03E+01	1.00E+00	0.0062
L5	30-40	0.0062	1.60E+03	1.60E+04	4.10E+00	4.00E-01	0.0025
L6	40-50	0.0062	3.20E+03	3.20E+04	8.20E+00	8.00E-01	0.0050
L7	50-60	0.0062	1.20E+03	1.20E+04	3.08E+00	3.00E-01	0.0019
			Total Mass		3.91E+01		
				TCE			
L1	0-1	0.0000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.0000
L2	01-10	0.0071	2.00E+04	1.80E+05	5.27E+01	5.56E-01	0.0039
L3	10-20	0.0318	2.04E+04	2.04E+05	2.68E+02	5.67E-01	0.0180
L4	20-30	0.0357	2.96E+04	2.96E+05	4.37E+02	8.22E-01	0.0294
L5	30-40	0.0550	3.20E+04	3.20E+05	7.28E+02	8.89E-01	0.0489
L6	40-50	0.0881	3.60E+04	3.60E+05	1.31E+03	1.00E+00	0.0881
L7	50-60	0.0793	2.48E+04	2.48E+05	8.13E+02	6.89E-01	0.0546
			Total Mass		3.61E+03		
				^{234}U			
L1	0-1	61.35	2.38E+05	2.38E+05	6.04E+11	1.00	61.35
L2	01-10	3.12	1.06E+05	9.58E+05	1.23E+11	0.45	1.39
L3	10-20	12.13	9.12E+04	9.12E+05	4.58E+11	0.38	4.65
L4	20-30	13.64	8.64E+04	8.64E+05	4.87E+11	0.36	4.95
L5	30-40	13.21	8.44E+04	8.44E+05	4.61E+11	0.35	4.69
L6	40-50	11.24	8.48E+04	8.48E+05	3.94E+11	0.36	4.01
L7	50-60	8.23	7.60E+04	7.60E+05	2.58E+11	0.32	2.63
			Total Mass		2.79E+12		
				^{235}U			
L1	0-1	7.75	2.38E+05	2.38E+05	7.62E+10	1.00	7.75
L2	01-10	0.40	5.72E+04	5.15E+05	8.43E+09	0.24	0.10
L3	10-20	0.50	4.00E+04	4.00E+05	8.29E+09	0.17	0.08
L4	20-30	0.50	3.36E+04	3.36E+05	6.93E+09	0.14	0.07
L5	30-40	0.52	2.72E+04	2.72E+05	5.80E+09	0.11	0.06
L6	40-50	0.51	1.64E+04	1.64E+05	3.46E+09	0.07	0.04
L7	50-60	0.58	1.12E+04	1.12E+05	2.67E+09	0.05	0.03
			Total Mass		1.12E+11		
				^{238}U			
L1	0-1	387.67	2.38E+05	2.38E+05	3.81E+12	1.00	387.67
L2	01-10	8.67	6.88E+04	6.19E+05	2.22E+11	0.29	2.51
L3	10-20	23.85	5.52E+04	5.52E+05	5.44E+11	0.23	5.53
L4	20-30	26.37	5.48E+04	5.48E+05	5.97E+11	0.23	6.07
L5	30-40	25.20	5.04E+04	5.04E+05	5.25E+11	0.21	5.34
L6	40-50	24.50	4.08E+04	4.08E+05	4.13E+11	0.17	4.20
L7	50-60	22.16	2.92E+04	2.92E+05	2.68E+11	0.12	2.72
			Total Mass		6.38E+12		

Table E.3.21. Summary of Source Term Characteristics Developed by SADA for SWMU 7 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Uranium			
L1	0-1	374.74	2.22E+05	2.22E+05	3.45E+06	1.00E+00	374.74
L2	01-10	16.16	4.72E+04	4.25E+05	2.84E+05	2.12E-01	3.43
L3	10-20	21.38	2.84E+04	2.84E+05	2.51E+05	1.28E-01	2.73
L4	20-30	16.18	3.40E+04	3.40E+05	2.27E+05	1.53E-01	2.47
L5	30-40	17.66	2.88E+04	2.88E+05	2.10E+05	1.29E-01	2.29
L6	40-50	12.34	2.88E+04	2.88E+05	1.47E+05	1.29E-01	1.60
L7	50-60	14.84	1.84E+04	1.84E+05	1.13E+05	8.27E-02	1.23
			Total Mass		4.68E+06		
				Vanadium			
L1	0-1	26.44	2.38E+05	2.38E+05	2.60E+05	1.59	41.95
L2	01-10	12.92	1.56E+05	1.40E+06	7.48E+05	1.04	13.40
L3	10-20	12.37	1.50E+05	1.50E+06	7.67E+05	1.00	12.37
L4	20-30	11.82	1.53E+05	1.53E+06	7.47E+05	1.02	12.04
L5	30-40	11.00	1.49E+05	1.49E+06	6.77E+05	0.99	10.91
L6	40-50	10.02	1.52E+05	1.52E+06	6.28E+05	1.01	10.13
L7	50-60	10.39	1.48E+05	1.48E+06	6.34E+05	0.98	10.23
			Total Mass		4.46E+06		
				Vinyl Chloride			
L1	0-1	0.000	0.00E+00	0.00E+00	0.00E+00	0.00	0.0000
L2	01-10	0.005	7.20E+03	6.48E+04	1.46E+01	0.64	0.0035
L3	10-20	0.13	9.20E+03	9.20E+04	5.05E+02	0.82	0.11
L4	20-30	0.15	9.20E+03	9.20E+04	5.88E+02	0.82	0.13
L5	30-40	0.23	1.12E+04	1.12E+05	1.07E+03	1.00	0.23
L6	40-50	0.59	2.40E+03	2.40E+04	5.80E+02	0.21	0.13
L7	50-60	0.59	3.20E+03	3.20E+04	7.74E+02	0.29	0.17
			Total Mass		3.53E+03		
				Zinc			
L1	0-1	82.26	2.38E+05	2.38E+05	8.09E+05	2.27	186.82
L2	01-10	32.01	1.05E+05	9.43E+05	1.25E+06	1.00	32.01
L3	10-20	31.23	1.05E+05	1.05E+06	1.35E+06	1.00	31.23
L4	20-30	33.48	8.52E+04	8.52E+05	1.18E+06	0.81	27.22
L5	30-40	34.59	7.80E+04	7.80E+05	1.12E+06	0.74	25.75
L6	40-50	35.59	7.08E+04	7.08E+05	1.04E+06	0.68	24.04
L7	50-60	37.33	7.96E+04	7.96E+05	1.23E+06	0.76	28.35
			Total Mass		7.98E+06		

[a] Radionuclides are in units of pCi/g for concentrations and pCi for mass.

E.3.1.6.3 Groundwater modeling results for SWMU 7

Table E.3.23 summarizes the predicted maximum groundwater concentrations at the POEs for the analytes modeled at SWMU 7. These contaminants were predicted by SESOIL to reach the water table within the 1,000 year period in concentrations that were greater then the groundwater background or greater than the groundwater child no action levels. Several contaminants that originally passed the screening for groundwater did not reach the water table in 1,000 years [i.e., benzo(a)pyrene, fluoranthene, nickel, PCB-1260, and vanadium] or exhibited groundwater concentrations that were less than the groundwater background or the groundwater child no action levels (i.e., cadmium, mercury, pyrene, selenium, tetrachloroethene, zinc and ^{235}U) (see Section 5.4 of the main text).

Table E.3.22. Chemical-Specific Parameters of the Analytes Used in SESOIL Modeling of SWMU 7

Analyte	Mol. Wt. (MW) (g/mol)	Solubility in water (mg/L)	Diffusion in air (cm^2/s)	Diffusion in water (m^2/hr)	Henry's Constant (atm.m3/ mol)	Koc (L/kg)	Kd[a] (L/kg)	Half Life (years)
1,1-DCE	97	2.25E+03	0.09	3.74E-06	0.0261	65	0.013	infinite
Arsenic	74.92	1.00E+07	NA	3.60E-07	NA	NA	29	infinite
Benzo(a)pyrene	252.32	1.62E-03	4.3E-02	3.24E-06	1.13E-06	9.69E+05	772	infinite
Cadmium	112.41	1.00E+07	NA	3.60E-07	NA	NA	75	infinite
cis-1,2-DCE	96.94	3.50E+03	0.07	4.07E-06	4.08E-03	35.5	0.028	infinite
Fluorathene	202.26	0.206	0.030	2.29E-06	1.61E-05	4.91E+04	39.3	infinite
Manganese	54.94	1.00E+07	NA	1.29E-07	NA	NA	65	infinite
Mercury	200.59	6.00E-02	3.07E-02	2.27E-06	2.44E-02	NA	52	infinite
Nickel	58.69	1.00E+07	NA	3.60E-07	NA	NA	300	infinite
PCB-1254	327	7.00E-02	1.56E-02	1.80E-06	3.40E-04	4.25E+04	34	infinite
PCB-1260	375.7	2.70E02	1.38E-02	1.56E-06	7.40E-05	2.07E+05	165.6	infinite
Pyrene	202.3	0.135	0.0272	2.61E-06	1.1E-05	6.8E+04	54.4	infinite
Selenium	80.98	1.00E+07	NA	3.60E-07	NA	NA	5	infinite
^{99}Tc	99	1.00E+07	NA	3.60E-07	NA	NA	0.2	2.13E+05
Tetrachloroethene	165.8	200	0.072	2.95E-06	0.0184	265	0.053	infinite
TCE	131	1,100	0.08	3.28E-06	0.0103	94	0.0752	26.6
^{234}U	234	1.00E+07	NA	3.60E-07	NA	NA	66.8	2.44E+05
^{235}U	235	1.00E+07	NA	3.60E-07	NA	NA	66.8	7.04E+08
^{238}U	238	1.00E+07	NA	3.60E-07	NA	NA	66.8	4.47E+09
Uranium	238	1.00E+07	NA	3.60E-07	NA	NA	66.8	4.47E+09
Vanadium	50.94	1.00E+07	NA	3.60E-07	NA	NA	1,000	infinite
Vinyl Chloride	63	2,760	0.11	4.43E-07	0.0270	18.8	0.0152	infinite
Zinc	67.41	1.00E+07	NA	3.60E-07	NA	NA	62	infinite

[a] The soil/water distribution coefficient (Kd) of an organic compound depends on the soil's organic content (f_{oc}) and compound's organic partition coefficient (Koc). Kd values presented for organic compounds are for UCRS soils (with f_{oc} value of 0.08%) only. Kds used in AT123D are different due to the f_{oc} of 0.02% in the RGA.

As shown in Table E.3.23, the predicted maximum groundwater concentrations for 1,1-DCE; arsenic; manganese; TCE; and vinyl chloride exceed the MCLs at the plant boundary. All analyte groundwater concentrations are less than the MCLs at the property boundary, and Little Bayou seeps. The HQs and cancer risks calculated in accordance with the Risk Methods Document (DOE 2001) are presented in Table E.3.24. The predicted TCE and arsenic concentrations result in the greatest HQs. 1,1-DCE, arsenic, TCE and vinyl chloride provides the highest cancer risk for SWMU 7. ^{99}Tc also was predicted to present cancer risks in the 10^{-5} range.

Figures 5.16 through 5.25 in Section 5 of the main text, show the predicted concentrations over time at each POE for analytes with a HQ greater than 0.1 and/or a risk greater than 1.0E-06 for contaminants migrating from SWMU 7. As shown in these figures, arsenic, TCE and vinyl chloride are predicted to exceed their respective MCLs at the plant boundary. No analytes were predicted to exceed their respective MCLs at the other POEs.

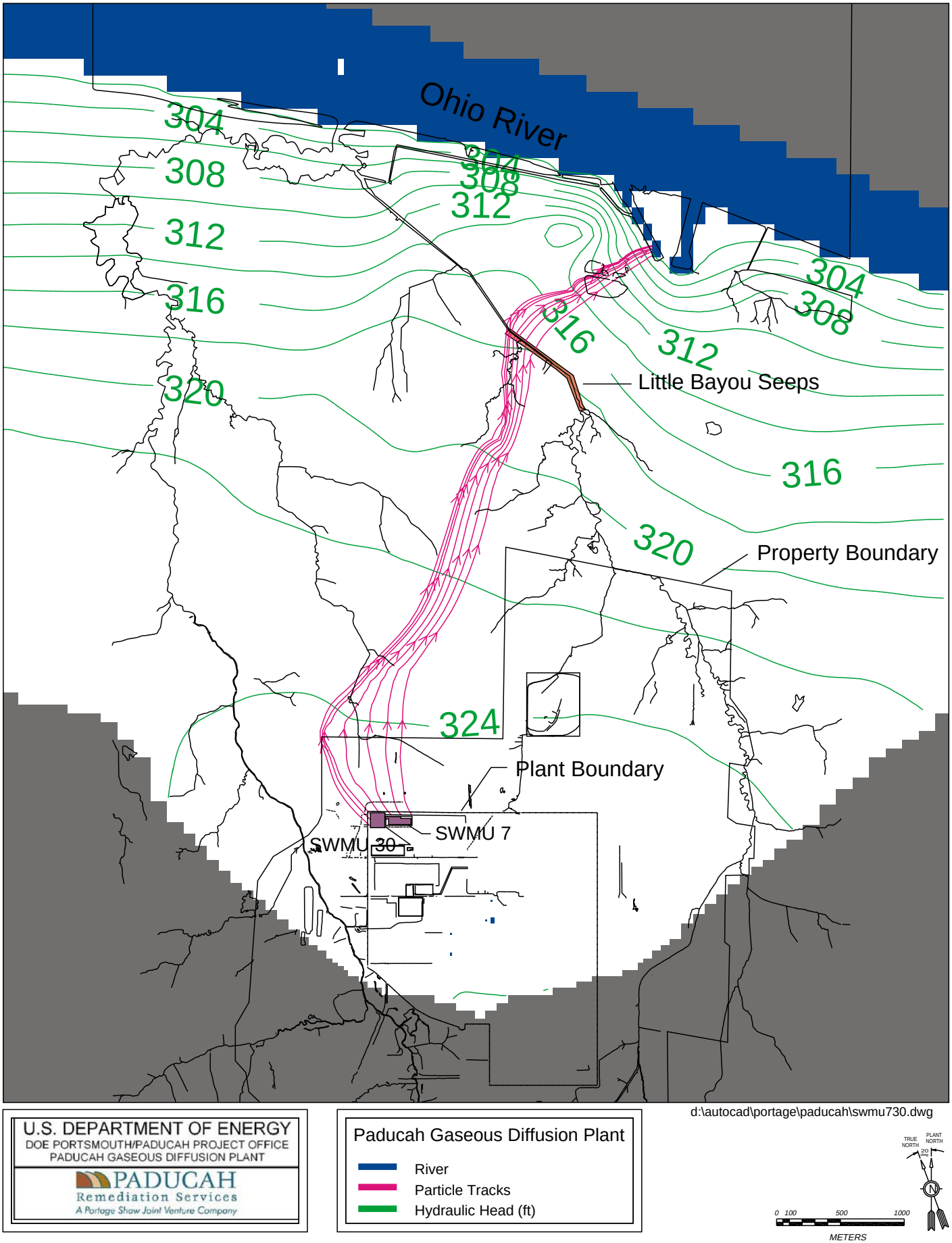


Figure E.3.4. Particle Tracks for SWMUs 7 and 30

Table E.3.23. Concentrations of the Analytes in Groundwater Predicted in SESOIL and AT123D Modeling of SWMU 7

	Predicted Maximum Groundwater Concentration[a,b]				
Analyte	**SWMU (mg/L)**	**Plant Boundary (mg/L)**	**Property Boundary (mg/L)**	**Little Bayou seeps (mg/L)**	**MCL (mg/L)**
1,1-DCE	***8.98E-02***	***8.24E-02***	1.10E-02	4.02E-03	0.07
Arsenic	***1.78E-02***	***1.26E-02***	2.35E-03	0	0.01
cis,-1,2-DCE	2.35E-02	2.15E-02	3.13E-03	1.17E-03	0.07
Manganese	***3.32E-01***	***2.41E-01***	1.05E-06	0	[d]
PCB-1254	5.23E-05	3.09E-05	3.05E-06	1.32E-12	[d]
^{99}Tc	***9.09E+02***	8.25E+02	2.70E+02	1.32E+02	900[c]
TCE	***1.09E-02***	***9.87E-03***	1.42E-03	5.06E-04	0.005
^{234}U	7.94E+00	5.79E+00	5.84E-06	0	[d]
^{238}U	7.59E+00	5.58E+00	5.85E-06	0	[d]
Uranium	3.46E-03	2.53E-03	2.68E-09	0	0.03
Vinyl Chloride	***1.35E-02***	***1.24E-02***	1.21E-03	4.13E-04	0.002

[a] Values in bold, italic font exceed the analyte's MCL
[b] Radionuclide concentrations are in pCi/L
[c] ^{99}Tc MCL based on a critical organ dose at 4 mrem/yr from drinking water consumption
[d] MCLs not available for these contaminants

Table E.3.24. Hazard and Cancer Risk Predicted from Maximum Groundwater Concentrations Derived in Modeling of SWMU 7 Using SESOIL and AT123D[a]

	SWMU		**Plant Boundary**		**Property Boundary**		**Little Bayou seeps**	
Analyte	**Hazard Quotient**	**Cancer Risk**	**Hazard Quotient**	**Cancer Risk**	**Hazard Quotient**	**Cancer Risk**	**Hazard Quotient**	**Cancer Risk**
1,1-DCE	0.85	2.08E-03	0.8	1.9E-03	0.1	2.5E-04	<0.1	9.3E-05
Arsenic	5.70	4.72E-04	4.0	3.3E-04	0.8	6.2E-05	[b]	[b]
cis,-1,2-DCE	1.24	[b]	1.1	[b]	0.2	[b]	<0.1	[b]
Manganese	0.71	[b]	0.5	[b]	<0.1	[b]	[b]	[b]
PCB-1254	4.20	7.09E-06	2.5	4.8E-06	0.2	<1.0E-06	<0.1	<1.0E-06
^{99}Tc	[b]	4.99E-05	[b]	4.5E-05	[b]	1.5E-05	[b]	7.3E-06
TCE	4.98	1.27E-04	4.5	3.1E-04	0.6	4.4E-05	0.2	1.6E-05
^{234}U	[b]	1.11E-05	[b]	8.2E-06	[b]	<1.0E-06	[b]	[b]
^{238}U	[b]	1.32E-05	[b]	9.7E-06	[b]	<1.0E-06	[b]	[b]
Uranium	0.55	[b]	0.40	[b]	<0.1	[b]	[b]	[b]
Vinyl Chloride	0.64	3.72E-04	0.6	3.6E-04	<0.1	3.6E-05	<0.1	1.2E-05

[a] Contaminants with a HQ greater than 0.1 or a cancer risk greater than 1.00E-06 are considered analytes.
[b] Value not calculated since the groundwater concentrations was reported as zero at this POE by AT123D, or the contaminant did not have a reported cancer slope factor or chemical toxicity RfD.

E.3.1.7 SWMU 30

SWMU 30 consists of an historical burn-and-burial pit and the location of a former incinerator, used from 1951 to 1970 to burn combustible trash which may have contained uranium contamination. The pit is reported to have been excavated to a depth of 12 ft. SWMU 30 is bounded on the east side by C-747-A Burial Ground (SWMU 7).

E.3.1.7.1 Conceptual model for source areas at SWMU 30

SWMU 30 occupies an area of approximately 128,000 ft^2 (2.9 acres). The thickness of the UCRS was estimated to be 61 ft (depth to the top of the RGA). The conceptual model for SWMU 30 is that potentially contaminated materials were buried in waste pits at SWMU 30. Subsequently, contaminants in disposed material directly impacted soils below or adjacent to the areas where material was buried and, through vertical infiltration in soil, contaminated the groundwater underlying these sources. The infiltrating groundwater migrates vertically through the UCRS and laterally in the RGA, which could transport the contaminants to the POEs.

E.3.1.7.2 Contaminant transport modeling for SWMU 30 using SESOIL and AT123D

For this modeling effort, the soil zones were arranged in four layers. The first soil layer represented the SADA surface soil data from 0 to 1 ft deep. The second soil layer was 9 ft thick representing SADA layer 2 from 1 to 9 ft in depth, the third layer was subdivided into 4 sublayers of equal thickness (10 ft each) representing SADA layers 3 through 6. SESOIL soil layer 4 was subdivided into 4 sublayers of equal thickness (2.75 ft each) to represent the total thickness of SADA layer 7 from 50 ft to 61 ft in depth, the four sublayer division of this layer allowed for better numerical solution of the final flux to the RGA Table E.3.25 presents the analytes remaining after the screening process and the source terms for each analyte. Table E.3.26 lists the chemical-specific parameters applicable to the SESOIL model of SWMU 30. Figure E.3.4 presents the head distribution and flowpaths of several particles released from the SWMU. The distances to the POEs used in the AT123D model for SWMU 30 are 107 ft to the plant boundary, 2,127 ft to the property boundary, and 13,013 ft to the Little Bayou seeps.

Table E.3.25. Summary of Source Term Characteristics Developed by SADA for SWMU 30

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
			1,1-DCE				
L1	0-1	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L2	01-10	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L5	30-40	5.00	8.00E+02	8.00E+03	1.65E+03	4.00E-01	2.00
L6	40-50	5.00	2.00E+03	2.00E+04	4.13E+03	1.00E+00	5.00
L7	50-61	5.00	2.00E+03	2.20E+04	4.55E+03	1.00E+00	5.00
			Total Mass		1.03E+04		
			Acenaphthene				
L1	0-1	0.28	5.16E+04	5.16E+04	6.06E+02	1.00E+00	0.28
L2	01-10	0.017	3.20E+03	2.88E+04	2.02E+01	6.20E-02	0.0011
L3	10-20	0.017	3.20E+03	3.20E+04	2.25E+01	6.20E-02	0.0011
L4	20-30	0.017	3.20E+03	3.20E+04	2.25E+01	6.20E-02	0.0011
L5	30-40	0.017	2.40E+03	2.40E+04	1.69E+01	4.65E-02	0.0008
L6	40-50	0.017	1.20E+03	1.20E+04	8.43E+00	2.33E-02	0.0004
L7	50-61	0.017	1.20E+03	1.32E+04	9.28E+00	2.33E-02	0.0004
			Total Mass		7.06E+02		

Table E.3.25. Summary of Source Term Characteristics Developed by SADA for SWMU 30 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Arsenic			
L1	0-1	5.86	9.24E+04	9.24E+04	2.24E+04	1.14E+00	6.67
L2	01-10	4.63	7.96E+04	7.16E+05	1.37E+05	9.80E-01	4.54
L3	10-20	4.40	8.12E+04	8.12E+05	1.48E+05	1.00E+00	4.40
L4	20-30	4.30	8.08E+04	8.08E+05	1.44E+05	9.95E-01	4.28
L5	30-40	4.07	8.16E+04	8.16E+05	1.37E+05	1.00E+00	4.09
L6	40-50	3.93	8.08E+04	8.08E+05	1.31E+05	9.95E-01	3.91
L7	50-61	3.86	8.20E+04	9.02E+05	1.44E+05	1.01E+00	3.90
			Total Mass		8.64E+05		
				Benzo(a)pyrene			
L1	0-1	1.00	9.72E+04	9.72E+04	4.01E+03	1.00E+00	1.00
L2	01-10	0.05	3.20E+03	2.88E+04	6.19E+01	3.29E-02	0.0017
L3	10-20	0.05	3.20E+03	3.20E+04	6.88E+01	3.29E-02	0.0017
L4	20-30	0.05	3.20E+03	3.20E+04	6.88E+01	3.29E-02	0.0017
L5	30-40	0.05	2.40E+03	2.40E+04	5.16E+01	2.47E-02	0.0013
L6	40-50	0.05	1.20E+03	1.20E+04	2.58E+01	1.23E-02	0.0006
L7	50-61	0.05	1.20E+03	1.32E+04	2.84E+01	1.23E-02	0.0006
			Total Mass		4.31E+03		
				Cadmium			
L1	0-1	1.92	4.68E+04	4.68E+04	3.72E+03	1.00E+00	1.925
L2	01-10	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
L7	50-61	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
			Total Mass		3.72E+03		
				Dibenzoanthracene			
L1	0-1	0.33	5.64E+04	5.64E+04	7.61E+02	1.00E+00	0.327
L2	01-10	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
L7	50-61	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
			Total Mass		7.61E+02		
				Fluorene			
L1	0-1	0.25	4.56E+04	4.56E+04	4.72E+02	1.00E+00	0.25
L2	01-10	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L7	50-61	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
			Total Mass		4.72E+02		

Table E.3.25. Summary of Source Term Characteristics Developed by SADA for SWMU 30 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Manganese			
L1	0-1	338.66	1.22E+05	1.22E+05	1.71E+06	1.46E+00	495.84
L2	01-10	250.12	8.36E+04	7.52E+05	7.78E+06	1.00E+00	250.12
L3	10-20	242.52	8.36E+04	8.36E+05	8.38E+06	1.00E+00	242.52
L4	20-30	238.27	8.36E+04	8.36E+05	8.24E+06	1.00E+00	238.27
L5	30-40	221.98	8.36E+04	8.36E+05	7.67E+06	1.00E+00	221.98
L6	40-50	206.94	8.36E+04	8.36E+05	7.15E+06	1.00E+00	206.94
L7	50-61	212.37	8.36E+04	9.20E+05	8.07E+06	1.00E+00	212.37
			Total Mass		4.90E+07		
				Mercury			
L1	0-1	0.111	8.48E+04	8.48E+04	3.88E+02	1.00E+00	0.111
L2	01-10	0.062	1.40E+04	1.26E+05	3.24E+02	1.65E-01	0.0103
L3	10-20	0.055	1.24E+04	1.24E+05	2.81E+02	1.46E-01	0.0080
L4	20-30	0.053	1.04E+04	1.04E+05	2.28E+02	1.23E-01	0.0065
L5	30-40	0.040	9.20E+03	9.20E+04	1.52E+02	1.08E-01	0.0043
L6	40-50	0.022	6.80E+03	6.80E+04	6.14E+01	8.02E-02	0.0018
L7	50-61	0.022	6.80E+03	7.48E+04	6.75E+01	8.02E-02	0.0018
			Total Mass		1.50E+03		
				Napthalene			
L1	0-1	0.31	8.00E+03	8.00E+03	1.03E+02	1.00E+00	0.31
L2	01-10	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L3	10-20	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L4	20-30	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L5	30-40	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L6	40-50	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
L7	50-61	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
			Total Mass		1.03E+02		
				Nickel			
L1	0-1	60.18	1.22E+05	1.22E+05	3.05E+05	1.65E+00	99.00
L2	01-10	17.40	7.44E+04	6.70E+05	4.82E+05	1.00E+00	17.40
L3	10-20	16.86	7.32E+04	7.32E+05	5.10E+05	9.84E-01	16.58
L4	20-30	16.42	7.32E+04	7.32E+05	4.97E+05	9.84E-01	16.16
L5	30-40	15.69	7.28E+04	7.28E+05	4.72E+05	9.78E-01	15.36
L6	40-50	15.44	7.28E+04	7.28E+05	4.65E+05	9.78E-01	15.11
L7	50-61	15.11	7.44E+04	8.18E+05	5.11E+05	1.00E+00	15.11
			Total Mass		3.24E+06		
				PCB-1254			
L1	0-1	0.200	3.00E+04	3.00E+04	2.48E+02	1.00E+00	0.200
L2	01-10	0.028	5.60E+03	5.04E+04	5.83E+01	1.87E-01	0.0052
L3	10-20	0.028	5.60E+03	5.60E+04	6.48E+01	1.87E-01	0.0052
L4	20-30	0.028	5.60E+03	5.60E+04	6.48E+01	1.87E-01	0.0052
L5	30-40	0.028	5.60E+03	5.60E+04	6.48E+01	1.87E-01	0.0052
L6	40-50	0.028	5.60E+03	5.60E+04	6.48E+01	1.87E-01	0.0052
L7	50-61	0.028	5.20E+03	5.72E+04	6.62E+01	1.73E-01	0.0049
			Total Mass		6.32E+02		

E.3.25. Summary of Source Term Characteristics Developed by SADA for SWMU 30 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				PCB-1260			
L1	0-1	1.54	1.22E+05	1.22E+05	7.81E+03	1.00E+00	1.54
L2	01-10	0.08	3.00E+04	2.70E+05	8.40E+02	2.45E-01	0.018
L3	10-20	0.07	2.76E+04	2.76E+05	7.92E+02	2.25E-01	0.016
L4	20-30	0.07	2.52E+04	2.52E+05	6.93E+02	2.06E-01	0.014
L5	30-40	0.06	2.12E+04	2.12E+05	5.27E+02	1.73E-01	0.010
L6	40-50	0.05	1.84E+04	1.84E+05	4.17E+02	1.50E-01	0.008
L7	50-61	0.05	1.68E+04	1.85E+05	4.14E+02	1.37E-01	0.007
			Total Mass		1.15E+04		
				Pyrene			
L1	0-1	2.16	1.08E+05	1.08E+05	9.66E+03	1.00E+00	2.16
L2	01-10	0.043	3.04E+04	2.74E+05	4.82E+02	2.81E-01	0.012
L3	10-20	0.042	2.96E+04	2.96E+05	5.16E+02	2.74E-01	0.012
L4	20-30	0.042	2.80E+04	2.80E+05	4.81E+02	2.59E-01	0.011
L5	30-40	0.041	2.56E+04	2.56E+05	4.32E+02	2.37E-01	0.010
L6	40-50	0.040	2.40E+04	2.40E+05	4.02E+02	2.22E-01	0.009
L7	50-61	0.040	2.20E+04	2.42E+05	4.00E+02	2.04E-01	0.008
			Total Mass		1.24E+04		
				Selenium			
L1	0-1	0.66	2.12E+04	2.12E+04	5.78E+02	1.56E+00	1.03
L2	01-10	0.91	1.40E+04	1.26E+05	4.73E+03	1.03E+00	0.94
L3	10-20	0.91	1.36E+04	1.36E+05	5.09E+03	1.00E+00	0.91
L4	20-30	0.90	1.32E+04	1.32E+05	4.93E+03	9.71E-01	0.88
L5	30-40	0.92	1.20E+04	1.20E+05	4.56E+03	8.82E-01	0.81
L6	40-50	0.96	1.08E+04	1.08E+05	4.27E+03	7.94E-01	0.76
L7	50-61	0.95	1.04E+04	1.14E+05	4.51E+03	7.65E-01	0.73
			Total Mass		2.87E+04		
				^{99}Tc			
L1	0-1	20.79	1.22E+05	1.22E+05	1.05E+11	1.00	20.79
L2	01-10	1.78	3.56E+04	3.20E+05	2.36E+10	0.29	0.52
L3	10-20	1.54	3.32E+04	3.32E+05	2.12E+10	0.27	0.42
L4	20-30	1.42	3.08E+04	3.08E+05	1.80E+10	0.25	0.36
L5	30-40	1.14	2.68E+04	2.68E+05	1.26E+10	0.22	0.25
L6	40-50	0.89	2.40E+04	2.40E+05	8.80E+09	0.20	0.17
L7	50-61	0.86	2.20E+04	2.42E+05	8.56E+09	0.18	0.15
			Total Mass		1.98E+11		
				TCE			
L1	0-1	0.0000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.0000
L2	01-10	37.4000	3.60E+03	3.24E+04	5.01E+04	1.00E+00	37.4000
L3	10-20	37.4000	2.80E+03	2.80E+04	4.33E+04	7.78E-01	29.0889
L4	20-30	37.4000	3.60E+03	3.60E+04	5.57E+04	1.00E+00	37.4000
L5	30-40	37.4000	2.00E+03	2.00E+04	3.09E+04	5.56E-01	20.7778
L6	40-50	37.4000	2.40E+03	2.40E+04	3.71E+04	6.67E-01	24.9333
L7	50-61	37.4000	1.20E+03	1.32E+04	2.04E+04	3.33E-01	12.4667
			Total Mass		2.37E+05		

E.3.25. Summary of Source Term Characteristics Developed by SADA for SWMU 30 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				^{234}U			
L1	0-1	42.53	1.22E+05	1.22E+05	2.15E+11	1.00	42.53
L2	01-10	4.39	6.56E+04	5.90E+05	1.07E+11	0.54	2.36
L3	10-20	4.64	6.76E+04	6.76E+05	1.30E+11	0.55	2.56
L4	20-30	4.54	6.64E+04	6.64E+05	1.25E+11	0.54	2.46
L5	30-40	4.04	6.80E+04	6.80E+05	1.14E+11	0.56	2.25
L6	40-50	3.99	6.60E+04	6.60E+05	1.09E+11	0.54	2.15
L7	50-61	3.50	7.00E+04	7.70E+05	1.11E+11	0.57	2.00
			Total Mass		9.11E+11		
				^{235}U			
L1	0-1	4.44	1.22E+05	1.22E+05	2.25E+10	1.00	4.44
L2	01-10	0.31	3.80E+04	3.42E+05	4.34E+09	0.31	0.10
L3	10-20	0.33	3.44E+04	3.44E+05	4.64E+09	0.28	0.09
L4	20-30	0.31	3.40E+04	3.40E+05	4.41E+09	0.28	0.09
L5	30-40	0.34	2.84E+04	2.84E+05	4.01E+09	0.23	0.08
L6	40-50	0.35	2.72E+04	2.72E+05	3.92E+09	0.22	0.08
L7	50-61	0.36	2.36E+04	2.60E+05	3.90E+09	0.19	0.07
			Total Mass		4.77E+10		
				^{238}U			
L1	0-1	103.92	1.22E+05	1.22E+05	5.26E+11	1.00	103.92
L2	01-10	7.61	5.96E+04	5.36E+05	1.69E+11	0.49	3.71
L3	10-20	9.37	5.80E+04	5.80E+05	2.25E+11	0.47	4.44
L4	20-30	9.55	5.32E+04	5.32E+05	2.10E+11	0.43	4.15
L5	30-40	8.75	5.16E+04	5.16E+05	1.87E+11	0.42	3.69
L6	40-50	8.99	4.60E+04	4.60E+05	1.71E+11	0.38	3.38
L7	50-61	8.64	4.48E+04	4.93E+05	1.76E+11	0.37	3.16
			Total Mass		1.66E+12		
				Uranium			
L1	0-1	797.22	2.88E+04	2.88E+04	9.49E+05	1.00E+00	797.22
L2	01-10	4.39	5.28E+04	4.75E+05	8.62E+04	1.83E+00	8.05
L3	10-20	4.20	5.40E+04	5.40E+05	9.38E+04	1.88E+00	7.88
L4	20-30	4.19	5.20E+04	5.20E+05	9.01E+04	1.81E+00	7.57
L5	30-40	3.97	5.40E+04	5.40E+05	8.87E+04	1.88E+00	7.45
L6	40-50	4.06	5.24E+04	5.24E+05	8.79E+04	1.82E+00	7.38
L7	50-61	3.87	5.40E+04	5.94E+05	9.50E+04	1.88E+00	7.25
			Total Mass		1.49E+06		
				Vanadium			
L1	0-1	25.32	1.22E+05	1.22E+05	1.28E+05	1.47	37.25
L2	01-10	14.34	8.32E+04	7.49E+05	4.44E+05	1.00	14.34
L3	10-20	13.51	8.32E+04	8.32E+05	4.65E+05	1.00	13.51
L4	20-30	12.98	8.36E+04	8.36E+05	4.49E+05	1.00	13.05
L5	30-40	12.05	8.36E+04	8.36E+05	4.16E+05	1.00	12.11
L6	40-50	11.28	8.36E+04	8.36E+05	3.90E+05	1.00	11.33
L7	50-61	11.04	8.36E+04	9.20E+05	4.20E+05	1.00	11.09
			Total Mass		2.71E+06		

E.3.25. Summary of Source Term Characteristics Developed by SADA for SWMU 30 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Zinc			
L1	0-1	105.49	1.22E+05	1.22E+05	5.34E+05	1.84	194.45
L2	01-10	42.25	6.72E+04	6.05E+05	1.06E+06	1.01	42.76
L3	10-20	41.98	6.60E+04	6.60E+05	1.15E+06	0.99	41.73
L4	20-30	42.44	6.52E+04	6.52E+05	1.14E+06	0.98	41.67
L5	30-40	42.67	6.44E+04	6.44E+05	1.14E+06	0.97	41.39
L6	40-50	43.94	6.36E+04	6.36E+05	1.16E+06	0.96	42.08
L7	50-61	44.35	6.64E+04	7.30E+05	1.34E+06	1.00	44.35
			Total Mass		7.51E+06		

[a] Radionuclides are in units of pCi/g for concentrations and pCi for mass.

Table E.3.26. Chemical-Specific Parameters of the Analytes Used in SESOIL Modeling of SWMU 30

Analyte	Mol. Wt. (MW) (g/mol)	Solubility in water (mg/L)	Diffusion in air (cm^2/s)	Diffusion in water (m^2/hr)	Henry's Constant (atm.m3/mol)	Koc (L/kg)	Kd[a] (L/kg)	Half Life (years)
1,1-DCE	97	2.25E+03	0.09	3.74E-06	0.0261	65	0.013	infinite
Acenapthene	154.0	4.20	0.04	2.77E-6	1.60E-04	4.90E+03	3.9	infinite
Arsenic	74.92	1.00E+07	NA	3.60E-07	NA	NA	29	infinite
Benzo(a)pyrene	252.32	1.62E-03	4.3E-02	3.24E-06	1.13E-06	9.69E+05	772	infinite
Cadmium	112.41	1.00E+07	NA	3.60E-07	NA	NA	75	infinite
Dibenzo(a,h) anthracene	278.33	0.0025	0.020	1.86E-06	1.47E-08	1.78E+06	1424	infinite
Fluorene	166.0	1.90	0.061	2.84E-06	7.7E-05	7.9E+03	6.3	infinite
Manganese	54.94	1.00E+07	NA	1.29E-07	NA	NA	65	infinite
Mercury	200.59	6.00E-02	3.07E-02	2.27E-06	2.44E-02	NA	52	infinite
Naphthalene	128.16	31.0	0.059	2.70E-06	4.83E-04	1.19E+03	0.95	infinite
Nickel	58.69	1.00E+07	NA	3.60E-07	NA	NA	300	infinite
PCB-1254	327	7.00E-02	1.56E-02	1.80E-06	3.40E-04	4.25E+04	34	infinite
PCB-1260	375.7	2.70E02	1.38E-02	1.56E-06	7.40E-05	2.07E+05	165.6	infinite
Pyrene	202.3	0.135	0.0272	2.61E-06	1.1E-05	6.8E+04	54.4	infinite
Selenium	80.98	1.00E+07	NA	3.60E-07	NA	NA	5	infinite
^{99}Tc	99	1.00E+07	NA	3.60E-07	NA	NA	0.2	2.13E+05
TCE	131	1,100	0.08	3.28E-06	0.0103	94	0.0752	26.6
^{234}U	234	1.00E+07	NA	3.60E-07	NA	NA	66.8	2.44E+05
^{235}U	235	1.00E+07	NA	3.60E-07	NA	NA	66.8	7.04E+08
^{238}U	238	1.00E+07	NA	3.60E-07	NA	NA	66.8	4.47E+09
Uranium	238	1.00E+07	NA	3.60E-07	NA	NA	66.8	4.47E+09
Vanadium	50.94	1.00E+07	NA	3.60E-07	NA	NA	1,000	infinite
Zinc	67.41	1.00E+07	NA	3.60E-07	NA	NA	62	infinite

[a] The soil/water distribution coefficient (Kd) of an organic compound depends on the soil's organic content (f_{oc}) and compound's organic partition coefficient (Koc). Kd values presented for organic compounds are for UCRS soils (with f_{oc} value of 0.08%) only. Kds used in AT123D are different due to the f_{oc} of 0.02% in the RGA.

E.3.1.7.3 Groundwater modeling results for SWMU 30

Table E.3.27 summarizes the predicted maximum groundwater concentrations at the POEs for the analytes modeled at SWMU 30. These contaminants were predicted by SESOIL to reach the water table within the 1,000 year period in concentrations that were greater then the groundwater background or greater than the groundwater child no action levels. Several contaminants that originally passed the screening for groundwater did not reach the water table in 1,000 years [i.e., benzo(a)pyrene, cadmium, dibenzo(a,h)anthracene, nickel, and vanadium] or exhibited groundwater concentrations that were less than the groundwater background or the groundwater child no action levels (i.e., acenapthene, fluorine, mercury, naphthalene, PCB-1254, PCB-1260, pyrene, zinc and ^{235}U) (see Section 5.4 of the main text) including acenaphthene, benzo(a)pyrene, cadmium, dibenzo(a,h)anthracene, fluorine, mercury, naphthalene, nickel, PCB-1254, PCB-1260, pyrene, ^{235}U, vanadium, and zinc.

Table E.3.27. Concentrations of the Analytes in Groundwater Predicted in SESOIL and AT123D Modeling of SWMU 30

	Predicted Maximum Groundwater Concentration[a,b]				
Analyte	**SWMU (mg/L)**	**Plant Boundary (mg/L)**	**Property Boundary (mg/L)**	**Little Bayou seeps (mg/L)**	**MCL (mg/L)**
1,1-DCE	6.05E-02	5.92E-02	4.41E-03	1.32E-03	0.07
Arsenic	***1.77E-02***	***1.17E-02***	2.34E-03	0	0.01
Manganese	***3.78E-01***	***2.51E-01***	2.85E-04	0	[d]
Selenium	1.51E-02	8.30E-03	9.21E-04	3.15E-04	0.05
^{99}Tc	2.87E+02	2.64E+02	7.08E+01	2.92E+01	900[c]
TCE	***7.12E-01***	***6.80E-01***	***5.87E-02***	***1.96E-02***	0.005
^{234}U	3.99E+00	2.75E+00	1.44E-03	0	[d]
^{238}U	5.91E+00	4.07E+00	1.98E-03	0	[d]
Uranium	8.40E-03	4.81E-03	2.41E-06	0	0.03

[a] Values in bold, italic font exceed the analyte's MCL
[b] Radionuclide concentrations are in pCi/L
[c] ^{99}Tc MCL based on a critical organ dose at 4 mrem/yr from drinking water consumption
[d] MCLs not available for these contaminants

As shown in Table E.3.27, the predicted maximum groundwater concentrations for arsenic, manganese, and TCE exceed their respective MCLs at the plant boundary. TCE is the only analyte that exceeds the MCLs at the property boundary, and Little Bayou seeps. The HQs and cancer risks calculated in accordance with the Risk Methods Document (DOE 2001) are presented in Table E.3.28. The predicted TCE concentrations result in the greatest HQ and cancer risk for SWMU 30. 1,1-DCE, arsenic and ^{99}Tc also exhibit elevated cancer risks.

Table E.3.28. Hazard and Cancer Risk Predicted from Maximum Groundwater Concentrations Derived in Modeling of SWMU 30 Using SESOIL and AT123D[a]

Analyte	SWMU		Plant Boundary		Property Boundary		Little Bayou seeps	
	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk
1,1-DCE	5.73	1.40E-03	0.6	1.4E-03	<0.1	1.0E-04	<0.1	3.0E-05
Arsenic	5.67	4.69E-04	3.8	3.1E-04	0.8	6.2E-05	[b]	[b]
Manganese	0.80	[b]	0.5	[b]	<0.1	[b]	[b]	[b]
Selenium	0.29	[b]	0.2	[b]	<0.1	[b]	<0.1	[b]
^{99}Tc	[b]	1.57E-05	[b]	1.4E-05	[b]	3.9E-06	[b]	1.6E-06
TCE	325	2.21E-02	311	2.1E-02	26.8	1.8E-03	9.0	6.1E-04
^{234}U	[b]	5.63E-06	[b]	3.9E-06	[b]	<1.0E-06	[b]	[b]
^{238}U	[b]	1.03E-05	[b]	7.1E-06	[b]	<1.0E-06	[b]	[b]
Uranium	1.34	[b]	0.8	[b]	<0.1	[b]	[b]	[b]

[a] Contaminants with a HQ greater than 0.1 or a cancer risk greater than 1.00E-06 are considered analytes.
[b] Value not calculated since the groundwater concentrations was reported as zero at this POE by AT123D, or the contaminant did not have a reported cancer slope factor or chemical toxicity RfD.

Figures 5.26 through 5.33 in Section 5 of the main text, show the predicted concentrations over time at each POE for analytes with a HQ greater than 0.1 and/or a risk greater than 1.0E-06 for contaminants migrating from SWMU 30. As shown in these figures, arsenic, manganese, and TCE are predicted to exceed their respective MCLs at the plant boundary. TCE is also predicted to exceed the MCL at the property boundary, Little Bayou seeps, and Ohio River.

E.3.1.8 SWMU 145

SWMU 145, located north of PGDP, began operation in the early 1950s. A 1973 document *The Discard of Scrap Materials by Burial at the Paducah Plant* (Union Carbide 1973), states this area was used by the contractor during the construction of PGDP to discard all types of scrap and waste materials. Use of the area for discard of scrap and waste by subcontractors continued until the early 1980s. Construction debris, such as concrete, roofing materials, wire, wood, shingles with asbestos, and welding rods are expected to have been disposed of in the area. Approximately once a year, the accumulated scrap piles were moved by plant personnel into piles or earth depressions and, whenever practicable, covered with dirt. The area was later permitted for the construction and operation of the C-746-S & T Landfills (BJC 2001). Currently, the C-746-S&T Landfills are located on top of SWMU 145 (DOE 1999b). Area P (SWMU 145) is defined by the encompassing C-746-S&T Landfills (SWMUs 9 and 10, respectively).

E.3.1.8.1 Conceptual model for source areas at SWMU 145

SWMU 145 occupies an area of approximately 1,916,640 ft^2 (44 acre). The thickness of the UCRS was estimated to be 60 ft (depth to the top of the RGA). The conceptual model for SWMU 145 is that potentially contaminated materials were buried and landfilled at SWMU 145. Subsequently, contaminants in the disposed material directly impacted soils below or adjacent to the areas where material was buried and, through vertical infiltration in soil, contaminated the groundwater underlying these sources. The infiltrating groundwater migrates vertically through the UCRS and laterally in the RGA, which could transport the contaminants to the POEs.

E.3.1.8.2 Contaminant transport modeling for SWMU 145 using SESOIL and AT123D

For this modeling effort, the soil zones were arranged in four layers. The first soil layer represented the SADA surface soil data from 0 to 1 ft deep. The second soil layer was 9 ft thick representing SADA layer 2 from 1 to 9 ft in depth, the third layer was subdivided into 4 sublayers of equal thickness (10 ft each)

representing SADA layers 3 through 6. SESOIL soil layer 4 was subdivided into 4 sublayers of equal thickness (2.0 ft each) to represent the total thickness of SADA layer 7 from 50 ft to 58 ft in depth, the four sublayer division of this layer allowed for better numerical solution of the final flux to the RGA. Table E.3.29 presents the analytes remaining after the screening process and the source terms for each analyte. Table E.3.30 lists the chemical-specific parameters applicable to the SESOIL model of SWMU 30. Figure E.3.5 presents the head distribution and flowpaths of several particles released from the SWMU. The distances to the POEs used in the AT123D model for SWMU 145 are 2,951 ft to the property boundary and 11,489 ft to the Ohio River.

Table E.3.29. Summary of Source Term Characteristics Developed by SADA for SWMU 145

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Antimony			
L1	0-1	0.00	0.00	0.00	0.00	0.00	0.00
L2	01-10	11.47	1.04E+06	9.36E+06	4.44E+06	1.04	11.93
L3	10-20	11.47	9.70E+05	9.70E+06	4.60E+06	0.97	11.13
L4	20-30	11.46	1.00E+06	1.00E+07	4.74E+06	1.00	11.46
L5	30-40	11.39	9.70E+05	9.70E+06	4.57E+06	0.97	11.05
L6	40-50	11.37	9.80E+05	9.80E+06	4.61E+06	0.98	11.14
L7	50-58	11.40	9.60E+05	7.68E+06	3.62E+06	0.96	10.94
			Total Mass		2.66E+07		
				Arsenic			
L1	0-1	0.00	0.00	0.00	0.00	0.00	0.00
L2	01-10	4.21	1.91E+06	1.72E+07	2.99E+06	0.97	4.10
L3	10-20	4.33	1.96E+06	1.96E+07	3.51E+06	1.00	4.33
L4	20-30	4.38	1.92E+06	1.92E+07	3.48E+06	0.98	4.29
L5	30-40	4.28	1.93E+06	1.93E+07	3.41E+06	0.98	4.21
L6	40-50	4.28	1.94E+06	1.94E+07	3.43E+06	0.99	4.24
L7	50-58	4.18	1.93E+06	1.54E+07	2.67E+06	0.98	4.12
			Total Mass		1.99E+07		
				PCB-1254			
L1	0-1	0.00	0.00	0.00	0.00	0.00	0.00
L2	01-10	0.59	2.40E+05	2.16E+06	5.28E+04	1.00	0.59
L3	10-20	1.90	2.00E+04	2.00E+05	1.57E+04	0.08	0.16
L4	20-30	1.90	1.00E+04	1.00E+05	7.86E+03	0.04	0.08
L5	30-40	1.90	1.00E+04	1.00E+05	7.86E+03	0.04	0.08
L6	40-50	0.00	0.00	0.00	0.00	0.00	0.00
L7	50-58	0.00	0.00	0.00	0.00	0.00	0.00
			Total Mass		8.57E+04		
				PCB-1260			
L1	0-1	0.00	0.00	0.00	0.00	0.00	0.00
L2	01-10	12.50	2.00E+04	1.80E+05	9.30E+04	1.00	12.50
L3	10-20	12.50	2.00E+04	2.00E+05	1.03E+05	1.00	12.50
L4	20-30	12.50	2.00E+04	2.00E+05	1.03E+05	1.00	12.50
L5	30-40	12.50	2.00E+04	2.00E+05	1.03E+05	1.00	12.50
L6	40-50	12.50	1.00E+04	1.00E+05	5.17E+04	0.50	6.25
L7	50-58	12.50	1.00E+04	8.00E+04	4.13E+04	0.50	6.25
			Total Mass		4.97E+05		

Table E.3.29. Summary of Source Term Characteristics Developed by SADA for SWMU 145 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Cadmium			
L1	0-1	0.00	0.00	0.00	0.00	0.00	0.00
L2	01-10	2.47	1.00E+04	9.00E+04	9.19E+03	0.20	0.49
L3	10-20	2.39	4.00E+04	4.00E+05	3.95E+04	0.80	1.91
L4	20-30	2.39	4.00E+04	4.00E+05	3.95E+04	0.80	1.91
L5	30-40	2.40	5.00E+04	5.00E+05	4.97E+04	1.00	2.40
L6	40-50	2.40	5.00E+04	5.00E+05	4.97E+04	1.00	2.40
L7	50-58	2.40	5.00E+04	4.00E+05	3.98E+04	1.00	2.40
			Total Mass		2.39E+05		
				Manganese			
L1	0-1	0.00	0.00	0.00	0.00	0.00	0.00
L2	01-10	146.59	2.55E+06	2.30E+07	1.39E+08	1.00	146.59
L3	10-20	147.65	2.55E+06	2.55E+07	1.56E+08	1.00	147.65
L4	20-30	143.48	2.55E+06	2.55E+07	1.51E+08	1.00	143.48
L5	30-40	140.68	2.55E+06	2.55E+07	1.48E+08	1.00	140.68
L6	40-50	170.30	2.55E+06	2.55E+07	1.80E+08	1.00	170.30
L7	50-58	170.13	2.55E+06	2.04E+07	1.43E+08	1.00	170.13
			Total Mass		9.51E+08		
				Mercury			
L1	0-1	0.00	0.00	0.00	0.00	0.00	0.00
L2	01-10	0.02	7.70E+05	6.93E+06	5.51E+03	0.95	0.02
L3	10-20	0.02	7.70E+05	7.70E+06	6.12E+03	0.95	0.02
L4	20-30	0.02	7.40E+05	7.40E+06	5.87E+03	0.91	0.02
L5	30-40	0.05	8.10E+05	8.10E+06	1.75E+04	1.00	0.05
L6	40-50	0.05	8.00E+05	8.00E+06	1.74E+04	0.99	0.05
L7	50-58	0.06	7.30E+05	5.84E+06	1.34E+04	0.90	0.05
			Total Mass		6.96E+04		
				Nickel			
L1	0-1	0.00	0.00	0.00	0.00	0.00	0.00
L2	01-10	10.21	2.00E+06	1.80E+07	7.60E+06	0.95	9.68
L3	10-20	10.22	2.00E+06	2.00E+07	8.45E+06	0.95	9.69
L4	20-30	9.87	1.95E+06	1.95E+07	7.96E+06	0.92	9.12
L5	30-40	10.50	2.11E+06	2.11E+07	9.16E+06	1.00	10.50
L6	40-50	10.08	2.11E+06	2.11E+07	8.80E+06	1.00	10.08
L7	50-58	10.20	2.06E+06	1.65E+07	6.95E+06	0.98	9.96
			Total Mass		4.98E+07		
				Vanadium			
L1	0-1	0.00	0.00	0.00	0.00	0.00	0.00
L2	01-10	18.43	1.21E+06	1.09E+07	8.30E+06	1.03	18.90
L3	10-20	18.47	1.20E+06	1.20E+07	9.16E+06	1.02	18.78
L4	20-30	19.44	1.18E+06	1.18E+07	9.48E+06	1.00	19.44
L5	30-40	19.94	1.18E+06	1.18E+07	9.73E+06	1.00	19.94
L6	40-50	19.55	1.18E+06	1.18E+07	9.54E+06	1.00	19.55
L7	50-58	18.71	1.19E+06	9.52E+06	7.36E+06	1.01	18.86
			Total Mass		5.54E+07		

Table E.3.29. Summary of Source Term Characteristics Developed by SADA for SWMU 145 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				Benzo(a)Pyrene			
L1	0-1	0.00	0.00	0.00	0.00	0.00	0.00
L2	01-10	0.00	0.00	0.00	0.00E+00	0.00	0.00
L3	10-20	0.00	0.00	0.00	0.00E+00	0.00	0.00
L4	20-30	0.00	0.00	0.00	0.00E+00	0.00	0.00
L5	30-40	0.00	0.00	0.00	0.00E+00	0.00	0.00
L6	40-50	0.00	0.00	0.00	0.00E+00	0.00	0.00
L7	50-58	0.00	0.00	0.00	0.00E+00	0.00	0.00
			Total Mass		1.82E+02		
				^{239}Pu			
L1	0-1	0.00	0.00	0.00	0.00E+00	0.00	0.00
L2	01-10	0.28	1.00E+05	9.00E+05	1.15E+10	1.00	0.28
L3	10-20	0.26	1.00E+05	1.00E+06	1.40E+10	1.00	0.26
L4	20-30	0.26	1.00E+05	1.00E+06	1.40E+10	1.00	0.26
L5	30-40	0.26	1.00E+05	1.00E+06	1.40E+10	1.00	0.26
L6	40-50	0.26	1.00E+05	1.00E+06	1.40E+10	1.00	0.26
L7	50-58	0.26	1.00E+05	8.00E+05	1.02E+10	1.00	0.26
			Total Mass		7.77E+10		
				^{99}Tc			
L1	0-1	0.00	0.00	0.00	0.00E+00	0.00	0.00
L2	01-10	26.67	1.10E+05	9.90E+05	1.09E+12	1.00	26.67
L3	10-20	15.98	1.30E+05	1.30E+06	8.59E+11	1.18	18.89
L4	20-30	15.98	1.30E+05	1.30E+06	8.59E+11	1.18	18.89
L5	30-40	15.98	1.30E+05	1.30E+06	8.59E+11	1.18	18.89
L6	40-50	11.91	1.30E+05	1.30E+06	6.40E+11	1.18	14.07
L7	50-58	11.91	1.30E+05	1.04E+06	5.12E+11	1.18	14.07
			Total Mass		4.82E+12		
				^{234}U			
L1	0-1	0.00	0.00	0.00	0.00E+00	0.00	0.00
L2	01-10	0.74	2.00E+04	1.80E+05	3.28E+11	1.00	0.74
L3	10-20	0.00	0.00	0.00	2.49E+12	0.00	0.00
L4	20-30	0.00	0.00	0.00	2.50E+12	0.00	0.00
L5	30-40	0.00	0.00	0.00	2.50E+12	0.00	0.00
L6	40-50	0.00	0.00	0.00	2.46E+12	0.00	0.00
L7	50-58	0.00	0.00	0.00	1.79E+12	0.00	0.00
			Total Mass		1.21E+13		
				^{235}U			
L1	0-1	0.00	0.00	0.00	0.00E+00	0.00	0.00
L2	01-10	0.30	5.00E+04	4.50E+05	6.16E+09	1.00	0.30
L3	10-20	0.19	5.00E+04	5.00E+05	7.16E+09	1.00	0.19
L4	20-30	0.19	5.00E+04	5.00E+05	4.22E+09	1.00	0.19
L5	30-40	0.19	5.00E+04	5.00E+05	4.22E+09	1.00	0.19
L6	40-50	0.00	0.00	0.00	0.00E+00	0.00	0.00
L7	50-58	0.00	0.00	0.00	0.00E+00	0.00	0.00
			Total Mass		2.18E+10		

Table E.3.29. Summary of Source Term Characteristics Developed by SADA for SWMU 145 (Continued)

SADA Layer	Depth (ft)	Average (mg/kg)[a]	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]	Concentration Factor	Adjusted Average (mg/kg)[a]
				^{238}U			
L1	0-1	0.00	0.00	0.00	0.00E+00	0.00	0.00
L2	01-10	2.62	1.21E+06	1.09E+07	2.02E+11	0.96	2.52
L3	10-20	6.77	1.14E+06	1.14E+07	1.36E+12	0.90	6.12
L4	20-30	6.60	1.17E+06	1.17E+07	3.51E+12	0.93	6.13
L5	30-40	6.14	1.26E+06	1.26E+07	3.51E+12	1.00	6.14
L6	40-50	5.62	1.26E+06	1.26E+07	3.52E+12	1.00	5.62
L7	50-58	5.67	1.25E+06	1.00E+07	3.22E+12	0.99	5.62
			Total Mass		2.34E+12		

[a] Radionuclides are in units of pCi/g for concentrations and pCi for mass.

Table E.3.30. Chemical-Specific Parameters of the Analytes Used in SESOIL Modeling of SWMU 145

Analyte	Mol. Wt. (MW) (g/mol)	Solubility in water (mg/L)	Diffusion in air (cm^2/s)	Diffusion in water (m^2/hr)	Henry's Constant (atm.m3/mol)	Koc (L/kg)	Kd[a] (L/kg)	Half Life (years)
Antimony	121.75	1.00E+07	NA	3.60E-07	NA	NA	45	infinite
PCB-1254	327	7.00E-02	1.56E-02	1.80E-06	3.40E-04	4.25E+04	34	infinite
PCB-1260	375.7	2.70E02	1.38E-02	1.56E-06	7.40E-05	2.07E+05	165.6	infinite
Arsenic	74.92	1.00E+07	NA	3.60E-07	NA	NA	29	infinite
Benzo(a)pyrene	252.32	1.62E-03	4.3E-02	3.24E-06	1.13E-06	9.69E+05	772	infinite
Cadmium	112.41	1.00E+07	NA	3.60E-07	NA	NA	75	infinite
Manganese	54.94	1.00E+07	NA	3.60E-07	NA	NA	65	infinite
Mercury	200.59	6.00E-02	3.07E-02	2.27E-06	2.44E-02	NA	52	infinite
Nickel	58.69	1.00E+07	NA	3.60E-07	NA	NA	300	infinite
Vanadium	50.94	1.00E+07	NA	3.60E-07	NA	NA	1000	infinite
^{238}U	238	1.00E+07	NA	3.60E-07	NA	NA	66.8	4.47E+09
^{235}U	235	1.00E+07	NA	3.60E-07	NA	NA	66.8	7.04E+08
^{234}U	234	1.00E+07	NA	3.60E-07	NA	NA	66.8	2.44E+05
^{99}Tc	99	1.00E+07	NA	3.60E-07	NA	NA	0.2	2.13E+05
^{239}Pu	239	1.00E+07	NA	3.60E-07	NA	NA	550	2.41e+04

[a] The soil/water distribution coefficient (Kd) of an organic compound depends on the soil's organic content (f_{oc}) and compound's organic partition coefficient (Koc). Kd values presented for organic compounds are for UCRS soils (with f_{oc} value of 0.08%) only. Kds used in AT123D are different due to the f_{oc} of 0.02% in the RGA.

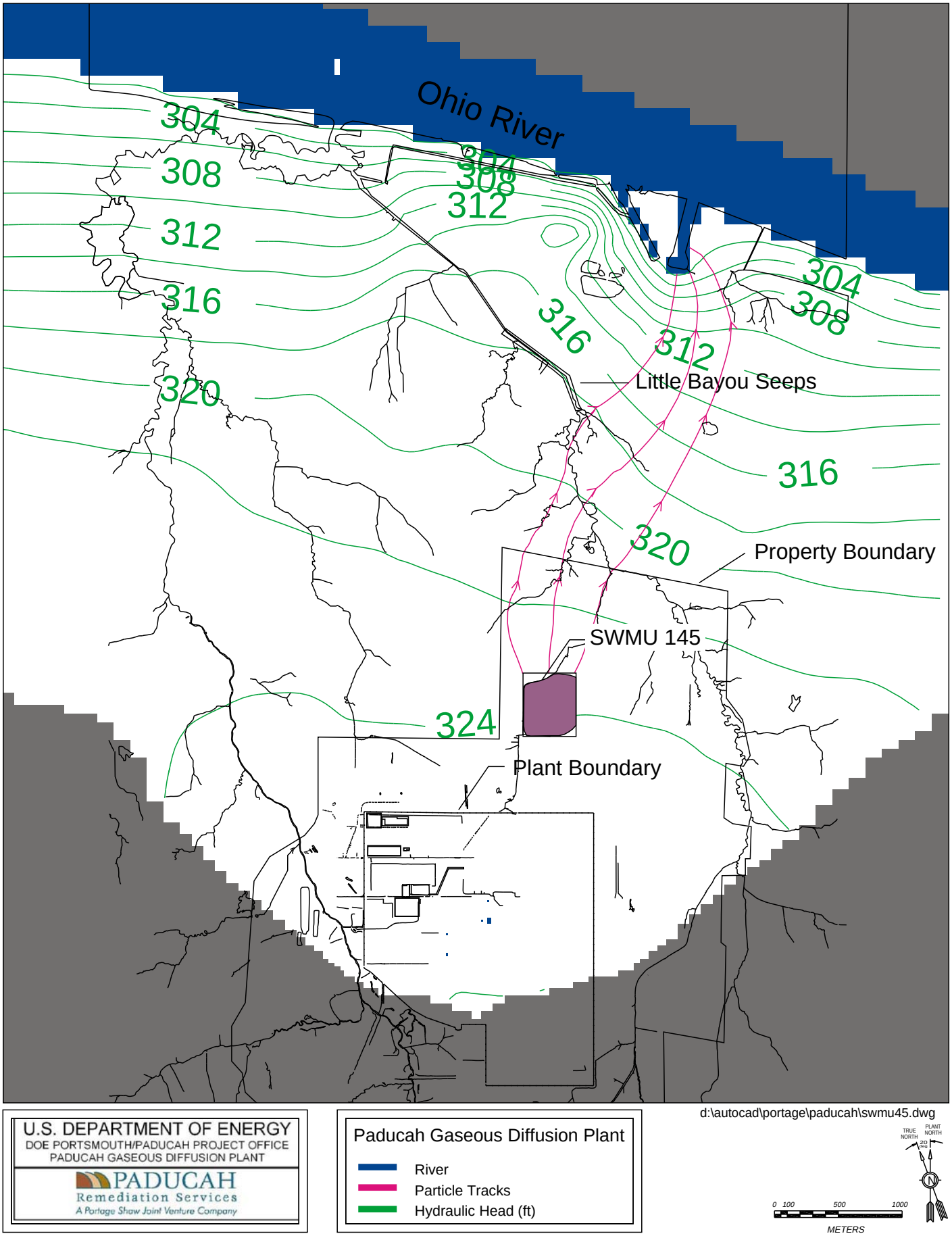


Figure E.3.5. Particle Tracks for SWMU 145

E.3.1.8.3 Groundwater modeling results for SWMU 145

Table E.3.31 summarizes the predicted maximum groundwater concentrations at the POEs for the analytes modeled at SWMU 145. These contaminants were predicted by SESOIL to reach the water table within the 1,000 year period in concentrations that were greater then the groundwater background or greater than the groundwater child no action levels. Several contaminants that originally passed the screening for groundwater did not reach the water table in 1,000 years [i.e., PCB-1254, benzo(a)pyrene, vanadium, ^{234}U, ^{235}U, and ^{239}Pu] or exhibited groundwater concentrations that were less than the groundwater background or the groundwater child no action levels (i.e., cadmium, mercury, and nickel) (see Section 5.4 of the main text).

Table E.3.31. Concentrations of the Analytes in Groundwater Predicted in SESOIL and AT123D Modeling of SWMU 145

Analyte	SWMU (mg/L)	Property Boundary (mg/L)	Ohio River (mg/L)	MCL (mg/L)
Antimony	***7.99E-02***	1.51E-06	0	0.006
Arsenic	***6.21E-02***	1.61E-03	0	0.01
PCB-1260	1.92E-03	0	0	d
Manganese	8.44E-01	0	0	d
^{99}Tc	***1.01E+04***	***1.84E+03***	***9.65E+02***	900[c]
^{238}U	7.67E-02	0	0	d

[a] Values in bold, italic font exceed the analyte's MCL
[b] Radionuclide concentrations are in pCi/L
[c] ^{99}Tc MCL based on a critical organ dose at 4 mrem/yr from drinking water consumption
[d] MCLs not available for these contaminants

As shown in Table E.3.31, the predicted maximum groundwater concentration for ^{99}Tc exceeds the MCLs at the property boundary and at the Ohio River. All remaining analytes are less than their MCLs at the POEs. The HQs and cancer risks calculated in accordance with the Risk Methods Document (DOE 2001) are presented in Table E.3.32. The predicted arsenic concentrations at the property boundary results in the greatest HQ, with both arsenic and ^{99}Tc providing elevated cancer risks.

Table E.3.32. Hazard and Cancer Risk Predicted from Maximum Groundwater Concentrations Derived in Modeling of SWMU 145 Using SESOIL and AT123D[a]

Analyte	SWMU		Property Boundary		Near Ohio River	
	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk	Hazard Quotient	Cancer Risk
Antimony	20	[b]	<0.1	[b]	[b]	[b]
Arsenic	19.9	1.65E-03	0.5	4.3E-05	[b]	[b]
PCB-1260	[b]	3.05E-02				
Manganese	1.80	[b]				
^{99}Tc	[b]	5.54E-04	[b]	1.0E-04	[b]	5.3E-05
^{238}U	[b]	1.10E-07				

[a] Contaminants with a HQ greater than 0.1 or a cancer risk greater than 1.00E-06 are considered analytes.
[b] Value not calculated since the groundwater concentrations was reported as zero at this POE by AT123D, or the contaminant did not have a reported cancer slope factor or chemical toxicity RfD.

Figures 5.34 through 5.36 in Section 5 of the main text, show the predicted concentrations over time at each POE for analytes with a HQ greater than 0.1 and/or a risk greater than 1.0E-06 for contaminants migrating from SWMU 145. As shown in these figures, manganese is predicted to continue rising in concentration at 1,000 years at the plant boundary exceeding the MCL, but has not reached the property boundary or Ohio River in the 1,000 year period. Arsenic is also increasing in concentration at the plant

boundary at 1,000 years, however the concentrations are less than the MCL. ^{99}Tc is not predicted to exceed the MCL at the POEs.

E.3.2 VAPOR TRANSPORT MODELING

The BGOU RI includes vapor transport modeling to evaluate the potential air concentrations in a residential basement for soil and groundwater contamination at the BGOU SWMUs and POEs. Modelers used the Johnson and Ettinger model (1991), coded into spreadsheets by EPA (2004), to assess the potential migration of VOCs into a residential basement.

Johnson and Ettinger (1991) introduced a screening-level model which incorporates both convective and diffusive mechanisms for estimating the transport of contaminant vapors emanating from either subsurface soils or groundwater into indoor spaces located directly above or in close proximity to the source of contamination. The Johnson and Ettinger model is a one-dimensional analytical solution to convective and diffusive vapor transport into indoor spaces and provides an estimated attenuation coefficient that relates the vapor concentration in the indoor space to the vapor concentration at the source of contamination.

Since the Johnson and Ettinger model is a screening level model, the number of parameter inputs is minimized. Table E.3.33 provides the input parameter values used in the vapor transport analysis. All analyses for the BGOU RI used the default chemical property library. The contaminant source inventories for the soil layers beneath the SWMUs were obtained from the SADA analyses presented in Section E.3.1.

Table E.3.34 presents the resulting basement air concentrations, predicted by the model. The HQs and cancer risks calculated in accordance with the Risk Methods Document (DOE 2001) are presented in Table E.3.35. The vapor transport modeling for mercury was conservatively based on the metallic form, which has a Henry's Law Constant of 1.07E-02 atm-m^3/mol. Metallic mercury, with its uniquely high vapor pressure relative to other metals, can enter the atmosphere from the groundwater environment as several different gaseous compounds. The rate of vaporization of mercury and certain of its inorganic compounds decrease in the sequence Hg > Hg_2Cl_2 > $HgCl_2$ > HgS > HgO. The Henry's Law Constant decreases dramatically down the sequence (for example, $HgCl_2$ has a value of 7.09E-10 atm-m^3/mol).

Table E.3.33. Vapor Transport Model Input Parameter Values

Parameter	Value	Reference
Average Soil Temperature (T_s)	15 ºC	Default value
Depth below grade to bottom of enclosed space floor (L_F)	200 cm	Default value
SCS soil type	Silty Clay	Table E.3.2
Soil dry bulk density (ρ_b)	1.46 g/cm^3	Table E.3.2
Soil total porosity (n)	0.45	Table E.3.2
Soil water-filled porosity (θ_w)	0.167	Default value
Soil organic carbon fraction (f_{oc})	0.08	Table E.3.2
Enclosed space floor thickness (L_{crack})	10 cm	Default value
Soil-building pressure differential (Δ_p)	40 g/cm-s^2	Default value
Enclosed space floor length (L_B)	1,000 cm	Default value
Enclosed space floor width (W_B)	1,000 cm	Default value
Enclosed space height (H_B)	366 cm	Default value
Floor-wall seam crack width (W)	0.1 cm	Default value
Indoor air exchange rate (ER)	0.5 hr^{-1}	Default value

Table E.3.34. Basement Air Concentrations Based on Vapor Transport Modeling Results for each BGOU SWMU

		Air concentration (mg/m^3)		
Source Area	**Contaminant**	**On-Site**	**Plant Boundary**	**Property Boundary**
SWMU 2	TCE	2.81E-02	1.09E-04	5.55E-05
	cis-1,2-DCE	1.95E-01	7.82E-04	3.89E-04
	Naphthalene	2.70E-07	1.56E-08	8.43E-09
SWMU 3	TCE	1.62E-05	8.52E-10	4.47E-10
	Mercury	7.22E-06	1.12E-14	0.00E+00
SWMU 4	TCE	4.90E-03	2.12E-04	1.08E-04
	cis-1,2-DCE	5.76E-03	8.80E-05	4.05E-05
	Vinyl Chloride	6.7E-03	1.98E-04	2.55E-06
SWMU 5	TCE	5.41E-06	1.98E-07	9.13E-08
	Acenapthene	2.04E-07	7.47E-08	4.30E-08
	Fluorene	5.16E-08	2.37E-08	1.27E-08
	Naphthalene	3.80E-06	9.75E-08	3.79E-08
	Pyrene	2.28E-09	NA	NA
SWMU 6	TCE	9.34E-06	3.88E-09	1.92E-09
SWMU 7	TCE	8.63E-05	4.96E-06	7.16E-07
	cis-1,2-DCE	2.13E-04	9.66E-06	1.42E-06
	Vinyl Chloride	1.23E-02	1.25E-05	1.22E-06
	1,1-DCE	1.03E-02	6.70E-05	9.03E-06
	Mercury	9.99E-06	2.22E-09	2.41E-12
	Pyrene	7.68E-09	4.93E-12	1.31E-12
	Tetrachloroethene	2.00E-05	6.40E-08	4.70E-09
SWMU 30	TCE	6.75E-02	3.42E-04	2.96E-05
	1,1-DCE	3.36E-02	4.85E-05	3.62E-06
	Acenapthene	2.77E-08	4.96E-09	9.22E-10
	Fluorene	3.92E-09	NA	NA
	Mercury	1.66E-05	8.91E-1	2.23E-11
	Pyrene	6.56E-10	2.47E-11	6.54E-12
	Naphthalene	3.10E-07	1.90E-08	1.85E-09
SWMU 145	Mercury	1.42E-05	7.95E-08	2.60E-14

Table E.3.35. Vapor Hazard Quotients and Risk-Based on Vapor Transport Modeling Results for Each BGOU SWMU

		On-Site		Plant Boundary		Property Boundary	
Source Area	**Contaminant**	**HQ**	**ECLR**	**HQ**	**ECLR**	**HQ**	**ECLR**
SWMU 2	TCE	**3.15E+00**	**1.84E-03**	1.22E-02	**7.14E-06**	6.22E-03	**3.64E-06**
	cis-1,2-DCE	**2.50E+01**	NA	1.00E-01	NA	4.99E-02	NA
	Naphthalene	4.03E-04	NA	4.99E-06	NA	1.26E-05	NA
SWMU 3	TCE	1.82E-03	**1.06E-06**	9.63E-08	5.68E-11	5.01E-08	2.93E-11
	Mercury	**1.08E-01**	NA	1.67E-10	NA	NA	NA
SWMU 4	TCE	**5.54E-01**	**3.23E-04**	2.38E-02	**1.39E-05**	1.21E-02	**7.07E-06**
	cis-1,2-DCE	**7.38E-01**	NA	1.13E-02	NA	5.19E-03	NA
	Vinyl Chloride	**2.99E-01**	**4.19E-05**	8.85E-03	**1.24E-06**	1.14E-04	1.60E-08
SWMU 5	TCE	6.06E-04	3.54E-07	2.22E-05	1.30E-08	1.02E-05	5.98E-09
	Acenapthene	4.37E-06	NA	1.60E-06	NA	9.21E-07	NA
	Fluorene	1.65E-06	NA	7.57E-07	NA	4.06E-07	NA
	Naphthalene	5.67E-03	NA	1.45E-03	NA	5.65E-04	NA
	Pyrene	9.71E-08	NA	NA	NA	NA	NA
SWMU 6	TCE	1.05E-03	6.12E-07	4.35E-07	2.54E-10	2.15E-07	1.26E-10
SWMU 7	TCE	9.68E-03	**5.65E-06**	5.56E-04	3.25E-07	8.03E-05	4.69E-08
	cis-1,2-DCE	2.73E-02	NA	1.24E-03	NA	1.82E-04	NA
	Vinyl Chloride	**5.48E-01**	**7.68E-05**	5.59E-04	7.83E-08	5.45E-05	7.64E-09
	1,1-DCE	**2.30E-01**	**3.66E-04**	1.50E-03	**2.39E-06**	2.02E-04	3.21E-07
	Mercury	**1.49E-01**	NA	3.31E-05	NA	3.59E-08	NA
	Pyrene	3.27E-07	NA	2.10E-10	NA	5.58E-11	NA
	Tetrachloroethene	1.49E-04	8.13E-09	4.78E-07	2.60E-11	3.51E-08	1.91E-12
SWMU 30	TCE	**7.57E+00**	**4.42E-03**	3.83E-02	**2.24E-05**	3.32E-03	**1.94E-06**
	1,1-DCE	**7.52E-01**	**1.20E-03**	1.09E-03	**1.73E-06**	8.10E-05	1.29E-07
	Acenapthene	5.93E-07	NA	1.06E-07	NA	1.97E-08	NA
	Fluorene	1.25E-07	NA	NA	NA	NA	NA
	Mercury	**2.47E-01**	NA	1.33E-05	NA	3.33E-07	NA
	Naphthalene	4.62E-04	NA	2.83E-05	NA	2.76E-06	NA
	Pyrene	2.80E-08	NA	1.05E-09	NA	2.79E-10	NA
SWMU 145	Mercury	**2.12E-01**	NA	1.19E-03	NA	3.88E-10	NA

NA = not applicable

E.3.3 UNCERTAINTY ANALYSIS FOR THE TRANSPORT MODELING

The SADA SESOIL and AT123D models were used for the investigation, resulting in the use of some simplifying assumptions. These assumptions resulted in modeling uncertainties.

E.3.3.1 Source Term Development

The source term was developed using sampling results, geospatial analyses in SADA, and considering SESOIL limitations. While the sampling results are appropriate for source identification, SESOIL requires input of the soil concentrations for each layer of interest in the UCRS. Due to SESOIL's requirement to use the same constant area for each layer, the analyte concentrations of all layers needed to be normalized against the area of the layer with the maximum estimated analyte mass; therefore, geospatial interpolation was used based on the SADA nearest neighbor algorithm to estimate the total mass in each UCRS layer based upon the sampling results.

The techniques in SADA that can be used for source term development are nearest neighbor, inverse distance, and ordinary kriging. The nearest neighbor technique was selected for source zone refinement because it yielded results that were most compatible with the conceptual site model of contaminant release, as described in Attachment 2 to Appendix E.

Each potential analyte source area was discretized using rows and columns with a uniform spacing. Multiple domains with varying depths were used to characterize the analyte source areas vertically in relation to the existing aquifers; therefore, the domain was further discretized into horizontal layers. analyte results for each domain were compiled, and analyte concentrations in each cell of the domain were predicted using geospatial interpolation (see Appendix E Attachment 2 for details).

The source term is based on a three-dimensional, geospatial analysis of the data using nearest neighbor interpolation in SADA. Therefore, sample data was assessed both horizontally within each layer and vertically between layers. This resulted in a conservative analysis of the subsurface data, such that sample detections in a layer with no corresponding sample locations in the adjacent vertical layers, resulted in predictions of contamination in these adjacent layers. For the BGOU RI, soil samples were typically collected from angled soil borings; thus, deeper samples did not underlay shallower samples. The lack of vertical control throughout the layers tended to result in contamination being estimated throughout the depth of the vertical layers to the RGA. This is illustrated in Table E.3.36 for TCE data at SWMU 4 (presenting the highest risk for all BGOU SWMUs) in which the maximum sample detection for the layers is generally much less than the maximum concentration predicted for a layer by SADA. In this case, the maximum concentration (i.e., 41 mg/kg) in layer 5 has been interpolated into layers 2, 3, 4, and 6 from layer 5. In general, SADA provides average TCE concentration in the layers that are greater in comparison to the average of the sample detections. Due to the lack of sample data points, the nearest neighbor interpolation tends to estimate large areas of contamination for which there are no data. For example, layer 2 contains two samples with detections; however, SADA predicts that 206 cells (20 ft by 20 ft grid cells) are contaminated. Therefore, SADA provides a maximum estimate of the total contamination and mass using the nearest neighbor interpolation method.

The SADA estimated uranium mass in relation to other metals (i.e., vanadium and manganese) appears to be underestimated. The mass of metals, such as vanadium and manganese also appear to be overestimated using SADA. The SADA interpolation estimates the mass between sample points. This results in an estimated mass of vanadium and manganese in the waste volume based on sample points located outside the waste zone, since these metals tend to be ubiquitous throughout the soils. Likewise, the sample points for uranium outside the waste zone are used to interpolate the mass in the waste zone. The transport of

uranium from the waste into the surrounding soils is limited due to the sorption of this metal. Since the waste was not sampled, the uranium mass estimates for the waste areas in the SADA model likely are underestimated due to the limited migration of uranium. The uncertainty in the mass of uranium present in waste will be further addressed during remedial alternatives screening in the feasibility study.

Table E.3.36. Comparison of Sample Data with SADA Predicted Concentrations for TCE at SWMU 4

SADA Layer	Depth (ft)	Number of Detects and Total Samples	Detect Average (mg/kg)	Detect Range (mg/kg)	SADA Predicted Number of Contaminated Cells[a]	SADA Predicted Average (mg/kg)	SADA Predicted Cell Contaminant Range (mg/kg)
L1	0-1	0/21	0.00	0	0	0.00	0
L2	01-10	2/67	0.006	0.004 – 0.008	206	2.39	0.0036 – 41.0
L3	10-20	6/77	0.095	0.016 – 0.4	165	2.85	0.0036 – 41.0
L4	20-30	6/73	0.29	0.0064 – 0.82	181	3.02	0.0036 – 41.0
L5	30-40	10/29	4.83	0.011 -41.0	240	2.56	0.0064 – 41.0
L6	40-50	11/29	2.14	0.012 – 9.2	246	2.45	0.0064 – 41.0
L7	50-63	13/39	4.44	0.02 – 25.0	249	3.15	0.0064 – 25.0

[a] Cells for SWMU 4 were 20 ft by 20 ft.

E.3.3.2 SESOIL and AT123D Transport Uncertainties

As noted previously, due to SESOIL's requirement to use the same constant area for each layer, the analyte concentrations of all layers needed to be normalized against the area of the layer with the maximum estimated analyte mass. The use of this methodology and uncertainty in the predictions were evaluated using TCE at SWMU 4 as an example and running each layer separately at its initial SADA concentration and area (i.e., no area and concentration normalization) and comparing these results to the original runs (i.e., normalized area and concentration). It should be noted that the results using this methodology will not match the total results presented previously for TCE at SWMU 4. By separating the layers, diffusion and volatilization gradients are different by individual layer compared to when all layers are modeled simultaneously in SESOIL; therefore, this is a comparison by layer and not by total mass in the system. The SADA data presented in Table E.3.37 were used in the analysis.

Table E.3.37. Summary of SADA Source Term Data for TCE at SWMU 4

SADA Layer	Depth (ft)	Total Mass (g)	Non-Normalized Average (mg/kg)	Non- Normalized Area (ft^2)	Normalized Average (mg/kg)	Normalized Area (ft^2)
L1	0-1	0.00E+00	0.00	0.00E+00	0.00	9.60E+04
L2	01-10	8.16E+04	2.39	8.24E+04	2.06	9.60E+04
L3	10-20	8.55E+04	2.85	6.60E+04	1.96	9.60E+04
L4	20-30	9.93E+04	3.02	7.24E+04	2.28	9.60E+04
L5	30-40	1.12E+05	2.56	9.60E+04	2.56	9.60E+04
L6	40-50	1.10E+05	2.45	9.84E+04	2.51	9.60E+04
L7	50-63	7.77E+04	3.15	9.96E+04	3.26	9.60E+04

The results of the analysis are presented in Figures E.3.6 through E.3.11. The results indicate that the normalization of the area and concentrations for input into SESOIL has an effect on the results but the differences are not considered significant when the total uncertainty of the sources from SADA are considered.

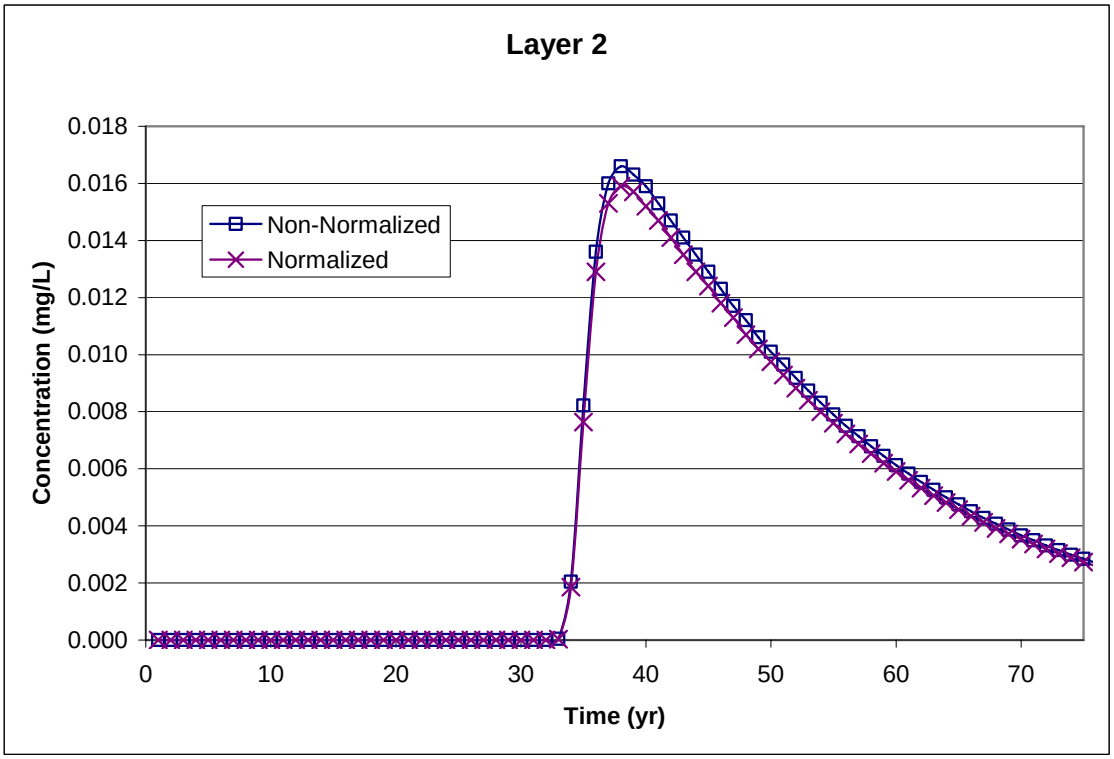


Figure E.3.6. Comparison of Predicted Groundwater Concentrations from a Layer 2 Source for TCE at SWMU 4 for the Normalized and Non-Normalized Area and Source Concentrations

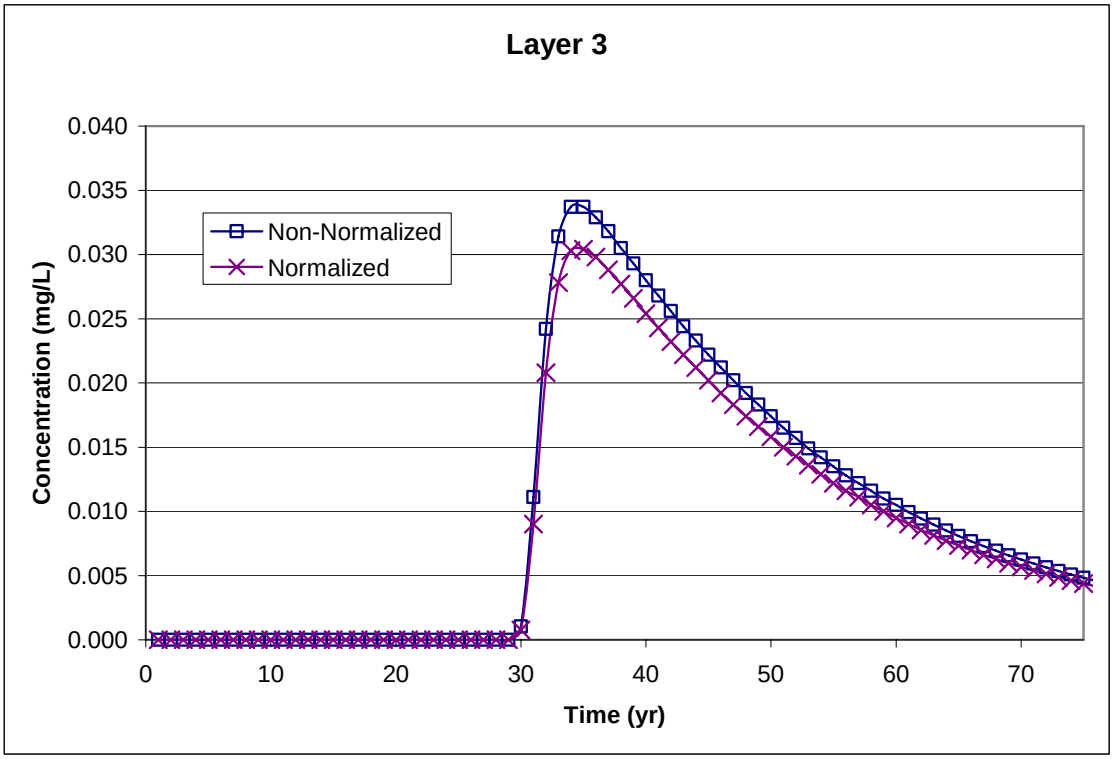


Figure E.3.7. Comparison of Predicted Groundwater Concentrations from a Layer 3 Source for TCE at SWMU 4 for the Normalized and Non-Normalized Area and Source Concentrations

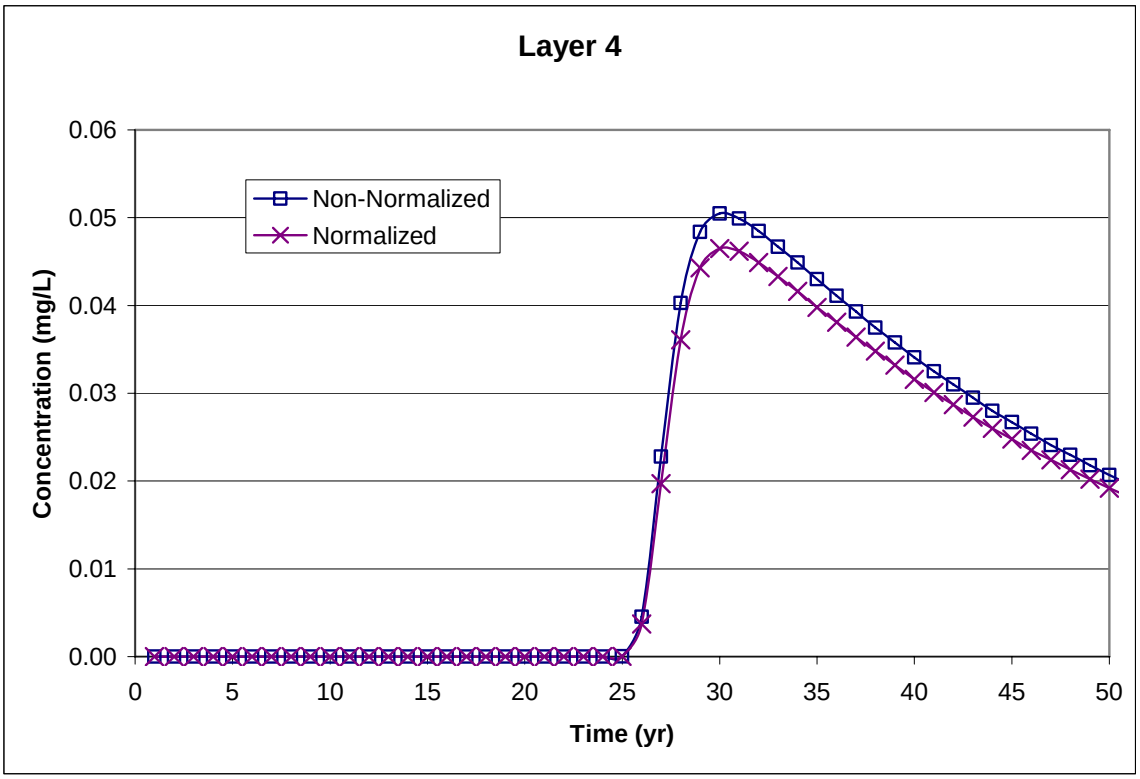


Figure E.3.8. Comparison of Predicted Groundwater Concentrations from a Layer 4 Source for TCE at SWMU 4 for the Normalized and Non-Normalized Area and Source Concentrations

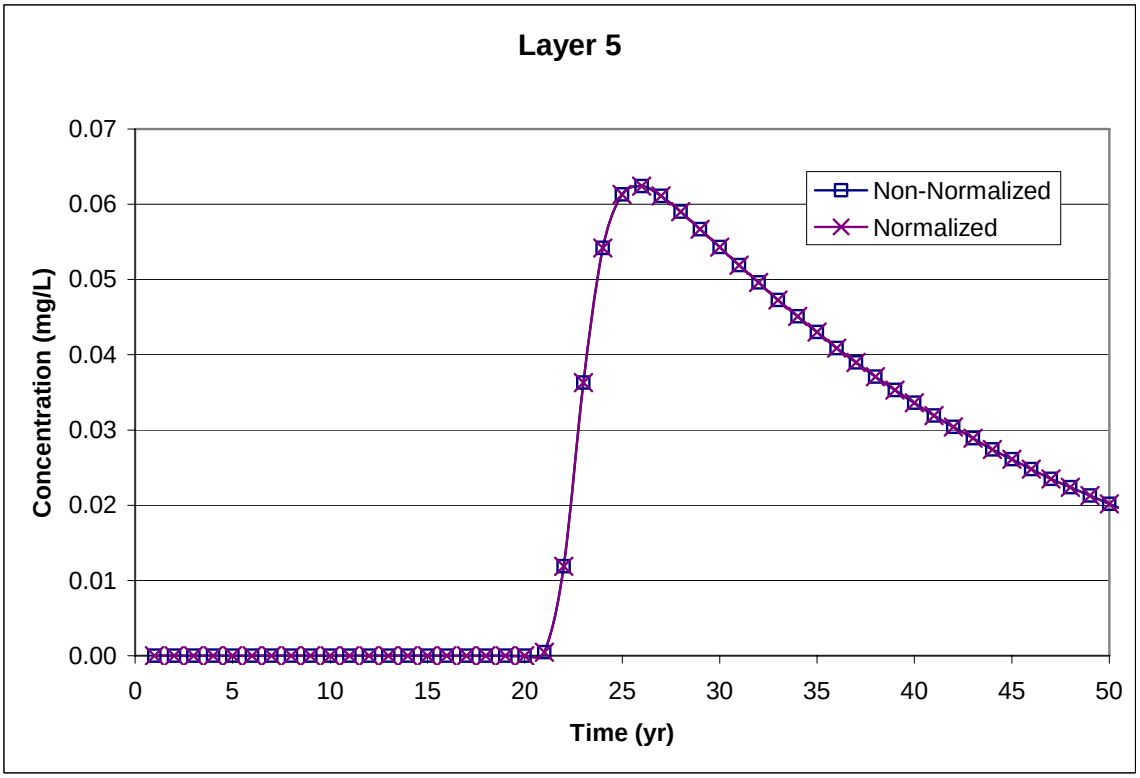


Figure E.3.9. Comparison of Predicted Groundwater Concentrations from a Layer 5 Source for TCE at SWMU 4 for the Normalized and Non-Normalized Area and Source Concentrations

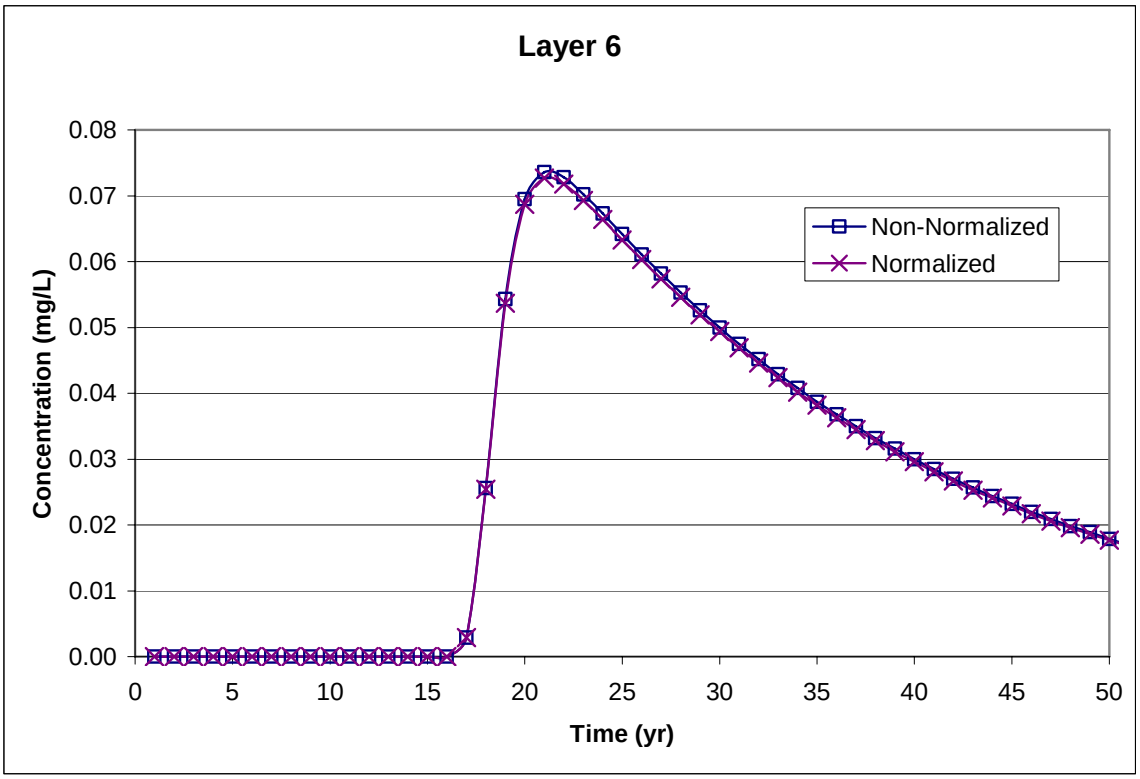


Figure E.3.10. Comparison of Predicted Groundwater Concentrations from a Layer 6 Source for TCE at SWMU 4 for the Normalized and Non-Normalized Area and Source Concentrations

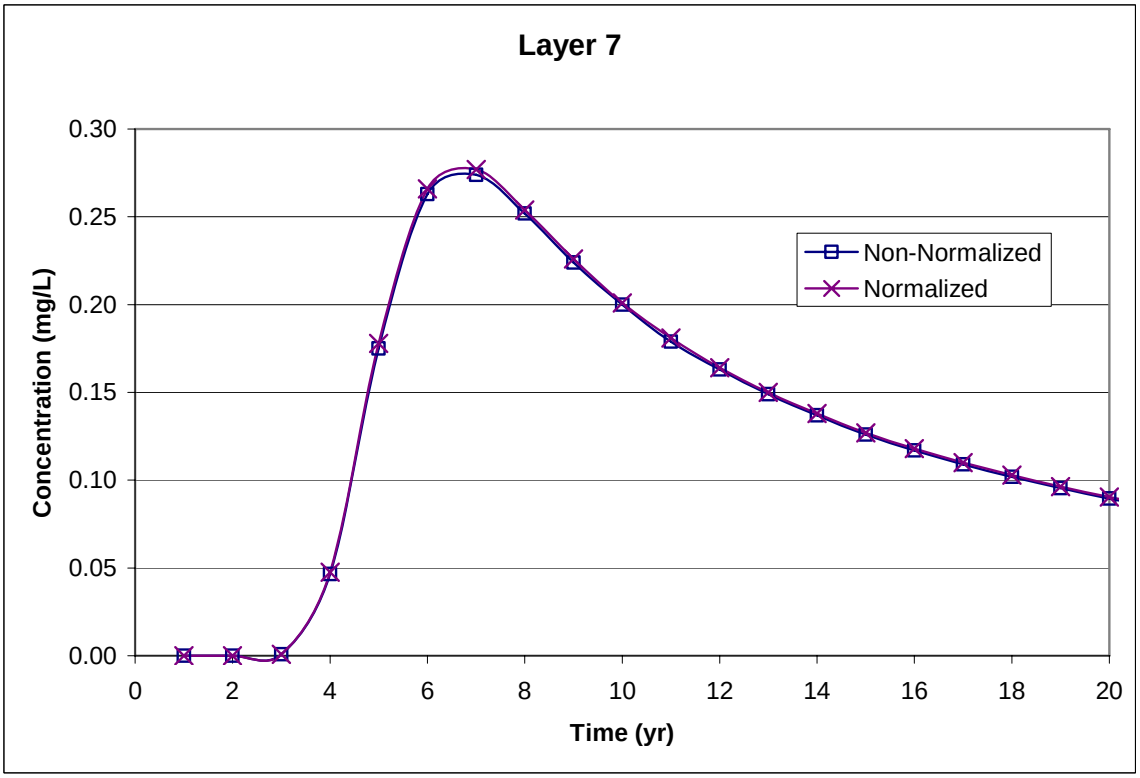
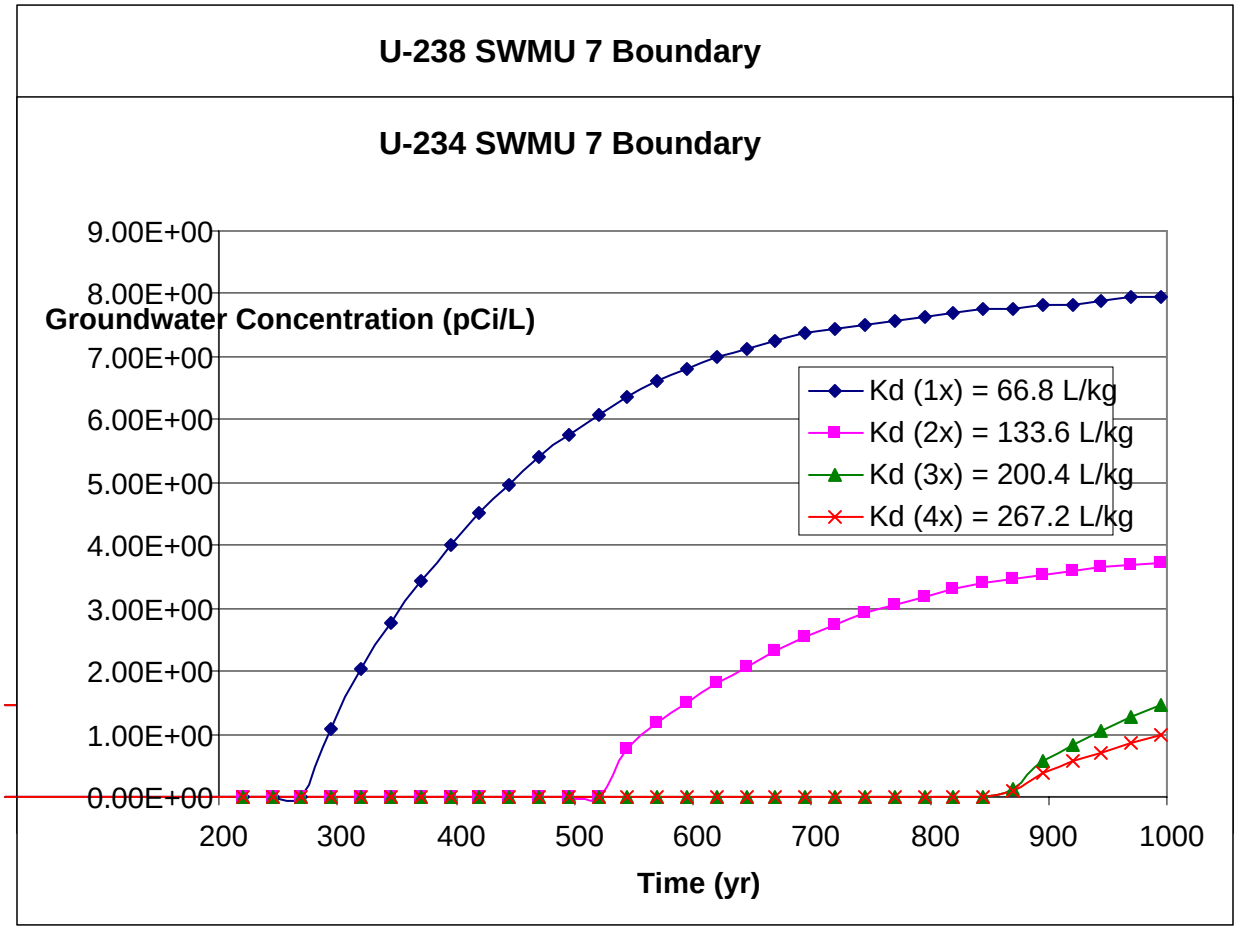


Figure E.3.11. Comparison of Predicted Groundwater Concentrations from a Layer 7 Source for TCE at SWMU 4 for the Normalized and Non-Normalized Area and Source Concentrations

An additional source of uncertainty in the AT123D modeling runs involves the use of a single hydraulic conductivity and hydraulic gradient. The hydraulic conductivity and gradient are variable from the SWMU locations to the various POEs. The MODPATH model was run to establish the steady-state head distribution in the RGA. MODPATH was used to track flowpaths of particles released from the SWMU location by using the steady-state, head distribution generated by MODFLOW. The distances from the SWMU to the POEs were taken along the flowpaths to determine the distance from the SWMU to the POEs. The hydraulic gradient from the SWMU to the property boundary was estimated using the head difference divided by the distance from the release point to the property boundary POE. The conductivity along the flowpath was also estimated for use in the AT123D model.

The selection of the sorption coefficient (K_d) for uranium in the UCRS was also evaluated for uncertainty. The sorption coefficient for sand, 66.8 L/kg was used in the analyses to provide conservatism and to account for uncertainty in the material properties directly below the SWMUs. However, site-specific measurements at PGDP have indicated that the uranium K_d in the UCRS may be much higher than used in the analyses. Therefore, the uncertainty in the uranium modeling results were evaluated using varying K_d values for uranium in the UCRS (i.e., 66.8, 133.6, 200.4, and 267.2 L/kg). The analysis was focused on SWMU 7 at the SWMU boundary and at the plant boundary. The results of the analysis for ^{238}U and ^{234}U are provided in Figures E.3.12 through E.3.15.



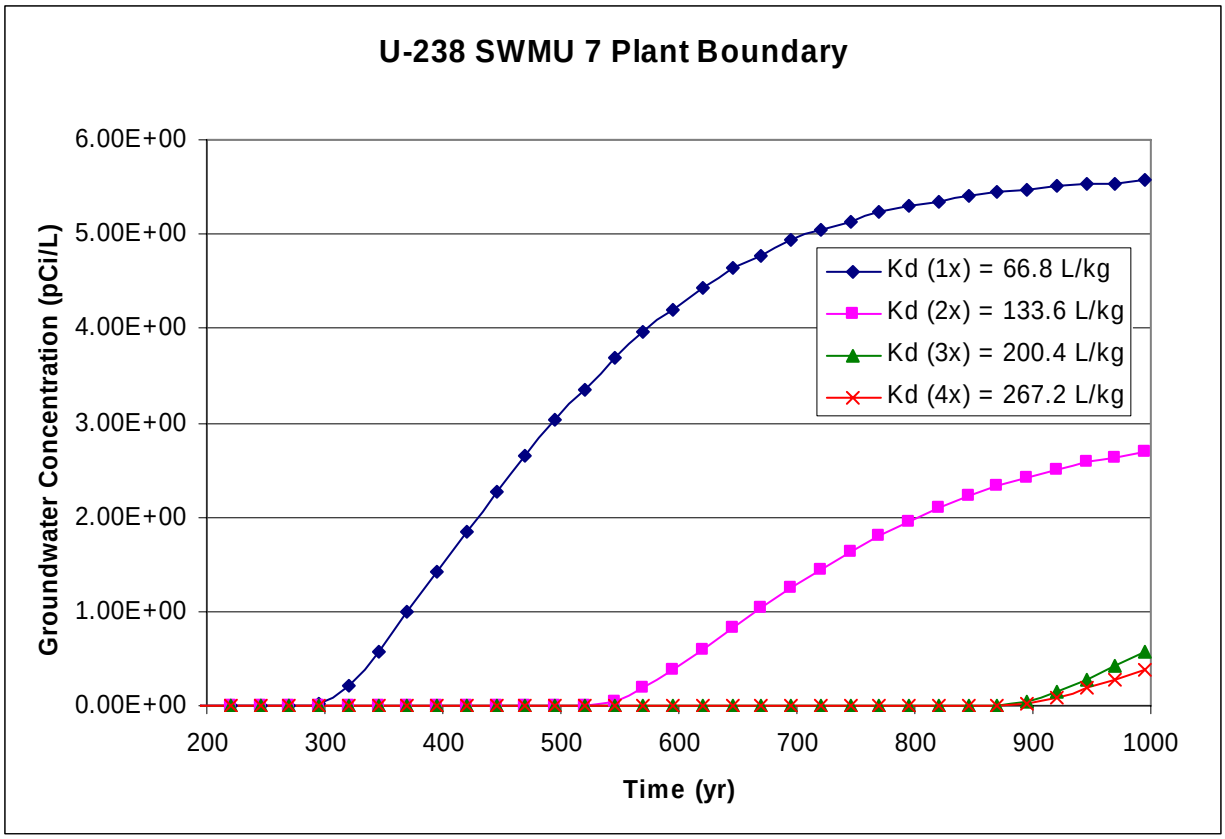


Figure E.3.14. SWMU 7 Groundwater Concentrations for ^{238}U at the Plant Boundary for Varying UCRS K_d Values

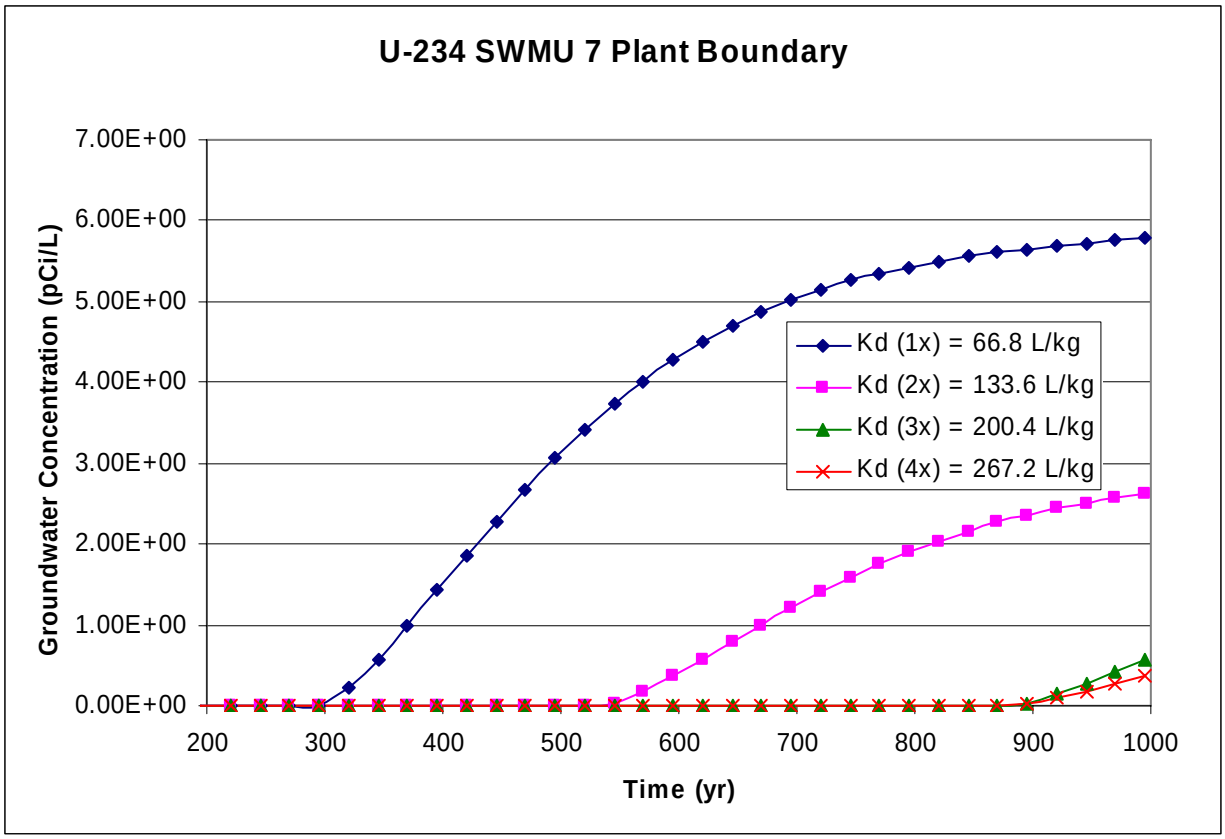


Figure E.3.15. SWMU 7 Groundwater Concentrations for ^{234}U at the Plant Boundary for Varying UCRS K_d Values

The analyses show that as the uranium K_d is increased, the arrival time of the contaminant at the POEs is shifted to later times. In addition, the maximum groundwater concentrations within the 1,000 year time period decrease. As the uranium K_d is increased beyond 4 times the original value of 66.8 L/kg, the contaminant no longer reaches the RGA water table within the 1,000 year analysis period. This analysis shows that the sand Kd of 66.8 L/kg used for the UCRS likely is low for PGDP, however, due to the lack of sample data in the waste areas, a conservative uranium K_d was chosen to estimate the risks and hazards from uranium at the SWMUs.

Another source of uncertainty in the fate and transport modeling involves earlier analyses of the SWMUs on the western side of the PGDP which indicated the presence of a water table in the UCRS that results in some waste being below the locally high water table. Site data indicate that at least some of the burial pits of the BGOU SWMUs are saturated, with the primary flow direction being down into the RGA. Insignificant horizontal flow is assumed to occur above the RGA. The modeling assumed that the soil zones above the RGA are unsaturated, with contaminants being transported vertically downward into the RGA. The assumption that these zones are unsaturated in the model may have resulted in overestimation of contaminant migration from the various sources to the RGA for SWMUs below the UCRS water table. Overestimation is the result of the interaction between layers with low vertical hydraulic conductivity (i.e., HU2 Confining and HU3) and the shallow water table. Generally, this interaction results in contaminant concentrations in pore water within each layer approaching equilibrium with soil prior to migration because the rate of migration is very slow. This phenomenon ultimately would result in rates of contaminant migration (i.e., flux) that are less than that which would result from the introduction (i.e., infiltration) of “clean” water from precipitation through an unsaturated layer.

An additional uncertainty involves the fact that SESOIL and AT123D do not consider contaminant transformation such as that for radioactive decay chain ingrowth of progeny. An analysis was conducted to evaluate the potential impact of progeny ingrowth from ^{238}U and ^{234}U at SWMU 7. To evaluate the movement of progeny, a simplified assumption was made that radioactive progeny travel at the same rate of the parent. This assumption has been shown to be conservative (Codell *et al*., 1982) and greatly simplifies the calculations. The assumption was also made that no progeny exist at the time of waste emplacement. The concentration of the i^{th} progeny in a decay chain at the receptor location is then calculated by:

$$C_i = Cparent \frac{DIF_i \times R_{d\ parent}}{DIFparent \times R_{d\,i}}$$

Where

DIF_i = decay ingrowth factor of the i^{th} progeny

$DIF_{\ parent}$ = decay-ingrowth factor of the parent

$R_{d\,i}$ = retardation factor of the parent

$R_{d\ parent}$ = retardation factor of the parent

C_{parent} = groundwater concentration of the parent (pCi/L)

The sorption coefficients for sand were used in the analysis for uranium (66.8 L/kg), thorium (3200 L/kg) and radium (500 L/kg) (Sheppard and Thibault 1990).

The decay-ingrowth factor for an *n* member decay chain is given by Scrable *et al*., (1974):

$$DIF_i(t) = \frac{\lambda_i}{\lambda_l}\left[\left(\prod_{i=1}^{n-1}\lambda_i\right)\sum_{i=1}^{n}\frac{e^{-\lambda t}}{\prod_{j=1,\ j\neq i}^{n}\left(\lambda_j - \lambda_i\right)}\right]$$

Where

λ_l = decay constant for the parent (yr^{-1})

λ_i = decay constant for the ith progeny (yr^{-1})

t = time (years)

The results of the analysis for ^{238}U and ^{234}U at SWMU 7 are provided in Figure E.3.16 and E.3.17.

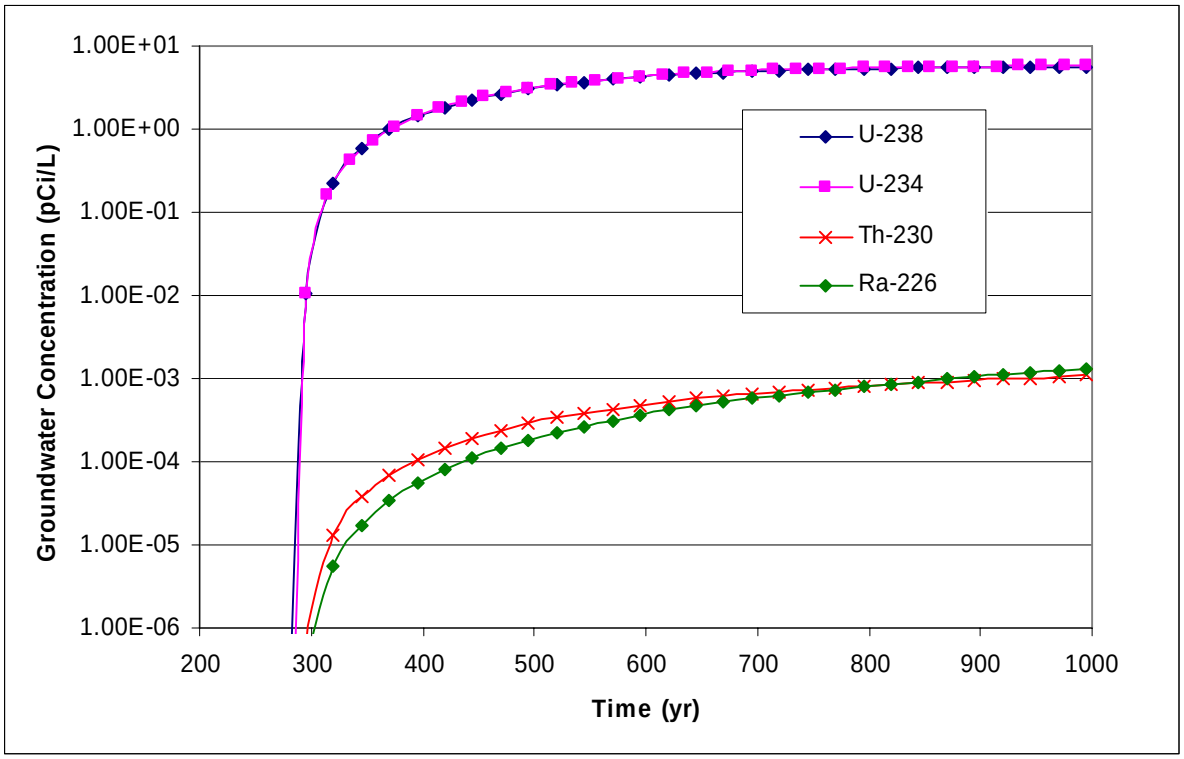


Figure E.3.16. SWMU 7 Groundwater Concentrations from Progeny Ingrowth from ^{238}U and ^{234}U at the Plant Boundary

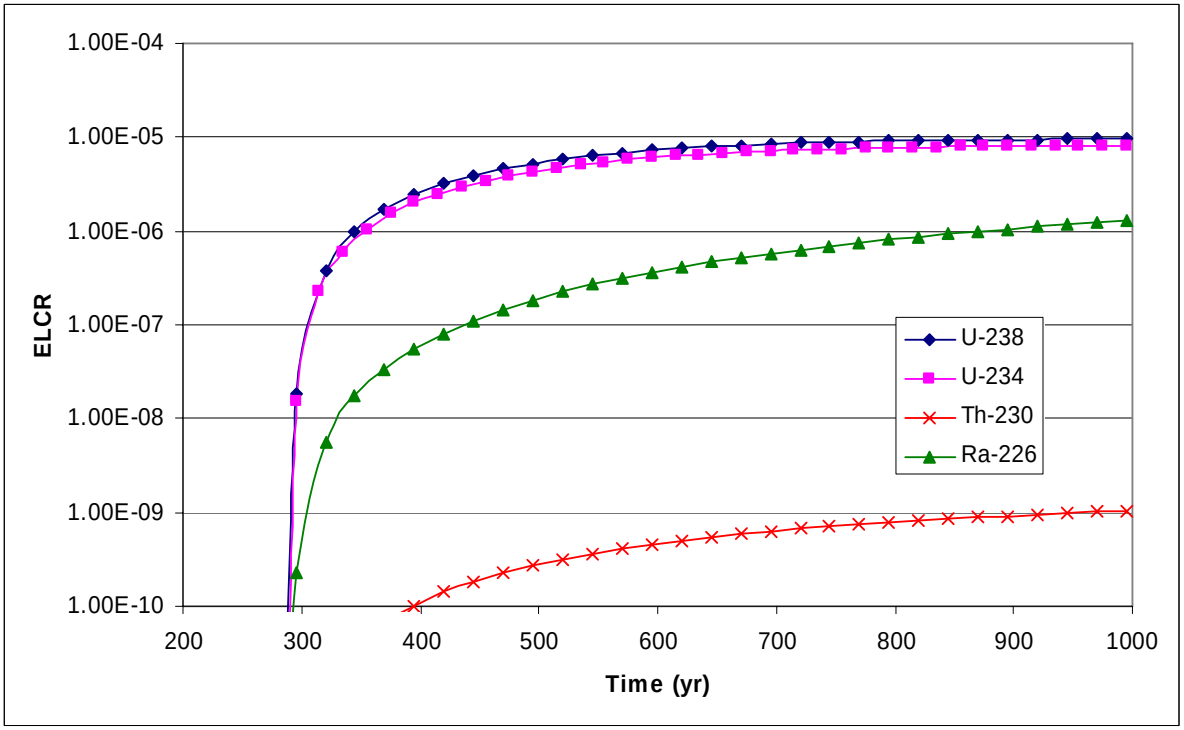


Figure E.3.17. SWMU 7 Groundwater ELCR from Progeny Ingrowth from ^{238}U and ^{234}U at the Plant Boundary

This analysis shows that the ingrowth of ^{226}Ra would provide an additional 7 % to the ELCR to that estimated for ^{238}U and ^{234}U at SWMU 7. However, this contribution is considered a conservative estimate since the progeny were assumed to transport with the uranium parents. In reality, the higher sorption coefficients for ^{230}Th and ^{226}Ra in comparison to uranium would result in differential transport such that the predicted concentrations of these progeny would be less than that provided by this simplified analysis.

E.3.3.3 Potential Interaction of Sources

The simulations presented in this report for the BGOU SWMUs are based on individual simulations of each SWMU. There is a potential that source plumes from the SWMUs could interact at the POEs. According to the flow paths presented in Figure E.3.18, the contaminant plumes from a few of the BGOU SWMUs would interact. The contaminant flow paths from SWMU 6 and SWMU 30 will interact, however, as noted previously, SWMU 6 did not have any groundwater analytes. The contaminant plumes from SWMU 3 and SWMU 5 will interact, and SWMU 2 will interact with a portion of the SWMU 5 contaminant plume. The interaction of the plumes could not be assessed using the SESOIL/AT123D model, since only one SWMU can be discretized in the model for each run.

An evaluation was conducted to ensure that analytes were not eliminated from the groundwater analyses from combined source contributions in the groundwater. The screening evaluation was conducted for the potential interaction of SWMU 2, 3, and 5. The analysis was based on the conservative summation of the maximum groundwater concentrations below each SWMU detailed in Section 5, Tables 5.5, 5.6, and 5.8. These combined contaminant concentrations are provided in Table E.3.38. These combined groundwater concentrations then were compared to the child resident NALs from Table A.18 of the 2001 Risk Methods Document and the provisional groundwater backgrounds shown in the 2001 Risk Method Document in Table A.13. The results of the conservative analysis indicate that the selection of analytes evaluated for risk and hazard would not change based on the combination of the source contributions to groundwater from SWMU 2, 3, and 5.

E.3.3.4 Location of the POEs

The POEs used in the modeling were placed at locations on the SWMU boundary, plant boundary, property boundary, Little Bayou seeps, and Ohio River where the greatest contaminant concentrations are expected in the future. By picking locations on the centerline of predicted contaminant plumes as the POEs, the modeling assumed that the hypothetical future resident would pick, by chance, the worst possible location to install a water supply well.

Based on particle tracks taken from the calibrated sitewide numerical flow model developed in MODFLOW for PGDP, SWMUs 2, 4, 5, and 145 were shown not to impact the Little Bayou seeps. If the SWMUs were to impact the seeps, it has been shown that SWMUs 2, 4, and 145 have modeled groundwater concentrations at the Ohio River that exceed MCLs for several analytes; therefore, the modeled groundwater concentrations at the Little Bayou seeps also would exceed the MCLs for these analytes. Modeling results for SWMU 5 show that the groundwater concentrations at the property boundary do not exceed the MCLs for any analytes modeled; therefore, the groundwater concentrations at the Little Bayou seeps also would be less than the MCLs for each analyte.

Table E.3.38. Evaluation of Combined Plume Interactions on Selection of Analytes

Analyte	Background Groundwater Concentration (mg/L)[a]	Groundwater Child Resident No Action Level (mg/L)[a]	Peak Conc Below SWMU 2 (mg/L)[a]	Peak Conc Below SWMU 3 (mg/L)[a]	Peak Conc Below SWMU 5 (mg/L)[a]	SUM of Peak Conc Below SWMUs (mg/L)[a]	Retain as Analyte			
							SWMU 2	SWMU 3	SWMU 5	SUM SWMUs
Acenaphthene	NA	1.36E-02			6.10E-03	6.10E-03			N	N
Anthracene	NA	7.66E-02			8.06E-03	8.06E-03			N	N
Arsenic	5.00E-03	3.50E-05	3.54E-02	3.29E-02	9.25E-03	7.76E-02	Y	Y	Y	Y
^{234}U	7.00E-01	5.46E-01	1.58E+00			1.58E+00	Y			Y
^{238}U	7.00E-01	4.43E-01	1.81E+00	1.59E+01		1.77E+01	Y	Y		Y
^{99}Tc	2.23E+01	1.40E+01	1.02E+02	5.56E+03	1.27E+02	5.79E+03	Y	Y	Y	Y
cis-1,2-DCE	NA	2.73E-03	1.15E+01			1.15E+01	Y			Y
Manganese	1.19E-01	3.50E-02	7.16E-01	8.95E-01	1.01E+00	2.62E+00	Y	Y	Y	Y
Mercury	2.00E-04	4.44E-04		9.29E-05		9.29E-05		N		N
Fluorene	NA	9.72E-03			3.63E-03	3.63E-03			N	N
Naphthalene	NA	2.85E-04	9.38E-04		5.55E-03	6.49E-03	Y		Y	Y
Nickel	3.05E-01	3.01E-02			2.01E-03	2.01E-03			N	N
Selenium	5.00E-03	7.54E-03			1.27E-03	1.27E-03			N	N
TCE	NA	1.60E-03	1.48E+00	3.45E-04	9.91E-04	1.48E+00	Y	N	N	Y
Uranium	2.00E-03	9.06E-04	9.86E-03	4.89E-02		5.88E-02	Y	Y		Y
Zinc	4.90E-02	4.50E-01	9.83E-03	9.30E-02	1.58E-01	2.61E-01	N	N	N	N

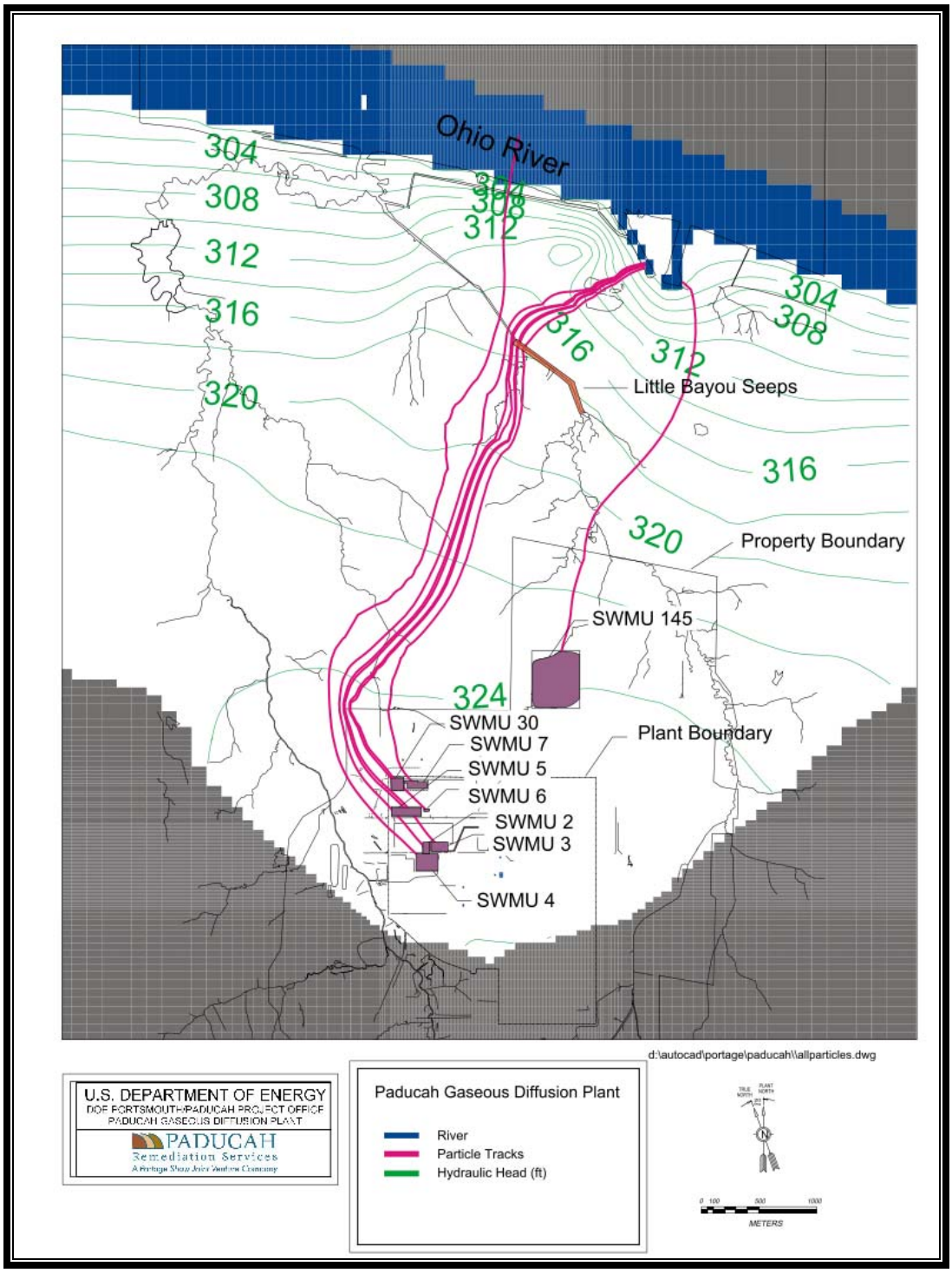


Figure E.3.18. Contaminant Plume Flow-Paths for All BGOU SWMUs

E.3.3.5 Future Environmental Changes

Several future environmental changes at the PGDP could impact the accuracy of the modeling predictions. These changes include plant shutdown and dam operation on the Ohio River. In a previous modeling effort for a landfill at PGDP, several sensitivity analyses were performed (DOE 2003b) to examine the impacts those changes may have on groundwater flow and contaminant transport. It was assumed in that sensitivity analysis that it can be expected that plant shutdown will lead to a changed recharge rate to the RGA through removal of ground cover (leading to increased recharge) and through reduced cooling water use (leading to decreased recharge); therefore, the sensitivity analysis of the groundwater travel time due to plant shutdown was studied by varying the recharge over a range of values. The results of the analysis indicated that a decrease in the recharge rate resulted in a monotonic increase in the travel time to the receptor. Thus, chemicals that have short degradation half-lives would show a decrease in concentration due to plant shutdown.

The Olmstead Dam operation is expected to increase the stage (water level) of the Ohio River; therefore, a sensitivity analysis was conducted (DOE 2003b) to assess changes in groundwater travel time in relation to dam operation, by increasing the river stage between 304.44 ft amsl and 310.04 ft amsl (the baseline river stage is 300.04 ft amsl). The results of the analysis indicated that the travel times in the aquifer changed very little in relation to the Ohio River stage; therefore, the dam operation would have little impact on the results shown in this report.

E.3.3.6 Burial Cell Waste

Sample data around and beneath the BGOU SWMUs were used to develop a source inventory of contaminants. The premise of this source inventory development is based on the inherent assumption that the contaminants around and beneath the BGOU SWMUs represent the release mass from the Burial Ground disposal cells. The groundwater transport analyses do not model potential future releases directly from the SWMU burial cells.

Waste at several SWMUs was containerized in drums before disposal. Previous inspections of buried drums at PGDP have indicated that the drums were highly corroded. It is considered unlikely that a significant portion of the drummed waste still is containerized at the BGOU SWMUs due to the length of time the drums have been buried and, thus, susceptible to a corrosive environment. The drums were not modeled in this RI report due to the overall objectives of the RI analyses and uncertainty in the degradation process. Due to the uncertainty in the degradation of the drummed waste, real measured sample data surrounding the SWMUs were used to evaluate the potential risk from the SWMU waste. This methodology resulted in the SWMUs with drummed waste exhibiting risk and hazard values that exceeded acceptable levels; therefore, the overall objectives of the RI analysis were met without requiring a detailed analysis of the degradation of drums.

E.3.3.7 SWMU 4 RGA TCE Source

The TCE source in SWMU 4 was assessed in this RI based on soil sample results. As discussed in Section 4.5.2, a discrete DNAPL zone, less than 200 ft wide, also may be present at the base of the RGA as evidenced by a discrete area with TCE concentrations greater than 10,000 µg/L in the lower RGA immediately downgradient of the SWMU. The volume of soil contaminated with TCE DNAPL at this SWMU is estimated to be approximately 31,480 yd^3. This estimate assumes a source area that is 100 ft by 100 ft with a thickness of 85 ft (depth to base of RGA, which is 100 ft minus the estimated depth to base of the waste cell of 15 ft.) The DNAPL source term for TCE in the RGA at SWMU 4 was not evaluated in the modeling analyses since the RGA concentrations in the lower RGA currently exceed the MCL. The UCRS TCE source concentrations were sufficient to indicate that actions should be taken for SWMU 4.

The uncertainties related to source term size and location will be better defined in a remedial design investigation prior to the design and implementation of a remedy.

E.3.3.8 SWMU 3 UCRS Groundwater Contamination

The groundwater analyses conducted for this RI are based on soil samples obtained from soils surrounding the SWMUs and their subsequent release to the RGA and transport through the RGA. In some instances, water samples from wells in the UCRS indicated additional contaminant concentrations that were not accounted for in the analyses. For example, UCRS wells MW85, MW88, MW91, and MW94 at SWMU 3 indicated elevated levels of TCE. Figures E.3.19 through E.3.22 show the TCE concentrations trends for these wells in the UCRS.

The water data was added to the SWMU 3 TCE soil concentrations and a SADA nearest neighbor interpolation was assessed. The results of the SADA analysis are presented in Table E.3.39.

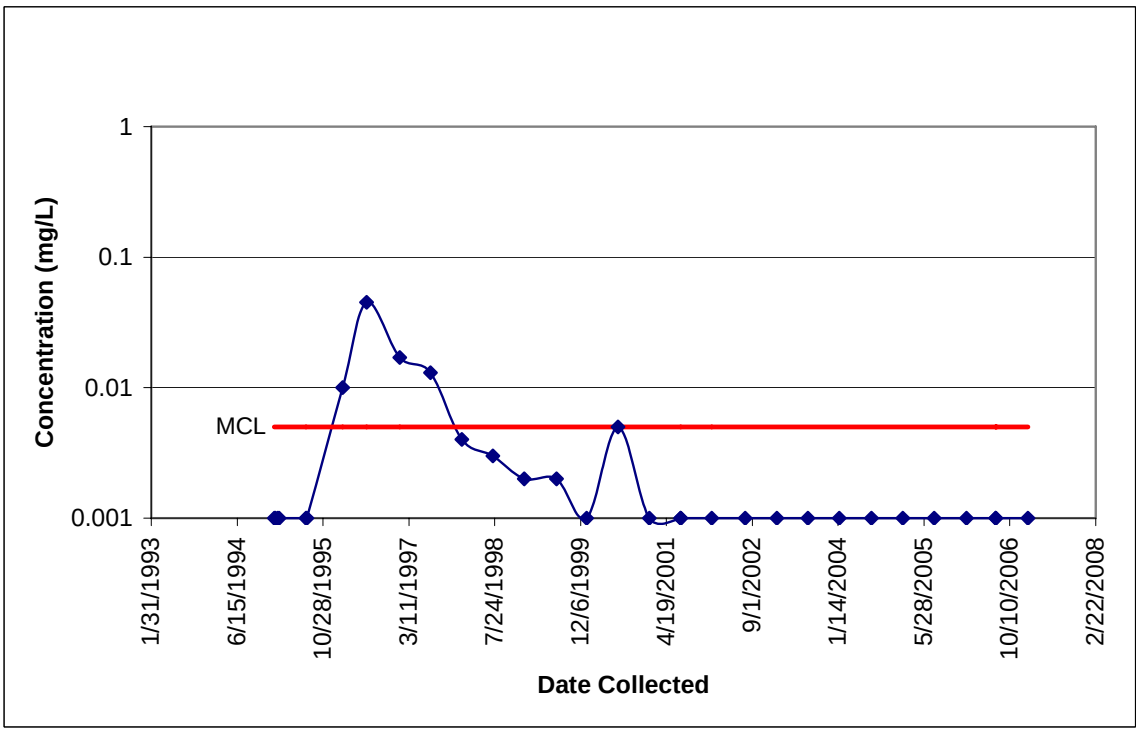


Figure E.3.19. UCRS TCE Contaminant Trend for SWMU 3 Well MW85

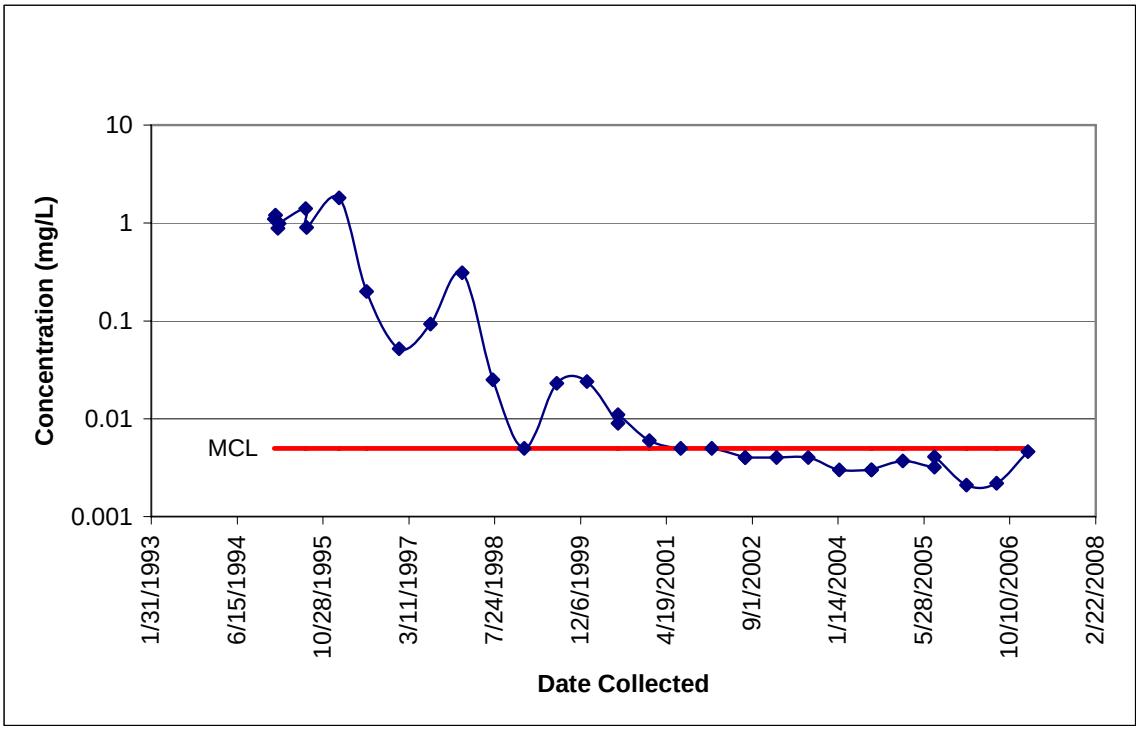


Figure E.3.20. UCRS TCE Contaminant Trend for SWMU 3 Well MW88

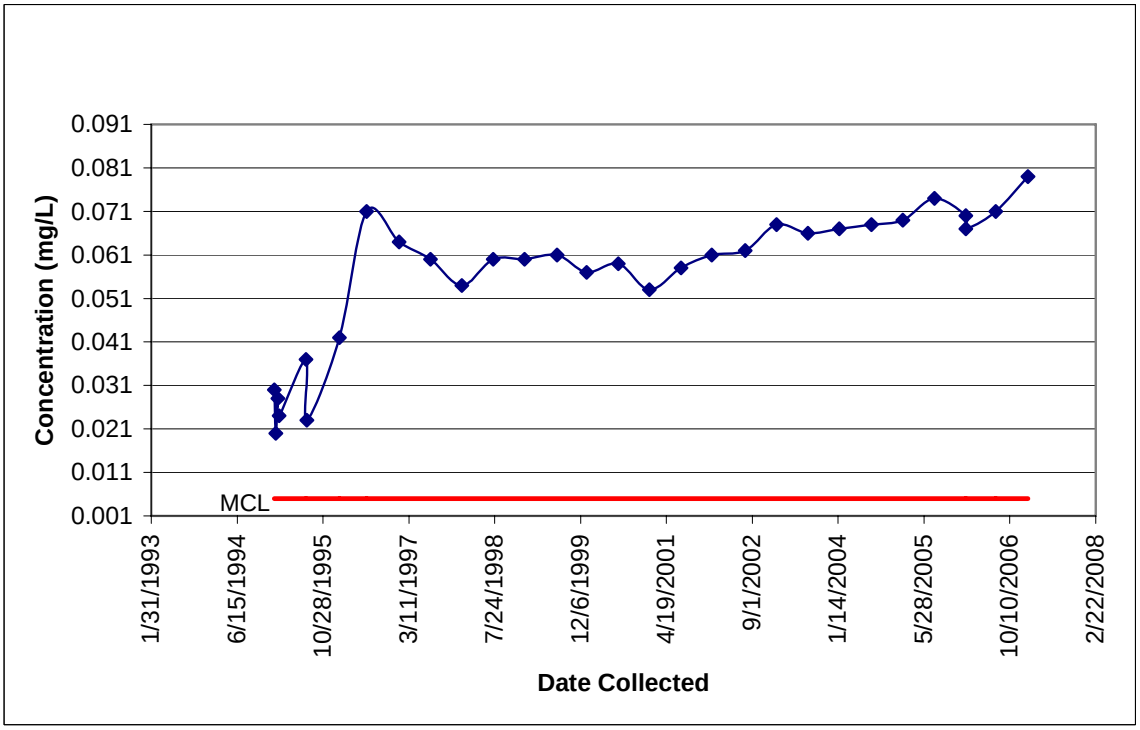


Figure E.3.21. UCRS TCE Contaminant Trend for SWMU 3 Well MW91

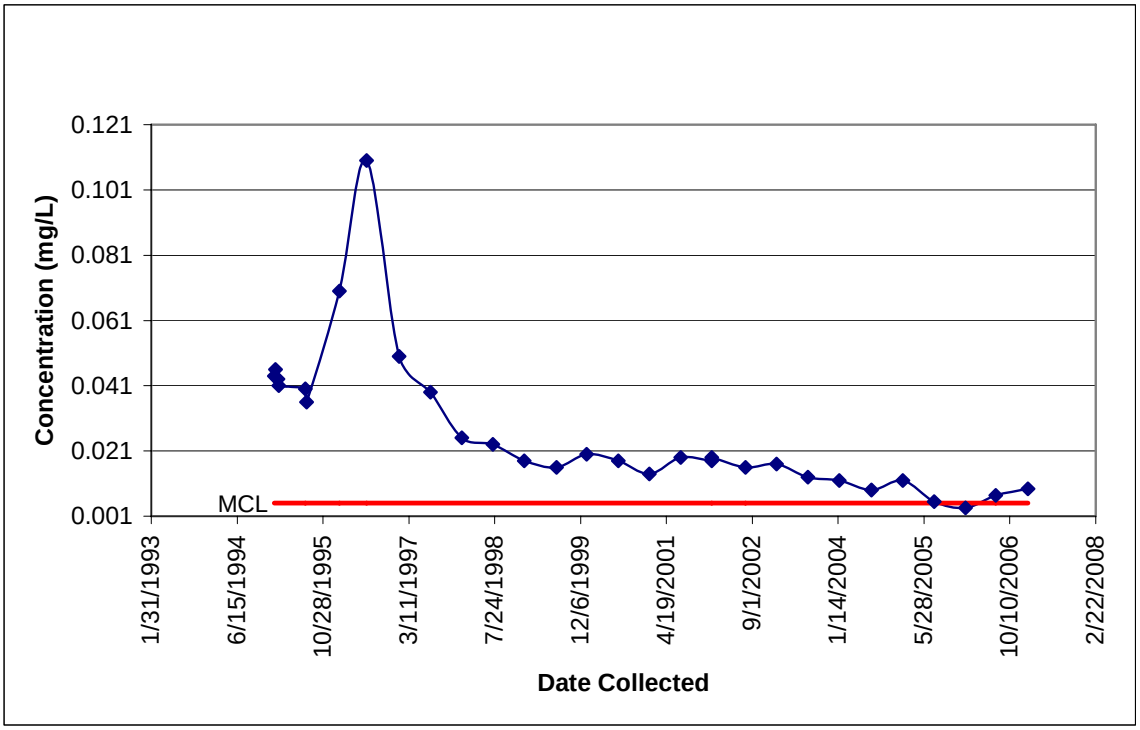


Figure E.3.22. UCRS TCE Contaminant Trend for SWMU 3 Well MW94

Table E.3.39. SWMU 3 TCE SADA Results With Well Data

Layer #	Depth Interval ft-ft bgs	Min mg/kg	Max mg/kg	Sum mg/kg	Count #	Avg mg/kg	Area ft^2	Volume ft^3	Mass gm
L0	0-1	0.01	0.01	0.02	3	0.0063	3.00E+04	3.00E+04	7.85E+00
L1	01-10	0.00	0.03	0.32	21	0.0155	2.10E+05	2.10E+06	1.34E+03
L2	10-20	0.00	0.03	0.33	22	0.0148	2.20E+05	2.42E+06	1.49E+03
L3	20-30	0.00	0.03	0.33	22	0.0148	2.20E+05	2.42E+06	1.49E+03
L4	30-40	0.00	0.03	0.33	23	0.0143	2.30E+05	2.53E+06	1.49E+03
L5	40-50	0.00	0.03	0.33	23	0.0143	2.30E+05	2.53E+06	1.49E+03
L6	50-58	0.00	0.03	0.33	23	0.0143	2.30E+05	2.30E+06	1.36E+03
								Total	**8.67E+03**

The groundwater analysis was conducted using the SADA results for both the UCRS TCE water data and the SWMU TCE soil data. The results of the analysis are provided in Figure E.3.23.

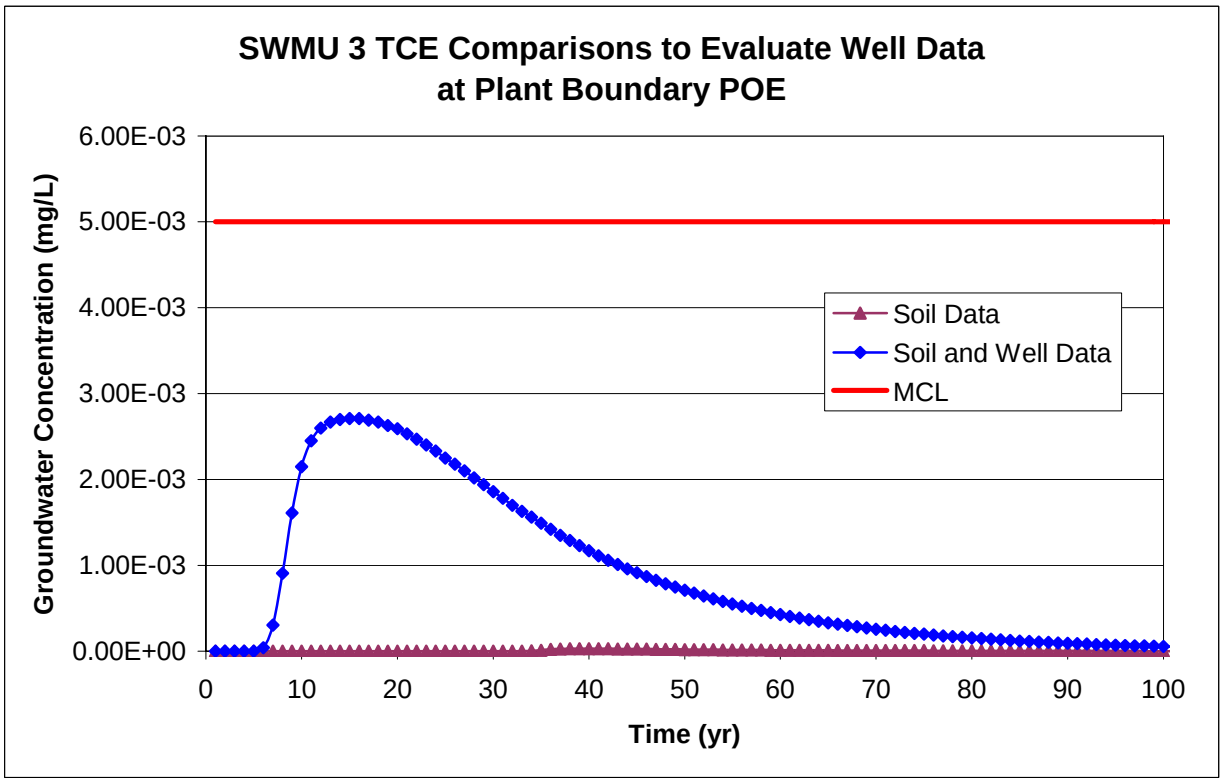


Figure E.3.23. Comparison of TCE at SWMU 3 with UCRS Well Sample Data and Soil Data

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APPENDIX E
ATTACHMENT 1

PREVIOUS FATE AND TRANSPORT MODELING FOR THE BGOU

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CONTENTS

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TABLES

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E1.1. INTRODUCTION

This attachment presents more detailed summaries and excerpts of previous fate and transport modeling for the Burial Ground Operable Unit SWMUs 2, 3, 4, 5, 6, 7, and 30. No previous modeling exists for SWMU 145.

E1.2. MODELING APPEARING IN THE WASTE AREA GROUP (WAG) 22, SWMUS 2 AND 3 FEASIBILITY STUDY (FS) AND ADDENDUMS, AND THE SWMU 2 DATA SUMMARY AND INTERPRETATION REPORT

This section describes previous groundwater modeling discussed in the WAG 22 SWMU 2 and 3 FS (DOE 1995a) and in the data summary and interpretation report for the SWMU 2 interim remedial design (DOE 1997).

E1.2.1 WAG 22 SWMU 2 AND 3 FS MODELING

The following is taken from the *Feasibility Study for Solid Waste Units 2 and 3 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, February 1995 (DOE 1995a).

GeoTrans (1992) conducted a modeling study of the hydrogeologic flow system beneath the PGDP to evaluate the feasibility and effectiveness of a proposed "pump-and-contain" groundwater extraction system. As part of this study, GeoTrans updated an existing model (GeoTrans 1990) by incorporating significant improvements in the hydrogeological characterization of the site. GeoTrans implemented the groundwater flow model using MODFLOW, the U. S. Geological Survey groundwater simulation code (McDonald 1988). The finite-difference grid for the GeoTrans model covered an area of approximately 60 km^2 (23 mi^2) and consisted of 91 columns, 117 rows and three layers. Layer 1 of the model represented the (UCRS); Model Layer 2 represented the RGA; and Model Layer 3 represented the McNairy Formation.

GeoTrans (1992) model used water levels from August 15, 1991, which were determined during data review to be representative of steady-state conditions, to calibrate the model. The model extended from the Ohio River in the north (simulated as a constant-head boundary) to the Porters Creek Clay terrace transition area in the south (simulated as a no-flow boundary). Constant heads simulated the observed potentiometric surface in the McNairy Formation; thus, the McNairy Formation was an infinite sink or source in the model depending on the hydraulic heads simulated in the RGA.

GeoTrans (1992) calibrated the model by matching water levels observed in the UCRS and RGA. Overall, the GeoTrans model simulates hydraulic heads more closely in the RGA. In the UCRS, the model generally mismatched hydraulic heads on the order of ±1.5 to 3 m (±5 to 10 ft). The apparent reason for the poor fit in the UCRS most likely was due to a lack of vertical discretization and the oversimplification of the hydraulic conductivity distribution in the UCRS.

McConnell (1992a; 1992b; 1993) has developed a number of groundwater flow models to study the shallow groundwater system at the PGDP site. McConnell (1993) developed a groundwater flow model to estimate the average vertical hydraulic conductivity of Hydrogeologic Unit (HU) 3, the hydraulic

properties of the McNairy Formation, and the connection between the McNairy Formation and the Ohio River.

McConnell's model results suggested that the RGA is in direct communication with the Ohio River, and during high river stage conditions, groundwater is driven down into the McNairy Formation.

Additional models developed by McConnell simulated groundwater flow conditions at the C-747-A Burial Ground Area (SWMUs 7 and 30) (McConnell 1992a) and the C-404 Landfill Area (SWMU 4) (McConnell 1992b). The local groundwater flow model developed for the C-747-A site evaluated the effectiveness of using an impermeable cap with and without a slurry trench partially surrounding the facility to dewater the UCRS immediately beneath the landfill. The model simulated only the UCRS and RGA HUs; a no-flow boundary represented the McNairy Formation in the model. Constant heads simulated a prescribed hydraulic gradient in the RGA and no-flow boundaries around the edges of the model in the overlying units precluded the possibility of horizontal groundwater flow in the UCRS. Model results suggested that the slurry trench in combination with the cap would be required to dewater the UCRS beneath the site.

The model of the C-404 Landfill Area (SWMU 4) (McConnell 1992b) was developed to improve the conceptual model of the groundwater flow system in the C-404 area, estimate hydraulic parameters, and assess the hydraulic effect of installing an impermeable cap over the C-404 area. This model consisted of eight model layers covering an area of 7,432 m^2 (80,000 ft^2) with minimum grid cell sizes of 15 by 15 m (50 by 50 ft). This model simulated the upper 6.1 m (20 ft) of the McNairy Formation; otherwise, boundary conditions were similar to the C-747-A model (McConnell 1992a). Due to the small size of the model and specified constant-head boundaries, the hydraulic conductivity of the RGA unit was insensitive. Model simulation results suggested that pumping in the RGA may induce leakage from the McNairy Formation, an effect inferred by Terran (1990) from the analysis of an aquifer test. Model simulations also showed that a cap installed over the landfill area reduces hydraulic heads beneath the facility, but would not be effective at dewatering it.

The objective of the McConnell study was to develop a regional model of groundwater flow at the PGDP for the purposes of testing and refining conceptual models of the groundwater flow system beneath the site and evaluating remedial alternatives for the C-749 Uranium Burial Ground, SWMU 2. Use of the model at this landfill site provided a quantitative basis for evaluating engineering alternatives and lead to informed technical and economic decisions concerning the remediation of groundwater beneath the facility. In addition, the development of this model served an important, longer range objective by providing a groundwater management tool for decision makers who needed to evaluate groundwater flow conditions at SWMUs 7 and 30, also a part of WAG 22, but which were deferred until a later date.

Previous modeling studies provided valuable information regarding hydraulic property estimates, aquifer system response, and hydrogeologic framework; however, because the previous models addressed different sets of objectives, they contained deficiencies that reduce their usefulness for this modeling study. Some of the deficiencies included the following:

Regional Model (GeoTrans 1992)

- The GeoTrans model was not satisfactorily calibrated in the UCRS layer, suggesting potential errors in the model recharge or hydraulic parameters estimates;

- The GeoTrans model did not contain sufficient vertical discretization in the UCRS and lacked sufficient horizontal discretization in the area of interest to represent heterogeneous geologic conditions beneath the PGDP;

- The GeoTrans model used a no-flow boundary condition to simulate the southern model boundary along the Porters Creek Clay terrace. Later work suggested groundwater flow may occur at this interface; and

- The hydraulic conductivity assigned to the RGA in the GeoTrans model was much higher than values that had been measured from pumping tests conducted at the site.

Site-Specific Models

- Models developed by McConnell (1992a; 1992b; 1993) did not incorporate regional groundwater flow components; and boundary conditions set close to area(s) of interest by McConnell's models overly constrained model predictions.

Geraghty & Miller's approach for their modeling study addressed the aforementioned deficiencies. The groundwater flow model resulting from this study provided a more reliable decision-making tool that incorporated regional-scale groundwater flow components in predictive simulations made at the scale appropriate for the site simulation.

To meet the objectives of the study, Geraghty & Miller developed a three-dimensional numerical model that simulates groundwater flow in the vicinity of the PGDP. Geraghty & Miller developed the model in two phases. In the first phase, Geraghty & Miller constructed and calibrated a groundwater flow model covering nearly 100 km^2 for the purpose of simulating groundwater flow on a regional scale in the principal water-bearing units beneath the site. The regional model simulated groundwater flow in a multi-aquifer system, consisting of the UCRS Hydrogeologic Unit (HU 2), RGA (HU 4/HU 5), and the McNairy Formation (HU 6), and incorporated detailed spatial information describing the distribution of heterogeneous sediments comprising the Upper Continental Deposits (HU 2). In the second phase, Geraghty & Miller used the regional modeling results to develop a site-scale groundwater flow model with the aim of evaluating the hydraulic effects of remedial alternatives on groundwater flow and contaminant migration pathways in the vicinity of SWMU 2.

For the simulation of groundwater flow at the PGDP, Geraghty & Miller selected the code MODFLOW, a publicly available groundwater flow simulation program developed by the U.S. Geological Survey (McDonald 1988). Using the 75 water-level targets selected for the calibration of the PGDP regional groundwater flow model, Geraghty & Miller evaluated the calibration of the model through the analysis of (1) simulated hydraulic head distribution in the HU 2A (Model Layer 1), HU 2B (Model Layer 2) and RGA units (Model Layer 3); (2) estimated hydraulic properties; and (3) residual statistics. The calibration objective for the PGDP regional groundwater flow model was to minimize the residual sum of squares computed for the 75 water-level calibration targets. The largest computed residual for the entire set of targets was -2.03 m (-9.95 ft); however, only six residuals out of the 75 targets exceeded +/- 1.5m (+/- 5 ft). Greater than 70% of the targets had residuals of +/- 0.6 m (+/- 2 ft) or less. Overall, the model showed a very good match to the measured water levels given the complex geologic conditions at the site. Residual statistics for the calibrated groundwater flow model also indicated good agreement between simulated and measured groundwater elevations. The mean was close to zero, and the residual standard deviation was less than 2% of the range of simulated water-level elevations for the entire model domain.

Following the calibration of the regional groundwater flow model for the PGDP, the second phase of model development was used to simulate the hydraulic effect(s) of postulated remedial alternatives on the groundwater flow system beneath SWMU 2. To perform detailed simulations of the remedial alternatives postulated for SWMU 2, Geraghty & Miller used a procedure known as telescopic mesh refinement or grid refinement to develop a site-scale model for the WAG 22 site. The finite-difference grid for the WAG 22 site model covered an area of 2.19 km^2 (0.85 mi^2) and consisted of 125 columns, 113 rows, and

four layers. In the area of interest near SWMU 2, the grid cells measure 3.05 m (10 ft) on a side. Vertical discretization (layer elevations) of the WAG 22 site model was identical to the regional groundwater flow model. To preserve the characteristics of the regional groundwater flow system, the site model placed constant head boundaries along its external boundaries based on hydraulic heads simulated by the regional model. Hydraulic properties (horizontal and vertical hydraulic conductivities) and internal boundary conditions (precipitation recharge, streams and rivers, and McNair Formation constant head boundary) simulated by the site model remained unchanged form the regional model. The site model also used MODFLOW to perform the steady-state simulations of groundwater flow at the SWMU 2 site. This WAG 22 site model was used to simulate six remedial alternatives for SWMU 2.

E1.2.2 SWMU 2 DATA SUMMARY AND INTERPRETATION REPORT MODELING

The following is taken from *Data Summary and Interpretation Report for Interim Remedial Design at Solid Waste Management Unit 2 of Waste Area Grouping 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, February 1997 (DOE 1997).

E1.2.2.1 MEPAS Modeling

To quantify the potential migration of contaminants in source materials (i.e., soil, waste, and groundwater) at SWMU 2 to exposure points, MEPAS was used. For groundwater, exposure points modeled were the PGDP property boundary and the PGDP security fence. The MEPAS modeling was used to determine contaminant concentrations at exposure points over time. Tables E1.1 and E1.2 show parameters defining the environmental setting and source term used.

Transportation of contamination into the RGA and to the integrator point was modeled over a 10,000-year period. At SWMU 2, the latest sampling data showed no TCE dense nonaqueous phase liquid (DNAPL) in the RGA. However, it is known that 450 gal of TCE were disposed of at SWMU 2. To account of this material, the entire 450-gal source was modeled as being within the waste volume. It was assumed that little or no biodegradation of TCE occurs (e.g., Wilson *et al*. 1983, Kleopfer *et al*. 1985, Fetter 1993). This assumption is conservative because over long periods of time (such as the 10,000-year duration modeled in this study) TCE will probably undergo degradation into something other than vinyl chloride (Fetter 1993).

The exposure points for the groundwater flow are located at the fence and DOE boundary. From SWMU 2, the distances are 1,875 ft to the fence and 2,475 ft to the DOE boundary. The site width is perpendicular to the groundwater flow direction (north), giving a site width and length of 160 and 200 ft, respectively. For modeling, the lesser of the maximum detected concentration and the upper 95% confidence limit on the mean concentration was used for detected analytes that were on the final SAP analyte list. For analytes that were on the final SAP analyte list but were not detected, the maximum nondetected value was used. (Note, the maximum nondetected values were used because previous information indicated that each of the analytes in the final SAP analyte list should be present at SWMU 2.)

Table E1.1. MEPAS Modeling Parameters: Soil Characteristics, Hydrology, and Hydrogeology

Parameter	Waste Soil	Top Soil	HU1	HU2A	HU2 Conf	HU2B	HU3	RGA
Soil Texture[a]	9	9	9	1	11	1	11	1
% Sand[b]	5	5	5	97	10	97	8	90
% Silt[b]	75	75	75	3	40	3	38	10
% Clay[b]	20	20	20	0	50	0	54	0
% Organic Matter[c]	0.1	0.1	0.1	0.1	0.07	0.1	0.08	0.03
% Iron & Aluminum[d]	2.0	2.4	2.0	2.0	2.1	2.6	4.2	2.0
pH[e]	6.0	5.5	6.0	6.0	6.0	5.8	6.1	6.6
% Vegetative Cover[f]	---	25	---	---	---	---	---	---
Top Soil Water Capacity[f]	---	0.33	---	---	---	---	---	---
SCS Curve#[f]	---	74	---	---	---	---	---	---
Thickness[g], ft	4.6	2.0	16.5	7.5	8	6	9	40
Bulk Density[h], g/cm^3	1.96	---	1.96	2.24	1.96	2.24	1.96	2.16
Total Porosity[j], %	33	---	33	25	40	25	38	30
Field Capacity[f], %	25	---	25	13	35	13	30	---
Effective Porosity[f], %	---	---	---	---	---	---	---	25
Longitudinal Dispersivity[j] (Thickness x 0.1), ft	1.65	---	1.65	0.75	0.8	0.6	0.9	---
Saturated Hydraulic Conductivity[k], cm/s	1E-7	---	1E-7	5E-6	8E-7	1E-6	5E-7	---
Darcy Velocity[f], ft/day	---	---	---	---	---	---	---	1.17
Travel Distance[l]	---	---	---	---	---	---	---	1,875/ 2,475
Longitudinal Dispersivity[j] (=Travel Dist*0.1), ft	---	---	---	---	---	---	---	187.5/ 247.5
Transverse Dispersivity[j] (=Long Disp*0.33), ft	---	---	---	---	---	---	---	61.9/ 81.7
Vertical Dispersivity[j] (=Long Disp*2.5E-3), ft	---	---	---	---	---	---	---	0.469/ 0.619
% of Flux into Aquifer[m]	---	---	---	---	---	---	---	100
Perpendicular Distance to Plume Centerline, ft	---	---	---	---	---	---	---	0
Vertical Distance below GW, ft	---	---	---	---	---	---	---	0

Notes:
Table taken from DOE 1997.
"---" indicates that these data are not required for that hydrogeologic layer when setting up the MEPAS model.
[a] Selected from MEPAS based on descriptions of soil characteristics contained in SAIC (1994), Claussen *et al*. (1996), and SAP field investigation where 9 is silty clay loam, 1 is sand, and 11 is silty clay.
[b] Values for top soil and HU1 taken from SAIC (1994). Value for HU2A taken from Claussen *et al*. (1996). Values for HU2 Confining, HU2B, HU2, and RGA are estimated based on results form SAP field investigation. Value for waste set equal to HU1.
[c] Estimated from results of SAP field investigation.
[d] Estimated from results of the Phases I and II Site Investigations (CH2M Hill 1991 and 1992).
[e] Values for top soil, HU1, HU2B, and HU2 Confining estimated from results of SAP field investigation. Values for HU2A and HU3 from analyses for monitoring wells MW48 and MW53 as found in the PGDP Environmental Information Management System data base. Value for waste soil set equal to HU1.
[f] Value is estimated from MEPAS default (Droppo *et al*. 1989) and is based on professional judgment.
[g] All values, except for waste, were estimated from results of SAP field investigation. Value for waste soil was calculated as shown in Appendix B and Table 2.19 [of DOE 1997].
[h] Value from McConnell (1993).
[j] Calculated value.
[k] Calculated from values in Table 4.1 [of DOE 1997].
[l] Determined from PGDP site map. First value is for migration to plant security fence; second value is for migration to DOE property boundary.
[m] Value set to maximum.

Table E1.2. MEPAS Modeling Parameters: Adsorption Coefficients

Parameter	Top Soil	HU1 & Waste	HU2A	HU2 Conf	HU2B	HU3	RGA
Arsenic	19.4	19.4	5.86	19.4	5.86	19.4	5.86
Barium	2,800	2,800	530	16,000	530	16,000	530
Beryllium	1,400	1,400	70	8,000	70	8,000	70
Cadmium	423	423	14.9	56.7	14.9	567	14.9
Chromium	56.5	56.5	16.8	360	16.8	360	16.8
Manganese	25.3	25.3	16.5	36.9	16.5	36.9	16.5
Nickel	58.6	58.6	12.2	650	12.2	650	12.2
Silver	4	4	0.4	40	0.4	40	0.4
Thallium	0.2	0.2	0	0.8	0	0.8	0
Uranium	253	253	1,170	3640	1,170	3,640	66.8
Vanadium	100	100	50	100	50	100	50
cis-1,2-dichloroethene	Analyte not found in MEPAS database						
trans-1,2-dichloroethene	0.0278	0.0278	0.007	0.115	0.007	0.012	0.0059
Aroclor 1016	1360	1,360	134	2160	134	2,300	111
Aroclor 1221	44	44	4.33	69.7	4.33	74.2	3.59
Aroclor 1232	5.84	5.84	0.575	9.26	0.575	9.86	0.477
Aroclor 1242	47.8	47.8	4.7	75.7	4.7	80.6	3.89
Aroclor 1248	2,100	2,100	207	3,330	207	3,540	171
Aroclor 1254	4,020	4,020	395	6,360	395	6,780	328
Aroclor 1260	50,800	50,800	5,000	80,500	5,000	85,700	4,140
Trichloroethene	0.955	0.955	0.094	1.51	0.094	1.61	0.0779
Vinyl chloride	0.432	0.432	0.0425	0.685	0.0425	0.729	0.0352
^{241}Am	200	200	82	1000	820	1,000	82
^{237}Np	3	3	3	3	3	3	3
^{239}Pu	100	100	10	250	10	250	10
^{234}Pa	50	50	0	500	0	500	0
^{99}Tc	20	20	3	20	3	20	3
^{230}Th	500	500	100	2,700	100	2,700	100
^{234}Th	500	500	100	2,700	100	2,700	100
^{234}U	243	243	906	1,580	906	1,580	62.98
^{235}U	243	243	906	1,580	906	1,580	62.98
^{238}U	243	243	906	1,580	906	1,580	62.98

Notes:
Table taken from DOE 1997.
All adsorption coefficients except those for uranium were generated by MEPAS. Values for uranium were taken from information gathered during recently completed SWMU 7 and 30 field investigation.

The results of the MEPAS modeling are shown in Tables E1.3. The results of the MEPAS model are not the total concentrations of SAP analytes that are present in the exposure medium (e.g., groundwater) at the exposure point but only the additional contamination that may be contributed by SWMU 2 sources.

The contributed concentration of all radionuclides, and most other analytes, is much less than the analyte's respective PRGs. This result indicates that for these SAP analytes, migration from soil and waste cells through groundwater to the exposure point at the security fence is not of concern over the 10,000 years modeled by MEPAS. However, the maximum contributed concentration of arsenic, Aroclor 1221, Aroclor 1232, Aroclor 1242, TCE, 1,1-dichloroethene, and vinyl chloride exceeds these analytes' respective human health risk-based PRG. In addition, the contributed concentration of TCE exceeds its regulatory value (i.e., MCL). Note, because similar results were obtained when MEPAS was used to model the maximum contributed concentration of SAP Analytes in RGA groundwater at the plant boundary, these results are not shown.

Table E1.3. MEPAS Results–Comparison of Estimated Maximum Concentrations of Contaminants in RGA Water at the PGDP Fence Line Originating from Soil and Waste Cells to Residential Preliminary Remediation Goals

			Preliminary Remediation Goals					
Analyte	**Maximum Concentration[a]**	**Time of Maximum Concentration[b]**	**ELCR[c]**	**HI[d]**	**Regulatory Value[e]**	**Background[f]**	**Criteria Exceeded[g]**	**Units**
Arsenic	4.93E-04	1,505	3.50E-06	4.52E-04	5.00E-02	1.10E-02	k	mg/L
Barium	0.00E+00	35		1.04E-01	2.00E+00	2.90E-01	No	mg/L
Beryllium	6.45E-33	9,975	1.05E-06	6.61E-03	4.00E-03	9.30E-03	No	mg/L
Cadmium	2.75E-07	9,975		6.61E-04	5.00E-03	2.10E-02	No	mg/L
Chromium	8.20E-06	9,975		7.05E-03	1.00E-01	1.30E-01	No	mg/L
Manganese	1.74E-02	2,765		6.81E-02	1.59E-01*	1.60E-01	No	mg/L
Nickel	3.48E-06	9,975		3.01E-02	6.19E-02	6.20E-02	No	mg/L
Silver	1.97E-04	1,715		7.50E-03	1.00E-01*	1.10E-01	No	mg/L
Thallium	1.07E-03	35			2.00E-03	1.10E-01	No	mg/L
Uranium	4.86E-03	665		4.53E-03	2.00E-02*		No	mg/L
Vanadium	3.08E+04	8,015		9.25E-03		1.40E-01	No	mg/L
Aroclor 1016	3.22E-31	9,975		4.69E-05	5.00E-04		No	mg/L
Aroclor 1221	1.37E-06	4,305	5.83E-07		5.00E-04		k, *h*	mg/L
Aroclor 1232	9.95E-06	595	6.67E-07		5.00E-04		k, *h*	mg/L
Aroclor 1242	1.26E-06	4,725	6.40E-07		5.00E-04		k *h*	mg/L
Aroclor 1248	8.13E-40	9,975	4.03E-07		5.00E-04		No	mg/L
Aroclor 1254	3.43E-43	9,975	4.13E-07	4.30E-05	5.00E-04		No	mg/L
Aroclor 1260	0.00E+00	35	2.27E-07		5.00E-04		No	mg/L
1,1-dichloroethene	4.78E-06	35	1.62E-06	1.34E-02	7.00E-03		g, *h*	mg/L
1,2-dichloroethene	5.35E-05	35	1.49E-02[i]		7.00E-02[i]		No	mg/L
Trichloroethene	5.64E-02	105	2.01E-04	7.86E-03	5.00E-03		k, L	mg/L
Vinyl chloride	7.74E-05	35	2.04E-06		2.00E-03		k	mg/L
^{225}Ac	1.55E-06	3,535	2.72E-01				No	pCi/L
^{227}Ac	1.89E-04	735	6.17E-02[j]				No	pCi/L
^{241}Am	6.28E-03	665	1.18E-01				No	pCi/L
^{210}Bi	6.94E-07	4,025	5.30E+00				No	pCi/L
^{237}Np	5.27E-02	35	1.29E-01[j]				No	pCi/L
^{231}Pa	1.97E-04	735	2.59E-01				No	pCi/L
^{233}Pa	5.27E-02	35	8.23E+00				No	pCi/L
^{210}Pb	6.94E-07	4,025	3.82E-02[j]				No	pCi/L

Table E1.3. MEPAS Results–Comparison of Estimated Maximum Concentrations of Contaminants in RGA Water at the PGDP Fence Line Originating from Soil and Waste Cells to Residential Preliminary Remediation Goals (Continued)

			Preliminary Remediation Goals					
Analyte	Maximum Concentration[a]	Time of Maximum Concentration[b]	ELCR[c]	HI[d]	Regulatory Value[e]	Background[f]	Criteria Exceeded[g]	Units
^{210}Po	6.94E-07	4,025	1.18E-01				No	pCi/L
^{239}Pu	2.66E-02	175	1.22E-01				No	pCi/L
^{223}Ra	1.89E-04	735	1.65E-01				No	pCi/L
^{225}Ra	1.55E-06	3,535	2.46E-01				No	pCi/L
^{226}Ra	4.00E-02	1,155	1.30E-01[j]				No	pCi/L
^{222}Rn	7.09E-07	4,025	1.03E+00[j]				No	pCi/L
^{99}Tc	3.46E-02	1,365	2.76E+01				No	pCi/L
^{227}Th	1.89E-04	735	9.56E-01				No	pCi/L
^{229}Th	1.55E-06	3,535	1.08E-01[j]				No	pCi/L
^{230}Th	1.04E-01	1,085	1.03E+00			1.40E+00	No	pCi/L
^{231}Th	1.34E-02	665	2.16E+01				No	pCi/L
^{234}Th	1.61E-01	665	2.00E+00				No	pCi/L
^{233}U	3.24E-05	315	8.62E-01				No	pCi/L
^{234}U	1.51E-01	665	8.70E-01			1.20E+00	No	pCi/L
^{235}U	1.34E-02	665	8.21E-01[j]			1.50E-01	No	pCi/L
^{238}U	1.61E-01	665	6.23E-01[j]			1.10E+00	No	pCi/L

Table taken from DOE 1997.

Blank cells indicate that value is not available or not applicable.

[a] Maximum concentration of analyte predicted to be in RGA water at the PGDP security fence by MEPAS. All modeling was performed over a 10,000-year period.

[b] Time at which MEPAS predicts maximum concentration will be reached.

[c] Direct contact residential use risk-based preliminary remediation goal calculated using $1X10^{-7}$ as the target excess lifetime cancer risk (ELCR) for chemicals and $1X\ 10^{-6}$ as the target ELCR for radionuclides.

[d] Direct contact residential use risk-based preliminary remediation goal calculated using 0.1 as the target hazard index.

[e] The value reported is the respective analyte's maximum contaminant level (MCL). All MCLs are Primary Drinking Water Standards except where marked with *. Marked values are either proposed Primary Drinking Water Standards or Secondary Drinking Water Standards (SMCLs).

[f] Concentration of analyte in uncontaminated media. For all water samples, the background values reported are those for the RGA.

[g] Preliminary remediation goals exceeded. In this table, maximum detected concentrations are not directly comparable to preliminary remediation goals because MEPAS only predicts the additional contamination added by migration. However, the difference in magnitude between preliminary remediation goals and the maximum predicted concentrations indicates that contaminants from SWMU 2 are unlikely to contribute significantly to contamination in water at the PGDP security fence over the next 10,000 years.

[h] Source term concentration based on maximum undetected concentration.

[I] MEPAS does not offer both *cis*-1,2-dichloroethene and *trans*-1,2-dichloroethene; therefore, both isomers were modeled as *trans*-1,2-dichloroethene. However, the preliminary remediation goals reported are the lesser of those for the respective isomers.

[j] Preliminary remediation goal calculated using the toxicity value (i.e., slop factor) for parent isotope and short-lived daughters.

[k] Exceeds human health risk based preliminary remediation goal (PRG).

[L] Exceeds regulatory value (i.e., MCL).

Of the seven chemicals found to have contributed concentrations that exceed screening criteria, the results for four, Aroclor 1221, Aroclor 1232, Aroclor 1242, and 1,1-dichloroethene, should be considered suspect because their contributed concentrations were based on the respective chemical's maximum nondetected concentration. Analytes that were not detected in any sample were retained in the source terms by using these analytes' maximum nondetected value. Although this approach was conservative, this procedure allowed these four chemicals, which have relative high detection limits in relation to their toxicity, to appear to migrate to exposure points at levels that may be of concern. In addition, the significance of arsenic's and vinyl chloride's contributed concentrations in relation to their screening criteria can be questioned because each chemical's contributed concentration is less than its MCL over the time period modeled.

The contributed concentrations of TCE, unlike the other chemicals, exceed both the human health risk-based PRG and the MCL in at least one time period. However, the concentrations of TCE exceed the MCL for only approximately the first 250 years modeled. After this time, the concentrations rapidly fall and are below the human health risk-based PRG based on ELCR prior to model year 500.

A secondary source of TCE may exist in the RGA at SWMU 2. Although the detected maximum concentration of TCE in RGA water is less than the criteria established for secondary sources in DOE (1996) (i.e., 10 mg/L); this concentration is 53.5% of this level. The results of the modeling of the potential secondary source in the RGA to the security fence and plant boundary are shown in Table E.1.4. The results in this table show that by year 105 from present, all contributed concentrations will be below TCE's PRGs at both the security fence and plant boundary. These results also show that the current concentration of TCE at the security fence and plant boundary exceed all of the respective analytes' PRGs and that the potential contributed concentration from SWMU 2 at 35 year is 0.5% and 0.3% respectively, of the current concentration at these locations.

Table E1.4. MEPAS Results–Comparison of Estimated Maximum Concentrations of Contaminants in RGA Water at the PGDP Fence Line Originating from Soil and Waste Cells to Residential Preliminary Remediation Goals

Time (years)	Concentration[a]	Preliminary Remediation Goals				Criteria Exceeded[f]	Units
		ELCR[b]	HI[c]	Regulatory Value[d]	Background[e]		
Results for 1,1-trichloroethene at the security fence							
Present[g]	1.50E+01	2.01E-04	7.86E-03	5.00E-03	None	PR	mg/L
35	6.11E-02					PR	mg/L
105	3.94E-07					No	mg/L
Results for 1,1-trichloroethene at the plant boundary							
Present[g]	1.50E+01	2.01E-04	7.86E-03	5.00E-03	None	PR	mg/L
35	4.51E-02					PR	mg/L
105	3.52E-06					No	mg/L

Note: Table taken from DOE 1997.

[a] Present concentrations are measured values; future concentrations are additional materials that will be in addition to materials that will be in addition to materials migrating from other sources (i.e., contributed concentrations).

[b] Direct contact residential use risk-based preliminary remediation goal calculated using $1X10^{-7}$ as the target excess lifetime cancer risk (ELCR) for chemicals.

[c] Direct contact residential use risk-based preliminary remediation goal calculated using 0.1 as the target hazard index.

[d] The value reported is the respective analyte's maximum contaminant level (MCL). All MCLs are Primary Drinking Water Standards.

[e] Concentration of analyte in uncontaminated media. For all water samples, the background values reported are those for the RGA.

[f] Summary of preliminary remediation goals exceeded. In this table, maximum detected concentrations are not directly comparable to preliminary remediation goals because MEPAS only predicts the additional contamination added by migration. However, the difference in magnitude between preliminary remediation goals and the maximum predicted concentrations indicates if the preliminary remediation goals may be exceeded. Definitions of codes are:

P One or both of the residential use human health risk-based preliminary remediation goals are exceeded.
R The regulatory value is exceeded.
No No preliminary remediation goals are exceeded.

[g] Present concentrations were taken from analyses performed for sample from EW230 taken on 11/28/95.

E1.2.2.2 RESRAD Modeling

The RESRAD (Version 5.6.1) computer code was used to model the specific case of migration of radionuclide contaminants from source areas to the RGA directly under SWMU 2. Therefore, the only exposure point considered using this model was the residential use of RGA groundwater drawn from below SWMU 2. The RESRAD computer code was not used to model transport of contaminants to exposure points at the property boundary and security fence because this code cannot model lateral transport. Tables E1.5 and E1.6 show environmental setting and source term used.

Table E1.5. RESRAD Modeling Parameters: Soil Characteristics, Hydrology, and Hydrogeology

Parameter	Waste Soil	HU1	HU2A	HU2 Conf	HU2B	HU3	RGA
Thickness, m[a]	1.40	5	2.29	2.44	1.83	2.74	---
Soil density[b], g/cm^3	1.96	1.96	2.24	1.96	2.24	1.963	2.16
Total porosity[c]	0.33	0.33	0.25	0.40	0.25	0.38	0.30
Effective porosity[d]	0.25	0.25	0.13	0.35	0.13	0.30	0.25
Soil-specific b parameter[e]	10.4	10.4	4.05	10.4	4.05	10.4	4.05
Hydraulic conductivity[f], m/yr	0.032	0.032	1.58	0.025	0.32	0.16	6,508
Hydraulic gradient[g]	---	---	---	---	---	---	0.02
Water table drop rate[h], m/yr	---	---	---	---	---	---	0.001
Distribution coefficients[i], cm^3/g							
^{241}Am	200	200	82	1,000	82	1,000	82
^{210}Pb	597	597	234	1,830	234	1,830	234
^{237}Np	3	3	3	3	3	3	3
^{239}Pu	100	100	10	250	10	250	10
^{231}Pa	50	50	0	500	0	500	0
^{226}Ra	100	100	24.3	124	24.3	124	24.3
^{99}Tc	20	20	3	20	3	20	3
^{229}Th	500	500	100	2,700	100	2,700	100
^{230}Th	500	500	100	2,700	100	2,700	100
^{233}U	253	253	1,170	3,640	1,170	3,640	66.8
^{234}U	253	253	1,170	3,640	1,170	3,640	66.8
^{235}U	253	253	1,170	3,640	1,170	3,640	66.8
^{238}U	253	253	1,170	3,640	1,170	3,640	66.8

Notes:
Table taken from DOE 1997.
"---" indicates that this parameter is not needed for the respective hydrogeologic unit.
[a] Taken from the site conceptual model for SWMU 2.
[b] Taken from McConnell (1993).
[c] Estimated value.
[d] Estimated value.
[e] RESRAD default estimated from soil characteristics.
[f] Taken from site conceptual model for SWMU 2.
[g] Taken from the site conceptual model for SWMU 2.
[h] Assumes minimal change due to pumping of residential well.
[i] All distribution coefficients, except for those for uranium isotopes, were default values taken from MEPAS. The distribution coefficients for uranium isotopes were those determined during the recently completed field investigation at SWMUs 7 and 30 of WAG 22. When selecting the default values for all other radioisotopes, the description of the soil characteristics of each hydrogeologic unit was used. Note, the soil type for the waste zone was assumed to be that found in HU1. This is a conservative estimate because the recently completed field investigation showed that non-native clay was used to backfill all waste pits.

Table E1.6. RESRAD Modeling Parameters: Initial Source Term Analyte Concentrations

	Input (pCi/g)[a]							
Analyte	**Surface**	**HU1**	**HU2A**	**HU2 Confining**	**HU2B**	**HU3**	**RGA**	**Waste**
^{241}Am	---	0.199	0.13	0.12	0.10	0.48	0.103	0.44
^{237}Np	0.32	0.032	0.02	0.03	0.12	0.00	0.028	0.15
^{239}Pu	7.9	0.032	0.01	0.09	0.02	0.05	0.033	0.07
^{99}Tc	58.0	0.664	0.023	0.29	0.00	0.04	0.017	0.012
^{230}Th	14.0	1.25	0.873	0.90	0.76	1.33	0.792	0.41
^{234}U	18.0	7.73	0.712	0.93	0.86	1.20	0.735	7.61
^{235}U	1.7	1.66	0.083	0.11	0.12	0.07	0.066	7.0E-06
^{238}U	69.0	53.70	0.756	0.97	0.93	1.27	0.787	10,200.00

Notes:
Table adapted from DOE 1997.
NA = not applicable.
[a] Maximum values selected from SAP database.

Table E1.7 presents the results of the RESRAD modeling. The result of this modeling is the additional contamination that may migrate to the RGA from the sources at SWMU 2. The table shows both the total contributed dose and the contributed dose from each source at SWMU 2.

Table E1.7. RESRAD Results–Contribution of Radionuclides in Soil and Waste Cells to Potential Total Dose to Resident (mrem/year) through Residential Ingestion of RGA Water

	Source Area									
Years	**RGA[a]**	**HU3**	**HU2B**	**HU2**	**HU2A**	**HU2 Total[b]**	**HU1**	**Waste Cells**	**Surface**	**Total Dose**
50	8.83E-01	3.58E-02	1.42E+00	5.44E-01	0.00E+00	1.96E+00	0.00E+00	0.00E+00	0.00E+00	2.88E+00
63	8.72E-01	4.20E-02	8.44E-01	3.54E-01	0.00E+00	1.20E+00	0.00E+00	0.00E+00	0.00E+00	2.11E+00
79.37	8.62E-01	4.92E-02	4.41E-01	2.06E-01	3.32E-01	9.79E-01	0.00E+00	0.00E+00	0.00E+00	1.89E+00
100	8.44E-01	5.71E-02	1.94E-01	1.04E-01	1.72E-01	4.71E-01	5.87E-01	1.44E+00	0.00E+00	3.40E+00
126	7.95E-01	6.05E-02	6.93E-02	4.42E-02	7.52E-02	1.89E-01	3.84E-01	3.50E-01	0.00E+00	1.78E+00
158.7	7.35E-01	6.35E-02	1.89E-02	1.50E-02	2.66E-02	6.04E-02	2.25E-01	5.91E-02	8.92E-02	1.23E+00
200	6.81E-01	6.73E-02	5.24E-03	4.18E-03	7.18E-03	1.66E-02	1.15E-01	6.35E-03	1.31E-04	8.57E-01
252	6.19E-01	7.17E-02	7.12E-04	9.66E-04	1.43E-03	3.10E-03	4.93E-02	4.65E-04	6.93E-07	7.44E-01
317.5	5.70E-01	7.69E-02	1.04E-04	2.83E-04	2.39E-04	6.26E-04	1.70E-02	1.09E-04	6.73E-07	6.64E-01
400	5.39E-01	8.44E-02	5.66E-05	1.44E-04	1.14E-04	3.14E-04	5.25E-03	1.10E-04	7.12E-07	6.29E-01
504	5.14E-01	9.21E-02	5.22E-05	8.69E-05	7.12E-05	2.10E-04	1.47E-03	1.01E-04	8.00E-07	6.08E-01
635	4.92E-01	9.79E-02	4.69E-05	5.02E-05	6.44E-05	1.62E-04	5.87E-04	9.17E-05	9.65E-07	5.91E-01
800	4.78E-01	1.03E-01	3.92E-05	2.74E-05	5.55E-05	1.22E-04	3.43E-04	7.92E-05	1.88E-03	5.83E-01
1008	4.63E-01	1.07E-01	3.00E-05	1.48E-05	4.39E-05	8.86E-05	2.09E-04	6.37E-05	7.33E-06	5.70E-01
1270	4.46E-01	1.09E-01	4.65E-03	1.23E-03	3.11E-05	5.91E-03	1.13E-04	4.66E-05	1.17E-06	5.61E-01
1600	4.26E-01	1.10E-01	9.46E-02	2.01E-02	1.94E-05	1.15E-01	5.40E-05	3.04E-05	1.21E-06	6.51E-01
2016	3.99E-01	1.09E-01	1.33E-01	3.46E-02	1.03E-05	1.68E-01	2.26E-05	1.75E-05	1.23E-06	6.75E-01
2540	3.67E-01	1.05E-01	1.69E-01	6.01E-02	5.81E-02	2.87E-01	9.31E-03	2.96E-03	1.28E-06	7.71E-01
3200	3.31E-01	1.00E-01	1.59E-01	5.93E-02	1.16E-01	3.34E-01	6.08E+02	1.73E-02	1.32E-06	8.44E-01
4032	2.92E-01	9.55E-02	1.61E-01	5.79E-02	1.36E-01	3.54E-01	8.92E-02	3.28E-02	1.38E-06	8.64E-01
5080	2.50E-01	9.04E-02	1.60E-01	5.81E-02	1.44E-01	3.62E-01	1.15E-01	5.49E-02	4.77E-02	9.20E-01
6400	2.07E-01	8.50E-02	1.45E+00	5.96E-02	1.43E-01	3.55E-01	1.15E-01	6.72E-02	1.01E-01	9.31E-01
8063	1.63E-01	7.89E-02	1.44E-01	6.17E-02	1.40E-01	3.46E-01	1.14E-01	8.77E-02	4.58E-02	8.35E-01
10160	1.21E-01	7.23E-02	1.35E-01	6.23E-02	1.31E-01	3.29E-01	1.55E-01	1.03E-01	4.35E+01	8.24E-01
12800	8.31E-02	6.46E-02	1.27E-01	4.66E-02	1.22E-01	2.95E-01	1.14E-01	1.21E-01	4.40E-02	7.22E-01
Maximum Dose	8.83E-01	1.10E-01	1.42E+00	5.44E-01	3.32E-01	1.96E+00	5.87E-01	1.44E+00	1.01E-01	3.44E+00
Year of Maximum	50	1,600	50	50	79.37	50	100	100	6,400	100

Note: Table taken from DOE 1997.

[a] The RGA source area was assumed to consist of hydrogeologic units 4 and 5.

[b] This column contains the sum of the results for HU2A, HU2 confining, and HU2B.

E1.3. MODELING APPEARING IN THE WAG 3 RI REPORT FOR SWMU 4

The conservative modeling in Appendix B of Volume 4 of the WAG 3 RI Report (DOE 2000a) was completed to determine if any contaminants could migrate from source areas at SWMU 4 to POEs at the plant boundary and property boundary at a rate that could result in maximum concentrations greater than risk-based screening levels. This modeling was completed using MEPAS and conservative source term estimates developed using comparisons of sampling results to background concentrations and SSLs for protection of groundwater taken from EPA sources.

The sampling results used in source term development were derived from the WAG 3 RI (DOE 2000a), the Data Gaps Investigation Report (DOE 2000b), and from earlier sampling completed in support of the PGDP Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) SI performed in the early 1990s (CH2M Hill 1991 and 1992). Source terms developed for SWMU 4 are presented in Table E1.8. As noted in the modeling report, "In all cases, modelers applied conservatism (worst case) in the definition of the extent of the source zones. In all cases, the maximum concentrations were used to develop each contaminant source-term inventory."

Input parameters used in the MEPAS modeling were based on site-specific data when available. When relevant on-site data were not available, data collected at nearby SWMUs having similar hydrogeologic conditions were used to define the input parameter. If no site-specific data were available, then default values provided by MEPAS were used. In the analysis, all sources were modeled as depleting over time and degrading in the environment. The modeled period was 10,000 years. Modeling inputs for SWMU 4 are presented in Table E1.9. The distribution coefficients (K_d) used were default values taken from MEPAS. These values are presented in Table E1.10.

The results of the MEPAS modeling for SWMU 4, taken from Appendix C of Volume 4 of the WAG 3 RI Report, are in Table E1.11. Interpretations of these results from the Southwest Groundwater Plume SI report (DOE 2006) are shown in Tables E1.12 and E1.13.

Based upon these results, the COCs for SWMU 4 for the plant boundary POE are cobalt; copper; iron; manganese; 1,1-DCE; carbon tetrachloride; TCE; vinyl chloride; ^{237}Np; ^{239}Pu; radium-226 (^{226}Ra); ^{99}Tc; ^{234}U; ^{235}U; and ^{238}U. The COCs for SWMU 4 for the property boundary POE are copper; iron; manganese; 1,1-DCE; TCE; vinyl chloride; ^{237}Np; ^{239}Pu; ^{99}Tc; ^{234}U; ^{235}U; and ^{238}U.

Table E1.8. Source Term for SWMU 4 Developed in the WAG 3 RI Report MEPAS Modeling[a]

Contaminant	Level[b] (mg/kg or pCi/g)	Parallel to Flow Axis (feet)	Perpendicular to Flow Axis (feet)	Thickness (feet)	Volume (ft^3)	Inventory[c] (g or Ci)	Note[d]
			Inorganic Chemicals (Metals)				
Aluminum	26,400	470	610	54	15,481,800	2.11E+10	Subsurface
Chromium	296	370	70	1	25,900	317,000	Surface
	42.3	NV	NV	1	22,049	38,600	Surface
	77.3	470	365	20	3,431,000	13,700,000	Subsurface
Cobalt	31.6	470	610	54	15,481,800	25,200,000	Subsurface
Copper	19.5	130	180	1	23,400	18,900	Surface
	30.1	80	165	1	13,200	16,400	Surface
	1,130	470	610	34	9,747,800	5.68E+08	Subsurface
Iron	30,700	NV	NV	1	22,049	28,000,000	Surface
	34,500	470	610	54	15,481,800	2.75E+10	Subsurface
Lead	62.5	470	175	20	1,645,000	5,300,000	Subsurface
Lithium	0.148	75	80	10	60,000	458	Subsurface
Manganese	2,920	470	640	24	7,219,200	1.09E+09	Subsurface
Nickel	153	NV	NV	1	22,049	139,000	Surface
Strontium	0.639	NV	NV	NV	NV	1,980	Subsurface
Organic Compounds							
1,1-DCE	0.340	470	610	45	10,786,500	226,000	Subsurface
1,2-DCE (mixed)	0.063	80	100	15	120,000	390	Subsurface
1,2-DCE, *cis*-	1.5	245	610	24	3,586,800	277,000	Subsurface
	11	245	610	19	2,839,550	1,610,000	Subsurface
2-Butanone	0.002	75	130	5	120,000	5.02	Subsurface
	0.031	65	105	5	34,125	54.5	Subsurface
2-Propanol	0.100	75	130	5	48,750	251	Subsurface
4-Methyl-3-penten-2-one	0.180	50	50	1	2,500	18.6	Surface
	0.67	80	100	5	40,000	1,380	Subsurface
6-(Acetyloxy)-2-hexanone	2	80	100	29	232,000	23,900	Subsurface
PCB-1016	2.5	470	610	19	5,447,300	702,000	Subsurface
PCB-1248	0.8	470	610	19	5,447,300	225,000	Subsurface
PCB-1254	27	470	610	19	5,447,300	7,580,000	Subsurface
PCB-1260	0.115	35	600	1	21,000	99.8	Surface
	0.041	450	35	1	15,750	26.7	Surface
	0.061	185	205	1	37,925	95.6	Surface
	500	470	610	19	5,447,300	140,000	Subsurface

Table E1.8. Source Term for SWMU 4 Developed in the WAG 3 RI Report MEPAS Modeling[a] (Continued)

Contaminant	Level[b] (mg/kg or pCi/g)	Parallel to Flow Axis (feet)	Perpendicular to Flow Axis (feet)	Thickness (feet)	Volume (ft^3)	Inventory[c] (g or Ci)	Note[d]
Bis(2-Methoxyethyl)phthalate	0.45	80	100	5	40,000	928	Subsurface
Carbon tetrachloride	0.170	165	95	12	188,100	1,650	Subsurface
Diethyl ether	0.009	70	45	54	170,100	78.9	Subsurface
Ethanol, 2,2'-oxybis, diacetate	2	80	100	5	40,000	4,120	Subsurface
Octachlorodibenzodioxin	8.2	80	100	5	40,000	16.9	Subsurface
Pentachlorophenol	0.21	80	100	5	40,000	433	Subsurface
TCE	48	470	610	45	10,786,500	31,900,000	Subsurface
Vinyl chloride	0.4	470	610	45	10,786,500	266,000	Subsurface
Radionuclides							
Cesium-137	1.48	210	610	10	1,281,000	0.0977	Subsurface
^{237}Np	0.266	80	165	1	13,200	0.000145	Surface
	5.78	470	610	10	2,867,000	1.62	Subsurface
^{239}Pu	0.0644	55	445	1	24,475	0.0000652	Surface
	4.17	470	610	19	2,867,000	1.17	Subsurface
^{226}Ra	2.51	470	610	19	2,867,000	0.705	Subsurface
^{99}Tc	269	NV	NV	NV	NV	75.5	Subsurface
^{230}Th	68.7	NV	NV	NV	NV	19.3	Subsurface
^{234}U	12.8	35	600	1	21,000	0.0111	Surface
	6.59	450	35	1	15,750	0.00429	Surface
	30.1	185	205	1	37,925	0.0472	Surface
	69	NV	NV	NV	NV	194	Subsurface
^{235}U	7.2	NV	NV	NV	NV	2.02	Subsurface
^{238}U	35.9	35	600	1	21,000	0.0312	Surface
	26.4	450	35	1	15,750	0.0172	Surface
	87.3	185	205	1	37,925	0.137	Surface
	126	NV	NV	NV	NV	1,760	Subsurface
Uranium, Total	6,260	282	110	15	465,300	150	Subsurface
	6,260	110	292	15	481,800	155	Subsurface

NV = no value reported in the WAG 3 RI Report.
^{230}Th = Thorium-230
[a] Information taken from Table B.5 in Appendix B of Volume 4 of the WAG 3 RI Report.
[b] The maximum concentration was used to estimate the contaminant inventory for all contaminants.
[c] Calculated using a bulk density of 1.46 g/cm^3 for Surface and 1.82 g/cm^3 for the Subsurface.
[d] Surface assumed to extend to 1 ft bgs. Thickness of subsurface differs with contaminant.

Table E1.9. Modeling Inputs for SWMU 4 MEPAS Modeling in the WAG 3 RI Report[a]

Description	Name	Value	Reference
	Top Soil Parameters (WT)		
Textural Classification	WT-CLASS	Silt loam	Soil Survey
Sand (%)	WT-SAND	15	Soil Survey
Silt (%)	WT-SILT	80	Maximum for soil type
Clay (%)	WT-CLAY	5	By difference
Organic Matter (%)	WT-OMC	0.05	CH2M Hill 1992
Iron and Aluminum (%)	WT-IRON	4	DOE 1995b
pH of Topsoil	WT-pH	7.32	RI
Vegetative Cover (%)	WT-VEGCOV	100	Description
Topsoil water capacity	WT-AVAILW	0.33	Soil Survey
SCS Curve Number	WT-SCSN	71	MEPAS
	Partially Saturated Zone Parameters (WP)		
Thickness	WP-THICK	54	RI
Textural classification	WP-CLASS	Sandy loam	RI
Sand (%)	WP-SAND	38	RI
Silt (%)	WP-SILT	41	RI
Clay (%)	WP-CLAY	21	RI
Organic Matter (%)	WP-OMC	0.05	WAG 6
Iron and Aluminum (%)	WP-IRON	4	DOE 1995b
pH of Pore Water	WP-pH	6.0	DOE 1995b
Bulk Density (g/cm^3)	WP-BULKD	1.82	RI
Total porosity (%)	WP-TOTPOR	31.28	RI
Field capacity (%)	WP-FIELDC	14	MEPAS
Longitudinal dispersivity (ft)	WP-LDISP	0.54	MEPAS
Saturated hydraulic conductivity	WP-CONDUC	3E-01 ft/day 1.06E-04 cm/sec	RI
Soil Moisture Content (%)	WS-MOISTC	31.28	MEPAS
	Saturated Zone Parameters (WZ)		
Textural classification	WZ-CLASS	Loamy sand	RI
Sand (%)	WZ-SAND	74	RI
Silt (%)	WZ-SILT	17	RI
Clay (%)	WZ-CLAY	9	RI
Organic Matter (%)	WZ-OMC	0.02	RI
Iron and Aluminum (%)	WZ-IRON	3	RI
pH of Pore Water	WZ-pH	6.36	RI
Total porosity (%)	WZ-TOTPOR	37	RI
Effective porosity (%)	WZ-EFFPOR	30	MEPAS
Darcy velocity (ft/day)	WZ-PVELOC	0.6	Conductivity = 1500 ft/d Gradient = 0.0004
Thickness	WZ-THICK	45	RI
Bulk Density (g/cm^3)	WZ-BULKD	1.67	RI
Travel Distance (ft)	WZ-DIST	Plant boundary: 890 Property boundary: 2,985	RI
Longitudinal dispersivity (ft)	WZ-LDISP	50	Bioscreen Model
Transverse dispersivity (ft)	WZ-TDISP	5.0	Bioscreen Model
Vertical dispersivity (ft)	WZ-VDISP	0.1	near zero
Total flux to aquifer (%)	WZ-FRACT	100	estimate
Perpendicular to receptor	WZ-YDIST	0	on plume centerline
Vertical to receptor	WZ-AQDEPTH	0	minimum

[a] Information taken from Table B.2 in Appendix C of Volume 4 of the WAG 3 RI Report.

Table E1.10. Distribution Coefficients (K_ds) Used for SWMU 4 MEPAS Modeling in the WAG 3 RI Report[a]

Contaminant	Surface Soil	Subsurface Soil	RGA
	Inorganic Chemicals (metals)		
Aluminum	3,980	35,300	35,300
Chromium	10	565	565
Cobalt	0.2	8.81	8.81
Copper	4.19	92.2	92.2
Iron	10	15	15
Lead	10	597	597
Lithium	0	0.2	0.2
Manganese	1.5	25.3	25.3
Nickel	1.2	58.6	58.6
Strontium	2.34	100	100
	Organic Compounds		
1,1-DCE	0.292	0.4	0.171
1,2-DCE (mixed)	0.0432	0.059	0.0253
1,2-DCE, *cis*-	NV	NV	NV
2-Butanone	NV	NV	NV
2-Propanol	NV	NV	NV
4-Methyl-3-penten-2-one	NV	NV	NV
6-(Acetyloxy)-2-hexanone	NV	NV	NV
PCB-1016	809	1,110	424
PCB-1248	1,250	1,700	729
PCB-1254	2,380	3,260	1,400
PCB-1260	30,100	41,200	17,600
Bis(2-Methoxyethyl)phthalate	NV	NV	NV
Carbon tetrachloride	2.26	3.09	1.32
Diethyl ether	NV	NV	NV
Ethanol, 2,2'-oxybis, diacetate	NV	NV	NV
Octachlorodibenzodioxin	NV	NV	NV
Pentachlorophenol	238	326	140
TCE	0.567	0.775	0.332
Vinyl chloride	0.256	0.35	0.15
	Radionuclides		
Cesium-137	10	249	249
^{237}Np	3	3	3
^{239}Pu	4	100	100
^{226}Ra	2.43	100	100
^{99}Tc	1	1	0.1
^{230}Th	40	500	500
^{234}U	0	50	50
^{235}U	0	50	50
^{238}U	0	50	50
Uranium, Total	0	50	50

NV = Value not listed in the WAG 3 RI Report.
^{230}Th = Thorium-230
[a] Information taken from Table B.1 in Appendix B of Volume 4 of the WAG 3 RI Report. All values in mL/g.

Table E1.11. MEPAS Results for SWMU 4[a]

		PGDP Plant Boundary		PGDP Property Boundary		
Source	**Contaminant[b]**	**Maximum Concentration[c]**	**Time of Maximum (Years)**	**Maximum Concentration[c]**	**Time of Maximum (Years)**	**MCL[d]**
Surface Soil	Chromium	2.81E-40	10,000	1.95E-52	10,000	1E-01
	Copper	4.40E-04	8,039	1.40E-04	9,585	1.3E+00
	Iron	1.97E+00	1,337	6.41E-01	1,525	3E-01*
	Nickel	2.53E-03	5,044	8.45E-04	6,107	1E-01
	PCB-1260	0	10,000	0	10,000	5E-04
	^{237}Np	5.33E-02	276	1.64E-02	315	NV
	^{239}Pu	4.16E-04	8,717	1.44E-04	10,260	NV
	^{234}U	1.37E+00	4,355	4.16E-01	5,166	20
	^{238}U	2.67E+00	4,356	8.08E-01	5,167	20
Subsurface Soil	Aluminum	0	10,000	0	10,000	2E-01*
	Chromium	1.15E-37	10,000	9.22E-53	10,000	1E-01
	Cobalt	3.29E+00	788	6.46E-01	961	NV
	Copper	7.32E+00	7,992	1.46E+00	9,539	1.3E+00
	Iron	1.16E+03	1,738	2.41E+02	2,055	3E-01*
	Lead	8.45E-42	10,000	7.54E-53	10,000	1.5E-02
	Lithium	1.76E-03	30	5.06E-04	36	NV
	Manganese	5.13E+01	2,248	9.46E+00	2,566	5E-02*
	Nickel	1.45E-01	5,019	4.29E-02	6,081	1E-01
	Strontium	2.54E-05	8,661	7.44E-06	10,450	NV
	1,1-DCE	2.57E-01	63	5.38E-02	69	7E-03
	1,2-DCE	2.24E-03	18	6.64E-04	21	7E-02**
	Carbon tetrachloride	5.94E-04	301	1.85E-04	307	5E-03
	PCB-1016	0	10,000	0	10,000	5E-04
	PCB-1248	0	10,000	0	10,000	5E-04
	PCB-1254	0	10,000	0	10,000	5E-04
	PCB-1260	0	10,000	0	10,000	5E-04
	Pentachlorophenol	3.35E-18	10,790	6.06E-19	12,910	1E-03
	TCE	2.26E+01	102	4.70E+00	111	5E-03
	Vinyl chloride	3.31E-01	57	6.90E-02	62	2E-03
	Cesium-137	0	12,920	0	12,920	NV
	^{237}Np	4.88E+02	316	9.83E+01	381	NV
	^{239}Pu	1.09E+01	8,665	2.05E+00	10,210	NV
	^{226}Ra	2.21E-01	8,208	2.16E-02	9,765	5
	^{99}Tc	6.34E+04	111	1.32E+04	113	900
	^{230}Th	3.56E-28	10,000	1.30E-43	10,000	NV
	^{234}U	4.51E+03	4,329	8.94E+02	5,140	20
	^{235}U	4.75E+01	4,330	9.45E+00	5,141	20
	^{238}U	8.33E+02	4,330	1.66E+02	5,141	20
	Total Uranium[e]	6.46E+03	4,330	2.13E+03	5,141	20

^{230}Th = Throrium-230

[a] Information taken from Table B.6 of Appendix B in Volume 4 of the WAG 3 RI Report.

[b] Table B.6 includes results for degradation products of radionuclides. These are not included here.

[c] Concentrations for chemicals and compounds in mg/L. Concentrations for radionuclides in pCi/L.

[d] Maximum contaminant levels (MCLs) taken from PGDP Risk Methods Document. MCLs for chemicals and compounds in mg/L. MCLs for radionuclides in pCi/L. All values except those marked with an asterisk (*) are primary MCLs. Values marked with an asterisk (*) are secondary MCLs. The MCL listed for 1,2-DCE (**) is the primary MCL for *cis*-1,2-DCE. The primary MCL for *trans*-1,2-DCE is 1E-01 mg/L.

[e] Modeled as ^{238}U.

Table E1.12. Estimated HQs for a Resident from Exposure to Maximum Modeled Concentrations from Sources at SWMU 4

		PGDP Plant Boundary		PGDP Property Boundary		
Source	**Contaminant**	**Maximum Concentration[a]**	**Hazard Quotient[b]**	**Maximum Concentration[a]**	**Hazard Quotient[b]**	**Risk-based Concentrations[c]**
Surface Soil	Chromium	2.81E-40	<0.1	1.95E-52	<0.1	1.76E+00
	Copper	4.40E-04	<0.1	1.40E-04	<0.1	5.57E-02
	Iron	1.97E+00	0.4	6.41E-01	0.1	4.49E-01
	Nickel	2.53E-03	<0.1	8.45E-04	<0.1	3.01E-02
	^{237}Np	5.33E-02	No value	1.64E-02	No value	No value
	^{239}Pu	4.16E-04	No value	1.44E-04	No value	No value
	^{234}U	1.37E+00	No value	4.16E-01	No value	No value
	^{238}U	2.67E+00	No value	8.08E-01	No value	No value
Subsurface Soil	Chromium	1.15E-37	<0.1	9.22E-53	<0.1	1.76E+00
	Cobalt	3.29E+00	3.6	6.46E-01	0.7	9.06E-02
	Copper	7.32E+00	13.1	1.46E+00	2.6	5.57E-02
	Iron	1.16E+03	258	2.41E+02	53.7	4.49E-01
	Lead	8.45E-42	No value	7.54E-53	No value	1.50E-02*
	Lithium	1.76E-03	<0.1	5.06E-04	<0.1	3.02E-02
	Manganese	5.13E+01	147	9.46E+00	27.0	3.50E-02
	Nickel	1.45E-01	0.5	4.29E-02	0.1	3.01E-02
	Strontium	2.54E-05	<0.1	7.44E-06	<0.1	9.01E-01
	1,1-DCE	2.57E-01	10.4	5.38E-02	2.2	2.46E-03
	1,2-DCE	2.24E-03	0.1	6.64E-04	<0.1	2.47E-03
	Carbon tetrachloride	5.94E-04	0.3	1.85E-04	0.1	1.90E-04
	Pentachlorophenol	3.35E-18	<0.1	6.06E-19	<0.1	2.34E-02
	TCE	2.26E+01	1,410	4.70E+00	294	1.60E-03
	Vinyl chloride	3.31E-01	10.8	6.90E-02	2.3	3.06E-03
	^{237}Np	4.88E+02	No value	9.83E+01	No value	No value
	^{239}Pu	1.09E+01	No value	2.05E+00	No value	No value
	^{226}Ra	2.21E-01	No value	2.16E-02	No value	No value
	^{99}Tc	6.34E+04	No value	1.32E+04	No value	No value
	^{230}Th	3.56E-28	No value	1.30E-43	No value	No value
	^{234}U	4.51E+03	No value	8.94E+02	No value	No value
	^{235}U	4.75E+01	No value	9.45E+00	No value	No value
	^{238}U	8.33E+02	No value	1.66E+02	No value	No value
	Total Uranium[d]	6.46E+03	No value	2.13E+03	No value	No value

^{230}Th = Throrium-230

[a] Concentrations for chemicals and compounds in mg/L. Concentrations for radionuclides in pCi/L.

[b] Calculated using comparison to risk-based concentration. Contaminants with an HQ greater than 0.1 are considered COCs.

[c] Risk-based no action screening value from Appendix A of the Risk Methods Document. In some cases, these updated values differ from those used in calculation in the WAG 3 RI Report. Values for chemicals and components are given in mg/L. Values for radionuclides are given in pCi/L. The value for lead (*) is the MCL.

[d] Evaluated as ^{238}U.

Table E1.13. Estimated Cancer Risks for a Resident from Exposure to Maximum Modeled Concentrations from Sources at SWMU 4

		PGDP Plant Boundary		PGDP Property Boundary		
Source	**Contaminant**	**Maximum Concentration[a]**	**Cancer Risk[b]**	**Maximum Concentration[a]**	**Cancer Risk[b]**	**Risk-based Concentrations[c]**
Surface Soil	Chromium	2.81E-40	No value	1.95E-52	No value	No value
	Copper	4.40E-04	No value	1.40E-04	No value	No value
	Iron	1.97E+00	No value	6.41E-01	No value	No value
	Nickel	2.53E-03	No value	8.45E-04	No value	No value
	^{237}Np	5.33E-02	<1.00E-06	1.64E-02	<1.00E-06	5.73E-01
	^{239}Pu	4.16E-04	<1.00E-06	1.44E-04	<1.00E-06	2.86E-01
	^{234}U	1.37E+00	2.41E-06	4.16E-01	<1.00E-06	5.46E-01
	^{238}U	2.67E+00	6.03E-06	8.08E-01	1.82E-06	4.43E-01
Subsurface Soil	Chromium	1.15E-37	No value	9.22E-53	No value	No value
	Cobalt	3.29E+00	No value	6.46E-01	No value	No value
	Copper	7.32E+00	No value	1.46E+00	No value	No value
	Iron	1.16E+03	No value	2.41E+02	No value	No value
	Lead	8.45E-42	No value	7.54E-53	No value	1.50E-02*
	Lithium	1.76E-03	No value	5.06E-04	No value	No value
	Manganese	5.13E+01	No value	9.46E+00	No value	No value
	Nickel	1.45E-01	No value	4.29E-02	No value	No value
	Strontium	2.54E-05	No value	7.44E-06	No value	No value
	1,1-DCE	2.57E-01	5.47E-03	5.38E-02	1.14E-03	4.70E-05
	1,2-DCE	2.24E-03	No value	6.64E-04	No value	No value
	Carbon tetrachloride	5.94E-04	3.28E-06	1.85E-04	1.02E-06	1.81E-04
	Pentachlorophenol	3.35E-18	<1.00E-06	6.06E-19	<1.00E-06	2.08E-04
	TCE	2.26E+01	1.31E-02	4.70E+00	2.72E-03	1.73E-03
	Vinyl chloride	3.31E-01	9.46E-03	6.90E-02	1.97E-03	3.50E-05
	^{237}Np	4.88E+02	8.52E-04	9.83E+01	1.72E-04	5.73E-01
	^{239}Pu	1.09E+01	3.81E-05	2.05E+00	7.17E-06	2.86E-01
	^{226}Ra	2.21E-01	2.21E-06	2.16E-02	<1.00E-06	1.00E-01
	^{99}Tc	6.34E+04	4.53E-03	1.32E+04	9.43E-04	1.40E+01
	^{230}Th	3.56E-28	<1.00E-06	1.30E-43	<1.00E-06	4.24E-01
	^{234}U	4.51E+03	8.26E-03	8.94E+02	1.64E-03	5.46E-01
	^{235}U	4.75E+01	8.83E-05	9.45E+00	1.76E-05	5.38E-01
	^{238}U	8.33E+02	1.88E-03	1.66E+02	3.75E-04	4.43E-01
	Total Uranium[d]	6.46E+03	1.46E-02	2.13E+03	4.81E-03	4.43E-01

^{230}Th = Throrium-230

[a] Concentrations for chemicals and compounds in mg/L. Concentrations for radionuclides in pCi/L.

[b] Calculated using comparison to risk-based concentration. Contaminants with a cancer risk greater than 1.00E-06 are considered COCs.

[c] Risk-based no action screening value from Appendix A of the Risk Methods Document. In some cases, these updated values differ from those used in calculation in the WAG 3 RI Report Values for chemicals and components in mg/L. Values for radionuclides are given in pCi/L. The value for lead (*) is the MCL.

[d] Evaluated as ^{238}U.

E1.4. MODELING APPEARING IN THE WAG 3 RI REPORT FOR SWMU 5

The conservative modeling in Appendix B of Volume 4 of the WAG 3 RI Report (DOE 2000a) was completed to determine if any contaminants could migrate from source areas at SWMU 5 to POEs at the plant boundary and property boundary at a rate that could result in maximum concentrations greater than risk-based screening levels. This modeling was completed using MEPAS and conservative source term estimates developed using comparisons of sampling results to background concentrations and SSLs for protection of groundwater taken from EPA sources. MEPAS transport parameters are given in Table E1.14.

Table E1.14. MEPAS Transport Parameters for SWMU 5

Input Parameter Description	Parameter Name	Value	Reference	
Topsoil parameters (wt)				
Textural classification	WT-CLASS	Silt loam	McCracken Co. Soil Survey (USDA 1976)	
Percent sand (%)	WT-SAND	15	McCracken Co. Soil Survey: conservative estimate (highest % sand)	
Percent silt (%)	WT-SILT	80	Maximum % silt for soil type	
Percent clay (%)	WT-CLAY	5	= 100% -% sand - % silt	
Percent organic matter (%)	WT-OMC	0.05	CERCLA Phase II Site Investigation (CH2M HILL 1992)	
Percent iron and aluminum (%)	WT-IRON	4	Background Concentrations and Human Health Risk-Based Screening Criteria for Metals in Soil at PGDP (DOE 1995b)	
pH of topsoil	WT-pH	8.25	WAG 3 RI data	
Percent vegetative cover off-site (%)	WT-VEGCOV	100	SWMU Maps	
Topsoil water capacity	WT-AVAILW	2.44	McCracken Co. Soil Survey = available water capacity (0.20 in./in.) × root zone depth from Table 2.1 MEPAS Guidance (12.2 in.) × vegetative cover (100%)	
SCS curve number	WT-SCSN	71	Antecedent Moisture Condition = II (normal moisture); Group C hydrologic soil group; vegetated surface, well vegetated, 60–100% vegetated	
Properties of the partially saturated zones (wp)				
Thickness (ft)	WP-THICK	WP1 39 WP2 20	WP1=1–40 ft (HU 1 + HU 2) WP2=HU 3	Boring logs at SWMU 5
Textural classification	WP-CLASS	WP1 sandy clay loam WP2 clay loam	Boring logs at SWMU 5	
Sand (%)	WP-SAND	WP1 = 38 WP2 = 10	Boring logs at SWMU 5	
Silt (%)	WP-SILT	WP1 = 27 WP2 = 30	Boring logs at SWMU 5	
Clay (%)	WP-CLAY	WP1 = 35 WP2 = 60	Boring logs at SWMU 5	

Table E1.14. MEPAS Transport Parameters for SWMU 5 (Continued)

Input Parameter Description	Parameter Name	Value	Reference
Organic matter content in soil (%)	WP-OMC	0.05	WAG 6 geotechnical data
Iron + aluminum in soil (%)	WP-IRON	4	DOE 1995b
pH of pore water in partially saturated zone	WP-pH	WP1 = 6 WP2 = 6.56	DOE 1995b and WAG 3 RI data for WP2
Bulk density(g/cm^3)	WP-BULKD	WP1 = 1.76 WP2 = 2.25	WAG 3 geotechnical data available for WP1; 2.65 × (1-Porosity)
Total porosity (%)	WP-TOTPOR	WP1 = 33.7 WP2 = 15	WAG 3 geotechnical data available for WP1; SWMU 6 boring logs used as estimate for WP2
Field capacity (%)	WP-FIELDC	WP1 = 24 WP2 = 10	Table 2.1 of MEPAS Guidance, based on soil type for WP1; SWMU 5 boring logs used as estimate for WP2
Longitudinal dispersivity (ft)	WP-LDISP	WP1 = 0.39 WP2 = 0.20	Estimated based on MEPAS guidance: D_L = 0.01 × thickness
Saturated hydraulic conductivity (ft/day)	WP-CONDUC	ft/day: 0.3; cm/sec: 1.06E-4	WAG 3 Work Plan
Moisture content (%)	WS-MOISTC	WP1 = 33.7 WP2 = 15	Moisture content = total porosity
Properties of the saturated zone (wz)			
Textural classification	WZ-CLASS	Loamy sand	WAG 3 Work Plan
Sand (%)	WZ-SAND	74	WAG 3 Work Plan
Silt (%)	WZ-SILT	17	WAG 3 Work Plan
Clay (%)	WZ-CLAY	9	WAG 3 Work Plan
Organic matter in soil (%)	WZ-OMC	0.02	WAG 3 Work Plan
Iron + aluminum in soil (%)	WZ-IRON	3	WAG 3 Work Plan
pH of pore water in saturated zone	WZ-pH	6.47	WAG 3 RI data
Total porosity (%)	WZ-TOTPOR	37	WAG 3 Work Plan
Effective porosity (%)	WZ-EFFPOR	30	Conservative estimate
Darcy velocity (ft/day)	WZPVELOC	0.6	Conservative estimate; uses conductivity of 1500 ft/day and gradient of 0.0004
Thickness (ft)	WZ-THICK	40	RGA (HU 4 + HU 5) interval: 60–100 ft bgs
Bulk density (ft)	WZ-BULKD	1.67	WAG 3 Work Plan
Travel distance (ft)	WZ-DIST	890 ft to PGDP boundary 2,780 ft to DOE property boundary	Distances measured along the groundwater flow direction from the northern perimeter of the SWMU to the PGDP boundary and to the DOE property boundary
Longitudinal dispersivity (ft)	WZ-LDISP	50.0	Reference: Bioplume groundwater model
Transverse dispersivity (ft)	WZ-TDISP	5.0	Reference: Bioplume groundwater model
Vertical dispersivity (ft)	WZ-VDISP	0.1	Conservative estimate
Percent of total flux to aquifer (%)	WZ-FRACT	100	Conservative estimate
Perpendicular distance from groundwater flow to receptor (ft)	WZ-YDIST	0	(Plume centerline concentrations)
Vertical distance below groundwater table (ft)	WZ-AQDEPTH	0	(Most conservative result)

The sampling results used in source term development were taken from sampling completed as part of the WAG 3 RI (DOE 2000), the Data Gaps Investigation Report (DOE 2000b), and from earlier sampling completed in support of the PGDP CERCLA SI performed in the early 1990s (CH2M HILL 1991 and 1992). Source terms developed for SWMU 5 are presented in Table E1.15. As noted in the modeling report, "In all cases, modelers applied conservatism (worst case) in the definition of the extent of the source zones. In all cases, the maximum concentrations were used to develop each contaminant source-term inventory."

Three model layers, two partially saturated and one saturated were delineated at SWMU 5. The partially saturated layer includes the loess deposits making up HU 1, the permeable but discontinuous sand and gravel lenses of the UCRS, and a silty clay aquitard, HU 3 (1–60 ft bgs). The saturated layer consists of the RGA and extends from 60 ft to 100 ft bgs. The travel distance from the source to each downgradient exposure point is 890 ft to the PGDP boundary and 2,780 ft to the DOE property boundary.

Surface and subsurface soil data provided by the WAG 3 RI (DOE 2000a) and the PGDP CERCLA SI (CH2M Hill 1991 and 1992) were used to develop the source terms and inventories for the site contaminants. Table E1.15 presents the source terms used in the MEPAS modeling for SWMU 5. Metals, organic compounds, and radionuclides were identified as present above screening levels in surface soils at SWMU 5. Originally identified contaminants that were not referenced in the MEPAS chemical database and, therefore, were not modeled included 3-nitrobenzenamine, benzo(ghi)perylene, and dibenzofuran. The results of the MEPAS modeling for SWMU 5 are presented in Table E1.16. Estimated HQs and cancer risks from these modeling results are not available.

Iron is projected to contribute to the RGA from three distinct sources. Results of modeling the sources to the PGDP boundary are 49.8 mg/L in 1,411 years, 18.8 mg/L in 1,591 years, and 464 mg/L in 1,873 years. At the DOE boundary, concentrations from these sources are 18.4 mg/L in 1,602 years, 6.61 mg/L in 1,871 years, and 82.7 mg/L in 2,069 years. Manganese is projected to contribute to the RGA, resulting in 11.54 mg/L at the PGDP boundary in 2,536 years and 7.53 mg/L at the DOE boundary in 2,952 years. Contributions to the RGA from other constituents are minor. ^{99}Tc is projected to contribute to the RGA resulting in 229 pCi/L at the PGDP boundary in 130.1 years and 99.6 pCi/L in 138.6 years.

Table E1.15. Development of Source Terms for SWMU 5

Contaminant	Initial source concentration		Length parallel to flow direction (ft)	Width perpendicular to flow direction (ft)	Thickness (ft)	Contaminant inventory calculation for MEPAS			Notes
						Volume (cm^3)	Bulk density (g/cm^3)	Inventory (g)	
Surface soil									
Aluminum	13,800	mg/kg	235	840	1	5.59E+09	1.46	1.13E+08	Entire SWMU boundary chosen as source term.
2-Methylnaphthalene	150	µg/kg						1.22E+03	
3-Nitrobenzenamine	9,450	µg/kg						7.71E+04	
Acenaphthylene	9,450	µg/kg						7.71E+04	
Benz(a)anthracene	19,000	µg/kg						1.55E+05	
Benzo(a)pyrene	24,800	µg/kg						2.02E+05	
Benzo(b)fluoranthene	49,200	µg/kg						4.02E+05	
Benzo(ghi)perylene	14,600	µg/kg						1.19E+05	
Dibenzofuran	3,520	µg/kg						2.87E+04	
Pentachlorophenol	357	µg/kg						2.91E+03	
PCB-1260	306	µg/kg						2.50E+03	
Phenanthrene	34,600	µg/kg						2.82E+05	
^{99}Tc	5.85	pCi/g	235	775	1	5.16E+09	1.46	4.40E-02	Entire length of SWMU chosen as source term for ^{99}Tc and approximately 3/4 width.
*Bulk density of 1.46 used in SWMU 1 MEPAS modeling									
Subsurface soil partially saturated zone WP1 (HU1 + HU2 Soils)									
Aluminum	12,400	mg/kg	235	840	39	2.18E+11	1.76	4.76E+09	Entire area and thickness of SWMU used for modeling.
Chromium	296	mg/kg	175	215	14	1.49E+10	1.76	7.77E+06	Metals values detected above screening levels at 005-017 in a 20–23 ft sample.
Iron	29,200	mg/kg						7.67E+08	
Cobalt	24.7	mg/kg	90	240	3	1.83E+09	1.76	7.98E+04	Metals detected above screening levels at H263 in shallow samples.
Iron	33,100	mg/kg			7	4.28E+09		2.49E+08	
Manganese	975	mg/kg						7.35E+06	

Table E1.15. Development of Source Terms for SWMU 5 (Continued)

Contaminant	Initial source concentration		Length parallel to flow direction (ft)	Width perpendicular to flow direction (ft)	Thickness (ft)	Contaminant inventory calculation for MEPAS			Notes
						Volume (cm^3)	Bulk density (g/cm^3)	Inventory (g)	
Benzo(ghi)perylene	260	µg/kg	90	240	7	4.28E+09	1.76	1.96E+03	Semivolatiles detected above
Dibenzofuran	87	µg/kg						6.56E+02	screening levels at H263 in shallow
Phenanthrene	1,300	µg/kg						9.80E+03	samples.
^{226}Ra	2.2	pCi/g	235	370	20	4.92E+10	1.76	1.91E-01	Just over 1/2 width of SWMU used for source term delineation and entire
^{238}U	2	pCi/g	235	370	31	7.63E+10	1.76	2.69E-01	length.
Subsurface soil partially saturated zone WP2 (HU3 Soils)									
Aluminum	16,400	mg/kg	235	840	20	1.12E+11	2.25	4.13E+09	Entire SWMU boundary chosen as
Cobalt	19.4	mg/kg						4.88E+06	source term.
Iron	29,400	mg/kg						7.40E+09	
Manganese	1,750	mg/kg						4.40E+08	
Toluene	7	µg/kg	110	310	6	5.79E+09	2.25	9.12E+01	Detected only at H002 in 36–42 ft sample.
^{226}Ra	1.73	pCi/g	235	370	20	4.92E+10	2.25	1.92E-01	Just over 1/2 width of SWMU used for
^{99}Tc	3.89	pCi/g	235	370	20	4.92E+10	2.25	4.31E-01	source term delineation and entire
^{238}U	1.71	pCi/g	235	630	20	8.38E+10	2.25	3.23E-01	length.

Table E1.16. MEPAS Results for SWMU 5

Source	Constituent (Daughter products are denoted with an asterisk)	PGDP boundary			DOE property boundary		
		Potential maximum concentration (mg/L or pCi/L)	Hazard Quotient	Cancer Risk	Potential maximum concentration (mg/L or pCi/L)	Hazard Quotient	Cancer Risk
Surface Soil	Aluminum	0	0.00E+00	No value	0	0.00E+00	No value
	PCB-1260	0	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00
	2-Methylnaphthalene	3.88E-05	1.38E-03	No value	7.00E-06	2.49E-04	No value
	Acenaphthylene	4.35E-03	No value	No value	8.05E-04	No value	No value
	Benz(a)anthracene	0	No value	0.00E+00	0	No value	0.00E+00
	Benzo(a)pyrene	0	No value	0.00E+00	0	No value	0.00E+00
	Benzo(b)fluoranthene	0	No value	0.00E+00	0	No value	0.00E+00
	Pentachlorophenol	1.08E-27	No value	6.00E-30	1.25E-28	No value	6.94E-31
	Phenanthrene	2.62E-03	No value	No value	3.69E-04	No value	No value
	^{99}Tc	5.78E+01	No value	3.18E-06	9.65E+00	No value	5.30E-07
UCRS-WP1	Aluminum	0	0.00E+00	No value	0	0.00E+00	No value
	Chromium	0	0.00E+00	No value	0	0.00E+00	No value
	Cobalt	2.51E-05	1.21E-04	No value	7.61E-06	3.66E-05	No value
	Iron	4.98E+01	1.60E+01	No value	1.84E+01	5.92E+00	No value
	Iron (at H263)	1.88E+01	6.05E+00	No value	6.61E+00	2.13E+00	No value
	Manganese	2.32E-01	1.81E+02	No value	8.44E-02	6.59E+01	No value
	Phenanthrene	6.09E-05	No value	No value	1.64E-05	No value	No value
	^{226}Ra	5.59E-03	No value	5.53E-06	1.13E-03	No value	1.12E-06
	^{238}U	5.14E-19	No value	8.92E-25	2.13E-19	No value	3.70E-25
	*^{234}Th	5.14E-19	No value	No value	2.13E-19	No value	No value
	*^{234}U	2.81E-20	No value	3.95E-26	1.21E-20	No value	1.70E-26
	*^{230}Th	2.40E-21	No value	2.31E-27	1.07E-21	No value	1.03E-27
	*^{226}Ra	1.93E-21	No value	1.91E-24	8.61E-22	No value	8.52E-25
	*^{222}Rn	1.93E-21	No value	No value	8.61E-22	No value	No value
	*^{210}Pb	1.92E-21	No value	No value	8.58E-22	No value	No value
	*^{210}Bi	1.92E-21	No value	No value	8.58E-22	No value	No value
	*^{210}Po	1.92E-21	No value	No value	8.58E-22	No value	No value
UCRS-WP2	Aluminum	0	0.00E+00	No value	0	0.00E+00	No value
	Cobalt	1.89E-03	9.09E-03	No value	2.81E-04	1.35E-03	No value
	Iron	4.64E+02	1.49E+02	No value	8.27E+01	2.66E+01	No value
	Manganese	1.56E+01	1.22E+04	No value	2.76E+00	2.16E+03	No value
	Toluene	2.78E-05	4.32E-05	No value	1.19E-05	1.85E-05	No value
	^{99}Tc	2.29E+02	No value	1.26E-05	9.96E+01	No value	5.47E-06
	^{226}Ra	5.33E-03	No value	5.28E-06	1.04E-03	No value	1.03E-06
	^{238}U	9.95E-19	No value	1.73E-24	1.91E-19	No value	3.32E-25
	*^{234}Th	9.95E-19	No value	No value	1.91E-19	No value	No value
	*^{234}U	5.45E-20	No value	7.65E-26	1.09E-20	No value	1.53E-26
	*^{230Th}	4.64E-21	No value	4.46E-27	9.57E-22	No value	9.20E-28
	*^{226}Ra	3.71E-21	No value	3.67E-24	7.72E-22	No value	7.64E-25
	*^{222}Rn	3.71E-21	No value	No value	7.72E-22	No value	No value
	*^{210}Pb	3.69E-21	No value	No value	7.69E-22	No value	No value
	*^{210}Bi	3.69E-21	No value	No value	7.69E-22	No value	No value
	*^{210}Po	3.69E-21	No value	No value	7.69E-22	No value	No value

^{210}Bi = Bismuth-210
^{210}Pb = Lead-210
^{210}Po = Polonium-210
^{222}Rn = Radon-222
^{230}Th = Throrium-230
^{234}Th = Throrium-234

E1.5. MODELING APPEARING IN THE WAG 3 RI REPORT FOR SWMU 6

The conservative modeling in Appendix B of Volume 4 of the WAG 3 RI Report (DOE 2000a) was completed to determine if any contaminants could migrate from source areas at SWMU 6 to POEs at the plant boundary and property boundary at a rate that could result in maximum concentrations greater than risk-based screening levels. This modeling was completed using MEPAS and conservative source term estimates developed using comparisons of sampling results to background concentrations and SSLs for protection of groundwater taken from EPA sources. MEPAS transport parameters are given in Table E1. 17.

The sampling results used in source term development were taken from sampling completed as part of the WAG 3 RI (DOE 2000a), the Data Gaps Investigation Report (DOE 2000b), and from earlier sampling completed in support of the PGDP CERCLA SI (CH2M HILL 1991 and 1992) performed in the early 1990s. Source terms developed for SWMU 6 are presented in Table E1.18. Benzo(ghi)perylene originally was identified as a contaminant to be modeled, but it was not referenced in the MEPAS chemical database and, therefore, could not be modeled. As noted in the modeling report, "In all cases, modelers applied conservatism (worst case) in the definition of the extent of the source zones. In all cases, the maximum concentrations were used to develop each contaminant source-term inventory."

Three model layers (two partially saturated and one saturated) were delineated at SWMU 6 (see Sect. 3.2.3 of Vol. 1). The first partially saturated layer extends to a depth of 40 ft bgs and includes the loess deposits making up HU1 and the HU2; the second partially saturated layer extends to a depth of 60 ft bgs and includes the silty clay aquitard, the HU3. The saturated layer includes the RGA and extends from an average depth of 60 ft to 100 ft bgs.

The travel distances from the source to each downgradient exposure point are 920 ft to the PGDP boundary and 2,820 ft to the DOE property boundary. The direction of groundwater flow in the RGA was assumed to be north, based on potentiometric maps of the area.

The results of the MEPAS modeling conducted for SWMU 6 are presented in Table E1.19. These results indicate that contributions from constituents in surface soil to groundwater in the RGA are negligible. Estimated HQs and cancer risks from these modeling results are not available.

Iron is contributing to the RGA from three distinct sources. Results from the sources to the PGDP boundary are 60.1 mg/L in 1,966 years, 32.8 mg/L in 1,787 years, and 7.77 mg/L in 1,787 years. At the DOE boundary, concentrations from these sources are 21.2 mg/L in 2,171 years, 11.9 mg/L in 2,076 years, and 2.56 mg/L in 2076 years. ^{99}Tc contamination from the SWMU 6 waste cell is predicted by the model to reach a maximum activity of 91.5 pCi/L at the PGDP boundary in 118.6 years and 31.8 pCi/L at the DOE property boundary in 120.1 years. Contributions to the RGA from other constituents are minor.

Table E1.17. MEPAS Transport Parameters for SWMU 6

Input Parameter Description	Parameter Name	Value	Reference
Topsoil parameters (wt)			
Textural classification	WT-CLASS	Silt loam	McCracken Co. Soil Survey (USDA 1976)
Percent sand (%)	WT-SAND	15	McCracken Co. Soil Survey: conservative estimate (highest % sand)
Percent silt (%)	WT-SILT	80	Maximum % silt for soil type
Percent clay (%)	WT-CLAY	5	= 100% -% sand - % silt
Percent organic matter (%)	WT-OMC	0.05	CERCLA Phase II Site Investigation (CH2M HILL 1992)
Percent iron and aluminum (%)	WT-IRON	4	Background Concentrations and Human Health Risk-Based Screening Criteria for Metals in Soil at PGDP (DOE 1995b)
pH of topsoil	WT-pH	7.98	WAG 3 RI Data
Percent vegetative cover of site (%)	WT-VEGCOV	90	SWMU Maps
Topsoil water capacity	WT-AVAILW	2.20	McCracken Co. Soil Survey = available water capacity (0.20 in./in.) × root zone depth from Table 2.1 MEPAS Guidance (12.2 in.) × vegetative cover (100%)
SCS curve number	WT-SCSN	71	Antecedent Moisture Condition = II (normal moisture); Group C hydrologic soil group; vegetated surface, well vegetated, 60–100% vegetated
Properties of the partially saturated zones (wp)			
Thickness (ft)	WP-THICK	WP1 39 WP2 20	WP1=1–40 ft (HU 1 + HU 2) WP2= HU 3 — Boring logs at SWMU 6
Textural classification	WP-CLASS	WP1 sandy clay loam WP2 clay loam	Boring logs at SWMU 6
Sand (%)	WP-SAND	WP1 = 38 WP2 = 10	Boring logs at SWMU 6
Silt (%)	WP-SILT	WP1 = 27 WP2 = 30	Boring logs at SWMU 6
Clay (%)	WP-CLAY	WP1 = 35 WP2 = 60	Boring logs at SWMU 6
Organic matter content in soil (%)	WP-OMC	0.05	WAG 6 geotechnical data
Iron + aluminum in soil (%)	WP-IRON	4	DOE 1995b
pH of pore water in partially saturated zone	WP-pH	WP1 = 6.76 WP2 = 6.29	WAG 3 RI data
Bulk density(g/cm^3)	WP-BULKD	WP1 = 1.66 WP2 = 2.25	WAG 3 geotechnical data available for WP1; 2.65 × (1-Porosity)
Total porosity (%)	WP-TOTPOR	WP1 = 37.19 WP2 = 15	WAG 3 geotechnical data available for WP1; SWMU 6 boring logs used as estimate for WP2
Field capacity (%)	WP-FIELDC	WP1 = 24 WP2 = 10	Table 2.1 of MEPAS Guidance, based on soil type for WP1; SWMU 6 boring logs used as estimate for WP2

Table E1.17. MEPAS Transport Parameters for SWMU 6 (Continued)

Input Parameter Description	Parameter Name	Value		Reference
Longitudinal dispersivity (ft)	WP-LDISP	WP1 = 0.39 WP2 = 0.20		Estimated based on MEPAS guidance: D_L = 0.01 × thickness
Saturated hydraulic conductivity (ft/day)	WP-CONDUC	ft/day 0.3	cm/sec 1.06E-4	WAG 3 Work Plan
Moisture content (%)	WS-MOISTC	WP1 = 37.19 WP2 = 15		Moisture content = total porosity
Properties of the saturated zone (wz)				
Textural classification	WZ-CLASS	Loamy sand		WAG 3 Work Plan
Sand (%)	WZ-SAND	74		WAG 3 Work Plan
Silt (%)	WZ-SILT	17		WAG 3 Work Plan
Clay (%)	WZ-CLAY	9		WAG 3 Work Plan
Organic matter in soil (%)	WZ-OMC	0.02		WAG 3 Work Plan
Iron + aluminum in soil (%)	WZ-IRON	3		WAG 3 Work Plan
pH of pore water in saturated zone	WZ-pH	6.275		WAG 3 RI data
Total porosity (%)	WZ-TOTPOR	37		WAG 3 Work Plan
Effective porosity (%)	WZ-EFFPOR	30		Conservative estimate
Darcy velocity (ft/day)	WZ-PVELOC	0.6		Conservative estimate; uses conductivity of 1500 ft/day and gradient of 0.0004
Thickness (ft)	WZ-THICK	40		RGA (HU 4 + HU 5) interval: 60–100 ft bgs
Bulk density (g/cm^3)	WZ-BULKD	1.67		WAG 3 Work Plan
Travel distance (ft)	WZ-DIST	920 ft to PGDP boundary 2820 ft to DOE property boundary		Distances measured along the groundwater flow direction from the northern perimeter of the SWMU to the PGDP boundary and to the DOE property boundary
Longitudinal dispersivity (ft)	WZ-LDISP	50.0		Reference: Bioplume groundwater model
Transverse dispersivity (ft)	WZ-TDISP	5.0		Reference: Bioplume groundwater model
Vertical dispersivity (ft)	WZ-VDISP	0.1		Conservative estimate
Percent of total flux to aquifer (%)	WZ-FRACT	100		Conservative estimate
Perpendicular distance from groundwater flow to receptor (ft)	WZ-YDIST	0		(Plume centerline concentrations)
Vertical distance below groundwater table (ft)	WZ-AQDEPTH	0		(Most conservative result)

Table E1.18. Development of Source Terms for SWMU 6

Contaminant	Initial source concentration		Length parallel to flow direction (ft)	Width perpendicular to flow direction (ft)	Thickness (ft)	Contaminant inventory calculation for MEPAS			Notes
						Volume (cm^3)	Bulk density (g/cm^3)	Inventory (g)	
Surface Soil									
Copper	21.3	mg/kg	65	80	1	1.47E+08	1.46	4.58E+03	Detected above screening levels in 006-001.
Benzo(ghi)perylene	124	µg/kg						2.67E+01	
Phenanthrene	461	µg/kg						9.91E+01	
^{99}Tc	18.8	pCi/g	115	85	1	2.77E+08	1.46	7.60E-03	Area for modeling encompasses 006-016 and 006-017.
SWMU 6 Waste Cells									
Aluminum	18,800	mg/kg	40	100	10	1.13E+09	1.66	3.53E+07	Source term is waste cell "J."
PCB-1016	255	µg/kg						4.79E+02	
^{237}Np	0.219	pCi/g						4.12E-04	
^{99}Tc	43.3	pCi/g						8.14E-02	
^{238}U	1.52	pCi/g						2.86E-03	
Subsurface soil partially saturated zone WP1 (HU1 + HU2 Soils)									
Chromium	116	mg/kg	45	60	17	1.30E+09	1.66	2.50E+05	Area for modeling surrounds 006-027, the area of a relatively high detection of chromium.
	56.8	mg/kg	90	150	25	9.56E+09	1.66	9.01E+05	Area for modeling is entire area of SWMU
Aluminum	12,100	mg/kg			39	1.49E+10		2.99E+08	
Cobalt	17.9	mg/kg			12	4.59E+09		1.36E+05	
Copper	20.9	mg/kg			28	1.07E+10		3.71E+05	
Iron	58,700	mg/kg			39	1.49E+10		1.45E+09	
Lead	35.4	mg/kg			9	3.44E+09		2.02E+05	
Manganese	1,550	mg/kg			12	4.59E+09		1.18E+07	
^{99}Tc	8.51	pCi/g	50	45	11	7.01E+08	1.66	9.90E-03	Detected above screening levels at 006-010.
^{237}Np	0.125	pCi/g						1.45E-04	
^{238}U	1.72	pCi/g						2.00E-03	

Table E1.18. Development of Source Terms for SWMU 6 (Continued)

Contaminant	Initial source concentration		Length parallel to flow direction (ft)	Width perpendicular to flow direction (ft)	Thickness (ft)	Contaminant inventory calculation for MEPAS			Notes
						Volume (cm^3)	Bulk density (g/cm^3)	Inventory (g)	
Subsurface soil partially saturated zone WP2 (HU3 Soils)									
Aluminum	22,500	mg/kg	80	185	20	8.38E+09	2.25	4.24E+08	Area for modeling is entire area of SWMU, less southeastern portion.
Cobalt	156	mg/kg						2.94E+06	
Iron	32,900	mg/kg						6.20E+08	
Lead	25.2	mg/kg						4.75E+05	
Iron	36,900	mg/kg	45	60	20	1.53E+09	2.25	1.27E+08	Detected above screening level at 006-027, outside SWMU boundary.

Table E1.19. MEPAS Results for SWMU 6

Source	Constituent (Daughter products are denoted with an asterisk)	PGDP boundary			DOE property boundary		
		Potential maximum concentration (mg/L or pCi/L)	Hazard Quotient	Cancer Risk	Potential maximum concentration (mg/L or pCi/L)	Hazard Quotient	Cancer Risk
Surface Soil	Copper	2.56E-12	6.15E-12	No value	2.11E-14	5.07E-14	No value
	Phenanthrene	9.78E-07	No value	No value	2.71E-07	No value	No value
	^{99}Tc	9.71E+00	No value	5.34E-07	3.15E+00	No value	1.73E-07
UCRS-Waste Cells	Aluminum	0	0.00E+00	No value	0	0.00E+00	No value
	PCB-1016	0	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00
	^{99}Tc	9.15E+01	No value	5.03E-06	3.18E+01	No value	1.75E-06
	^{237}Np	1.68E-01	No value	4.20E-07	5.53E-02	No value	1.38E-07
	*^{233}Pa	1.68E-01	No value	No value	5.53E-02	No value	No value
	*^{233}U	2.45E-04	No value	No value	9.33E-05	No value	No value
	*^{229}Th	3.99E-06	No value	No value	1.69E-06	No value	No value
	*^{225}Ra	3.99E-06	No value	No value	1.68E-06	No value	No value
	*^{225}Ac	3.99E-06	No value	No value	1.68E-06	No value	No value
	^{238}U	4.80E-19	No value	8.33E-25	1.42E-19	No value	2.47E-25
	*^{234}Th	4.80E-19	No value	No value	1.42E-19	No value	No value
	*^{234}U	2.66E-20	No value	3.74E-26	8.12E-21	No value	1.14E-26
	*^{230}Th	2.28E-21	No value	2.19E-27	7.22E-22	No value	6.94E-28
	*^{226}Ra	1.83E-21	No value	1.81E-24	5.84E-22	No value	5.78E-25
	*^{222}Rn	1.83E-21	No value	No value	5.84E-22	No value	No value
	*^{210}Pb	1.82E-21	No value	No value	5.82E-22	No value	No value
	*^{210}Bi	1.82E-21	No value	No value	5.82E-22	No value	No value
	*^{210}Po	1.82E-21	No value	No value	5.82E-22	No value	No value
UCRS-WP1	Aluminum	0	0.00E+00	No value	0	0.00E+00	No value
	Chromium	0	0.00E+00	No value	0	0.00E+00	No value
	Cobalt	8.06E-05	3.88E-04	No value	2.33E-05	1.12E-04	No value
	Copper	3.13E-11	7.52E-11	No value	2.44E-13	5.87E-13	No value
	Iron	6.01E+01	1.93E+01	No value	2.12E+01	6.82E+00	No value
	Lead	0	0.00E+00	No value	0	0.00E+00	No value
	Manganese	4.08E-01	3.19E+02	No value	1.41E-01	1.10E+02	No value
	^{99}Tc	1.16E+01	No value	6.37E-07	3.86E+00	No value	2.12E-07
	^{237}Np	5.97E-02	No value	4.26E-08	1.95E-02	No value	1.39E-08
	*^{233}Pa	5.9E-02	No value	No value	1.95E-02	No value	No value
	*^{233}U	9.02E-05	No value	No value	3.29E-05	No value	No value
	*^{229}Th	1.47E-06	No value	No value	5.95E-07	No value	No value
	*^{225}Ra	1.47E-06	No value	No value	5.95E-07	No value	No value
	*^{225}Ac	1.47E-06	No value	No value	5.95E-07	No value	No value
	^{238}U	3.49E-19	No value	6.06E-25	1.00E-19	No value	1.74E-25
	*^{234}Th	3.49E-19	No value	No value	1.00E-19	No value	No value
	*^{234}U	1.93E-20	No value	2.71E-26	5.75E-21	No value	8.08E-27
	*^{230}Th	1.66E-21	No value	1.60E-27	5.11E-22	No value	4.91E-28
	*^{226}Ra	1.33E-21	No value	1.32E-24	4.13E-22	No value	4.09E-25
	*^{222}Rn	1.33E-21	No value	No value	4.13E-22	No value	No value
	*^{210}Pb	1.33E-21	No value	No value	4.12E-22	No value	No value
	*^{210}Bi	1.33E-21	No value	No value	4.12E-22	No value	No value
	*^{210}Po	1.33E-21	No value	No value	4.12E-22	No value	No value

Table E1.19. MEPAS Results for SWMU 6 (Continued)

Source	Constituent (Daughter products are denoted with an asterisk)	PGDP boundary			DOE property boundary		
		Potential maximum concentration (mg/L or pCi/L)	Hazard Quotient	Cancer Risk	Potential maximum concentration (mg/L or pCi/L)	Hazard Quotient	Cancer Risk
UCRS-WP2	Aluminum	0	0.00E+00	No value	0	0.00E+00	No value
	Cobalt	1.66E-03	7.98E-03	No value	4.96E-04	2.38E-03	No value
	Iron	3.28E+01	1.05E+01	No value	1.19E+01	3.83E+00	No value
	Iron (from 006-027)	7.77E+00	2.50E+00	No value	2.56E+00	8.23E-01	No value
	Lead	0	0.00E+00	No value	0	0.00E+00	No value

^{225}Ac = Actinium-225
^{210}Bi = Bismuth-210
^{210}Pb = Lead-210
^{210}Po = Polonium-210
^{233}Pa = Protactinium-233
^{222}Rn = Radon-222
^{225}Ra = Radium-225
^{229}Th = Throrium-229
^{230}Th = Throrium-230
^{234}Th = Throrium-234
^{233}U = Uranium-233

E1.6. MODELING APPEARING IN THE WAG 22, SWMUS 7 AND 30 RI/FS

The conservative modeling in Section 5 and Appendix D of the WAG 22, SWMUs 7 and 30 RI/FS Report (DOE 1998a) was completed to determine if any contaminants could migrate from source areas at SWMUs 7 and 30 to groundwater in the UCRS and RGA at a rate that could result in maximum concentrations greater than risk-based screening levels. The following discussion is taken directly from "*Remedial Investigation Report for Solid Waste Management Units 7 and 30 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant Paducah, Kentucky*," DOE/OR/07-1604/V1&D2 (DOE 1998a). Source terms developed for SWMUs 7 and 30 are presented in Tables E1.20 through E1.23. Modeling results are discussed for the four source areas, the UCRS, and the RGA. The use of four source areas (designated Pit A, Pit B/C, F Pits, and areas within SWMUs 7 and 30 outside of Pits A, B, C), the UCRS, and the RGA reflects the distribution of contaminants in the SWMU 7 and 30 source areas and surrounding environmental media. Contaminants disposed of in the three primary source areas of SWMUs 7 and 30, Pit A, Pit B/C Pits, and the F Pits include metals, radionuclides (primarily ^{99}Tc and uranium), organic solvents (primarily TCE), and fuel-related VOCs and SVOCs. Of the contaminants disposed of in the source areas , only ^{99}Tc and several VOCs were detected in the UCRS and RGA. Metals, other radionuclides, and SVOCs were not detected in either unit.

The complex nature of the hydrogeology and contaminants in SWMUs 7 and 30 preclude development of a single computer model to describe fate and transport of contaminants at this site. Rather, a combination of small-scale analytical groundwater transport models and simple estimates of contaminant attenuation/dilution along specific pathways are combined in the framework of the conceptual model for fate and transport analysis.

The output of the contaminant fate and transport modeling is presented as the expected maximum concentration of modeled contaminants at the receptor locations. These data will allow prediction of the approximate locations of future maximum concentrations resulting from the integration of the contributions from multiple sources and different pathways. For the purpose of this analysis, SWMUs 7 and 30 were divided into four source areas representing the disposal areas: (1) Pit A, (2) Pit B/C, (3) F Pits, and (4) the areas within SWMUs 7 and 30 outside of Pits A, B, C. The quantitative modeling accounted for the following:

- Contents of the source area,
- Presence of DNAPL in the source area,
- Presence or absence of a discrete cap,
- Identifiable geologic strata beneath the source area,
- Thickness of each layer in the vadose zone,
- Vertical permeability of the unsaturated soils,
- Presence of contaminated soils submerged in the groundwater,
- Water table fluctuations, and
- Receptor locations.

Once the leachate modeling for these four source areas was completed, the predicted maximum leachate concentrations were compared against the existing groundwater concentrations in the UCRS. If the predicted leachate concentrations exceeded the concentrations in the UCRS, then the leachate concentrations were compared against their respective groundwater risk-based concentrations (RBCs) that were derived using cancer risk of 1E-6 or hazard index of 1.0. For the remaining constituents, the groundwater concentrations in the UCRS were compared against their respective RBCs. All the constituents that exceeded the groundwater RBCs were selected for vertical transport modeling from the UCRS to the RGA. The constituents with concentrations (both in UCRS groundwater and predicted leachate) below the RBC were eliminated from the list of contaminant migration COPCs (CMCOPCs) and no further evaluations were performed. After performing vertical transport modeling of the CMCOPCs from the UCRS to the RGA, the predicted leachate concentrations were again compared with their respective RBCs, and if the maximum predicted leachate concentration of a COPC exceeded the groundwater RBC, it was selected for horizontal transport modeling using AT123D. If the predicted maximum leachate concentration was below the groundwater RBC, the contaminant was eliminated from the list of CMCOPCs, and no further evaluations were performed.

E1.6.1 SESOIL MODELING

The SESOIL model used for leachate modeling, when applicable, estimates pollutant concentrations in the soil profile following introduction via direct application and/or interaction with other media. The model defines the soil compartment as a soil column extending from the ground surface through the unsaturated zone and to the upper level of the saturated soil zone. Processes simulated in SESOIL are categorized in three cycles - the hydrologic cycle, sediment-cycle, and pollutant cycle. Each cycle is a separate submodule in the SESOIL code. The hydrologic cycle includes rainfall, surface runoff, infiltration, soil-water content, evapo-transpiration, and groundwater recharge. The sediment cycle includes sediment washload as a result of rainstorms (i.e., soil erosion that results from surface runoff). The pollutant cycle includes convective transport, volatilization, adsorption/desorption, and degradation/decay. A contaminant in SESOIL can partition in up to four phases (liquid, adsorbed, air, and pure).

Table E1.20. Initial COPCs Based on Soil Screening from the Burial Pit A, WAG 22

Site Related Contaminant	Exposure Concentration[a]	SSL	Is Exposure Concentration > SSL?
Metals and Inorganics[b]			
Aluminum	79508.96	22,400	YES
Antimony	7.00	0.3	YES
Arsenic	10.00	1	YES
Barium	386.00	82	YES
Cadmium	10.00	0.4	YES
Chromium	55.00	2	YES
Copper	141.00	21.2	YES
Cyanide	0.64	2	NO
Lead	5,760.06	400	YES
Manganese	5,239.00	511	YES
Mercury	0.60	0.02	YES
Molybdenum	0.02	9.43E+00	NO
Nickel	132.00	7	YES
Selenium	1.00	0.3	YES
Tin	10.80	4,020	NO
Vanadium	40.00	300	NO
Zinc	364.05	620	NO
Volatile Organic Compounds[c]			
1,1-Dichloroethane	27.04	1,000	NO
1,2-Dichlorobenzene	17.60	N/A	YES
1,2-Dichloroethane	0.91	1	NO
cis-1,2-DCE	20.73	20	YES
trans-1,2-DCE	0.58	30	NO
1,3-Dichlorobenzene	39.42	1,400	NO
1,4-Dichlorobenzene	26.23	100	NO
4-Methy-2pentanone	7.71	200	NO
Acetone	1.71	800	NO
Benzene	2.20	2	YES
Chlorobenzene	88.31	70	YES
Chloroethene	33.62	235.08	NO
Chloromethane	2.19	0.32	YES
Ethylbenzene	9.83	700	NO
Methylene chloride	5.69	1	YES
Toluene	5.52	600	NO

Table E1.20. Initial COPCs Based on Soil Screening from the Burial Pit A, WAG 22 (Continued)

Site Related Contaminant	Exposure Concentration[a]	SSL	Is Exposure Concentration > SSL?
TCE	2.02	3	NO
Vinyl chloride	3.12	0.7	YES
Xylenes	25.82	1,000	NO
Semivolatile Organic Compounds[c]			
1,2,4- Trichlorobenzene	9.31	300	NO
2,4-Dichlorophenol	0.65	50	NO
2,4-Dimethylphenol	56.30	400	NO
2-Methylnaphthalene	6.79	*N/A*	YES
2-Methylphenol	0.57	8.00E+02	NO
4-Methylphenol	0.40	*N/A*	YES
Acenapththene	2,046.00	29,000	NO
Anthracene	2,609.00	590,000	NO
Benzo(a)anthracene	5,616.00	80	YES
Benzo(a)pyrene	5,427.00	400	YES
Benzo(a)f1uoranthene	15,000.00	200	YES
Benzo(ghi)perylene	4,400.00	4,280	YES
Chrysene	5,804.00	800	YES
Dibenzofuran	1,172.00	81.6	YES
Bis(2-ethylhexyl)phthalate	37,798.72	180,000	NO
Di-n-octyl phthalate	407,184,020.00	1.00E+07	YES
Diethyl phthalate	0.20	2.30E+04	NO
Fluoranthene	23,000.00	210,000	NO
Fluorene	1,796.00	*2,8000*	NO
Indeno (1,2,3-c,d)pyrene	2,860.00	700	YES
Naphthalene	923.70	4,000	NO
Phenanthrene	13,190.00	*N/A*	YES
Pyrene	15,000.00	210,000	NO
Pesticides and PCBs[c]			
PCB-1254	165.30	1,000	NO
PCB-1260	3,047.26	1,000	YES
Radionuclides[d]			
Gross Alpha	24.00	*N/A*	YES
Gross Beta	35.00	*N/A*	YES
^{237}Np	1.80	0.033	YES
^{239}Pu	5.05	1.46	YES
^{99}Tc	18.00	*0.0828*	YES
^{230}Th	38.61	33.99206	YES
^{234}U	562.04	2.2	YES
^{235}U	1.01	2.16	NO
$^{235/236}$U	42.79	2.16	YES
^{238}U	686.09	2.29	YES

[a] Soil exposure concentrations represent either back-calculated soil concentrations or soil concentrations obtained from soil sampling analysis.
[b] Concentrations of all metals and inorganics are expressed in mg/kg.
[c] Concentrations of all VOCs, SVOCs, and PCBs are expressed in µg/kg.
[d] Concentrations of all radionuclides are expressed in pCi/g.

Table E1.21 Initial COPCs Based on Soil Screening from Burial Pits B/C, WAG 22

Site Related Contaminant	Exposure Concentration[a]	SSL	Is Exposure Concentration > SSL?
Metals and Inorganics[b]			
Aluminum	1,950,219.70	22400	YES
Antimony	186.36	0.3	YES
Arsenic	41.00	1	YES
Barium	2,322.52	82	YES
Beryllium	31.21	3.00	YES
Cadmium	165.10	0.4	YES
Chromium	371.08	2	YES
Cobalt	3,861.50	1,180	YES
Copper	31,933.45	21.2	YES
Cyanide	0.77	2	NO
Lead	63,520.67	400	YES
Manganese	40,636.65	511	YES
Mercury	2.04	0.0205	YES
Molybdenum	21.28	9.42756	YES
Nickel	122,168.78	7	YES
Silver	65.86	2	YES
Tin	94.54	4020	NO
Uranium	3,544.37	N/A	YES
Vanadium	1,800.30	300.0	YES
Zinc	114,284.86	620	YES
Volatile Organic Compounds[c]			
1, 1- Dichloroethane	5.60	1,000	NO
1, 2-DCE (total)	454.78	51.5	YES
cis-1,2-DCE	0.88	20.0	NO
1, 4-Dichlorobenzene	70.00	100	NO
2-Butanone	29.52	126	NO
4-Methyl-2-Pentanone	35.84	200	NO
Acetone	82.51	800	NO
Benzene	34.73	2	YES
Chloroethane	4.74	235.0855	NO
Ethylbenzene	179.50	700	NO
Methylene Chloride	20.52	1	YES
Toluene	753.40	600	YES
TCE	7.00	3	YES
Vinyl chloride	65.80	7.00E-01	YES
Xylenes, Total	1,065.00	10,000	NO
Semivolatile Organic Compounds[C]			
1,2,4-Trichlorobenzene	77.00	300	NO
2-Chlorophenol	39.00	200	NO
2,4,5-Trich1orophenol	35.00	14,000	NO
2,4,6- Trichlorophenol	41.00	8	YES
2,4- Dimethylphenol	5,034.00	400	YES
2-Methylnaphthalene	958.30	*N/A*	YES
2-Methylphenol	664.40	800	NO
4-Methylphenol	8,129.00	*N/A*	YES
Acenaphthene	31.00	29,000	NO
Benzo(b)fluoranthene	789.60.	200	YES
bis(2-ehthylhexyl)phthalate	947.10	180,000	NO
Chlorobenzene	7.00	70	NO

Table E1.21 Initial COPCs Based on Soil Screening from Burial Pits B/C, WAG 22 (Continued)

Site Related Contaminant	Exposure Concentration[a]	SSL	Is Exposure Concentration > SSL?
Chrysene	590.20	800	NO
Di-n-butylphthalate	91.00	270,000	NO
Dibenzofuran	0.79	81.62258881	NO
Diethyl phthalate	0.57	23,000	NO
Fluoranthene	795.90	210,000	NO
Hexachlorobutadiene	58.00	36.6	YES
Hexachloroethane	34.00	12.4	YES
Naphthalene	8.72	4,000	NO
Phenanthrene	967.20	*N/A*	YES
Phenol	702.60	5,000	NO
Pyrene	609.40	210,000	NO
Pesticides and PCBs[c]			
PCB-1248	720.70	1,000	NO
PCB-1254	7,913.80	1,000	YES
PCB-1260	11,375.23	1,000	YES
Radionuclides[d]			
Gross Alpha	37.00	NA	YES
Gross Beta	47.00	NA	YES
^{237}Np	19.00	0.033	YES
$^{239/240}$Pu	72.00	1.46	YES
^{99}Tc	656.50	0.0828	YES
^{230}Th	95.70	34	YES
^{234}U	362.80	2.2	YES
^{235}U	150.00	2.16	YES
$^{235/236}$U	14.28	2.16	YES
^{238}U	2,100.00	2.29	YES

[a] Soil exposure concentrations represent either back-calculated soil concentrations or soil concentrations obtained from soil sampling analysis.
[b] Concentrations of all metals and inorganics are expressed in mg/kg.
[c] Concentrations of all VOCs, SVOCs, and PCBs are expressed in µg/kg.
[d] Concentrations of all radionuclides are expressed in pCi/g.

Table E1.22. Initial COPCs Based on Soil Screening from Burial Pit F, WAG 22

Site Related Contaminant	Exposure Concentration[a]	SSL	Is Exposure conc. > SSL?
Metals and Inorganics[b]			
Aluminum	615,069.29	22,352.98	YES
Barium	180.00	82	YES
Beryllium	·12.00	3.00E+00	YES
Cobalt	247.03	1,177.9812	NO
Lead	5,120.05	400	YES
Manganese	1,200.00	51 I	YES
Molybdenum	175.24	9.42756	YES
Nickel	1,891.06	7	YES
Nitrate	0.52	N/A	YES
Tin	3.80	4,020	NO
Uranium	21,013.03	N/A	YES
Vanadium	700.12	300	YES
Zinc	2,080.27	620	YES
Volatile Organic Compounds[c]			
1,1,1- Trichloroethane	5.11	1.00E+02	YES
1,1,2- Trichloro-l,2,2, trifluoroethene	3.79	56,085.504	YES
1,I-Dichloroethane	34.55	1.00E+03	YES
cis-1,2-DCE	0.64	2.00E+0l	YES
1,3-Dichlorobenzene	0.90	1,400.137787	YES
Acetone	14.00	800	YES
Benzene	1.46	2	YES
Chloroethane	4.35	235.0855911	YES
Ethylbenzene	34.04	700	YES
Tetrachloroethene	0.76	3	YES
Toluene	4.41	600	YES
TCE	0.65	3.00E+00	YES
Vinyl chloride	3.89	7.00E-0l	YES
Xylenes	160.17	10,000	YES
Semivolatile Organic Compounds[c]			
1,2,4- Trichlorobenzene	37.00	300	NO
2,4-Dimethylphenol	20.15	400	NO
2-Methylnaphthalene	21.62	N/A	YES
4-Methylphenol	0.75	N/A	YES
4-chloro-3-methylphenol	3.70	N/A	YES
Bis(2-ethylhexyl) phthalate	483.64	1.80E+05	NO
Diethyl phthalate	0.24	2.30E+04	NO
Di-n-octylphthalate	72.00	1.00E+07	NO
Napthalene	9.79	4.00E+03	NO
Pesticides and PCBs[c]			
PCB-1016	33.02	N/A	YES
PCB-1248	8,522.20	1,000	YES
PCB-1260	565.19	1.00E+03	NO

Table E1.22. Initial COPCs Based on Soil Screening from Burial Pit F, WAG 22 (Continued)

Site Related Contaminant	Exposure Concentration[a]	SSL	Is Exposure conc. > SSL?
Radionuclides[d]			
Gross Alpha	23.00	15.8	YES
Gross Beta	42.00	27.9	YES
^{237}Np	0.04	0.033012	YES
$^{239/240}$Pu	2.06	1.464244	YES
^{99}Tc	4.17	0.0828	YES
^{230}Th	9.34	33.99206	NO
^{234}U	193.42	2.2	YES
$^{235/236}$U	29.37	2.16	YES
^{238}U	1,243.06	2.29	YES

[a] Soil exposure concentrations represent either back-calculated soil concentrations or soil concentrations obtained from soil sampling analysis.
[b] Concentrations of all metals and inorganics are expressed in mg/kg.
[c] Concentrations of all VOCs, SVOCs, and PCBs are expressed in µg/kg.
[d] Concentrations of all radionuclides are expressed in pCi/g.

Table E1.23. Initial COPCs Based on Soil Screening from Subsurface Soils Outside Pits

Site Related Contaminant	Exposure Concentration[a]	SSL	Is Exposure conc. > SSL?
Metals and Inorganics[b]			
Aluminum	7,242	22,400	NO
Antimony	4.24	0.3	YES
Arsenic	3.143	1	YES
Barium	104.3	82	YES
Beryllium	0.6603	3’	NO
Cadmium	1.85	0.4	YES
Chromium	21.45	2	YES
Cobalt	8.279	1,180	NO
Copper	16.18	21.2	NO
Cyanide	0.393	2	NO
Lead	12.26	400	NO
Manganese	417.7	511	NO
Nickel	15.99	7	YES
Selenium	0.2117	0.3	NO
Silver	0.9728	2	NO
Thallium	0.9309	0.04	YES
TIN	4.6		NO
Vanadium	23.95	300	NO
Zinc	38.95	620	NO
Volatile Organic Compounds[c]			
1,2,4- Trichlorobenzene	33	300	NO
1,4-Dichlorobenzene	25	100	NO
2-Butanone	4	126	NO
2-Chlorophenol	23	200	NO
4-Methyl-2-Pentanone	6	200	NO
Acetone	404.3	800	NO
Carbon Disulfide	4.243	2,000	NO
Methylene Chloride	87.11	1	YES
Tetrachloroethene	2	3	NO
TCE	4.108	3	YES

Table E1.23. Initial COPCs Based on Soil Screening from Subsurface Soils Outside Pits (Continued)

Site Related Contaminant	Exposure Concentration[a]	SSL	Is Exposure conc. > SSL?
Semivolatile Organic Compounds[c]			
Acenepthene	17	29,000	NO
Benzo(a)anthracene	56	80	NO
Benzo(a)pyrene	77	400	NO
Benzo(b)fluoroanthene	91	200	NO
Benzo(k)fluoroanthene	81	2,000	NO
bis(2-ethylhexyl)phthalate	235.9	180,000	NO
Chrysene	83	800	NO
Di-n-butylphthalate	181.7	270,000	NO
Fluoroanthene	170	210,000	NO
Indeno (1,2,3-c,d)pyrene	73	700	NO
N-nitrosodiphenylamine	140	26.4	YES
Octachlorodibenzo-p-dioxin	0.6	0.16	YES
Pentachlorophenol	120	5	YES
Phenanthrene	110	1	NO
Pyrene	140		NO
Indeno (1,2,3-c,d)pyrene	73	210,000	NO
Pesticides and PCBs[c]			
PCB-1248	27.68	1,000	NO
PCB-1260	55.93	1,000	NO
Radionuclides[d]			
Gross Alpha	11.92		
Gross Beta	18.49		
^{237}Np	2.362	0.033	YES
^{239}Pu	5.986	1.46	YES
^{99}Tc	280	0.0828	YES
^{230}Th	22.38	34 2	NO
^{234}U	44	.2	YES
^{235}U	3.2	2.16	YES
$^{235/236}$U	0.4	2.16	NO
^{238}U	160	2.29	YES

[a] Soil exposure concentrations represent either back-calculated soil concentrations or soil concentrations obtained from soil sampling analysis.
[b] Concentrations of all metals and inorganics are expressed in mg/kg.
[c] Concentrations of all VOCs, SVOCs, and PCBs are expressed in µg/kg.
[d] Concentrations of all radionuclides are expressed in pCi/g.

E1.6.1.1 Source Areas

Although 27 constituents from Pit A were identified as the initial COPCs, only 7 of them were selected for SESOIL modeling. Similarly, 14 of the 38 initial COPCs from Pits B/C, 4 of 26 initial COPCs from the F Pits, and 7 of 18 initial COPCs from Subsurface Outside of the Pits were selected for SESOIL Modeling. The model was calibrated against the percolation rate by varying the hydraulic conductivity and the disconnectedness index and keeping all other site-specific geotechnical parameters fixed. The final parameter values used in this modeling are as follows: soil bulk dry density of 1.5 g/cm^3, porosity of 0.40, organic carbon content of 0.34%, and volumetric moisture content of 27.5%. Additional parameter values used in the model included a disconnectedness index of 10.0 and an intrinsic permeability of 9.0 x 10^{-10} cm^2, which was derived during calibration of the model to a percolation rate of 4.6 inches/year. The percolation rate was derived using water balance data for the site (Geotrans 1992).

The SESOIL model was set up using four layers extending from the ground surface to the average water table surface at 12 ft bgs. The first layer of the model extended from ground surface to 1 ft bgs and corresponds to the observed soil cover over the pits. The second layer extended from 1 ft bgs to 5 ft bgs and corresponds to the sampling interval; therefore, this layer represents the loading zone. The third layer extended from 5 ft bgs to 10 ft bgs. Most of the pit water was collected in this interval, which was used to back-calculate to corresponding soil concentrations; therefore, this layer also represents the loading zone. The fourth layer extended from 10 to 12 ft bgs, formed the leaching zone, and was divided into 5 sub layers for better resolution.

E1.6.1.2 UCRS

SESOIL-predicted maximum leachate concentrations from the individual source areas were compared against the currently observed maximum groundwater concentrations, as stated earlier, and the source term concentrations for transporting the contaminants vertically down to the RGA were developed. However, only 17 of 42 initial COPCs from the UCRS were selected for SESOIL modeling. As before, the model was calibrated against the percolation rate by varying the hydraulic conductivity and the disconnectedness index and keeping all other site-specific geotechnical parameters fixed. The final parameter values used in the modeling from UCRS are as follows: soil bulk dry density of 1.5 g/cm^3, porosity of 0.40, organic carbon content of 0.26%, and volumetric moisture content of 29.5%. Additional parameter values used in the model included a disconnectedness index of 10.0 and an intrinsic permeability of 1.65 x 10-^{10} cm^2. Of these parameters, porosity, density, and disconnectedness index represent default values for silty-clay, and organic carbon content represents the average measured value. The volumetric moisture content and the intrinsic permeability were derived during calibration of the model to a percolation rate of 4.3 inches/year. The percolation rate was derived using water balance data for the site (Geotrans 1992).

The SESOIL model was set up using three layers extending from the top of the HU2 to the top of the RGA at 45 ft bgs. The first layer of the model extended from top of the HU2 to the top of the confining zone and corresponds to the contaminated zone. This layer was divided into five sublayers and contaminant loading was performed in each of these sub layers which represented the back-calculated soil concentrations. The second layer extended from the top of the confining zone to the top of the RGA and formed the leaching zone. This layer was also divided into five sublayers for better resolutions. The third layer of 0.5 ft was used to read the output concentrations at the water table.

E1.6.1.3 Modeling Results

The results of contaminant fate and transport analysis for individual source areas are summarized below:

E1.6.1.3.1 Pit A

Table E1.24 summarizes the results of fate and transport analyses for Pit A. Presented in this table are the source term concentrations (i.e., either back-calculated soil concentrations or the observed soil concentrations representing the 95% UCL values), the predicted peak contributing concentrations in the UCRS groundwater beneath the source, and the corresponding time for peak concentrations. In addition, this table presents for comparison the current maximum concentrations in the UCRS groundwater and drinking water MCLs or risk-based concentrations (RBCs) (if a MCL is not available). As can be seen from this table, cadmium, chromium, ^{237}Np, and ^{99}Tc were predicted to reach the peak contributing concentrations exceeding groundwater Remedial Goal Options (RGOs). Predicted peak contributing concentrations of methylene chloride, chlorobenzene, and chloromethane among the organics also exceed their respective groundwater RGOs.

Table E1.24. Summary of Leachate Modeling Results for the COPCs[1] from the Burial Pit A

COPCs	Exposure concentration	Predicted Cgw,max[2] in the UCRS	Predicted Tmax	Observed Cgw,max in the UCRS	Groundwater RGOs	Comment
Metals[a]						
Cadmium	10.0	0.375	545	N/A	0.005	M
Chromium	55.0	1.95	415	0.91	0.10	M
Radionuclides[b]						
^{237}Np	1.8	119	338	0.4	1.31	R
^{99}Tc	18	66,441	5	99	276	R
Volatile Organic Compounds[c]						
Methylene chloride	5.69	12.0	4	N/A	5.00	M
Chlorobenzene	88.31	53.4	12	N/A	l2.7	R
Chloromethane	2.19	2.27	4	N/A	1.33	R

[1] These COPCs represent the constituents that were selected for SESOIL modeling.
[2] It should be noted here that the predicted Cgw, max in the UCRS represent the peak leachate concentration before reaching the water table based on contaminant leaching from the existing source concentrations.
[a] Concentrations of all inorganic compounds are expressed in mg/kg or mg/L.
[b] Concentrations of radionuclides are expressed as pCi/g or pCi/L.
[c] Concentrations of organic compounds are expressed as µg/g or µg/L.
M = MCL R = Risk-based N/A = Not available

E1.6.1.3.2 Pit B/C

The results of fate and transport analyses for Pit B/C are summarized in Table E1.25. Presented in this table are the source term concentrations (i.e., either back-calculated soil concentrations or the observed soil concentrations representing the 95% UCL values), the predicted peak concentrations in the UCRS groundwater beneath the source, and the corresponding time for peak concentrations. In addition, this table presents for comparison the current maximum concentrations in the UCRS groundwater and drinking water MCLs or RBCs (if a MCL is not available). As can be seen from this table, arsenic, barium, cadmium, chromium, copper, mercury, ^{237}Np, and ^{99}Tc, were predicted to reach the peak contributing concentrations exceeding groundwater RGOs. Predicted peak contributing concentrations of benzene; methylene chloride; toluene; and 2,4-dimethylphenol among the organics also exceed their respective groundwater RGOs.

E1.6.1.3.3 F Pits

The results of fate and transport analyses for the F Pits are summarized in Table E1.26. Presented in this table are the source term concentrations (i.e., either back-calculated soil concentrations or the observed

soil concentrations representing the 95% UCL values), the predicted peak concentrations in groundwater beneath the source, and the corresponding time for peak concentrations. In addition, this table presents for comparison the current maximum concentrations in the UCRS groundwater and drinking water MCLs or RBCs (if a MCL is not available). As can be seen from this table, only ^{99}Tc and ^{237}Np were predicted to reach the peak contributing concentrations exceeding groundwater RGOs.

Table E1.25. Summary of Leachate Modeling Results for the COPCs[1] from the Burial Pits B/C

COPCs	Exposure concentration	Predicted Cgw,max[2] in the UCRS	Predicted Tmax	Observed Cgw,max in the UCRS	Groundwater RGOs	Comment
Metals[a]						
Arsenic	41	2.48	254	0.28	0.05	M
Barium	232.22	13.61	784	4.3	2	M
Cadmium	165.1	6.96	524	N/A	0.005	M
Chromium	371.08	19.72	391	0.91	0.1	M
Copper	31,933	634	456	0.46	0.602	R
Mercury	2.04	0.009	114	0.0011	0.002	M
Radionuclides[b]						
^{237}Np	19.0	879	327	0.4	1.31	R
^{99}Tc	656.5	3,555,651	4	99	276	R
Volatile organic compounds[c]						
Benzene	34.7	62.2	6	12	5	M
Methylene chloride	20.52	60.5	4	N/A	5	M
Toluene	753.4	678.2	9	59	1,000	M
Semivolatile organic compounds[d]						
2,4,6-Trichlorphenol	41	3.25	215	N/A	3.99	R
2,4-Dimethylphenol	5,034	1l,390	10	4.4	230	R
Hexachloroethane	34.0	0.8	585	NA	3.29	R

[1] These COPCs represent the constituents that were selected for SESOIL modeling.
[2] It should be noted that the predicted $C_{gw,max}$ in the UCRS represent the peak leachate concentration before reaching the water table based on contaminant leaching from the existing source concentrations.
[a] Concentrations of all inorganic compounds are expressed as mg/kg or mg/L.
[b] Concentrations of radionuclides are expressed as pCi/g or pCi/L.
[c] Concentrations of organic compounds are expressed as µg/g or µg/L.
M = MCL R = Risk-based N/A = Not available

Table E1.26. Summary of Leachate Modeling Results for the COPCs[1] from the Burial Pit F

COPCs	Exposure concentration	Predicted Cgw,max[2] in the UCRS	Predicted Tmax	Observed Cgw,max in the UCRS	Groundwater RGOs	Comment
Radionuclides[a]						
^{237}Np	0.04	1.73	338	0.4	1.31	R
^{99}Tc	4.17	26,430	5	99	276	R
Semivolatile organic compounds[b]						
4-Methylphenol	0.75	1.69	8	0.21	N/A	

[1] These COPCs represent the constituents that were selected for SESOIL modeling.
[2] It should be noted that the predicted $C_{gw,max}$ in the UCRS represent the peak leachate concentration before reaching the water table based on contaminant leaching from the existing source concentrations.
[a] Concentrations of radionuclides are expressed as pCi/g or pCi/L.
[b] Concentrations of organic compounds are expressed as µg/g or µg/L.
M = MCL R = Risk-based N/A = Not available

E1.6.1.3.4 Subsurface Source Outside of the Pits

The results of fate and transport analyses for Subsurface Source Outside of the Pits are summarized in Table E1.27. Presented in this table are the source term concentrations (i.e., either back-calculated soil concentrations or the observed soil concentrations representing the lesser of 95% UCL or maximum values), the predicted peak concentrations in groundwater beneath the source, and the corresponding time for peak concentrations. In addition, this table presents for comparison the current maximum concentrations in the UCRS groundwater and drinking water MCLs or RBCs (if a MCL is not available). As can be seen from this table, arsenic, barium, cadmium, chromium, ^{99}Tc, ^{237}NP, and methylene chloride were predicted to reach the peak contributing concentrations exceeding groundwater RGOs.

Table E1.27. Summary of Leachate Modeling Results for the COPCs[1] from the Subsurface Soil Outside Pits

COPCs	Exposure concentration	Predicted Cgw,max[2] in the UCRS	Predicted Tmax	Observed Cgw,max in the UCRS	Groundwater RGOs	Comment
Metals[a]						
Arsenic	3.143	1.06	265	0.28	0.05	M
Barium	104.3	8.92	827	4.3	2	M
Cadmium	1.85	0.37	557	N/A	0.005	M
Chromium	21.45	2.37	419	0.91	0.1	M
Radionuclides[b]						
^{237}Np	2.36	428.58	360	0.4	1.31	R
^{99}Tc	280.0	977,625	5	99	276	R
Volatile organic compounds[c]						
Methylene chloride	87.1	710.4	4	N/A	5	M

[1] These COPCs represent the constituents that were selected for SESOIL modeling.
[2] It should be noted that the predicted $C_{gw,max}$ in the UCRS represent the peak leachate concentration before reaching the water table based on contaminant leaching from the existing source concentrations.
[a] Concentrations of all inorganic compounds are expressed as mg/kg or mg/L.
[b] Concentrations of radionuclides are expressed as pCi/g or pCi/L.
[c] Concentrations of organic compounds are expressed as µg/g or µg/L.
M = MCL R = Risk-based N/A = Not available

E1.6.1.3.5 UCRS

As discussed in E1.6.1.2, SESOIL modeling for the UCRS used either the maximum leachate concentrations predicted by SESOIL modeling for the four source areas (Pit A, Pit B/C, F Pits, and Subsurface Source Outside of the Pits) or the maximum observed groundwater concentrations to predict the peak leachate concentration in the UCRS. The results of this transport modeling in the UCRS are summarized in Table E1.28. Presented in this table are source concentrations (i.e., either predicted maximum leachate concentrations based on SESOIL modeling of the sources (i.e., Pit A, Pit B/C, F Pits, and the Areas within SWMU 7 and 30 outside of Pits A, B, and C) or the maximum observed groundwater concentrations in the UCRS, whichever is greater), the predicted peak contributing concentrations in the leachate before reaching the RGA, and the corresponding time of peak concentrations. In addition, this table presents for comparison the current maximum concentrations in the RGA groundwater and drinking water MCLs or RBCs (if a MCL is not available). As can be seen from this table, the predicted peak contributing concentrations of 1,2-DCE; *cis*-1,2-DCE; 2,4 dimethylphenol; methylene chloride; TCE; vinyl chloride; ^{99}Tc; and mercury exceed their respective groundwater RGOs; therefore, these constituents were considered for lateral transport modeling in the RGA using AT123D (see Section E1.6.2). Mercury was dropped from this list. The maximum concentration of mercury, although slightly higher than its MCL, decreases to lower than its MCL with dilution.

Table E1.28. Summary of Leachate Modeling Results for the COPCs[1] from the UCRS

COPCs	Exposure concentration	Predicted $C_{gw,max}$[2] in the UCRS	Predicted Tmax	Observed $C_{gw,max}$ in the UCRS	Groundwater RGOs	Comment
Metals[a]						
Mercury	0.09	0.0042	405	0.0012	0.002	M
Radionuclides[b]						
^{99}Tc	355.6	763,627	14	3,670	276	R
Volatile organic compounds[c]						
1,1,1-Trichloroethane	94.77	27.5	26	1.3	200	M
1,2-Dichloroethane	0.59	0.32	14	3	5	M
1,1-DCE	3.89	0.31	16	3.7		
1,2-DCE	1,591.9	281.3	18	110	136	R
cis-l,2-DCE	406.1	133.7	13	140	149	R
4-Methyl 2-2-pentanone	0.09	0.09	10	2.9	N/A	
Acetone	2.54	2.73	9	430	1,510	R
Benzene	1.93	0.48	16	N/A	5	M
Chloromethane	0.03	0.01	10	14	1.33	R
Methylene chloride	18.47	9.40	10	N/A	5	M
TCE	464.4	56.53	20	19,000	5	M
Vinyl chloride	362.7	15.21	12	N/A	2	M
Semivolatile organic compounds[d]						
2,4-Dimethylphenol	6,189.3	1,983.42	30	N/A	230	R

[1] These COPCs represent the constituents that were selected for SESOIL modeling.
[2] It should be noted that the predicted $C_{gw,max}$ in the UCRS represent the peak leachate concentration before reaching the water table based on contaminant leaching from the existing source concentrations.
[a] Concentrations of all inorganic compounds are expressed as mg/kg or mg/L.
[b] Concentrations of radionuclides are expressed as pCi/g or pCi/L.
[c] Concentrations of organic compounds are expressed as µg/g or µg/L.
M = MCL R = Risk-based N/A = Not available

E1.6.2 AT123D MODELING

AT123D is an analytical groundwater pollutant fate and transport model chosen to predict the future receptor concentrations for the contaminants. It computes the spatial-temporal concentration distribution of wastes in the aquifer system and predicts the transient spread of a contaminant plume through a groundwater aquifer. The fate and transport processes accounted for in AT123D are advection, dispersion, adsorption/retardation, and decay. This model can be used as a tool for estimating the dissolved concentration of a chemical in three dimensions in the groundwater resulting from a mass release over a source area (point, line, area, or volume source). The model can handle instantaneous as well as continuous source loadings of chemicals of interest at the site. AT123D frequently is used by the scientific and technical community to perform quick and conservative estimates of groundwater plume movement in space and time. In RISKPRO, SESOIL and AT123D are linked so that mass loading to the groundwater predicted by SESOIL can be directly transferred to AT123D.

Six organic compounds and one radionuclide were selected for AT123D modeling in the RGA based on source loading from the UCRS predicted by SESOIL. Maximum concentrations at two receptor locations (PGDP boundary and DOE property boundary) were simulated for these constituents. Maximum concentrations at the end of 30 years of simulation also were predicted for these constituents.

E1.6.2.1 RGA

The results of fate and transport modeling in the RGA based on future contaminant loading from SWMUs 7 and 30 are summarized in Table E1.29. Presented in this table are the predicted peak contributing concentrations in groundwater beneath the source, predicted peak contributing concentrations at 30 years and in 100 years at the PGDP boundary in the direction of flow, and the peak contributing concentrations in 30 and 100 years at the DOE property boundary in the direction of flow. In addition, this table presents for comparison the current maximum concentrations in the RGA groundwater and drinking water MCLs or RBCs (if a MCL is not available). As can be seen from this table, ^{99}Tc is predicted to reach the peak contributing concentrations exceeding its groundwater RBC at all locations and for both 30- and 100-year scenarios. None of the organic COPCs are predicted to reach the peak contributing concentrations exceeding their respective groundwater RBCs; however, the predicted results for all the COPCs but ^{99}Tc are quite low, when compared to their maximum concentrations currently observed in the RGA. For ^{99}Tc, the observed maximum concentrations of 3,670 pCi/L falls within the predicted range of 1,996 pCi/L (30-year peak) to 21,686 pCi/L (100-year peak).

Table E1.29. Summary of Transport Modeling in the RGA Based on Future Contaminant Loading from SWMUs 7 and 30

Constituent	Unit	Predicted maximum concentration beneath the source	Predicted GW concentration at the PGDP boundary in the direction of flow		Predicted GW concentration at the DOE property boundary in the direction of flow	
			30 years	100 years	30 years	100 years
1,2-DCE	µg/L	27	16.8	24.3	5.2	5.2
cis-12-DCE	µg/L	12.3	4.6	11.3	1.5	2.7
TCE	µg/L	5.3	3.8	4.6	1.1	1.1
Methylene chloride	µg/L	0.8	0.14	0.8	0.05	0.19
Vinyl chloride	µg/L	1.0	0.15	0.96	0.06	.23
2,4-Dimethylphenol	µg/L	200	174	1.74	4.1	40.7
^{99}Tc	pCi/L	23,580	1,996	21,686	1,205	5,077

Note: All the constituents that were identified as the initial contaminant migration COPCs in the source areas (i.e., SWMUs 7 and 30, and also the UCRS beneath the site) were modeled to the RGA. However, only the constituents that were predicted to arrive at the RGA with concentrations exceeding their groundwater MCLs/RBCs were modeled to the receptors using AT123D and are shown in this table. All the concentrations shown in this table represent only the contributed concentrations and do not account for the existing concentrations that already have contaminated the RGA groundwater.

Based on fate and transport analyses results, it appears that ^{99}Tc is the only constituent that will continue to be a major problem at the receptor locations. Therefore, ^{99}Tc was chosen for further fate and transport evaluations in order to address the source units within SWMUs 7 and 30, separately, in terms of contaminant contributions to the receptor locations. Vertical transport of ^{99}Tc from the individual source units through the UCRS to the RGA were performed using SESOIL. The results from the SESOIL modeling were used to create input for an AT123D model that was applied for predicting lateral migration of ^{99}Tc to the receptor locations. These results are summarized in Table E1.30. Concentration contributions from the individual source units are added to provide the total contributed concentrations based on future loading from SWMUs 7 and 30. The relative (%) contributions of individual source units are also shown (values in parentheses) in this table.

Table E1.30. Results of ^{99}Tc Modeling in the RGA Based on Future Contaminant Loading from the Individual Source Units within SWMUs 7 and 30

Constituent	Units	Predicted Maximum Concentration Beneath the Source	Predicted GW Concentration at the PGDP Boundary in the Direction of Flow		Predicted GW Concentration at the DOE Property Boundary in the Direction of Flow	
			30 years	100 years	30 years	100 years
Burial Pit A	pCi/L	60.8 (0.65)	3.1 (0.46)	34.2 (0.47)	1.3 (0.35)	6.3 (0.4)
Burial Pits B/C	pCi/L	3,253.8 (35.02)	165.2 (24.79)	1,822.8 (25.09)	71.2 (19.03)	291.3 (19.1)
Burial Pit F	pCi/L	12.7 (0.14)	0.6 (0.09)	6.5 (0.09)	0.2 (0.05)	1.0 (0.07)
Subsurface soils outside these pits	pCi/L	5,962.5 (64.19)	497.4 (74.66)	5,400.3 (74.35)	301.5 (80.67)	1,228.0 (80.43)
Combined SWMUs 7 and 30	pCi/L	9289.8 (100.00)	666.3 (100.00)	7263.8 (100.00)	347.2 (100.00)	1526.6 (100.00)

Note: All the concentrations shown in this table represent only the contributed concentrations and do not account for the existing concentrations that are already present in the aquifer. Percent of total contribution from SWMUs 7 and 30 combined are shown in parentheses.

E1.7. MODELING APPEARING IN THE SITEWIDE RISK ASSESSMENT MODEL AND ENVIRONMENTAL BASELINE REPORT

Groundwater fate and transport modeling and risk modeling for SWMUs 2, 3, 4, 5, 6, 7, and 30 was performed as part of the PGDP sitewide risk assessment model and environmental baseline (DOE 2003). This section summarizes the results of this modeling for these SWMUs and is taken from *Sitewide Risk Assessment Model and Environmental Baseline for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2003).

The models selected for groundwater modeling were SESOIL for soil leachability and AT123D for lateral transport in groundwater. The MODFLOW/MODPATH models were used to support the AT123D

modeling. The COPC list for groundwater transport modeling was derived from the full list of significant COPCs. The results of this modeling include the chemical-specific maximum source contributions to cancer risk, hazard and dose for the SWMUs at four integrator points.

Four groundwater integrator points were determined to be relevant to the exposure conceptual site model and endstate goals. At each of these locations, it was assumed that residents could be exposed to contamination originating at PGDP through household use of groundwater, even though no water wells used for this purpose are present at these locations at this time. These integrator points are:

- **Integrator Point 1 (GW-NW-P).** This integrator point is located on the northwest side of the DOE reservation at the center of the current northwest TCE groundwater plume. Sources to this integrator point include SWMUs 2, 3, 5, 6, 7, and 30.

- **Integrator Point 2 (GW-SW-P).** This integrator point is located on the northwest side of the DOE reservation to the west of Integrator Point 1 at a point to which the center of the southwest TCE plume is expected to migrate. (The southwest plume has *not* reached this location.) Sources to this integrator point include SWMU 4.

- **Integrator Point 3 (GW-NE-P).** This integrator point is located on the northeast side of the DOE reservation at the center of the current northeast TCE plume.

- **Integrator Point 4 (GW-North).** This integrator point is located on the north side of the DOE reservation between Integrator Points 1 and 3 and is not associated with any currently identified plume.

E1.7.1 SESOIL MODELING

The SESOIL model is described in Section E1.6.1. The input data are divided into four types: climatic, chemical, soil, and application data. An overview of the parameters used for the sitewide risk assessment modeling follows. Specific parameters used are presented in Appendix E of *Sitewide Risk Assessment Model and Environmental Baseline for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2003)

E1.7.1.1 Climate Data

The climatic data file of SESOIL consists of an array of values for various climatic parameters. These monthly data span 1 year and are derived from Paducah. The climatic parameters are used within SESOIL to generate the hydrologic model responsible for contaminant transport.

E1.7.1.2 Chemical Data

The pollutant fate cycle of SESOIL uses several chemical transport and transformation processes that occur in the soil zone. The processes of volatilization/diffusion, adsorption/desorption, and biodegradation are used in SESOIL modeling for the purpose of the soil leachability analysis.

E1.7.1.3 Soil Data

The soil data file of SESOIL contains input parameters describing the physical characteristics of the subsurface soil. The parameters include soil bulk density, intrinsic permeability, soil disconnectedness index, Freundlich exponent, total porosity, and organic carbon content. The groundwater recharge rates (infiltration rates) were obtained from the PGDP sitewide groundwater model (DOE 1998b). These

recharge rates were used in SESOIL modeling as a calibration target. The intrinsic permeability for the vadose zone is a critical model parameter in that it permits calibration to the target groundwater recharge rate. The intrinsic permeability was varied in iterative runs until the groundwater recharge rate predicted by SESOIL matched the recharge rate obtained from the groundwater model. Unit-specific data were not available for some of the parameters); therefore, EPA default values were used as input to the model. These parameters included the soil disconnectedness index and Freundlich exponent. There is no measurement method for the soil disconnectedness index (described below), nor is there a measured value of the related Freundlich exponent (used in calculating the adsorbed contaminant concentration). The soil disconnectedness index replaces moisture retention curves (or characteristic curves) used by other unsaturated zone leaching models. The soil disconnectedness index was calibrated for four different soil types ranging from sandy loam to clay (Hetrick *et al*. 1986). This parameter has a minor impact upon the groundwater recharge rate and is varied (within the range specified for the corresponding soil type) in the final stages of model calibration. The SESOIL default value was used for the Freundlich exponent.

E1.7.1.4 Application Parameters

The SESOIL application data describe the soil layer configuration and the initial contaminant concentrations in each model layer. The SESOIL model was arranged in layers and sublayers that facilitate contaminant loading at intervals closely approximating the actual waste placement in the disposal facility. They represent constituent loading or leaching zones, as appropriate. The initial loading concentrations (source term) for SESOIL layers are the soil concentrations observed at individual sites. The SESOIL model for any group of SWMUs contained four major layers with multiple sublayers to model leaching through the vadose zone. The thickness of the layers varied depending on depth to the RGA and thickness of the contaminated soil zone within the vadose zone. In these analyses in general, Layers 1 and 2 are assumed for source loading, and the remaining layers are assigned for leaching zones. The last sublayer of Layer 4 represents the interface of the vadose zone and the RGA beneath the site. The predicted leachate concentration is determined in this last sublayer of Layer 4. The simulations using SESOIL were continued until the maximum concentration in leachate beneath the source was attained or a maximum time period of 1,000 years was reached. The maximum predicted leachate concentrations were input into the AT123D model to predict the maximum groundwater concentration at the integrator points.

E1.7.2 AT123D MODELING

The AT123D model is described in Section E1.6.2. For the sitewide risk assessment modeling, AT123D was chosen to predict the future integrator point concentrations for the COPCs. Specific model input parameters for the AT123D are presented in Appendix E of *Sitewide Risk Assessment Model and Environmental Baseline for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2003).

E1.7.3 MODFLOW AND MODPATH MODELING

The MODFLOW/MODPATH models were used to identify the locations of the integrator points and estimate hydraulic gradients, flow distances, and hydraulic conductivities along SWMU-to-integrator flowpaths. This information was subsequently used to support the AT123D modeling effort. MODFLOW is a three-dimensional, finite-difference model capable of simulating both steady-state and transient head distribution for a saturated groundwater flow field. In contrast, MODPATH is a three-dimensional, particle-tracking model capable of using the steady-state, head distribution generated by MODFLOW to track flowpaths of particles released in the groundwater flow field modeled by MODFLOW.

The MODFLOW model used in this analysis was the sitewide groundwater flow model developed earlier by DOE (1998b). This model covers most of the DOE reservation except that portion above the Porter's Creek Clay terrace. It has been approved by both the PGDP Modeling Steering Committee and the Risk Assessment Working Group; therefore, this model was used without any modification. The parameters used in this model are summarized in the PGDP Quarterly Modeling Report (BJC 2001) and are not discussed further here.

As noted above, the MODPATH model was used to track flowpaths of particles released from a location by using the steady-state head distribution generated by MODFLOW. The key parameter of MODPATH is the particle depth at release. For grouping the SWMUs assigned to different integrator points, the mid-depth of Layer 3 was assumed to represent the average flow condition, and the particles were released from this depth of an aquifer.

E1.7.4 MODELING ASSUMPTIONS

A highly conservative approach was used for this analysis. Several assumptions were made in developing the mathematical models for this analysis. The important assumptions are listed below.

- Infiltration of water through vadose zone soil consists of one-dimensional, steady flow through soil with no dispersion and with uniform average soil properties. More complex flow could either increase or decrease contaminant mobility and transport to the RGA.

- The use of K_d and R_d (retardation factor) to describe the reaction term of the transport equation assumes that an equilibrium relationship exists between the solid- and solution-phase concentrations and that the relationship is linear and reversible.

- Most of the K_d values used in this analysis for the COPCs represent literature-based or calculated values and might not represent the actual site conditions.

- No biodegradation takes place in the vadose zone (i.e., SESOIL modeling assumes no decay) or in the groundwater (i.e., AT123D modeling without accounting for biodegradation).

- In case of radionuclides and organic compounds, ingrowth and decay are not considered.

- Flow and transport in the vadose zone are one-dimensional (i.e., take place in only the vertical direction).

- Initial condition is disregarded in the vadose zone modeling.

- Flow and transport are not affected by density variations.

- Areal distribution of soil contamination is not considered.

- The aquifer is assumed to be homogenous and isotropic.

- The integrator point is located at a nearest downgradient distance.

The inherent uncertainties associated with using these assumptions must be recognized. Because K_d values are highly sensitive to changes in the major chemistry of the solution phase, it is important that the

values be measured or estimated under conditions that will represent, as closely as possible, those of the contaminant plume. It is also important to note that the contaminant plume will change over time and be affected by multiple solutes that are present at the site. Projected organic concentrations in the aquifer are uncertain because of the lack of site-specific data on constituent decay in the vadose zone and groundwater. Use of literature values could produce either over- or underestimation of constituents' concentrations in the aquifer. Deviations from assumed literature values could significantly affect contaminant fate predictions.

E1.7.5 COPC LIST USED IN GROUNDWATER TRANSPORT MODELING

The COPC list for soil and sediment that act as a source for contamination that might arrive at a groundwater integration point (i.e., a location downgradient from the source) was derived from the full list of significant COPCs by deleting those COPCs that could not reasonably be expected to migrate through the groundwater pathway and arrive at an integration point at a concentration greater than the screening levels. The COPCs not expected to migrate through the groundwater pathway were selected by considering each COPC's site-specific K_d and removing those inorganic chemical and radionuclide COPCs with a K_d greater than 500 L/kg and those organic compound COPCs with a K_d greater than 10 L/kg. Additionally, all radionuclides with a half-life less than 6 years (i.e., will pass through five half-lives in a 30-year period) were removed. The COPCs expected to migrate through the groundwater pathway are indicated in Table E1.31.

Table E1.31. COPC List for Groundwater Transport Modeling

Inorganic Chemicals		Organic Compounds		Radionuclides	
Significant COPC	**CAS Number**	**Significant COPC**	**CAS Number**	**Significant COPC**	**CAS Number**
Antimony	7440360	Acrylonitrile	107131	Neptunium-237+D	13994202
Arsenic	7440382	Benzene	71432	Strontium-90+D	10098972
Cadmium	7440439	Carbon tetrachloride	56235	Technetium-99	14133767
Chromium III	16065831	Chloroform	67663	Uranium-234	13966295
Chromium VI	18540299	1,1-Dichloroethene	75354	Uranium-235+D	15117961
Chromium (Total)	7440473	1,2-Dichloroethene (mixed)	540590	Uranium-238+D	7440611
Copper	7440508	*trans*-1,2-Dichloroethene	156605		
Iron	7439896	*cis*-1,2-Dichloroethene	156592		
Lead	7439921	Ethylbenzene	100414		
Manganese	7439965	Naphthalene	91203		
Mercury	7439976	Tetrachloroethene	127184		
Molybdenum	7439987	Trichloroethene	79016		
Nickel	7440020	Vinyl chloride	75014		
Selenium	7782492	Xylenes (mixture)	1330207		
Silver	7440224				
Thallium	7440280				
Uranium	NA				

Note: Table adapted from DOE 2003.
CAS=Chemical Abstracts Service.
NA = not applicable.
[a] The list of significant COPCs matches that presented in Table 3.1 [of DOE 2003], except individual organic compounds comprising the total PAHs, total PCBs, and total dioxins/furans groups are not listed.
[b] The COPCs not expected to migrate through the groundwater pathway were selected by considering each COPC's site-specific K_d and removing those inorganic chemical and radionuclide COPCs with a K_d greater than 500 L/kg and those organic compound COPCs with a K_d greater than 10 L/kg. Additionally, all radionuclides with a half-life less than 6 years (i.e., will pass through five half-lives in a 30-year period) were removed.

E1.7.6 MODELING RESULTS

Table E1.32 presents the chemical-specific maximum source contributions to cancer risk, hazard, and dose for SWMUs 2, 3, 4, 5, 6, 7, and 30 at the groundwater integrator points (DOE property boundary). The concentrations used to derive the risks and doses came from the maximum flux contribution information resulting from the groundwater modeling. The table also includes the expected maximum COPC concentrations predicted by the groundwater modeling.

Table E1.32. Maximum Cancer Risk, Hazard, and Dose for Sources Contributing at the DOE Property Boundary

COPC[a]	SWMU						
	2	3	4	5	6	7	30
	Concentrations (mg/L or pCi/L)						
Antimony	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Arsenic	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cadmium	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chromium	1.80E-02	2.07E-02	1.50E-01	1.77E-01	6.95E-02	4.23E-01	0.00E+00
Copper	1.27E-02	8.28E-03	3.92E-01	7.10E-03	9.05E-03	1.18E+01	2.43E-02
Iron	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lead	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Manganese	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mercury	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Molybdenum	2.62E-03	2.11E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Selenium	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.20E-10	0.00E+00
Silver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thallium	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Uranium	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.80E-03	0.00E+00
Carbon tetrachloride	0.00E+00	0.00E+00	2.21E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chloroform	0.00E+00	0.00E+00	4.90E+02	0.00E+00	0.00E+00	9.86E-04	0.00E+00
Dichloroethene (mixed), 1,2-	0.00E+00	0.00E+00	6.34E+01	0.00E+00	0.00E+00	5.92E-03	0.00E+00
Dichloroethene, 1,1-	0.00E+00	0.00E+00	1.68E+01	2.33E-01	0.00E+00	0.00E+00	0.00E+00
Dichloroethene, *cis*-1,2-	1.98E+01	0.00E+00	2.15E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dichloroethene, *trans*-1,2-	0.00E+00	0.00E+00	9.24E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ethylbenzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.41E-03	0.00E+00
Naphthalene	3.94E-03	6.01E-03	0.00E+00	3.50E-01	0.00E+00	6.32E-03	2.11E-02
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.58E-05	0.00E+00
Trichloroethene	8.06E+00	0.00E+00	4.10E+01	5.18E-04	2.19E-04	1.02E-03	5.70E-04
Vinyl chloride	6.08E-02	0.00E+00	2.90E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xylenes (mixture)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.81E-02	0.00E+00
Neptunium-237+D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Strontium-90+D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	4.83E+02	9.69E+01	2.08E+03	6.53E+01	3.60E+02	1.12E+04	4.79E+03
Uranium-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Uranium-235+D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Uranium-238+D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table E1.32. Maximum Cancer Risk, Hazard, and Dose for Sources Contributing at the DOE Property Boundary (Continued)

COPC[a]	SWMU						
	2	3	4	5	6	7	30
	Cancer Risk						
Antimony	NR	NR	NR	NR	NR	NR	NR
Arsenic	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cadmium	NR	NR	NR	NR	NR	NR	NR
Chromium	NR	NR	NR	NR	NR	NR	NR
Copper	NR	NR	NR	NR	NR	NR	NR
Iron	NR	NR	NR	NR	NR	NR	NR
Lead	NR	NR	NR	NR	NR	NR	NR
Manganese	NR	NR	NR	NR	NR	NR	NR
Mercury	NR	NR	NR	NR	NR	NR	NR
Molybdenum	NR	NR	NR	NR	NR	NR	NR
Nickel	NR	NR	NR	NR	NR	NR	NR
Selenium	NR	NR	NR	NR	NR	NR	NR
Silver	NR	NR	NR	NR	NR	NR	NR
Thallium	NR	NR	NR	NR	NR	NR	NR
Uranium	NR	NR	NR	NR	NR	NR	NR
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.51E-05	0.00E+00
Carbon	0.00E+00	0.00E+00	1.22E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chloroform	0.00E+00	0.00E+00	2.25E+00	0.00E+00	0.00E+00	4.52E-06	0.00E+00
Dichloroethene (mixed), 1,2-	NR	NR	NR	NR	NR	NR	NR
Dichloroethene, 1,1-	0.00E+00	0.00E+00	3.58E-01	4.96E-03	0.00E+00	0.00E+00	0.00E+00
Dichloroethene, *cis*-1,2-	NR	NR	NR	NR	NR	NR	NR
Dichloroethene, *trans*-1,2-	NR	NR	NR	NR	NR	NR	NR
Ethylbenzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.37E-06	0.00E+00
Naphthalene	NR	NR	NR	NR	NR	NR	NR
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.59E-08	0.00E+00
Trichloroethene	4.66E-03	0.00E+00	2.37E-02	3.00E-07	1.27E-07	5.91E-07	3.29E-07
Vinyl	1.74E-03	0.00E+00	8.29E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xylenes	NR	NR	NR	NR	NR	NR	NR
Neptunium-237+D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Strontium-90+D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	3.45E-05	6.92E-06	1.49E-04	4.67E-06	2.57E-05	8.00E-04	3.42E-04
Uranium-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Uranium-235+D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Uranium-238+D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table E1.32. Maximum Cancer Risk, Hazard, and Dose for Sources Contributing at the DOE Property Boundary (Continued)

COPC[a]	SWMU 2	SWMU 3	SWMU 4	SWMU 5	SWMU 6	SWMU 7	SWMU 30
	Hazard Results						
Antimony	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Arsenic	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cadmium	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chromium	1.02E-03	1.18E-03	8.54E-03	1.01E-02	3.95E-03	2.40E-02	0.00E+00
Copper	2.28E-02	1.49E-02	7.04E-01	1.27E-02	1.63E-02	2.12E+01	4.37E-02
Iron	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lead	NR	NR	NR	NR	NR	NR	NR
Manganese	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mercury	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Molybdenum	3.48E-02	2.80E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Selenium	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.25E-09	0.00E+00
Silver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thallium	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Uranium	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.15E+00	0.00E+00
Carbon tetrachloride	0.00E+00	0.00E+00	1.16E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chloroform	0.00E+00	0.00E+00	1.71E+06	0.00E+00	0.00E+00	3.44E+00	0.00E+00
Dichloroethene (mixed), 1,2-	0.00E+00	0.00E+00	2.57E+03	0.00E+00	0.00E+00	2.40E-01	0.00E+00
Dichloroethene, 1,1-	0.00E+00	0.00E+00	1.10E+02	1.52E+00	0.00E+00	0.00E+00	0.00E+00
Dichloroethene, *cis*-1,2-	7.26E+02	0.00E+00	7.89E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dichloroethene, *trans*-1,2-	0.00E+00	0.00E+00	1.69E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ethylbenzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.14E-02	0.00E+00
Naphthalene	1.38E+00	2.11E+00	0.00E+00	1.23E+02	0.00E+00	2.22E+00	7.42E+00
Tetrachloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.63E-04	0.00E+00
Trichloroethene	5.04E+02	0.00E+00	2.56E+03	3.24E-02	1.37E-02	6.39E-02	3.56E-02
Vinyl chloride	1.99E+00	0.00E+00	9.48E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xylenes (Mixture)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.11E-01	0.00E+00
Neptunium-237+D	NR	NR	NR	NR	NR	NR	NR
Strontium-90+D	NR	NR	NR	NR	NR	NR	NR
Technetium-99	NR	NR	NR	NR	NR	NR	NR
Uranium-234	NR	NR	NR	NR	NR	NR	NR
Uranium-235+D	NR	NR	NR	NR	NR	NR	NR
Uranium-238+D	NR	NR	NR	NR	NR	NR	NR
	Dose Results[b]						
Neptunium-237+D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Strontium-90+D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	4.93E-01	9.91E-02	2.13E+00	6.68E-02	3.68E-01	1.14E+01	4.90E+00
Uranium-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Uranium-235+D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Uranium-238+D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Note: Table adapted from DOE 2003.
"NR" = Result is not reported because no screening value is available.
[a] Only COPCs identified as being mobile through the groundwater pathway are listed.
[b] Does results are only applicable to radionuclides.

Most of the metals and radionuclides are not expected to migrate to the integrator points at any measurable concentrations. The only metal that that is predicted to have a higher concentration is chromium. SWMUs 7 and 5, and 4 might be contributing to the chromium problem at Integrator Points 4, 1, and 2, respectively. The only radionuclide that is predicted to have a higher concentration is ^{99}Tc. The contributing sources for ^{99}Tc are SWMU 4 for Integrator Point 2, and SWMUs 7 and 30 for Integrator Point 1. The chlorinated solvents are expected to migrate to their respective integrator points at significant concentrations from multiple SWMUs, including SWMUs 2 and 5 for Integrator Point 1 and SWMUs 4 and 1 for Integrator Point 2. None of the SWMUs is expected to contribute chlorinated solvents to either Integrator Points 3 or 4. Among the semivolatile organic compounds (SVOCs), major contribution of naphthalene is expected to move from SWMU 30 to Integrator Point 1.

The greatest contributors of the COPCs presenting the maximum potential cancer risks are as follows. (All values reported below are potential cancer risks to the resident that are projected to exist if only the reported source contributed contaminants to groundwater.)

- 1,1-DCE: SWMU 4 (3.58E-01) and SWMU 5 (4.96E-03)
- Carbon tetrachloride: SWMU 4 (1.22E-01)
- Chloroform: SWMU 4 (>1)
- TCE: SWMU 2 (4.66E-03) and SWMU 4 (2.37E-02)
- Vinyl chloride: SWMU 2 (1.74E-03) and SWMU 4 (8.29E-03)
- ^{99}Tc: SWMU 2 (3.45E-05), SWMU 3 (6.92E-06), SWMU 4 (1.49E-04), SWMU 5 (4.67E-06), SWMU 6 (2.75E-05), SWMU 7 (8.00E-04), and SWMU 30 (3.23E-04),

The greatest contributors of the COPCs presenting the maximum potential hazards are as follows. (All values reported below are potential hazards to the resident that are projected to exist if only the reported source contributed contaminants to groundwater.)

- *cis*-1,2-DCE: SWMU 2 (726) and SWMU 4 (789,000)
- *trans*-1,2-DCE: SWMU 4 (169,000)
- Carbon tetrachloride: SWMU 4 (11,600)
- Chloroform: SWMU 4 (>1,000,000)
- TCE: SWMU 2 (504)
- Naphthalene: SWMU 2 (1.38), SWMU 3 (2.11), SWMU 5 (123), SWMU 7 (2.22), and SWMU 30 (7.24)
- Copper: SWMU 7 (21.2).

Finally, the greatest contributors of the COPCs presenting the maximum potential dose (in mrem/year) from ^{99}Tc are SWMU 4 (2.13), SWMU 7 (11.4), and SWMU 30 (4.90). (As before, the dose values are potential doses to the resident that are projected to exist if only the reported source contributed contaminants to groundwater.)

The assumptions for groundwater modeling were discussed in Section E1.7.4. The inherent uncertainties associated with using the assumptions must be recognized. Because K_d values are highly sensitive to changes in the major chemistry of the solution phase, it is important that the values be measured or estimated under conditions that will represent, as closely as possible, those of a contaminant plume. It is also important to note that any contaminant plume predicted to occur will change over time and be affected by multiple solutes that are currently present or may be present in the future at the site. Projected organic concentrations in the aquifer are overestimated because site-specific data on constituent decay in the vadose zone and in the groundwater is lacking, and zero decay was assumed for all organic compounds.

Neither the SESOIL nor AT123D models account for the in-growth of radionuclides. This may have resulted in an underestimation of representative concentrations of decay products with mobility higher than the starting radionuclide, and an overestimation of representative concentrations of decay products with mobility lower than the starting radionuclide. Similarly, because decay will reduce the concentration of the starting radionuclide in the source, the representative concentrations of the starting radionuclide may be overestimated. Fortunately, most of the radionuclide COPCs included in the modeling either have very short half-lives relative to the time modeled (i.e., ^{90}Sr) or very long half-lives relative to the time modeled (i.e., ^{99}Tc, ^{238}U, etc.). Therefore, in general, the decay and in-growth of radiological constituents should have very little effect on the risk characterization.

The effects of heterogeneity, anisotropy, and spatial distribution of fractures are not addressed in these simulations. The present modeling study using SESOIL and AT123D does not address the effects of flow and contaminant transport across interfaces in a sharply varying heterogeneous media. The migration distance predicted by the model may be uncertain mainly because of homogenous and isotropic assumptions were used in these models whereas site data indicate otherwise.

As such, a conservative approach was used to address the uncertainties. Based upon the data available, the values of the model parameters were selected to ensure that contaminant transport was not underestimated. Such an approach can be expected to lead to overestimates of COPC concentrations in groundwater at the integrator points and, subsequently, to overestimates of the cancer risks, hazards, and doses estimated.

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APPENDIX E
ATTACHMENT 2

SOURCE TERM DEVELOPMENT

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CONTENTS

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FIGURES

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E2.1 SOURCE TERM DEVELOPMENT

E2.1.1 INTRODUCTION

This attachment documents the development of Upper Continental Recharge System (UCRS) contaminant source terms for fate and transport modeling in the Burial Grounds Operable Unit (BGOU) Remedial Investigation (RI). The BGOU consists of Solid Waste Management Units (SWMUs) 2, 3, 4, 5, 6, 7, 30, and 145, as shown in Figure E2.1.

It is almost never possible to collect data at all possible locations in an area of interest. Although sampling will provide information at some locations, it still is necessary to use some method to "interpolate" the data that is available to estimate or predict the values at nondata locations. Spatial analysis, specifically geospatial interpolation techniques in Spatial Analysis and Decision Assistance (SADA)(UT 2002) was used to characterize the source zone in the UCRS soils.

The BGOU RI assesses the risk posed by contaminants for each SWMU; consequently fate and transport assessment requires separate models for each SWMU (and each assessed contaminant within each SWMU). Model domains extend from ground surface down to the top of the Regional Gravel Aquifer (RGA), commonly in seven layers that are discretized into rows and columns of uniform spacing. Table E2.1 summarizes the source term model domains.

Table E2.1. Summary of the Source Term Model Domains

SWMU	Modeled Area (acres)	Depth (ft) Simulated in Model	Grid Block Size (ft x ft)	Table of SADA Source Characterization Results[a]
2	0.73	64	20 x 20	SWMU 2 results.xls
3	3.86	65	100 x 100	SWMU 3 results.xls
4	6.49	63	20 x 20	SWMU 4 results.xls
5	4.43	60	20 x 20	SWMU 5 results.xls
6	0.19	63	10 x 10	SWMU 6 results.xls
7	2.53	60	20 x 20	SWMU 7 results.xls
30	2.70	61	20 x 20	SWMU 30 results.xls
145	44.40	58	100 x 100	SWMU 145 results.xls

[a] These SADA files are contained on the CD under the SADA directory

The discretized rows, columns, and layers defined the soil domain (volume). Observed data within the domain were compiled, and contaminant concentration in every cell of the domain was predicted using geospatial interpolation. Observed data were available at well sample locations scattered throughout the domain, and the interpolation was used to estimate the mass of contaminant between the sample locations.

Source term development consisted of the following steps:

- Initial interpolation runs of the observed data within the model domain
- Visual inspection of the results of interpolation runs
- Selection of an acceptable interpolation
- Final interpolation
- Analysis (post processing) of the final interpolation

The model domain consisted of a surface soil (0–1 ft below surface) layer and six other layers down to the top of the RGA. Only the surface soil (Layer 0) was interpolated separately because the majority of Layer 1 samples were sediments that were different in nature than the subsurface soils.

The geospatial interpolation techniques available in SADA for three-dimensional analyses are as follows:

- Nearest neighbor
- Inverse distance
- Kriging

An example of the geospatial analyses is provided for arsenic, *cis*-1,2-DCE, and TCE at SWMU 2. Figure E.2.1 provides the sample locations for SWMU 2. The measured data at the sample locations were used in SADA to evaluate the predicted mass for the contaminants using the various geospatial interpolation techniques. Three-dimensional fence diagrams of the interpolated arsenic, *cis*-1,2-DCE, and TCE concentrations were constructed using the Mining Visualization System, Version 9.0, by the C Tech Development Corporation. The fence diagrams are shown in Figures E2.2 through E2.4. These diagrams were used for comparison to the SADA interpolation results.

The results of the geospatial analysis using SADA for the three interpolation techniques are provided in Tables E2.2 through E2.10 for arsenic, *cis*-1,2-DCE and TCE.

Table E2.2. Nearest Neighbor Source Term Characteristics Developed by SADA f or Arsenic a t SWMU 2

SADA Layer	Depth (ft)	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]
L1	0-1	4.80E+04	4.80E+04	4.39E+04
L2	01-10	3.96E+04	3.56E+05	1.37E+05
L3	10-20	3.96E+04	4.36E+05	1.23E+05
L4	20-30	3.96E+04	4.36E+05	1.04E+05
L5	30-40	3.96E+04	4.36E+05	1.16E+05
L6	40-50	3.96E+04	4.36E+05	1.06E+05
L7	50-64	3.96E+04	3.56E+05	7.26E+04
		Total Mass		7.03E+05

Table E2.3. Inverse Distance Source Term Characteristics Developed b y SADA f or Arsenic a t SWMU 2

SADA Layer	Depth (ft)	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]
L1	0-1	4.80E+04	4.80E+04	0.00E+00
L2	01-10	3.96E+04	3.56E+05	1.65E+05
L3	10-20	3.96E+04	4.36E+05	8.01E+04
L4	20-30	3.96E+04	4.36E+05	5.93E+04
L5	30-40	3.96E+04	4.36E+05	1.06E+05
L6	40-50	3.96E+04	4.36E+05	1.34E+05
L7	50-64	3.96E+04	3.56E+05	3.25E+04
		Total Mass		5.78E+05

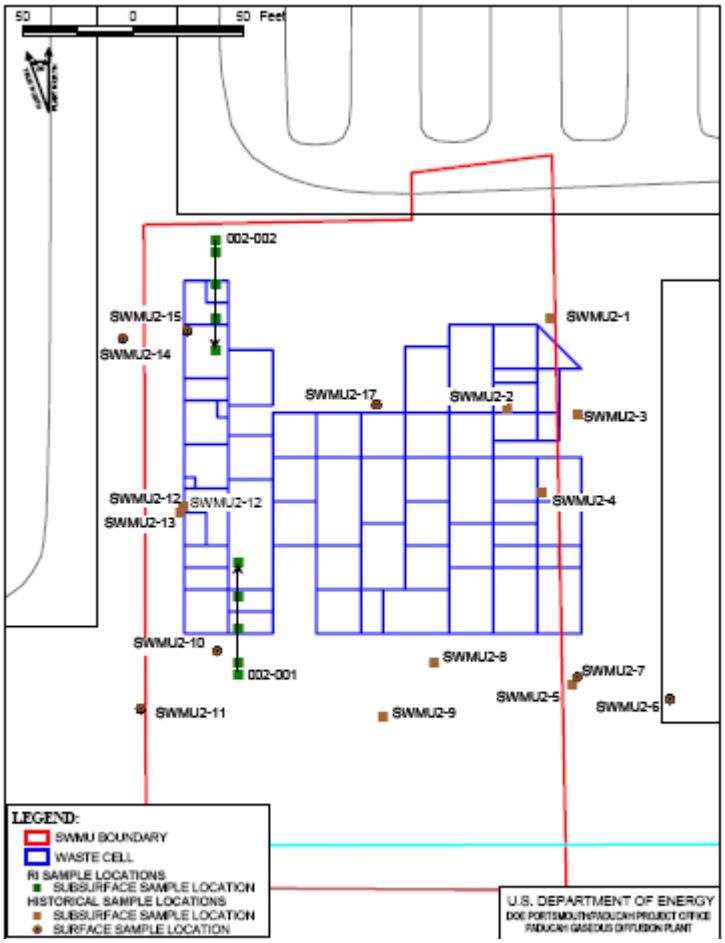

Figure E2.1. Samples Locations at SWMU 2

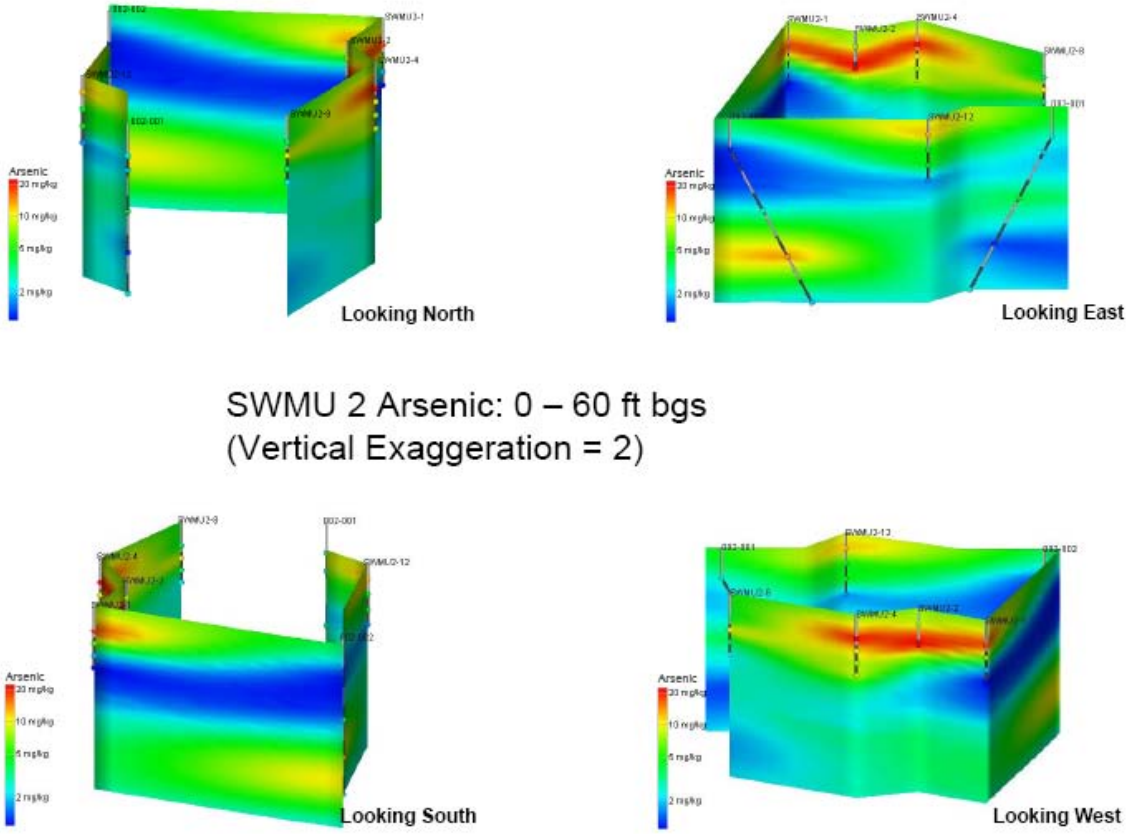

Figure E2.2. Arsenic Concentration Fence Diagrams for SWMU 2

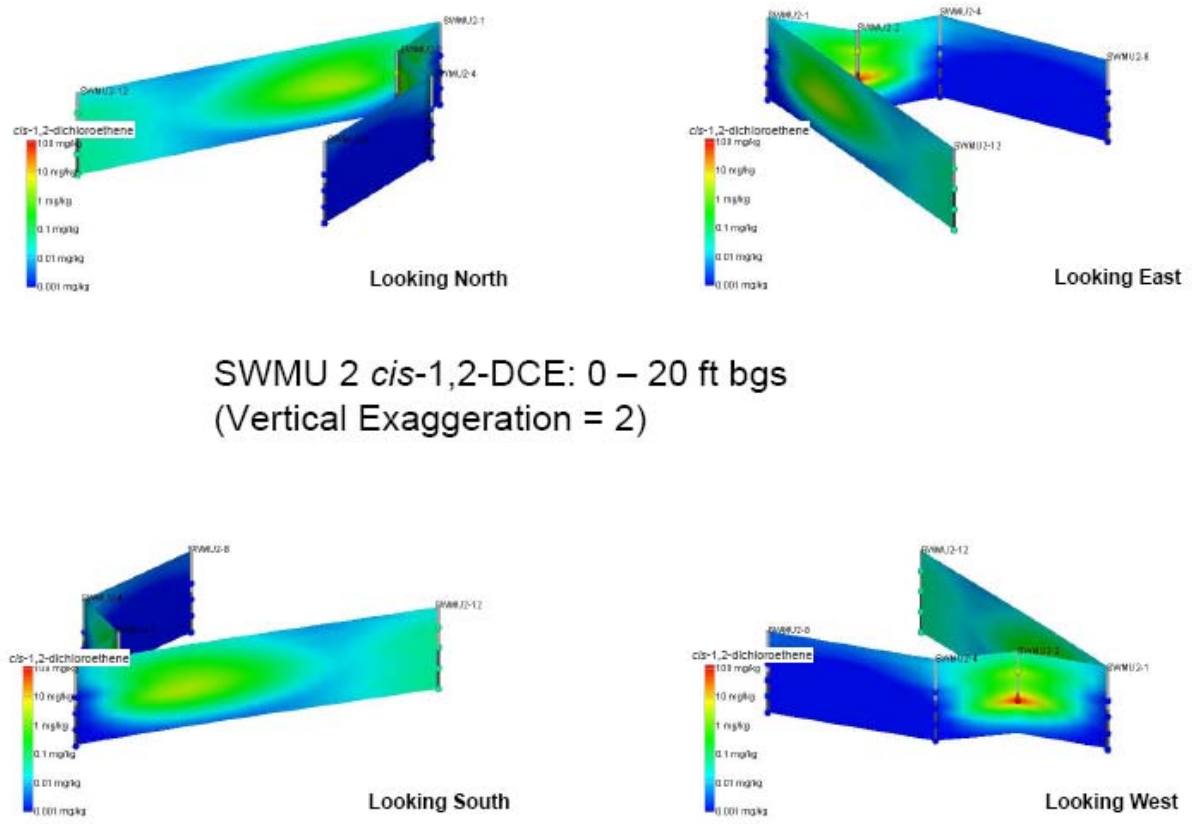

Figure E2.3. *Cis*-1,2-DCE Concentration Fence Diagrams for SWMU 2

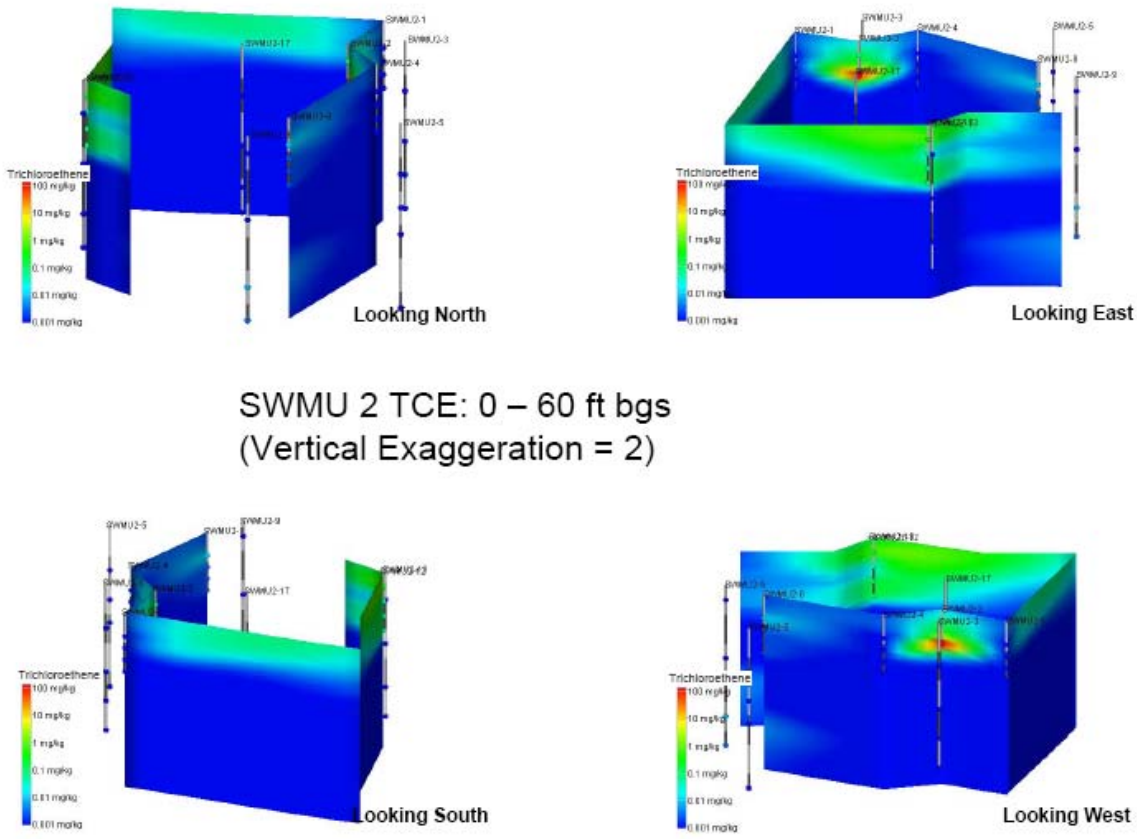

Figure E2.4. TCE Concentration Fence Diagrams for SWMU 2

Table E2.4. Ordinary Kriging Source Term Characteristics Developed by SADA for Arsenic at SWMU 2

SADA Layer	Depth (ft)	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]
L1	0-1	4.80E+04	4.80E+04	4.38E+04
L2	01-10	3.96E+04	3.56E+05	1.44E+05
L3	10-20	3.96E+04	4.36E+05	8.47E+04
L4	20-30	3.96E+04	4.36E+05	6.19E+04
L5	30-40	3.96E+04	4.36E+05	9.85E+04
L6	40-50	3.96E+04	4.36E+05	1.32E+05
L7	50-64	3.96E+04	3.56E+05	3.25E+04
		Total Mass		5.97E+05

Table E2.5. Nearest Neighbor Source Term Characteristics Developed by SADA for cis-1,2-DCE at SWMU 2

SADA Layer	Depth (ft)	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]
L1	0-1	0.00E+00	0.00E+00	0.00E+00
L2	01-10	1.64E+04	1.48E+05	7.17E+03
L3	10-20	6.80E+03	7.48E+04	3.55E+05
L4	20-30	9.60E+03	1.06E+05	3.08E+05
L5	30-40	8.40E+03	9.24E+04	3.08E+05
L6	40-50	1.16E+04	1.28E+05	2.37E+05
L7	50-64	1.12E+04	1.01E+05	1.55E+05
		Total Mass		1.37E+06

Table E2.6. Inverse Distance Source Term Characteristics Developed by SADA for cis-1,2-DCE at SWMU 2

SADA Layer	Depth (ft)	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]
L1	0-1	0.00E+00	0.00E+00	0.00E+00
L2	01-10	3.96E+04	3.56E+05	4.18E+04
L3	10-20	3.96E+04	4.36E+05	3.64E+04
L4	20-30	0.00E+00	0.00E+00	0.00E+00
L5	30-40	3.96E+04	4.36E+05	6.67E+02
L6	40-50	3.96E+04	4.36E+05	1.07E+03
L7	50-64	3.96E+04	3.56E+05	1.07E+02
		Total Mass		8.00E+04

Table E2.7. Ordinary Kriging Source Term Characteristics Developed by SADA for cis-1,2-DCE at SWMU 2

SADA Layer	Depth (ft)	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]
L1	0-1	0.00E+00	0.00E+00	0.00E+00
L2	01-10	2.52E+04	2.27E+05	7.94E+04
L3	10-20	3.20E+04	3.52E+05	2.33E+05
L4	20-30	0.00E+00	0.00E+00	0.00E+00
L5	30-40	3.84E+04	4.22E+05	6.03E+02
L6	40-50	3.96E+04	4.36E+05	1.09E+03
L7	50-64	3.96E+04	3.56E+05	1.06E+02
		Total Mass		3.15E+05

Table E2.8. Nearest Neighbor Source Term Characteristics Developed by SADA for TCE at SWMU 2

SADA Layer	Depth (ft)	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]
L1	0-1	0.00E+00	0.00E+00	0.00E+00
L2	01-10	9.60E+03	8.64E+04	5.11E+02
L3	10-20	9.20E+03	1.01E+05	1.78E+05
L4	20-30	1.16E+04	1.28E+05	1.28E+05
L5	30-40	1.16E+04	1.28E+05	7.69E+04
L6	40-50	1.28E+04	1.41E+05	5.20E+04
L7	50-64	1.08E+04	9.72E+04	8.06E+02
		Total Mass		4.37E+05

Table E2.9. Inverse Distance Source Term Characteristics Developed by SADA for TCE at SWMU 2

SADA Layer	Depth (ft)	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]
L1	0-1	0.00E+00	0.00E+00	0.00E+00
L2	01-10	4.80E+04	4.32E+05	2.73E+04
L3	10-20	4.80E+04	5.28E+05	3.80E+04
L4	20-30	4.80E+04	5.28E+05	9.20E-01
L5	30-40	4.80E+04	5.28E+05	3.27E+02
L6	40-50	4.80E+04	5.28E+05	2.22E+02
L7	50-64	4.80E+04	4.32E+05	2.85E+03
		Total Mass		6.87E+04

Table E2.10. Ordinary Kriging Source Term Characteristics Developed by SADA for TCE at SWMU 2

SADA Layer	Depth (ft)	Area (ft^2)	Volume (ft^3)	Mass (gm)[a]
L1	0-1	0.00E+00	0.00E+00	0.00E+00
L2	01-10	2.84E+04	2.56E+05	6.07E+04
L3	10-20	2.08E+04	2.29E+05	6.19E+04
L4	20-30	1.56E+04	1.72E+05	9.82E-01
L5	30-40	2.92E+04	3.21E+05	6.02E+02
L6	40-50	4.28E+04	4.71E+05	1.07E+03
L7	50-64	4.80E+04	4.32E+05	1.90E+03
		Total Mass		1.26E+05

The nearest neighbor geospatial interpolation provided the maximum total mass of contaminants in the system when compared to the inverse distance and ordinary kriging algorithms. This addresses in part the known low bias in the data caused by the inability to sample the waste. The nearest neighbor interpolation was selected because it provided greater contrast of the interpolated concentrations among the model cells and greater ease of source delineation through visual inspection as shown in Figures E2.5 through E2.7 for TCE. The inverse distance interpolation did not distinctly delineate the modeled contaminant plumes. Kriging interpolations in SADA involved variogram modeling. Modelers concluded that kriging interpolations were not suitable because semi-variogram values for the observed data did not follow monotonically increasing trends as shown in Figure E2.8.

The verification report for SADA (EPA 2000) states that "although geostatistical-based kriging interpolation approaches are more mathematically rigorous than the simple interpolation approaches using nearest neighbor, they are not necessarily better representations of the data. Statistical and geostatistical approaches attempt to minimize the mathematical constraint, similar to a least squares minimization used in curve-fitting of data. While the solution provided is the "best" answer within the mathematical constraints applied to the problem, it is not necessarily the best fit of the data. There are two reasons for this:

"First, in most environmental problems, the data are insufficient to determine the optimum model to use to assess the data. Typically, there are several different models that can provide a defensible assessment of spatial correlation in the data. Each of these models has its own strengths and limitations, and the model choice is subjective" (EPA 2000).

"This conundrum leads to the second reason for the difficulty, if not impossibility, of finding the most appropriate model to use for interpolation–which is that unless the analyst is extremely fortunate, the measured data will not conform to the mathematical model used to represent the data At best, the interpolation can be reviewed to determine if it is consistent with the data" (EPA 2000).

The nearest neighbor algorithm was used to evaluate the remaining COPCs at all SWMUs. Figure E2.9 shows typical flood contours of the source zone in the UCRS developed from the SADA interpolation in plan view. Three-dimensional figures illustrating the spatial distribution of COCs under each SWMU are provided in Figures E2.10–17. In addition, Figures E2.11 through E2.18 provide examples of the SADA nearest neighbor interpolation results for the layers with the highest total mass for COCs providing the majority of the risk or hazard at the SWMUs. Sample location circles were shaded to match legend scale on right side of

figure. Due to the large number of maps created with SADA (882 total) only one individual soil layer per SWMU with highest total mass was illustrated.

E2.2. REFERENCES

EPA. 2000. Environmental Technology Verification Report: Spatial Analysis and Decision Assistance (SADA), EPA/600/R-00/036, United States Environmental Protection Agency. February 2000.

UT (University of Tennessee) 2002. *Spatial Analysis and Decision Assistance (SADA*), Version 2.3, User Guide, January. Accessible at http://www.tiem.utk.edu/~sada/

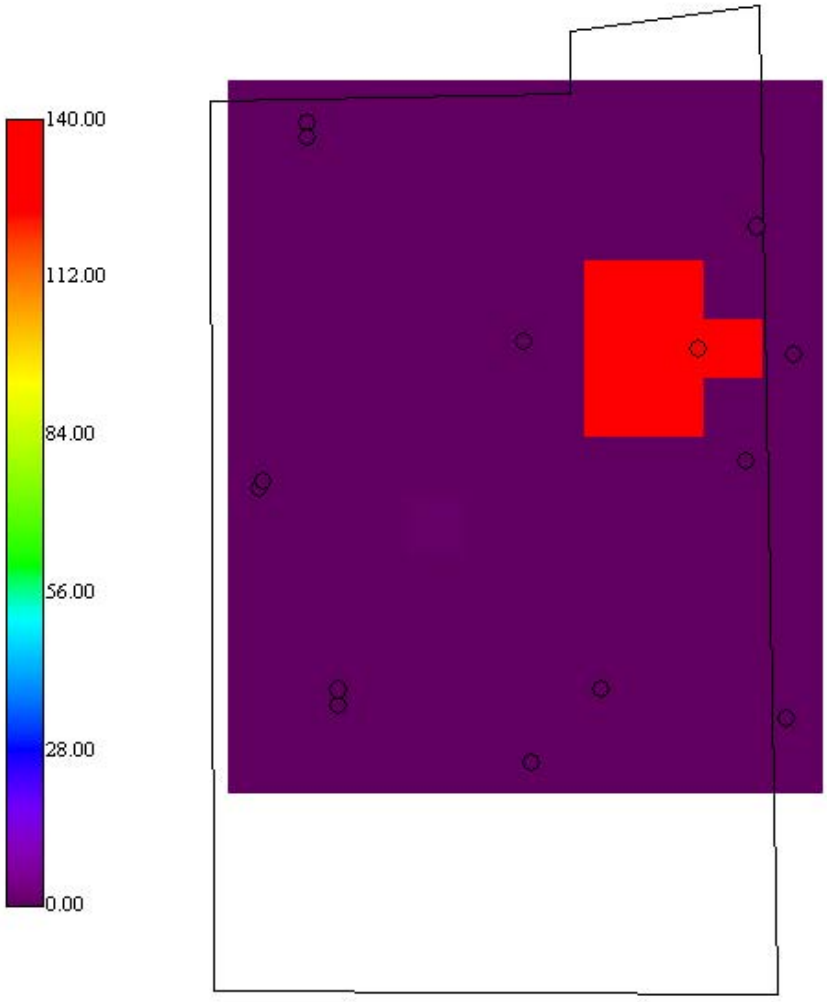

Figure E2.5. Interpolation Nearest Neighbor for SWMU 2–TCE

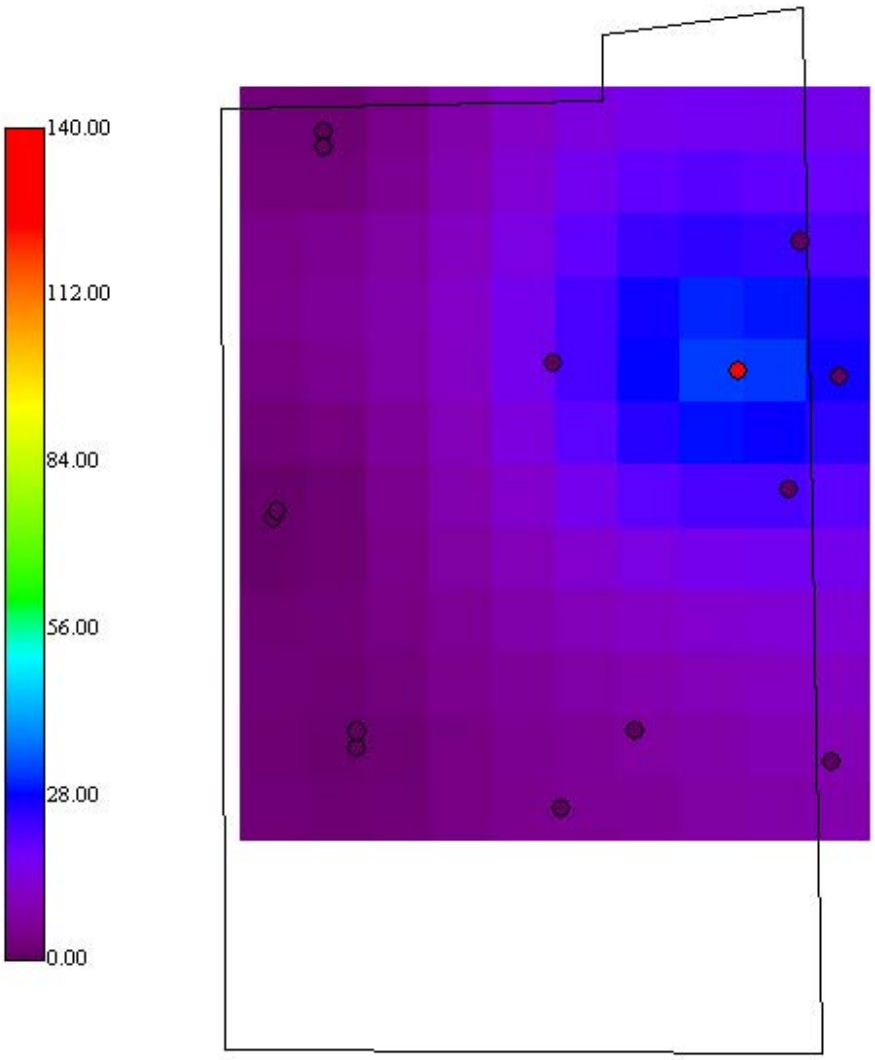

Figure E2.6. Interpolation Inverse Distance for SWMU 2–TCE

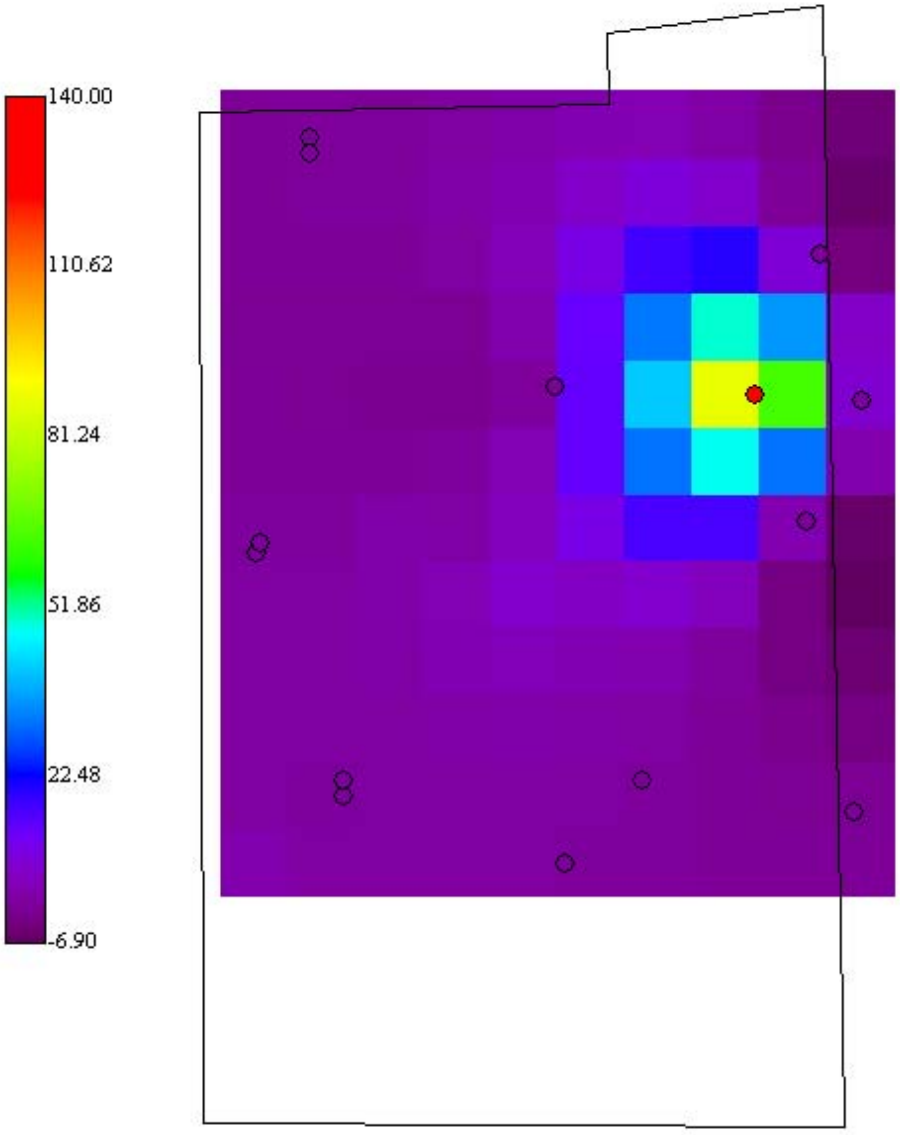

Figure E2.7. Interpolation Ordinary Kriging for SWMU 2–TCE

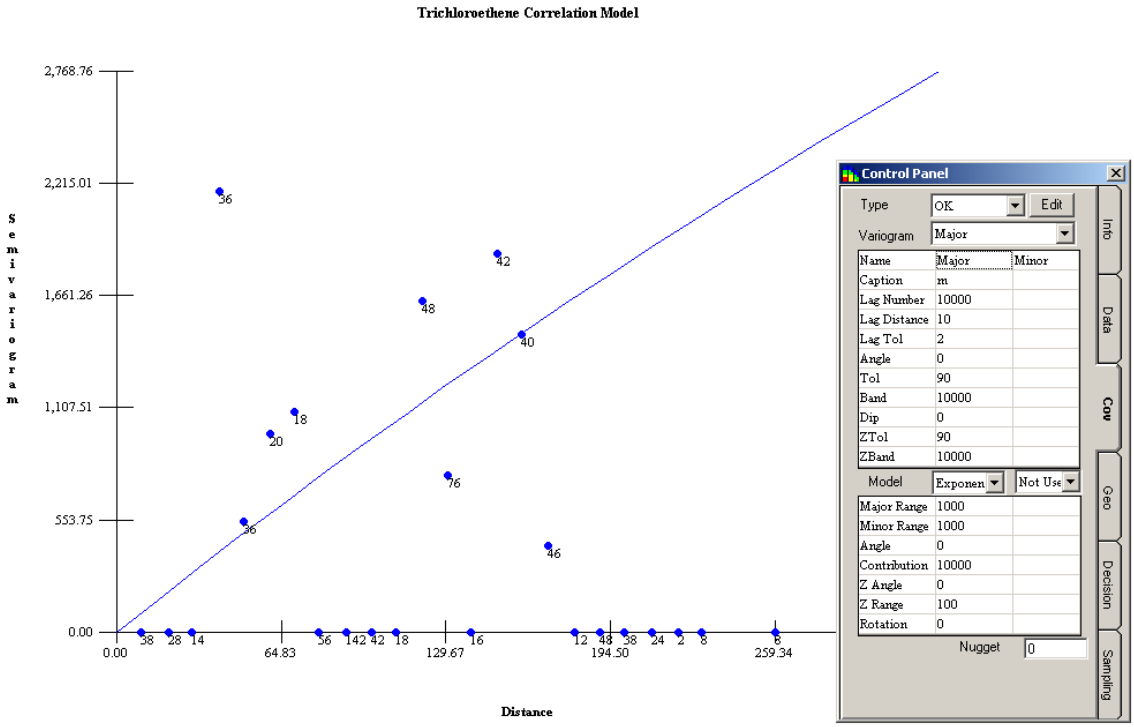

Figure E2.8. Ordinary Kriging Semi-Variogram for SWMU 2–TCE

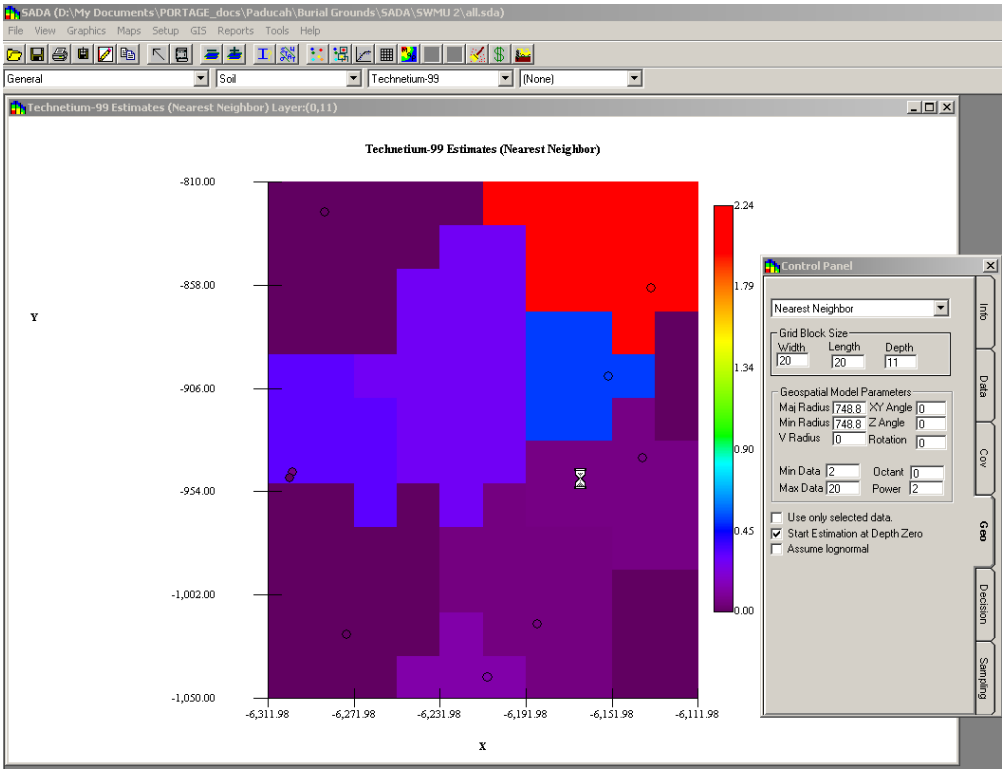

Figure E2.9. Typical SADA Nearest Neighbor Interpolation Map

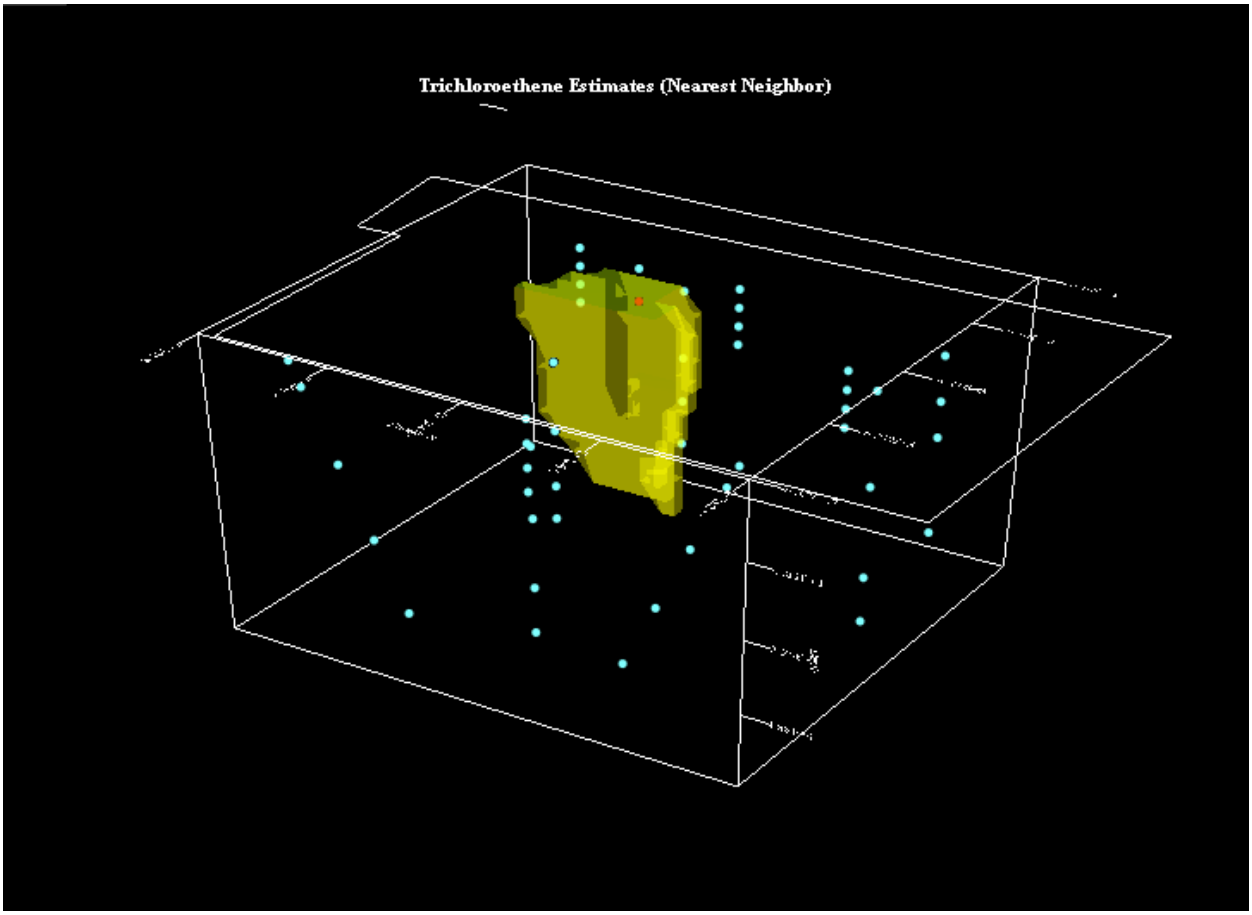

Figure E2.10. SWMU 2 TCE SADA Nearest Neighbor Interpolation Map (3-D)

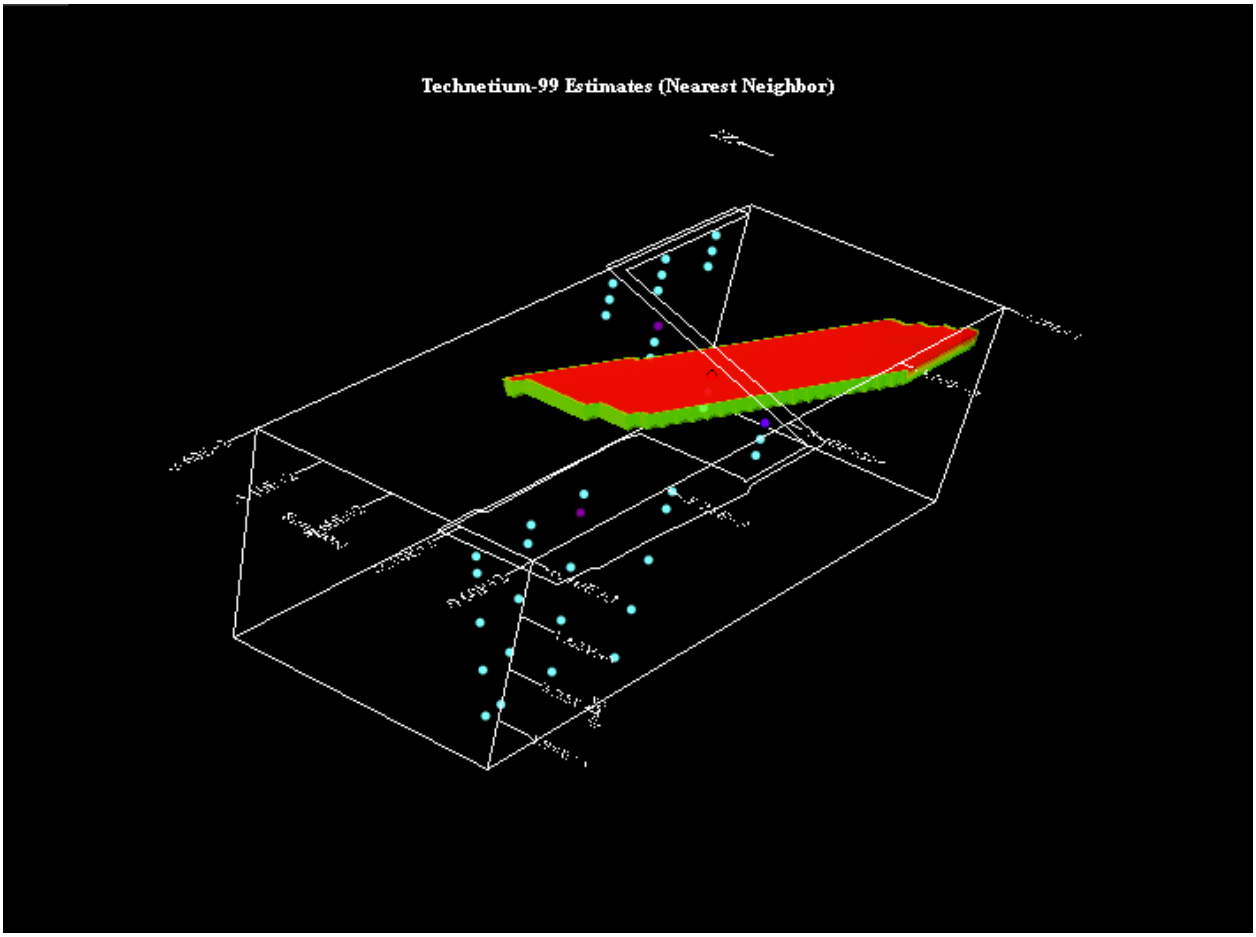

Figure E2.11. SWMU 3 ^{99}Tc SADA Nearest Neighbor Interpolation Map (3-D)

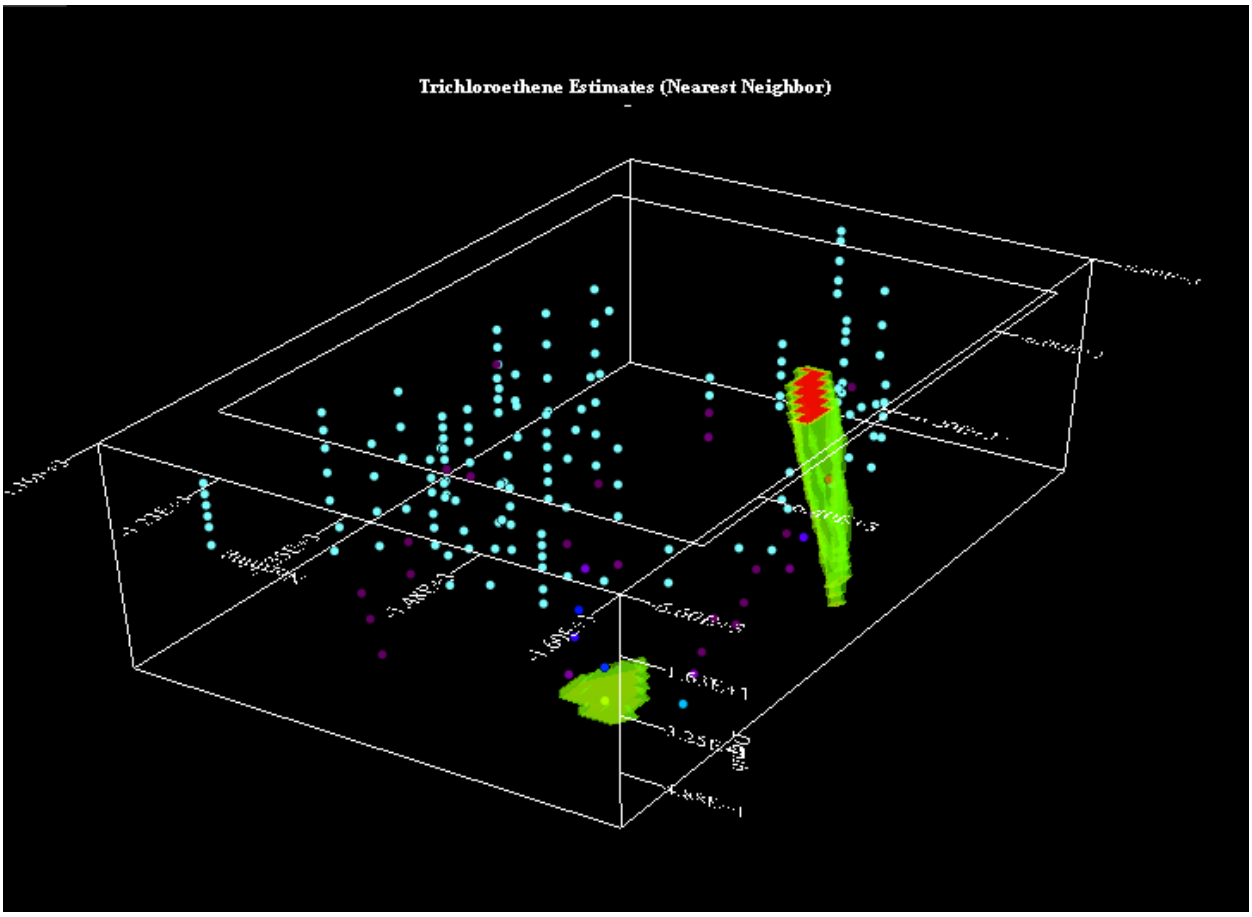

Figure E2.12. SWMU 4 TCE SADA Nearest Neighbor Interpolation Map (3-D)

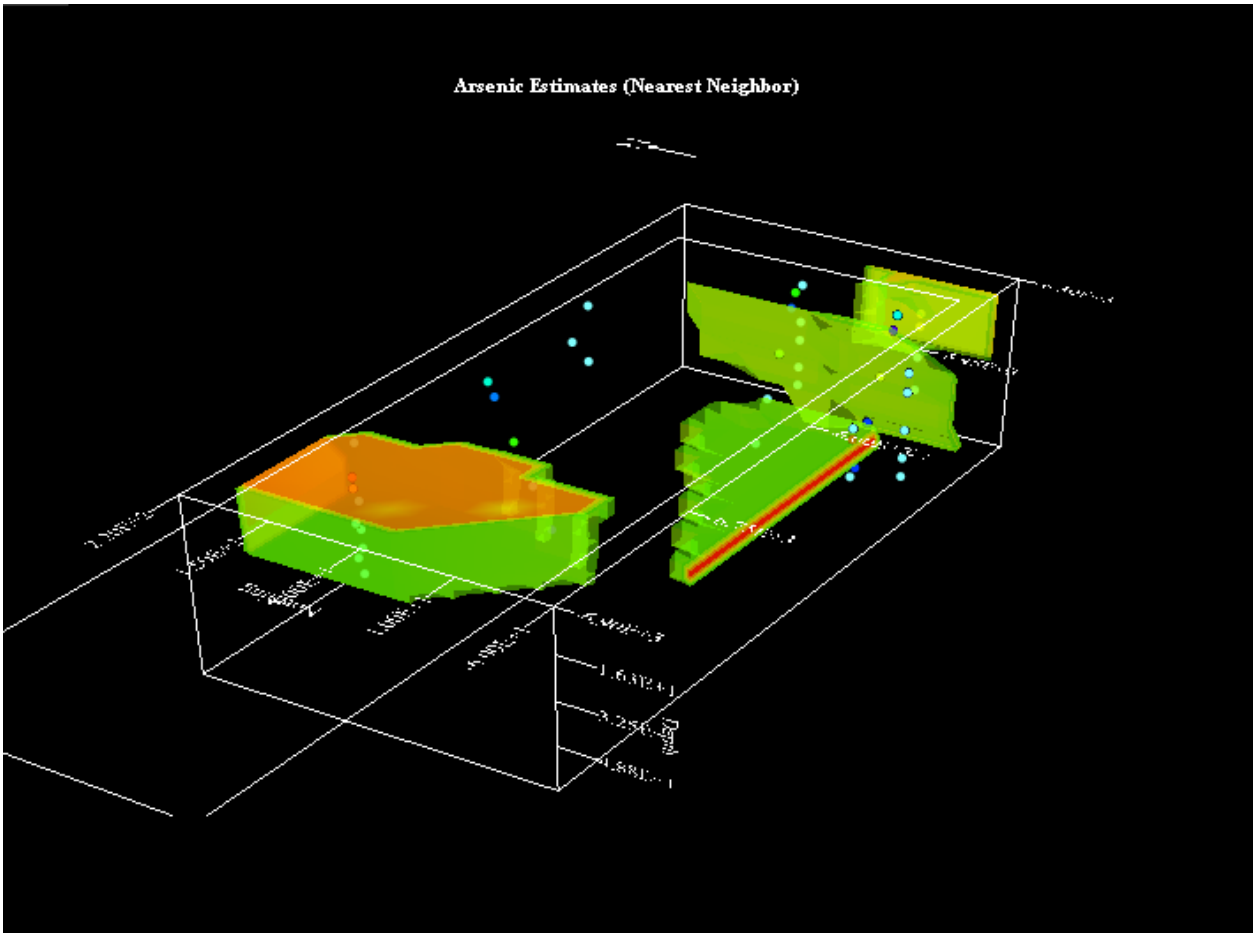

Figure E2.13. SWMU 5 Arsenic SADA Nearest Neighbor Interpolation Map (3-D)

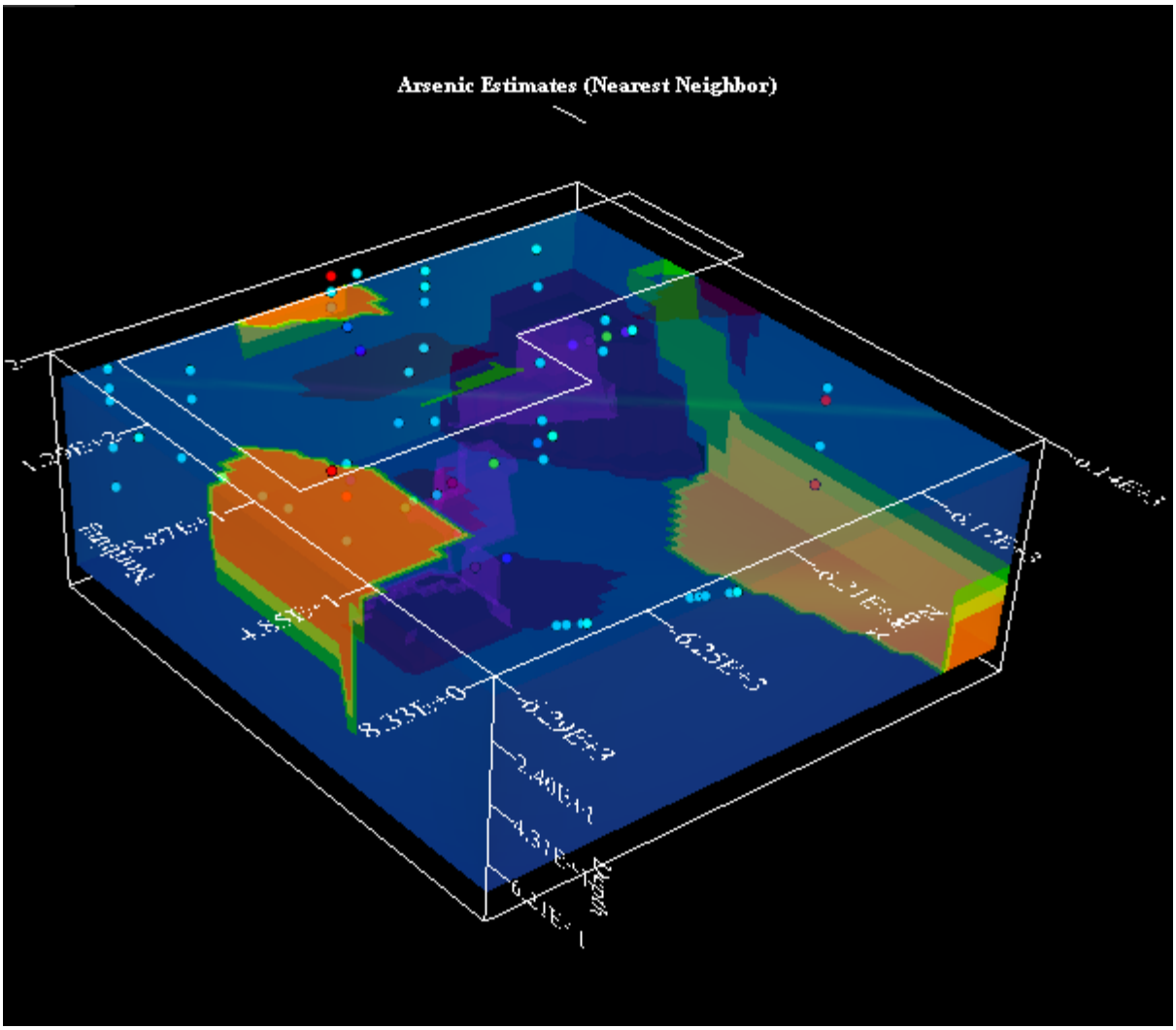

Figure E2.14. SWMU 6 Arsenic SADA Nearest Neighbor Interpolation Map (3-D)

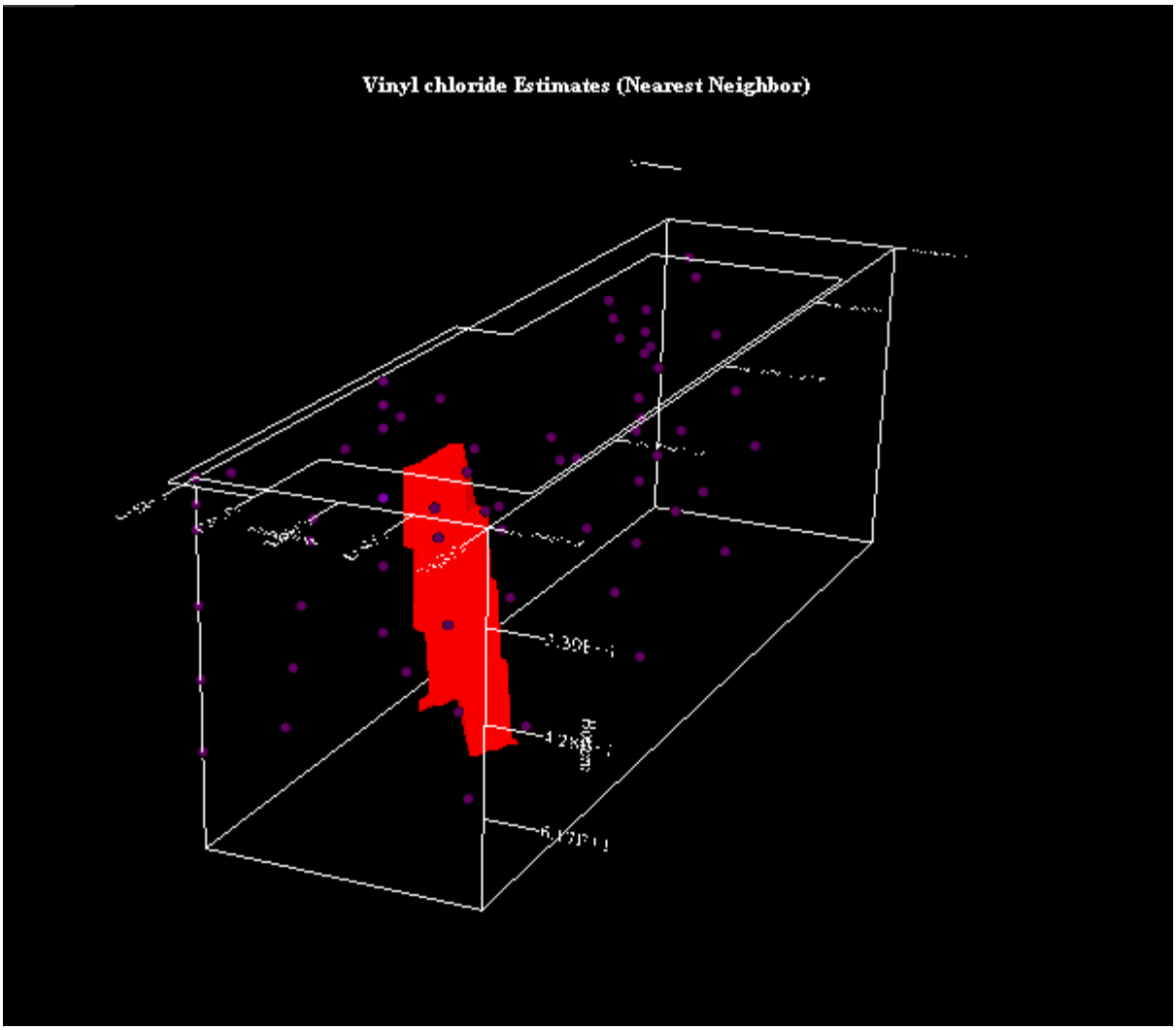

Figure E2.15. SWMU 7 Vinyl Chloride SADA Nearest Neighbor Interpolation Map (3-D)

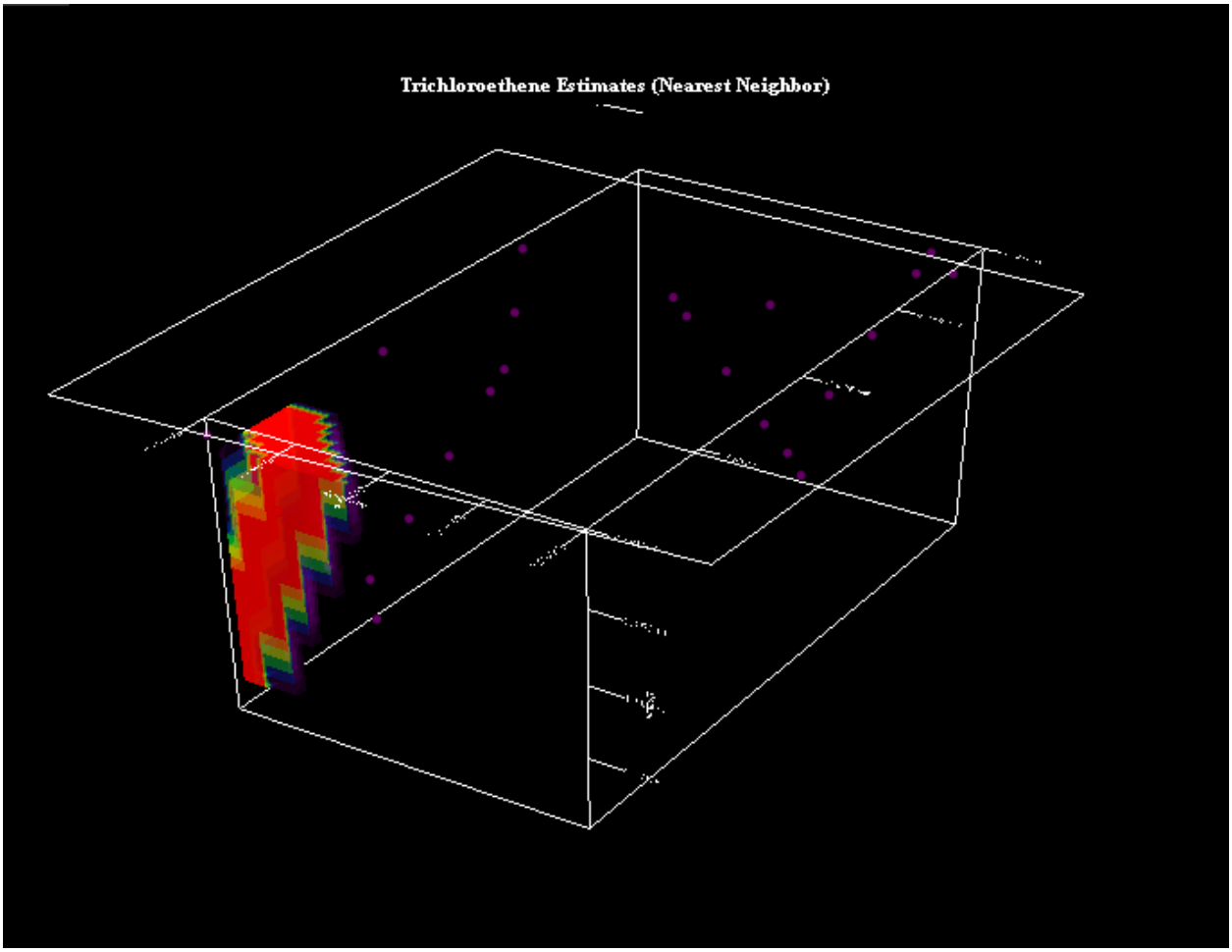

Figure E2.16. SWMU 30 TCE SADA Nearest Neighbor Interpolation Map (3-D)

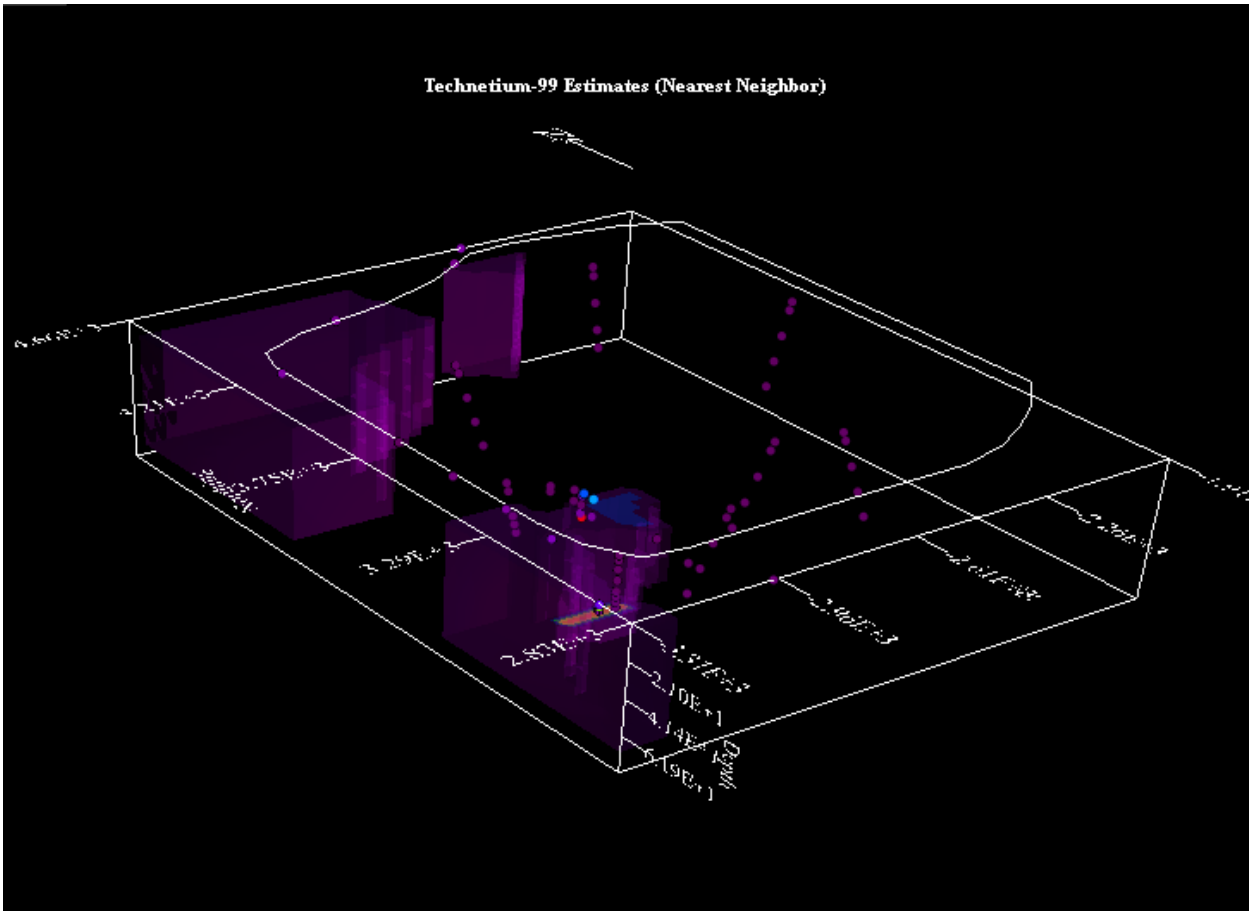

Figure E2.17. SWMU 145 ^{99}Tc SADA Nearest Neighbor Interpolation Map (3-D)

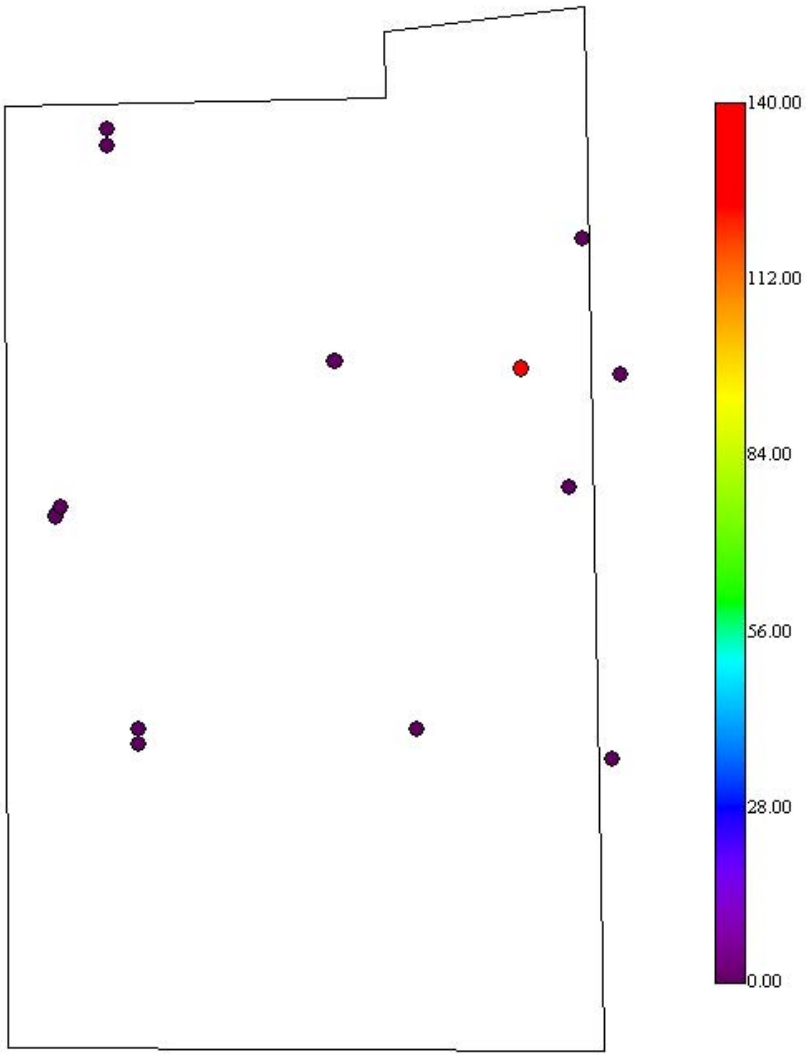

Figure E2.18. SWMU 2, TCE 10-20 ft bgs

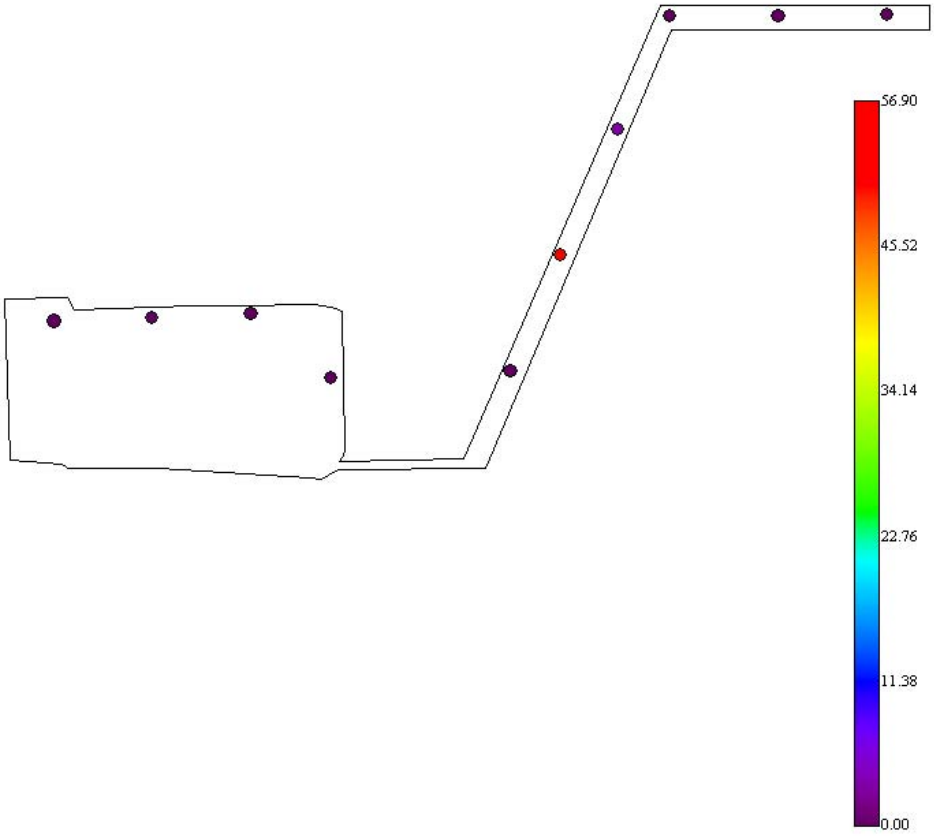

Figure E2.19. SWMU 3, ^{99}Tc 1-10 ft bgs

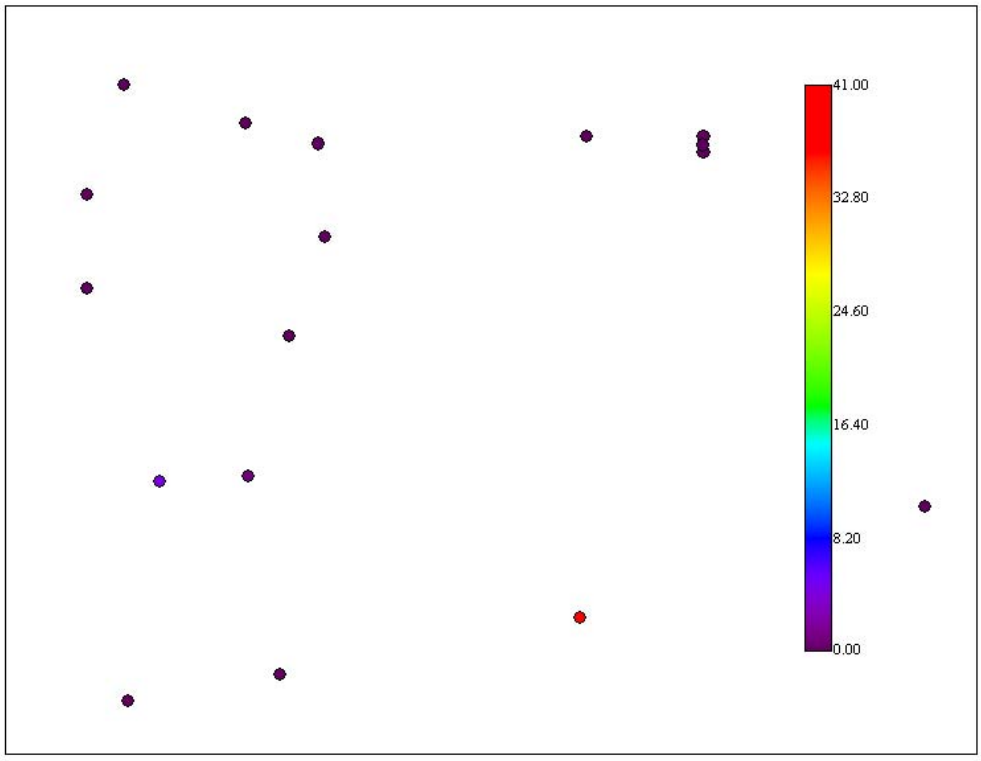

Figure E2.20. SWMU 4, TCE 30-40 ft bgs

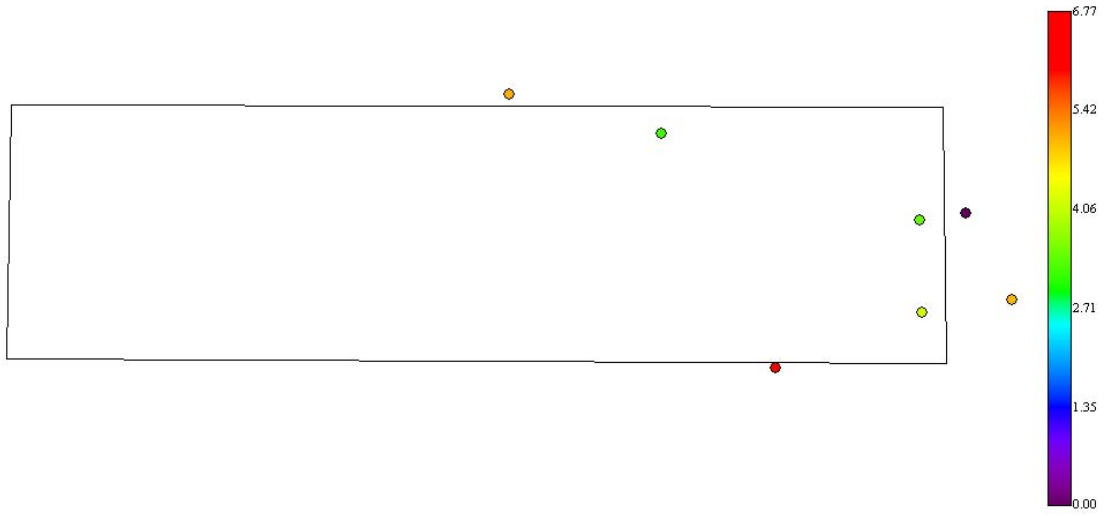

Figure E2.21. SWMU 5, Arsenic 20-30 ft bgs

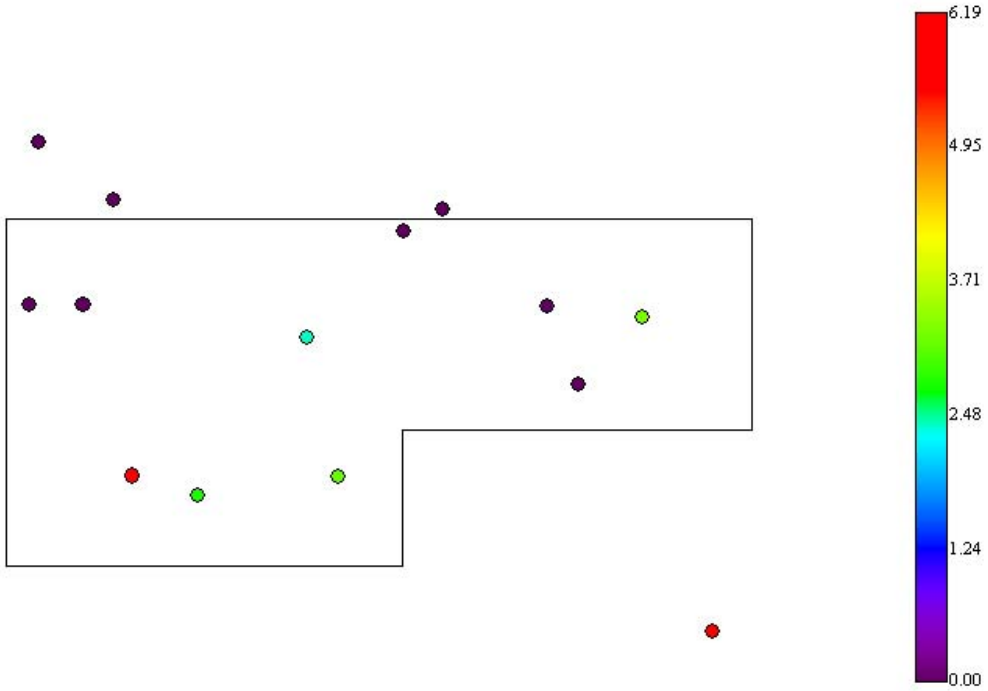

Figure E2.22. SWMU 6, Arsenic 20-30 ft bgs

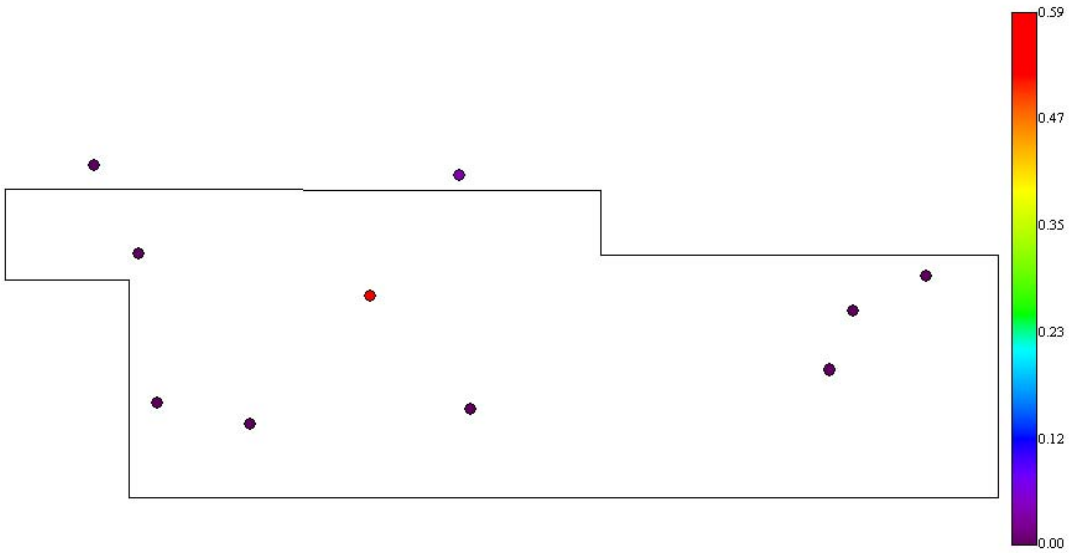

Figure E2.23. SWMU 7, Vinyl Chloride 30-40 ft bgs

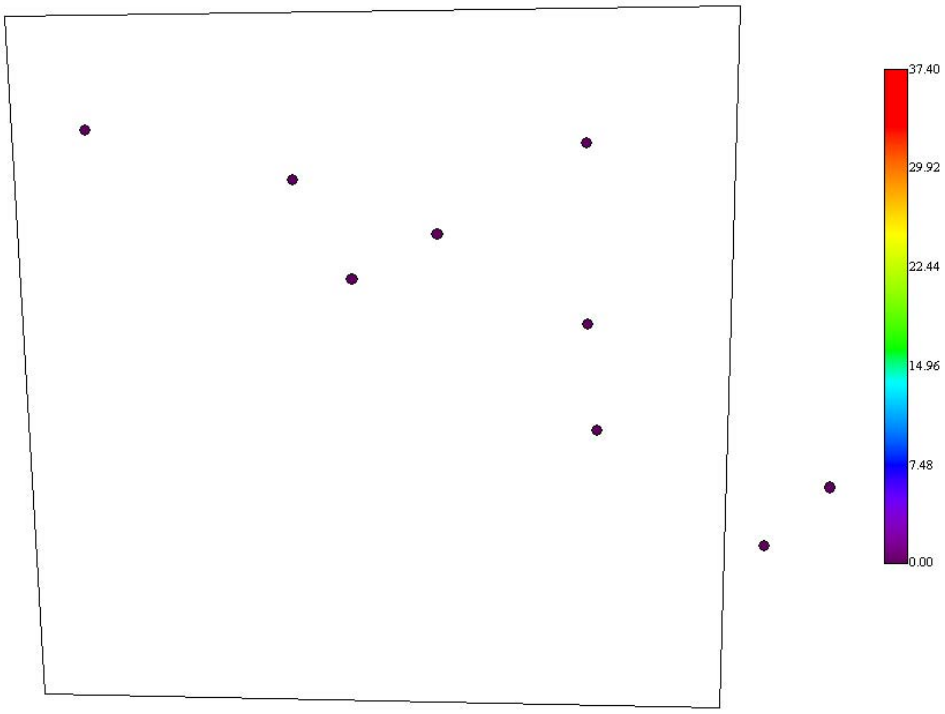

Figure E2.24. SWMU 30, TCE 1-10 ft bgs

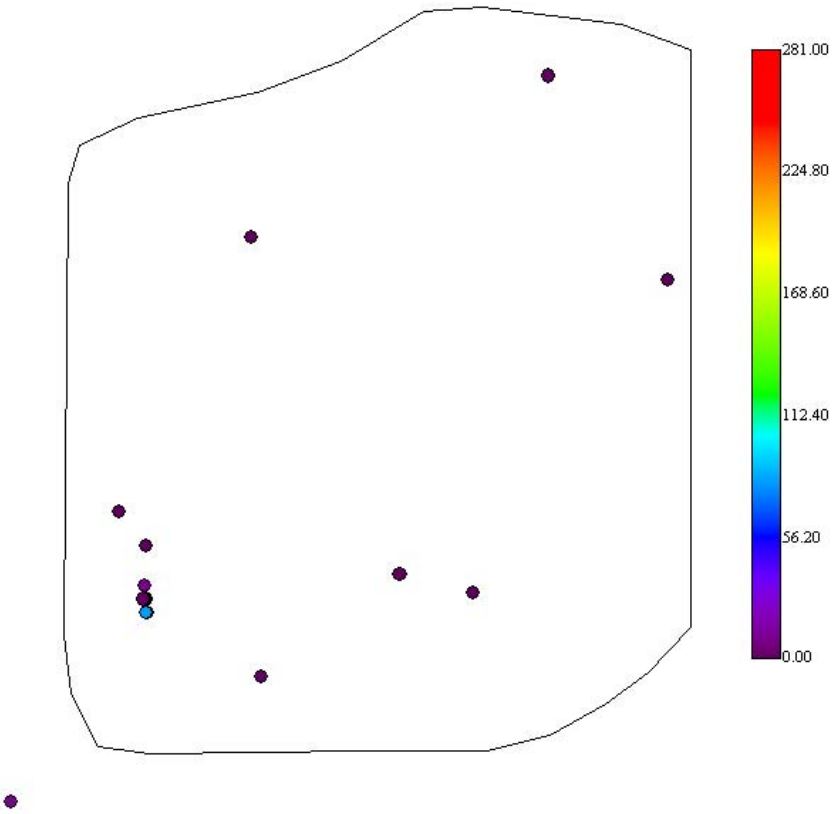

Figure E2.25. SWMU 145, ^{99}Tc 1-10 ft bgs

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APPENDIX E
ATTACHMENT 3

GROUNDWATER ANALYTE SCREENING ANALYSIS

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TABLES

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Tables E3.1 to E3.8 show the comparison of maximum detected concentration of analytes in soil (in any soil horizon) to soil screening levels (SSLs) protective of groundwater and the other criteria described in Section 5 of this Remedial Investigation (RI). These criteria were used to determine which soil analytes were selected to be modeled to groundwater. Modeled groundwater values were compared to residential child groundwater no action levels (NALs) as described in Section 5 to produce the final list of groundwater analytes and their modeled concentrations that were used in the risk assessment in Appendix F.

Table E3.1. Summary of Screening for Detected Analytes–SWMU 2 Groundwater

Analyte	SSL Protective of Groundwater[A]	Exceed SSL	Maximum Detection	Detection Frequency	Included in Groundwater Modeling
Metals (mg/kg)					
Aluminum	NA[G]		1.10E+04	5/5	No
Antimony	2.54E-02	Yes	1.01E+01	2/5	Yes
Arsenic	1.05E-03	Yes	3.00E+01	21/21	Yes
Barium	NA[G]		3.50E+02	21/21	No
Beryllium	2.11E+00	No	1.80E+00	22/23	No
Calcium[B]	NA[G]		2.40E+03	3/3	No
Chromium	3.17E+06	No	3.00E+01	21/21	No
Cobalt	NA[G]		4.74E+00	3/3	No
Copper	NA[G]		7.80E+00	3/3	No
Iron	NA[G]		4.10E+04	3/3	No
Lead	NA[G]		2.90E+01	4/4	No
Magnesium[B]	NA[G]		1.60E+03	3/3	No
Manganese	2.26E+00	Yes	1.20E+03	21/21	Yes
Mercury	2.22E-02	Yes	1.40E-01	1/3	No[I]
Nickel	1.98E+00	Yes	3.70E+01	21/21	Yes
Potassium[B]	NA[G]		9.40E+02	2/2	No
Sodium[B]	NA[G]		2.01E+02	3/3	No
Thallium	NA[G]		4.50E+00	12/21	No
Uranium	NA[G]		1.50E+03	12/50	Yes
Vanadium	9.25E+00	Yes	3.80E+01	21/21	Yes
Zinc	2.78E+01	Yes	1.40E+02	3/3	No[I]
Organic Compounds (mg/kg)					
Total PCB[C]	4.92E-02	Yes	4.35E+00	NA	No[E]
Total PAH[D]	NA[G]		1.67E-01	NA	No[E]
alpha-Chlordane	NA[G]		7.80E-04	1/3	No
delta-BHC	NA[G]		6.50E-03	1/6	No
Gamma-Chlordane	NA[G]		3.00E-03	2/3	No
Benzo(a)pyrene	1.95E-03	Yes	1.40E-01	1/3	Yes
Benzo(b)fluoranthene	NA[G]		2.70E-01	2/3	No
Benzo(ghi)perylene	NA[G]		1.50E-01	1/3	No
Dibenzofuran	NA[G]		1.80E-01	2/3	No
Naphthalene	1.21E-03	Yes	1.80E-01	1/2	No[I]
Phenanthrene	NA[G]		5.70E-01	2/3	No
Pyrene	3.81E+00	No	2.00E-01	1/2	No
cis-1,2-DCE	NA[G]		1.30E+02	4/23	No
Methylene chloride	NA[G]		1.30E-03	3/4	No
TCE	9.69E-04	Yes	1.40E+02	8/50	Yes
Vinyl Chloride	1.17E-05	Yes	1.40E+00	1/21	No[H]

Table E3.1. Summary of Screening for Detected Analytes–SWMU 2 Groundwater (Continued)

Analyte	SSL Protective of Groundwater[A]	Exceed SSL	Maximum Detection	Detection Frequency	Included in Groundwater Modeling
Radionuclides (pCi/g)					
Americium-241	3.89E+07	No	4.65E+00	54/55	No
Cesium-137[F]	NA[G]		5.10E+01	16/55	No
Neptunium-237	6.20E+03	No	3.10E-01	51/54	No
Plutonium-238	4.62E+04	No	1.30E-01	1/1	No
Plutonium-239	4.46E+00	Yes	1.61E+01	21/55	Yes
Technetium-99	2.63E+01	No	1.46E+01	54/54	Yes
Uranium-234	1.22E+01	Yes	1.55E+02	55/55	Yes
Uranium-235/236	1.14E+01	Yes	2.58E+01	55/55	Yes
Uranium-238	8.62E+00	Yes	9.47E+02	55/55	Yes

[A] Based on a residential child with dilution attenuation factor (DAF) = 1 (DOE 2001)
[B] Compound is considered an essential nutrient and has been excluded in accordance with the PGDP Risk Methods Document (2001)
[C] Total polychlorinated biphenyl (PCB) maximum concentration reported as actual analytical value and EPC reported as sum of all detected aroclors
[D] Total polyaromatic hydrocarbon (PAH) reported as benzo(a)pyrene toxicity equivalence factor (TEF)
[E] Groundwater modeling was not performed for Total PCB and Total PAH as they represent groups of compounds. PCBs and PAHs were assessed individually for groundwater modeling.
[F] Not applicable as the radionuclide does not reach groundwater within 10,000 years precluding receptor uptake per Section 5 of main text and Appendix E
[G] SSL not listed in Table A.7 of PGDP Risk Methods Document (2001)
[H] Less than 5% detects, so analyte not retained
[I] Maximum detected value less than the soil/sediment no action level (NAL) for a child resident in Table A.17 of PGDP Risk Methods Document (2001), so analyte not retained

Table E3.2. Summary of Screening for Detected Analytes–SWMU 3 Groundwater

Analyte	SSL Protective of Groundwater[A]	Exceed SSL	Maximum Detection	Detection Frequency	Included in Groundwater Modeling
Metals (mg/kg)					
Aluminum	NA[D]		1.18E+04	55/55	No
Antimony	2.54E-02	Yes	1.57E+01	6/55	Yes
Arsenic	1.05E-03	Yes	1.37E+01	50/55	Yes
Barium	NA[D]		1.27E+02	57/57	No
Beryllium	2.11E+00	No	1.06E+00	5/55	No
Calcium[B]	NA[D]		3.56E+04	56/57	No
Chromium	3.17E+06	No	3.57E+01	57/57	No
Cobalt	NA[D]		2.00E+01	42/58	No
Copper	NA[D]		3.00E+01	57/57	No
Iron	NA[D]		4.20E+04	57/57	No
Lead	NA[D]		2.39E+01	56/56	No
Magnesium[B]	NA[D]		2.50E+03	57/57	No
Manganese	2.26E+00	Yes	6.44E+02	57/57	Yes
Mercury	2.22E-02	Yes	2.40E-02	9/56	No[E]
Molybdenum	1.55E-01	Yes	1.80E+01	6/57	Yes
Nickel	NA[F]		1.61E+01	11/56	No[E]
Sodium[B]	NA[D]		4.45E+02	1/57	No
Uranium	NA[D]		6.10E-01	1/57	No

Table E3.2. Summary of Screening for Detected Analytes–SWMU 3 Groundwater (Continued)

Analyte	SSL Protective of Groundwater[A]	Exceed SSL	Maximum Detection	Detection Frequency	Included in Groundwater Modeling
Uranium	NA[D]		8.36E+01	19/58	Yes
Vanadium	9.25E+00	Yes	3.37E+01	56/57	Yes
Zinc	2.78E+01	Yes	5.00E+01	31/57	No[E]
Organic Compounds (mg/kg)					
TCE	9.69E-04	Yes	4.28E-01	4/56	Yes
Radionuclides (pCi/g)					
Americium-241	3.89E+07	No	8.00E-02	2/57	No
Cesium-137[C]	NA[D]		4.56E-01	2/55	No
Plutonium-239	4.46E+00	No	5.62E-02	3/57	No
Technetium-99	2.63E+01	Yes	5.69E+01	8/57	Yes
Uranium-234	1.22E+01	No	3.02E+00	25/57	No
Uranium-238	8.62E+00	Yes	2.24E+01	29/57	Yes

[A] Based on a residential child with dilution attenuation factor (DAF) = 1 (DOE 2001)
[B] Compound is considered an essential nutrient and has been excluded in accordance with the PGDP Risk Methods Document (2001)
[C] Not applicable as the radionuclide does not reach groundwater within 10,000 years precluding receptor uptake, per Section 5 of main text and Appendix E
[D] SSL not listed in Table A.7 of PGDP Risk Methods Document (2001)
[E] Maximum detected value less than the soil/sediment no action level (NAL) for a child resident in Table A.17 of PGDP Risk Methods Document (2001), so analyte not retained

Table E3.3. Summary of Screening for Detected Analytes–SWMU 4 Groundwater

Analyte	SSL Protective of Groundwater[A]	Exceed SSL	Maximum Detection	Detection Frequency	Included in Groundwater Modeling
Inorganic Chemicals (Metals) (mg/kg)					
Aluminum	NA[G]		1.90E+04	139/139	No
Arsenic	1.05E-03	Yes	1.71E+01	16/138	Yes
Barium	NA[G]		3.13E+02	139/139	No
Beryllium	2.11E+00	No	2.02E+00	96/139	No
Calcium[B]	NA[G]		1.31E+05	138/138	No
Chromium	3.17E+06	No	2.96E+02	139/139	No
Cobalt	NA[G]		3.16E+01	137/139	No
Copper	NA[G]		4.64E+01	134/139	No
Iron	NA[G]		4.19E+04	139/139	No
Lead	NA[G]		3.02E+01	4/139	No
Magnesium[B]	NA[G]		2.65E+03	138/139	No
Manganese	2.26E+00	Yes	2.70E+03	138/139	Yes
Mercury	2.22E-02	Yes	4.50E-01	1/139	No[H]
Nickel	1.98E+00	Yes	1.53E+02	95/139	Yes
Potassium[B]	NA[G]		2.39E+03	139/139	No
Sodium[B]	NA[G]		3.15E+03	83/139	No
Uranium	NA[G]		2.05E+04	8/36	Yes
Vanadium	9.25E+00	Yes	7.55E+01	139/139	Yes
Zinc	2.78E+01	Yes	9.37E+01	116/139	Yes

Table E3.3. Summary of Screening for Detected Analytes–SWMU 4 Groundwater (Continued)

Analyte	SSL Protective of Groundwater[A]	Exceed SSL	Maximum Detection	Detection Frequency	Included in Groundwater Modeling
Organic Compounds (mg/kg)					
Total PCB[C]	4.92E-02	Yes	2.83E+01	NA	No[E]
Total PAH[D]	NA[G]		4.10E-01	NA	No[E]
Aroclor-1254	7.67E-03	Yes	2.70E+01	7/184	No[H]
Aroclor-1260	2.49E-02	Yes	5.00E-01	7/184	No[H]
Bis(2-ethylhexyl)phthalate	NA[G]		7.47E-01	6/139	No
Diethyl phthalate	NA[G]		2.80E+00	2/139	No
Di-n-butyl phthalate	NA[G]		6.10E+00	22/139	No
1,1,2-TCA	NA[G]		2.10E-02	1/115	No
1,1-DCE	1.95E-05	Yes	1.40E-02	1/339	No[H]
Chloroform	8.32E-06	Yes	0.012	1/113	No[H]
cis-1,2-DCE	7.80E-04	Yes	9.8	23/338	Yes
trans-1,2-DCE	1.86E-03	Yes	0.45	1/339	No[H]
TCE	9.69E-04	Yes	4.10E+01	47/335	Yes
Vinyl chloride	1.17E-05	Yes	0.29	7/339	Yes
Radionuclides (pCi/g)					
Cesium-137[F]	NA[G]		1.81E+02	8/179	No
Technetium-99	2.63E+01	Yes	2.69E+02	15/200	Yes
Neptunium-237	6.20E+03	No	5.78E+00	13/47	No
Plutonium-239	4.46E+00	Yes	2.71E+01	10/48	Yes
Uranium-234	1.22E+01	Yes	6.90E+01	21/29	Yes
Uranium-235	1.14E+01	No	4.20E+00	1/171	No
Uranium-238	8.62E+00	Yes	1.26E+02	21/29	Yes

[A] Based on a residential child with dilution attenuation factor (DAF) = 1 (DOE 2001)
[B] Compound is considered an essential nutrient and has been excluded in accordance with the PGDP Risk Methods Document (2001)
[C] Total polychlorinated biphenyl (PCB) maximum concentration reported as sum of all detected aroclors
[D] Total polyaromatic hydrocarbon (PAH) reported as benzo(a)pyrene toxicity equivalence factor (TEF)
[E] Groundwater modeling was not performed for Total PCB and Total PAH as they represent groups of compounds. PCBs and PAHs were assessed individually for groundwater modeling.
[F] Not applicable as the radionuclide does not reach groundwater within 10,000 years precluding receptor uptake, per Section 5 of main text and Appendix E
[G] SSL not listed in Table A.7 of PGDP Risk Methods Document (2001)
[H] Less than 5% detects, so analyte not retained.

Table E3.4. Summary of Screening for Detected Analytes–SWMU 5 Groundwater

Analyte	SSL Protective of Groundwater[A]	Exceed SSL	Maximum Detection	Detection Frequency	Included in Groundwater Modeling
Metals (mg/kg)					
Aluminum	NA[G]		1.64E+04	84/84	No
Arsenic	1.05E-03	Yes	1.22E+01	24/85	Yes
Barium	NA[G]		3.43E+02	85/85	No
Beryllium	2.11E+00	Yes	2.59E+00	41/84	No
Calcium[B]	NA[G]		2.07E+05	84/84	No
Chromium	3.17E+06	No	2.96E+02	84/85	No
Cobalt	NA[G]		2.85E+01	69/84	No
Copper	NA[G]		1.44E+01	82/84	No
Iron	NA[G]		3.29E+04	84/84	No
Lead	NA[G]		2.00E+02	18/85	No
Magnesium[B]	NA[G]		4.78E+03	84/84	No
Manganese	2.26E+00	Yes	1.75E+03	84/84	Yes
Mercury	2.22E-02	Yes	3.60E-02	1/85	No[H]
Nickel	1.98E+00	Yes	1.35E+02	69/85	No[I]
Potassium[B]	NA[G]		1.89E+03	55/55	No
Selenium	3.92E-02	Yes	1.23E+00	2/85	Yes
Silver	6.67E-02	Yes	5.14E+00	1/85	No[H]
Sodium[B]	NA[G]		3.89E+02	37/72	No
Uranium	NA[G]		2.17E+02	6/29	No
Vanadium	9.25E+00	Yes	5.69E+01	84/84	Yes
Zinc	2.78E+01	Yes	1.63E+02	54/84	No[I]
Organic Compounds (mg/kg)					
Total PCB[C]	4.92E-02	Yes	3.06E-01	NA	No[E]
Total PAH[D]	NA[G]		1.15E+02	NA	No[E]
Acenaphthene	1.92E-01	Yes	3.20E+01	18/96	Yes
Acenaphthylene	NA[G]		9.45E+00	2/96	No
Anthracene	4.53E+00	Yes	4.00E+01	20/96	No[I]
Aroclor-1260	2.49E-02	Yes	3.06E-01	6/79	Yes
Benz(a)anthracene	NA[G]		1.30E+02	30/96	No
Benzo(a)pyrene	1.95E-03	Yes	8.00E+01	30/96	Yes
Benzo(b)fluoranthene	NA[G]		1.70E+02	29/96	No
Benzo(ghi)perylene	NA[G]		2.80E+01	26/97	No
Benzo(k)fluoranthene	NA[G]		1.17E+01	6/55	No
Bis(2-ethylhexyl)phthalate	NA[G]		5.70E+00	23/96	No
Carbazole	NA[G]		7.10E+01	10/96	No
Chrysene	NA[G]		9.50E+01	30/96	No

Table E3.4. Summary of Screening for Detected Analytes–SWMU 5 Groundwater (Continued)

Analyte	SSL Protective of Groundwater[A]	Exceed SSL	Maximum Detection	Detection Frequency	Included in Groundwater Modeling
Organic Compounds (mg/kg)					
Dibenz(a,h)anthracene	NA[G]		7.49E-01	2/55	Yes
Dibenzofuran	NA[G]		3.52E+00	3/55	No
Di-n-butyl phthalate	NA[G]		7.30E+00	27/55	No
Fluoranthene	4.67E+00	Yes	2.00E+01	3/34	No[I]
Fluorene	2.66E-01	Yes	2.80E+01	16/96	No[I]
2-Methylnaphthalene	NA[G]		7.30E+00	2/96	No
Naphthalene	1.21E-03	Yes	1.60E+01	3/96	Yes
Phenanthrene	NA[G]		6.40E+01	31/96	No
Pyrene	3.81E+00	Yes	1.50E+02	35/96	Yes
1,1-DCE	1.95E-05	Yes	2.80E+00	1/102	No[H]
TCE	9.69E-04	Yes	5.10E-03	12/102	Yes
Radionuclides (pCi/g)					
Cesium-137[F]	NA[G]		2.80E+00	23/61	No
Technetium-99	2.63E+01	No	1.73E+01	52/90	Yes
Uranium-234	1.22E+01	No	1.47E+00	11/40	No
Uranium-235	1.14E+01	No	6.40E+00	10/31	No
Uranium-238	8.62E+00	No	2.26E+00	21/40	No

[A] Based on a residential child with dilution attenuation factor (DAF) = 1 (DOE 2001)
[B] Compound is considered an essential nutrient and has been excluded in accordance with the PGDP Risk Methods Document (2001)
[C] Total polychlorinated biphenyl (PCB) maximum concentration reported as sum of all detected aroclors
[D] Total polyaromatic hydrocarbon (PAH) reported as benzo(a)pyrene toxicity equivalence factor (TEF)
[E] Groundwater modeling was not performed for Total PCB and Total PAH as they represent groups of compounds. PCBs and PAHs were assessed individually for groundwater modeling.
[F] Not applicable as the radionuclide does not reach groundwater within 10,000 years precluding receptor uptake, per Section 5 of main text and Appendix E
[G] SSL not listed in Table A.7 of PGDP Risk Methods Document (2001)
[H] Less than 5% detects, so analyte not retained.
[I] Maximum detected value less than the soil/sediment no action level (NAL) for a child resident in Table A.17 of PGDP Risk Methods Document (2001), so analyte not retained

Table E3.5. Summary of Screening for Detected Analytes–SWMU 6 Groundwater

Analyte	SSL Protective of Groundwater[A]	Exceed SSL	Maximum Detection	Detection Frequency	Included in Groundwater Modeling
Metals (mg/kg)					
Aluminum	NA[F]		2.25E+04	85/85	No
Arsenic	1.05E-03	Yes	6.38E+00	25/85	Yes
Barium	NA[F]		1.53E+02	85/85	No
Beryllium	2.11E+00	Yes	3.07E+00	41/85	Yes
Chromium	3.17E+06	No	1.16E+02	85/85	No
Cobalt	NA[F]		1.56E+02	76/85	No
Copper	NA[F]		2.13E+01	82/85	No
Iron	NA[F]		5.87E+04	85/85	No
Lead	NA[F]		3.54E+01	24/85	No
Magnesium[B]	NA[F]		4.41E+03	85/85	No
Manganese[B]	2.26E+00	Yes	1.55E+03	85/85	Yes
Nickel	1.98E+00	Yes	6.86E+01	52/85	Yes
Uranium	NA[F]		1.23E+00	16/33	Yes
Vanadium	9.25E+00	Yes	7.91E+01	84/85	Yes
Zinc	2.78E+01	Yes	1.28E+02	57/85	No[H]
Organic Compounds (mg/kg)					
Total PCB[C]	4.92E-02	Yes	6.00E-02	NA	No[E]
Total PAH[D]	NA[F]		4.99E-01	NA	No[E]
Anthracene	4.53E+00	No	1.56E-01	1/62	No
Benz(a)anthracene	NA[F]		2.55E-01	2/62	No
Benzo(a)pyrene	1.95E-03	Yes	4.02E-01	1/62	No[G]
Benzo(b)fluoranthene	NA[F]		5.00E-01	2/62	No
Benzo(ghi)perylene	NA[F]		1.24E-01	2/62	No
Bis(2-ethylhexyl)phthalate	NA[F]		6.00E-01	3/62	No
Fluoranthene	4.67E+00	No	6.36E-01	2/55	No
Pyrene	3.81E+00	No	6.63E-01	2/62	No
Acetone	NA[F]		8.50E-02	6/48	No
TCE	9.69E-04	Yes	1.01E-02	5/115	Yes
Radionuclides (pCi/g)					
Technetium-99	2.63E+01	No	1.88E+01	3/90	Yes

[A] Based on a residential child with dilution attenuation factor (DAF) = 1 (DOE 2001)
[B] Compound is considered an essential nutrient and has been excluded in accordance with the PGDP Risk Methods Document (2001)
[C] Total polychlorinated biphenyl (PCB) maximum concentration reported as method detection limit as there were no detections for Total PCB
[D] Total polyaromatic hydrocarbon (PAH) reported as benzo(a)pyrene toxicity equivalence factor (TEF)
[E] Groundwater modeling was not performed for Total PCB and Total PAH as they represent groups of compounds. PCBs and PAHs were assessed individually for groundwater modeling.
[F] SSL not listed in Table A.7 of PGDP Risk Methods Document (2001)
[G] Less than 5% detects, so analyte not retained.
[H] Maximum detected value less than the soil/sediment no action level (NAL) for a child resident in Table A.17 of PGDP Risk Methods Document (2001), so analyte not retained

Table E3.6. Summary of Screening for Detected Analytes–SWMU 7 Groundwater

Analyte	SSL Protective of Groundwater[A]	Exceed SSL	Maximum Detection	Detection Frequency	Included in Groundwater Modeling
Metals (mg/kg)					
Aluminum	NA[G]		1.60E+04	83/83	No
Arsenic	1.05E-03	Yes	1.60E+01	72/83	Yes
Barium	NA[G]		1.80E+02	83/83	No
Beryllium	2.11E+00	No	1.55E+00	29/85	No
Cadmium	5.02E-02	Yes	1.30E+00	12/83	Yes
Calcium[B]	NA[G]		2.10E+05	83/83	No
Chromium	3.17E+06	No	5.58E+01	83/85	No
Cobalt	NA[G]		1.77E+01	56/83	No
Copper	NA[G]		9.90E+01	70/83	No
Iron	NA[G]		3.47E+04	83/83	No
Lead	NA[G]		1.20E+02	83/83	No
Magnesium[B]	NA[G]		3.30E+03	83/83	No
Manganese	2.26E+00	Yes	1.20E+03	83/83	Yes
Mercury	2.22E-02	Yes	9.20E-02	22/85	Yes
Nickel	1.98E+00	Yes	1.40E+02	58/83	Yes
Potassium[B]	NA[G]		8.70E+02	20/20	No
Selenium	3.92E-02	Yes	8.80E-01	8/83	Yes
Sodium[B]	NA[G]		4.00E+02	47/83	No
Silver	6.67E-02	Yes	1.90E+00	7/83	No[I]
Thallium	NA[G]		2.00E+00	17/83	No
Tin	NA[G]		1.50E+01	20/20	No
Uranium	NA[G]		1.27E+03	31/85	Yes
Vanadium	9.25E+00	Yes	5.20E+01	76/83	Yes
Zinc	2.78E+01	Yes	2.40E+02	47/83	No[I]
Organic Compounds (mg/kg)					
Total PCB[C]	4.92E-02	Yes	1.81E+01	NA	No[E]
Total PAH[D]	NA[G]		6.37E+00	NA	No[E]
Aroclor-1254	7.67E-03	Yes	1.30E-01	4/86	Yes
Aroclor-1260	2.49E-02	Yes	2.45E+00	13/86	Yes
1,2,4-Trichlorobenzene	NA[G]		7.70E-02	2/80	No
1,4-Dichlorobenzene	NA[G]		7.00E-02	2/88	No
2,4,6-Trichlorophenol	NA[G]		4.10E-02	2/160	No
2-Methylphenol	NA[G]		2.00E-02	1/17	No
3-Methylcholanthrene	NA[G]		1.10E-01	1/17	No
4-Methylphenol	NA[G]		1.60E-02	1/17	No
Acenaphthene	1.92E-01	Yes	4.40E-01	2/80	No[I]
Acenaphthylene	NA[G]		1.90E-02	1/80	No
Benz(a)anthracene	NA[G]		4.30E+00	7/80	No
Benzo(a)pyrene	1.95E-03	Yes	4.10E+00	7/80	Yes
Benzo(b)fluoranthene	NA[G]		5.20E+00	7/80	No
Benzo(ghi)perylene	NA[G]		3.80E+00	3/80	No
Benzo(k)fluoranthene	NA[G]		1.70E+00	6/80	No

Table E3.6. Summary of Screening for Detected Analytes–SWMU 7 Groundwater (Continued)

Analyte	SSL Protective of Groundwater[A]	Exceed SSL	Maximum Detection	Detection Frequency	Included in Groundwater Modeling
Organic Compounds (mg/kg)(Continued)					
Bis(2-ethylhexyl)phthalate	NA[G]		3.90E-01	2/80	No
Chrysene	NA[G]		4.20E+00	7/80	No
Dibenz(a,h)anthracene	NA[G]		9.20E-01	1/80	No
Di-n-octylphthalate	NA[G]		7.20E-02	1/80	No
Fluoranthene	4.67E+00	Yes	7.90E+00	8/80	Yes
Fluorene	2.66E-01	Yes	4.10E-01	1/80	No[I]
Hexachloroethane	NA[G]		3.40E-02	1/80	No
Indeno(1,2,3-cd)pyrene	NA[G]		3.80E+00	3/80	No
Naphthalene	1.21E-03	Yes	5.60E-02	1/80	No[I]
Pentachlorophenol	NA[G]		6.90E-02	1/80	No
Pyrene	3.81E+00	Yes	9.00E+00	9/80	Yes
1,1,1-TCA	NA[G]		1.59E+02	2/71	No
1,1,2-TCA	NA[G]		1.49E+02	2/71	No
1,1-DCE	1.95E-05	Yes	1.66E+00	4/71	Yes
1,2-Dichloroethane	NA[G]		1.63E+01	2/71	No
Acetone	NA[G]		8.37E+01	10/71	No
cis-1,2-DCE	7.80E-04	Yes	6.84E-01	15/71	Yes
Methylene chloride	NA[G]		5.70E+00	5/71	No
Tetrachloroethene	3.38E-04	Yes	6.20E-03	1/71	No[H]
TCE	9.69E-04	Yes	2.60E-01	11/71	Yes
Vinyl chloride	1.17E-05	Yes	5.85E-01	5/71	Yes
Radionuclides (pCi/g)					
Americium-241	3.89E+07	No	2.00E+00	3/64	No
Cesium-137[F]	NA[G]	No	1.83E-01	3/64	No
Neptunium-237	6.20E+03	No	7.20E-01	26/86	No
Plutonium-239	4.46E+00	No	6.80E-01	19/86	No
Technetium-99	2.63E+01	Yes	4.06E+02	37/84	Yes
Uranium-234	1.22E+01	Yes	3.18E+02	59/94	Yes
Uranium-235	1.14E+01	No	6.03E+00	22/22	No
Uranium-238	8.62E+00	Yes	2.39E+03	53/94	Yes

[A] Based on a residential child with dilution attenuation factor (DAF) = 1 (DOE 2001)
[B] Compound is considered an essential nutrient and has been excluded in accordance with the PGDP Risk Methods Document (2001)
[C] Total polychlorinated biphenyl (PCB) maximum concentration reported as sum of all detected aroclors
[D] Total polyaromatic hydrocarbon (PAH) reported as benzo(a)pyrene toxicity equivalence factor (TEF)
[E] Groundwater modeling was not performed for Total PCB and Total PAH as they represent groups of compounds. PCBs and PAHs were assessed individually for groundwater modeling.
[F] Not applicable as the radionuclide does not reach groundwater within 10,000 years precluding receptor uptake, per Section 5 of main text and Appendix E
[G] SSL not listed in Table A.7 of PGDP Risk Methods Document (2001)
[H] Less than 5% detects, so analyte not retained
[I] Maximum detected value less than the soil/sediment no action level (NAL) for a child resident in Table A.17 of PGDP Risk Methods Document (2001), so analyte not retained

Table E3.7. Summary of Screening for Detected Analytes–SWMU 30 Groundwater

Analyte	SSL Protective of Groundwater[A]	Exceed SSL	Maximum Detection	Detection Frequency	Included in Groundwater Modeling
Inorganic Chemicals (Metals) (mg/kg)					
Aluminum	NA[F]		1.90E+04	33/33	No
Arsenic	1.05E-03	Yes	1.20E+01	30/33	Yes
Barium	NA[F]		1.70E+02	35/35	No
Beryllium	2.11E+00	No	1.48E+00	15/33	No
Cadmium	5.02E-02		2.80E+00	6/35	Yes
Calcium[B]	NA[F]		2.40E+04	33/33	No
Chromium	3.17E+06	No	4.90E+01	35/35	No
Cobalt	NA[F]		1.40E+01	25/33	No
Copper	NA[F]		1.70E+02	32/33	No
Iron	NA[F]		2.90E+04	33/33	No
Lead	NA[F]		7.10E+01	33/35	No
Magnesium[B]	NA[F]		2.20E+03	33/33	No
Manganese	2.26E+00	Yes	1.20E+03	33/33	Yes
Mercury	2.22E-02	Yes	1.70E-01	12/35	Yes
Nickel	1.98E+00	Yes	5.70E+02	29/33	Yes
Potassium[B]	NA[F]		1.50E+03	12/12	No
Selenium	3.92E-02	Yes	1.00E+00	28/35	No[G]
Sodium[B]	NA[F]		1.87E+02	9/33	No
Thallium	NA[F]		1.80E+00	5/35	No
Uranium	NA[F]		1.40E+03	16/33	Yes
Vanadium	9.25E+00	Yes	4.00E+01	32/33	Yes
Zinc	2.78E+01	Yes	7.50E+02	11/33	Yes
Organic Compounds (mg/kg)					
Total PCB[C]	4.92E-02	Yes	7.60E-01	NA	No[E]
Total PAH[D]	NA[F]		1.25E+01	NA	No[E]
Aroclor-1254	7.67E-03	Yes	2.00E-01	3/36	Yes
Aroclor-1260	1.92E-01	Yes	1.70E+00	5/34	Yes
Acenaphthene	1.92E-01	Yes	1.70E+00	5/34	No[G]
Acenaphthylene	NA[F]		9.10E-02	3/34	No
Anthracene	4.53E+00	No	3.20E+00	3/34	No
Benz(a)anthracene	NA[F]		9.10E+00	10/34	No
Benzo(a)pyrene	1.95E-03	Yes	8.40E+00	7/34	Yes
Benzo(b)fluoranthene	NA[F]		9.60E+00	8/34	No
Benzo(ghi)perylene	NA[F]		5.20E+00	6/34	No
Benzo(k)fluoranthene	NA[F]		4.30E+00	7/34	No
Benzoic acid	NA[F]		5.00E+02	7/34	No
Bis(2-ethylhexyl)phthalate	NA[F]		6.20E-01	2/34	No
2-Chlorophenol	NA[F]		2.30E-02	1/34	No
Chrysene	NA[F]		9.90E+00	9/34	No
Dibenz(a,h)anthracene	NA[F]		1.60E+00	30/34	No[G]
Dibenzofuran	NA[F]		8.30E-01	3/34	No
Di-n-butyl phthalate	NA[F]		1.00E-01	2/34	No

Table E3.7. Summary of Screening for Detected Analytes–SWMU 30 Groundwater (Continued)

Analyte	SSL Protective of Groundwater[A]	Exceed SSL	Maximum Detection	Detection Frequency	Included in Groundwater Modeling
Fluoranthene	NA[F]		2.00E+01	3/34	No
Fluorene	NA[F]		1.30E+00	3/34	No[G]
Indeno(1,2,3-cd)pyrene	NA[F]		5.40E+00	6/34	No
2-Methylnaphthalene	NA[F]		2.70E-01	2/34	No
Naphthalene	NA[F]		3.10E-01	1/34	No[G]
Phenanthrene	NA[F]		1.70E+01	9/34	No
Pyrene	3.81E+00	Yes	2.30E+01	11/34	No[G]
1,2,4-Trichlorobenzene	NA[F]		3.30E-02	1/54	No
1,1-DCE	1.95E-05	Yes	5.00E-03	1/28	Yes
1,4-Dichlorobenzene	NA[F]		2.50E-02	1/39	No
Acetone	NA[F]		1.80E-02	3/26	No
TCE	9.69E-04	Yes	3.74E-02	1/28	Yes
Radionuclides (pCi/g)					
Neptunium-237	6.20E+03	No	1.68E+00	9/33	No
Plutonium-239	4.46E+00	No	6.20E-01	11/33	No
Technetium-99	2.63E+01	Yes	3.60E+02	13/34	Yes
Uranium-234	1.22E+01	Yes	1.15E+02	27/34	Yes
Uranium-235	1.14E+01	Yes	1.66E+01	14/34	Yes
Uranium-238	8.62E+00	Yes	5.65E+02	24/36	Yes

[A] Based on a residential child with dilution attenuation factor (DAF) = 1 (DOE 2001)
[B] Compound is considered an essential nutrient and has been excluded in accordance with the PGDP Risk Methods Document (2001)
[C] Total polychlorinataed biphenyl (PCB) maximum concentration reported as sum of all detected aroclors
[D] Total polyaromatic hydrocarbon (PAH) reported as benzo(a)pyrene toxicity equivalence factor (TEF)
[E] Groundwater modeling was not performed for Total PCB and Total PAH as they represent groups of compounds. PCBs and PAHs were assessed individually for groundwater modeling.
[F] SSL not listed in Table A.7 of PGDP Risk Methods Document (2001)
[G] Maximum detected value less than the soil/sediment no action level (NAL) for a child resident in Table A.17 of PGDP Risk Methods Document (2001), so analyte not retained

Table E3.8. Summary of Screening for Detected Analytes–SWMU 145 Groundwater

Analyte	SSL Protective of Groundwater[A]	Exceed SSL	Maximum Detection	Detection Frequency	Included in Groundwater Modeling
Inorganic Chemicals (Metals)(mg/kg)					
Aluminum	NA[F]		1.62E+04	74/74	No
Antimony	2.54E-02	Yes	2.02E+01	18/74	Yes
Arsenic	1.05E-03	Yes	2.19E+01	52/79	Yes
Barium	NA[F]		3.00E+02	88/88	No
Beryllium	2.11E+00	No	2.08E+00	50/89	No
Cadmium	5.02E-02	Yes	2.47E+00	13/89	No[I]
Calcium[B]	NA[F]		8.30E+04	74/74	No
Chromium	3.17E+06	No	1.20E+02	89/89	No
Cobalt	NA[F]		2.05E+01	70/89	No
Copper	NA[F]		1.35E+02	72/74	No
Iron	NA[F]		3.14E+04	74/74	No
Lead	NA[F]		4.67E+01	68/88	No
Magnesium[B]	NA[F]		2.35E+03	74/74	No
Manganese	2.26E+00	Yes	1.90E+03	74/74	Yes
Mercury	2.22E-02	Yes	4.70E-01	31/89	Yes
Molybdenum	NA[F]		3.39E+00	13/32	No
Nickel	1.98E+00	Yes	1.01E+02	65/74	Yes
Potassium[B]	NA[F]		1.30E+03	32/34	No
Selenium	3.92E-02	Yes	1.10E+00	2/86	No[H]
Sodium[B]	NA[F]		6.93E+02	46/70	No
Silver	6.67E-02	Yes	1.96E+01	3/88	No[H]
Thallium	NA[F]		1.20E+00	14/74	No
Uranium	NA[F]		3.11E+02	26/55	No
Vanadium	9.25E+00	Yes	6.52E+01	54/74	Yes
Zinc	2.78E+01	Yes	2.61E+02	52/79	No[I]
Organic Compounds (mg/kg)					
Total PCB[C]	4.92E-02	Yes	1.44E+01	NA	No[E]
Total PAH[D]	NA[F]		5.31E-02	NA	No[E]
Aroclor-1260	2.49E-02	Yes	1.25E+01	3/90	Yes
Benz(a)anthracene	NA[F]		5.00E-02	1/14	No
Benzo(a)pyrene	1.95E-03	Yes	4.40E-02	1/13	Yes
Benzo(b)fluoranthene	NA[F]		4.00E-02	1/13	No
Chrysene	NA[F]		6.70E-02	1/13	No
Di-n-butyl phthalate	NA[F]		8.10E-01	1/9	No
Fluoranthene	4.67E+00	No	1.30E-01	1/9	No
Phenanthrene	NA[F]		1.10E-01	1/13	No
Pyrene	3.81E+00	No	8.40E-02	1/13	No
1,2-Dimethylbenzene	NA[F]		3.60E-02	2/62	No
2-Butanone	NA[F]		1.13E-02	3/64	No
4-Methyl-2-pentanone	NA[F]		1.50E-02	1/64	No
Acetone	NA[F]		1.16E-01	20/64	No

Table E3.8. Summary of Screening for Detected Analytes–SWMU 145 Groundwater (Continued)

Analyte	SSL Protective of Groundwater[A]	Exceed SSL	Maximum Detection	Detection Frequency	Included in Groundwater Modeling
Ethylbenzene	4.48E-03	Yes	1.80E-02	3/64	No
m,p-Xylene	6.35E-02	No	0.022	2/62	No
Toluene	NA[F]		0.037	5/63	No
Methylene chloride	NA[F]		3.00E-03	2/64	No
Radionuclides (pCi/g)					
Americium-241	3.89E+07	No	1.10E+01	13/79	No
Cesium-137[G]	NA[F]	No	5.34E-01	14/67	No
Neptunium-237	6.20E+03	No	1.22E+00	18/86	No
Plutonium-239	4.46E+00	Yes	1.01E+01	21/75	Yes
Technetium-99	2.63E+01	Yes	2.81E+02	26/79	Yes
Uranium-234	1.22E+01	Yes	2.54E+02	58/86	Yes
Uranium-235	1.14E+01	Yes	1.66E+01	25/71	Yes
Uranium-238	8.62E+00	Yes	3.26E+02	59/86	Yes

[A] Based on a residential child with dilution attenuation factor (DAF) = 1 (DOE 2001)

[B] Compound is considered an essential nutrient and has been excluded in accordance with the PGDP Risk Methods Document (2001)

[C] Total polychlorinated biphenyl (PCB) maximum concentration reported as sum of all detected aroclors

[D] Total polyaromatic hydrocarbon (PAH) reported as benzo(a)pyrene toxicity equivalence factor (TEF)

[E] Groundwater modeling was not performed for Total PCB and Total PAH as they represent groups of compounds. PCBs and PAHs were assessed individually for groundwater modeling.

[F] SSL not listed in Table A.7 of PGDP Risk Methods Document (2001)

[G] Not applicable as the radionuclide does not reach groundwater within 10,000 years precluding receptor uptake, per Section 5 of the main text and Appendix E[H] Less than 5% detects, so analyte not retained.

[I] Maximum detected value less than the soil/sediment no action level (NAL) for a child resident in Table A.17 of PGDP Risk Methods Document (2001), so analyte not retained

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APPENDIX F

BASELINE HUMAN HEALTH RISK ASSESSMENT

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CONTENTS

FIGURES

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TABLES

ACRONYMS

ABS	dermal absorption factor
ATSDR	Agency for Toxic Substances and Disease Registry
BAF	bioaccumulation factor
BGOU	Burial Grounds Operable Unit
bgs	below ground surface
BHHRA	Baseline Human Health Risk Assessment
BRA	baseline risk assessment
CAS	Chemical Abstract Service
CDI	chronic daily intake
CNS	central nervous system
COC	contaminant of concern
COPC	chemical of potential concern
CSM	conceptual site model
DAF	dilution attenuation factor
DCE	dichloroethene
DHHS	Department of Health and Human Services
DNA	deoxyribonucleic acid
DOE	U.S. Department of Energy
ELCR	excess lifetime cancer risk
EPA	U. S. Environmental Protection Agency
EPC	exposure point concentration
GI	gastrointestinal tract
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HQ	hazard quotient
IARC	International Agency for Research on Cancer
IRIS	Integrated Risk Information System
KDEP	Kentucky Department for Environmental Protection
LET	linear energy transfer
MCL	maximum contaminant level
MEPAS	Multimedia Environmental Pollution Assessment System
NAL	no action level
NCEA	National Center for Environmental Assessment
NSDD	North-South Diversion Ditch
OREIS	Oak Ridge Environmental Information System
PAH	polyaromatic hydrocarbon
PCB	polychlorinated biphenyl
PGDP	Paducah Gaseous Diffusion Plant
POC	pathway of concern
POE	point of exposure
PRG	preliminary remediation goal
PVC	polyvinyl chloride
RAGS	Risk Assessment Guidance for Superfund
RAIS	Risk Assessment Information System
RCRA	Resource Conservation and Recovery Act
RESRAD	RESidual RADioactive Materials
RfC	reference concentration
RfD	reference dose

RGA	Regional Gravel Aquifer
RGO	remedial goal option
RI	remedial investigation
RME	reasonable maximum exposure
SF	slope factor
SI	site investigation
SQL	sample quantitation limit
SSL	soil screening level
SVOC	semivolatile organic compound
SWMU	solid waste management unit
SWOU	Surface Water Operable Unit
^{99}Tc	technetium-99
TCE	trichloroethene
TEF	toxicity equivalence factor
TVA	Tennessee Valley Authority
VOC	volatile organic compound
WAG	waste area grouping
WKWMA	West Kentucky Wildlife Management Area

BASELINE HUMAN HEALTH RISK ASSESSMENT

This baseline human health risk assessment (BHHRA) utilizes information collected during the recently completed remedial investigation (RI) of eight Burial Grounds Operable Unit (BGOU) Solid Waste Management Units (SWMUs), in addition to information collected during previous investigations (listed in Section F.1), to characterize the baseline risks posed to human health from contact with contaminants in soil and water at these SWMUs and at locations to which contaminants may migrate. The units included are SWMU 2, SWMU 3, SWMU 4, SWMU 5, SWMU 6, SWMU 7, SWMU 30, and SWMU 145 located at the Paducah Gaseous Diffusion Plant (PGDP) in Paducah, Kentucky. A summary of the data used is presented in Attachment F1 to this appendix.

Part of Goal 2 for the BGOU RI, as presented in the BGOU work plan (DOE 2006), was to determine if contaminants at the BGOU units are contributing to groundwater contamination; this risk assessment supports that goal by using modeled concentrations of contaminants to the Regional Gravel Aquifer (RGA) to support the refinement of an assessment of risks to human health and the environment through groundwater. The work plan also specified that the RI should include a risk assessment for residential, industrial, and recreational receptors. Risk assessments for each of those scenarios are presented here.

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/OR/07-1506&D2 (DOE 2001). 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 PGDP.

Consistent with the 2001 revision to the Risk Methods Document, this BHHRA is presented in nine sections. The first section reviews the results of previous risk assessments that are useful in understanding the risks posed to human health by contaminants at or migrating from the source areas. Identification of chemicals of potential concern (COPCs) is in the second section. The third section documents the exposure assessment for the sources, including 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). The fourth section presents 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 reports the results of the risk characterization for current and future land use and identifies contaminants, pathways, and land use scenarios of concern. The sixth section contains qualitative and quantitative analyses of the uncertainties affecting the results of the BHHRA. The seventh section summarizes the methods used in the BHHRA and presents the BHHRA's conclusions and observations. The eighth section uses the results of the BHHRA to develop site-specific risk-based remedial goal options (RGOs). The ninth section contains references.

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F.1. RESULTS OF PREVIOUS STUDIES

Four previous reports contain risk assessment results for one or more of the burial grounds considered in this RI. The results of these assessments are summarized here and are presented in more detail in Attachment F2 to this appendix. For groundwater, these previous assessments were based on measured groundwater concentrations, while this risk assessment used modeled concentrations. In the previous assessments summarized here, lead had exceedingly high hazard indices (HIs) and was the overwhelming risk driver. This finding may be attributed to the use of a very conservative (1.0E-07 mg/kg-day) reference dose (RfD) value provided by KDEP. That RfD is no longer in use by KDEP; therefore, the contaminants of concern (COCs), risks, and hazards from those reports presented in this appendix are based on the assessment with lead excluded as a COPC, which also was presented in these previous reports. This issue is discussed further in the uncertainty section of this appendix. Reports containing previous assessments and the year the assessment was completed are listed below:

- *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1895/V1-V4&D1, U.S. Department of Energy, Paducah, KY (DOE 2000).

- *Remedial Investigation Report for Solid Waste Management Units 7 and 30 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1604/V1&D2, U.S. Department of Energy, Paducah, KY (DOE 1998a).

- *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds Solid Waste Management Units 2 and 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1141&D2, U.S. Department of Energy, Paducah, KY (DOE 1994).

- *Data Summary and Interpretation Report for Interim Remedial Design at Solid Waste Management Unit 2 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1549&D1, U.S. Department of Energy, Paducah, KY (DOE 1997).

F.1.1 RESULTS OF REMEDIAL INVESTIGATION REPORT FOR WASTE AREA GROUPING 3 AT THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

The Waste Area Grouping (WAG) 3 RI report BHHRA contains results for SWMU 4, SWMU 5, and SWMU 6 (DOE 2000). Scenarios assessed included the following:

- **Current industrial worker**
  Incidental ingestion of soil
  Dermal contact with soil
  Inhalation of vapors and particulates emitted from soil
  External exposure to ionizing radiation emitted from soil

- **Future industrial worker**
  Incidental ingestion of soil
  Dermal contact with soil
  Inhalation of vapors and particulates emitted from soil
  External exposure to ionizing radiation emitted from soil
  Ingestion of groundwater

Dermal contact with groundwater while showering
Inhalation of vapors emitted by groundwater while showering

- **Future excavation worker**
  Incidental ingestion of soil (soil and waste)
  Dermal contact with soil (soil and waste)
  Inhalation of vapors and particulates emitted from soil (soil and waste)
  External exposure to ionizing radiation emitted from soil (soil and waste)

- **Future recreational user**
  Ingestion of venison grazing on vegetation grown in contaminated soil
  Ingestion of rabbit grazing on vegetation grown in contaminated soil
  Ingestion of quail grazing on vegetation grown in contaminated soil

- **Future on-site rural resident**
  Incidental ingestion of soil
  Dermal contact with soil
  Inhalation of vapors and particulates emitted from soil
  External exposure to ionizing radiation emitted from soil
  Ingestion of groundwater
  Dermal contact with groundwater while showering
  Inhalation of vapors emitted by groundwater during household use
  Inhalation of vapors emitted by groundwater while showering
  Ingestion of vegetables grown in contaminated soil

- **Off-site rural resident (at PGDP security fence)**
  Ingestion of groundwater
  Dermal contact with groundwater while showering
  Inhalation of vapors emitted by groundwater during household use
  Inhalation of vapors emitted by groundwater while showering

For all SWMUs in WAG 3, the cumulative human health systemic toxicity and excess lifetime cancer risk (ELCR) exceeded the accepted standards of KDEP and EPA for one or more land use scenarios when assessed using default exposure parameters. The land use scenarios for which risks exceeded *de minimis* levels [i.e., for KDEP, a cumulative HI of 1 or a cumulative ELCR of 1.0E-06, and for EPA, an HI of 1 and a range of E-04–E-06 for ELCR] are summarized in the WAG 3 report and Tables F2.13 through F2.15 in Attachment F2 of this appendix.

F.1.1.1 Exposure Routes

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. This is a direct result of using dermal absorption factors that exceed gastrointestinal absorption values and may be overly conservative. In such circumstances, risk estimates from the dermal exposure route may be unrealistic and exceed the real risk posed by this route of exposure. Although chemical-specific dermal absorption factor (ABS) values were used when available, default ABS values were used for most chemicals because chemical-specific values are lacking. Chemical-specific ABS values are available for polychlorinated biphenyls (PCBs) and cadmium and were used in this BHHRA. Remedial decisions based on the dermal contact with soil exposure route should be carefully considered because of the uncertainty associated with risk from this exposure route. While the dermal exposure route may represent an important route of contaminant uptake for persons exposed to soil at WAG 3, ingestion of groundwater appears to represent the most important mechanism of uptake of

contaminants from the RGA aquifer and McNairy Formation, with ingestion of groundwater-irrigated vegetables also representing a significant exposure route for the hypothetical on-site resident.

F.1.1.2 Current and Future Industrial Worker

Soil hazards (total HIs) for the current industrial worker exceed *de minimis* levels (HI >1 or ELCR >1.0E-06) at only SWMU 4+ (HI = 3.62) (Exhibit 1.23, p. 1-171, DOE 2000). The contaminants at SWMU 4 contributing more than 10% to total HI are chromium, iron, and vanadium, with dermal contact as the driving exposure route (Exhibit 1.55, p. 1-208, DOE 2000). Soil cancer risks (total ELCRs) for the current industrial worker exceed 1.0E-04 at SWMUs 4, 5, and 6 (Exhibit 1.25, p. 1-172, DOE 2000). The major contaminant in surface soils at these SWMUs is beryllium, with significant contributions from polyaromatic hydrocarbons (PAHs) at SWMUs 5 and 6 (Exhibit 1.26, p. 1-172, DOE 2000). For SWMUs 4, 5, and 6, dermal contact is the driving exposure route (Exhibits 1.55, 1.56, 1.57, pp.1-208 to 1-215, DOE 2000). The future industrial land use scenario is identical to the current industrial land use scenario except that the future industrial land use scenario also evaluates use of groundwater. Groundwater HIs for the future industrial worker exceed *de minimis* levels at SWMUs 4, 5, and 6 (16,000–216,000); however, these hazards are markedly reduced by excluding lead as a COPC (19.1–75.9) (Exhibits 1.27, 1.28, pp. 1-174 to 1-175, DOE 2000). Including lead as a COPC masks the contribution from other COPCs. Iron, manganese, vanadium, and trichloroethene (TCE) contribute more than 10% to total HIs, with ingestion as the driving exposure route (Exhibits 1.55, 1.56, 1.57, pp.1-208 to 1-215, DOE 2000). Iron is both widespread and predominant as a COC, contributing 61–80% to HI, depending on location (Exhibit 1.28, p. 1-175, DOE 2000). Groundwater ELCRs for the future industrial worker exceed 1.0E-04 at SWMUs 4, 5, and 6 (>1.0E-04) (Exhibit 1.35, p. 1-180, DOE 2000). Arsenic, beryllium, TCE, and radium-226 (^{226}Ra) contribute more than 10% to ELCR, with ingestion as the driving exposure route (Exhibits 1.55, 1.56, 1.57, pp.1-208 to 1-215, DOE 2000).

F.1.1.3 Future Excavation Worker

Total soil and waste HIs for the future excavation worker exceed *de minimis* levels at SWMUs 4, 5, and 6 (2.16–1750), but fall below 3 when lead is excluded as a COPC (Exhibits 1.33, 1.34, p. 1-179, DOE 2000). Including lead as a COPC masks the contribution from other COPCs. Chromium, iron, manganese, and vanadium are the contaminants contributing more than 10% to HI, with dermal contact as the driving exposure route (Exhibits 1.55, 1.56, 1.57, pp.1-208 to 1-215, DOE 2000). Total soil and waste ELCRs for the future excavator exceed 1.0E-04 at SWMUs 4, 5, and 6 (Exhibit 1.41, p. 1-184, DOE 2000). Total Uranium is the major contributor to ELCR at SWMU 4 (83%), with external exposure as the driving exposure route (Exhibit 1.55, p. 1-208, DOE 2000). Beryllium and Total PAHs contribute 10% or more to ELCR at SWMU 5, with dermal contact as the driving exposure route (Exhibit 1.56, p. 1-211, DOE 2000). Beryllium is the major contributor to ELCR at SWMU 6, with dermal contact as the driving exposure route (Exhibit 1.57, p. 1-213, DOE 2000).

F.1.1.4 Future Rural Resident

Soil HIs for the future child on-site rural resident exceed *de minimis* levels at SWMUs 4, 5, and 6, but are less than 100 when lead is excluded as a COPC (Exhibit 1.29, p. 1-176, DOE 2000). Including lead as a COPC masks the contribution from other COPCs. Aluminum, arsenic, chromium, iron, and nickel contribute more than 10% to total HIs, with dermal contact with soil and ingestion of vegetables raised in soil as the driving exposure routes (Exhibits 1.55, 1.56, 1.57, pp.1-208 to 1-215, DOE 2000). The uncertainty associated with the dermal exposure route has been previously discussed. Exclusion of the vegetable exposure route would reduce soil HIs for the rural resident by as much as 87% (Exhibits 1.55, 1.56, 1.57, pp.1-208 to 1-215, DOE 2000). Soil ELCRs for the future rural resident exceed *de minimis* levels at SWMUs 4, 5, and 6 (> 1.0E-03). Beryllium and uranium-238 (^{238}U) contribute 10% or more to

ELCR at SWMU 4, with dermal contact as the driving exposure route (Exhibit 1.55, p. 1-208, DOE 2000). Arsenic and Total PAHs contribute 10% or more to ELCR at SWMU 5, with ingestion of vegetables as the driving exposure route (Exhibit 1.56, p. 1-211, DOE 2000). Beryllium and Total PAHs contribute 10% or more to ELCR at SWMU 6, with ingestion of vegetables as the driving exposure route (Exhibit 1.57, p. 1-213, DOE 2000). Exclusion of the vegetable exposure route would reduce soil ELCRs for the rural resident by as much as 90% (Exhibits 1.55, 1.56, 1.57, pp.1-208 to 1-215, DOE 2000).

Groundwater HIs for the future child on-site rural resident exceed *de minimis* levels at SWMUs 4, 5, and 6 (178,000 – 2,390,000), but are reduced by several orders of magnitude, with lead excluded as a COPC (223−798) (Exhibits 1.29, 1.30, p. 1-176 to 1-177, DOE 2000). Including lead as a COPC masks the contribution from other COPCs. Iron, manganese, vanadium, carbon tetrachloride, and TCE contribute 10% or more to total HI, with ingestion of water and ingestion of vegetables irrigated with water as the driving exposure routes (Exhibits 1.55, 1.56, 1.57, pp.1-208 to 1-215, DOE 2000). As with the future industrial worker land use scenario, iron is both widespread and predominant as a COC, contributing 49–77% to HI, depending on location (Exhibits 1.55, 1.56, 1.57, pp.1-208 to 1-215, DOE 2000). Exclusion of the vegetable exposure route would reduce groundwater HIs for the rural resident by as much as 40% (Exhibits 1.55, 1.56, 1.57, pp.1-208 to 1-215, DOE 2000). Groundwater ELCRs for the future rural resident exceed *de minimis* levels at SWMUs 4, 5, and 6 (> 1.0E-03). Arsenic, beryllium, 1,1-dichloroethene (DCE), trichloroethene (TCE), ^{226}Ra, and technetium-99 (^{99}Tc) contribute more than 10% to ELCR, with ingestion of water and ingestion of vegetables irrigated with water as the driving exposure routes (Exhibits 1.55, 1.56, 1.57, pp.1-208 to 1-215, DOE 2000). Exclusion of the vegetable exposure route would reduce groundwater ELCRs for the rural resident by as much as 46% (Exhibits 1.55, 1.56, 1.57, pp.1-208 to 1-215, DOE 2000).

F.1.1.5 Future Recreational User

The future recreational user scenario is not of concern regarding total soil HI at any WAG 3 SWMU (Exhibit 1.32, p. 1-178, DOE 2000). In terms of cancer risks, total soil ELCR exceeds *de minimis* levels only at SWMU 5 (1.0E-05), where PAHs contribute 96% to risk, with ingestion of rabbit as the driving exposure route (Exhibits 1.55, 1.56, 1.57, pp.1-208 to 1-215, DOE 2000).

F.1.1.6 Modeled On-site and Off-site COCs

As noted previously, this baseline risk assessment (BRA) used results of fate and transport modeling [Multimedia Environmental Pollution Assessment System (MEPAS)] to estimate the baseline risks posed to human health through contact with media impacted by contaminants migrating off-site from the various sources in WAG 3. The following chemicals are "priority COCs" for MEPAS-modeled off-site use of groundwater (i.e., rural residential use in the home). These COCs may migrate from a source at a SWMU in WAG 3 to an off-site location and present a chemical-specific HI or ELCR to the rural resident that is greater than 0.1 or 1.0E-06, respectively (Section 1.5.5, p. 1-185, DOE 2000).

- SWMU 4—arsenic, cobalt, copper, iron, manganese, nickel, vanadium, 1,1-DCE, 1,2-DCE, carbon tetrachloride, TCE, vinyl chloride, neptunium-237 (^{237}Np), plutonium-239 (^{239}Pu), ^{99}Tc, Total Uranium (assessed as ^{238}U), and ^{238}U

- SWMU 5—iron and manganese

- SWMU 6—iron and manganese

The RESidual RADioactive Materials (RESRAD) model was used to model both dose and excess cancer risk for radionuclides, accounting for in-growth of decay products. The following chemicals are "priority

COCs" for modeled on-site soil use (i.e., industrial and excavator) and on-site groundwater use (i.e., rural residential use in the home). These chemicals are radionuclides that, through in-growth of decay products, present a chemical-specific ELCR that exceeds 1.0E-06 from exposure to surface and subsurface soil and waste at SWMUs in WAG 3 and radionuclides that may migrate from a source at a SWMU in WAG 3 to on-site RGA groundwater and present a chemical-specific ELCR to the rural resident that is greater than 1.0E-06 (Section 1.5.6, p. 1-190, DOE 2000):

- SWMU 4—thorium-230 (^{230}Th), Total Uranium (modeled as ^{238}U), and ^{238}U
- SWMU 5—^{226}Ra and ^{238}U
- SWMU 6— ^{237}Np, ^{99}Tc, and ^{238}U

F.1.2 RESULTS OF *REMEDIAL INVESTIGATION REPORT FOR SOLID WASTE MANAGEMENT UNITS 7 AND 30 OF WASTE AREA GROUPING 22 AT THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY* DOE/OR/07-1604/V1&D2

The following is a summary of the results of the BHHRA found in the RI report for the WAG 22, Burial Grounds Solid Waste Management Units 7 and 30 (DOE 1998a). A complete summary of the BRA result can be found in WAG 22 report and in Attachment F2.

- **Current Industrial Worker**
  Soil ingestion
  Inhalation of volatile organic compounds (VOCs) or airborne soil particulates
  Dermal contact
  External exposure to ionizing radiation

- **Future Industrial Worker**
  Soil ingestion
  Inhalation of VOCs or airborne soil particulates
  Dermal contact
  External exposure to ionizing radiation
  Ingestion of groundwater
  Inhalation of VOCs released from groundwater while showering
  Dermal contact with groundwater contaminants while showering

- **Future On-site Rural Resident**
  Soil ingestion
  Inhalation of VOCs or airborne soil particulates
  Dermal contact
  External exposure to ionizing radiation
  Ingestion of groundwater
  Inhalation of VOCs released from groundwater while showering
  Dermal contact with groundwater contaminants while showering
  Exposure to contaminated biota (i.e., garden vegetables)

- **Future Excavation Worker**
  Soil ingestion
  Inhalation of VOCs or airborne soil particulates
  Dermal contact
  External exposure to ionizing radiation

- **Future Recreational User**
  Ingestion of game species including deer, rabbit, and quail

The total ELCR values calculated using default exposure factors were > 1.0E-04 for all receptor scenarios except the recreational user. The total HI value calculated using default factors was > 1 for all scenarios. Total ELCR values calculated for the recreational user were within the 1.0E-04 to 1.0E-06 range.

F.1.2.1 Exposure Routes

The dermal contact with soil exposure route poses considerable risk, and most of this risk comes from contact with metals in soil. In fact, for all land use scenarios evaluated, the systemic toxicity and the ELCR posed through the soil dermal exposure route exceeds that posed by the soil ingestion route. This is a direct result of using ABS values that may be too conservative because they exceed gastrointestinal absorption values. This observation indicates that the risk estimates from the dermal exposure route may be unrealistic and exceed 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 are lacking. Chemical-specific ABS values were available for dioxins, PCBs, cadmium, and carbon disulfide and are used in this BHHRA. Remedial decisions based on the dermal contact with soil exposure route should be carefully considered because of the uncertainty associated with risk from this exposure route.

F.1.2.2 HI and ELCR Discussions

In the next subsections, soil hazards (HI) and ELCRs are compared to *de minimis* levels for each of the scenarios evaluated. Two types of HIs and ELCRs were calculated for this risk assessment and are summarized here. The first is the total HI/ELCR derived using all default exposure values and will be referred to as the default HI/ELCR. The second is the total site-specific or average HI/ELCR without groundwater, with EPA default dermal values, without lead, and without food exposure routes. These risk and hazard values are referred to as site-specific HI/ELCR. The values that will be discussed are those that exceed *de minimis* levels, HI > 0.1 and ELCR > 1.0E-06.

F.1.2.2.1 Current Industrial Worker

The default HI of 4,800 for combined exposure to soil and groundwater for SWMU 7 and 3,900 for SWMU 30 exceeded *de minimis* levels. The default ELCR of 4E-03 for both SWMUs and the site-specific ELCR, 1.0E-05 for both SWMUs exceeded *de minimis* levels. For both SWMUs 7 and 30, dermal contact with soil is the driving exposure route. The primary contributing COC for ELCR is beryllium, and the primary contributing COC for HI is iron (Sections 1.5.3.1, 1.5.3.2, 1.7.4.3, pp. p.1-101, 1-146, DOE 1998a).

F.1.2.2.2 Future Industrial Worker

The default HI of 53,000 for combined exposure to soil and groundwater for SWMU 7 and 22,000 for SWMU 30 and the site-specific HIs of 0.3 for SWMU 7 and 0.2 for SWMU 30 exceeded *de minimis* levels. The default ELCR of 6.0E-03 for SWMU 7 and 4.0E-03 for SWMU 30 and the site-specific ELCRs of 2.0E-04 for both SWMUs exceeded *de minimis* levels. For SWMU 7, the driving exposure route is dermal contact with soil for ELCR, with beryllium being the primary contributor. The driving exposure route for HI is ingestion of groundwater, and the primary contributor is PCBs. For SWMU 30, the driving exposure route is dermal contact with soil, with the contributing COCs as beryllium for ELCR and TCE for HI (Sections 1.5.4.1, 1.5.4.2, 1.7.4.3, p. 1-102, 1-146, DOE 1998a).

F.1.2.2.3 Future On-site Rural Resident

The default HI of 860,000 for SWMU 7 and 460,000 for SWMU 30 and the site-specific HIs of 2 for both SWMUs exceeded *de minimis* levels. The default ELCR of 5.0E-02 for SWMU 7 and 4.0E-02 for SWMU 30 and the site-specific ELCRs of 1.0E-03 for SWMU 7 and 8.0E-04 for SWMU 30 exceeded *de minimis* levels. The future child rural resident scenario was evaluated to determine the exposure route for HI. The driving exposure route for HI is ingestion of vegetables from groundwater with 1,2-DCE (total) being the primary contributor for SWMU 7. The driving exposure route for HI is ingestion of vegetables from soil, with uranium being the primary contributor for SWMU 30. A combined child and adult rural resident was evaluated to determine the driving exposure routes for ELCR. The driving exposure route also was ingestion of vegetables from soil, and beryllium was the primary contributor for both SWMUs (Sections 1.5.4.1, 1.5.4.2, 1.7.4.3, p. 1-102, 1-146, DOE 1998a).

F.1.2.2.4 Future Excavation Worker

The default HI of 7,100 for SWMU 7 and 5,100 for SWMU 30 exceeded *de minimis* levels. Only the default ELCR of 2.0E-03 for SWMU 7 and 1.0E-03 for SWMU 30 exceeded *de minimis* levels. For both SWMUs 7 and 30, the driving exposure route was determined to be dermal contact with soil. Beryllium was the primary contributor for ELCR, and iron was the primary contributor for HI (Sections 1.5.4.1, 1.5.4.2, 1.7.4.3, p. 1-102, 1-146, DOE 1998a).

F.1.2.2.5 Future Recreational User

The default HI of 3 for SWMU 7 and 2 for SWMU 30 exceeded *de minimis* levels. The default ELCR of 1E-05 for SWMU 7 and 2E-05 for SWMU 30 exceeded *de minimis* levels. (Note: the default ELCR for SWMU 30 is reported incorrectly in Table ES.6 and in Section 1.7.4.3 of DOE 1998a. The default ELCR is reported as 1.50E-05 in Table 1.67, so 2E-05 is shown here.) The future adult recreational user scenario was used to determine the exposure route for ELCR. HI was not evaluated because the exposure pathway HI was less than 0.1. The driving exposure route for both SWMUs is ingestion of rabbit, and dibenz(a,h)anthracene was the primary contributor (Sections 1.5.4.1, 1.5.4.2, 1.7.4.3, p. 1-102, 1-146, DOE 1998a).

F.1.2.3 COCs

The COCs were identified in the BHHRA using the approach set forth in the PGDP Risk Methods Document (DOE 2001). The COCs were identified by applying the *de minimis* thresholds to the quantitative risk results for applicable use scenarios including the industrial worker, excavation worker, and off-site rural residential scenarios. A number of COPCs were not evaluated because no toxicity information was available. These COPCs were not retained as COCs in the BHHRA.

Chemicals of concern identified for SWMUs 7 and 30 include VOCs in groundwater; semivolatile organic compounds (SVOCs) in SWMU 7 soil, SWMU 30 soil, and drainage ditch sediments; PCBs in SWMU 30 soil and drainage ditch sediments; metals in SWMU 7 soil, SWMU 30 soil, and drainage ditch sediments; and radionuclides in SWMU 7 soil, SWMU 30 soil, groundwater, and drainage ditch sediments. No COCs were identified for surface water in the ditches because surface-water flow in the ditches is intermittent and not available for exposure. The COCs identified are listed below (Section 1.5.7.2, p. 1-110, DOE 1998a):

VOCs: vinyl chloride;

SVOCs: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene;

PCBs: Aroclor-1260;

Metals: aluminum, antimony, arsenic, beryllium, cadmium, chromium, copper, iron, nickel, manganese, uranium, vanadium;

Radionuclides: ^{237}Np, ^{239}Pu, ^{99}Tc, uranium-234 (^{234}U), uranium-235 (^{235}U), uranium-235/236 ($^{235/236}$U), ^{238}U.

COCs were identified as those contaminants that had chemical-specific ELCRs summed over all exposure routes within the use scenario of concern that were greater than or equal to 1×10^{-6} or whose hazard quotients (HQs) summed over all exposure routes within a use scenario of concern were greater than or equal to 0.1. Results from SESOIL modeling and modeling for ^{99}Tc are provided in Appendix E, Section E.1.6.

F.1.3 RESULTS OF *REMEDIAL INVESTIGATION ADDENDUM FOR WASTE AREA GROUPING 22, BURIAL GROUNDS SOLID WASTE MANAGEMENT UNITS 2 AND 3 AT THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY*, DOE/OR/07-1141&D2

The following is a summary of the BRA found in the RI Addendum for the WAG 22, Burial Grounds Solid Waste Management Units 2 and 3 (DOE 1994). A complete summary of the BRA result can be found in WAG 22 report and in Tables F2.1 through F2.12 in Attachment F2.

- **Current Industrial Worker**
  Soil ingestion
  Dermal absorption
  Inhalation
  External exposure to ionizing radiation

- **Site-specific Industrial Worker**
  Soil ingestion
  Dermal absorption
  Inhalation
  External exposure to ionizing radiation

- **Future On-site and Off-site Rural Resident**
  Ingestion of groundwater contaminants from groundwater use
  Inhalation of VOCs from groundwater use

The future resident scenario exhibited a total ELCR value > 1.0E-04 when calculated using default exposure factors. The future resident scenario also exhibited total HIs > 1.0E-04 calculated using default exposure factors > 1. Site-specific and current industrial worker scenarios exhibited total ELCR values that fell between 1.0E-04 and 1.0E-06. The site-specific and current industrial worker scenarios also exhibited HI values < 1 (Sections 2.6.1.4.1, 2.6.1.4.2, pp.2-76 to 2-83, DOE 1994).

F.1.3.1 Exposure Routes

From the evaluation of the chemical ELCR, soil ingestion was the driving exposure route and from the evaluation of the radiological ELCR, external exposure to ionizing radiation was the driving exposure route. Through the HI calculation, dermal absorption was the driving exposure route. The dominant driving exposure route for groundwater was ingestion of groundwater. Remedial decisions based on the dermal absorption exposure route should be carefully considered because of the uncertainty associated with risk from this exposure route.

F.1.3.2 HI and ELCR Discussions

In the next subsections soil hazards (HI) and ELCRs are compared to the *de minimis* ELCR level, ELCR > 1.0E-06, and to HI > 0.1 for each of the scenarios evaluated. The values that are discussed are those that exceed these levels. The chemical ELCR and radiological ELCR are presented separately in the original document and each is compared to the *de minimis* ELCR level of 1.0E-06. The HI is compared to the level of 1.0.

F.1.3.2.1 Current Industrial Worker

The chemical ELCR, 5.0E-06, exceeded *de minimis* levels and arsenic was the primary contributing COC. The driving exposure route was soil ingestion. The radiological ELCR was calculated separately in this assessment, 1.0E-04, exceeded *de minimis* level, with ^{235}U being the primary contributor. The driving exposure route was external exposure to ionizing radiation. The HI did not exceed 0.1 with a result of 0.007 (Attachment 2-4, 2-5, 2-6, DOE 1994).

F.1.3.2.2 Site-specific Industrial Worker

The chemical ELCR, 5.0E-07, did not exceed *de minimis* level. The radiological ELCR, 1.0E-05, did exceed *de minimis* level, with ^{235}U being the primary contributor. The driving exposure route was external exposure to ionizing radiation. The HI did not exceed 0.1 at a result of 0.07, and the driving exposure route was dermal absorption (Attachment 2-1, 2-2, 2-3, DOE 1994).

F.1.3.2.3 Future On-site and Off-site Rural Resident

The chemical ELCR of 2.0E-03 exceeded *de minimis,* with N-nitroso-di-n-propylamine being the primary contributor. The radiological ELCR of 1.0E-05 exceeded *de minimis* with the primary contributor as ^{99}Tc. The HI exceeded 0.1, and the primary contributor was manganese. The dominant exposure route was ingestion of groundwater (Attachment 2-7, 2-10, 2-12, DOE 1994).

F.1.3.3 COCs

The COCs were identified as those contaminants that had chemical-specific ELCRs summed over all exposure routes within the use scenario of concern that were greater than or equal to 1×10^{-6} or whose HQs summed over all routes within a use scenario of concern were greater than or equal to 0.1 for any of the scenarios evaluated: industrial worker, excavation worker, and off-site rural residential scenarios. A number of COPCs were not evaluated because no toxicity information was available. These COPCs were not retained as COCs in the BHHRA. The COCs identified are as listed below (Table 2-23, DOE 1994):

VOCs: TCE.

Metals: arsenic, barium, beryllium, cadmium, chromium, manganese, nickel, silver, thallium, vanadium, uranium (total).

Radionuclides: ^{99}Tc.

F.1.4 *DATA SUMMARY AND INTERPRETATION REPORT FOR INTERIM REMEDIAL DESIGN AT SOLID WASTE MANAGEMENT UNIT 2 OF WASTE AREA GROUP 22 AT THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY,* DOE/OR/07-1549&D1

F.1.4.1 Screening Approach

This document presents a screening risk assessment for SWMU 2 based on an updated CSM, but, unlike the other documents summarized here, has no BRA. The preliminary remediation goals (PRGs) used for the screening were the residential and industrial PRGs from the 1996 Risk Assessments Methods document (DOE 1996). The PRGs for groundwater were based on residential use. A summary of the COPCs from the comparison to PRGs presented in this document is detailed here.

F.1.4.2 Comparison to Industrial PRGs (based on HQ=1 and risk =1E-04)

Sediment COPCs (Section 5.2.1.1, p. 5-4, DOE 1994)**:**
- Arsenic, iron, and vanadium
- Cesium-137 (^{137}Cs), ^{235}U, ^{238}U, ^{239}Pu

Surface soil COPCs (Section 5.2.1.2, p. 5-4, DOE 1994)**:**
- Arsenic, beryllium, manganese, and vanadium
- PCBs
- ^{235}U and ^{238}U

F.1.4.3 Residential comparison to PRGs (Section 5.2.1.7, p. 5-6, DOE 1994)

Groundwater (RGA):
- All inorganic chemicals which were analyzed for (particularly arsenic, beryllium, manganese)
- *trans*-1,2-DCE
- ^{238}U, ^{99}Tc, ^{239}Pu, ^{237}Np, and Americium-241 (^{241}Am)

Because this was a screening assessment, the process stopped at COPC selection and no additional determination of COCs was made in this document.

F.1.5 COPCs FOR GROUNDWATER IDENTIFIED IN BGOU RI WORK PLAN SCREENING

A screening of measured concentrations in the groundwater against no action levels (NALs) and action levels from the 2001 PGDP Risk Methods Document (DOE 2001) is presented in Appendix E of the BGOU RI Work Plan. The priority COCs identified in the screening of measured groundwater data for each of these SWMUs are listed below:

- SWMU 2–arsenic, barium, beryllium, cadmium, iron, manganese, nickel, uranium, vanadium, 1,1-DCE, *cis*-1,2-DCE, TCE, and vinyl chloride

- SWMU 3–arsenic, uranium, TCE, and ^{234}U

- SWMU 4–aluminum, ammonia, antimony, arsenic, barium, beryllium, boron, cadmium, cobalt, copper, iron, manganese, mercury, nickel, nitrate, vanadium, zinc, acetone, PCB-1254, carbon tetrachloride, chloroform, 1,1-DCE, *cis*-1,2-DCE, *trans*-1,2-DCE, naphthalene, 1,1,2-TCA, TCE, vinyl chloride, and ^{99}Tc

- SWMU 5–aluminum, arsenic, barium, beryllium, cadmium, cobalt, copper, iron, manganese, nickel, vanadium, zinc, TCE, and $^{226}Ra+D$

- SWMU 6–aluminum, arsenic, barium, beryllium, cadmium, cobalt, copper, iron, manganese, nickel, uranium, vanadium, PCB-1016, TCE, $^{237}Np+D$, ^{99}Tc, and ^{234}U

- SWMUs 7 and 30–aluminum, arsenic, barium, beryllium, cadmium, cobalt, copper, iron, manganese, molybdenum, nickel, uranium, acetone, PCB-1016, PCB-1248, PCB-1254, benzene, carbon tetrachloride, chlorobenzene, chloroform, 1,3-dichlorobenzene, 1,4-dichlorobenzene, *cis*-1,2-DCE, 2,4-dimethylphenol, tetrachloroethene, TCE, vinyl chloride, $^{222}Rn+D$, ^{99}Tc, and ^{234}U

- SWMU 145–aluminum, antimony, arsenic, barium, boron, iron, manganese, molybdenum, nickel, uranium, vanadium, white phosphorus, acetone, PCB-1016, benzene, chloroform, m-cresol, TCE, $^{222}Rn+D$, and ^{234}U

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F.2. IDENTIFICATION OF COPCs

Soil COPCs for direct contact were determined in the previous studies as outlined in Section F.1. Detected soil analytes were screened as described in Section 5 and Appendix E to determine which analytes would be modeled to determine concentrations in groundwater. The maximum detected soil concentrations (surface to 60 ft bgs) was compared to the child resident soil screening levels[1] (SSLs) with a dilution attenuation factor (DAF)=1 (DOE 2001). Those analytes with a maximum concentration greater than their respective SSLs then were compared to soil/sediment child resident NALs (DOE 2001). Those constituents greater than both the SSL and NAL were retained as COPCs for groundwater modeling. TCE, ^{99}Tc, and uranium isotopes were retained in all SWMUs, as they are significant risk contributors or known to be part of the facility's process history. Following the review and screening process, the COPCs retained then were modeled as described in Section 5 and Appendix E of the RI Report. Modeled concentrations for groundwater under the SWMU exceeding the criteria in Section 5 and Appendix E were carried through the BHHRA shown in this appendix. Groundwater concentrations used in the assessment also were modeled as shown in Section 5 to several points of exposure away from the SWMU. These were as follows:

- Plant boundary
- Property boundary
- Little Bayou seeps (when particle modeling showed a contribution to the seep), and
- Monitoring well located near the Ohio River

Cancer risk and HIs were calculated for groundwater exposure for the rural resident at both the on-site and off-site locations.

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[1] SSLs are risk-based soil concentrations considered to be protective of groundwater (DOE 2001).

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F.3. EXPOSURE ASSESSMENT

This section describes the exposure assessment used to determine the pathways of exposure that were considered for the groundwater risk assessment presented in this appendix. Specifically, the exposure assessment process is delineated, the exposure settings of the BGOU 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 BGOU and the CDIs used when calculating ELCR and HI in Section 5.

F.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 for that COPC.

F.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 RI report. Physical descriptions of SWMU 2, SWMU 3, SWMU 4, SWMU 5, SWMU 6, SWMU 7, SWMU 30, and SWMU 145 are summarized within this exposure assessment to support later discussions of the conceptual model and its uncertainties.

F.3.2.1 C-749 Uranium Burial Ground (SWMU 2)

The C-749 Uranium Burial Ground (SWMU 2) is located within the west-central portion of the plant, north of Virginia Avenue. SWMU 2 encompasses an area of approximately 32,000 ft^2, with approximate dimensions of 160 ft by 200 ft. Records indicate that when the burial ground was in use, pits were excavated to an estimated depth of 7 to 17 ft. After the burial ground no longer was in use, the area was covered with a 6-inch thick clay cap and an 18-inch thick soil layer covered with vegetation (DOE 1995).

F.3.2.2 C-404 Low-Level Radioactive Waste Burial Ground (SWMU 3)

The C-404 Low-Level Radioactive Waste Burial Ground (SWMU 3) includes 1.2 acres located in the west-central portion of the plant area. The unit originally was constructed as a rectangular, aboveground, surface impoundment measuring 387 ft by 137 ft with a floor area of approximately 53,000 ft^2. The floor of the surface impoundment was constructed of well-tamped earth and clay dikes to a height of 6 ft. The C-404 impoundment was designed with an overflow weir at its southwest corner. From the weir, the surface impoundment effluent flowed west in a ditch [not the North-South Diversion Ditch (NSDD)] and eventually discharged into Kentucky Pollutant Discharge Elimination System Outfall 015

In March 2003, an additional 37,000 ft^2 of area were added to the SWMU when a northeast-southwest ditch just east of SWMU 3 was included as part of the SWMU. This ditch was impacted by the discharge of a now-abandoned pipeline with historic leachate flow into the NSDD (DOE 2003). When the C-404 impoundment was converted into a disposal facility, a sump was installed at the weir. The sump was used to pump leachate into an underground transfer line. The transfer line discharged into a northeast-southwest ditch just east of C-404. From this ditch, the leachate flowed into the NSDD. The date of termination of the leachate discharge from the underground transfer line to the NSDD has not been determined. However, it is known that, prior to landfill closure in 1986, this underground transfer line into the NSDD was not in operation, and leachate from the C-404 Landfill was being collected in the sump for treatment at C-400. The wastewater from the treatment of the leachate was discharged to C-403 and, ultimately, to the NSDD. At some time following closure of C-404 Landfill, treatment of leachate from C-404 at C-400 was discontinued and treatment of the leachate was transferred to the C-752 Remedial Action Waste Holding Facility.

F.3.2.3 C-747 Contaminated Burial Yard and C-748-B Burial Area (SWMU 4)

The C-747 Contaminated Burial Yard and the C-748-B Burial Area (SWMU 4) is located in the western section of the plant area. SWMU 4 (which covers an area of approximately 286,700 ft^2) is bounded on the north by Virginia Avenue, on the east by 6th Street, on the west by 4th Street, and on the south by an active railroad spur. This SWMU is an open grass field that, at one time, was used for the burial and disposal of various waste materials in designated burial cells. There have been no permanent structures built on the site. SWMU 4 is bounded on three sides (north, east, and west) by shallow drainage swales that direct surface runoff to the northwest corner of the site. There is an elevation difference of approximately 10 ft between the highest point in the SWMU and the adjacent drainage swales. The entire burial yard was covered with 2 to 3 ft of soil material and a 6-inch clay cap was placed over the area in 1982 (DOE 1998b).

F.3.2.4 C-746-F Burial Yard (SWMU 5)

The C-746-F Burial Yard is located in the northwestern section of PGDP. SWMU 5 (which covers an area of approximately 197,400 ft^2) is located adjacent to the C-746-P Scrap Yard to the north and SWMU 6 to the east. Disposal pits were located on a grid system. Documentation of the size of these grids ranges from 10 ft by 10 ft cells to 20 ft by 20 ft cells excavated to a depth of 6 to 15 ft bgs. Waste placed in the yard disposal pits was covered with 2 to 3 ft of soil. SWMU 5 is fenced to limit access to authorized personnel only. The ground surface is covered with short grasses and various flowering herbaceous plants (DOE 1998b). The suspected burial area within this SWMU starts approximately 120 ft east of the western boundary of the SWMU and extends to the eastern boundary of the SWMU.

F.3.2.5 C-747-B Burial Ground (SWMU 6)

The C-747-B Burial Ground is located in the northwestern section of the plant area east of SWMU 5. SWMU 6 was in operation from 1960 to 1976. The entire burial area covers an area of approximately 13,500 ft^2, which is divided into five separate burial cells (Areas H, I, J, K, and L). The following are the dimensions of each of the cells.

- Area H—This disposal site covers an area of about 12 ft by 15 ft and is about 6 ft deep. A 3 ft cover of soil was placed on top of the buried drums.

- Area I—This discard pit is approximately 8 ft by 35 ft and is about 8 ft deep. The waste was covered with about 5 ft of soil.

- Area J—This burial site is about 4,000 ft^2 (37 ft by 110 ft) and was excavated to a depth of about 6 ft. The area was covered with about 3 ft of soil.

- Area K—This disposal site consists of an area of about 12 ft by 15 ft and is about 6 ft deep. A 3 ft cover of soil was placed on top of the buried drums.

- Area L—This burial area is about 20 ft by 30 ft and about 6 ft deep. The disposed waste was covered with about 3 ft of soil.

This area is relatively flat and is bounded to the north by the roadbed of an abandoned railroad track, to the east by a 5-ft-wide by 4-ft-deep drainage ditch that drains into Ditch 001, and unnamed gravel roads to the west and south. The ground surface is covered by medium to tall grasses (up to 3 ft high).

F.3.2.6 C-747-A Burial Ground (SWMU 7)

The C-747-A area is located in the northwest corner of PGDP. SWMU 7 comprises the eastern two-thirds of C-747-A. The SWMU is bounded on the north and south sides by perimeter ditches, on the west side by the C-747-A Burn Area (SWMU 30), and on the east side by the C-746-E Contaminated Scrap Yard. SWMU 7 covers approximately 240,900 ft^2 and includes five discrete burial pit areas (Burial Pits B, C, D, F, and G) (DOE 1998a).

Records indicate the burial pits were excavated to a depth of 6 to 7 ft bgs, filled with wastes, and covered with approximately 3 ft of earth; however, the Phase II Site Investigation (SI) discovered waste to a depth of 10 ft on the west side of Burial Pit B, and borings sampled waste to a minimum depth of 8 ft in Burial Pit C (Union Carbide 1978). A stockpile of radiologically-contaminated scrap drums, locally known as Drum Mountain, formerly was located on the southeast corner.

The land surface slopes within SWMU 7. Burial Pits B and C form a slight hill on the north side of SWMU 7, and Burial Pit F forms a lesser mound on the south side of the SWMU. Pit D underlies a level area north of where Drum Mountain once was located. Shallow drainage swales occur on the west side of Burial Pit B and between Burial Pits C and D. The ground surface is covered by grassy vegetation, except where gravel roads extend through the site.

The surface water that drains from SWMU 7 into the surrounding ditches is carried west through Outfall 001 into Bayou Creek. In 2002, a sedimentation basin was constructed to contain runoff from PGDP scrap yards. Runoff now flows into the sedimentation basin and is released periodically into Outfall 001.

F.3.2.7 C-747-A Burn Area (SWMU 30)

SWMU 30 includes the western one-third of C-747-A. It consists of an historical burn-and-burial pit (Burial Pit A) and the location of a former incinerator. The SWMU is bounded on the north and south sides by ditches, on the west side by an unnamed paved road, and on the east side by the C-747-A Burial Ground (SWMU 7). The unit encompasses approximately 128,000 ft^2. The pit is reported to have been excavated to a depth of 12 ft and covered with 4 ft of earth. The land surface slopes gently, and a slight mound rises over Burial Pit A. SWMU 30 is bordered by drainage ditches on the north and south side. Grassy vegetation covers the ground, except where gravel roads extend through the site.

F.3.2.8 Area P (SWMU 145)

Area P (SWMU 145) is located north of PGDP and is defined by encompassing SWMUs 9 and 10 (the C-746-S&T Landfills, respectively). The SWMU is approximately 44 acres and began operation in the early 1950s. Currently, the C-746-S&T Landfills are located on top of SWMU 145 (DOE 1999). The boundaries of the area are not well defined outside of the area utilized by the C-746-S&T Landfills.

F.3.2.9 Demography and Land Use

As shown in the physical descriptions presented above, current land use of all sources investigated during the BGOU RI is industrial. Under current use, because of access restrictions, only plant workers and authorized visitors are allowed access to the source areas. As discussed in the PGDP Site Management Plan (DOE 2004a), foreseeable future land use of the area is expected to be industrial as well.

At present, both recreational and residential land uses occur in areas surrounding PGDP. Recreational use occurs in the Western Kentucky Wildlife Management Area (WKWMA). The WKWMA is used primarily for hunting and fishing, but other activities include horseback riding, field trials, hiking, and bird watching. An estimated 5,000 fishermen visit the area annually, according to the Kentucky Department of Fish and Wildlife Resources manager of the WKWMA. Residential use near the plant and in areas to which the groundwater from the BGOU may migrate is rural residential and includes agricultural activities. However, current response actions have eliminated exposure to contaminated groundwater by these rural residents. More urban residential use occurs in the villages of Heath, Grahamville, and Kevil, which are within 3 miles of U.S. Department of Energy (DOE) property boundaries, but outside of the area projected to be potentially impacted by the BGOU. The closest major urban area is the municipality of Paducah, Kentucky, which has a population of approximately 26,000 and is approximately 10 miles from PGDP. Other municipalities in the region near PGDP are Cape Girardeau, Missouri, which is approximately 40 miles west of the plant; and the cities of Metropolis and Joppa, Illinois, which are across the Ohio River from PGDP. Total population within a 50-mile radius of the plant is approximately 732,000 people, with about 88,500 people living within 10 miles. The population of McCracken County, in which PGDP lies, is estimated at 65,000 people.

In the area near PGDP and in western Kentucky, in general, the economy has historically been agriculturally based; however, industry has increased in recent years. PGDP is a major employer with approximately 1,400 workers. Another major employer near PGDP is the Tennessee Valley Authority (TVA) Shawnee Steam Plant, which employs approximately 260 individuals.

F.3.3 IDENTIFICATION OF EXPOSURE PATHWAYS

Exposure pathways describe how a contaminant travels from its source to an individual. A complete exposure pathway includes all links between the source and the exposed population. That is, a complete

pathway consists of the source of release, a mechanism of release, a transport medium, a point of potential human contact, and an exposure route. The following discussions focus on points of potential human contact, types of receptors, and exposure routes that are relevant to exposure to contaminated groundwater evaluated in this BHHRA.

F.3.3.1 Points of Human Contact – Land Use Considerations

As discussed earlier, the potential sources to the BGOU are in an industrial area located within a large industrial facility; therefore, the current land use is industrial. Per KDEP and EPA agreement (Risk Methods Document), industrial land use limits the current exposure scenario to an industrial worker (with exposure to the first foot of surface soil) and an excavation worker (with potential exposure to soil in the 0-10 ft bgs depth). The current scenarios do not include any current use of groundwater drawn from the RGA at the sources.

Also as discussed earlier, the current land use can be expected to continue in the foreseeable future, and the most plausible future land use of the BGOU also is industrial. In the future, the expected exposure frequencies and durations may be higher than duration and frequency of the current exposure. Additionally, use of groundwater drawn from the RGA at the sources is not expected; however, uses of areas surrounding PGDP indicate that it would be prudent to examine a range of land uses to provide managers with estimates of the risk that may be posed to humans under alternate uses, however unlikely. In addition, consideration of a range of land uses is consistent with requirements outlined in the Risk Methods Document. Additional possible future land uses considered in earlier BHHRAs of the source areas were recreational and rural residential. Recreational and residential scenarios would include use of groundwater drawn from the RGA and potential exposure to groundwater at the seeps at Little Bayou Creek in addition to soil exposure. Baseline risks under each of these uses are presented for each of the SWMUs in the data summary tables in this appendix.

F.3.3.2 Potential Receptor Populations

As noted above, the potential receptor population under current conditions at the source units are the industrial worker and the excavation worker. The potential receptor populations under future conditions in BGOU areas also include recreational and residential exposures. Residential and recreational exposures would include exposure to groundwater

F.3.3.3 Delineation Of Exposure Point/Exposure Routes

As discussed, human health risks are assessed by determining 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 groundwater in all BHHRA per the Risk Methods Document 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.

Ingestion Groundwater as a Drinking Water Source. Residential and industrial use of groundwater is common in western Kentucky. Potential receptors for this pathway are rural residents. This exposure route is assessed quantitatively in this BHHRA.

Inhalation of Volatile Constituents Emitted While Using Groundwater. As noted previously, residential and industrial use of groundwater is common in western Kentucky. Rural residents are potential receptors for this exposure route. This exposure route is assessed quantitatively in this BHHRA.

Dermal Contact With Groundwater While Showering. As noted earlier, residential and industrial use of groundwater is common in western Kentucky. Rural residents are potential receptors for this exposure route. This exposure route is assessed quantitatively in this BHHRA.

Inhalation Of Vapor Released From The Ground Water Into Home Basements. This exposure route was modeled quantitatively in this BHHRA for rural residents. Potentially, industrial workers also could be exposed through this route. Because the resident has an exposure time of 24 hrs/day for this exposure route, the rural resident quantitative assessment is protective of any potential worker exposure.

Inhalation of Volatile Organic Compounds During Irrigation with Contaminated Groundwater. In the Midwest, irrigation of farmland with groundwater using center pivot irrigation is common. Rural residents are potential receptors for this exposure route. Because only modeled groundwater data are available for this BHHRA in areas where migration may occur in the future and because earlier assessments have shown that risk from this exposure route is minimal, this exposure route is not assessed quantitatively in this BHHRA.

Dermal Contact with Water While Swimming or Wading in Privately Owned Fish Ponds Filled with Groundwater. Contamination found in BGOU soils has a reasonable potential of contaminating surface waters through dissolution into the groundwater. Contaminants also may be contacted through suspension of fine particles in the ponds, also originating from groundwater. Recreational use of these ponds by residents may reasonably be expected to occur. During recreational use (e.g., swimming or wading), dermal contact with water could occur. Rural residents are potential receptors for this exposure route. Because only modeled groundwater data are available for this BHHRA in areas where this activity may occur in the future, this exposure route is not assessed quantitatively in this BHHRA.

Incidental Ingestion of Sediment While Swimming or Wading in Privately Owned Fishponds Filled with Groundwater. The rationale for considering ponds is presented previously. In addition, recreational use of these ponds by residents may reasonably be expected to occur. During recreational activities, incidental ingestion of sediment contaminated by constituents in groundwater is possible. Rural residents are potential receptors for this exposure route. Because only modeled groundwater data are available for this BHHRA in areas where this activity may occur in the future, this exposure route is not assessed quantitatively in this BHHRA.

External Exposure to Ionizing Radiation Emitted by Contaminants in Groundwater While Swimming or Wading in Privately Owned Fish Ponds Filled with Groundwater. The rationale for considering ponds is presented previously. During use of these ponds by residents, exposure to ionizing radiation emitted by radionuclides in water could occur. Rural residents are potential receptors for this exposure route. Because only modeled groundwater data primarily were used this BHHRA in areas where this activity may occur in the future, this exposure route is not assessed quantitatively in this BHHRA.

External Exposure to Ionizing Radiation Emitted by Contaminants in Sediment While Swimming or Wading in Privately Owned Fish Ponds Filled with Groundwater. The rationale for considering ponds is presented previously. During use of these ponds by residents, exposure to ionizing radiation emitted by radionuclides in groundwater and sediment could occur. Rural residents are potential receptors for this exposure route. Because only modeled groundwater data primarily were used for this BHHRA in areas where this activity may occur in the future, this exposure route is not assessed quantitatively in this BHHRA.

Consumption of Fish Raised in Privately Owned Fish Ponds Filled with Groundwater. The fish raised in ponds would be exposed to contaminants in groundwater and may accumulate some contaminants in their edible tissues. These fish, caught in either a “pay-to-fish” or a commercial pond by

residents, could reasonably be expected to be consumed. Recreational users (i.e., visitors) and rural residents are potential receptors for this exposure route. Because only modeled groundwater data primarily were used for this BHHRA in areas where this activity may occur in the future, this exposure route is not assessed quantitatively in this BHHRA.

Incidental Ingestion of Surface Water in Creeks or Ponds. Open bodies of water, such as Bayou Creek or settling ponds, are attractive for recreation (e.g., swimming and wading). Although such bodies of water are not included in the assessment of the source areas, contaminants may migrate from the sources to these creeks or ponds. Recreational users and industrial workers are potential receptors for this exposure route. This exposure route is not assessed quantitatively in this BHHRA because earlier BHHRAs have concluded that mixing with surface water results in risks that are insignificant. Additionally, risks associated with surface water will be evaluated as part of the Surface Water Operable Unit (SWOU).

Dermal Contact with Surface Water While Swimming or Wading in Creeks or Ponds. Open bodies of water, such as Bayou Creek or settling ponds, are attractive for recreation (e.g., swimming and wading). Although such bodies of water are not included in this assessment of the source areas, contaminants may migrate from sources to these bodies of water. Recreational users and industrial workers are potential receptors for this exposure route. This exposure route is not assessed quantitatively in this BHHRA because earlier BHHRAs have concluded that mixing with surface water results in risks that are insignificant. Additionally, risks associated with surface water will be evaluated as part of the SWOU.

Incidental Ingestion of Sediment While Swimming or Wading in Creeks or Ponds. Open bodies of water, such as Bayou Creek or settling ponds, are attractive for recreation (e.g., swimming and wading). Although such bodies of water are not included in this assessment of the source areas, contaminants may migrate from sources to these bodies of water. Recreational users and industrial workers are potential receptors for this exposure route. This exposure route is not assessed quantitatively in this BHHRA because earlier BHHRAs have concluded that mixing with surface water results in risks that are insignificant. Additionally, risks associated with surface water will be evaluated as part of the SWOU.

External Exposure to Ionizing Radiation Emitted by Contaminants in Surface Water While Swimming or Wading in Creeks or Ponds. Open bodies of water, such as Bayou Creek or settling ponds, are attractive for recreation (e.g., swimming and wading). Although such bodies of water are not included in this assessment of the source areas, contaminants may migrate from sources to these bodies of water. Recreational users and industrial workers are potential receptors for this exposure route. This exposure route is not assessed quantitatively in this BHHRA because earlier BHHRAs have concluded that mixing with surface water results in risks that are insignificant. Additionally, risks associated with surface water will be evaluated as part of the SWOU.

External Exposure to Ionizing Radiation Emitted by Contaminants in Sediment While Swimming or Wading in Creeks or Ponds. Open bodies of water, such as Bayou Creek or settling ponds, are attractive for recreation (e.g., swimming and wading). Although such bodies of water are not included in this assessment of the source areas, contaminants may migrate from sources to these bodies of water. Recreational users and industrial workers are potential receptors for this exposure route. This exposure route is not assessed quantitatively in this BHHRA because earlier BHHRAs have concluded that mixing with surface water results in risks that are insignificant. Additionally, risks associated with surface water will be evaluated as part of the SWOU.

Consumption of Fish Taken from Creeks and Ponds Containing Contaminated Surface Water. Fish living in Bayou Creek or settling ponds may accumulate contaminants in surface water in their edible

tissues. Although such bodies of water are not included in this assessment of the source areas, contaminants may migrate from sources to these bodies of water. Recreational users and residents may catch and consume fish from the potentially impacted surface water bodies. Potential receptors for this route of exposure are recreational users. This exposure route is not assessed quantitatively in this BHHRA because earlier BHHRAs have concluded that mixing with surface water results in risks that are insignificant. Additionally, risks associated with surface water will be evaluated as part of the SWOU.

Consumption of Beef from Cattle Contaminated by Consuming Vegetation (Pasture and Concentrates) Irrigated with Groundwater and Drinking Groundwater. During interviews, Agriculture Extension Agents for Ballard and McCracken counties indicated that small scale cow-calf operations are common in western Kentucky. (See Section 2 of Appendix 5 of the Risk Methods Document.) They further noted that slaughtering feeder cattle for home consumption is common. In the study area, such beef may be contaminated by incidental ingestion of soil while on pasture, by consumption of contaminated vegetation (pasture and concentrate), and by ingestion of contaminated groundwater. Residents may eat this beef; therefore, potential receptors for this route of exposure are rural residents. This exposure route was considered in earlier BHHRAs, but is not reassessed in this BHHRA because new soil data are not available, and only modeled groundwater data are available in this BHHRA in areas where this activity may occur in the future. The potential impact of excluding the contribution from this pathway is addressed qualitatively in the uncertainty section.

Consumption of Dairy Products (i.e., Milk) from Cows Contaminated by Consuming Vegetation (Pasture or Concentrates) Irrigated with Groundwaterand Drinking Groundwater. During interviews, Agriculture Extension Agents for Ballard and McCracken counties noted that dairy farming still occurs in their counties. (See Section 2 of Appendix 5 of the Risk Methods Document.) Furthermore, the agents stated that these cattle are fed stored feed and are allowed to graze on pasture. As noted previously, the soil at source units is contaminated, and the vegetation may become contaminated. Dairy cattle raised at the sources after the industrial infrastructure is removed may become contaminated through incidental ingestion of soil while on pasture, consumption of contaminated vegetation, and ingestion of contaminated groundwater. Products made from milk from these cows could, in turn, be consumed by residents; therefore, potential receptors for this route of exposure are rural residents. This exposure route was considered in earlier BHHRAs, but is not reassessed in this BHHRA because new soil data are not available, and only modeled groundwater data are available in this BHHRA in areas where this activity may occur in the future. The potential impact of excluding the contribution from this pathway is addressed qualitatively in the uncertainty section.

Consumption of Poultry Given Groundwater to Drink. During interviews, Agriculture Extension Agents for Ballard and McCracken counties noted that commercial broiler production did occur in their counties, but not near PGDP. (See Section 2 of Appendix 5 of the Risk Methods Document.) (Home flocks for both meat and eggs were noted as being uncommon.) Furthermore, they stated that broilers were fed bought (not locally raised) feed, that normal resident time in poultry houses was 2 months, and that commercial distribution of the product occurs. The agents did note that the birds are most likely watered with groundwater; therefore, broilers may become contaminated through ingestion of contaminated groundwater. For this exposure assessment, the receptor assumed to consume the contaminated poultry is the rural resident. Because only modeled groundwater data are available for this BHHRA in areas where this activity may occur in the future, this exposure route is not assessed quantitatively in this BHHRA. The potential impact of excluding the contribution from this pathway is addressed qualitatively in the uncertainty section.

Consumption of Pork from Swine Watered with Groundwater. During interviews, Agriculture Extension Agents for Ballard and McCracken counties noted that both large commercial and small hog farms exist in their counties. (See Section 2 of Appendix 5 of the Risk Methods Document.) Furthermore,

they indicated that swine on both types of farms were fed locally raised feed and, on the smaller farms, that farm-raised pork was consumed by farmers. Any swine raised may be contaminated through consumption of contaminated feed and groundwater, and this pork may be eaten by rural residents; therefore, rural residents are potential receptors for this pathway. Because only modeled groundwater data are available for this BHHRA in areas where this activity may occur in the future, this exposure route is not assessed quantitatively in this BHHRA. The potential impact of excluding the contribution from this pathway is addressed qualitatively in the uncertainty section.

Out of the potential routes described above, five routes of exposure to groundwater were considered in the BHHRA in this RI for the BGOU:

- Ingestion of water while using groundwater as a drinking water source ..... Table F.43
- Dermal contact with groundwater while showering..... Table F.44
- Inhalation of volatiles in groundwater while showering ..... Table F.45
- Inhalation of volatiles in groundwater during household use..... Table F.46
- Inhalation of volatiles as a result of vapor intrusion into home basements.. Appendix E

CDIs, which are calculated for inorganic and organic constituents, and radionuclide intakes, calculated for radionuclides, represent the exposure to a COPC as mass contacted per unit body weight per unit time for the applicable receptor (EPA 1991). Doses, which apply only to radionuclide COPCs, represent the activity of a COPC in contact with an exchange boundary (EPA 1991). Unless otherwise noted, CDIs, RIs and doses are calculated using the values presented in Tables F.1 through F.4, and are from the 2001 approved version of the Risk Methods Document. Values obtained from the draft 2008 revision of the Risk Methods Document are footnoted (DOE 2008). Values in these tables marked as "chemical-specific" were obtained from tables in Appendix B and Appendix D of the draft 2008 Risk Methods Document. The ABS factors used are from the draft 2008 Risk Methods Document as well, because these factors apply only to COPCs evaluated for dermal toxicity.

Table F.1. Ingestion of Groundwater by a Rural Resident

Chronic Daily Intake (mg/kg-day) = CDI = [C_w*IR*EF*ED/(BW*AT)] Radionuclide Intake (pCi) = RI = [A_w*IR*EF*ED]		
Parameter	**Value Used**	**Units**
Chemical concentration in water = C_w	Chemical-specific	mg/L
Radiological activity in water = A_w	Chemical-specific	pCi/L
Ingestion rate = IR	2 (adult)	L/day
	1.5 (child)[a]	L/day
Exposure frequency = EF	350	day/yr
Exposure duration = ED	24 (adult)[a]	day
	6 (child)	day
Body weight = BW	70 (adult)	kg
	15 (child)	kg
Averaging time = AT	70 x 365(carcinogenic)	yr × day/yr
	ED x 365(noncarcinogenic)	yr × day/yr

[a]Value from 2008 draft revision of the Risk Methods Document (DOE 2008)

Table F.2. Dermal Contact with Water While Showering by a Rural Resident

Chronic Daily Intake (mg/kg-day)$_{inorganic}$ = $CDI_{inorganic}$ = [C_w*SA*K_p*CF*EF*ED*ET/(BW*AT)]
Chronic Daily Intake (mg/kg-day)$_{organic}$ = $CDI_{organic}$ = [C_w*$DA_{eventfactor}$*SA*CF*ED*EF*EV/(BW*AT)]

Parameter	Value Used	Units
Chemical concentration in water = C_w	Chemical-specific	mg/L
Skin surface area exposed = SA	1.815[b]	m^2
	0.65 [a,b]	m^2
Skin permeability constant = K_p	Chemical-specific[a]	cm/hr
Absorbed dose factor per event = $DA_{eventfactor}$	Chemical-specific[a]	L/cm^2-event
Conversion factor (inorganic) = CF	10	(L-m)/(cm-m^3)
Conversion factor (organic) = CF	10^3	cm^2/m^2
Exposure frequency = EF	350	baths/yr
Exposure duration = ED	24 (adult) [a]	day
	6 (child)	day
Exposure time = ET	0.2	hr/bath
Event = EV	1	Event/day
Body weight = BW	70 (adult)	kg
	15 (child)	kg
Averaging time = AT	70 x 365 (carcinogenic)	yr × day/yr
	ED x 365 (noncarcinogenic)	yr × day/yr

[a]Value from 2008 draft revision of the Risk Methods Document
[b] Entire surface area of body for both adult and child

Table F.3. Inhalation of Volatile Organic Compounds in Water While Showering by a Rural Resident

Chronic Daily Intake (mg/kg-day) = CDI = [C_{shower}*IR_{air}*EF*ED*ET/(BW*AT)]
Radionuclide Intake (pCi) = RI = [A_{gw}*IR_{air}*ED*EF*IEF]
C_{shower} = [((C_{amax}/2)*t_1)+(C_{amax}*t_2)]/(t_1+t_2)
C_{amax} = (C_{gw}*f*F_w*t_1)/V_a

Parameter	Value Used	Units
Chemical concentration in groundwater = C_{gw}	Chemical-specific	mg/L
Radionuclide activity in groundwater = A_{gw}	Chemical-specific	pCi/L
Time-adjusted concentration in shower = C_{shower}	Chemical-specific	mg/m^3
Indoor inhalation rate = IR_{air}	0.833 [a]	m^3/hr
Exposure frequency = EF	350	day/yr
Exposure duration = ED	24 (adult) [a]	day
	6 (child)	day
Exposure time = ET	0.2	hr/day
Inhalation exposure factor = IEF	Chemical-specific [a]	(L-hr)/(m^3-day)
Maximum air concentration = C_{amax}	Chemical-specific [a]	mg/m^3
Time of shower = t_1	0.1	hr
Time after shower = t_2	0.1	hr
Fraction volatilized = f	0.75	unitless
Water flow rate = F_w	890	L/hr
Bathroom volume = V_a	11	m^3
Body weight = BW	70 (adult)	kg
	15 (child)	kg
Averaging time = AT	70 x 365 (carcinogenic)	yr × day/yr
	ED x 365 (noncarcinogenic)	yr × day/yr

[a]Value from 2008 draft revision of the Risk Methods Document

Table F.4. Inhalation of Volatile Organic Compounds in Water During Household Use by a Rural Resident

Chronic Daily Intake (mg/kg-day) = CDI = $[C_{house}*IR_{air}*EF*ED*ET/(BW*AT)]$
Radionuclide Intake (pCi) = RI = $[A_{gw}*IR_{air}*ED*EF*IEF]$
$C_{house} = C_{gw}*WHF*f/(HV*ER*MC)$

Parameter	Value Used	Units
Chemical concentration in groundwater = C_{gw}	Chemical-specific	mg/L
Radionuclide activity in groundwater = A_{gw}	Chemical-specific	pCi/L
Concentration in household air = C_{house}	Chemical-specific	mg/m^3
Indoor inhalation rate = IR_{air}	0.833	m^3/hr
Exposure frequency = EF	350	day/yr
Exposure duration = ED	24 (adult) [a]	day
	6 (child)	day
Exposure time = ET	24 [a]	hr/day
Inhalation exposure factor = IEF	Chemical-specific [a]	$(L\text{-}hr)/(m^3\text{-}day)$
Water flow rate = WHF	890	L/day
Fraction volatilized = f	0.5	unitless
House volume = HV	450	m^3/change
Exchanged rate = ER	10	changes/day
Mixing coefficient = MC	0.5	unitless
Body weight = BW	70 (adult)	kg
	15 (child)	kg
Averaging time = AT	70 x 365 (carcinogenic)	yr × day/yr
	ED x 365 (noncarcinogenic)	yr × day/yr

[a]Value from 2008 draft revision of the Risk Methods Document

F.3.3.4 Development of Conceptual Site Models

Using the information presented in the previous subsections, a CSM was developed for the BGOU. This CSM (Figure F.3) illustrates the sources, pathways of migration, and routes of exposure relevant to this and earlier BHHRAs. For this screening and the subsequent BHHRA, surface soil was defined as 0–1 ft bgs and subsurface soil was defined as 0–10 ft bgs. Surface soil was used to evaluate direct exposure for residential, recreational, and industrial receptors. Subsurface soil was used to evaluate direct exposure for excavation worker. Table F.5 shows the media evaluated for each land use scenario for each SWMU.

Table F.5. Land Uses And Media Assessed For Each Source Area in Current and Previous BRAs for the BGOU

	Location							
	SWMU 2	**SWMU 3**	**SWMU 4**	**SWMU 5**	**SWMU 6**	**SWMU 7**	**SWMU 30**	**SWMU 145**
Future On-site Industrial Worker								
Surface Soil	P	P	P	PX	P	P	P	NA
Surface Water	NA	NA	NA	NA	NA	NA	NA	NA
Future On-site Excavation Worker								
Subsurface Soil	NA	NA	P	P	P	P	P	NA
Future Recreational User								
Game (Soil)	P	P	P	P	P	P	P	NA
Surface Soil	NA	NA	NA	NA	P	P	P	NA
Surface Water	NA	NA	NA	NA	NA	NA	NA	NA
Future On-site Rural Resident								
Soil	NA	NA	P	P	P	P	P	NA
Groundwater [a]	PX	PX	PX	PX	PX	PX	PX	X
Vapor Intrusion [c]	X	X	X	X	X	X	X	X
Future Off-site Rural Resident								
Groundwater [b]	X	X	X	X	X	X	X	X
Vapor Intrusion [c]	X	X	X	X	X	X	X	X
Future On-site Terrestrial Biota								
Soil	P	NA	P	P	P	P	P	NA
Surface Water	NA	NA	NA	NA	NA	NA	NA	NA

Notes: Scenarios that were assessed in this RI BRA are marked with an X. Scenarios assessed in previous BRAs are marked with a P. Scenarios assessed in both the past and current RBA are marked with a PX. Scenarios not assessed because the scenario is not applicable, or for which the medium is not present, are marked with an NA.

[a] The earlier BHHRAs assessed risks from use of water drawn from the RGA separately from use of water drawn from the McNairy Formation. The risks assessed in this RI BRA are for use of water drawn from the RGA.

[b] Modeling results were used to assess groundwater risk to the off-site rural resident. POEs are at the PGDP plant boundary, at the PGDP property boundary, Little Bayou seeps and in a groundwater well at the Ohio River. These POEs are presented in Figure 5.1

[c] Vapor intrusion was modeled for residential basements.

F.3.4 QUANTIFICATION OF EXPOSURE

F.3.4.1 Calculation of EPCs of COPCs

EPCs for groundwater used to determine potential future risks for residential use of groundwater at four POEs (i.e., plant boundary, property boundary, Ohio River, and seeps at Little Bayou Creek) were developed from modeling. The modeled concentrations in groundwater over time at the four POEs (unit boundary, plant boundary, property boundary, and Ohio River) are provided in the figures in Section 5. The maximum modeled groundwater concentration over the 1,000 year time frame (see Appendix E for details of the modeling) at each POE was used as the EPC for calculation of the groundwater CDI.

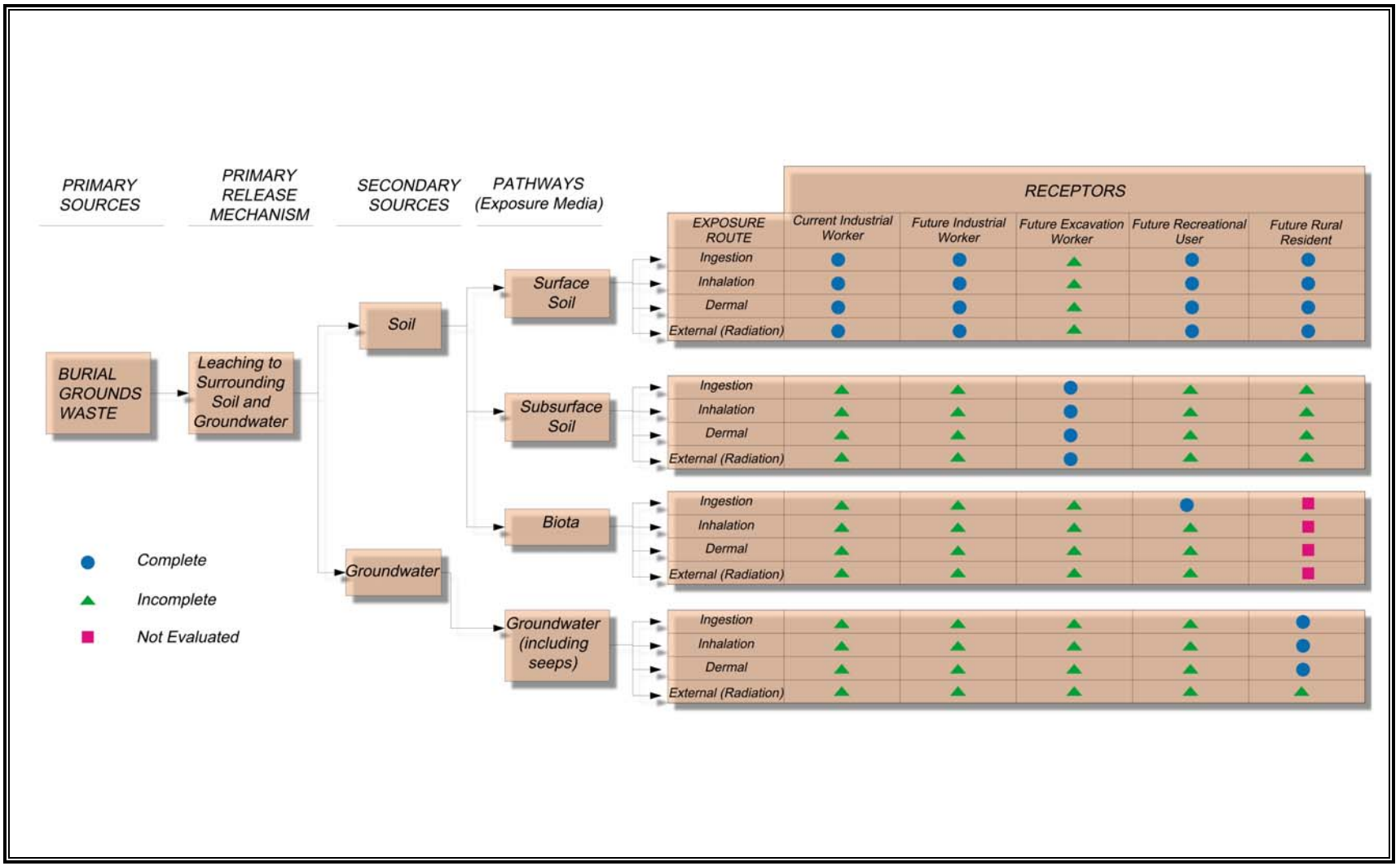

Figure F.1. Conceptual Site Model for BGOU

F.3.4.2 Chronic Daily Intakes

All exposure estimates in this BHHRA represent normalized exposure rates that are evaluated for sources of uncertainty such as variability in data, modeling results, and/or parameter assumptions. Specifically, in this BHHRA, the exposure estimates are an estimation of the reasonable maximum exposure (RME) that can be expected to occur under current or future site conditions. An RME estimate is a conservative estimate of exposure that falls within the upper bound of the range of all possible exposure estimates. In situations where populations are exposed through multiple pathways, RME estimates are calculated for both individual and multiple exposure pathways. Risk estimates for soil and groundwater were calculated separately.

Consistent with the Risk Methods Document, the focus of the exposure assessment for this BHHRA is to determine chronic intake or dose. The chronic exposure estimate is used because it allows for estimation of health consequences that result from long-term or unrestricted exposure to contaminants.

Using the human exposure models for groundwater, the CSM, and the EPCs, the CDIs of groundwater for each of the COPCs were determined. These CDIs are presented in Tables F.6 through F.29. In this presentation, the CDIs used to estimate HI (i.e., noncarcinogenic effects) are presented first, and the values used to estimate ELCR follow.

F.3.5 SUMMARY OF EXPOSURE ASSESSMENT

The receptors evaluated in the current assessment are the adult and child resident for exposure to groundwater.

Table F.6. Chronic Daily Intakes (Non-Carcinogenic) for Child Residential Groundwater User at SWMU 2

		Exposure Route-Chronic Daily Intake[b]			
COPC	**Exposure Point Concentration[a]**	**Ingestion of Water**	**Dermal Contact**	**Shower Inhalation**	**Household Inhalation**
Inorganic Compounds					
Arsenic	3.54E-02	3.39E-03	2.94E-06		
Manganese	7.16E-01	6.87E-02	5.95E-05		
Uranium	9.86E-03	9.45E-04	8.19E-07		
Organic Compounds					
cis-1,2-DCE	1.15E+01	1.10E+00	3.89E-02	5.57E-01	4.36E+00
Acenaphthene	6.01E-03	5.76E-04	2.27E-04	4.94E+00	2.28E-03
Naphthalene	9.38E-04	8.99E-05	1.63E-05	8.77E-02	3.56E-04
TCE	1.48E+00	1.42E-01	6.64E-03	7.17E-02	5.61E-01

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a]Units for metals and organic compounds are mg/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day).

Table F.7. Chronic Daily Intakes (Non-Carcinogenic) for Adult Residential Groundwater User at SWMU 2

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Arsenic	3.54E-02	9.70E-04	1.76E-06		
Manganese	7.16E-01	1.96E-02	3.56E-05		
Uranium	8.86E-03	2.70E-04	4.90E-07		
Organic Compounds					
cis-1,2-DCE	1.15E+01	3.15E-01	2.33E-02	1.19E-01	9.34E-01
Acenaphthene	6.01E-03	1.65E-04	1.36E-04	1.06E+00	4.88E-04
Naphthalene	9.38E-04	2.57E-05	9.76E-06	1.88E-02	7.62E-05
TCE	1.48E+00	4.05E-02	3.97E-03	1.54E-02	1.20E-01

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day).

Table F.8. Chronic Daily Intakes (Carcinogenic) for Residential Groundwater User at SWMU 2

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Arsenic	3.54E-02	3.33E-04	6.04E-07		
Organic Compounds					
TCE	1.48E+00	1.39E-02	1.36E-03	5.27E-03	4.12E-02
Radionuclides					
Technetium-99	1.02E+02	1.71E+06			
Uranium-234	1.66E+00	2.65E+04			
Uranium-238	1.81E+00	3.04E+04			

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L. Units for radionuclides are pCi/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day). Units for intakes for radionuclides are pCi /(kg-day).

Table F.9. Chronic Daily Intakes (Non-Carcinogenic) for Child Residential Groundwater User at SWMU 3

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Arsenic	3.29E-02	3.15E-03	2.73E-06		
Manganese	8.95E-01	8.58E-02	7.44E-05		
Uranium	4.89E-02	4.69E-03	4.06E-06		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day).

Table F.10. Chronic Daily Intakes (Non-Carcinogenic) for Adult Residential Groundwater User at SWMU 3

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Arsenic	3.29E-02	9.01E-04	1.64E-06		
Manganese	8.95E-01	2.45E-02	4.45E-05		
Uranium	4.89E-02	1.34E-03	2.43E-06		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day).

Table F.11. Chronic Daily Intakes (Carcinogenic) for Residential Groundwater User at SWMU 3

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Arsenic	3.29E-02	5.79E-04	7.95E-07		
Radionuclides					
Technetium-99	5.56E+03	1.11E+08			
Uranium-238	1.59E+01	3.16E+05			

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L. Units for radionuclides are pCi/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day). Units for intakes for radionuclides are pCi /(kg-day).

Table F.12. Chronic Daily Intakes (Non-Carcinogenic) for Child Residential Groundwater User at SWMU 4

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Arsenic	1.77E-02	1.70E-03	1.47E-06		
Manganese	5.76E-01	5.52E-02	4.79E-05		
Organic Compounds					
cis-1,2-DCE	6.68E-01	6.41E-02	2.26E-03	3.24E-02	2.53E-01
TCE	1.18E+00	1.13E-01	5.28E-03	5.72E-02	4.47E-01
Vinyl Chloride	2.61E-02	2.50E-03	5.40E-05	2.70E-04	9.90E-03

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day).

Table F.13. Chronic Daily Intakes (Non-Carcinogenic) for Adult Residential Groundwater User at SWMU 4

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Arsenic	1.77E-02	4.85E-04	8.80E-07		
Manganese	5.76E-01	1.58E-02	2.86E-05		
Organic Compounds					
cis-1,2-DCE	6.68E-01	1.83E-02	1.35E-03	6.91E-03	5.43E-02
TCE	1.18E+00	3.23E-02	3.16E-03	1.22E-02	9.59E-02
Vinyl Chloride	2.61E-02	7.15E-04	3.23E-05	2.70E-04	2.12E-03

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day).

Table F.14. Chronic Daily Intakes (Carcinogenic) for Residential Groundwater User at SWMU 4

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Arsenic	1.77E-02	3.12E-04	4.28E-07		
Organic Compounds					
TCE	1.18E+00	2.08E-02	1.54E-03	9.10E-03	7.12E-02
Vinyl Chloride	2.61E-02	4.60E-04	1.05E-02	2.01E-04	1.58E-03
Radionuclides					
Technetium-99	9.01E+03	1.80E+08			

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L. Units for radionuclides are pCi/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day). Units for intakes for radionuclides are pCi/(kg-day).

Table F.15. Chronic Daily Intakes (Non-Carcinogenic) for Child Residential Groundwater User at SWMU 5

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Arsenic	9.25E-03	8.87E-04	7.69E-07		
Manganese	1.01E+00	9.68E-02	8.39E-05		
Organic Compounds					
Naphthalene	5.55E-03	5.32E-04	9.66E-05	2.69E-04	2.10E-03

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day).

Table F.16. Chronic Daily Intakes (Non-Carcinogenic) for Adult Residential Groundwater User at SWMU 5

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Arsenic	9.25E-03	2.53E-04	4.60E-07		
Manganese	1.01E+00	2.77E-02	5.02E-05		
Organic Compounds					
Naphthalene	5.55E-03	1.52E-04	5.78E-05	5.76E-05	4.51E-04

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a]Units for metals and organic compounds are mg/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day).

Table F.17. Chronic Daily Intakes (Carcinogenic) for Residential Groundwater User at SWMU 5

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Arsenic	9.25E-03	1.63E-04	2.24E-07		
Radionuclides					
Technetium-99	1.27E+02	2.53E+06			

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a]Units for metals and organic compounds are mg/L. Units for radionuclides are pCi/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day). Units for intakes for radionuclides are pCi /(kg-day).

Table F.18. Chronic Daily Intakes (Non-Carcinogenic) for Child Residential Groundwater User at SWMU 6

COPC	Exposure Point Concentration	Exposure Route-Chronic Daily Intake			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
NO COPCs[1]					

[1]Modeling analysis (Appendix E) did not show any of the identified COPCs at this site as migrating to groundwater.

Table F.19. Chronic Daily Intakes (Non-Carcinogenic) for Adult Residential Groundwater User at SWMU 6

COPC	Exposure Point Concentration	Exposure Route-Chronic Daily Intake			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
NO COPCS[1]					

[1]Modeling analysis (Appendix E) did not show any of the identified COPCs at this site as migrating to groundwater.

Table F.20. Chronic Daily Intakes (Carcinogenic) for Residential Groundwater User at SWMU 6

COPC	Exposure Point Concentration	Exposure Route-Chronic Daily Intake			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
NO COPCs[1]					

[1]Modeling analysis (Appendix E) did not show any of the identified COPCs at this site as migrating to groundwater.

Table F.21. Chronic Daily Intakes (Non-Carcinogenic) for Child Residential Groundwater User at SWMU 7

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Arsenic	1.78E-02	1.71E-03	1.48E-06		
Manganese	3.32E-01	3.18E-02	2.76E-05		
Uranium	3.46E-03	3.32E-04	2.88E-07		
Organic Compounds					
1,1-DCE	8.98E-02	8.61E-03	3.23E-04	4.35E-03	3.40E-02
cis-1,2-DCE	2.35E-02	2.25E-03	7.95E-05	1.14E-03	8.91E-03
Total PCBs	5.23E-05	5.02E-06	5.09E-05	2.54E-06	1.98E-05
TCE	1.09E-02	1.05E-03	4.89E-05	5.28E-04	4.13E-03
Vinyl Chloride	1.35E-02	1.29E-03	2.79E-05	6.54E-04	5.12E-03

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a]Units for metals and organic compounds are mg/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day).

Table F.22. Chronic Daily Intakes (Non-Carcinogenic) for Adult Residential Groundwater User at SWMU 7

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Arsenic	1.78E-02	4.88E-04	8.85E-07		
Manganese	3.32E-01	9.10E-03	1.65E-05		
Uranium	3.46E-03	9.48E-05	1.72E-07		
Organic Compounds					
1,1-DCE	8.98E-02	2.46E-03	1.93E-04	9.30E-04	7.30E-03
cis-1,2-DCE	2.35E-02	6.44E-04	4.76E-05	2.43E-04	1.91E-03
Total PCBs	5.23E-05	1.43E-06	3.05E-05	5.41E-07	4.25E-06
TCE	1.09E02	2.99E-04	2.93E-05	1.13E-04	8.86E-04
Vinyl Chloride	1.35E-02	3.70E-04	1.67E-05	1.40E-04	1.10E-03

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a]Units for metals and organic compounds are mg/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day).

Table F.23. Chronic Daily Intakes (Carcinogenic) for Residential Groundwater User at SWMU 7

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Arsenic	1.78E-02	3.14E-04	4.30E-07		
Organic Compounds					
1,1-DCE	8.98E-02	1.58E-03	9.39E-05	6.93E-04	5.42E-03
Total PCBs	5.23E-05	9.21E-07	1.48E-05	4.04E-07	3.16E-06
TCE	1.09E-02	1.92E-04	1.42E-05	8.41E-05	6.58E-04
Vinyl Chloride	1.35E-02	2.38E-04	8.12E-06	1.04E-04	8.15E-04
Radionuclides					
Technetium-99	9.09E+02	1.81E+07			
Uranium-234	7.90E+00	1.58E+05			
Uranium-238	7.59E+00	1.51E+05			

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L. Units for radionuclides are pCi/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day). Units for intakes for radionuclides are pCi/(kg-day).

Table F.24. Chronic Daily Intakes (Non-Carcinogenic) for Child Residential Groundwater User at SWMU 30

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Arsenic	1.77E-02	1.70E-03	1.47E-06		
Manganese	3.78E-01	3.62E-02	3.14E-05		
Selenium	1.51E-02	1.45E-03	1.25E-06		
Uranium	8.40E-03	8.05E-04	6.98E-07		
Organic Compounds					
1,1-DCE	6.05E-02	5.80E-03	2.17E-04	2.93E-03	2.29E-02
TCE	7.12E-01	6.83E-02	3.20E-03	3.45E-02	2.70E-01

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day).

Table F.25. Chronic Daily Intakes (Non-Carcinogenic) for Adult Residential Groundwater User at SWMU 30

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Arsenic	1.77E-02	4.85E-04	8.80E-07		
Manganese	3.78E-01	1.04E-02	1.88E-05		
Selenium	1.51E-02	4.14E-04	7.51E-07		
Uranium	8.40E-03	2.30E-04	4.18E-07		
Organic Compounds					
1,1-DCE	6.05E-02	5.00E-02	5.00E-02	5.71E-02	5.71E-02
TCE	7.12E-01	1.95E-02	1.91E-03	7.40E-03	5.78E-02

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L. Units for radionuclides are pCi/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day). Units for intakes for radionuclides are pCi/(kg-day).

Table F.26. Chronic Daily Intakes (Carcinogenic) for Residential Groundwater User at SWMU 30

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Arsenic	1.77E-02	3.12E-04	4.28E-07		
Organic Compounds					
1,1- DCE	6.05E-02	1.07E-03	6.32E-05	4.66E-04	3.66E-03
TCE	7.12E-01	1.25E-02	9.29E-04	5.50E-03	4.29E-02
Radionuclides					
Technetium-99	2.87E+02	5.73E+06			
Uranium-234	4.00E+00	7.96E+04			
Uranium-238	5.91E+00	1.18E+05			

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L. Units for radionuclides are pCi/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day). Units for intakes for radionuclides are pCi/(kg-day).

Table F.27. Chronic Daily Intakes (Non-Carcinogenic) for Child Residential Groundwater User at SWMU 145

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Antimony	7.99E-02	7.66E-03	6.64E-06		
Arsenic	6.21E-02	5.95E-03	5.16E-06		
Manganese	8.44E-01	8.09E-02	7.01E-05		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day).

Table F.28. Chronic Daily Intakes (Non-Carcinogenic) for Adult Residential Groundwater User at SWMU 145

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Antimony	7.99E-02	2.19E-03	3.97E-06		
Arsenic	6.21E-02	1.70E-03	3.09E-06		
Manganese	8.44E-01	2.31E-02	4.20E-05		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day).

Table F.29. Chronic Daily Intakes (Carcinogenic) for Residential Groundwater User at SWMU 145

COPC	Exposure Point Concentration[a]	Exposure Route-Chronic Daily Intake[b]			
		Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation
Inorganic Compounds					
Arsenic	6.21E-02	1.09E-03	1.50E-06		
Organic Compounds					
Total PCBs[c]	1.92E-03	3.38E-05	7.14E+00	1.48E-05	6.91E-01
Radionuclides					
Technetium-99	1.01E+04	2.02E+08			
Uranium-238	7.67E-02	1.53E+02			

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L. Units for radionuclides are pCi/L.
[b] Units for intakes for metals and organic compounds are mg/(kg-day). Units for intakes for radionuclides are pCi/(kg-day).
[c] Total PCBs modeled as PCB-1260.

F.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) prepared by the Toxicology and Risk Analysis Section of Oak Ridge National Laboratory for DOE (DOE 2004b). This site also lists toxicity values taken from the EPA's Integrated Risk Information System (IRIS) database (EPA 2004a), 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 (ATSDR) 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). 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 slope factor for chemicals is defined as a plausible upperbound estimate of the probability of a response (i.e., development of cancer) per unit intake of a chemical over a lifetime (EPA 1989). Slope factors are specific for each chemical and route of exposure. Slope factors currently are available for ingestion and inhalation pathways. The slope factors used for oral and inhalation routes of exposure for the COPCs considered in this report are shown in Table F.30.

Table F.30. Toxicity Values For Chronic Exposure to Carcinogens Via the Ingestion and Inhalation Exposure Routes

		Oral Slope			Inhalation			
COPC[a]	Class	Oral Slope Factor[b]	Factor Source[c]	Oral Unit Risk[d]	Inhalation Slope Factor[e]	Slope Factor Source[c]	Inhalation Unit Risk[f]	Types of Cancers
Inorganic Chemicals (Metals)								
Arsenic	A			5.00E-02	1.51E+01			
Organic Compounds								
1,1-DCE	C	6.00E-01	a	1.70E-02	1.75E-01	a	5.00E-05	Kidney, adenocarcinoma
Aroclor-1254	B2	4.00E-01	b		3.50E-01	b		Liver
Aroclor-1260	B2	2.00E+00	a		2.00E+00	a	5.71E-01	Liver

Table F.30. Toxicity Values For Chronic Exposure to Carcinogens Via the Ingestion and Inhalation Exposure Routes (Continued)

COPC[a]	Class	Oral Slope Factor[b]	Oral Slope Factor Source[c]	Oral Unit Risk[d]	Inhalation Slope Factor[e]	Inhalation Slope Factor Source[c]	Inhalation Unit Risk[f]	Types of Cancers
TCE[i]	C-B2	3.22E-01	c		3.22E-01	c	1.10E-01	Liver and lung cancer
Vinyl Chloride	A				3.08E-02		8.80E-06	Liver, lung, digestive tract, and brain tumors
				Radionuclides				
	ICRP[g] Lung Class							
Technetium-99	M	2.75E-12	a		1.41E-11	a		
Uranium-234	M	7.07E-11	a					Various
Uranium-238	M	7.18-11	a					

Note: Blank cells indicate that data are not available or are not appropriate.
[a] All groundwater COPCs are listed.
[b] The units for the oral slope factors are $(mg/kg \times day)^{-1}$ for nonradionuclides and risk/pCi for radionuclides.
[c] Source codes are defined as follows:
a: Risk Assessment Information System
b: 2008 *Risk Methods Document* (DOE 2008)
c: KDEP
[d] The units for the oral unit risks are $(mg/L)^{-1}$
[e] The units for the inhalation slope factors are $(mg/kg \times day)^{-1}$ for nonradionuclides and risk/pCi for radionuclides.
[f] The units for inhalation unit risks are $m^3/\mu g$.
[g] ICRP Publication 72 is referenced in the HEAST user's guide (ICRP, 1996). Lung class absorption types are defined as follows:
S = slow (particulate)
M = medium (particulate)
F = fast (particulate)
[h] Value used is from KDEP (2004) review of TCE slope factors. The slope factors used in previous assessments were 0.052 for the oral slope factor and 0.002 for the inhalation slope factor. This issue is discussed further in the uncertainty section.

Toxicity values used in risk calculations also include the chronic RfD, 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 and inhalation routes of exposure for the COPCs considered in this report are presented in Table F.31.

Table F.31. Toxicity Values for Chronic Exposure to Noncarcinogens Via the Ingestion and Inhalation Exposure Routes

COPC[a]	Oral Reference Dose[b]	Oral Reference Dose Source[c]	Inhalation Reference Dose[d]	Inhalation Reference Concentration[e]	Inhalation Reference Concentration Source[c]	RfD basis (vehicle)[f]	Target Organ Critical Effect	Confidence Level[f]	Uncertainty Factor/Modifying Factor[f]
Inorganic Chemicals (Metals)									
Antimony	4.00E-04	a				(O)LOAEL	GI	(O)Low	(O)UF=1,000 (O)MF=1
Arsenic	3.00E-04	a				(O)NOAEL/ LOAEL	Skin	Medium	(O)UF=3 (O)MF=1
Manganese	4.60E-02	c	1.43E-05		c	(O)NOAEL	NA	Low	(I)UF=1,000 (I)MF=1 (O)=100
Selenium	5.00E-03	a				NOAEL/ LOAEL	Lungs (selenosis)	High	(O)UF=3 (O)MF=1
Uranium	6.00E-04	a,e				LOAEL	Kidney	NA	(O)UF=100 (O)MF=1
Organic Compounds									
1,1-DCE	5.00E-02	a	5.71E-02	2.00E-01		LOAEL	Liver	Medium	(O)UF=1,000 (O)MF=1
1,2-DCE, *cis*-	1.00E-02	a	9.97E-03	3.49E-02	ex	NOAEL	Blood	Low	(O)UF=3,000 (O)MF=1
Aroclor-1254	2.00E-05	c	1.99E-05		c	(O)LOAEL	Endocrine System	Medium	(O)UF=300 (O)MF=1
TCE	3.00E-04	v	1.14E-02	4.00-02	ex	NA	Liver, kidney, CNS	NA	NA
Vinyl Chloride	3.00E-03	a	2.86E-02	1.00E-01	a	(I)NOAEL/ LOAEL (O)NOAEL/ LOAEL	Liver, kidney, CNS	Medium	(I)UF=30 (I)MF=1 (O)UF=3 (I)MF=1
Naphthalene	2.00E-02	a	8.57E-04	3.00E-03	a	(O)NOAEL (I)LOAEL	Decreased body weight Respir-atory	(O)Low (I)Medium	(O)UF=3,000 (O)MF=1 (I)UF=3,000 (I)MF=1

Table F.31. Toxicity Values for Chronic Exposure to Noncarcinogens Via the Ingestion and Inhalation Exposure Routes (Continued)

Notes: Blank cells indicate that data are not available or are not appropriate. NA=information not readily available at this time; GI=gastrointestinal; CNS=central nervous system
[a] All groundwater COPCs are listed.
[b] The units for the oral reference doses are mg/(kg × day).
[c] Source codes are defined as follows:
a: *Integrated Risk Information System* (IRIS) (EPA 2004a)
b: *Health Effects Assessment Summary Tables* (HEAST) (EPA 1998)
c: 2008 *Risk Methods Document* (DOE 2008)
e: Also see Soil Screening Guidance for Radionuclides: User's Guide.
ex: Value is extrapolated from the oral reference dose.
u: The inhalation slope factor was calculated from inhalation unit risk as described in *RAGS: Region 4 Bulletins, Human Health Risk Assessment (Interim Guidance)* (November 1995).
v: A provisional value provided to DOE's Oak Ridge Operations by EPA's Superfund Health Risk Technical Support Center.
w: This value was withdrawn from IRIS or HEAST, but is used in the assessment per guidance in the Risk Methods Document.
x: A provisional value from EPA National Center for Environmental Assessment (NCEA).
[d] The units for the inhalation reference doses are mg/(kg × day).
[e] The units for the inhalation reference concentrations are mg/m^3.
[f] O=oral; I=inhalation; UF=uncertainty factor; MF=modifying factor; NA=not available.

For the dermal routes of exposure (i.e., dermal exposure to contaminated water during swimming or bathing), 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 slope factors that also are expressed in terms of absorbed dose. Currently, EPA has not produced lists of RfDs and slope factors based on absorbed dose but have produced guidance concerning the estimation of absorbed dose RfDs and slope factors from administered dose RfDs and slope factors. 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 2004b) 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 Tables F.32 and F.33, respectively.

Table F.32. Toxicity Values for Chronic Dermal Contact Exposure to Carcinogens

COPC[a]	Dermal Slope Factor[b]	GI ABS Factor[c]
	Inorganic Chemicals (Metals)	
Arsenic	3.66E+00	0.41
	Organic Compounds	
1,1-DCE	6.00E-01	0.1
Aroclor-1254	4.44E-01	0.9
Aroclor-1260	2.20E+00	0.9
TCE	2.67E+00	0.15
Vinyl Chloride	1.50E+00	1.0

Note: Blank cells indicate that data are not available or are not appropriate.
[a] All groundwater COPCs are listed.
[b] The units for these dermal dose slope factors are $(mg/kg \times d)^{-1}$ for nonradionuclides. Absorbed cancer slope factors are calculated by dividing the administered cancer slope factor by GI absorption factor; this value is used in the BHHRA to calculate contribution to cancer risk from dermal exposure.

[c] All GI ABS factors from 2008 Risk Methods Document (DOE 2008)

Table F.33. Toxicity Values for Chronic Exposure to Noncarcinogens Via the Dermal Contact Exposure Route

COPC[a]	Dermal Reference Dose[b]	Administered Reference Dose[c]	GI ABS[d]
Antimony	8.00E-06	4.00E-04	0.02
Arsenic	1.23E-04	3.00E-04	0.41
Manganese	1.84E-03	2.40E-02	0.04
Selenium	2.20E-03	5.00E-03	0.44
Uranium[e]	5.10E-04	6.00E-04	0.85
1,1-DCE	5.00E-02	9.00E-03	1
1,2-DCE, *cis*-	1.00E-02	1.00E-02	1
Aroclor-1254	1.80E-05	2.00E-05	0.9
Aroclor-1260	1.80E-05	2.00E-05	0.9
Naphthalene	1.60E-02	2.00E-02	0.8
TCE	4.50E-05	6.00E-03	0.15
Vinyl Chloride	3.00E-03	3.00E-03	1

Note: Blank cells indicate that data are not available or are not appropriate.
[a] All groundwater COPCs are listed except radionuclides because external exposure to water is not assessed.
[b] The units for the absorbed doses are mg/(kg × day). All dermal reference dose were obtained from the 2008 Risk Methods Document (DOE 2008).
[c] Administered reference doses are equivalent to the oral reference dose and were used to calculate all dermal reference doses listed in the 2008 Risk Methods Document (DOE 2008). The units are mg/(kg x day).
[d] GI absorption factors are from the 2008 Risk Methods Document (DOE 2008) and are unitless
[e]Uranium Source: 40 *CFR* Part 141 (2000).

F.4.1 INORGANIC COMPOUNDS

F.4.1.1 Antimony (CAS 007440-36-0) (RAIS)

Antimony is a naturally occurring silvery-white metal that is found in the earth's crust. Antimony ores are mined and then mixed with other metals to form antimony alloys or combined with oxygen to form antimony oxide. Little antimony is currently mined in the United States. It is brought into this country from other countries for processing; however, there are companies in the United States that produce antimony as a by-product of smelting lead and other metals. Antimony is used in lead storage batteries, solder, sheet and pipe metal, bearings, castings, and pewter. Antimony oxide is added to textiles and plastics to prevent them from catching fire. It also is used in paints, ceramics, and fireworks, and as enamels for plastics, metal, and glass.

Metallic antimony and a few trivalent antimony compounds are the most significant regarding exposure potential and toxicity. Antimony is a common urban air pollutant, occurring at an average concentration of 0.001 $\mu g/m^3$. Exposure to antimony may occur via inhalation oral and dermal routes.

Acute oral and inhalation exposure of humans and animals to high doses of antimony or antimony-containing compounds (antimonials) may cause gastrointestinal disorders (vomiting, diarrhea), respiratory difficulties, and death at extremely high doses. Subchronic and chronic oral exposure may affect hematologic parameters. Long-term oral exposure to high doses of antimony or antimonials has been shown to adversely affect longevity in animals. Long-term occupational exposure of humans has resulted in electrocardiac disorders, respiratory disorders, and possibly increased mortality. Antimony levels for these occupational exposure evaluations ranged from 2.2 to 11.98 mg Sb/m^3. Based on limited data,

occupational exposure of women to metallic antimony and several antimonials has reportedly caused alterations in the menstrual cycle and an increased incidence of spontaneous abortions.

The Department of Health and Human Services (DHHS), the International Agency for Research on Cancer (IARC), and the EPA have not classified antimony as to its human carcinogenicity.

Chronic RfDs for antimony are available in RAIS. The oral RfD used in the BHHRA is 4.00E-04 (mg/kg-day). The absorbed dose RfD is 8.00E-06 (mg/kg-day), which was calculated using a GI absorption factor of 2%, per the Risk Methods Document (DOE 2008).

F.4.1.2 Arsenic (CAS 007440-38-2) (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 mainly used to preserve wood. Organic arsenic compounds are used as pesticides, primarily on cotton plants. Arsenic cannot be destroyed in the environment. It can only change its form. Arsenic in air will settle to the ground or is 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 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 values used in the BHHRA are 1.50E+00, 1.51E+01, and 3.66E+00 $[mg/(kg \times day)]^{-1}$ for the oral, inhalation, and dermal exposure routes, respectively. The slope factor for the dermal exposure route was calculated by assuming a GI absorption factor of 41% (DOE 2008).

Chronic RfDs for arsenic also are available in RAIS. The values used in the BHHRA were 3.00E-04 and 1.23E-04 mg/(kg × day) for the oral and dermal routes, respectively. The dermal RfD was calculated by assuming a GI absorption factor of 41%.

F.4.1.3 Manganese (CAS 007439-96-5) (RAIS)

Manganese is a silver-colored, naturally occurring metal that is found in many types of rocks and makes up about 0.10% of the earth's crust. Manganese is not found alone, but combines with other substances such as oxygen, sulfur, or chlorine. Manganese also can be combined with carbon to make organic manganese compounds, including pesticides (e.g., maneb or mancozeb) and methylcyclopentadienyl manganese tricarbonyl, a fuel additive in some gasolines. Manganese is an essential trace element and is necessary for good health. Normal nutritional requirements of manganese are satisfied through the diet, which is the normal source of the element, with minor contributions from water and air. The National Research Council recommends a dietary allowance of 2-5 mg/day for a safe and adequate intake of manganese for an adult human. Manganese can be found in several food items, including grains, cereals, and tea.

Manganese can elicit a variety of serious toxic responses upon prolonged exposure to elevated concentrations, either orally or by inhalation. The central nervous system is the primary target. Initial symptoms are headache, insomnia, disorientation, anxiety, lethargy, and memory loss. These symptoms progress with continued exposure and eventually include motor disturbances, tremors, and difficulty in walking, symptoms similar to those seen with Parkinsonism. These motor difficulties are often irreversible. Some individuals exposed to very high levels of manganese for long periods of time at work developed mental and emotional disturbances and slow and clumsy body movements. This combination of symptoms is a disease called "manganism."

There are no human cancer data available for manganese. Manganese has been placed in the EPA weight-of-evidence classification D: not classifiable as to human carcinogenicity. No slope factors, therefore, were used in this BHHRA.

The oral, inhalation, and dermal RfDs from RAIS used in the BHHRA were 4.60E-02, 1.43E-05, and 1.84E-03 mg/(kg × day), respectively. The inhalation RfD was calculated using the inhalation reference concentration (RfC). The dermal RfD was calculated using a GI absorption factor is 4% (DOE 2008).

F.4.1.4 Selenium (CAS 007782-49-2) (RAIS)

Selenium is a metal commonly found in rocks and soil; much of the selenium in rocks is combined with sulfide minerals or with silver, copper, lead, and nickel minerals. Selenium and oxygen combine to form several compounds. Selenium sulfide is a bright red-yellow powder used in anti-dandruff shampoo. Industrially produced hydrogen selenide is a colorless gas with a disagreeable odor. It is probably the only selenium compound that might pose a health concern in the workplace. Selenium dioxide is an industrially produced compound that dissolves in water to form selenious acid. Selenious acid can be found in gun bluing (a solution used to clean the metal parts of a gun). Selenium is an essential trace element important in many biochemical processes that take place in human cells. Recommended human dietary allowances for selenium for adults is about 40-70 µg.

In humans, acute oral exposures can result in excessive salivation, garlic odor to the breath, shallow breathing, diarrhea, pulmonary edema, and death. Other reported signs and symptoms of acute selenosis include tachycardia, nausea, vomiting, abdominal pain, abnormal liver function, muscle aches and pains, irritability, chills, and tremors. The exact levels at which these effects occur are not known. GI absorption in animals and humans of various selenium compounds ranges from about 44% to 95% of the ingested dose. If too much selenium is ingested over long periods of time, brittle hair and deformed nails can

develop. Upon contact with skin, selenium compounds have caused rashes, swelling, and pain. Respiratory tract absorption rates of 97% and 94% for aerosols of selenious acid have been reported for dogs and rats, respectively. In humans, inhalation of selenium or selenium compounds primarily affects the respiratory system. Dusts of elemental selenium and selenium dioxide can cause irritation of the skin and mucous membranes of the nose and throat, coughing, nosebleed, loss of sense of smell, dyspnea, bronchial spasms, bronchitis, and chemical pneumonia.

Studies of laboratory animals and humans show that most selenium compounds probably do not cause cancer. In fact, human studies suggest that lower-than-normal selenium levels in the diet might increase the risk of cancer. Other forms of selenium may, however, be carcinogenic according to the DHHS. Selenium sulfide produced a significant increase in the incidence of lung and liver tumors in rats and mice. EPA has placed selenium and selenious acid in Group D, not classifiable as to carcinogenicity in humans, while selenium sulfide is placed in Group B2, probable human carcinogen. Selenium sulfide is very different from the selenium compounds found in foods and in the environment. Selenium sulfide has not caused cancer in animals when it is placed on the skin, and the use of anti-dandruff shampoos containing selenium sulfide is considered safe.

Chronic RfDs from RAIS were available for selenium. The RfDs used in the BHHRA for the oral and dermal routes of exposure were 5.00E-03 and 2.20E-03 mg/(kg × day), respectively. The dermal route RfD was based on a GI absorption factor of 44% (DOE 2008).

F.4.1.5 Uranium (metal and soluble salts) (CAS 007440-61-1)

Uranium is a hard, silvery white amphoteric metal and is a radioactive element. In its natural state it consists of three isotopes: ^{234}U, ^{235}U, and ^{238}U. More than 100 uranium minerals exist; those of commercial importance are the oxides and oxygenous salts. The processing of uranium ore generally involves extraction then leaching either by an acid or a carbonate method. In addition, the metal may be obtained from its halides by fused salt electrolysis. The primary use of natural uranium is in nuclear energy as a fuel for nuclear reactors, in plutonium production, and as feeds for gaseous diffusion plants; it is also a source of radium salts. Uranium compounds are used in staining glass, glazing ceramics, and enameling; in photographic processes; for alloying steels; and as a catalyst for chemical reactions, radiation shielding, and aircraft counterweights (Sittig 1985).

The primary route of exposure to uranium metals and salts is through dermal contact. Uranium soluble compounds act as a poison to cause kidney damage under acute exposure and pneumoconiosis or pronounced blood changes under chronic exposure conditions. Furthermore, it is difficult to separate the toxic chemical effects of uranium and its compounds from their radiation effects. The chronic radiation effects are similar to those produced by ionizing radiation. Reports now confirm that carcinogenicity is related to dose and exposure time. Cancer of the lung, osteosarcoma, and lymphoma have all been reported (Sittig 1985). An EPA weight-of-evidence classification for uranium metal was not located in the available literature. Slope factors for uranium metal also were not available for use in the BHHRA.

Chronic RfDs from the Risk Methods Document were available for uranium metal (listed as uranium soluble salts). The oral and dermal RfD used in the BHHRA were 6.00E-04 and 5.10E-04 mg/(kg × day), respectively. A GI absorption factor of 85% was used to derive the dermal RfD (DOE 2008).

F.4.2 ORGANIC COMPOUNDS

F.4.2.1 1,1-DCE (CAS 000075-35-4) (RAIS)

1,1-DCE, also known as 1,1-dichloroethene and vinylidine chloride, is a colorless liquid that is used in the production of polyvinylidine chloride (PVC) copolymers and as an intermediate for the synthesis of organic chemicals. The major application of PVC copolymers is the production of flexible films for food packaging.

1,1-DCE is not a naturally-occurring chemical, but is found in the environment due to releases associated with its production and transport and with its polymer production. Because of its high volatility, releases to the atmosphere are the greatest source of ambient 1,1-DCE. Smaller amounts are released to surface waters and soils. Loss of 1,1-DCE from water and soils is primarily due to volatilization. Human exposure to 1,1-DCE is potentially highest in workplace settings and in the vicinity of hazardous waste sites where the compound may contaminate environmental media.

The primary effect of acute exposure to high concentrations (approximately 4,000 ppm) of 1,1-DCE vapor in humans is central nervous system (CNS) depression, which may progress to unconsciousness. Occupational exposure has been reported to cause liver disfunction in workers. 1,1-DCE is a skin irritant and prolonged contact can cause first degree burns. Direct contact with the eyes may cause conjunctivitis and transient corneal injury. Based on EPA guidelines, 1,1-DCE was assigned to weight-of-evidence group C, possible human carcinogen.

Slope factors for 1,1-DCE are available from RAIS. The values used in the BHHRA for oral, inhalation and dermal slope factors are 6.00E-01, 1.75E-01, and 6.00E-01 mg/(kg × day), respectively. The slope factor for the dermal route was calculated using a GI absorption factor of 100% (DOE 2008).

Chronic RfDs for 1,1-DCE are available from RAIS. The values used in the BHHRA for the oral, inhalation, and dermal routes were 5.00E-02, 5.71E-02, and 5.00E-02 mg/(kg × day), respectively. The inhalation RfD was extrapolated from the inhalation RfC. The dermal RfD was derived using a GI absorption factor of 100% (DOE 2008).

F.4.2.2 *Cis*-1,2-DCE (CAS 000156-59-) (RAIS)

1,2-DCE, also called 1,2-dichloroethene, is a highly flammable, colorless liquid with a sharp, harsh odor. It is used to produce solvents and in chemical mixtures. Very small amounts of 1,2-DCE may be smelled in air (about 17 ppm). There are two forms of 1,2-DCE: *cis*-1,2-DCE and *trans*-1,2-DCE. Sometimes both forms are present as a mixture. Commercial use is not extensive, but mixtures of *cis*- and *trans*-1,2-DCE have been used as intermediates in the production of other chlorinated solvents and compounds, as well as low temperature extraction solvents for dyes, perfumes, and lacquers. Additionally, *cis*- and *trans*-1,2-DCE react violently with potassium hydroxide, sodium, and sodium hydroxide and form shock-sensitive explosives when combined with dinitrogen tetraoxide. Both forms of 1,2-DCE are degradation products of TCE.

Humans are exposed to 1,2-DCE primarily by inhalation, but exposure also can occur by oral and dermal routes. Breathing high levels of 1,2-DCE can cause nausea, drowsiness, and tiredness in humans; very high levels can cause death. Animals that ingested extremely high doses of *cis*-1,2-DCE died. Lower doses of *cis*-1,2-DCE caused effects on the blood, such as decreased numbers of red blood cells, and also on the liver.

No cancer bioassays or epidemiological studies were available to assess the carcinogenicity of 1,2-DCE. EPA has placed *cis* -1,2-DCE in weight-of-evidence group D, not classifiable as to human carcinogenicity, based on the lack of or negative human or animal cancer data. No cancer slope factors for *cis* -1,2-DCE are available; therefore, carcinogenicity from exposure could not be quantified in the BHHRA.

The oral, inhalation, and dermal chronic RfDs for *cis*-1,2-DCE used in the BHHRA are 1.00E-02, 9.97E-03, and 1.00E-02 mg/(kg × day), respectively. The inhalation RfD used in the BHHRA was extrapolated from the inhalation RfC. The dermal RfD was derived from the oral toxicity value using a GI absorption factor of 100% (DOE 2001).

F.4.2.3 Aroclor-1254 (CAS 011097-69-1)

Aroclor-1254 is a PCB mixture containing approximately 21% $C_{12}H_6Cl_4$, 48% $C_{12}H_5Cl_5$, 23% $C_{12}H_4Cl_6$, and 6% $C_{12}H_3Cl_7$, with an average chlorine content of 54%. 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. 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; however, biodegradation, especially of lower chlorinated PCBs, can occur. PCBs have high bioconcentration factors and due to their lipophilicity, especially of highly chlorinated congeners, 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 location of the chlorine atoms on the phenyl rings is an important factor in PCB metabolism and excretion. The major route of PCB excretion is in the urine and feces; however, more important is the elimination in human milk. Metabolites are predominately found in urine and bile, while small amounts of the parent compound are found in the feces. Biliary excretion appears to be the source of fecal excretion.

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, acneform eruptions, edema of the arms and legs, neurological symptoms such as headache and limb numbness, and liver disturbance.

Hepatotoxicity is a prominent effect of Aroclor-1254 that has been well characterized. Effects include hepatic microsomal enzyme induction, increased serum levels of liver-related enzymes indicative of hapocellular damage, liver enlargement, lipid deposition, fibrosis, and necrosis.

Data are suggestive but not conclusive concerning the carcinogenicity of PCBs in humans. The EPA has not determined a weight-of-evidence classification or slope factor for Aroclor-1254 specifically. Hepatocellular carcinomas in rat and mice studies have led EPA to classify PCBs as group B2, probable human carcinogen.

Slope factors for Aroclor-1254 are available from RAIS. The values used in the BHHRA for oral, inhalation and dermal slope factors are 4.00E-01, 3.50E-01, and 4.44E-01 mg/(kg × day), respectively. The slope factor for the dermal route was calculated using a GI absorption factor of 90% (DOE 2008).

Chronic RfDs for Aroclor-1254 are available from IRIS. The values used in the BHHRA for the oral, inhalation, and dermal routes were 2.00E-05, 1.99E-05, and 1.80E-05 mg/(kg × day), respectively. The

inhalation RfD was extrapolated from the inhalation RfC. The dermal RfD was derived using a GI absorption factor of 90% (DOE 2008).

F.4.2.4 Aroclor-1260 (CAS 11096-82-5)

Aroclor-1260 is a PCB mixture containing approximately 38% $C_{12}H_4Cl_6$, 41% $C_{12}H_3Cl_7$, 8% $C_{12}H_2Cl_8$, and 12% $C_{12}H_5Cl_5$, with an average chlorine content of 60%. 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. 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; however, biodegradation, especially of lower chlorinated PCBs, can occur. PCBs have high bioconcentration factors and due to lipophilicity, especially of highly chlorinated congeners, tend to accumulate in the fat of fish, birds, mammals, and humans. The use of PCBs in the United States was limited to closed systems in 1974, and in February, 1977, the EPA issued final regulations prohibiting PCB discharge into waterways.

PCBs are absorbed after oral, inhalation, or dermal exposure and are stored in adipose tissue. The location of the chlorine atoms on the phenyl rings is an important factor in PCB metabolism and excretion. The major route of PCB excretion is in the urine and feces; however, of more importance is elimination in human milk. Metabolites are predominately found in urine and bile, while small amounts of parent compound are found in the feces.

No RfD or RfC have been verified for Aroclor-1260. Data are suggestive but not conclusive concerning the carcinogenicity of PCBs in humans. 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.

Specific information on the chronic oral toxicity of Aroclor-1260 to humans is not available; however, information from accidental poisonings that occurred in Japan and Taiwan and from occupational exposure to PCBs is available. Oral Exposures Primary target organs are the liver and skin. Hepatotoxicity is a well-characterized effect of Aroclor-1260 and other PCBs. The spectrum of effects include hepatic microsomal enzyme induction, increased serum levels of liver-associated enzymes suggestive of possible liver damage, liver enlargement, lipid deposition, fibrosis and necrosis. Chloracne has been observed in humans and several animal species following PCB exposure.

F.4.2.5 Naphthalene (CAS 000091-20-3)

Naphthalene is a white solid that is found naturally in fossil fuels and that exhibits a typical mothball odor. Naphthalene is a polycyclic aromatic hydrocarbon composed of two fused benzene rings. Burning tobacco or wood produces naphthalene. It occurs in crude oil, from which it may be recovered directly as white flakes; it can also be isolated from cracked petroleum, coke-oven emissions, or from high-temperature carbonization of bituminous coal. The major products made from naphthalene are moth repellents. It is also used for making dyes, resins, leather, tanning agents, and the insecticide carbaryl.

Naphthalene can be absorbed by the oral, inhalation, and dermal routes of exposure and can cross the placenta in amounts sufficient to cause fetal toxicity. Exposure to large amounts of naphthalene may damage or destroy some red blood cells, causing a low level until the body replaces the destroyed cells. People, particularly children, have developed this problem after eating naphthalene-containing mothballs or deodorant blocks. Some of the symptoms of this problem are fatigue, lack of appetite, restlessness, and pale skin. Exposure to large amounts of naphthalene may also cause neurotoxic effects (confusion, lethargy, listlessness, vertigo), gastrointestinal distress, hepatic effects (jaundice, hepatomegaly, elevated serum enzyme levels), renal effects, and ocular effects (cataracts, optical atrophy). The estimated lethal dose of naphthalene is 5-15 g for adults and 2-3 g for children. Animals sometimes develop cloudiness in

their eyes after swallowing naphthalene. It is not clear if this also develops in people. When mice were repeatedly exposed to naphthalene vapors for 2 years, their noses and lungs became inflamed and irritated.

Available cancer bioassays were insufficient to assess the carcinogenicity of naphthalene. Using EPA's 1996 Proposed Guidelines for Carcinogen Risk Assessment, the human carcinogenic potential of naphthalene via the oral or inhalation routes "cannot be determined" at this time based on human and animal data. There is suggestive evidence (observations of benign respiratory tumors and one carcinoma in female mice only exposed to naphthalene by inhalation) that naphthalene may cause cancer. Additional support includes increase in respiratory tumors associated with exposure to 1-methylnaphthalene.

Chronic RfDs for naphthalene are available from RAIS. The values used in the BHHRA for the oral, inhalation, and dermal routes were 2.00E-02, 8.57E-04, and 1.60E-02 mg/(kg × day). The inhalation RfD was extrapolated from the inhalation RfC. The dermal RfD was derived using a GI absorption factor of 80% (DOE 2008).

F.4.2.6 TCE (CAS 000079-01-6) (RAIS)

TCE, also known as trichloroethylene, is a colorless, highly volatile liquid that is miscible with water and a number of organic solvents. TCE is a man-made chemical and is not known to occur naturally. It is mainly used as a solvent in industrial degreasing and cleaning of metals, but it also is used as a solvent for waxes, fats, resins, oils, and in numerous other applications. Prior to 1977, TCE had been used as an anesthetic, grain fumigant, disinfectant, and extractant of spice oleoresins in food and of caffeine in the production of decaffeinated coffee. The evaluation of the toxicity of TCE is complicated by the presence or absence of other chemicals. Industrial grade TCE usually contains stabilizers that are known to be toxic such as triethylamine, triethanolamine, epichlorohydrin, or stearates. In the absence of stabilizers, TCE readily decomposes. These decomposition products also are toxic.

Human and animal data indicate that exposure to TCE can result in toxic effects on a number of organs and systems, including the liver, kidney, blood, skin, immune system, reproductive system, nervous system, and cardiovascular system. Breathing small amounts of TCE may cause headaches, lung irritation, dizziness, poor coordination, and difficulty concentrating. Breathing large amounts of TCE may cause impaired heart function, unconsciousness, and death. Breathing it for long periods may cause nerve, kidney, and liver damage. Drinking large amounts of TCE may cause nausea, liver damage, unconsciousness, impaired heart function, or death. Drinking small amounts of TCE for long periods may cause liver and kidney damage, impaired immune system function, and impaired fetal development in pregnant women, although the extent of some of these effects is not yet clear. Skin contact with TCE for short periods may cause skin rashes.

Epidemiologic studies have been inadequate to determine if a correlation exists between exposure to TCE and increased cancer risk in humans. Some human studies with exposure over long periods to high levels of TCE in drinking water or in workplace air have found evidence of increased cancer; however, these results are inconclusive because the cancer could have been caused by other chemicals. Some studies with mice and rats have suggested that high levels of TCE may cause liver or lung cancer. Although EPA's Science Advisory Board recommended a weight-of-evidence classification of C-B2 continuum (C = possible human carcinogen; B2 = probable human carcinogen), the agency has not adopted a current position on the weight-of-evidence classification. In an earlier evaluation, TCE was assigned to weight-of-evidence Group B2, probable human carcinogen. The IARC has determined that TCE is not classifiable as to human carcinogenicity.

Cancer slope factors for TCE are available from RAIS. The slope factors from EPA for the oral, inhalation, and dermal exposure routes are 4.00E-01, 4.00E-01, and 2.67E+00 $[mg/(kg \times day)]^{-1}$, respectively. The

slope factor for the dermal exposure route was calculated using the EPA oral slope factor by assuming a GI absorption factor of 15% (DOE 2008). Cancer slope factors also are available from the review done by KDEP (KDEP 2004). The slope factor from KDEP for the oral exposure route is 3.22E-01 $(mg/kg \times day)^{-1}$ Following guidance in the draft revised Risk Methods Document, the KDEP oral slope factor was used as the slope factor for both the oral and inhalation routes in this BHHRA. Uncertainties related to the selection of toxicity values among the 2001 Risk Methods Document, the EPA value, and the KDEP value are discussed in the uncertainty section.

Chronic RfDs for TCE are available from RAIS. The values used in the BHHRA for the oral, dermal, and inhalation routes were 3.00E-04, 4.50E-05, and 1.14E-02 mg/(kg × day). The inhalation RfD was extrapolated from the inhalation RfC. The dermal RfD was derived using a GI absorption factor of 15% (DOE 2008).

F.4.2.7 Vinyl Chloride (CAS 000075-01-4) (RAIS)

Vinyl chloride, also known as chloroethene, is a halogenated aliphatic hydrocarbon. It is a colorless gas with a mild sweetish odor that is slightly soluble in water and soluble in hydrocarbons, oil, alcohol, chlorinated solvents, and most common organic liquids. Vinyl chloride is produced by thermal cracking of ethylene chloride and does not occur naturally. It is used primarily as an intermediate in the manufacture of PVC; limited quantities are used as a refrigerant and as an intermediate in the production of chlorinated compounds. It is a biodegradation product of TCE, tetrachloroethylene, and 1,1,1-TCA. Vinyl chloride may leach into groundwater from spills, landfills, and industrial sources.

Vinyl chloride is rapidly absorbed from the digestive tract and lungs. Breathing high levels of vinyl chloride can cause dizziness or sleepiness. Breathing very high levels can cause passing out, and breathing extremely high levels can cause death. Humans exposed to vinyl chloride in air for long periods of time can develop changes to the structure of their livers. Workers exposed to vinyl chloride have developed nerve damage and immune reactions. Other workers have developed problems with the blood flow in their hands: the tips of their fingers turn white and hurt when they are in cold temperatures. Sometimes, the bones in the tips of their fingers have broken down. The effects of drinking high levels of vinyl chloride are unknown. If vinyl chloride is spilled on skin, numbness, redness, and blisters may occur. Animal studies have shown that long-term (365 days or longer) exposure to vinyl chloride can damage the sperm and testes. It has not been proven that vinyl chloride causes birth defects in humans, but animal studies have shown that breathing vinyl chloride can harm unborn offspring and also may cause increases in early miscarriages.

Studies show that vinyl chloride causes liver cancer in humans. On the basis of sufficient evidence for carcinogenicity in human epidemiology studies, vinyl chloride is considered to best fit the weight-of-evidence Category “A,” according to current EPA Risk Assessment Guidelines. Agents classified into this category are considered known human carcinogens. This classification is supported by positive evidence for carcinogenicity in animal bioassays including several species and strains, and strong evidence for genotoxicity.

Cancer slope factors for vinyl chloride are available from EPA’s IRIS. The slope factors used in the BHHRA for the oral, inhalation, and dermal exposure routes are and 1.50E+00, 3.08E-02, and 1.50E+00 $[mg/(kg \times day)]^{-1}$, respectively. The slope factor for the dermal exposure route was calculated by assuming a GI absorption factor of 100%.

Chronic RfDs for vinyl chloride are available from RAIS. The values used in the BHHRA for the oral, inhalation, and dermal routes were 3.00E-03, 2.86E-02, and 3.00E-03 mg/(kg × day), respectively. The inhalation RfD was extrapolated from the inhalation RfC. The dermal RfD was derived using a GI absorption factor of 100% (DOE 2008).

F.4.3 RADIONUCLIDES

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 (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, cesium-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.

F.4.3.1 Technetium-99 (CAS 014133-76-7) (EPA)

Technetium is a radioactive element that occurs in a number of isotopic forms. Technetium is found in some extraterrestrial material (i.e., stars); however, no appreciable amounts have been found in nature due to the relatively short half-lives of its radioactive isotopes (Kutegov *et al.* 1968). While no isotopes of technetium are stable, the existence of three technetium isotopes is well established. Two common forms of technetium, ^{97}Tc and ^{98}Tc, have half-lives of 2.6×10^6 and 1.5×10^6 years, respectively. The third isotope, ^{99}Tc, has a half-life of 2.12×10^5 years. None, however, possesses a half-life sufficiently long to

allow technetium to occur naturally (Boyd 1959). Technetium is made artificially for industrial use, and natural technetium, particularly ^{99}Tc, has been identified and isolated from the spontaneous fission of uranium, as well as other fissionable material or via the irradiation of molybdenum (Venugopal and Luckey 1978; Clarke and Podbielski 1988).

Technetium is an emitter of beta particles of low specific activity (Boyd 1959). It does not release nuclear energy at a rate sufficient to make the element attractive for the conventional applications of radioactivity (Boyd 1959). ^{99}Tc is the only long-lived isotope that is readily available and is the isotope on which most of the chemistry of technetium is based. Although gamma radiation has not been associated with ^{99}Tc, the secondary X rays may become important with larger amounts of the element.

Oral and inhalation cancer slope factors used in the BHHRA for ^{99}Tc are 2.75E-12 and 1.41E-11 risk/pCi, respectively. Dermal and external exposure cancer slope factors were not calculated because these routes of exposure are not evaluated for groundwater in the BHHRA. Oral, dermal, and inhalation RfDs are not available for this element; therefore, systemic toxicity due to exposure to ^{99}Tc is not quantified in the BHHRA.

F.4.3.2 Uranium (CAS 007440-62-2 for metal, CAS 013966-29-5 for Uranium-234, and CAS 007440-61-1 for Uranium-238) (ATSDR)

Uranium is a mildly radioactive element that occurs widely in the earth's crust. It is found in all soils, most rocks, and, in lesser concentrations, in water, vegetation, and animals, including humans. Uranium emits a low level of alpha particles and a much lower level of gamma rays. Alpha particles are unable to penetrate skin, but can travel short distances in the body if ingested or inhaled. Consequently, uranium represents a significant carcinogenic hazard only when taken into the body, where alpha particle energy is absorbed by small volumes of tissue. Although the penetrating (gamma) radiation of uranium is not considered to be significant (ATSDR 1989), one of its daughter radionuclides is a strong gamma emitter; therefore, gamma radiation may be a concern in areas containing uranium.

Natural uranium contains the uranium isotopes ^{238}U (which averages 99.27% of total uranium mass), ^{235}U (0.725), and ^{234}U (0.0056%), each of which undergoes radioactive decay. Natural uranium, therefore, contains the radionuclide daughter products from the decay of ^{238}U and ^{235}U (Bowen 1979; ATSDR 1989). The half-lives of the isotopes are 200,000, 700 million, and 5 billion years for ^{234}U, ^{235}U, and ^{238}U, respectively.

Uranium is a radioactive element, but it also is a metallic element. Toxicological effects from the ingestion of uranium are the result of the action of uranium as a metal and its radioactive properties. The primary toxic chemical effect of uranium is seen in kidney damage. Studies in rabbits, mice, and dogs showed effects on the kidney to be dose-related. Fetal skeletal abnormalities and fetal death were found in pregnant mice exposed to 6 mg/kg or uranyl acetate dihydrate.

The primary human exposure studies to uranium have been studies of uranium miners or uranium factory workers. These studies have shown an increase in lung cancer deaths among these workers, which may be attributable to the decay of uranium into radon and its daughters. These workers are exposed to high levels of uranium dust and fumes and other radioactive elements in confined conditions (ATSDR 1989).

Oral cancer slope factors used in the BHHRA for ^{234}U are 7.07E-11 risk/pCi. Oral cancer slope factors used in the BHHRA for ^{238}U are 7.18E-11 risk/pCi. The slope factors for ^{238}U include ingrowth of short-lived degradation products. Dermal and external exposure cancer slope factors were not calculated for the uranium isotopes because these routes of exposure are not considered significant for radionuclides in groundwater and are not evaluated in the BHHRA. Oral, dermal, and inhalation RfDs are available for uranium and are listed earlier in this section.

F.4.4 CHEMICALS FOR WHICH NO EPA TOXICITY VALUES ARE AVAILABLE

Over all COPCs identified for RGA groundwater associated with the BGOU, oral RfD values exist for all of the inorganic chemical COPCs. Oral RfDs exist for all of the organic COPCs included.

All the inorganic chemical COPCs, except manganese lack inhalation RfD values. Absorbed dose RfD values exist for all of the inorganic and organic chemical COPCs included in the BHHRA.

Arsenic is the only inorganic chemical COPC with an oral slope factor. The organic compound COPCs without an oral slope factor are *cis*-1,2-DCE and naphthalene.

EPA-approved inhalation slope factors are available for only a few of the COPCs. The only inorganic chemical COPC with an inhalation slope factor is arsenic. Most organic compound COPCs have an approved inhalation slope factor. Those without an inhalation slope factor are *cis*-1,2-DCE and naphthalene.

COPCs with absorbed dose slope factors mirror those with oral slope factors. The COPCs without absorbed dose slope factors are all of the inorganic chemicals, except arsenic, and 1,1-DCE, *cis*-1,2-DCE, and naphthalene. All radionuclide COPCs except ^{234}U and ^{238}U have both oral and inhalation slope factors.

F.4.5 UNCERTAINTIES RELATED TO TOXICITY INFORMATION

Standard EPA RfDs and slope factors 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 slope factors and RfDs. 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 and slope factor. 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. For TCE, there is currently no IRIS slope factor, but several draft slope factors are available. The oral slope factor from the EPA draft reassessment is 4.00E-01 $(mg/kg \times day)^{-1}$ and the KDEP oral slope factor is 3.22E-01 $(mg/kg \times day)^{-1}$. These slope factors are significantly higher than the ones used in previous BHHRAs for PGDP. The KDEP oral slope factor was used in this BHHRA, but neither that value nor the EPA one has received final approval.

The dose-response relationship between cancer and ionizing radiation has been evaluated in many reports. Risk factors are extrapolated from the cancer risk established using the Japanese Atomic Bomb Survivors database and a relative risk projection model. EPA's methodology for estimating radionuclide carcinogenic risks currently is being reevaluated.

F.4.6 SUMMARY OF TOXICITY ASSESSMENT

A breakdown of the groundwater COPCs and their available toxicity information by SWMU is provided in the following subsections. These COCs relate to the soil samples that were used for determining the concentrations used for groundwater modeling.

F.4.6.1 SWMU 2 COPC Toxicity Summary

Ten COPCs were retained in groundwater for SWMU 2. Three are inorganic chemicals, all of which have toxicity information; four are organic compounds, all of which have toxicity information; and three are radionuclides, all of which have toxicity information.

F.4.6.2 SWMU 3 COPC Toxicity Summary

Five COPCs were retained in groundwater for SWMU 3. Three are inorganic chemicals, all of which have toxicity information; and two are radionuclides, both of which have toxicity information.

F.4.6.3 SWMU 4 COPC Toxicity Summary

Six COPCs were retained in groundwater for SWMU 4. Two are inorganic chemicals, both of which have toxicity information; three are organic compounds, for which the individual compounds all have toxicity information; and one is a radionuclide that has toxicity information.

F.4.6.4 SWMU 5 COPC Toxicity Summary

Four COPCs were retained in groundwater for SWMU 5. Two are inorganic chemicals, both of which have toxicity information; one is an organic compound, that has toxicity information; and one is a radionuclide, that has toxicity information.

F.4.6.5 SWMU 6 COPC Toxicity Summary

SWMU 6 did not contain any groundwater COPCs.

F.4.6.6 SWMU 7 COPC Toxicity Summary

Eleven COPCs were retained in groundwater for SWMU 7. Three are inorganic chemicals, all of which have toxicity information; five are organic compounds, for which the individual components all have toxicity information; and three are radionuclides, all of which have toxicity information.

F.4.6.7 SWMU 30 COPC Toxicity Summary

Nine COPCs were retained in groundwater for SWMU 30. Four are inorganic chemicals, all of which have toxicity information; two are organic compounds, for which the individual components all have toxicity information; and three are radionuclides, all of which have toxicity information.

F.4.6.8 SWMU 145 COPC Toxicity Summary

Six COPCs were retained in groundwater for SWMU 145. Three are inorganic chemicals, one is an organic chemical, that has toxicity information; and two are radionuclides, both of which have toxicity information.

F.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.

F.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 of a chemical, from a single pathway to the appropriate RfD. This ratio also is referred to as a HQ. This value is calculated as shown in the following equation:

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

where:

HQ is the hazard quotient, dimensionless
CDI is the chronic daily intake of a particular chemical, mg/(kg × day)
RfD is the chronic reference dose for a particular chemical and pathway, mg/(kg × day)

When performing this calculation, the proper RfD was used for each CDI. 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 CDIs that reflect inhalation exposure, the RfD used was that for inhalation. Similarly, the RfD that was appropriate for the duration of exposure was used. For all adult exposures, the period of exposure was greater than 7 years; therefore, the chronic RfD was used. For all exposures to children, regardless of duration, the chronic RfD was used (Risk Methods Document).

If several chemicals may reach a receptor through a common pathway, guidance (RAGS, Risk Methods Document) 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:

$$\text{Pathway HI} = HQ_1 + HQ_2 + HQ_3 + ... + HQ_n$$

where:

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 (Risk Methods Document) 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:

$$\text{Total HI} = HI_1 + HI_2 + HI_3 + ... + HI_n$$

where:

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 and assumptions used in deriving the RfD. 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.

F.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.

F.5.2.1.1 Chemical Excess Cancer Risk

The numeric estimate of the ELCR resulting from exposure to a single chemical carcinogen is derived by multiplying the CDI through a particular pathway by the slope factor appropriate to that pathway. The resulting value is referred to as a chemical-specific ELCR. This value is calculated as shown in the following equation:

$$\textbf{Chemical} - \textbf{specific ELCR} = \textbf{CDI} \times \textbf{SF}$$

where:

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 is the chronic daily intake of the chemical [mg/(kg × day)]
SF is the slope factor for the specific chemical $[(mg/(kg \times day)]^{-1}$

As with the calculation used to derive HQs, the proper slope factor was used for each CDI when performing this calculation. For CDIs that reflect ingestion, the slope factor was that for an administered dose. For CDIs that reflect absorption, the slope factor was that for absorbed dose. Finally, for CDIs that reflect inhalation exposure, the slope factor 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:

$$\textbf{Pathway ELCR} = \textbf{ELCR}_1 + \textbf{ELCR}_2 + \textbf{ELCR}_3 + \ldots + \textbf{ELCR}_n$$

where:

Pathway ELCR is the sum of the 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:

$$\textbf{Total ELCR} = \textbf{ELCR}_{\textbf{P1}} + \textbf{ELCR}_{\textbf{P2}} + \textbf{ELCR}_{\textbf{P3}} + \textbf{...} + \textbf{ELCR}_{\textbf{Pn}}$$

where:

Total ELCR is the sum of all pathways relevant to a single receptor, dimensionless
$ELCR_{P1}$ to $ELCR_{P2}$ 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.

F.5.2.1.2 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 equation:

$$\textbf{Radionuclide} - \textbf{specific ELCR} = \textbf{CDI} \times \textbf{SF}$$

where:

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 is the ingestion and inhalation chronic daily intake of the radionuclide, pCi
SF is the ingestion and inhalation slope factor for the specific radionuclide, risk/pCi
(Note: For external exposure, the units for CDI and SF are pCi-year/g and risk-g/pCi-year, respectively.)

As with the calculation used to derive chemical-specific ELCRs, the proper slope factor was used for each CDI when performing this calculation. For CDIs that reflect ingestion, the slope factor was that for ingestion. Similarly, for CDIs that reflect inhalation exposure, the slope factor 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 Subsection F.5.2.1. 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 F.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 F.6.

F.5.3 RISK CHARACTERIZATION FOR SOIL

2.718.88.51.317.240.7 227.310.72.28**61**1.68.30.3/2400.2.829112i21.059370.8100.65.4For the risk characterization for soil, the results of the previous risk assessments described in Section F.1 are used. For most of the SWMUs, no new surface data have been collected since the previous risk assessments were performed. The soils at these units are outside the scope of the BGOU as noted in the approved work plan; therefore, a new quantitative risk assessment was not performed for soils. Vapor intrusion modeling was performed to examine potential risks from vapors from soil contaminants, intruding into basements. The percent contribution listed for each soil COC is listed with the same accuracy (i.e., 2% or 2.0%) as is in the original document from which the value was taken.

F.5.3.1 Systemic Toxicity and Excess Lifetime Cancer Risk (Direct Exposure to Soil)

Results of previous risk assessments are available for SWMUs 2, 3, 4, 5, 6, 7, and 30 (DOE 1994; DOE 1998b; DOE 2000). The results for systemic toxicity (HI) and ELCR for soil exposure are discussed in Section F.1 and presented in Attachment F2 of this appendix.

F.5.3.2 Vapor Intrusion into Basements from Soil

Exposure of on-site residents to vapors from soil contaminants intruding into basements is a potential pathway. To examine potential risks and hazards, vapor intrusion modeling was completed and examined for three POEs: the property boundary, the plant boundary, and a future on-site resident. The HQs and ELCRs for the modeled vapor concentrations are presented in Table E.3.35 of Appendix E. Modeled concentrations for the on-site POE showed an HQ greater than 0.1 for vapor intrusion from TCE, *cis*-1,2-DCE, 1,1-DCE, vinyl chloride, or mercury intrusion for the following:

- SWMU 2: TCE, and *cis*-1,2-DCE
- SWMU 3: mercury
- SWMU 4: TCE, *cis*-1,2-DCE, and vinyl chloride
- SWMU 7: 1,1-DCE, mercury, and vinyl chloride
- SWMU 30: mercury, 1,1-DCE, and TCE
- SWMU 145: mercury

ELCRs for the on-site POE were greater than 1E-06 for several SWMUs based on modeled contaminant concentrations. The following summarizes those SWMUs exhibiting elevated risks based on modeled soil concentrations.

- SWMUs 2: TCE
- SWMU 3: TCE
- SWUM 4: TCE and vinyl chloride
- SWMU 7: TCE, vinyl chloride, and 1,1-DCE
- SWMU 30: TCE and 1,1-DCE

Vapor intrusion into basements also was modeled at the plant boundary and property boundary. At the plant boundary all HIs were below 0.1. ELCRs were below 1E-06 for all SWMUs except for SWMUs 2, 4, 7, and 30. The following lists the risk driver for each SWMU:

- SWMU 2: TCE
- SWMU 4: TCE and vinyl chloride
- SWMU 7: 1,1-DCE
- SWMU 30: TCE and 1,1-DCE

At the property boundary all HIs were below 0.1. The ELCR for TCE exceeded *de minimis* risk levels at the property boundary for TCE at SWMUs 2 , 4, and 30. All other risks/hazards were below *de minimums* levels at the property boundary. The quantitative assessment of potential risks and hazards due to exposure to vapor intrusion is summarized in Table 5.14.

F.5.4 RISK CHARACTERIZATION FOR RESIDENTIAL USE OF GROUNDWATER DRAWN FROM THE RGA

This subsection presents the risk for residential use of groundwater drawn from the RGA. Tables and discussion in this subsection provide the total HI or ELCR for the each source area and list the major exposure routes and COPCs contributing to the total HI or ELCR. Environmental data for each source area was used to model groundwater concentrations at the POEs (see Section 5 and Appendix E for details of the groundwater modeling). The EPCs for groundwater are equal to the maximum concentration over the 1,000 year period over which groundwater was modeled. The groundwater assessment is conducted only for the residential scenario, but was conducted for all SWMUs including SWMU 145. Characterization of risks from groundwater at off-site POEs (plant boundary, property boundary, and Ohio River) are discussed in Section F.5.5.

F.5.4.1 Systemic Toxicity (Groundwater Use)

Tables F.34 through F.49 summarize the HIs for the modeled groundwater concentrations at each SWMU for the child and adult resident. As shown in these tables, the total scenario HIs are greater than 1 for the all of the SWMUs except SWMU 6 for both the child and adult resident. The source with the greatest HI for the child receptor is SWMU 2, which has a HI=1300, with the major contribution coming from ingestion of water containing TCE (52.1%) and *cis*-1,2-DCE (46.8%).The source with the greatest HI for the adult is SWMU 2, which has a HI=379, with the major contribution coming from ingestion of water (45%) and household inhalation (27.5%). The major contributors are TCE (62.1%) and *cis*-1,2-DCE (36.8%).

Table F.34. HI Child Residential Groundwater Use at SWMU 2

	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Hazard[b]	Percent of Total Hazard
Inorganic Compounds							
Arsenic	3.54E-02	1.13E+01	2.39E-02			1.13E+01	0.9%
Manganese	7.16E-01	1.49E+00	3.23E-02			1.52E+00	0.1%
Uranium	9.86E-03	1.58E+00	1.68E-03			1.58E+00	0.1%
Organic Compounds							
cis-1,2-DCE	1.15E+01	1.10E+02	3.89E+00	5.59E+01	4.37E+02	6.07E+02	46.8%
Naphthalene	9.38E-04	4.50E-03	1.02E-03	5.31E-02	4.15E-01	4.74E-01	0.0%
TCE	1.48E+00	4.73E+02	1.48E+02	6.29E+00	4.92E+01	6.76E+02	52.1%
Total Hazard		5.98E+02	1.52E+02	6.22E+01	4.87E+02	1.30E+03	**100.00%**
% of Total Hazard		46.0%	11.7%	4.8%	37.5%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.35. HI Child Residential Groundwater Use at SWMU 3

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Hazard[b]	Percent of Total Hazard
Inorganic Compounds							
Arsenic	3.29E-02	1.05E+01	2.22E-02			1.05E+01	47.9%
Manganese	8.95E-01	3.58E+00	7.75E-02			3.65E+00	16.6%
Uranium	4.89E-02	7.82E+00	7.97E-03			7.82E+00	35.5%
Total Hazard		2.19E+01	1.08E-01	0.00E+00	0.00E+00	**2.20E+01**	**100.0%**
% of Total Hazard		99.5%	0.5%	0.0%	0.0%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.36. HI Child Residential Groundwater Use at SWMU 4

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Hazard[b]	Percent of Total Hazard
Inorganic Compounds							
Arsenic	1.77E-02	5.66E+00	1.20E-02			5.67E+00	1.0%
Manganese	5.76E-01	1.20E+00	2.60E-02			1.23E+00	0.2%
Organic Compounds							
cis-1,2-DCE	6.68E-01	6.41E+00	2.26E-01	3.25E+00	2.54E+01	3.53E+01	6.1%
TCE	1.18E+00	3.77E+02	1.17E+02	5.02E+00	3.92E+01	5.39E+02	292.5%
Vinyl Chloride	2.61E-02	8.34E-01	1.80E-02	9.45E-03	3.46E-01	1.21E+00	0.2%
Total Hazard		3.91E+02	1.18E+02	8.27E+00	6.50E+01	5.82E+02	100.0%
% of Total Hazard		67.2%	20.2%	1.4%	11.2%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.37. HI Child Residential Groundwater Use at SWMU 5

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Hazard[b]	Percent of Total Hazard
Inorganic Compounds							
Arsenic	9.25E-03	2.96E+00	6.25E-03			2.96E+00	37.5%
Manganese	1.01E+00	2.11E+00	4.56E-02			2.15E+00	27.2%
Organic Compounds							
Naphthalene	5.55E-03	2.66E-02	6.04E-03	3.14E-01	2.45E+00	2.80E+00	35.4%
Total Hazard		5.09E+00	5.79E-02	3.14E-01	2.45E+00	**7.91E+00**	**100.0%**
% of Total Hazard		64.3%	0.7%	4.0%	31.0%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.38. HI Child Residential Groundwater Use at SWMU 6

COPC	Exposure Point Concentration	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Hazard	Percent of Total Hazard
NO COPCS[1]							

[1]Modeling analysis (Appendix E) did not show any of the identified COPCs at this site as migrating to groundwater.

Table F.39. HI Child Residential Groundwater Use at SWMU 7

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Hazard[b]	Percent of Total Hazard
Inorganic Compounds							
Arsenic	1.78E-02	5.69E+00	1.20E-02			5.70E+00	30.2%
Manganese	3.32E-01	6.92E-01	1.50E-02			7.07E-01	3.7%
Uranium	3.46E-03	5.53E-01	5.64E-04			5.54E-01	2.9%
Organic Compounds							
1,1-DCE	8.98E-02	1.72E-01	6.45E-03	7.62E-02	5.96E-01	8.51E-01	4.5%
cis-1,2-DCE	2.35E-02	2.25E-01	7.95E-03	1.14E-01	8.94E-01	1.24E+00	6.6%
Total PCBs	5.23E-05	2.51E-01	2.83E+00	1.27E-01	9.94E-01	4.20E+00	22.3%
TCE	1.09E-02	3.48E+00	1.09E+00	4.63E-02	3.63E-01	4.98E+00	26.4%
Vinyl Chloride	1.35E-02	4.32E-01	9.30E-03	2.29E-02	1.79E-01	6.43E-01	3.4%
Total Hazard		1.15E+01	3.97E+00	3.87E-01	3.03E+00	**1.89E+01**	**100.0%**
% of Total Hazard		60.9%	21.0%	2.0%	16.0%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.40. HI Child Residential Groundwater Use at SWMU 30

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Hazard[b]	Percent of Total Hazard
Inorganic Compounds							
Arsenic	1.77E-02	5.66E+00	1.20E-02			5.67E+00	1.7
Manganese	3.78E-01	7.88E-01	1.71E-02			8.05E-01	0.2%
Selenium	1.51E-02	2.90E-01	5.70E-04			2.90E-01	0.1%
Uranium	8.40E-03	1.34E+00	1.37E-03			1.34E-01	0.4%
Organic Compounds							
1,1-DCE	6.05E-02	1.16E-01	4.35E-03	5.13E-02	4.01E-01	5.73E-01	0.2%
TCE	7.12E-01	2.28E+02	7.10E+01	3.03E+00	2.37E+01	3.25E+02	97.4%
Total Hazard		2.36E+02	7.10E+01	3.08E+00	2.41E+01	3.34E+02	**100.0%**
% of Total Hazard		70.6%	21.3%	0.9%	7.2%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.41. HI Child Residential Groundwater Use at SWMU 145

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Hazard[b]	Percent of Total Hazard
Inorganic Compounds							
Antimony	7.99E-02	1.92E+01	8.30E-01			2.00E+01	48.0%
Arsenic	6.21E-02	1.98E+01	4.20E-02			1.99E+01	47.7%
Manganese	8.44E-01	1.76E+00	3.81E-02			1.80E+00	4.3%
Total Hazard		4.08E+01	9.10E-01	0.00E+00	0.00E+00	**4.17E+01**	**100.0%**
% of Total Hazard		97.8%	2.2%	0.0%	0.0%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.42. HI Adult Residential Groundwater Use at SWMU 2

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Hazard[b]	Percent of Total Hazard
Inorganic Compounds							
Arsenic	3.54E-02	3.23E+00	1.43E-02			3.25E+00	0.9%
Manganese	7.16E-01	4.26E-01	1.93E-02			4.46E-01	0.1%
Uranium	9.86E-03	4.50E-01	9.61E-04			4.51E-01	0.1%
Organic Compounds							
cis-1,2-DCE	1.15E+01	3.15E+01	2.33E+00	1.20E+01	9.37E+01	1.40E+02	36.8%
Naphthalene	9.38E-04	1.28E-03	6.10E-04	1.14E-02	8.89E-02	1.02E-01	0%
TCE	1.48E+00	1.35E+02	8.83E+01	1.35E+00	1.05E+01	2.35E+02	62.1%
Total Hazard		1.71E+02	9.07E+01	1.33E+01	1.04E+02	3.79E+02	**100.00%**
% of Total Hazard		45.0%	23.9%	3.5%	27.5%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.43. HI Adult Residential Groundwater Use at SWMU 3

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Hazard[b]	Percent of Total Hazard
Inorganic Compounds							
Arsenic	3.29E-02	3.00E+00	1.33E-02			3.02E+00	47.7%
Manganese	8.95E-01	1.02E+00	4.64E-02			1.07E+00	16.9%
Uranium	4.89E-02	2.23E+00	4.77E-03			2.24E+00	35.4%
Total Hazard		6.26E+00	6.44E-02	0.00E+00	0.00E+00	**6.32E+00**	**100.0%**
% of Total Hazard		99.0%	1.0%	0.0%	0.0%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.44. HI Adult Residential Groundwater Use at SWMU 4

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Hazard[b]	Percent of Total Hazard
Inorganic Compounds							
Arsenic	1.77E-02	1.62E+00	7.16E-03			1.62E+00	0.8%
Manganese	5.76E-01	3.43E-01	1.56E-02			3.59E-01	0.2%
Organic Compounds							
cis-1,2-DCE	6.68E-01	1.83E+00	1.35E-01	6.94E-01	5.44E+00	8.10E+00	4.1%
TCE	1.18E+00	1.08E+02	7.02E+01	1.07E+00	8.41E+00	1.87E+02	94.7%
Vinyl Chloride	2.61E-02	2.38E-01	1.08E-02	9.45E-03	7.41E-02	3.33E-01	0.2%
Total Hazard		1.12E+02	7.03E+01	1.77E+00	1.39E+01	**1.98E+02**	**100.0%**
% of Total Hazard		56.5%	35.6%	0.9%	7.0%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.45. HI Adult Residential Groundwater Use at SWMU 5

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Hazard[b]	Percent of Total Hazard
Inorganic Compounds							
Arsenic	9.25E-03	8.45E-01	3.74E-03			8.48E-01	40.8%
Manganese	1.01E+00	6.02E-01	2.73E-02			6.29E-01	30.2%
Organic Compounds							
Naphthalene	5.55E-03	7.60E-03	3.61E-03	6.72E-02	5.26E-01	6.05E-01	29.0%
Total Hazard		1.45E+00	3.46E-02	6.72E-02	5.26E-01	**2.08E+00**	**100.0%**
% of Total Hazard		69.8%	1.7%	3.2%	25.3%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.46. HI Adult Residential Groundwater Use at SWMU 6

COPC	Exposure Point Concentration	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Hazard	Percent of Total Hazard
NO COPCS[1]							

[1]Modeling analysis (Appendix E) did not show any of the identified COPCs at this site as migrating to groundwater.

Table F.47. HI Adult Residential Groundwater Use at SWMU 7

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Hazard[b]	Percent of Total Hazard
Inorganic Compounds							
Arsenic	1.78E-02	1.63E+00	7.20E-03			1.63E+00	25.5%
Manganese	3.32E-01	1.98E-01	8.97E-03			2.07E-01	3.2%
Uranium	3.46E-03	1.58E-01	3.37E-04			1.58E-01	2.5%
Organic Compounds							
1,1-DCE	8.98E-02	4.92E-02	3.86E-03	1.63E-02	1.28E-01	1.97E-01	3.1%
cis-1,2-DCE	2.35E-02	6.44E-02	4.76E-03	2.44E-02	1.92E-01	2.85E-01	4.5%
Total PCBs	5.23E-05	7.16E-02	1.69E+00	2.71E-02	2.13E-01	2.01E+00	31.4%
TCE	1.09E-02	9.95E-01	6.50E-01	9.90E-03	7.77E-02	1.73E+00	27.1%
Vinyl Chloride	1.35E-02	1.23E-01	5.57E-03	4.89E-03	3.84E-02	1.72E-01	2.7%
Total Hazard		3.29E+00	2.37E+00	8.26E-02	6.48E-01	**6.39E+00**	**100.0%**
% of Total Hazard		51.4%	37.2%	1.3%	10.1%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.48. HI Adult Residential Groundwater Use at SWMU 30

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Hazard[b]	Percent of Total Hazard
Inorganic Compounds							
Arsenic	1.77E-02	1.62E+00	7.16E-03			1.62E+00	1.4%
Manganese	3.78E-01	2.25E-01	1.02E-02			2.35E-01	0.2%
Selenium	1.51E-02	8.27E-02	3.41E-04			8.31E-02	0.1%
Uranium	8.40E-03	3.84E-01	8.19E-04			3.84E-01	0.3%
Organic Compounds							
1,1-DCE	6.05E-02	5.00E-01	2.50E-01	3.99E-01	3.99-01	1.55E+00	1.3%
TCE	7.12E-01	6.50E+01	4.25E+01	6.49E-01	5.07E+00	1.13E+02	96.7%
Total Hazard		6.78E+01	4.27E+01	1.05E+00	5.47E+00	**1.17E+02**	**100.0%**
% of Total Hazard		57.9%	36.5%	0.9%	4.7%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.49. HI Adult Residential Groundwater Use at SWMU 145

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Hazard[b]	Percent of Total Hazard
Inorganic Compounds							
Antimony	7.99E-02	5.47E+00	4.97E-01			5.97E+00	49.0%
Arsenic	6.21E-02	5.67E+00	2.51E-02			5.70E+00	46.7%
Manganese	8.44E-01	5.03E-01	2.28E-02			5.25E-01	4.3%
Total Hazard		1.16E+01	5.45E-01	0.00E+00	0.00E+00	**1.22E+01**	**100.0%**
% of Total Hazard		95.5%	4.5%	0.0%	0.0%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L.
[b]Only COPCs relevant to the endpoint are included in the table.

F.5.4.2 Excess Lifetime Cancer Risk (Groundwater Use)

Tables F.50 through F.57 summarize the ELCRs for the modeled groundwater exposure above each SWMU for the rural resident over a lifetime. As shown in these tables, the total ELCRs (bold value in "Total Risk" column) are greater than both 1×10^{-6} and 1×10^{-4} for all of the SWMUs except SWMU 6, which has no groundwater COCs. The source with the greatest ELCR is SWMU 2, which has an ELCR of 4.69×10^{-2}. The major pathway is inhalation of vapor during household water use (61.3%).The major contribution is from TCE (98%).

Table F.50. ELCR Residential Groundwater Use at SWMU 2

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Risk[b]	Percent of Total Risk
Inorganic Compounds							
Arsenic	3.54E-02	9.35E-04	3.13E-06			9.38E-04	2.0%
Organic Compounds							
TCE	1.48E+00	8.39E-03	5.16E-03	3.68E-03	2.88E-02	3.09E-02	98.0%
Radionuclides							
Technetium-99	1.02E+02	5.60E-06				5.60E-06	0.0%
Uranium-234	1.58E+00	2.23E-06				2.23E-06	0.0%
Uranium-238	1.81E+00	2.68E-06				2.68E-06	0.0%
Total Risk		9.34E-03	5.16E-03	3.68E-03	2.88E-02	**4.69E-02**	**100.0%**
% of Total Risk		19.9%	11.0%	7.8%	61.3%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L. Units for radionuclides are pCi/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.51. ELCR Residential Groundwater Use at SWMU 3

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COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Risk[b]	Percent of Total Risk
Inorganic Compounds							
Arsenic	3.29E-02	8.69E-04	2.91E-06			8.72E-04	72.4%
Radionuclides							
Technetium-99	5.56E+03	3.05E-04				3.05E-04	25.3%
Uranium-238	1.59E+01	2.76E-05				2.76E-05	2.3%
Total Risk		1.20E-03	2.91E-06	0.00E+00	0.00E+00	**1.20E-03**	**100.0%**
% of Total Risk		99.8%	0.2%	0.0%	0.0%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L. Units for radionuclides are pCi/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.52. ELCR Residential Groundwater Use at SWMU 4

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Risk[b]	Percent of Total Risk
Inorganic Compounds							
Arsenic	1.77E-02	4.68E-04	1.57E-06			4.69E-04	0.9%
Organic Compounds							
TCE	1.18E+00	6.69E-03	4.10E-03	2.93E-03	2.29E-02	3.67E-02	67.7%
Vinyl Chloride	2.61E-02	6.90E-04	1.58E-02	6.20E-06	4.85E-05	1.65E-02	30.5%
Radionuclides							
Technetium-99	9.01E+03	4.94E-04	NA	NA	NA	4.94E-04	0.9%
Total Risk		8.34E-03	1.99E-02	2.94E-03	2.30E-02	**5.41E-02**	100.0%
% of Total Risk		15.4%	36.7%	5.4%	42.4%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L. Units for radionuclides are pCi/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.53. ELCR Residential Groundwater Use at SWMU 5

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Risk[b]	Percent of Total Risk
Inorganic Compounds							
Arsenic	9.25E-03	2.44E-04	8.18E-07			2.45E-04	97.2%
Radionuclides							
Technetium-99	1.27E+02	6.97E-06				6.97E-06	2.8%
Total Risk		2.51E-04	8.18E-07	0.00E+00	0.00E+00	**2.52E-04**	**100.0%**
% of Total Risk		99.7%	0.3%	0.0%	0.0%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L. Units for radionuclides are pCi/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.54. ELCR Residential Groundwater Use at SWMU 6

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Risk[b]	Percent of Total Risk
NO COPCs[1]							

[1]Modeling analysis (Appendix E) did not show any of the identified COPCs at this site as migrating to groundwater.

Table F.55. ELCR Residential Groundwater Use at SWMU 7

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Risk[b]	Percent of Total Risk
Inorganic Compounds							
Arsenic	1.78E-02	4.70E-04	1.57E-06			4.72E-04	15.1%
Organic Compounds							
1,1-DCE	8.98E-02	9.49E-04	5.63E-05	1.21E-04	9.48E-04	2.08E-03	66.4%
Total PCBs	5.23E-05	3.68E-07	6.58E-06	1.41E-07		7.09E-06	0.2%
TCE	1.09E-02	6.18E-05	3.80E-05	2.71E-05		1.27E-04	4.1%
Vinyl Chloride	1.35E-02	3.57E-04	1.22E-05	3.21E-06		3.72E-04	11.9%
Radionuclides							
Technetium-99	9.09E+02	4.99E-05				4.99E-05	1.6%
Uranium-234	7.494E+00	1.11E-05				1.11E-05	0.4%
Uranium-238	7.59E+00	1.32E-05				1.32E-05	0.4%
Total Risk		1.91E-03	1.15E-04	1.52E-04	9.48E-04	**3.13E-03**	**100.0%**
% of Total Risk		61.2%	3.7%	4.9%	30.3%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L. Units for radionuclides are pCi/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.56. ELCR Residential Groundwater Use at SWMU 30

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Risk[b]	Percent of Total Risk
Inorganic Compounds							
Arsenic	1.77E-02	4.68E-04	1.57E-06			4.69E-04	2.0%
Organic Compounds							
1,1-DCE	6.05E-02	6.39E-04	3.79E-05	8.16E-05	6.41E-04	1.40E-03	5.8%
TCE	7.12E-01	4.04E-03	2.48E-03	1.77E-03	1.38E-02	2.21E-02	92.1%
Radionuclides							
Technetium-99	2.87E+02	1.57E-05				1.57E-05	0.1%
Uranium-234	3.99E+00	5.63E-06				5.63E-06	0.0%
Uranium-238	5.91E+00	1.03E-05				1.03E-05	0.0%
Total Risk		5.18E-03	2.52E-03	1.85E-03	1.45E-02	**2.40E-02**	**100.0%**
% of Total Risk		21.6%	10.5%	7.7%	60.2%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L. Units for radionuclides are pCi/L.
[b]Only COPCs relevant to the endpoint are included in the table.

Table F.57. ELCR Residential Groundwater Use at SWMU 145

COPC	Exposure Point Concentration[a]	Ingestion of Water	Dermal Contact	Shower Inhalation	Household Inhalation	Total Risk[b]	Percent of Total Risk
Inorganic Compounds							
Arsenic	6.21E-02	1.64E-03	2.28E-05			1.66E-03	5.1%
Organic Compounds							
Total PCBs	1.92E-03	6.76E-05	3.04E-02			3.05E-02	93.2%
Radionuclides							
Technetium-99	1.01E+04	5.54E-04				5.54E-04	1.7%
Uranium-238	7.67E-02	1.10E-07				1.10E-07	0.0%
Total Risk		82.26E-03	3.04E-02	0.0%	0.0%	**3.27E-02**	**100.0%**
% of Total Risk		6.9%	93.1%	0.0%	0.0%		

Blank cells indicate that the exposure route is not appropriate to the COPC.
[a] Units for metals and organic compounds are mg/L. Units for radionuclides are pCi/L.
[b]Only COPCs relevant to the endpoint are included in the table.

F.5.5 RISK CHARACTERIZATION FOR RESIDENTIAL USE OF GROUNDWATER AT FUTURE MODELED CONCENTRATIONS AT BOUNDARY AND RIVER POEs

This subsection discusses the potential future risks to a hypothetical resident using RGA groundwater contaminated by migration of COPCs from the SWMU 2, SWMU 3, SWMU 4, SWMU 5, SWMU 6, SWMU 7, SWMU 30, and SWMU 145 sources. As discussed in Section 2 of this BHHRA, the POEs to which contaminants were modeled were the PGDP plant boundary, PGDP property boundary, and near either the Little Bayou Seeps or the Ohio River. Information about the methods used in the model is provided in Section 5 and Appendix E of this RI.

Table F.58 presents the chemical-specific HIs for the child and adult rural residents from exposure to the modeled peak concentration over the 1,000 year time frame of the COPCs in the RGA at the POEs based on household use of groundwater. The major contributors are arsenic, TCE, and *cis*-1,2-DCE. Table F.59 presents the chemical-specific ELCRs for a rural resident from exposure to maximum modeled concentrations over the 1,000 year time frame of contaminants in the RGA groundwater at the POEs based on household use of water. The major contributors to ELCR are TCE, vinyl chloride, and ^{99}Tc. Table F.60 presents the chemical-specific ELCRs for a rural resident from exposure to maximum modeled concentrations of contaminants in the RGA at the seeps at Little Bayou Creek. Peak concentrations for contaminants in groundwater emerging at the seeps were modeled based on contaminants migrating from SWMUs 3, 7, and 30.

Tables F.58 through F.60 show the HIs and ELCRs for the predicted maximum (peak) concentrations for individual contaminants over the 1,000 year time frame of the model. Different contaminants migrate at different rates; therefore, the total HI or ELCR in groundwater at a given time may be less than the sum of the maximum risks of individual COCs. Figures F.2 to F.15 show the total hazard and total risks from the predicted concentrations of all COCs at each time step in the model for each SWMU except SWMU 6 (which had no modeled COCs). These hazards and risks are calculated using the NALs (DOE 2001) for residential use of groundwater. The values for total hazard or risk for all COCs calculated from the NALs for residential groundwater use and the time at which the total risk or hazard peaks are provided in Tables F.61 and F.62. These figures and tables show that at all SWMUs except SWMU 7, risk and hazard associated with modeled groundwater contaminants at the SWMU unit peak at the same time. For SWMUs 2, 4, and 30, these peaks occur in within the first twenty years of the model run. For SWMUs 3,

5, and 145, these peaks occur at the 1,000 year boundary of the model. For SWMU 7, the risk peaks very early in the model run, but the hazard value continues increasing to the end of the 1,000 year time frame. For SWMUs with contaminants that may migrate to other POEs such as the plant boundary and property boundary, the same pattern of peak times is seen as for the SWMU unit boundary except at SWMU 3. At SWMU 3, the ELCR at the unit boundary increases over the time frame of the model, but risk at the plant boundary and property boundary peak early because a different contaminant acts as the risk driver. These results indicate that some contaminants in the soil column at the SWMUs, which are not currently significant contributors to risk and hazard in groundwater, may become contributors in the future. Section 5 and Appendix E of the RI provide a discussion of the rates of migration for individual contaminants.

Table F.58. HIs for Peak Modeled Water Concentrations at the Plant Boundary, Property Boundary, and Near the Ohio River for Household Use of Groundwater Water Contaminated by COPC Migration from the BGOU SWMUs

	HI (child) at POE			HI (adult) at POE		
COPC[a]	**Plant Boundary**	**Property Boundary**	**Near Ohio River**	**Plant Boundary**	**Property Boundary**	**Near Ohio River**
			SWMU 2			
Arsenic	9.32E-01	2.67E-06	NA	2.67E-01	7.66E-07	NA
Manganese	4.04E-05	NA	NA	1.20E-05	NA	NA
Uranium	1.35E-01	NA	NA	3.81E-06	NA	NA
cis-1,2-DCE	9.19E+01	4.53E+01	1.79E+01	1.60E+01	1.04E+01	4.10E+00
Naphthalene	1.43E-01	4.18E-02	1.73E-02	3.08E-02	9.01E-03	3.73E-03
TCE	9.91E+01	5.03E+01	4.61E+00	3.45E+01	1.75E+01	2.59E+00
			SWMU 3			
Arsenic	3.98E-01	NA	--	1.12E-01	NA	--
Manganese	8.69E-10	NA	--	2.54E-10	NA	--
Uranium	3.63E-11	NA	--	1.04E-11	NA	--
			SWMU 4			
Arsenic	8.65E-01	1.57E-03	NA	2.48E-01	4.49E-04	NA
Manganese	1.07E-02	NA	NA	3.12E-03	NA	NA
cis-1,2-DCE	1.04E+01	4.72E+00	5.70E-01	2.38E+00	1.08E+00	3.84E-01
TCE	1.93E+02	9.77E+01	3.27E+01	6.70E+01	3.40E+01	1.22E+01
Vinyl Chloride	2.83E-01	1.20E-01	2.77E-02	7.58E-02	3.23E-02	9.97E-03
			SWMU 5			
Arsenic	5.70E-01	4.07E-02	NA	1.63E-01	1.16E-02	NA
Manganese	1.85E-01	4.90E-11	NA	5.41E-02	1.43E-11	NA
Naphthalene	4.95E-01	1.88E-01	5.45E-02	1.07E-01	4.05E-02	1.18E-02
			SWMU 6[a]			
NA	NA	NA	NA	NA	NA	--
			SWMU 7			
Arsenic	4.04E+00	7.53E-01	--	1.16E+00	2.16E-01	--
Manganese	5.13E-01	2.24E-06	--	1.50E-01	6.54E-07	--
Uranium	4.05E-01	4.29E-07	--	1.16E-01	1.23E-07	--
1,1-DCE	7.81E-01	1.04E-01	--	1.81E-01	2.41E-02	--
cis-1,2-DCE	1.14E+00	1.65E-01	--	2.61E-01	3.80E-02	--
Total PCBs	2.48E+00	2.45E-01	--	1.18E+00	1.17E-01	--
TCE	4.51E+00	6.49E-01	--	1.57E+00	2.26E-01	--
Vinyl Chloride	5.90E-01	5.76E-02	--	1.58E-01	1.54E-02	--
			SWMU 30			
Arsenic	3.75E+00	7.50E-01	--	1.07E+00	2.15E-01	--
Manganese	5.35E-01	6.07E-04	--	1.56E-01	1.77E-04	--
Selenium	1.59E-01	1.77E-02	--	4.57E-02	5.07E-03	--
Uranium	7.70E-01	3.86E-04	--	2.20E-01	1.10E-04	--
1,1-DCE	5.60E-01	4.18E-02	--	1.30E-01	9.68E-03	--
TCE	3.11E+02	2.68E+01	--	1.08E+02	9.33E+00	--
			SWMU 145			
Antimony	---[b]	3.78E-04	NA	---[b]	1.13E-04	NA
Arsenic	---[b]	5.16E-01	NA	---[b]	1.48E-01	NA

-- = not a POE for groundwater from this SWMU.
NA = not applicable. Modeling results indicate that the constituent does not contribute significantly to groundwater at this point within the 1,000 year modeling time period, and therefore is insignificant at these POEs.
[a] None of the modeled constituents migrated from SWMU 6 at concentrations with a significant HI.
[b] Exposure point not modeled because SWMU 145 lies outside the plant boundary.

Table F.59. ELCRs for Peak Modeled Water Concentrations at the Plant Boundary, Property Boundary, and Near the Ohio River for Household Use of Groundwater Water Contaminated by COPC Migration from BGOU SWMUs

	ELCR at POE		
COPC	**Plant Boundary**	**Property Boundary**	**Near Ohio River**
SWMU 2			
Arsenic	7.71E-05	2.21E-10	NA
TCE	6.74E-03	3.42E-03	1.28E-03
Technetium-99	8.72E-07	4.42E-07	1.71E-07
Uranium-234	2.47E-11	NA	NA
Uranium-238	3.53E-11	NA	NA
SWMU3			
Arsenic	3.23E-05	NA	NA
Technetium-99	9.92E-05	7.46E-05	NA
Uranium-238	1.27E-16	NA	NA
SWMU 4			
Arsenic	7.15E-05	1.30E-07	NA
TCE	1.99E-02	6.65E-03	2.38E-03
Vinyl Chloride	1.92E-04	7.44E-05	2.30E-05
Technetium-99	1.37E-04	6.58E-05	2.08E-05
SWMU 5			
Arsenic	4.72E-05	3.37E-06	NA
Technetium-99	2.74E-06	1.45E-06	4.78E-07
SWMU 6			
	NA [a]	NA	NA
SWMU 7			
Arsenic	3.34E-04	6.23E-05	NA
1,1-DCE	1.90E-03	2.54E-04	NA
Total PCBs	4.84E-06	4.78E-07	NA
TCE	3.07E-04	4.38E-05	NA
Vinyl Chloride	3.65E-04	3.56E-05	NA
Technetium-99	4.52E-05	1.48E-05	NA
Uranium-234	8.17E-06	1.30E-12	NA
Uranium-238	9.69E-06	1.02E-11	NA
SWMU 30			
Arsenic	3.10E-04	6.20E-05	NA
1,1-DCE	1.37E-03	1.02E-04	NA
TCE	2.11E-02	1.83E-03	NA
Technetium-99	1.45E-05	3.88E-06	NA
Uranium-234	3.88E-06	2.03E-09	NA
Uranium-238	7.07E-06	3.44E-09	NA
SWMU 145			
Arsenic	--- [b]	4.27E-05	NA
Technetium-99	--- [b]	1.01E-04	5.29E-05

NA = not applicable. Modeling results indicate that the constituent does not contribute significantly to groundwater at this point within the 1,000-year modeling time period, and therefore is insignificant at these POEs.

[a] Results for SWMU 6, none of the constituents modeled migrated at concentrations with a significant ELCR.

[b] Exposure point not modeled because SWMU 145 lies outside the plant boundary.

Table F.60. HIs and ELCRs for Residential Groundwater Use at the Little Bayou Creek Seeps

	COPC	HI (child)	HI (adult)	ELCR
SWMU 3 Seep	Technetium-99	NA	NA	4.41E-05
SWMU 7	1,1-DCE	3.81E-02	8.82E-03	9.29E-05
	cis-1,2-DCE	8.45E-02	1.91E-02	NA
	Total PCBs	1.06E-07	5.06E-08	2.07E-13
	TCE	2.31E-01	8.05E-02	1.57E-05
	Vinyl Chloride	1.97E-02	5.26E-03	1.21E-05
	Technetium-99	NA	NA	7.26E-06
SWMU 30 Seep	Selenium	6.05E-03	1.73E-03	NA
	1,1-DCE	1.25E-02	2.89E-03	3.05E-05
	TCE	8.95E+00	3.12E+00	6.09E-04
	Technetium-99	NA	NA	1.60E-06

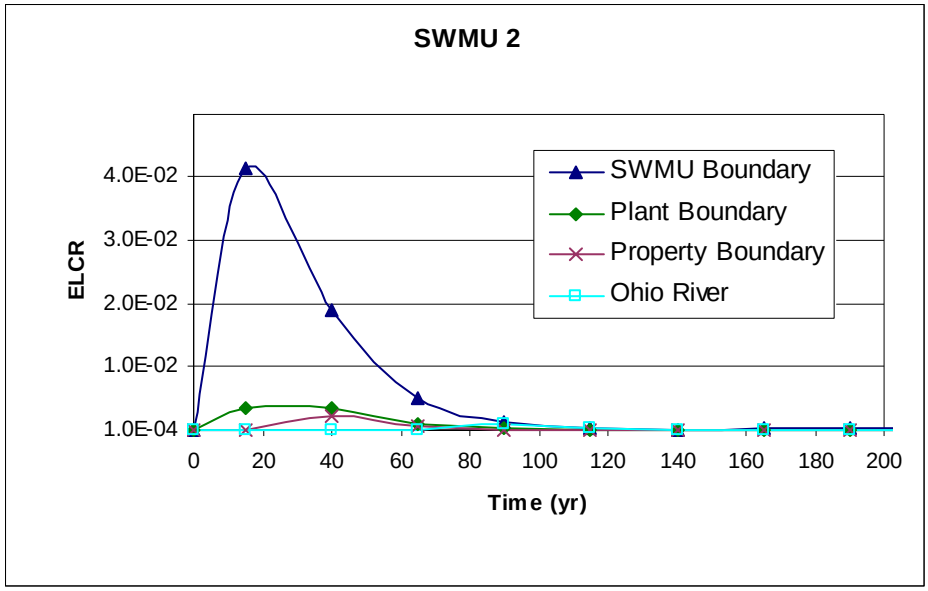

Figure F.2. Total ELCR from All Carcinogenic COCs at SWMU 2

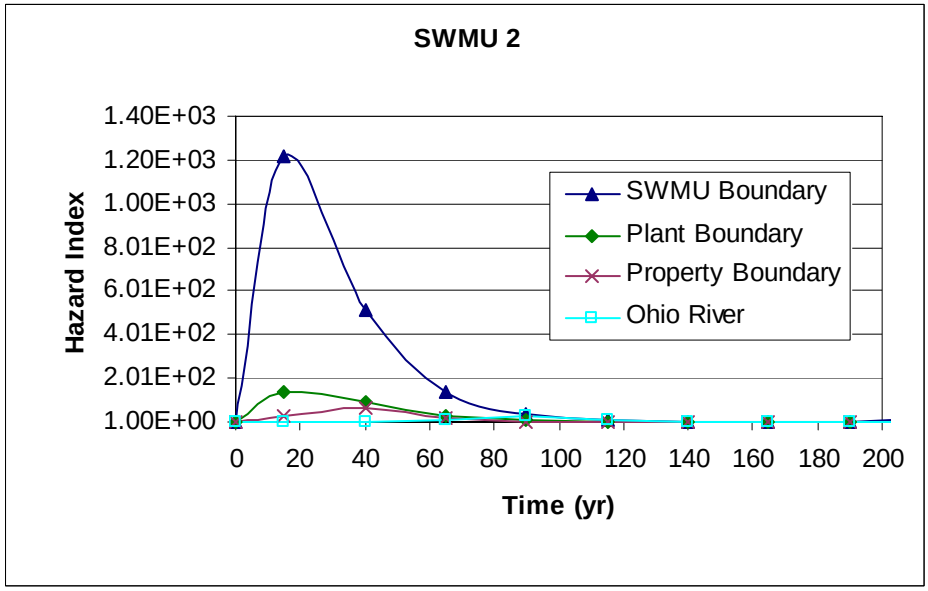

Figure F.3. Total HI from All Noncarcinogenic COCs at SWMU 2

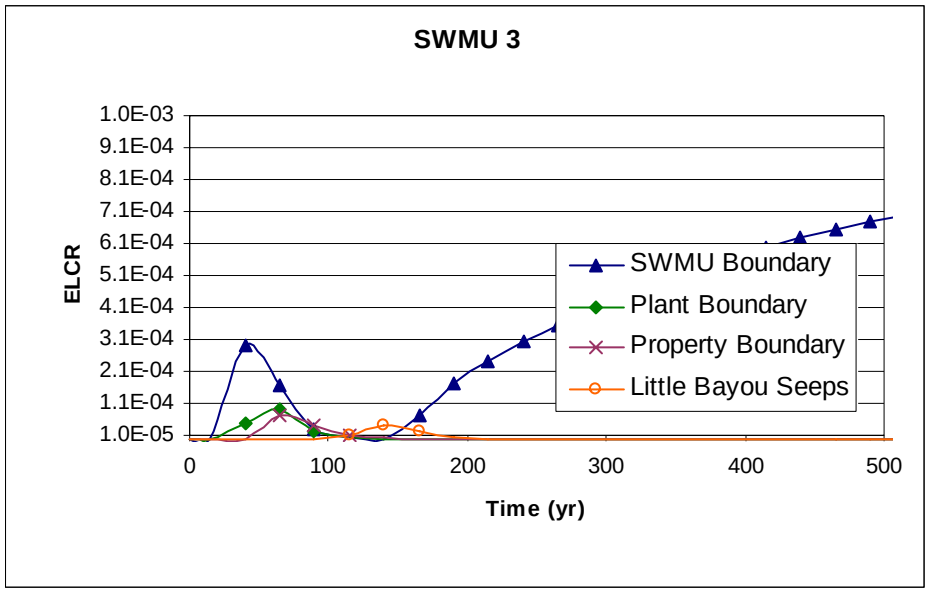

Figure F.4. Total ELCR from All Carcinogenic COCs at SWMU 3

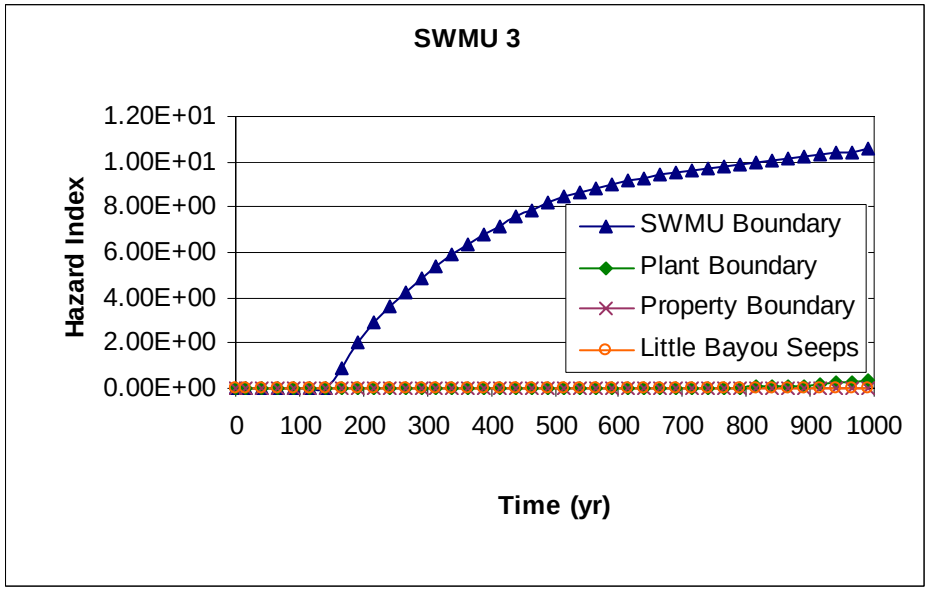

Figure F.5. Total HI from All Noncarcinogenic COCs at SWMU 3

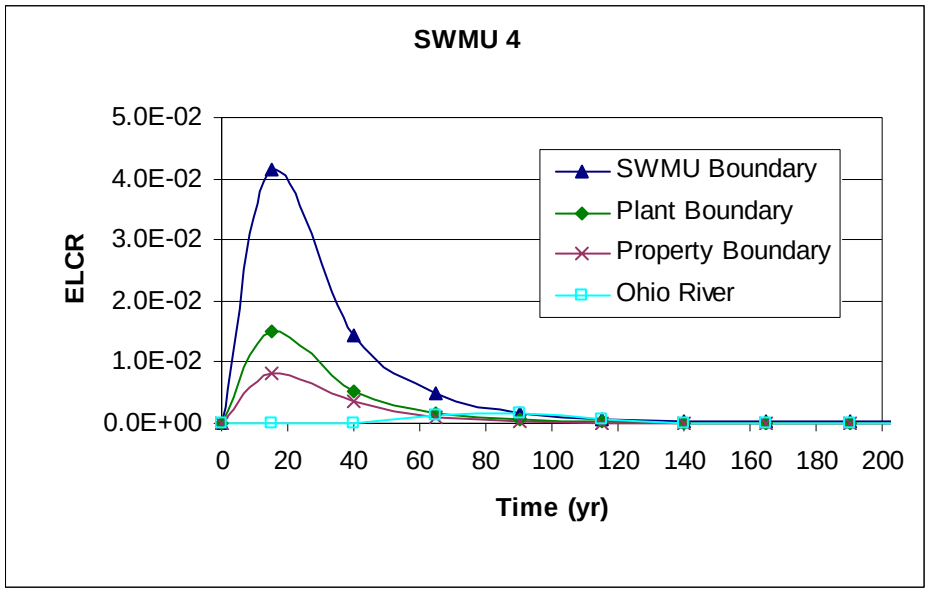

Figure F.6. Total ELCR from All Carcinogenic COCs at SWMU 4

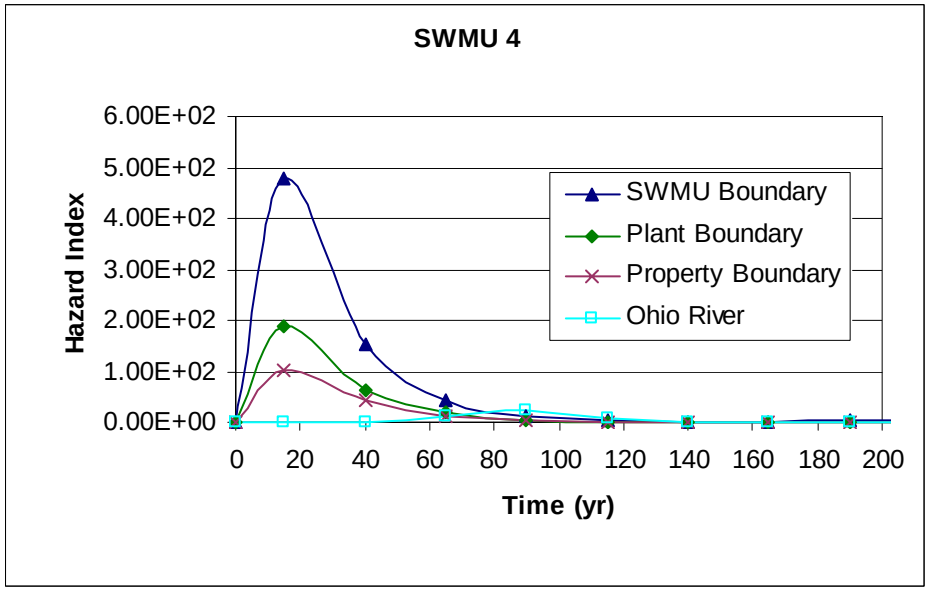

Figure F.7. Total HI from All Noncarcinogenic COCs at SWMU 4

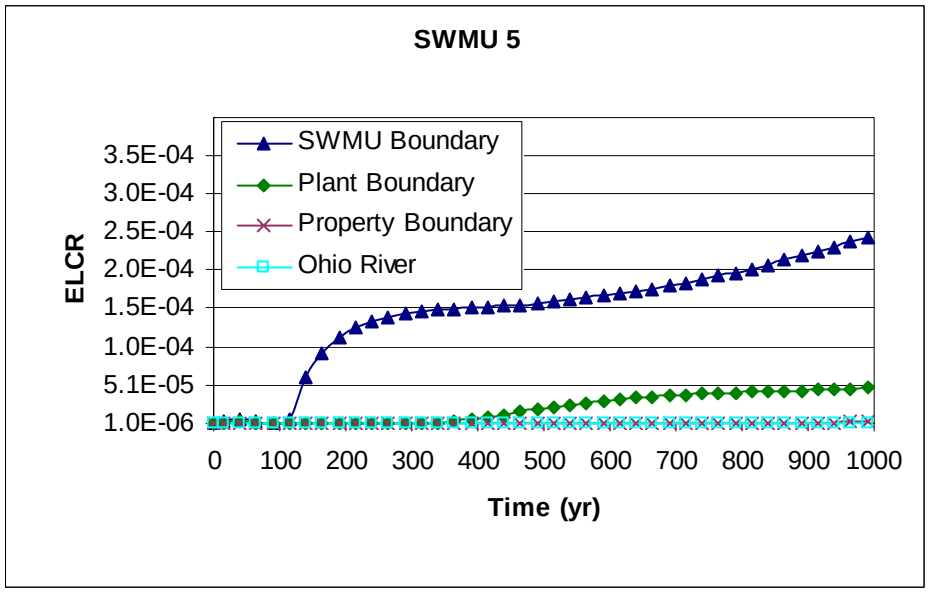

Figure F.8. Total ELCR from All Carcinogenic COCs at SWMU 5

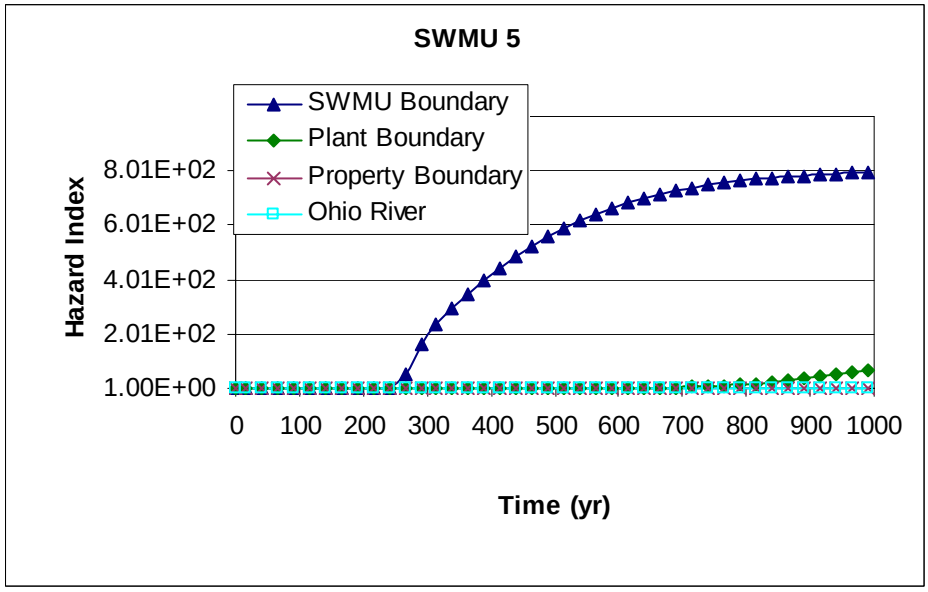

Figure F.9. Total HI from All Noncarcinogenic COCs at SWMU 5

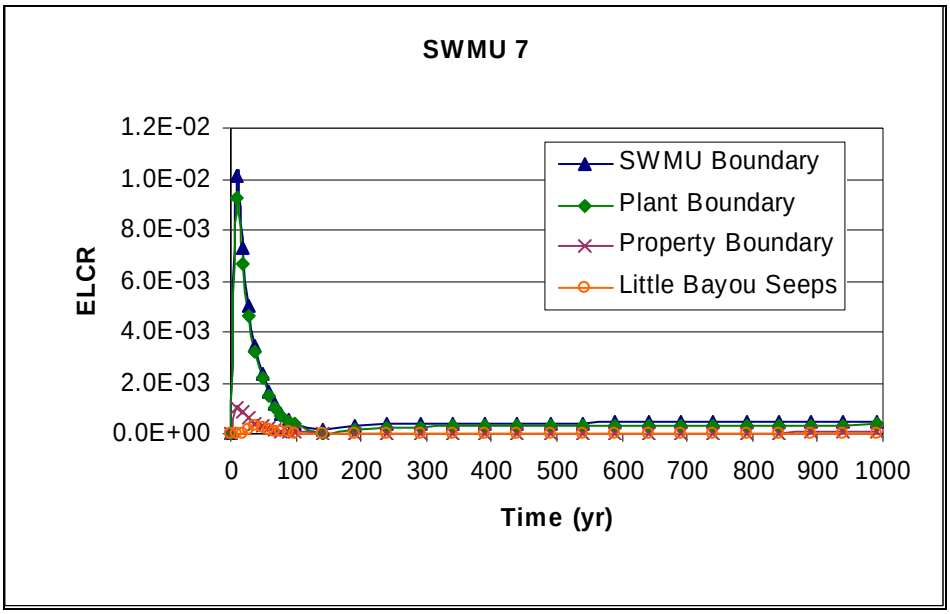

Figure F.10. Total ELCR from All Carcinogenic COCs at SWMU 7

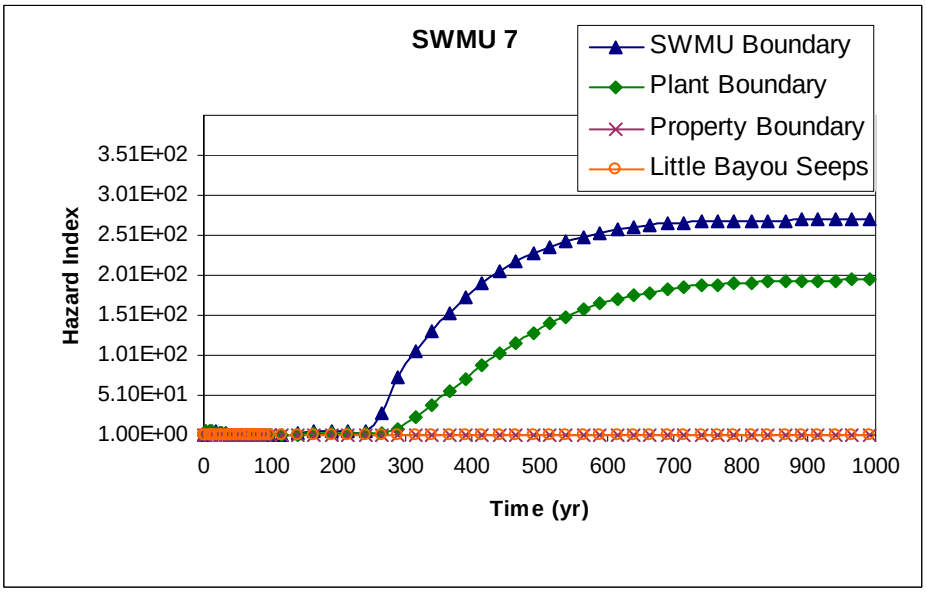

Figure F. 11. Total HI from All Noncarcinogenic COCs at SWMU 7

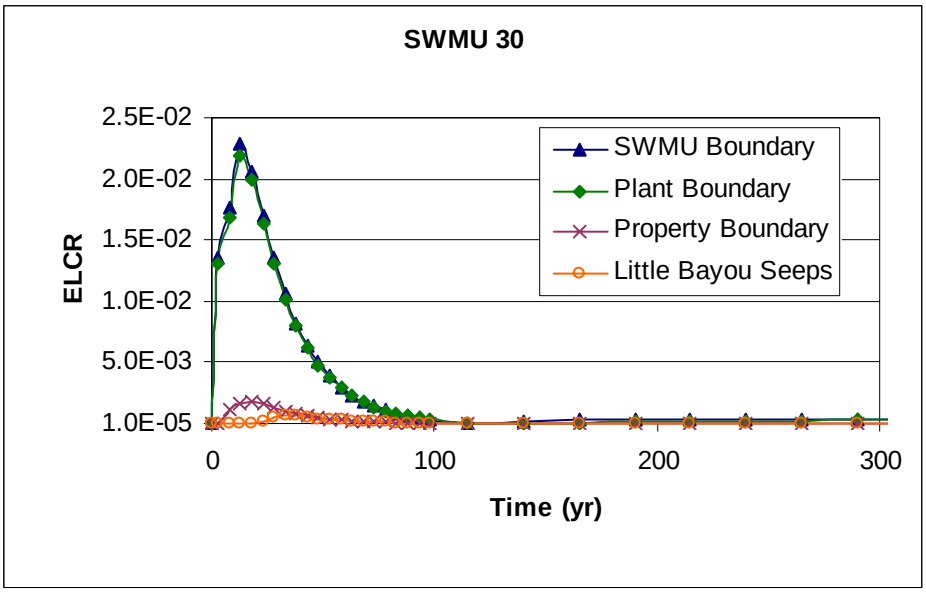

Figure F.12. Total ELCR from All Carcinogenic COCs at SWMU 30

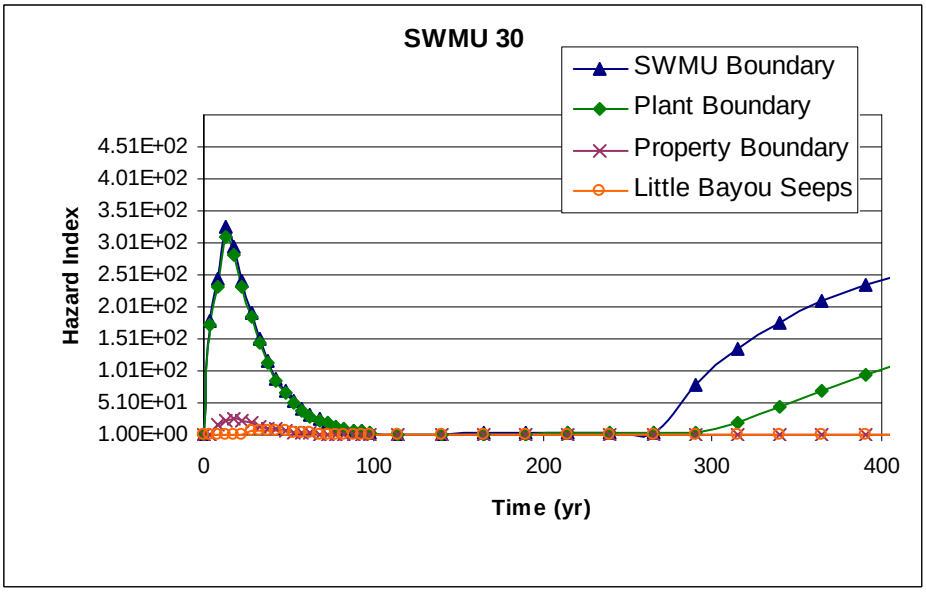

Figure F.13. Total HI from All Noncarcinogenic COCs at SWMU 30

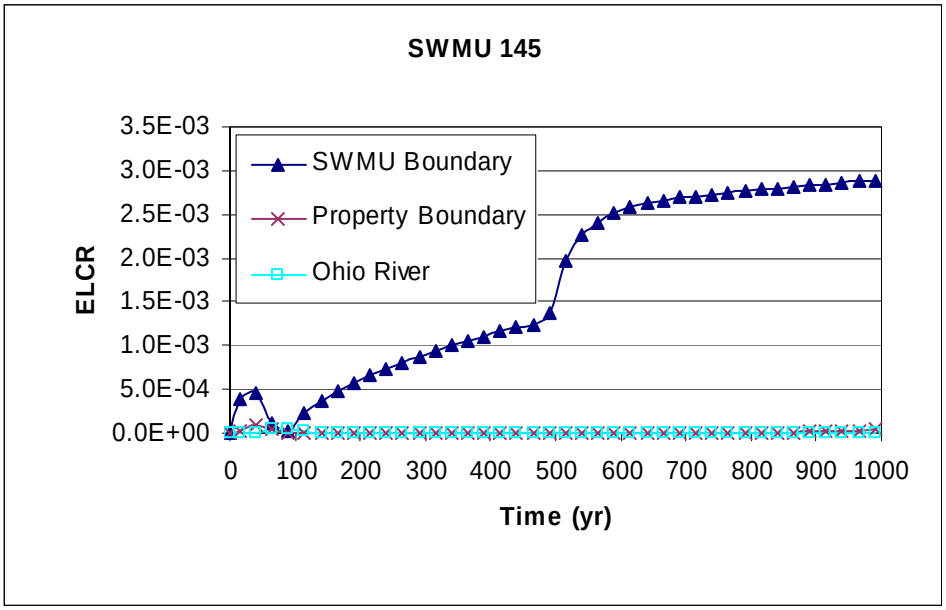

Figure F.14. Total ELCR from All Carcinogenic COCs at SWMU 145

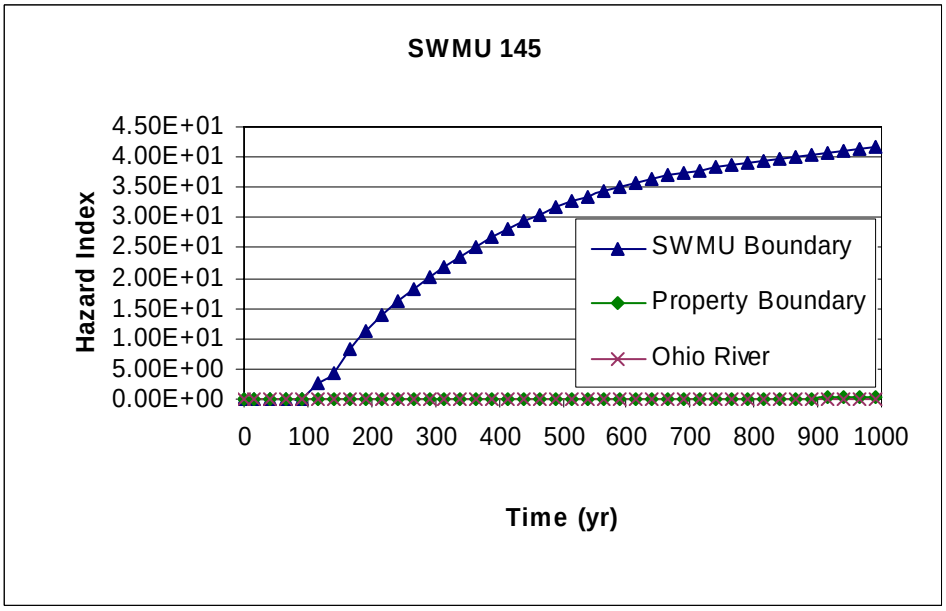

Figure F.15. Total HI from All Noncarcinogenic COCs at SWMU 145

The values for total hazard or risk for all COCs calculated from the NALs for residential groundwater use and the time at which the total risk or hazard peaks are provided in Tables F.61 and F.62.

As shown in Table F.61, the total HI for the child exceeded one for all SWMUs at the SWMU boundary. The total HI for the child for migration from the SWMU 2, SWMU 4, SWMU 5, SWMU 7, and SWMU 30 sources exceeds a HI of 1 at the plant boundary. The total HI for the child for migration from SWMU 2, SWMU 4, and SWMU 30 exceeds an HI of 1 at the property boundary. The total HI for the child for

migration from SWMU 2 and SWMU 4 exceeds an HI of 1 at the Ohio River. The total HI for the child for migration from SWMU 7 and SWMU 30 exceeds an HI of 1 at the Ohio River.

As shown in Table F.62, the total ELCRs resulting from COPC migration are above or equal to 1×10^{-6} at the SWMU boundary, the plant boundary, and the PGDP property boundary POEs for all sources. The total ELCRs were greater than 1×10^{-6} at the Little Bayou Seeps for SWMUs 3, 7, and 30. In addition, total ELCRs were greater than 1×10^{-6} at the Ohio River for SWMU 2, SWMU 4, and SWMU 145.

F.5.6 IDENTIFICATION OF LAND USE SCENARIOS, PATHWAYS, MEDIA, AND CONTAMINANTS OF CONCERN

This subsection outlines land use scenarios, exposure pathways, media, and COCs for each source area. As discussed in Section F.5.3, the results of the previous risk assessments for SWMUs 2, 3, 4, 5, 6, 7, and 30 are used for the risk characterization for soil. (The results of these previous risk assessments are discussed in Section F.1 and presented in Attachment F2 of this appendix.) Section F.8 presents the RGOs for each location and land use scenario.

Table F.61. Maximum Total HIs for Residential Groundwater Use at Each POE

	SWMU Boundary		Plant Boundary		Property Boundary		Little Bayou Seeps		Ohio River	
SWMU	Time (yr)	Peak Hazard	Time (yr)	Peak Hazard	Time (yr)	Peak Hazard	Time (yr)	Peak Hazard	Time (yr)	Peak Hazard
2	20	1.24E+03	20	1.87E+02	30	9.30E+01	na	na	80	3.46E+01
3	1000	10.5	1000	0.391	0	0	0	0	na	na
4	5	565	10	201	15	101	na	na	75	36.7
5	1000	792	1000	68.5	1000	4.07E-02	na	na	0	0
7	1000	270	1000	195	1000	0.998	36	3.46E-01	na	na
30	13	325	14	311	17	26.8	36	8.96	na	na
145	1000	19.9	na	na	1000	5.16E-01	na	na	0	0

Table F.62. Maximum Total ELCRs for Residential Groundwater Use at Each POE

	SWMU Boundary		Plant Boundary		Property Boundary		Little Bayou Seeps		Ohio River	
SWMU	Time (yr)	Peak Risk	Time (yr)	Peak Risk	Time (yr)	Peak Risk	Time (yr)	Peak Risk	Time (yr)	Peak Risk
2	20	4.60E-02	25	6.74E-03	30	3.42E-03	na	na	85	1.28E-03
3	1000	8.75E-04	55	9.94E-05	70	7.49E-05	140	4.42E-05	na	na
4	5	5.32E-02	10	1.69E-02	15	8.25E-03	na	na	75	2.81E-03
5	1000	2.46E-04	1000	4.73E-05	1000	3.38E-06	na	na	155	4.79E-07
7	3	1.05E-02	4	9.65E-03	9	1.02E-03	34	3.56E-04	na	na
30	13	2.29E-02	14	2.19E-02	17	1.89E-03	36	6.29E-04	na	na
145	1000	1.65E-03	na	na	40	1.01E-04	na	na	80	5.30E-05

F.5.6.1 Land Use Scenarios of Concern

To determine whether a land use scenario is 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 a) 1 for HI and b) 1×10^{-6} for ELCR. Land use scenarios with total HIs exceeding the benchmark of 1 are deemed land use scenarios of concern for non-cancer hazard. Land use scenarios with a total ELCR exceeding the benchmark of 1×10^{-6} are deemed land use scenarios of concern for cancer risk. These criteria were used in the previous risk assessments for SWMUs 4, 5, 6, 7, and 30 (DOE 1998a; DOE 2000). For the risk characterization of soil for SWMUs 2 and 3, land use scenarios of concern were determined by using EPA guidance and policy in effect at the time of the risk assessment (DOE 1994). The following are land uses of concern for BGOU at the SWMUs indicated.

- Industrial: SWMUs 2, 3, 4, 5, 6, 7, and 30
- Excavation: SWMUs 4, 5, 6, 7, and 30
- Recreational: SWMUs 5, 7, and 30
- On-Site Residential: SWMUs 2, 3, 4, 5, 6, 7, 30, and 145
- Off-Site Residential: SWMUs 2, 3, 4, 5, 7, 30, and 145

Table F.63 outlines all land use scenarios for all SWMUs that exceed *de minimis* risk or hazard levels.

F.5.6.2 Contaminants of Concern (Soil)

To make a determination about whether contaminants are of concern in soil, quantitative risk and hazard results over all pathways from the previous risk assessments for SWMUs 2, 3, 4, 5, 6, 7, and 30 (DOE 1994; DOE 1998a; DOE 2000) were compared to risk and hazard benchmarks for land use scenarios of concern. The benchmarks used for this comparison were a) 0.1 for HI and b) 1×10^{-6} for ELCR. For SWMUs 2 and 3, the WAG 22 RI calculated risks and hazards for soil for the two SWMUs as a combined unit; therefore, the soil entries for those two SWMUs are identical in the summary tables. The tables present risk and hazard values from the previous risk assessments calculated excluding consideration of lead because, at the time those assessments were written, a now withdrawn RfD for lead from Kentucky still was in use.

Contaminants with chemical-specific HIs or ELCRs exceeding these benchmarks are deemed COCs. Priority COCs are contaminants whose chemical-specific HI is greater than 1 or whose ELCR is greater than 1×10^{-4} for one or more scenarios. The following are priority COCs found in soil at individual SWMUs.

- SWMU 2–none
- SWMU 3–none
- SWMU 4–barium, beryllium, cadmium, chromium, iron, nickel, uranium, vanadium, Total dioxins/furans, Total PCBs, ^{234}U, and ^{238}U
- SWMU 5–aluminum, arsenic, beryllium, chromium, nickel, Total PAHs, and Total PCBs
- SWMU 6–beryllium, chromium, nickel, and Total PAHs
- SWMU 7–aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, manganese, nickel, uranium, vanadium, benzo(a)pyrene, dibenzo(a,h)anthracene, Aroclor-1254, Aroclor-1260, ^{239}Pu, ^{234}U, ^{235}U, $^{235/236}U$, and ^{238}U

- SWMU 30–aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, manganese, mercury, nickel, uranium, vanadium, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, Aroclor-1254, Aroclor-1260, ^{234}U, $^{235/236}U$, and ^{238}U.

Table F.63. Scenarios for Which Human Health Risk Exceeds *De Minimis* Levels[a]

Scenario	Location							
	SWMU 2	**SWMU 3**	**SWMU 4**	**SWMU 5**	**SWMU 6**	**SWMU 7**	**SWMU 30**	**SWMU 145**
Results for excess lifetime cancer risk:								
Current On-site Industrial Worker								
Exposure to Soil	X	X	X	X	X	X	X	NA
Future On-site Industrial Worker								
Exposure to Soil	X	X	X	X	X	X	X	NA
Exposure to Surface Water	NA	NA	NA	NA	NA	NA	NA	NA
Future On-site Excavation Worker								
Exposure to Soil/Soil and Waste	NA	NA	X	X	X	X	X	NA
Future On-site Recreational User								
Exposure to Game	NA	NA	---	X	---	X	X	NA
Exposure to Soil	NA	NA	NA	NA	NA	NA	NA	NA
Future On-site Rural Resident								
Exposure to Soil	NA	NA	X	X	X	X	X	NA
Exposure to Groundwater [b]	X	X	X	X	---	X	X	X
Vapor Intrusion [c]	X	X	X	---	---	X	X	---
Future Off-site Rural Resident								
Exposure to Groundwater [b]	X	X	X	X	---	X	X	X
Vapor Intrusion [c]	X	---	X	---	---	---	X	---
Result for Systematic Toxicity [b]								
Current On-site Industrial Worker								
Exposure to Soil	---	---	X	---	---	X	X	NA
Future On-site Industrial Worker								
Exposure to Soil	---	---	X	---	---	X	X	NA
Future On-site Excavation Worker								
Exposure to Soil/Soil and Waste	**NA**	NA	X	X	X	X	X	NA
Future On-site Recreational User								
Exposure to Game	NA	NA	---	---	---	---	---	NA
Exposure to Soil	NA	NA	NA	NA	NA	NA	NA	NA
Exposure to Surface Water	**NA**	NA	NA	NA	NA	NA	NA	NA
Future On-site Rural Resident								
Exposure to Soil	NA	NA	X	X	X	X	X	NA
Exposure to Groundwater [b]	X	X	X	X	---	X	X	X
Vapor Intrusion [c]	X	X	X	---	---	X	X	X
Future Off-site Rural Resident								
Exposure to Groundwater [b]	X	---	X	---	---	X	X	---
Vapor Intrusion [c]	---	---	---	---	---	---	---	---

Notes: Scenarios where risk exceeds *de minimis* levels are marked with an X. Scenarios where risk did not exceed *de minimis* levels are marked with a ---. NA indicates that the scenario/land use combination was not assessed.

[a] Consistent with the PGDP Risk Methods Document (DOE 2001), the *de minimis* levels used are a cumulative ELCR of 1×10^{-6} and a total HI of 1.

[b] Systemic toxicity results summarized here for the resident and recreational user are for the child. The off-site POE considered is the property boundary.

[c] Based on results of preliminary deterministic contaminant transport modeling. The POE is the property boundary. X indicates that the location contains a source of unacceptable off-site contamination, and --- indicates that the location is not a source of off-site contamination

F.5.6.3 Contaminants of Concern (Groundwater – Modeled from Soil)

Similarly for groundwater, to determine 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 a) 0.1 for HI and b) 1×10^{-6} for ELCR.

Contaminants with chemical-specific HIs or ELCRs exceeding these benchmarks were deemed COCs. Priority COCs are contaminants whose chemical-specific HI is greater than 1 or whose ELCR is greater than 1×10^{-4} for one or more scenarios. The following presents priority COCs found in groundwater at individual SWMUs.

- SWMU 2–arsenic; manganese; uranium; *cis*-1,2-DCE; and TCE
- SWMU 3–arsenic, manganese, uranium, and ^{99}Tc
- SWMU 4–arsenic; manganese; *cis*-1,2-DCE; TCE; vinyl chloride; and ^{99}Tc
- SWMU 5–arsenic, manganese, and naphthalene
- SWMU 6–none
- SWMU 7–arsenic; 1,1-DCE; *cis*-1,2-DCE; Total PCBs; TCE; vinyl chloride
- SWMU 30–arsenic; 1,1-DCE; TCE
- SWMU 145–antimony, arsenic, manganese, Total PCBs, and ^{99}Tc

"Priority COCs" are identified in this section as an aid to risk managers during decision making. Table F.64 summarizes the COCs for both soil and groundwater.

F.5.6.4 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 a) 0.1 for HI and b) 1×10^{-6} for ELCR. For soil, the quantitative risk and hazard results from the previous risk assessments for SWMUs 2, 3, 4, 5, 6, 7, and 30 (DOE 1994, DOE 1998a; DOE 2000) were used in the comparison. Exposure routes with HIs and ELCRs exceeding these benchmarks are considered POCs. These POCs are shown by SWMU in Table F.73. Each of the pathways included in the BHHRA is a POC for at least one SWMU.

F.5.6.5 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 and RGA groundwater are media of concern for all eight SWMUs. Table F.74 provides specific information concerning how each media contributes to risks and hazards for BGOU.

F.5.6.6 Summary of Risk Characterization

Tables F.65 to F.72 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 F.64. COCs and Exposure Medium for Residential Receptor at Each SWMU[a]

COC[b]	SWMU 2[c]		SWMU 3[c]		SWMU 4[d]		SWMU 5[d]		SWMU 6[d]		SWMU 7[e]		SWMU 30[e]		SWMU 145[f]	
	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR
Inorganic Compounds																
Aluminum							S				S		S			
Antimony											S		S		GW	
Arsenic	GW	GW	GW	GW	GW	GW	S,GW	S,GW			S,GW	S,GW	S,GW	S,GW	GW	GW
Barium					S						S		S			
Beryllium					S	S	S	S	S	S	S	S	S	S		
Cadmium					S						S		S			
Chromium					S		S		S		S		S			
Cobalt											S					
Copper											S		S			
Iron					S						S		S			
Manganese	GW		GW		GW		GW				S,GW		S,GW		GW	
Mercury													S			
Nickel					S		S		S		S		S			
Selenium													GW			
Uranium	GW		GW								S,GW		S,GW			
Vanadium					S						S		S			
Zinc							S		S		S		S			
Organic Compounds																
1,1-DCE											GW	GW	GW	GW		
cis-1,2-DCE	GW				GW						GW					
Benzo(a)anthracene												S		S		
Benzo(a)pyrene												S		S		
Benzo(b)fluoranthene												S		S		
Benzo(k)fluoranthene												S		S		
Bis(2-ethylhexyl)phthalate														S		
Chrysene														S		
Dibenzo(a,h)anthracene												S		S		
Indeno(1,2,3-cd)pyrene												S		S		
Naphthalene	GW						GW									

Table F.64. COCs and Exposure Medium for Residential Receptor at Each SWMU (Continued)

COC[b]	SWMU 2[c]		SWMU 3[c]		SWMU 4[d]		SWMU 5[d]		SWMU 6[d]		SWMU 7[e]		SWMU 30[e]		SWMU 145[f]									
	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR
Vinyl Chloride							GW	GW									GW	GW						
Total PAHs														S		S								
Aroclor-1254																	S	S	S	S				
Aroclor-1260																		S		S		GW		
Total PCBs											S			S			GW	GW						

Table F.64. COCs and Exposure Medium for Residential Receptor at Each SWMU[a] (Continued)

COC[b]	SWMU 2[c]		SWMU 3[c]		SWMU 4[d]		SWMU 5[d]		SWMU 6[d]		SWMU 7[e]		SWMU 30[e]		SWMU 145[f]	
	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR	Total Hazard Child	Total ELCR
Radionuclides																
[b]																
Neptunium-237												S		S		
Plutonium-239 [b]												S				
Technetium-99		GW		GW		GW		GW				GW		GW		GW
Uranium-234		GW				S						S,GW		S,GW		
Uranium-235												S		S		
Uranium-235/236												S		S		
Uranium-238		GW		S, GW		S						S,GW		S,GW		GW

[a] Only COPCs that exceed a chemical-specific HI of 0.1 or a chemical-specific ELCR of 1×10^{-6} for a scenario with total HI>1 are for the child resident and total ELCR $>1 \times 10^{-6}$ for the resident are listed as COCs.
[b] Plutonium-239/240 included with Plutonium-239.
[c] Soil was not evaluated for residential receptor at SWMUs 2 and 3 (DOE 1994).
[d] From DOE 2000.
[e] From DOE 1998a.
[f] A previous risk assessment was not performed for SWMU 145 and this site is covered by a cap; therefore, this SWMU was not evaluated for soil exposure.
"S" indicates this chemical is a COC for exposure to soil.
"GW" indicates this chemical is a COC for exposure to groundwater.

Table F.65. Summary of Risk Characterization for SWMU 2

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker/intruder at current concentrations (soil) (from WAG 22 RI Addendum[b])	1.2E-05	^{235}U + daughters ^{238}U + daughters	83.8 10.7	External exposure	94.7	.6.8E-03	*No COCs		*No COCs	
Future industrial worker at current concentrations (soil) (from WAG 22 RI Addendum[b])	1.2E-04	Arsenic ^{235}U + daughters ^{238}U + daughters	2.8 83.9 10.7	Ingestion External exposure	4.7 94.7	7.0E-02	*No COCs		*No COCs	
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	1.30E+03	Arsenic Manganese Uranium *cis*-1,2-DCE Naphthalene TCE	0.9 0.1 0.1 46.8 0.0 52.1	Ingestion Dermal Shower inhalation Household inhalation	46.0 11.7 4.8 37.5

Table F.65. Summary of Risk Characterization for SWMU 2 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future adult rural resident at current concentrations (RGA groundwater only)	4.69E-02	Arsenic TCE ^{99}Tc ^{234}U ^{238}U	2.0 98.0 0.0 0.0 0.0	Ingestion Dermal Shower inhalation Household inhalation	19.9 11.0 7.8 61.3	3.79E+02	Arsenic Manganese Uranium *cis*-1,2-DCE Naphthalene TCE	0.9 0.1 0.1 36.8 0.0 62.1	Ingestion Dermal Shower inhalation Household inhalation	45.0 23.9 3.5 27.5
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	1.9292E+02	Arsenic *cis*-1,2-DCE Naphthalene TCE	0.5 48 0.1 52	Ingestion Dermal Shower inhalation Household inhalation	45 12.4 5.4 38
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	6.82E-03	Arsenic TCE	1.1 98.9	Ingestion Dermal Shower inhalation Household inhalation	19.2 11.1 7.9 61.8	5.08E+01	Arsenic *cis*-1,2-DCE Naphthalene TCE	0.5 31.50.1 67.9	Ingestion Dermal Shower inhalation Household inhalation	62 27 1.2 10
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA	9.56E+01	*cis*-1,2-DCE TCE	47.4 52.6	Ingestion Dermal Shower inhalation Household inhalation	45.4 11.8 4.9 38.0
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	3.42E-03	TCE	100	Ingestion Dermal Shower inhalation Household inhalation	18.3 11.2 8.0 62.5	2.79E+01	*cis*-1,2-DCE TCE	37.3 62.7	Ingestion Dermal Shower inhalation Household inhalation	44.4 24.1 3.6 27.9
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	NA	NA	NA	NA	NA	2.25E+01	*cis*-1,2-DCE TCE	79.4 20.5	Ingestion Dermal Shower inhalation Household inhalation	16.2 18.8 7.4 57.7
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	1.28E-03	TCE	100	Ingestion Dermal Shower inhalation Household inhalation	18.3 11.2 8.0 62.5	6.7E+00	*cis*-1,2-DCE TCE	61.2 38.7	Ingestion Dermal Shower inhalation Household inhalation	15.5 37.7 5.3 41.5

Table F.65. Summary of Risk Characterization for SWMU 2 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI

ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern

Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.

. *No COCs = there are no COCs or POCs at this SWMU for this endpoint (may apply to ELCR or HI)

[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.

[b] *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1141&D2, September 1994 (DOE 1994). Attachment 2-1 through 2-6. This risk assessment combined SWMU 2 and 3.

Table F.66. Summary of Risk Characterization for SWMU 3

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker/intruder at current concentrations (soil) (from WAG 22 RI Addendum[b])	1.2E-05	^{235}U + daughters ^{238}U + daughters	83.8 10.7	External exposure	94.7	6.8E-03	*No COCs		*No COCs	NE
Future industrial worker at current concentrations (soil) (from WAG 22 RI Addendum[b])	1.2E-04	Arsenic ^{235}U + daughters ^{238}U + daughters	2.8 83.9 10.7	Ingestion External exposure	4.7 94.7	7.0E-02	*No COCs		*No COCs	NE
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	2.20E+01	Arsenic Manganese Uranium	47.9 16.6 35.5	Ingestion Dermal	99.5 0.5
Future adult rural resident at current concentrations (RGA groundwater only)	1.20E-03	Arsenic ^{99}Tc ^{238}U	72.4 25.3 2.3	Ingestion Dermal	99.8 0.2	6.32E+00	Arsenic Manganese Uranium	47.7 16.9 35.4	Ingestion	99.0
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	3.98E-01	Arsenic	100	Ingestion	97.9
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	1.32E-04	Arsenic ^{99}Tc	24.6 75.4	Ingestion	99.9	1.12E-01	Arsenic	100	Ingestion	99.6
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA		*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	7.46E-05	^{99}Tc	100	Ingestion	100		*No COCs		*No COCs	

Table F.66. Summary of Risk Characterization for SWMU 3 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child rural resident at modeled concentrations (RGA groundwater drawn at Little Bayou Seeps)	NA	NA	NA	NA	NA		*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Little Bayou Seeps)	4.41E-05	^{99}Tc	100.0				*No COCs		*No COCs	
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		Not a POE for groundwater from this SWMU.								
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		Not a POE for groundwater from this SWMU.								

ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern

Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.

*No COCs = there are no COCs or POCs.

[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.

[b] *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1141&D2, September 1994 (DOE 1994). Attachment 2-1 through 2-6. This risk assessment combined SWMU 2 and 3.

Table F.67. Summary of Risk Characterization for SWMU 4

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil) (WAG 3 RI[b])	5.4E-04	Beryllium ^{238}U	97 2	Dermal External exposure	97 2	3.62E+00	 Beryllium Chromium Iron Vanadium Barium	 5 45 24 24 2	Dermal	99
Future industrial worker at current concentrations (soil) (WAG 3 RI[b])	5.4E-04	Beryllium ^{238}U	97 2	Dermal External exposure	97 2	3.62E+00	Beryllium Chromium Iron Vanadium Barium	5 45 24 24 2	Dermal	99
Future child rural resident at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	9.82E+01	Barium Beryllium Cadmium Chromium Iron Nickel Vanadium	2 2 2 24 60 2 9	Ingestion Dermal Ingestion of vegetables	1 21 78
Future adult rural resident at current concentrations (soil) (WAG 3 RI[b])	4.3E-03	Beryllium Total PCB ^{234}U ^{238}U	72 5 6 17	Dermal External exposure Ingestion of vegetables	36 2 61	2.84E+01	Barium Beryllium Cadmium Chromium Iron Nickel Vanadium	2 2 2 22 63 2 8	Dermal Ingestion of vegetables	14 85
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	5.82E+02	Arsenic Manganese *cis*-1,2-DCE TCE Vinyl Chloride	1.0 0.2 6.1 92.5 0.2	Ingestion Dermal Shower inhalation Household inhalation	67.2 20.2 1.4 11.2
Future adult rural resident at current concentrations (RGA groundwater only)	5.41E-02	Arsenic TCE Vinyl chloride ^{99}Tc	0.9 67.7 30.5 0.9	Ingestion Dermal Shower inhalation Household inhalation	15.4 36.7 5.4 42.4	1.98E+02	Arsenic Manganese *cis*-1,2-DCE TCE Vinyl chloride	0.8 0.2 4.1 94.7 0.2	Ingestion Dermal Shower inhalation Household inhalation	56.5 35.6 0.9 7.0
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	2.04E+02	Arsenic *cis*-1,2-DCE TCE Vinyl chloride	0.4 4.6 94.4 0.1	Ingestion Dermal Shower inhalation Household inhalation	67.5 20.6 1.4 10.6

Table F.67. Summary of Risk Characterization for SWMU 4 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	2.03E-02	Arsenic TCE Vinyl chloride ^{99}Tc	0.4 98.0 0.9 0.7	Ingestion Dermal Shower inhalation Household inhalation	13.6 7.2 5.2 74.0	6.97E+01	Arsenic *cis*-1,2-DCE TCE	0.4 3.0 96.6	Ingestion Dermal Shower inhalation Household inhalation	56.5 36.1 0.8 6.6
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA	1.03E+02	*cis*-1,2-DCE TCE Vinyl chloride	4.6 95.3 0.1	Ingestion Dermal Shower inhalation Household inhalation	67.6 20.8 1.3 10.3
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	6.79E-03	TCE Vinyl chloride ^{99}Tc	97.9 1.1 1.0	Ingestion Dermal Shower inhalation Household inhalation	19.8 11.0 7.8 61.3	3.51E+01	*cis*-1,2-DCE TCE	3.1 96.8	Ingestion Dermal Shower inhalation Household inhalation	56.4 36.3 0.8 6.4
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	NA	NA	NA	NA	NA	3.33E+01	*cis*-1,2-DCE TCE	1.7 98.2	Ingestion Dermal Shower inhalation Household inhalation	74.6 22.9 1.4 1.0
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	2.43E-03	TCE Vinyl chloride ^{99}Tc	98.2 0.9 0.9	Ingestion Dermal Shower inhalation Household inhalation	19.6 11.0 7.9 61.5	1.26E+01	*cis*-1,2-DCE TCE	3.0 96.9	Ingestion Dermal Shower inhalation Household inhalation	56.4 36.3 0.8 6.4
Future child recreational user at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	< 1	*No COCs		*No COCs	
Future teen recreational user at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	< 1	*No COCs		*No COCs	
Future adult recreational user at current concentrations (soil) (WAG 3 RI[b])	< 1.0E-06	*No COCs		*No COCs		< 1	*No COCs		*No COCs	

Table F.67. Summary of Risk Characterization for SWMU 4 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future excavation worker at current concentrations (soil and waste) (WAG 3 RI[b])	2.7E-03	Arsenic	1	Ingestion	37	2.61E+00	Aluminum	8	Ingestion	13
		Beryllium	7	Dermal	10		Arsenic	4	Dermal	87
		Total dioxins/furans	4	External exposure	54		Barium	2		
		Total PCB	2				Beryllium	2		
		^{226}Ra	2				Cadmium	1		
		Total uranium	83				Chromium	24		
		^{238}U	1				Iron	24		
							Manganese	14		
							Vanadium	20		

ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern

Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.

*No COCs = There are no COCs or POCs.

[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.

[b] *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, DOE/OR/07-1895&D1*, September 2000 (DOE 2000), Table 1.55. In this table, lead has been excluded as a COC.

Table F.68. Summary of Risk Characterization for SWMU 5

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil) (WAG 3 RI[b])	4.1E-04	Arsenic Beryllium Total PAH	6 49 45	Ingestion Dermal	2 98	< 1	*No COCs		*No COCs	
Future industrial worker at current concentrations (soil) (WAG 3 RI[b])	4.1E-04	Arsenic Beryllium Total PAH	6 49 45	Ingestion Dermal	2 98	< 1	*No COCs		*No COCs	
Future child rural resident at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	4.62E+01	Aluminum Arsenic Beryllium Chromium Nickel Zinc	24 53 1 17 3 1	Ingestion Dermal Ingestion of vegetables	1 12 87
Future adult rural resident at current concentrations (soil) (WAG 3 RI[b])	>1.0E-02*	Arsenic Beryllium Total PAH Total PCB	21 9 68 2	Dermal Ingestion of vegetables	9 90	1.39E+01	Aluminum Arsenic Beryllium Chromium Nickel Zinc	24 55 1 15 3 1	Dermal Ingestion of vegetables	8 92
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	7.91E+00	Arsenic Manganese Naphthalene	37.5 27.2 35.4	Ingestion Shower inhalation Household inhalation	64.3 4.0 31.0
Future adult rural resident at current concentrations (RGA groundwater only)	2.52E-04	Arsenic ^{99}Tc	97.2 2.8	Ingestion	99.7	2.08E+00	Arsenic Manganese Naphthalene	40.8 30.2 29.0	Ingestion Household inhalation	69.8 25.3
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	1.25E+00	Arsenic Manganese Naphthalene	45.6 14.8 39.6	Ingestion Household inhalation	60.4 34.7
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	4.99E-05	Arsenic ^{99}Tc	94.5 5.5	Ingestion	99.7	3.24E-01	Arsenic Naphthalene	50.3 33.0	Ingestion	66.5

Table F.68. Summary of Risk Characterization for SWMU 5 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA	2.28E-01	Naphthalene	82.2	Household inhalation	72.0
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	4.81E-06	Arsenic ^{99}Tc	69.9 30.1	Ingestion	99.8	<0.1	*No COCs		*No COCs	
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	NA	NA	NA	NA	NA		*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		*No COCs		*No COCs			*No COCs		*No COCs	
Future child recreational user at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	< 1	*No COCs		*No COCs	
Future teen recreational user at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	< 1	*No COCs		*No COCs	
Future adult recreational user at current concentrations (soil) (WAG 3 RI[b])	1.0E-05	Arsenic Total PAH Total PCB	2 96 2	Ingestion of venison Ingestion of rabbit Ingestion of quail	16 63 21	< 1	*No COCs		*No COCs	
Future excavation worker at current concentrations (soil and waste) (WAG 3 RI[b])	2.9E-04	Arsenic Beryllium Total PAH Total PCB	8 62 28 1	Ingestion Dermal	13 87	2.16E+00	Aluminum Arsenic Barium Beryllium Chromium Iron Manganese	9 7 2 3 18 38 22	Ingestion Dermal	18 82

ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern

Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.

*No COCs = There are no COCs or POCs.

* = The ELCR is approximate because the linearized multistage model returns imprecise values at risks > 1.0E-02.

[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.

[b] *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, DOE/OR/07-1895&D1*, September 2000 (DOE 2000), Table 1.56. In this table, lead has been excluded as a COC.

Table F.69. Summary of Risk Characterization for SWMU 6

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil) (WAG 3 RI[b])	2.4E-04	Beryllium Total PAH	90 10	Dermal	99	< 1	*No COCs		*No COCs	
Future industrial worker at current concentrations (soil) (WAG 3 RI[b])	2.4E-04	Beryllium Total PAH	90 10	Dermal	99	< 1	*No COCs		*No COCs	
Future child rural resident at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	9.38E+00	Beryllium Chromium Nickel Zinc	8 72 15 5	Dermal Ingestion of vegetables	34 65
Future adult rural resident at current concentrations (soil) (WAG 3 RI[b])	2.4E-03	Beryllium Total PAH	54 46	Dermal Ingestion of vegetables	30 69	2.57E+00	Beryllium Chromium Nickel Zinc	7 70 17 6	Dermal Ingestion of vegetables	24 75
Future child rural resident at current concentrations (RGA groundwater only)		*No COCs		*No COCs			*No COCs		*No COCs	
Future adult rural resident at current concentrations (RGA groundwater only)		*No COCs		*No COCs			*No COCs		*No COCs	
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)		*No COCs		*No COCs			*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)		*No COCs		*No COCs			*No COCs		*No COCs	
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)		*No COCs		*No COCs			*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)		*No COCs		*No COCs			*No COCs		*No COCs	
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		*No COCs		*No COCs			*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		*No COCs		*No COCs			*No COCs		*No COCs	

Table F.69. Summary of Risk Characterization for SWMU 6 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child recreational user at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	< 1	*No COCs		*No COCs	
Future teen recreational user at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	< 1	*No COCs		*No COCs	
Future adult recreational user at current concentrations (soil) (WAG 3 RI[b])	< 1.0E-06	*No COCs		*No COCs		< 1	*No COCs		*No COCs	
Future excavation worker at current concentrations (soil and waste) WAG 3 RI[b])	2.3E-04	Beryllium Total PAH	90 9	Ingestion Dermal	5 95	2.44E+00	Aluminum Barium Beryllium Chromium Iron Manganese Vanadium	8 2 3 15 32 15 26	Ingestion Dermal	12 88

ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern
Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.
– = There are no COCs or POCs.
[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.
[b] *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, DOE/OR/07-1895&D1*, September 2000 (DOE 2000), Table 1.57. In this table, lead has been excluded as a COC.

Table F.70. Summary of Risk Characterization for SWMU 7

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil) (from WAG 22 RI[b])	3.8E-03	Arsenic Beryllium Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{234}U ^{235}U $^{235/236}U$ ^{238}U	0.6 97.6 <0.1 0.3 <0.1 0.4 0.1 <0.1 <0.1 0.2 0.3 2.1	Ingestion Dermal External exposure	0.5 97.4 2.5	5.0E+00	Aluminum Antimony Arsenic Beryllium Chromium Iron Manganese Uranium Vanadium	4.1 4.4 2.6 9.6 13.6 20.6 10.7 13.7 17.7	Ingestion Dermal	3.6 96.4
Future industrial worker at current concentrations (soil) (from WAG 22 RI[b])	3.9E-03	Arsenic Beryllium Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{234}U ^{235}U $^{235/236}U$ ^{238}U	0.6 96.0 <0.1 0.3 <0.1 0.4 0.1 <0.1 <0.1 0.2 0.3 2.1	Ingestion Dermal External exposure	0.5 97.1 2.4	5.0E+00	Aluminum Antimony Arsenic Beryllium Chromium Iron Manganese Uranium Vanadium	4.1 4.4 2.6 9.6 13.6 20.6 10.7 13.7 17.7	Ingestion Dermal	3.6 96.4
Future child rural resident at current concentrations (soil) (from WAG 22 RI[b])	NA	NA	NA	NA	NA	3.7E+02	Aluminum Antimony Arsenic Barium Beryllium Cadmium Chromium Cobalt Copper Iron Manganese Nickel Uranium Vanadium Zinc Aroclor-1254	2.7 0.9 6.2 0.3 1.3 0.8 2.7 0.1 0.3 19.7 1.9 0.4 58.4 2.4 0.2 1.7	Ingestion Dermal Ingestion of vegetables from soil	1.4 7.7 90.9 9

Table F.70. Summary of Risk Characterization for SWMU 7 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future adult rural resident at current concentrations (soil) (from WAG 22 RI[b])	3.4E-02	Arsenic Beryllium Aroclor-1254 Aroclor-1260 Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{239}Pu ^{234}U ^{235}U $^{235/236}$U ^{238}U	7.3 65.4 0.2 0.4 0.2 1.7 0.2 <0.1 1.9 0.3 0.2 0.4 3.3 0.3 0.5 17.6	Ingestion Dermal External exposure Ingestion of vegetables from soil	0.5 33.0 1.9 64.6	1.1E+02	Aluminum Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Iron Manganese Nickel Uranium Vanadium Zinc Aroclor-1254	2.7 0.8 6.5 0.3 1.1 0.8 2.3 0.3 19.8 1.6 0.4 59.5 2.0 0.2 1.7	Ingestion Dermal Ingestion of vegetables from soil	0.5 5.0 94.6
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	1.89E+01	Arsenic Manganese Uranium 1,1-DCE *cis*-1,2-DCE Total PCBs TCE Vinyl chloride	30.2 3.7 2.9 4.5 6.6 22.3 26.4 3.4	Ingestion Dermal contact Inhalation while showering Inhalation household use	60.9 21.0 2.0 16.0
Future adult rural resident at current concentrations (RGA groundwater only)	3.13E-03	Arsenic 1,1-DCE Total PCBs TCE Vinyl chloride ^{99}Tc ^{234}U ^{238}U	15.1 66.4 0.2 4.1 11.9 1.6 0.4 0.4	Ingestion Dermal contact Inhalation while showering Inhalation during household use	61.2 3.7 4.9 30.3	6.39E+00	Arsenic Manganese Uranium 1,1-DCE *cis*-1,2-DCE Total PCBs TCE Vinyl chloride	25.5 3.2 2.5 3.1 4.5 31.4 27.1 2.7	Ingestion Dermal contact Inhalation household use	51.4 37.2 10.1

Table F.70. Summary of Risk Characterization for SWMU 7 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	1.45E+01	Arsenic Manganese Uranium 1,1-DCE *cis*-1,2-DCE Total PCBs TCE Vinyl chloride	27.9 3.6 2.8 5.4 7.9 17.2 31.2 4.1	Ingestion Dermal contact Inhalation while showering Inhalation household use	62.3 18.7 2.2 16.9
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	2.98E-03	Arsenic 1,1-DCE Total PCBs TCE Vinyl chloride ^{99}Tc ^{234}U ^{238}U	11.2 63.9 0.2 10.3 12.3 1.5 0.3 0.3	Ingestion Dermal contact Inhalation while showering Inhalation during household use	55.4 3.4 4.7 36.5	4.78E+00	Arsenic Manganese Uranium 1,1-DCE *cis*-1,2-DCE Total PCBs TCE Vinyl chloride	24.2 3.1 2.4 3.8 5.5 24.8 32.9 3.3	Ingestion of groundwater Dermal contact Inhalation household use	53.8 33.8 11.0
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA	1.97E+00	Arsenic 1,1-DCE *cis*-1,2-DCE Total PCBs TCE	38.1 5.3 8.4 12.4 32.9	Ingestion Dermal contact Inhalation household use	66.3 15.8 15.9
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	4.11E-04	Arsenic 1,1-DCE TCE Vinyl chloride ^{99}Tc	15.1 61.8 10.7 8.7 3.6	Ingestion Dermal contact Inhalation while showering Inhalation during household use	56.7 3.2 4.5 35.5	6.36E-01	Arsenic Total PCBs TCE	33.9 18.4 35.5	Ingestion Dermal contact	58.8 29.3
Future child rural resident at modeled concentrations (RGA groundwater drawn at Little Bayou Seeps)	NA	NA	NA	NA	NA	3.373E-01	TCE	61.0	Ingestion Inhalation household use	52.5 30.0
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Little Bayou Seeps)	1.28E-04	1,1-DCE TCE Vinyl chloride ^{99}Tc	72.6 12.3 9.5 5.7	Ingestion Dermal contact Inhalation while showering Inhalation during household use	49.6 3.6 5.3 41.4	1.15E-01	*No COCs		*No COCs	

Table F.70. Summary of Risk Characterization for SWMU 7 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		Not a POE for groundwater from this SWMU.								
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		Not a POE for groundwater from this SWMU.								
Future child recreational user at current concentrations (from WAG 22 RI[b])	NA	NA	NA	NA	NA	7.3E-02	*No COCs		*No COCs	
Future teen recreational user at current concentrations (from WAG 22 RI[b])	NA	NA	NA	NA	NA	6.4E-02	*No COCs		*No COCs	
Future adult recreational user at current concentrations (from WAG 22 RI[b])	1.1E-05	Aroclor-1260 Benzo(a)pyrene Dibenzo(a,h)anthracene ^{238}U	18.6 9.5 42.5 15.7	Ingestion of deer Ingestion of rabbit Ingestion of quail	10.0 70.9 21.8	7.5E-02	*No COCs		*No COCs	
Future excavation worker at current concentrations (soil) (from WAG 22 RI[b])	1.6E-03	Arsenic Beryllium Benzo(a)pyrene Dibenzo(a,h)anthracene ^{237}Np ^{239}Pu ^{234}U ^{235}U $^{235/236}U$ ^{238}U	1.8 42.2 0.1 1.7 0.4 0.5 3.4 9.1 0.4 41.3	Ingestion Dermal External exposure	25.6 43.8 32.5	5.4E+00	Aluminum Antimony Arsenic Chromium Copper Iron Manganese Nickel Uranium Vanadium	5.0 11.3 3.4 17.6 2.9 21.3 11.0 3.9 7.5 10.9	Ingestion Dermal	18.4 81.5

ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern

Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.

*No COCs = There are no COCs or POCs.

[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.

[b] *Remedial Investigation Report for Solid Waste Management Units 7 and 30 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1604/V1&D2, January 1998 (DOE 1998b), Tables 1.59 through 1.68, excluding lead as a COC.

Table F.71. Summary of Risk Characterization for SWMU 30

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil) (from WAG 22 RI[b])	3.7E-03	Arsenic Beryllium Aroclor-1260 Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{234}U ^{235}U $^{235/236}U$ ^{238}U	0.5 97.5 0.1 0.1 0.8 0.1 0.3 0.1 <0.1 <0.1 0.2 0.3 1.4	Ingestion Dermal External exposure	0.5 97.3 1.7	4.4E+00	Aluminum Antimony Arsenic Beryllium Cadmium Chromium Iron Manganese Uranium Vanadium	5.1 3.7 2.7 10.8 3.5 13.5 19.8 11.3 9.0 17.6	Ingestion Dermal	2.9 97.1
Future industrial worker at current concentrations (soil) (from WAG 22 RI[b])	3.8E-03	Arsenic Beryllium Aroclor-1260 Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{34}U ^{35}U $^{235/236}U$ ^{238}U	0.5 96.2 0.1 0.1 0.8 0.1 0.3 0.1 <0.1 <0.1 0.2 0.3 1.4	Ingestion Dermal External exposure	0.5 97.8 1.7	4.4E+00	Aluminum Antimony Arsenic Beryllium Cadmium Chromium Iron Manganese Uranium Vanadium	5.1 3.7 2.7 10.8 3.5 13.5 19.8 11.3 9.0 17.6	Ingestion Dermal	2.9 97.1
Future child rural resident at current concentrations (soil) (from WAG 22 RI[b])	NA	NA	NA	NA	NA	2.6E+02	Aluminum Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Iron Manganese Mercury Nickel Uranium Vanadium Zinc Aroclor-1254	4.1 0.9 7.5 0.6 1.8 2.2 3.2 0.6 22.6 2.5 0.7 0.8 46.8 3.0 0.2 2.6	Ingestion Dermal Ingestion of vegetables from soil	1.3 9.4 89.3

Table F.71. Summary of Risk Characterization for SWMU 30 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future adult rural resident at current concentrations (soil) (from WAG 22 RI[b])	3.2E-02	Arsenic Beryllium Aroclor-1254 Aroclor-1260 Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene bis(2-ethylhexyl)phthalate Chrysene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{234}U ^{235}U $^{235/236}$U ^{238}U	6.8 66.7 0.2 1.8 0.4 4.4 0.5 <0.1 <0.1 <0.1 1.7 0.4 0.2 4.5 0.3 0.6 11.5	Ingestion Dermal External exposure Ingestion of vegetables from soil	0.5 35.4 1.3 62.8	7.9E+01	Aluminum Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Iron Manganese Mercury Nickel Uranium Vanadium Zinc Aroclor-1254	4.1 0.8 7.9 0.6 1.5 2.2 2.9 0.6 22.8 2.1 0.7 0.9 47.5 2.4 0.2 2.7	Ingestion Dermal Ingestion of vegetables from soil	0.5 6.1 93.4
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	3.34E+02	Arsenic Manganese Selenium Uranium 1,1-DCE TCE	1.7 0.2 0.1 0.4 0.2 97.4	Ingestion Dermal contact Inhalation while showering Inhalation household use	70.6 21.3 0.9 7.2
Future adult rural resident at current concentrations (RGA groundwater only)	2.40E-02	Arsenic 1,1-DCE TCE ^{99}Tc ^{234}U ^{238}U	2.0 5.8 92.1 0.1 0.0 0.0	Ingestion Dermal contact Inhalation while showering Inhalation household use	21.6 10.5 7.7 60.2	1.17E+02	Arsenic Manganese Uranium 1,1-DCE TCE	1.4 0.2 0.3 1.3 96.7	Ingestion Dermal contact Inhalation while showering Inhalation household use	57.9 36.5 0.9 4.7
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	3.16E+02	Arsenic Manganese Selenium Uranium 1,1-DCE TCE	1.2 0.2 0.1 0.2 0.2 98.2	Ingestion of groundwater Dermal contact Inhalation while showering Inhalation household use	70.4 21.4 0.9 7.3
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	2.28E-02	Arsenic 1,1-DCE TCE ^{99}Tc ^{234}U ^{238}U	1.4 6.0 92.5 0.1 0.0 0.0	Ingestion Dermal contact Inhalation while showering Inhalation household use	21.1 10.6 7.8 60 .6	1.10E+02	Arsenic Manganese Uranium 1,1-DCE TCE	1.0 0.1 0.2 0.1 98.5	Ingestion Dermal contact Inhalation while showering Inhalation household use	58.0 37.0 0.6 4.5

Table F.71. Summary of Risk Characterization for SWMU 30 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA	2.76E+01	Arsenic TCE	2.7 97.1	Ingestion Dermal contact Inhalation while showering Inhalation household use	70.7 21.2 0.9 7.2
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	1.99E-03	Arsenic 1,1-DCE TCE Technetium-99	3.1 5.1 91.6 0.2	Ingestion Dermal contact Inhalation while showering Inhalation household use	22.3 10.4 7.6 59.7	9.56E+00	Arsenic TCE	2.2 97.6	Ingestion Dermal contact Inhalation household use	58.4 36.6 4.4
Future child rural resident at modeled concentrations (RGA groundwater drawn at Little Bayou Seeps)	NA	NA	NA	NA	NA	8.97E+00	TCE	99.8	Ingestion Dermal contact Inhalation household use	69.9 21.8 7.4
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Little Bayou Seeps)	6.41E-04	1,1-DCE TCE ^{99}Tc	4.8 95.0 0.2	Ingestion Dermal contact Inhalation while showering Inhalation household use	19.8 10.8 7.9 61.6	3.12E+00	TCE	99.9	Ingestion Dermal contact Inhalation household use	57.4 37.5 4.5
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		Not a POE for groundwater from this SWMU								
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		Not a POE for groundwater from this SWMU								
Future child recreational user at current concentrations (from WAG 22 RI[b])	NA	NA	NA	NA	NA	4.2E-02	*No COCs		*No COCs	
Future teen recreational user at current concentrations (from WAG 22 RI[b])	NA	NA	NA	NA	NA	3.8E-02	*No COCs		*No COCs	

Table F.71. Summary of Risk Characterization for SWMU 30 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future adult recreational user at current concentrations (from WAG 22 RI[b])	1.5E-05	Aroclor-1260 Benzo(a)pyrene Dibenzo(a,h)anthracene	48.2 12.9 20.8	Ingestion of deer Ingestion of rabbit Ingestion of quail	8.7 80.0 11.3	4.3E-02	*No COCs		*No COCs	
Future excavation worker at current concentrations (soil) (from WAG 22 RI[b])	1.2E-03	Arsenic Beryllium Aroclor-1248 Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{239}Pu ^{234}U ^{235}U $^{235/236}U$ ^{238}U	1.9 93.7 0.1 0.1 0.8 0.1 0.4 0.1 0.3 0.2 0.8 0.1 0.8 0.6	Ingestion Dermal External exposure	6.3 91.7 3.3	4.5E+00	Aluminum Antimony Arsenic Beryllium Cadmium Chromium Copper Iron Manganese Uranium Vanadium	4.6 6.3 3.3 3.8 3.0 10.2 7.6 19.8 14.3 12.2 12.7	Ingestion Dermal	26.4 73.5

ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern

Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.

[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.

[b] *Remedial Investigation Report for Solid Waste Management Units 7 and 30 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1604/V1&D2, January 1998 (DOE 1998a), Tables 1.59 through 1.68, excluding lead as a COC.

Table F.72. Summary of Risk Characterization for SWMU 145

Receptor	Total ELCRa	COCs	% Total ELCR	POCs	% Total ELCR	Total HIa	COCs	% Total HI	POCs	% Total HI
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	4.17E+01	Antimony Arsenic Manganese	48.0 47.7 4.3	Ingestion Dermal contact	97.8 2.2
Future adult rural resident at current concentrations (RGA groundwater only)	3.27E-02	Arsenic ^{99}Tc Total PCBs	5.1% 1.7% 93.2%	Ingestion Dermal contact	99.8 0.2	1.22E+01	Antimony Arsenic Manganese	49.046. 7 4.3	Ingestion Dermal contact	6.9 93.1
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA	5.16E-01	Arsenic	99.9	Ingestion	99.8
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	1.44E-04	Arsenic ^{99}Tc	29.7 70.3	Ingestion	99.9	1.48E-01	Arsenic	99.9	Ingestion	99.6
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	NA	NA	NA	NA	NA		*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	5.29E-05	^{99}Tc	100.0	Ingestion	100		*No COCs		*No COCs	
Future child recreational user at current concentrations (soil)	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

Table F.72. Summary of Risk Characterization for SWMU 145 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future teen recreational user at current concentrations (soil)	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Future adult recreational user at current concentrations (soil)	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Future excavation worker at current concentrations	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern
Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.
NE = not evaluated: land use scenario was not assessed because surface soil was not assessed for this SWMU.
[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.

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F.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: those associated with data, exposure assessment, toxicity assessment, and risk characterization. For this BRA, only groundwater was evaluated, and the evaluation used maximum concentrations modeled at the SWMU unit over a 1,000 year time frame. Some of the uncertainties, therefore, involve the screening of soil analytes to be modeled to groundwater and the model used. These uncertainties are discussed in Section 5 and Appendix E. Other uncertainties arise from the use of the results of previously conducted BRAs for soil. Those uncertainties are discussed here, as are uncertainties related to the baseline risk calculations done for groundwater.

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.

F.6.1 UNCERTAINTIES ASSOCIATED WITH DATA AND DATA EVALUATION

F.6.1.1 Determination of EPCs—Future Conditions

One uncertainty is the potential risk that may develop as COPCs in media at the BGOU sources 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 each SWMU to POEs for groundwater exposure away from the source area. (See Appendix E.) While the modeling estimated contaminant transport though groundwater based on contaminant concentrations in the surrounding soil, uncertainty still exists in the POE at which exposure may occur in the future and the contaminant mass that is present in the source areas contributing to the future groundwater concentrations of contaminants. This is particularly true for wastes that originally were containerized. For these wastes, the impact on estimation of future contaminant concentrations in soil depends on whether the wastes already have been released from the containers (in which case, the surrounding soil concentrations may reflect the future contaminant mass) or whether the material may escape the containers in the future (which could result in an increase in the source term/contaminant mass). These uncertainties are discussed in Appendix E. 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. The potential effect of the status of the containerized wastes could have a significant effect on the risk estimates if drum failure has not yet occurred.

F.6.1.2 Determination of EPCs—Data Collected after Previous Risk Assessments

For most SWMUs, no new surface soil samples have been collected and analyzed after the previous BHHRAs were completed. At SWMUs 3 and 7, however, additional surface soil samples have been collected. Attachment F1 contains a summary of maximum detected concentrations and a comparison to the NALs from DOE (2001) for these new samples.

At SWMU 7, for all metals and most radionuclides, the maximum detected concentration associated with the new samples is well below the maximum detected concentration used in the previous risk assessment for SWMU 7 and, therefore, would not alter the results of that assessment. The maximum detected concentration of total PCBs (14.8 mg/L) in the new surface samples exceeds the value used in the risk assessment, but PCBs already were retained as a COC for SWMU 7. Uranium -234, uranium-235, and uranium-236 also were detected at higher maximum concentrations in the new surface soil samples at SWMU 7. These radionuclides already were retained as COCs for SWMU 7; the new data therefore do not substantially impact the results of the assessment already conducted and summarized in this appendix.

At SWMU 3, the previous risk assessment included only the industrial worker. The comparison of maximum detected concentrations to NALs in Attachment F1 includes both the industrial worker and the resident child. For the industrial worker, four metals (arsenic, antimony, iron, and uranium metal), TCE, and three radionuclides (cesium-137, thorium-228, and uranium-238) all exceeded the worker NAL in the new samples. Arsenic and uranium-238 already were COCs for the industrial worker at SWMU 3, but the other analytes exceeding the industrial worker NAL would increase the estimated risk and hazard at this SWMU and should be considered in future actions regarding surface soil.

The analyses conducted in this risk assessment for potential migration of soil contaminants to groundwater used the all soil data collected for surface and subsurface soil, including the data collected after approval of the work plan. Those analyses, therefore, included the new sample results collected after the previous BRAs discussed above for SWMUs 3 and 7.

F.6.2 UNCERTAINTIES ASSOCIATED WITH EXPOSURE ASSESSMENT

Uncertainties associated with the exposure assessment are from three sources. These are uncertainties in biota fate and transport modeling, in use of the RME scenario, and in the development of the CSM and selection of pathways. Each of these uncertainties is discussed in the following material.

F.6.2.1 Uncertainties in Use of RME Scenarios

For each groundwater exposure pathway modeled, assumptions were made about the number of times a year an activity could occur, routes of exposure, and rate of intake of contaminated media. Because site-specific data were not available for many parameters, defaults from the Risk Methods Document were used. Because most of these defaults are conservative to prevent the underestimation of risk estimates, the risk estimates tend to be conservative and may overestimate risk.

F.6.2.2 Uncertainties Related to Development of the Conceptual Site Model

Generally, the level of uncertainty in the development of the CSM is small.

Exposure pathways for some land use scenarios is expected to be small. All pathways that could contribute significantly to exposures to workers, residents, and recreational users at these SWMUs were included in the previous BRAs for direct soil exposure and in the current BRA for residential exposure to

groundwater, including a separate evaluation of vapor intrusion from groundwater into residential buildings. Exposure pathways related to fishing at ponds filled using potentially contaminated groundwater were not evaluated in this or previous BRAs.

F.6.3 UNCERTAINTIES ASSOCIATED WITH TOXICITY ASSESSMENT

Uncertainties related to the toxicity assessment are from the following three sources: uncertainty because of lack of toxicity values for some COPCs, uncertainty in the calculation of toxicity values by EPA, and uncertainty in the calculation of absorbed dose toxicity values from administered dose toxicity values. Each of these is discussed in the following paragraphs.

F.6.3.1 Uncertainties Because of Lack of Toxicity Values for Some Chemicals

Because virtually all COPCs had a toxicity value for either HI or ELCR, the only uncertainty to consider here is the use of provisional or withdrawn values in the BHHRA. The uncertainty from the use of provisional or withdrawn values is important to the results of the BHHRA. Some COPCs did not have approved toxicity values, so a provisional or withdrawn value was used. The most notable of these COPCs was TCE, which was evaluated using the current KDEP oral slope factor of 0.322 $(mg/kg \times day)^{-1}$. This factor is similar to the EPA provisional oral slope factor of 0.4 $(mg/kg \times day)^{-1}$, but both these values are very different from the values for TCE from the 2001 Risk Methods Document that were used in previous assessments. If the residential ELCR for TCE in groundwater at SWMU 2 is calculated with the previously used toxicity values, the ELCR would be 1.03E-03 instead of the 4.6E-02 ELCR derived with the KDEP value. The risk estimated using the new toxicity values is 45 times the risk calculated using the old toxicity factors and indicates the magnitude of the uncertainty associated with the choice of slope factor for this chemical.

F.6.3.2 Exclusion of Lead from Soil Risks

The results of the previous BHHRAs reported here are the risk and hazard calculations done without including lead as one of the COPCs. In the previous assessments, lead had exceedingly high HIs and was the overwhelming risk driver. This finding may be attributed to the use of a very conservative (1.0E-07 mg/kg-day) RfD value provided by the Kentucky Department for Environmental Protection (KDEP). That RfD is no longer in use by KDEP. The current EPA screening levels for lead in soil for residential use is 400 mg/kg. As shown in the screening tables (Tables E3.1 through E3.8) show the maximum detected concentration in lead detected in soil at SWMUs 2, 3, 4, 7, 30, and 145. These maximum values are all less than 100 mg/kg. The maximum detected concentrations of lead in soil at SWMUs 5 and 6 both were at or under 200 mg/kg. These maximum detected values all are less than half the EPA screening level for residential soil, indicating that lead does not need to be considered as a COC at any of the BGOU SWMUs based on comparison with the EPA screening value.

F.6.3.3 Uncertainties in Deriving Toxicity Values

Standard EPA RfDs and slope factors were used to estimate potential noncarcinogenic and carcinogenic health effects from exposure to chemicals. Considerable uncertainty is associated with the method applied to derive slope factors and RfDs. The EPA has working groups that review all relevant human and animal studies for each compound and select the studies pertinent to the derivation of the specific RfD and slope factor. 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 risk assessments. The effect of uncertainties in calculation of chemical toxicity values is moderate.

Unlike the uncertainty associated with chemical toxicity values, the uncertainty associated with radionuclide toxicity values is small. The dose-response relationship between cancer and ionizing radiation has been evaluated in many reports, some describing exposed human populations, and is well established.

RfDs and slope factors for some constituents used in the soil BRAs have been updated since the original soil risk assessment was performed. The adjusted values could impact the cancer risk and HIs for SWMUs whose COCs have new values. COCs impacted significantly by updated toxicity factors include these:

- *Beryllium-RfD*. The current oral RfD of 2.00E-03 mg/kg x day and inhalation RfD of 5.71E-06 mg/kg x day are less than the old oral RfD of 5.00E-03 mg/kg x day and inhalation RfD of 5.71E-03 mg/kg x day and would increase the HI for beryllium, especially through the inhalation route of exposure.

- *Beryllium-cancer slope factor*. At the time the WAG 22 RI and the WAG 3 RI were developed, beryllium was still evaluated as a carcinogen. The cancer slope factor for beryllium has been withdrawn from IRIS, and there has been an agreement not to use this withdrawn value for risk assessments at PGDP. At several SWMUs, beryllium was a significant contributor to the total cancer risk from soil exposure, generally beryllium accounted for greater than 90% of the risk to the industrial worker and greater than 65% of the risk to the resident. When beryllium is removed from consideration as a carcinogen, the total ELCR becomes much lower at those SWMUs for which it is a COC:

  — SWMU 4: 1.6E-05 for future industrial worker and 1.2E-03 for the resident

  — SWMU 5: 2.1E-04 for future industrial worker; no significant change for the resident value

  — SWMU 6: 2.4E-05 for future industrial worker and 1.1E-03 for the resident

  — SWMU 7: 1.6E-04 for future industrial worker and 1.2E-02 for the resident

  — SWMU 30: 1.4E-04 for future industrial worker and 1.1E-02 for the resident

For SWMUs 4 and 6, removal of the contribution of beryllium to the ELCR reduces the total ELCR to within the EPA risk range for the industrial worker scenario.

- *Iron*. The current oral RfD of 7.00E-01 mg/kg x day is higher than the old oral RfD of 3.00E-01, which would result in a decreased hazard index.

- *Total Uranium*. The current oral RfD of 6.00E-04 mg/kg x day is less than the old oral RfD of 3.00E-03 mg/kg x day and would increase the HI.

The remainder of the COCs with updated toxicity factors changed marginally. For example, the oral RfD for copper changed slightly from 3.70E-02 mg/kg x day to 4.00E-02 mg/kg x day. The inhalation slope factor for nickel increased slightly from 8.40E-01 $(mg/kg \times day)^{-1}$ to 9.10E-01 $(mg/kg \times day)^{-1}$. The majority of the toxicity value changes would have minimal impact on the His or cancer risk. The uncertainty therefore is considered small for COCs with marginal changes to toxicity values.

Those COCs with significant toxicity value changes would not substantially impact the soil risk assessment. To illustrate, the SWMU 5 excavation worker soil exposure scenario had the lowest total HI for all soil exposure scenarios of 2.16E+00. Beryllium accounted for 3% of the HI and iron accounted for 38%. Although the change in RfDs for beryllium and iron would alter the hazard slightly, the total HI still would be greater than the 0.1. This is also true for total uranium at SWMU 30. Total uranium contributes 9% of the total hazard for the industrial worker soil exposure scenario. With the total HI at 4.40E+00 using the older toxicity value, changing the RfD would not significantly impact the final results of the risk assessment. The effect of changed toxicity values is considered low.

F.6.3.4 Uncertainties Because of Calculation of Absorbed Dose Toxicity Values from Administered Dose Toxicity Values

Uncertainty exists in the validity of the calculations used to convert an administered dose toxicity value to an absorbed dose. Of greatest importance is the lack of consideration of point-of-contact effects in this calculation. For example, some organic analytes can cause a toxic or cancer response in skin. This effect is not considered in the calculation of absorbed dose toxicity values from administered dose toxicity values using EPA protocols. Similarly, the administered dose response for many chemicals relies on the delivery of a high concentration of contaminants to the liver via the portal system after ingestion; this effect is not seen if a contaminant is absorbed through the skin because of the larger distribution space for the contaminant absorbed through the skin. However, even with these uncertainties, the effect of the uncertainty in calculation of absorbed dose toxicity values from administered dose toxicity values upon the risk estimates is estimated to be small because the overall contribution of dermal exposure to total risk and hazard is much smaller due to the use of the new, lower dermal absorption factors.

F.6.4 UNCERTAINTIES ASSOCIATED WITH RISK CHARACTERIZATION

Three uncertainties are related to risk characterization. The first is the method used to combine HQs over pathways and combine pathway HIs to calculate total HI. This method also is used to combine chemical- and pathway-specific ELCRs to derive total ELCRs. The second is the uncertainty added to the assessment by combining risks from chemicals and radionuclides. These uncertainties are discussed in the following subsections.

F.6.4.1 Combining Chemical-specific Risk Values and Pathway Risk Values

The primary uncertainty in risk characterization is the method used to combine HQs and chemical-specific ELCRs over pathways and combine pathway HIs and ELCRs to calculate total HI and ELCR. The uncertainties in this method are discussed in the following text.

The method used to calculate pathway HIs and ELCRs in the BHHRA followed EPA protocols (Risk Methods Document). This guidance calls for the simple summation of HQs and chemical-specific ELCRs to calculate pathway HIs and ELCRs, respectively. This method assumes that all effects between chemicals are additive. EPA makes this assumption because information concerning the effect of chemical mixtures is lacking. Specific limitations of this approach for systemic toxicity effects (HI) have been reported by EPA.

Little is known about the effects of chemical mixtures; although additivity is assumed, the interaction of multiple chemicals possibly could be synergistic or antagonistic.

The RfDs and reference concentrations do not have equal accuracy or precision and are not based on the same severity of effects.

Dose additivity is most properly applied to compounds that induce the same effect by the same mechanism of action. While the approach recommended by EPA is a useful screening-level approach, the potential for at least noncarcinogenic effects to occur can be overestimated for chemicals that act by different mechanisms and on different target organs.

The effect of this uncertainty on the estimate of HI depends on how many contaminants drive HI and if the contaminants have different endpoints. In this BHHRA, several contaminants do affect HI, and these contaminants do have differing endpoints and target organs (see Tables F.40 and F.41). Because only a few "priority COCs"[2] drive HI, as shown in Section 5, and because the HI from each of these "priority COCs"[2] alone is great enough that a systemic toxic effect may be reasonably expected, the effect of this uncertainty on HIs is small.

Specific limitations for this approach in regard to chemical carcinogenesis also have been reported by EPA in RAGS:

- Cancer risks (i.e., ELCRs) are based on slope factors that represent an upper 95th percentile estimate of potency; the upper 95th percentiles of probability distributions are not strictly additive. Summing these risks can result in an overly conservative estimate of lifetime ELCR (EPA 1991).

- Combined cancer risks for chemical carcinogens and radionuclides are presented, but may not be additive because the slope factors used to characterize the risk from chemicals are derived differently from the slope factors used to characterize risk from radionuclides.

- Not all slope factors contain the same weight-of-evidence for human carcinogenicity. As explained in Section 4, EPA recognizes this by placing weight-of-evidence classifications on all slope factors. Those contaminants with an A weight-of-evidence should probably receive more attention in the selection of a remedial design than contaminants with a B or C classification. Similarly, a contaminant with a B classification should probably receive greater attention than one with a C classification. The simple combination of ELCRs does not take this hierarchy into account.

The uncertainties involved in combining chemical-specific ELCRs and pathway ELCRs are considerable. The effect of these uncertainties on the total ELCRs presented in the BHHRA is small because as noted above, only a few "priority COCs" dominate the pathway ELCR for most pathways; therefore, the potential effect of mixtures is reduced.

F.6.4.2 Chemical-specific Risk Values Exceeding 1E-02

At SWMU 2, the risk calculated for TCE exposure through groundwater is 3E-02. Risk estimates greater than 1E-02 are not accurate when calculated using EPA slope factors , which are based on a linearized multistage model. The one-hit model may provide a better estimate of risk in these cases (EPA 1989). One hit values were not calculated for this BRA because the purpose of the risk estimates is only to determine which COPCs have risks greater than 1E-04 which indicates the COPC should be a COC for the feasibility study (FS).

F.6.5 SUMMARY OF UNCERTAINTIES

As is shown in the previous subsections, the risk estimates could vary if different assumptions were used in deriving the risk estimates or if better information was available for some parameters. The following text summarizes the estimated effects of each uncertainty mentioned previously.

No uncertainties were estimated to have a large effect on the risk characterization, and only three were estimated to have a moderate effect.

Following is a list of uncertainties with effects estimated to be moderate:

- Exclusion of some potential biota pathways (fish from ponds) for future receptors,
- Migration of groundwater to off-site receptors, and
- Calculation of toxicity values for chemicals (particularly TCE).

Following is a list of uncertainties with effects estimated to be small:

- Determination of exposure points for future concentrations,
- Use of RME default exposure values instead of central tendency exposure values,
- Use of provisional and withdrawn toxicity values,
- Determination of radionuclide toxicity values, and values.

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F.7. CONCLUSIONS

This section summarizes the results of this and previous BHHRAs 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 BHHRAs are combined with the uncertainties in the risk assessment.

F.7.1 CHEMICALS OF POTENTIAL CONCERN

Through a series of screening steps, which follow the Risk Methods Document (DOE 2001) and other regulatory agency approved procedures, the data sets were reduced to lists of COPCs for the entire BGOU. Conclusions are compiled from the previous BHHRAs [i.e., WAG 22 RI Addendum for SWMUs 2 and 3 (DOE 1994); WAG 3 RI for SWMUs 3, 4, and 6 (DOE 2000)]; and WAG 22 RI for SWMUs 7 and 30 (DOE 1998a)] and Tables F.3 through F.10.

F.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, recreational users, and on-site rural residents. The potential receptor populations under future conditions in BGOU areas are recreational and residential. Within these broad categories, the recreational users and rural residents contain age cohorts. For the recreational users, the cohorts include the child (aged 1 to 7), teen (aged 8 to 20), and the adult (older than 21). For rural residents, the cohorts include children (aged 1 to 7) and older individuals (termed adults in this and previous BHHRAs). The recreational user and the rural resident population may also contain sensitive subpopulations such as pregnant women, young children (aged 0 to 1), the elderly, and the infirm. In this and earlier BHHRAs, exposure by these subpopulations is not quantified because much of the information that is needed is not available. Finally, this and earlier assessments assume that the recreational user is a rural resident who has repeated access to the study area. Recreational users not residing in the study area are not considered separately because nearby residents were determined to be the individuals most likely to take part in recreational activities at PGDP on a continual basis. In addition, the exposure assessment determined that little information useful in remedy selection would be obtained by including a separate visiting recreational user in the assessment. The groundwater exposure scenarios are hypothetical (i.e., at the plant boundary, property boundary, and near the Ohio River) because the areas containing the POEs currently are used for recreational and industrial purposes and do not contain residences. Table F.15 in the CSM section shows the scenarios and media evaluated in this risk assessment. The exposure routes considered are listed below.

Industrial Worker

Ingestion of surface soil and sediments (considered as one media type)
Dermal contact with surface soil
Inhalation of vapors emitted by surface soil
External exposure to ionizing radiation

Groundwater exposure was evaluated in previous risk assessments for the industrial worker scenario, but this exposure was not included in the BHHRA. Groundwater exposures are not commonly included in the industrial worker scenario because institutional controls are assumed to be in place.

Future Excavation Worker

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

Future recreational user

Ingestion of surface soil
Dermal contact with surface soil
Inhalation of vapors emitted by surface soil
Ingestion of game
External exposure to ionizing radiation

The listing above includes all exposure routes included in each previous risk assessment. SWMUs 2, 3, and 145 did not have a recreational user scenario; however, when it was performed at other SWMUs the ELCR from ingestion of game was the driver for this scenario.

Future on-site rural resident

Ingestion of surface soil
Dermal contact with surface soil
Inhalation of vapors emitted by surface soil
External exposure to ionizing radiation
Ingestion of groundwater
Vapor intrusion
Dermal contact with groundwater while showering
Inhalation of vapors emitted by groundwater during household use and
Inhalation of vapors emitted by groundwater while showering
Ingestion of produce

Future off-site rural resident

Ingestion of surface soil
Dermal contact with surface soil
Inhalation of vapors emitted by surface soil
External exposure to ionizing radiation
Ingestion of groundwater
Dermal contact with groundwater while showering
Inhalation of vapors emitted by groundwater during household use and
Inhalation of vapors emitted by groundwater while showering
Vapor intrusion

F.7.3 TOXICITY ASSESSMENT

The majority of toxicity values used in the risk assessment were taken from the RAIS and the TCE slope factor was taken from KDEP. After compiling toxicity information, the determination was made that the majority of the COPCs had a toxicity value available for one or more routes of exposure (see Section F.4.6).

F.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. For soil, results from previous risk assessments for SWMUs 2, 3, 4, 5, 6, 7, and 30 (DOE 1994; DOE 1998a; DOE 2000) were used. For most of the SWMUs, no new surface data have been collected since the previous risk assessments were performed. In addition, the soils at these units are outside the scope of this BGOU BHHRA as noted in the approved work plan; therefore, a new quantitative risk assessment was not performed for soils. Significant findings are summarized below. (See Table F.83).

F.7.4.1 Land Use Scenarios of Concern

The following are land uses of concern for BGOU:

Industrial: SWMUs 2, 3, 4, 5, 6, 7, and 30
Excavation: SWMUs 4, 5, 6, 7, and 30
Recreational: SWMUs 5, 7, and 30
On-Site Residential: SWMUs 2, 3, 4, 5, 6, 7, 30, and 145
Off-Site Residential: SWMUs 2, 3, 4, 5, 7, 30, and 145

F.7.4.2 Contaminants of Concern for Soil

To make a determination about whether contaminants are of concern in soil, quantitative risk and hazard results over all pathways from the previous risk assessments for SWMUs 2, 3, 4, 5, 6, 7, and 30 (DOE 1994; DOE 1998a; DOE 2000) were compared to risk and hazard benchmarks for land use scenarios of concern. The benchmarks used for this comparison were a) 0.1 for HI and b) 1×10^{-6} for ELCR. Lead results in the previous risk assessments were derived with toxicity values that are no longer used.

Contaminants with chemical-specific HIs or ELCRs exceeding these benchmarks are deemed COCs. Priority COCs are contaminants whose chemical-specific HI is greater than 1 or whose ELCR is greater than 1×10^{-4} for one or more scenarios. The following are priority COCs found in soil at individual SWMUs.

SWMU 2–none

SWMU 3–none

SWMU 4–barium, beryllium, cadmium, chromium, iron, nickel, uranium, vanadium

SWMU 5–aluminum, arsenic, beryllium, chromium, nickel, and Total PAHs

SWMU 6–Total PAHs, beryllium, chromium, nickel

SWMU 7–aluminum, antimony, arsenic, beryllium, cadmium, chromium, iron, manganese, nickel, uranium, vanadium, benzo(a)pyrene, dibenzo(a,h)anthracene, Aroclor-1254, Aroclor-1260, ^{239}Pu, ^{234}U, ^{235}U, $^{235/236}$U, and ^{238}U

SWMU 30–aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, manganese, mercury, nickel, uranium, vanadium, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, Aroclor-1254, Aroclor-1260, ^{234}U, ^{235}U, $^{235/236}$U, and ^{238}U

Table F.73. Scenarios for Which Human Health Risk Exceeds *De Minimis* Levels[a]

	Location							
Scenario	**SWMU 2**	**SWMU 3**	**SWMU 4**	**SWMU 5**	**SWMU 6**	**SWMU 7**	**SWMU 30**	**SWMU 145**
Results for excess lifetime cancer risk:								
Current On-site Industrial Worker Exposure to Soil	X	X	X	X	X	X	X	NA
Future On-site Industrial Worker Exposure to Soil	X	X	X	X	X	X	X	NA
Exposure to Surface Water	NA	NA	NA	NA	NA	NA	NA	NA
Future On-site Excavation Worker Exposure to Soil/Soil and Waste	NA	NA	X	X	X	X	X	NA
Future On-site Recreational User Exposure to Game	NA	NA	---	X	XNA	X	X	NA
Exposure to Soil	NA	NA	NA	NA		NA	NA	NA
Future On-site Rural Resident Exposure to Soil	NA	NA	X	X	X	X	X	NA
Exposure to Groundwater [b]	X	X	X	X	---	X	X	X
Vapor Intrusion [c]	X	X	X	---	---	X	X	---
Future Off-site Rural Resident Exposure to Groundwater [b]	X	X	X	X	---	X	X	X
Vapor Intrusion [c]	X	---	X	---	---	---	X	---
Result for Systematic Toxicity [b]								
Current On-site Industrial Worker Exposure to Soil	---	---	X	---	---	X	X	NA
Future On-site Industrial Worker Exposure to Soil	---	---	X	---	---	X	X	NA
Future On-site Excavation Worker Exposure to Soil/Soil and Waste	**NA**	NA	X	X	X	X	X	NA
Future On-site Recreational User Exposure to Game	NA	NA	---	---	---	---	---	NA
Exposure to Soil	NA	NA	NA	NA	NA	NA	NA	NA
Exposure to Surface Water	**NA**	NA	NA	NA	NA	NA	NA	NA
Future On-site Rural Resident Exposure to Soil	NA	NA	X	X	X	X	X	NA
Exposure to Groundwater [b]	X	X	X	X	---	X	X	X
Vapor Intrusion [c]	X	X	X	---	---	X	X	X
Future Off-site Rural Resident Exposure to Groundwater [b]	X	---	X	---	---	X	X	---
Vapor Intrusion [c]	---	---	---	---	---	---	---	---

Notes: Scenarios where risk exceeds *de minimis* levels are marked with an X. Scenarios where risk did not exceed *de minimis* levels are marked with a ---. NA indicates that the scenario/land use combination was not assessed because the scenario is not applicable, or the medium is not present.

[a] Consistent with the PGDP Risk Methods Document (DOE 2001), the *de minimis* levels used are a cumulative ELCR of 1×10^{-6} and a cumulative HI of 1.

[b] Systemic toxicity results summarized here for the resident and recreational user are for the child. The off-site POE considered is the property boundary.

[c] Based on results of preliminary deterministic contaminant transport modeling. The POE is the property boundary. X indicates that the location contains a source of unacceptable off-site contamination, and --- indicates that the location is not a source of off-site contamination

F.7.4.3 Contaminants of Concern for Groundwater

Similarly for groundwater, to determine whether modeled concentrations of 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 a) 0.1 for HI and b) 1×10 for ELCR.

Contaminants with chemical-specific HIs or ELCRs exceeding these benchmarks were deemed COCs. Priority COCs are contaminants whose chemical-specific HI is greater than 1 or whose ELCR is greater than 1×10^{-4} for one or more scenarios. The following presents priority COCs found in groundwater at individual SWMUs.

SWMU 2–arsenic; manganese; uranium; *cis*-1,2-DCE; and TCE
SWMU 3–arsenic; manganese; uranium; and ^{99}Tc
SWMU 4–arsenic, manganese; *cis*-1,2-DCE; TCE; vinyl chloride; and ^{99}Tc
SWMU 5–arsenic; manganese, and naphthalene
SWMU 6–none
SWMU 7–arsenic, 1,1-DCE; *cis*-1,2-DCE; Total PCBs, TCE, vinyl chloride.
SWMU 30–arsenic; 1,1-DCE; TCE
SWMU 145–antimony; arsenic; manganese; Total PCBs; and ^{99}Tc

"Priority COCs" are identified in this section as an aid to risk managers during decision making. The priority COCs identified above in this risk assessment are based on the modeled groundwater concentrations at all POEs. [2]

F.7.4.4 Pathways of Concern

Each of the pathways included in the BHHRA is a POC.

F.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 and RGA groundwater are media of concern at all eight SWMUs.

F.7.5 OBSERVATIONS

Consistent with regulatory guidance and agreements contained in the PGDP Risk Methods Document, this and previous BHHRAs presents risks for land use scenarios representing current use, as well as several reasonable future uses. Risk evaluation of surface soil was conducted for all SWMUs as part of the evaluation of the scenarios specified in the work plan. The oral slope factor for beryllium was withdrawn in 1998. The inhalation slope factor for beryllium is 8.4 $(mg/kg\text{-}day)^{-1}$. The Inhalation Slope Factor was calculated from inhalation unit risk as described in Supplemental Guidance from *RAGS: Region 4 Bulletins, Human Health Risk Assessment* (Interim Guidance) as described in the RAIS online toxicity values. A review of the pathways for exposure reveals inhalation of particulates is a minor contributor to cumulative ELCR. Inhalation of particulates is consistently less than 1% of the cumulative ELCR; therefore, cumulative ELCRs are shown with and without the contribution from beryllium in this section.

[2] "Priority COCs" are identified as an aid to risk managers during decision making; however, all COCs will be addressed through remediation, removal, management, or other enforceable control.

In addition, total PAH and individual PAH compounds (depending on how the risks were calculated in previous risk assessments) contribute to risk in many scenarios. PAH compounds are ubiquitous and may be products of anthropogenic activities other than the PGDP. However, there is not a definitive study that describes the concentrations of PAHs in nearby areas that are not influenced by the PGDP. Until a definitive study is prepared, the risks of PAH compounds are included in this document. The scenarios described in the BHHRAs are as follows:

- Future on-site industrial use–direct contact with surface soil (soil found 0 to 1 ft bgs). Groundwater was assessed in some the previous risk assessments as part of the industrial use scenario. These results for groundwater were not included in the on-site industrial scenario for this BHHRA.Future on-site excavation worker–direct contact with surface and subsurface soil (soil 0 to 10 ft bgs).

- Future recreational user–direct contact with surface soils and consumption of game exposed to surface soils.

- Future on-site rural resident–direct contact with surface soil at and use of groundwater drawn from the RGA at source areas and vapor intrusion into basements.

- Future off-site rural resident–use in the home of groundwater drawn from the RGA at the DOE plant boundary, property boundary, and the Ohio River.

Specific observations for this BHHRA are presented below.

F.7.5.1 Observations—Future Industrial Worker

Cumulative HIs for the industrial worker were greater than 1 at SWMUs 4, 7 and 30 based on soil exposure. At SWMU 4, chromium, iron, and vanadium were the primary drivers contributing 45%, 24%, and 24% to the HI, respectively. At SWMU 7, beryllium, chromium, iron, manganese, uranium, and vanadium were the major drivers (> 5%) contributing 9.6%, 13.6%, 20.6%, 10.7%, 13.7%, 13.7%, and 17.7% to the HI, respectively. At SWMU 30, aluminum, beryllium, chromium, iron, manganese, uranium, and vanadium were the major drivers contributing 5.1%, 10.8%, 13.5%, 19.8%, 11.3%, 9.0%, and 17.6% to the HI, respectively.

Cumulative ELCRs exceeded 1E-04 for all SWMUs and were greater than 1E-03 at SWMU 7 and SWMU 30 for exposure to soil (SWMU 145 was not evaluated for this scenario). The following summarizes the cumulative risk estimates and major contributors (> 5%) to the ELCR for these SWMUs.

- SWMU 2 cumulative ELCR 1.20E-04; drivers are ^{235}U+daughters at 83.9%, ^{238}U+daughters at 10.7%.

- SWMU 3 cumulative ELCR 1.20E-04; drivers are ^{235}U+daughters at 83.9% and ^{238}U+daughters at 10.7%.

- SWMU 4 cumulative ELCR 5.40E-04; the primary driver is beryllium at 97%. If beryllium risk is not included the cumulative ELCR is 1.62E-05.

- SWMU 5 cumulative ELCR 4.10E-04; drivers are arsenic at 6%, beryllium at 49%, and Total PAH at 45%. If the contribution from beryllium is discounted, the cumulative ELCR is 2.13E-04.

- SWMU 6 cumulative ELCR 2.40E-04; drivers are beryllium at 90% and Total PAH at 10%. Excluding beryllium, the cumulative ELCR is 2.4E-05

- SWMU 7 cumulative ELCR 3.90E-03 the primary driver is beryllium at 96%. If beryllium is not included in the cumulative ELCR, the risk is 1.5E-04 with ^{238}U and arsenic contributing to the risk.

- SWMU 30 cumulative ELCR 3.80E-03; the primary driver is beryllium at 96.2%. If beryllium is not incorporated in the total, the cumulative ELCR for soils is 1.42E-04, with arsenic contributing 13% and various PAHs contributing 35%.

Cumulative HIs for the current industrial/maintenance worker were the same as the cumulative HIs for the future industrial worker (i.e., same HI values and drivers including their percent contributions) with the exception of SWMUs 2 and 3. SWMUs 2 and 3 calculated risk and systemic toxicity by using exposure frequencies of 25 days per year for the current industrial worker and 250 days per year for future industrial workers.

The current industrial/maintenance worker had ELCRs exceeding 1E-04 for all SWMUs. Specifically, the cumulative ELCRs at SWMUs 7 and 30 were 3.80E-03 and 3.70E-03, respectively. Approximately 96% of the risk at SWMUs 7 and 30 under this scenario was due to the risk from beryllium. As previously noted, the oral slope factor for beryllium has been withdrawn. If the risks from exposure to beryllium are discounted, the cumulative ELCR is reduced, as described in the summary for future industrial workers above.

F.7.5.2 Observations—Future Excavation Worker

Cumulative HIs for the future excavation worker were greater than 1 for SWMUs 4, 5, 6, 7, and 30 based on soil exposure. This exposure scenario was not evaluated for SWMU 2, SWMU 3, or SWMU 145. The following summarizes the cumulative HIs and major contributors to elevated hazards at these SWMUs.

- SWMU 4 cumulative HI 2.61; drivers are aluminum at 8%, chromium at 24%, iron at 24%, manganese 14%, and vanadium 20%.

- SWMU 5 cumulative HI 2.16; drivers are aluminum at 9%, arsenic at 7%, chromium at 8%, iron at 38%, and manganese at 22%.

- SWMU 6 cumulative HI 2.44; drivers are aluminum at 8%, chromium at 15%, iron at 32%, manganese at 15%, and vanadium at 26%.

- SWMU 7 cumulative HI 5.40; drivers are antimony at 11.3%, chromium at 17.6%, iron at 21.3%, manganese at 11%, uranium at 7.5%, and vanadium at 10.9%.

- SWMU 30 cumulative HI 4.50; drivers are antimony at 6.3%, chromium at 10.2%, copper at 7.6%, iron at 19.8%, manganese at 14.3%, uranium at 12.2%, and vanadium at 12.7%.

Cumulative ELCRs exceeded 1E-04 for all SWMUs (except SWMUs 2, 3, and 145) and were greater than 1E-03 at SWMU 4, SWMU 7, and SWMU 30 for exposure to soil. The following summarizes the cumulative risk estimates and major contributors (> 5%) to the ELCR for these SWMUs.

- SWMU 4 cumulative ELCR 2.70E-03; drivers are beryllium at 7% and total uranium (the total uranium risk was calculated using ^{238}U slope factors) at 83%. If the contribution from beryllium were discounted, the cumulative is ELCR 2.51E-03.

- SWMU 5 cumulative ELCR 2.9E-04 ; drivers are arsenic at 8%, beryllium at 62%, and Total PAH at 28%. If the risk from beryllium is not included, the cumulative ELCR would be 1.1E-04.

- SWMU 6 cumulative ELCR 2.30E-04; drivers are beryllium at 90% and Total PAH at 9%. If the risk from beryllium is removed, the cumulative ELCR would be 2.3E-05.

- SWMU 7 cumulative ELCR 1.60E-03; drivers are beryllium at 42.2%, ^{235}U at 9.1%, and ^{238}U at 41.3%. If the risk from beryllium were discounted, the cumulative ELCR would be 9.2E-04.

- SWMU 30 cumulative ELCR 1.20E-03; driver is beryllium at 93.7%. If the risk from beryllium were discounted, the cumulative ELCR would be 7.6E-05. PAHs, arsenic and radionuclides contribute the remaining risk.

F.7.5.3 Observations—Future Recreational Users

Cumulative HIs for the child, teen, and adult recreational users were less than 1 for SWMUs 4, 5, 6, 7, and 30 based on soil exposure. Cumulative ELCRs exceeded 1E-06 for future adult recreational users only at SWMUs 5, 7, and 30 based on consumption of game. This exposure scenario was not evaluated at SWMUs 2, 3, and 145. The contributors to cumulative ELCR include beryllium and PAH compounds. As stated previously, inclusion of these contaminants, especially beryllium, may artificially increase risk. The following summarizes the cumulative risk estimates and major contributors to the ELCR for these SWMUs.

- SWMU 5 cumulative ELCR 1.0E-05; driver is Total PAH at 96%.

- SWMU 7 cumulative ELCR 1.1E-05; drivers are Aroclor-1260 at 18.6%, benzo(a)pyrene at 9.5%, dibenzo(a,h)anthracene at 42.5%, and ^{238}U at 15.7%.

- SWMU 30 cumulative ELCR 1.2E-05; driver is beryllium at 93.7%. Without the contribution from beryllium the cumulative ELCR is 7.6E-07.

F.7.5.4 Observations—Future On-Site Rural Residents

Because of the nature of residential use, risk and hazard contributions were noted for both soil and groundwater exposure. The following summarizes the cumulative HIs and ELCRs observed for each resident.

Hazards—Future Child Residential Exposure to Soil. Cumulative HIs based on direct contact with soil for the child rural resident were greater than 1 for SWMUs 4, 5, 6, 7, and 30. This exposure scenario was not evaluated for SWMUs 2, 3, and 145. The major contributors to elevated hazards are as follows:

- SWMU 4 cumulative HI 98.2: chromium at 24%, iron 60%, and vanadium at 9%
- SWMU 5 cumulative HI 46.2: aluminum at 24%, arsenic at 55%, and chromium at 15%
- SWMU 6 cumulative HI 9.38: beryllium at 8%, chromium at 72%, and nickel at 15%
- SWMU 7 cumulative HI 370: arsenic at 6.2%, iron at 19.7%, and uranium at 58.4%
- SWMU 30 cumulative HI 260: arsenic at 7.5%, iron at 22.6%, and uranium at 46.8%

Hazard—Future Adult Resident Exposure to Soil. Cumulative HIs for the future on-site adult resident were greater than 1 for SWMUs 4, 5, 6, 7, and 30. SWMU 145 was evaluated for excavation worker scenario only. This exposure scenario was not evaluated for SWMUs 2, 3, and 145. The major contributors to elevated hazards are as follows:

- SWMU 4 cumulative HI 28.4: chromium at 22%, iron at 63%, and vanadium at 8%
- SWMU 5 cumulative HI 13.9: aluminum at 24%, arsenic at 55%, and chromium at 15%
- SWMU 6 cumulative HI 2.57: beryllium at 7%, zinc at 6%, nickel at 17% and chromium at 70%
- SWMU 7 cumulative HI 110: arsenic at 6.5%, iron at 19.8%, and uranium at 59.5%
- SWMU 30 cumulative HI 79: arsenic at 7.9%, iron at 22.8%, and uranium at 47.5%

Risks—Future Adult Residential Exposure to Soil. Cumulative ELCRs exceeding 1E-03 from direct contact with soil was observed for SWMUs 4, 5, 6, 7, and 30. This exposure scenario was not evaluated for SWMUs 2, 3, and 145. The contributors to cumulative ELCR include beryllium and PAH compounds. As stated previously, inclusion of these contaminants, especially beryllium, may artificially increase risk. Cumulative ELCRs greater than 1E-02 were identified for SWMUs 3 5, 7, and 30. The major contributors to elevated risks are as follows:

- SWMU 4 cumulative ELCR 4.3E-03: beryllium at 72%, total PCBs at 5%, ^{234}U at 6%, and ^{238}U at 17%. The cumulative ELCR, without the contribution from beryllium, is 1.24E-03.
- SWMU 5 cumulative ELCR 1.0E-02: arsenic at 21%, beryllium at 9%, and Total PAH at 68%. The cumulative ELCR, without the contribution from beryllium, is 9.1E-03.
- SWMU 6 cumulative ELCR 2.4E-03: beryllium at 54% and Total PAH at 46%. The cumulative ELCR, without the contribution from beryllium, is 1.1E-03.
- SWMU 7 cumulative ELCR 3.4E-02: arsenic at 7.3%, beryllium at 65.4%, and ^{238}U at 17.6%. The cumulative ELCR, without the contribution from beryllium, is 1.19E-02.
- SWMU 30 cumulative ELCR 3.2E-02: arsenic at 6.8%, various PAH compounds totaling 7%, beryllium at 66.7%, and ^{238}U at 11.5%. The cumulative ELCR, without the contribution from beryllium, is 1.06E-02.

Hazards—Future Resident Exposure to Groundwater. Cumulative HIs based on exposure to groundwater for the future on-site rural resident were greater than 1 for all of the SWMUs, except SWMU 6. The following lists those constituents that contributed to the elevated HIs. The major contaminants driving the hazard were ingestion of uranium metal and iron and ingestion and inhalation of TCE and *cis*-1,2 DCE.

The following lists those constituents that contributed to elevated HIs by SWMU for the Child Resident:

- SWMU 2: TCE at 52.1% and *cis*-1,2-DCE at 46.8%
- SWMU 3: arsenic at 47.9%, uranium at 35.5%, and manganese at 16.6%
- SWMU 4: TCE at 92.5% and *cis*-1,2-DCE at 6.1%
- SWMU 5: arsenic at 37.5%, naphthalene at 35.4%, and manganese at 27.2%
- SWMU 7: arsenic at 30.2%, TCE at 26.4%, Total PCBs at 22.3%, and *cis*-1,2-DCE at 6.6%
- SWMU 30: TCE at 96.7%
- SWMU 145: antimony at 48.0% and arsenic at 47.7%

Risks—Future Residential Exposure to Groundwater. Cumulative ELCRs exceeding 1E-06 from direct exposure to groundwater was observed for all of the SWMUs. Cumulative ELCRs greater than 1E-04

were identified for all of the SWMUs, except SWMU 6. The major contaminants driving risk were ingestion of arsenic and TCE.

The following lists those constituents that contributed to elevated risks by SWMU:

- SWMU 2: TCE at 98.0%
- SWMU 3: arsenic at 72.3% and ^{99}Tc at 25.3%
- SWMU 4: TCE at 67.7% and vinyl chloride at 30.5%
- SWMU 5: arsenic at 97.2%
- SWMU 7: 1,1-DCE at 66.4%, arsenic at 15.1%, and vinyl chloride at 11.9%
- SWMU 30: 1,1-DCE at 5.8% and TCE at 92.1%
- SWMU 145: arsenic at 5.1% and Total PCBs at 93.2%

F.7.5.5 Observations—Future Off-Site Rural Residents

Risk and hazard estimates for future off-site residential use are based on peak modeled groundwater concentrations. The following summarizes the results of the quantitative assessment at the plant boundary, property boundary, and at the Ohio River (or seeps).

Future Residential Exposure to Groundwater–Plant Boundary. SWMU 6 was not evaluated for groundwater exposure, and SWMU 145 lies outside the plant boundary. Cumulative HIs based on exposure to groundwater at the DOE plant boundary were greater than one for SWMU 2, SWMU 4, SWMU 5, SWMU 7, and SWMU 30. The major contaminants contributing to hazard were TCE, *cis*-1,2-DCE, arsenic, manganese, and Total PCBs. The cumulative ELCR was greater than 1E-06 for SWMU 2, SWMU 3, SWMU 4, SWMU 5, SWMU 7, and SWMU 30. The cumulative ELCR was greater than 1E-04 for SWMU 2, SWMU 3, SWMU 4, SWMU 7, and SWMU 30. The major contaminants contributing to risk were TCE, 1,1-DCE, vinyl chloride, ^{99}Tc, and arsenic.

Below are descriptions of the risk at the plant boundary from exposure to groundwater over time, and the contaminants that contribute to the risk during various time periods. The information below provides a summary of the Tables in Section F.5.5 which describe risk over time. Section 5 also provides additional detail of groundwater modeling results.

SWMU 2-At the plant boundary, the risks from SWMU 2 peak during 15 to 40 years due to the concentration of TCE. By 200 years, the concentration of TCE has decreased and the risk has decreased to approximately 1E-06. The risk continues this downward trend until the concentration of arsenic begins to increase at approximately 700 years. The risk increases moderately to the end of the simulation (1000 years) where it is approximately 7.7E-05.

SWMU 3-At the plant boundary, the risks from SWMU 3 peak at approximately 65 years, primarily due to ^{99}Tc. At year 125, the risk from SWMU 3 at the plant boundary is at 1E-06 and continues to decline to the end of the simulation.

SWMU 4-At the plant boundary, the risks from SWMU 4 peak at approximately 15 years, primarily due to TCE and vinyl chloride concentrations. At approximately 50 years, ^{99}Tc begins to contribute to the total risk. The risk decreases to 1E-06 at approximately 240 years and decreases until approximately 400 years into the simulation. At approximately 400 years, the risk from arsenic concentrations begins to increase until 1000 years when the risk is approximately 7E-05.

SWMU 5-At the plant boundary, the risks from SWMU 5 peak briefly in the first 50 years just above 1E-06 due to TCE and to some degree ^{99}Tc. The risk declines until about 300 years when arsenic

concentration begins to increase risk back to 1E-06 and then increases to approximately 5E-5 at 1,000 years.

SWMU 7-At the plant boundary, the risks from SWMU 7 peak in the first 5 years because of TCE, 1,1 DCE, and vinyl chloride concentrations. The risk decreases in 170 years from these contaminants to a risk near 1E-06. The risk begins to increase primarily due to increased concentrations of arsenic after 170, with the risk remaining a approximately 3 E-04 until the end of the simulation (1,000 years).

SWMU 30-At the plant boundary, the risks from SWMU 30 peak in the initial 10 to 20 years due to concentrations of TCE, 1,1 DCE, and ^{99}Tc. At approximately 100 years, the concentrations of these contaminants decrease sufficiently that arsenic concentrations begin to be the primary contributors to risk. The risk from the organic compounds is at approximately 4E-04 at 100 years. The risk due primarily to arsenic after 100 years remains near 1E-04 until the end of the simulation (1,000 years).

Future Residential Exposure to Groundwater – Property Boundary. Cumulative HIs based on exposure to groundwater at the DOE property boundary were greater than 1 for SWMU 2, SWMU 4, SWMU 7, and SWMU 30. The major contaminants driving hazard were ingestion of arsenic, TCE, *cis*-1,2-DCE, and Total PCBs.

Cumulative ELCR exceeded 1E-06 for groundwater exposure for all of the SWMUs, except SWMU 6. Cumulative ELCRs greater than 1E-04 from groundwater use were identified for SWMUs 2, 4, 7, 30, and 145. The major contaminants driving risk were ingestion of arsenic, TCE, 1,1-DCE, vinyl chloride, and ^{99}Tc.

Below are descriptions of the risk at the property boundary from exposure to groundwater over time, and the contaminants that contribute to the risk during various time periods. The information below provides a summary of the Tables in Section F.5.5, which describe risk over time. Section 5 also provides additional detail of groundwater modeling results. The descriptions below address the SWMUs that produced a cumulative ELCR greater than 1E-04.

SWMU 2-At the property boundary, the risks from SWMU 2 peak at approximately 40 years due to the concentrations of TCE. The peak risk is greater than 3E-03, but, after 40 years, the concentrations decrease and at approximately 190 years the risk is near 1E-06. The risk decreases until approximately 600 years when arsenic concentrations contribute to risk and begin to increase the risk for the next 400 years to an approximate average of 5E-05.

SWMU 4-At the property boundary, the risks from SWMU 4 peak at approximately 15 years due to TCE and vinyl chloride. The risk from these compounds diminishes to 1E-06 in approximately 220 years. The risk remains below 1E-06 until the end of the simulation (1,000 years).

SWMU 7-At the property boundary, the risks from SWMU 7 peak at approximately 15 years due to TCE, 1,1-DCE, and vinyl chloride. The risks decrease from these contaminants and reach 1E-06 at approximately year 120. After year 120, the influence of arsenic begins to increase risk until the end of the simulation. The maximum risk primarily from arsenic is 7E-05 at 1,000 years.

SWMU 30-At the property boundary, the risks from SWMU 30 peak at about 15 years primarily due to TCE and 1,1-DCE. Technetium-99 contributes to the risk, but the concentration of ^{99}Tc does not peak until approximately 50 years. The risk from TCE, ^{99}Tc, and 1,1-DCE decreases to 1E-06 at approximately 120 years. At approximately 500 years, risk primarily due to arsenic begins to increase from 1 E-06 to 6E-05 at 1,000 years.

Future Residential Exposure to Groundwater – Ohio River or Seeps. Cumulative HIs based on exposure to groundwater for the future off-site rural resident at the Ohio River were greater than 1 for SWMUs 2, 4, and 30. The major contaminants driving hazard were ingestion of TCE and *cis*-1,2-DCE.

Cumulative ELCRs of 1E-06 from groundwater exposure were observed for SWMUs 2, 3, 4, 7, 30, and 145. Cumulative ELCRs greater than 1E-04 from groundwater use were identified for SWMUs 2, 4, 7, and 30. The contaminants driving risk were ingestion of TCE, 1,1-DCE, vinyl chloride, and ^{99}Tc.

Below are descriptions of the risk at the Ohio River or the Little Bayou seeps from exposure to groundwater over time, and the contaminants which contribute to the risk during various time periods. The information below provides a summary of the Tables in Section F.5.5, which describes risk over time. Section 5 also provides additional detail of groundwater modeling results. The descriptions below address the SWMUs that produced a cumulative ELCR greater than 1E-04.

SWMU 2-At the Ohio River, the risks from SWMU 2 peaked at approximately 90 years due primarily to TCE. After 90 years, the risk continued to decrease during the 1,000 year simulation and reached a risk of 1E-6 at approximately 200 years.

SWMU 4-At the Ohio River, the risks from SWMU 4 peaked at approximately 90 years due primarily to TCE and vinyl chloride. After 90 years, the risk continued to decrease during the 1,000 year simulation and reached a risk of 1E-6 at approximately 240 years.

SWMU 7-At the Little Bayou Seeps, the risks from SWMU 7 peaked at approximately 35 years due primarily to 1,1-DCE, TCE, and vinyl chloride. After the peak, the risk decreased to 1E-06 at approximately 120 years.

F.7.5.6 Summary of Observations

The following summarize the observations noted for this and previous BHHRAs for BGOU. The discussion focuses on the individual exposure scenarios examined for the assessment.

F.7.5.6.1 Future Industrial Worker

SWMUs 4, 7, and 30 hazard levels exceed 1 for industrial worker exposure to soil, with chromium, iron, and vanadium serving as the primary hazard drivers for elevated HIs. All SWMUs (SWMU 145 was not evaluated for this scenario) exceed risk levels of 1E-04 for industrial worker exposure to soil, with ^{235}U+daughters, ^{238}U+daughters, and beryllium serving as the primary risk drivers. Other COCs contributing to elevated risks include Total PAH and arsenic. SWMUs 2, 3, 5, 7 and 30 exceed risk levels of 1E-04 for industrial worker exposure to soil, if beryllium is not include in the cumulative ELCR for each of the SWMUs.

F.7.5.6.2 Future Excavation Worker

SWMUs 4, 5, 6, 7, and 30 exceed a hazard level of 1 for excavation worker exposure to soil (SWMUs 4, 5, and 6 were evaluated for exposure to soil and waste), with aluminum, antimony, chromium, iron, manganese, uranium, and vanadium serving as the primary hazard driver for elevated HIs. Other COCs contributing to hazards include arsenic and copper. SWMUs 4, 5, 6, 7, and 30 exceed the risk level of 1E-04 for excavation worker exposure to soil, with beryllium, uranium, Total PAH, and ^{238}U serving as the primary risk drivers. Other COCs contributing to elevated risks include arsenic and ^{235}U. SWMUs 4, 5, and 7 exceed the risk level of 1E-04 for excavation worker exposure to soil when beryllium is not

included in the cumulative ELCR. SWMUs 4, 5, and 6 included exposure to soil and waste, which was included in this BHHRA but referred to as one media type, soil.

F.7.5.6.3 Future On-Site Residents (Groundwater)

For residential groundwater use at the SWMU boundary, ELCR was greater than 1E-04 and HI was greater than 1 for all SWMUs except SWMU 6. The primary risk drivers are TCE, arsenic, vinyl chloride, 1,1-DCE, and ^{99}Tc.

F.7.5.6.4 Future Off-Site Residents (Groundwater)

SWMUs 2, 4, 5, 7, and 30 exceed a hazard level of 1 for off-site residential exposure to groundwater at the PGDP plant boundary. SWMUs 2, 4, 7, and 30 exceed a hazard level of 1 at the property boundary. SWMUs 2, 4, and 30 exceed a hazard level of 1 at the Ohio River (or seeps). The primary drivers for hazard are arsenic, TCE, *cis*-1,2-DCE, and 1,1-DCE. SWMUs 2, 3, 4, 7, and 30 at the plant boundary, SWMUs 2, 4, 7, 30, and 145 at the property boundary, and SWMUs 2, 4, 7, and 30 at the Ohio River (or seeps) exceed a risk level of 1E-04 for off-site residential exposure to groundwater. The primary risk drivers are TCE, 1,1-DCE, and ^{99}Tc.

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F.8. REMEDIAL GOAL OPTIONS

This section presents RGOs for the COCs identified in Section 5 and the methods used to calculate the RGOs. These RGOs should not be interpreted as being cleanup goals, but as risk-based values that may be used to guide the development of cleanup goals by risk managers. Cleanup goals will be determined in later decision documents.

RGOs were calculated for each groundwater COC from the modeled groundwater concentrations considering use of groundwater at each source. When calculating the HI-based RGOs, the more conservative child-based values are reported. In addition, for comparison to the RGOs, the maximum contaminant level (MCL) for each COC is presented. Note, MCLs are not clean-up criteria. The National Contingency Plan notes that clean-up criteria different from MCLs may be required if multiple contaminants are present or if contaminants may reach a receptor through exposure routes different from those considered in the development of MCLs. Risks for use of contaminated groundwater must be presented in addition to a simple screen against MCLs so that risk managers can make appropriate decisions.

F.8.1 CALCULATION OF GROUNDWATER RGOs

EPA guidance (EPA 1991) directs that RGOs are to be calculated for all COCs identified in a BHHRA. The COCs identified in this risk assessment and their RGOs are presented in Table F.74. These RGOs 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 remedial goal option.
Target Risk is one of the values listed in Table F.74.

F.8.2 PRESENTATION OF RGOs

RGOs for soil COCs determined in the previous risk assessments are the 2008 draft NALs (DOE 2008) for the listed analyte and receptor. The previous risk assessments for soil calculated RGOs for soil COCs, but both toxicity factors and exposure factors for some of the COCs have been updated since that time. Therefore, the current NALs for the same soil exposure scenarios (residential, industrial, and excavation) are presented as the RGOs in Table F.84 for soil.

The equation developed in the previous subsection was applied for each groundwater COC. The RGOs developed for all COCs using this equation are presented in Table F.75. In addition, these tables present the groundwater EPCs used in the BHHRA.

Table F.74. RGOs for Soil COCs of the BGOU SWMUs

COC[A]	Cancer NAL	Noncancer NAL	RGO[B] at HI=0.1	RGO at HI=1	RGO at HI=3	RGO at ELCR= 1×10^{-6}	RGO at ELCR= 1×10^{-5}	RGO at ELCR= 1×10^{-4}	Units
Residential User Soil Exposure									
Aluminum		9.69E+02	9.69E+01	9.69E+02	2.91E+03				mg/kg
Antimony		8.69E-02	8.69E-03	8.69E-02	2.61E-01				mg/kg
Arsenic	1.44E-01	1.16E+00	1.16E-01	1.16E+00	3.48E+00	1.44E-01	1.44E+00	1.44E+01	mg/kg
Barium		1.40E+02	1.40E+01	1.40E+02	4.20E+02				mg/kg
Beryllium and compounds	1.19E-03	2.20E-01	2.20E-02	2.20E-01	6.60E-01	1.19E-03	1.19E-02	1.19E-01	mg/kg
Cadmium	2.00E+00	3.26E+00	3.26E-01	3.26E+00	9.78E+00	2.00E+00	2.00E+01	2.00E+02	mg/kg
Chromium	1.10E+02	8.32E+01	8.32E+00	8.32E+01	2.50E+02	1.10E+02	1.10E+03	1.10E+04	mg/kg
Cobalt	4.69E+02	6.95E+01	6.95E+00	6.95E+01	2.09E+02	4.69E+02	4.69E+03	4.69E+04	mg/kg
Copper		9.39E+01	9.39E+00	9.39E+01	2.82E+02				mg/kg
Iron		4.14E+02	4.14E+01	4.14E+02	1.24E+03				mg/kg
Manganese		5.60E+01	5.60E+00	5.60E+01	1.68E+02				mg/kg
Nickel	5.06E+03	4.35E+01	4.35E+00	4.35E+01	1.31E+02	5.06E+03	5.06E+04	5.06E+05	mg/kg
Uranium		2.57E+00	2.57E-01	2.57E+00	7.71E+00				mg/kg
Vanadium		7.71E-01	7.71E-02	7.71E-01	2.31E+00				mg/kg
Zinc		5.21E+02	5.21E+01	5.21E+02	1.56E+03				mg/kg
Aroclor 1260	6.08E-02					6.08E-02	6.08E-01	6.08E+00	mg/kg
Benz[a]anthracene	7.48E-02					7.48E-02	7.48E-01	7.48E+00	mg/kg
Benzo[a]pyrene	7.48E-03					7.48E-03	7.48E-02	7.48E-01	mg/kg
Benzo[b]fluoranthene	7.48E-02					7.48E-02	7.48E-01	7.48E+00	mg/kg
Dibenz[a,h]anthracene	7.48E-03					7.48E-03	7.48E-02	7.48E-01	mg/kg
Total Dioxins/Furans	6.78E-07					6.78E-07	6.78E-06	6.78E-05	mg/kg
Indeno[1,2,3-cd]pyrene	7.48E-02					7.48E-02	7.48E-01	7.48E+00	mg/kg
Total PCBs	5.78E-02					5.78E-02	5.78E-01	5.78E+00	mg/kg
Total PAHs	7.48E-03					7.48E-03	7.48E-02	7.48E-01	mg/kg
Neptunium-237+D	8.39E-02					8.39E-02	8.39E-01	8.39E+00	pCi/g
Plutonium-239*	3.15E+00					3.15E+00	3.15E+01	3.15E+02	pCi/g
Radium-226+D	7.94E-03					7.94E-03	7.94E-02	7.94E-01	pCi/g
Uranium-234	5.47E+00					5.47E+00	5.47E+01	5.47E+02	pCi/g
Uranium-235+D	1.22E-01					1.22E-01	1.22E+00	1.22E+01	pCi/g
Uranium-238+D	5.17E-01					5.17E-01	5.17E+00	5.17E+01	pCi/g

Table F.74. RGOs for Soil COCs of the BGOU SWMUs (Continued)

COC	Cancer NAL	Noncancer NAL	RGO at HI=0.1	RGO at HI=1	RGO at HI=3	RGO at ELCR= 1×10^{-6}	RGO at ELCR= 1×10^{-5}	RGO at ELCR= 1×10^{-4}	Units
Industrial Worker Soil Exposure									
Aluminum		4.22E+03	4.22E+02	4.22E+03	1.27E+04				mg/kg
Antimony		3.46E-01	3.46E-02	3.46E-01	1.04E+00				mg/kg
Arsenic	4.84E-01	7.78E+00	7.78E-01	7.78E+00	2.33E+01	4.84E-01	4.84E+00	4.84E+01	mg/kg
Barium		5.92E+02	5.92E+01	5.92E+02	1.78E+03				mg/kg
Beryllium and compounds	2.83E-03	8.68E-01	8.68E-02	8.68E-01	2.60E+00	2.83E-03	2.83E-02	2.83E-01	mg/kg
Cadmium	1.49E+01	1.97E+01	1.97E+00	1.97E+01	5.91E+01	1.49E+01	1.49E+02	1.49E+03	mg/kg
Chromium	2.11E+02	3.26E+02	3.26E+01	3.26E+02	9.78E+02	2.11E+02	2.11E+03	2.11E+04	mg/kg
Cobalt	9.05E+02	4.48E+02	4.48E+01	4.48E+02	1.34E+03	9.05E+02	9.05E+03	9.05E+04	mg/kg
Copper		4.91E+02	4.91E+01	4.91E+02	1.47E+03				mg/kg
Iron		1.90E+03	1.90E+02	1.90E+03	5.70E+03				mg/kg
Manganese		2.29E+02	2.29E+01	2.29E+02	6.87E+02				mg/kg
Nickel	9.75E+03	2.22E+02	2.22E+01	2.22E+02	6.66E+02	9.75E+03	9.75E+04	9.75E+05	mg/kg
Uranium		1.88E+01	1.88E+00	1.88E+01	5.64E+01				mg/kg
Vanadium		3.04E+00	3.04E-01	3.04E+00	9.12E+00				mg/kg
Zinc		2.50E+03	2.50E+02	2.50E+03	7.50E+03				mg/kg
Aroclor 1260	1.75E-01					1.75E-01	1.75E+00	1.75E+01	mg/kg
Benz[a]anthracene	1.94E-01					1.94E-01	1.94E+00	1.94E+01	mg/kg
Benzo[a]pyrene	1.94E-02					1.94E-02	1.94E-01	1.94E+00	mg/kg
Benzo[b]fluoranthene	1.94E-01					1.94E-01	1.94E+00	1.94E+01	mg/kg
Dibenz[a,h]anthracene	1.94E-02					1.94E-02	1.94E-01	1.94E+00	mg/kg
Total Dioxins/Furans	1.89E-06					1.89E-06	1.89E-05	1.89E-04	mg/kg
Indeno[1,2,3-cd]pyrene	1.94E-01					1.94E-01	1.94E+00	1.94E+01	mg/kg
Total PCBs	1.63E-01					1.63E-01	1.63E+00	1.63E+01	mg/kg
Total PAHs	1.94E-02					1.94E-02	1.94E-01	1.94E+00	mg/kg
Neptunium-237+D	2.71E-01					2.71E-01	2.71E+00	2.71E+01	pCi/g
Plutonium-239*	1.07E+01					1.07E+01	1.07E+02	1.07E+03	pCi/g
Radium-226+D	2.56E-02					2.56E-02	2.56E-01	2.56E+00	pCi/g
Uranium-234	1.89E+01					1.89E+01	1.89E+02	1.89E+03	pCi/g
Uranium-235+D	3.95E-01					3.95E-01	3.95E+00	3.95E+01	pCi/g
Uranium-238+D	1.70E+00					1.70E+00	1.70E+01	1.70E+02	pCi/g

Table F.74. RGOs for Soil COCs of the BGOU SWMUs (Continued)

COC	Cancer NAL	Noncancer NAL	RGO at HI=0.1	RGO at HI=1	RGO at HI=3	RGO at ELCR= 1×10^{-6}	RGO at ELCR= 1×10^{-5}	RGO at ELCR= 1×10^{-4}	Units
Excavation Worker Soil Exposure									
Aluminum		4.84E+03	4.84E+02	4.84E+03	1.45E+04				mg/kg
Antimony		4.52E-01	4.52E-02	4.52E-01	1.36E+00				mg/kg
Arsenic	3.13E-01	5.03E+00	5.03E-01	5.03E+00	1.51E+01	3.13E-01	3.13E+00	3.13E+01	mg/kg
Barium		7.11E+02	7.11E+01	7.11E+02	2.13E+03				mg/kg
Beryllium and compounds	3.83E-03	1.15E+00	1.15E-01	1.15E+00	3.45E+00	3.83E-03	3.83E-02	3.83E-01	mg/kg
Cadmium	2.12E+00	1.45E+01	1.45E+00	1.45E+01	4.35E+01	2.12E+00	2.12E+01	2.12E+02	mg/kg
Chromium	2.85E+02	4.36E+02	4.36E+01	4.36E+02	1.31E+03	2.85E+02	2.85E+03	2.85E+04	mg/kg
Cobalt	1.22E+03	3.11E+02	3.11E+01	3.11E+02	9.33E+02	1.22E+03	1.22E+04	1.22E+05	mg/kg
Copper		4.37E+02	4.37E+01	4.37E+02	1.31E+03				mg/kg
Iron		2.02E+03	2.02E+02	2.02E+03	6.06E+03				mg/kg
Manganese		2.90E+02	2.90E+01	2.90E+02	8.70E+02				mg/kg
Nickel	1.32E+04	2.05E+02	2.05E+01	2.05E+02	6.15E+02	1.32E+04	1.32E+05	1.32E+06	mg/kg
Uranium		1.10E+01	1.10E+00	1.10E+01	3.30E+01				mg/kg
Vanadium		4.03E+00	4.03E-01	4.03E+00	1.21E+01				mg/kg
Zinc		2.50E+03	2.50E+02	2.50E+03	7.50E+03				mg/kg
Aroclor 1260	1.55E-01					1.55E-01	1.55E+00	1.55E+01	mg/kg
Benz[a]anthracene	2.16E-01					2.16E-01	2.16E+00	2.16E+01	mg/kg
Benzo[a]pyrene	2.16E-02					2.16E-02	2.16E-01	2.16E+00	mg/kg
Benzo[b]fluoranthene	2.16E-01					2.16E-01	2.16E+00	2.16E+01	mg/kg
Dibenz[a,h]anthracene	2.16E-02					2.16E-02	2.16E-01	2.16E+00	mg/kg
Total Dioxins/Furans	1.79E-06					1.79E-06	1.79E-05	1.79E-04	mg/kg
Indeno[1,2,3-cd]pyrene	2.16E-01					2.16E-01	2.16E+00	2.16E+01	mg/kg
Total PCBs	1.48E-01					1.48E-01	1.48E+00	1.48E+01	mg/kg
Total PAHs	2.16E-02					2.16E-02	2.16E-01	2.16E+00	mg/kg
Neptunium-237+D	3.27E-01					3.27E-01	3.27E+00	3.27E+01	pCi/g
Plutonium-239*	1.62E+00					1.62E+00	1.62E+01	1.62E+02	pCi/g
Radium-226+D	3.30E-02					3.30E-02	3.30E-01	3.30E+00	pCi/g
Uranium-234	2.83E+00					2.83E+00	2.83E+01	2.83E+02	pCi/g
Uranium-235+D	4.55E-01					4.55E-01	4.55E+00	4.55E+01	pCi/g
Uranium-238+D	1.17E+00					1.17E+00	1.17E+01	1.17E+02	pCi/g

[A] COC = contaminant of concern
[B] RGO = remedial goal option. RGOs for soil for both HI and ELCR are calculated from the 2008 draft NALs (DOE 2008).

Table F.75. RGOs for Groundwater COCs of the BGOU SWMUs

Residential User Groundwater Exposure

COC[A]	EPC[B]	SWMU[C]	ELCR at EPC	HI at EPC	RGO[D] at HI=0.1	RGO at HI=1	RGO at HI=3	RGO at ELCR= 1 x 10^{-6}	RGO at ELCR= 1 x 10^{-5}	RGO at ELCR= 1 x 10^{-4}	MCL	mg/L
Antimony	7.99E-02	145		5.97E+00	1.34E-03	1.34E-02	1.34E-01				0.006	mg/L
Arsenic	6.21E-02	145	1.65E-03	1.99E+01	3.12E-04	3.12E-03	9.36E-03	3.76E-05	3.76E-04	3.76E-03	0.010	mg/L
Manganese	1.01E+00	5		2.15E+00	4.70E-02	4.70E-01	1.41E+00				---	mg/L
Selenium	1.51E-02	30		2.90E-01	5.21E-03	5.21E-02	1.56E-01				0.05	mg/L
Uranium	4.89E-02	3		7.82E+00	604	603	1.88E-02				0.03	
Total PCBs	5.23E-05	7	7.09E-06	4.20E+00	1.25E-06	1.25E-05	3.74E-05	7.38E-06	7.38E-05	7.38E-04	0.0005	mg/L
1,1-DCE	8.98E-02	7	2.08E-03	8.51E-01	1.06E-02	1.06E-01	3.17E-01	4.32E-05	4.32E-04	4.32E-03	---	mg/L
cis-1,2-DCE	1.15E+01	2		6.07E+02	1.89E-03	1.89E-02	5.68E-02				0.07	mg/L
Naphthalene	5.55E-03	5		2.80E+00	1.98E-04	1.98E-03	5.95E-03				---	mg/L
TCE	1.18E+00	4	3.67E-02	5.39E+02	2.19E-04	2.19E-03	6.57E-03	3.22E-05	3.22E-04	3.22E-03	0.005	mg/L
Vinyl Chloride	2.61E-02	4	1.65E-02	1.21E+00	2.16E-03	2.16E-02	6.47E-02	1.58E-06	1.58E-05	1.58E-04	0.002	mg/L
Technetium-99	1.01E+04	145	5.54E-04					1.82E+01	1.82E+02	1.82E+03	900[E]	pCi/L
Uranium-234	7.94E+00	7	1.11E-05					7.12E-01	7.12E+00	7.12E+01	20[F]	pCi/L
Uranium-238	1.59E+01	3	2.76E-05					5.76E-01	5.76E+00	5.76E+01	20[F]	pCi/L

[A] COC = contaminant of concern
[B] EPC = exposure point concentration; represents maximum EPC value for all SWMUs where constituent was a COC for the applicable scenario
[C] SWMU = the SWMU associated with the maximum EPC value
[D] RGO = remedial goal option
[E] converted from MCL of 4 mrem/yr dose (DOE 2001)
[F] converted from MCL for total uranium of 0.03 mg/L (DOE 2001)

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ATTACHMENT F1

SUMMARY TABLES FOR NEW SURFACE SOIL DATA

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Table F1.1 Summary of New Maximum Detected Concentrations in SWMU 3 Surface Soil

Analyte	New Max Value for SWMU 3	Residental Child No Action Limit*	Exceeds Residential Child NAL	Industrial Worker No Action Limit*	Exceeds Industrial Worker NAL	Background Concent-ration	Background Exceeded?	COPC for Child Resident?	COPC for Industrial Worker?
Metals (mg/kg)									
Aluminum	8,570	732	Yes	4,640	Yes	13,000	No	No	No
Antimony	15.7	0.0635	Yes	0.379	Yes	0.21	Yes	Yes	Yes
Arsenic	7.62	0.132	Yes	0.523	Yes	12	Yes	Yes	Yes
Barium	87.7	37	Yes	229	No	200	No	No	No
Calcium	3,5200	NA	NA	NA	NA	200,000	No	No	No
Chromium	12.5	60.5	No	356	No	16	Yes	No	No
Cobalt	6.41	209	No	1920	No	14	No	No	No
Copper	10.6	68.1	No	493	No	19	No	No	No
Iron	15,700	314	Yes	2070	Yes	2,8000	Yes	Yes	Yes
Lead	12.7	50	No	50	No	36	No	No	No
Magnesium	2,500	NA	NA	NA	NA	7,700	No	No	No
Manganese	558	7.46	Yes	45.2	Yes	1,500	No	No	No
Mercury	0.024	100,000 or 0.158	No	100,000 or 0.982	No	0.2	No	No	No
Molybdenum	6.21	10.9	Yes	83	No	NA	NA	Yes	No
Nickel	10.7	0.34	Yes	242	No	21	Yes	Yes	No
Sodium	112	NA	NA	NA	NA	320	No	No	No
Tin	15	439	No	2790	No	NA	NA	No	No
Uranium	43	2.16	Yes	20.2	Yes	4.9	Yes	Yes	Yes
Vanadium	33.7	0.562	Yes	3.32	Yes	38	No	No	No
Zinc	31.8	401	No	2,730	No	65	Yes	No	No
PCBs (mg/kg)									
None Detected									
Organics (mg/Kg)									
Acetone	8.11	53.4	No	358	No	NA	NA	No	No
Trichloroethene	6.33	0.741	Yes	2.51	Yes	NA	NA	Yes	Yes

Table F1.1 Summary of New Maximum Detected Concentrations in SWMU 3 Surface Soil (Continued)

Analyte	New Max Value for SWMU 3	Residental Child No Action Limit*	Exceeds Residential Child NAL	Industrial Worker No Action Limit*	Exceeds Industrial Worker NAL	Background Concent-ration	Background Exceeded?	COPC for Child Resident?	COPC for Industrial Worker?
Radionuclides (pCi/g)									
Cesium-137	0.344	0.0128	Yes	0.0858	Yes	0.49	Yes	Yes	Yes
Plutonium-239	0.0562	2.22	Yes	11.5	No	0.025	Yes	Yes	No
Technetium-99	21.6	67.4	No	362	No	2.5	Yes	No	No
Thorium-228	0.442	0.00418	Yes	0.028	Yes	NA	NA	Yes	Yes
Thorium-230	0.46	2.85	No	14.9	No	1.5	Yes	No	No
Thorium-232	0.519	2.61	Yes	13.5	No	NA	NA	Yes	No
Uranium	7.02	NA	NA	NA	NA	NA	NA	No	No
Uranium-234	0.958	3.81	Yes	19.8	No	2.5	Yes	Yes	No
Uranium-235/236	0.079	0.0591	Yes	0.395	No	0.14	Yes	Yes	No
Uranium-238	5.99	0.261	Yes	1.71	Yes	1.2	Yes	Yes	Yes

* NAL values are from DOE 2001. *Methods for Conducting Human Health Risk Assessment and Risk Evaluations at the Paducah Gaseous Diffusion Plant*, DOE/OR/07-1506&D1, U. S. Department of Energy, Paducah, KY, December.

Note: -- means that there was no value recorded in the applicable table for that analyte

Table F1.2 Summary of New Maximum Detected Concentrations in SWMU 7 Surface Soil

Analyte	New Max Value for SWMU 7	No Action Limit*	Exceeds Residential Child NAL	Background Concentration	Background Exceeded?	COPC?	SWMU 7 COPC
Metals (mg/kg)							
Aluminum	8,910	732	Yes	13,000	No	No	Yes
Arsenic	3.14	0.132	Yes	12	No	No	Yes
Barium	61.2	37	Yes	200	No	No	No
Calcium	2,100	--	NA	200,000	No	No	No
Chromium	17.9	60.5	No	16	Yes	No	Yes
Cobalt	6.75	209	No	14	No	No	Yes
Copper	53.9	68.1	No	19	Yes	No	No
Iron	13,100	314	Yes	28,000	No	No	Yes
Lead	11.9	50	No	36	No	No	Yes
Magnesium	1,040	--	NA	7,700	No	No	No
Manganese	122	7.46	Yes	1,500	No	No	No
Mercury	0.043	100,000 or 0.158	No	0.2	No	No	No
Nickel	29.8	0.34	Yes	21	Yes	Yes	Yes
Uranium	1,270	2.16	Yes	4.9	Yes	Yes	Yes
Vanadium	31	0.562	Yes	38	No	No	Yes
Zinc	37.8	401	No	65	Yes	No	Yes
PCBs (ug/kg)							
PCB-1248	14,800	57.4	Yes	--	NA	Yes	--
PCB-1254	130	38.8	Yes	--	NA	Yes	Yes
PCB Total	14,800	1,640 or 57.4	Yes	--	NA	Yes	--

Table F1.2 Summary of New Maximum Detected Concentrations in SWMU 7 Surface Soil (Continued)

Analyte	New Max Value for SWMU 7	No Action Limit*	Exceeds Residential Child NAL	Background Concentration	Background Exceeded?	COPC?	SWMU 7 COPC
Organics (ug/Kg)							
Acetone	83.7	5,340	No	--	NA	No	--
Di-n-butylphthalate	940	264,000	No	--	NA	No	--
Methylene chloride	5.7	3,920	No	--	NA	No	No
Radionuclides (pCi/g)							
Alpha activity	65.1	--	NA	--	NA	No	Yes
Beta activity	139	--	NA	--	NA	No	Yes
Neptunium-237	0.0775	0.0405	Yes	0.1	No	No	Yes
Plutonium-239	0.141	2.22	No	0.025	Yes	No	Yes
Technetium-99	11.1	67.4	No	2.5	Yes	No	No
Thorium-228	3.36	0.00418	Yes	1.6	Yes	Yes	--
Thorium-230	1.94	2.85	No	1.5	Yes	No	No
Thorium-232	0.459	2.61	No	1.5	No	No	--
Thorium-234	2,650	--	NA	--	NA	No	--
Uranium	2,750	--	NA	--	NA	No	--
Uranium-234	318	3.81	Yes	2.5	Yes	Yes	Yes
Uranium-235/236	42.1	0.0591	Yes	0.14	Yes	Yes	Yes
Uranium-238	2,390	0.261	Yes	1.2	Yes	Yes	Yes

Note: -- means that there was no value recorded in the applicable table for that analyte

* NAL values are from DOE 2001. *Methods for Conducting Human Health Risk Assessment and Risk Evaluations at the Paducah Gaseous Diffusion Plant*, DOE/OR/07-1506&D1, U. S. Department of Energy, Paducah, KY, December.

ATTACHMENT F2

HISTORICAL RISK ASSESSMENT TABLES

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TABLES

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Table F2.1. Cancer Risk Estimates for Direct Contact to Soil

Future Industrial Exposure
Scenario: unrestricted worker (250 days/year)

Chemical	Slope Factor (mg/kg-day)-1	Soil Conc. mg/kg	Chronic Daily Intake mg/kg-day	Excess Lifetime Cancer Risk
INGESTION				
Pentachlorophenol	0.12	0.1000	1.7E-08	2.1E-09
OCDD (total)	150	0.0033	5.8E-10	8.6E-08
PCB-1248	7.7	0.2100	3.7E-08	2.8E-07
PCB-1260	7.7	0.1300	2.3E-08	1.7E-07
Arsenic	1.75	10.1700	1.8E-06	3.1E-06
Beryllium	4.3	0.7400	1.3E-07	5.6E-07
pathway sum=				4E-06
DERMAL ABSORPTION				
Pentachlorophenol				
OCDD (total)	0.12	0.1000	1.1E-08	1.3E-09
PCB-1248	150	0.0033	3.6E-10	5.4E-08
PCB-1260	7.7	0.2100	2.3E-08	1.BE-07
Arsenic	7.7	0.1300	1.4E-08	1.1E-07
Beryllium	1.75	10.1700	1.1E-07	1.9E-07
	4.3	0.7400	8.1E-09	3.5E-08
pathway sum=				6E-07
	Unit Risk (ug/m^3)-1			
INHALATION				
OCDD (total)	0.000000033	0.0033	5.0E-14	5.8E-18
Arsenic	0.0043	10.1700	1.5E-10	2.3E-09
Beryllium	0.0024	0.7400	1.1E-11	9.4E-11
Chromium VI	0.012	19.0000	2.9E-10	1.2E-08
Nickel (soluble salt)	0.00024	25.1000	3.8E-10	3.2E-10
pathway sum=				1E-08
sum of pathways=				5E-06

Ingestion: Intake (mg/kg-d)=(conc. in soil-IngR*CF*FI*EF*ED)/(BW*AT)
Dermal Absorption: Abs dose(mg/kg-d)=(soil conc.*CF*SA*AF*ABS*EF*ED)/(BW*AT)
Inhalation: Inh dose (mg/kg-d)=(soil conc.*EF*ED*InhR*(1/PEF)/(BW*AT)
SFI=Unit Risk*(BW/InhR)*1000

exposure parameters

IngR=Ingestion rate (mg soil/day)	50	
CF=Conversion factor (10E-6)	1E-06	
FI=Fraction ingested	1	
EF=Exposure frequency (days/year)	250	
ED=Exposure duration (year)	25	
BW=Body weight (kg)	70	
AT=Averaging time (days	25,550	
SA=Skin surface area (cm^2)	3,120	
AF=Soil to skin adherence (mg/cm^2)	1	
ABS=Absorption (0.l % metals; l % organics)	0.001	0.01
PEF=Particulate emission (m^3/kg)	4.63E+09	
InhR=Inhalation rate (m^3/day)	20	

Table taken from Attachment 2-1 *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds, Solid Waste Management Units 2 and 3, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* DOE/OR/07-1141&D2 (KY/ER-32 & D2) September 1994 Revision 2.

Table F2.2. Chronic Hazard Index Estimates for Direct Contact to Soil

Future Industrial Exposure
Scenario: unrestricted worker (250 days/year)

Chemical	Reference Dose mg/kg-day	Soil Conc. mg/kg	Chronic Daily Intake mg/kg-day	Chronic Hazard
INGESTION				
Pentachlorophenol	0.03	0.10	4.9E-08	2E-06
Arsenic	0.0003	10.17	5.0506	2E-02
Barium	0.07	132.68	6.5E-05	9E-04
Beryllium	0.005	0.74	3.6E-07	7E-05
Chromium VI	0.005	19.00	9.3E-06	2E-03
Copper	0.037	24.71	1.2E-05	3E-04
Manganese	0.14	2,541.05	1.2E-03	9E-03
Mercury	0.0003	0.15	7.3E-08	2E-04
Nickel (soluble salt)	0.02	25.10	1.2E-05	6E-04
Selenium	0.005	0.40	2.0E-07	4E-05
Silver	0.005	5.38	2.6E-06	5E-04
Vanadium	0.007	31.80	1.6E-05	2E-03
Zinc	0.3	67.05	3.3E-05	1 E-04
Uranium (soluble salt)	0.003	83.58	4.1 E-05	1 E-02
pathway sum=				0.05
DERMAL ABSORPTION				
Pentachlorophenol	0.03	0.10	3.1E-08	1E-06
Arsenic	0.0003	10.17	3.1E-07	1E-03
Barium	0.07	132.68	4.1E-06	6E-05
Beryllium	0.005	0.74	2.3E-08	5E-06
Chromium VI	0.005	19.00	5.8E-07	1E-04
Copper	0.037	24.71	7.5E-07	2E-05
Manganese	0.005	2,541.05	7.8E-05	2E-02
Mercury	0.0003	0.15	4.6E-09	2E-05
Nickel (soluble salt)	0.02	25.10	7.7E-07	4E-05
Selenium	0.005	0.40	1.2E-08	2E-06
Silver	0.005	5.38	1.6E-07	3E-05
Vanadium	0.007	31.80	9.7E-07	1E-04
Zinc	0.3	67.05	2.0E-06	7E-06
Uranium (soluble salt)	0.003	83.58	2.6E-06	9E-04
pathway sum=				0.02
	Reference Conc. mg/m^3			
INHALATION				
Barium	0.0005	132.68	5.6E-09	4E-05
Chromium VI	0.000002	19.00	8.oE-10	1 E-03
Manganese	0.0004	2,541.05	1.1 E-07	9E-04
Mercury	0.0003	0.15	6.3E-12	7E-08
pathway sum=				0.002
sum of pathways=				0.07

Ingestion: Intake (mg/kg-d)=(conc. in soil-IngR*CF*FI*EF*ED)/(BW*AT)
Dermal Absorption: Abs dose(mg/kg-d)=(soil conc.*CF*SA*AF*ABS*EF*ED)/(BW*AT)
Inhalation: Inh dose (mg/kg-d)=(soil conc.*EF*ED*InhR*(1/PEF)/(BW*AT)
SFI=Unit Risk*(BW/InhR)*1000

Table F2.2. Chronic Hazard Index Estimates for Direct Contact to Soil (Continued)

exposure parameters		
IngR=Ingestion rate (mg soil/day)	50	
CF=Conversion factor (10E-6)	1E-06	
FI=Fraction ingested	1	
EF=Exposure frequency (days/year)	250	
ED=Exposure duration (year)	25	
BW=Body weight (kg)	70	
AT=Averaging time (days	25,550	
SA=Skin surface area (cm^2)	3,120	
AF=Soil to skin adherence (mg/cm^2)	1	
ABS=Absorption (0.l % metals; l % organics)	0.001	0.01
PEF=Particulate emission (m^3/kg)	4.63E+09	
InhR=Inhalation rate (m^3/day)	20	

Table taken from Attachment 2-2 *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds, Solid Waste Management Units 2 and 3, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* DOE/OR/07-1141&D2 (KY/ER-32 & D2) September 1994 Revision 2.

Table F2.3. Excess Lifetime Risk of Cancer Incidence for Direct Contact to Soil

Future Industrial Exposure
Scenario: unrestricted worker (250 days/year)

Radionuclide[a]	Soil Concentration (pCi/g) (SC)	Annual Intake (pCi)	Total Intake (pCi)	Dose Conversion Factor[b] (mrem/pCi) or (mrem*g/pCi/h)	Committed Effective Dose Equivalent 1 Yr Intake (mrem/yr)[c]	Total Committed Effective Dose Equivalent (mrem)	Cancer Incidence Risk Factor (pCi)-1[d] or (g/pCi-1)	Risk of Cancer Incidence
INGESTION								
Neptunium-237+D	0.32	4.00	100.0	4.4E-03	1.8E-02	4.4E-01	2.2E-10	2.2E-08
Plutonium-239	7.90	98.75	2,468.8	3.7E-04	3.6E-02	9.1E-01	2.3E-10	5.7E-07
Thorium-230	14.00	175.00	4,375.0	5.5E-04	9.6E-02	2.4E+00	1.3E-11	5.7E-08
Uranium-234	18.00	225.00	5,625.0	2.8E-04	6.4E-02	1.6E+00	1.6E-11	9.0E-08
Ursnium-235+D	1.70	21.25	531.3	2.7E-04	5.7E-03	1.4E-01	1.6E-11	8.5E-09
Uranium-238+D	69.00	862.50	21,562.5	2.6E-04	2.2E-01	5.5E+00	2.8E-11	6.0E-07
Technetium-99	58.00	725.00	18,125.0	1.5E-06	1.l E-03	2.6E-02	1.3E-l2	2.4E-08
Pathway sum=					4.4E-01	1.1E+0l		1 E-06
INHALATION								
Neptunium-237+D	0.32	3.5E-04	8.6E-03	5.4E-01	1.9E-04	4.7E-03	2.9E-08	2.5E-10
Plutonium-239	7.90	8.5E-03	2.1E-01	3.1E-01	2.6E-03	6.6E-02	3.8E-08	8.1E-09
Technetium-99	14.00	1.5E-02	3.8E-01	8.3E-06	1.3E-07	3.1 E-06	8.3E-12	3.1E-12
Thorium-230	18.00	1.9E-02	4.9E-01	2.6E-01	5.1E-03	1.3E-01	2.9E-08	1.4E-08
Uranium-234	1.70	1.8E-03	4.6E-02	1.3E-01	2.4E-04	6.1E-03	2.6E-08	1.2E-09
Ursnium-235+D	69.00	7.5E-02	1.9E+00	1.2E-01	9.2E-03	2.3E-01	2.5E-08	4.7E-08
Uranium-238+D	58.00	6.3E-02	1.6E+00	1.2E-01	7.4E-03	1.8E-01	5.2E-08	8.1E-08
Pathway sum=					2.5E-02	6.2E-0l		2 E-07
EXPOSURE TO EXTERNAL RADIATION								
Neptunium-237+D	0.32			1.0E-04	8.4E-02	1.6E+00	4.3E-07	8.2E-07
Plutonium-239	7.90			4.2E-08	6.6E-04	1.7E-02	1.7E-11	8.0E-10
Technetium-99	14.00			1.5E-08	4.2E-04	1.0E-02	6.0E-13	5.0E-11
Thorium-230	18.00			1.2E-07	4.3E-03	1.1E-01	5.4E-11	5.8E-09
Uranium-234	1.70			5.7E-08	1.9E-04	4.8E-03	3.0E-11	3.0E-10
Ursnium-235+D	69.00			3.8E-05	5.2E+00	1.3E+02	2.4E-07	9.9E-05
Uranium-238+D	58.00			7.5E-06	8.7E-01	2.2E+01	3.6E-08	1.2E-05
Pathway sum=					6.2E+00	1.5E+02		1E-04
Sum of the Pathways=					6.6E+00	1.7E+02		1E-04

exposure assumptions

Ingestion Rate IR (g/day)	0.05	Ingestion Risk= SCx IRxEFx EDx RF
Exposure Frequency (EF) (day/yr)	250	Inhalation Risk = SC + IR x EF x ED x CF x l/PEF x RF
Exposure Duration (ED) (years)	25	External Radiation Risk = SC x ED x Te x (1-SF) x RF
Particulate emission factor (m^3/kg):	4.63E+09	
Worker inhalation rate (m^3/day):	20	
Conversion factor(1000 g/kg):	1000	
Exposure Time (ET) (hr/day)	8	
Shielding factor (SF):	0	
Fraction of year exposed (Te):	0.24	Te = (ET x EF) / (8400 HR/YR)

NOTES:

(a) Radionuclides shown with +D include short lived daughter products in risk calculations.

(b) Ingestion and inhalation dose factors were taken from Federal Guidance Report 11. "Limiting Values of Radionuclide Intake and Air Concentration and Dose Factors for Inhalation, Submersion, and Ingestion"(EPA-520/1-88-020). Dose after intake of parent radionuclide. External Radiation dose factors were taken from NUREG/CR-5512 "Residual Radioactive Contamination from Decommissioning,
Technical Basis for Translating Contamination Levels to Annual Dose."

(c) Committed effective dose equivalent expressed as committed (50 yr) dose (mrem) due to one year of exposure(mrem/yr).

(d) Cancer risk factors taken from January1992 HEAST tables.

Table taken from Attachment 2-3 *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds, Solid Waste Management Units 2 and 3, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* DOE/OR/07-1141&D2 (KY/ER-32 & D2) September 1994 Revision 2.

Table F2.4. Cancer Risk Estimates for Direct Contact to Soil

Current Industrial Exposure
Scenario: worker/intruder (25 days/year)

Chemical	Slope Factor (mg/kg-day)-1	Soil Conc. (mg/kg)	Chronic Daily Intake (mg/kg-day)	Excess Lifetime Cancer Risk
INGESTION				
Pentachlorophenol	0.12	0.10	1.7E-09	2.1E-10
OCDD (total)	150	0.0033	5.8E-11	8.6E-09
PCB-1248	7.7	0.21	3.7E-09	2.8E-08
PCB-1260	7.7	0.130	2.3E-09	1.7E-08
Arsenic	1.75	10.17	1.8E-07	3.1E-07
Beryllium	4.3	0.74	1.3E-08	5.6E-08
Pathway sum=				4E-07
DERMAL ABSORPTION				
Pentachlorophenol	0.12	0.10	1.1 E-09	1.3E-10
OCDD (total)	150	0.0033	3.6E-11	5.4E-09
PCB-1248	7.7	0.21	2.3E-09	1.8E-08
PCB-1260	7.7	0.130	1.4E-09	1.1 E-08
Arsenic	1.75	10.17	l.lE-08	1.9E-08
Beryllium	4.3	0.74	8.1E-10	3.5E-09
Pathway sum=				6E-08
	Unit Risk (ug/m^3)-1			
INHALATION				
OCDD (total)	0.000000033	0.0033	5.OE-15	5.8E-19
Arsenic	0.0043	10.17	1.5E-11	2.3E-10
Beryllium	0.0024	0.74	l.lE-12	9.4E-12
Chromium VI	0.01 2	19.00	2.9E-11	1.2E-09
Nickel (soluable salts)	0.00024	25.10	3.8E-11	3.2E-11
Pathway sum=				1E-09
Sum of pathways=				5E-07

Ingestion: Intake (mg/kg-d)=(conc. in soil*IngR*CF*FI*ED)/(BW*AT)
Abs dose(mg/kg-d)=(soil conc. *CF*SA*AF*ABS*EF*ED)/(BW*AT)

Dermal Absorption:

Inhalation: Inh dose (mg/kg-d)=(soil conc. *EF*ED*InhR*(l/PEF)/(BW*AT)
SFi=Unit Risk*(BW/InhR)*1000

exposure parameters

IngR=Ingestion rate (mg soil/day)		
CF=Conversion factor (10E-6)	50	
FI=Fraction ingested	1E-06	
EF=Exposure frequency (days/year)	1	
ED=Exposure duration (year)	25	
BW=Body weight (kg)	25	
AT=Averaging time (days	70	
SA=Skin surface area (cm^2)	25,550	
AF=Soil to skin adherence (mg/cm^2)	3,120	
ABS=Absorption (0.l % metals; l % organics)	1	
PEF=Particulate emission (m^3/kg)	0.001	0.01
InhR=Inhalation rate (m^3/day)	4.63E+09	
	20	

Table taken from Attachment 2-4 *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds, Solid Waste Management Units 2 and 3, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* DOE/OR/07-1141&D2 (KY/ER-32 & D2) September 1994 Revision 2.

Table F2.5. Chronic Hazard Index Estimates for Direct Contact to Soil

Current Industrial Exposure
Scenario: worker/intruder (25 days/year)

Chemical	Reference Dose mg/kg-day	Soil Conc. mg/kg	Chronic Daily Intake mg/kg-day	Hazard Quotient
INGESTION				
Pentachlorophenol	0.03	0.10	4.9E-09	1.6E-07
Arsenic	0.0003	10.17	5.0E-07	1.7E-03
Barium	0.07	132.68	6.5E-06	9.3E-05
Beryllium	0.005	0.74	3.6E-08	7.2E-06
Chromium VI	0.005	19.00	9.3E-07	1.9E-04
Copper	0.037	24.71	1.2E-06	3.3E-05
Manganese	0.14	2,541.05	1.2E-04	8.9E-04
Mercury	0.0003	0.15	7.3E-09	2.4E-05
Nickel (soluble salt)	0.02	25.10	1.2E-06	6.1E-05
Selenium	0.005	0.40	2.0E-08	3.9E-06
Silver	0.003	5.38	2.6E-07	8.8E-05
Vanadium	0.007	31.80	1.6E-06	2.2E-04
Zinc	0.30	67.05	3.3E-06	1.1E-05
Uranium (soluble salt)	0.003	83.58	4.1 E-06	1.4E-05
pathway sum=				0.005
DERMAL ABSORPTION				
Pentachlorophenol	0.03	0.10	3.1E-09	1.0E-07
Arsenic	0.0003	10.17	3.1E-08	1.0E-04
Barium	0.07	132.68	4.1E-07	5.8E-06
Beryllium	0.005	0.74	2.3E-09	4.5E-07
Chromium VI	0.005	19.00	5.8E-08	1.2E-05
Copper	0.037.	24.71	7.5E-08	2.0E-06
Manganese	0.005	2,541.05	7.8E-06	1.6E-03
Mercury	0.0003	0.15	4.6E-10	1.5E-06
Nickel (soluble salt)	0.02	25.10	7.7E-08	3.8E-06
Selenium	0.005	0.40	1.2E-09	2.4E-07
Silver	0.003	5.38	1.6E-08	5.5E-06
Vanadium	0.007	31.80	9.7E-08	1.4E-05
Zinc	0.3	67.05	2.0E-07	6.8E-07
Uranium (soluble salt)	0.003	83.58	2.6E-07	8.5E-05
pathway sum=				0.002
	Reference Conc. mg/m^3			
INHALATION				
Barium	0.0005	132.68	5.6E-10	3.9E-06
Chromium VI	0.000002	19.00	8.0E-11	1.4E-04
Manganese	0.0004	2,541.05	1.1E-08	9.4E-05
Mercury	0.0003	0.15	6.3E-13	7.4E-09
pathway sum=				0.0002
sum of pathways=				0.007
Ingestion:	Intake (mg/kg-d)=(conc. in soil-IngR*CF*FI*EF*ED)/(BW*AT)			
Dermal Absorption:	Abs dose(mg/kg-d)=(soil conc.*CF*SA*AF*ABS*EF*ED)/(BW*AT)			
Inhalation:	Inh dose (mg/kg-d)=(soil conc.*EF*ED*InhR*(1/PEF)/(BW*AT)			
	SFI=Unit Risk*(BW/InhR)*1000			

Table F2.5. Chronic Hazard Index Estimates for Direct Contact to Soil (Continued)

exposure parameters		
IngR=Ingestion rate (mg soil/day)	50	
CF=Conversion factor (10E-6)	1E-06	
FI=Fraction ingested	1	
EF=Exposure frequency (days/year)	25	
ED=Exposure duration (year)	25	
BW=Body weight (kg)	70	
AT=Averaging time (days	25,550	
SA=Skin surface area (cm^2)	3,120	
AF=Soil to skin adherence (mg/cm^2)	1	
ABS=Absorption (0.l % metals; l % organics)	0.001	0.01
PEF=Particulate emission (m^3/kg)	4.63E+09	
InhR=Inhalation rate (m^3/day)	20	

Table taken from Attachment 2-5 *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds, Solid Waste Management Units 2 and 3, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* DOE/OR/07-1141&D2 (KY/ER-32 & D2) September 1994 Revision 2.

Table F2.6. Excess Lifetime Risk of Cancer Incidence for Direct Contact to Soil

Current Industrial Exposure
Scenario: worker/intruder (25 days/year)

Radionuclide[a]	Soil Concentration (pCi/g) (SC)	Annual Intake (pCi)	Total Intake (pCi)	Dose Conversion Factor[b] (mrem/pCi) or (mrem*g/pCi/h)	Committed Effective Dose Equivalent 1 Yr Intake (mrem/yr)[c]	Total Committed Effective Dose Equivalent (mrem)	Cancer Incidence Risk Factor (pCi)-1[d] or (g/pCi-1)	Risk of Cancer Incidence
INGESTION								
Neptunium-237+D	0.36	0.45	11.3	4.4E-03	2.0E-03	5.0E-02	2.2E-10	2.5E-09
Plutonium-239	7.90	9.88	246.9	3.7E-04	3.6E-03	9.1E-01	2.3E-10	5.7E-08
Thorium-230	14.00	17.50	437.5	5.5E-04	9.6E-03	2.4E-01	1.3E-11	5.7E-09
Uranium-234	18.00	22.50	562.5	2.8E-04	6.4E-03	1.6E-01	1.6E-11	9.0E-09
Ursnium-235+D	1.70	2.13	53.1	2.7E-04	5.7E-04	1.4E-02	1.6E-11	8.5E-10
Uranium-238+D	69.00	86.25	2156.3	2.6E-04	2.2E-02	5.5E-01	2.8E-11	6.0E-08
Technetium-99	58.00	72.50	1812.5	1.5E-06	1.l E-04	2.6E-03	1.3E-l2	2.4E-09
Pathway sum=					4.4E-02	1.1E+00		1 E-07
INHALATION								
Neptunium-237+D	0.36	3.9E-05	9.7E-04	5.4E-01	2.1E-05	5.2E-04	2.9E-08	2.8E-11
Plutonium-239	7.90	8.5E-04	2.1E-02	3.1E-01	2.6E-04	6.6E-03	3.8E-08	8.1E-10
Technetium-99	14.00	1.5E-03	3.8E-02	8.3E-06	1.3E-08	3.1 E-07	8.3E-12	3.1E-13
Thorium-230	18.00	1.9E-03	4.9E-02	2.6E-01	5.1E-04	1.3E-02	2.9E-08	1.4E-09
Uranium-234	1.70	1.8E-04	4.6E-03	1.3E-01	2.4E-05	6.1E-04	2.6E-08	1.2E-10
Ursnium-235+D	69.00	7.5E-03	1.9E-01	1.2E-01	9.2E-04	2.3E-02	2.5E-08	4.7E-09
Uranium-238+D	58.00	6.3E-03	1.6E-01	1.2E-01	7.4E-04	1.8E-02	5.2E-08	8.1E-09
Pathway sum=	7.90				2.5E-03	6.2E-02		2 E-08
EXPOSURE TO EXTERNAL RADIATION								
Neptunium-237+D	0.36			1.0E-04	7.2E-03	1.8E-01	4.3E-07	9.2E-08
Plutonium-239	7.90			4.2E-08	6.6E-05	1.7E-03	1.7E-11	8.0E-11
Technetium-99	14.00			1.5E-08	4.2E-05	1.0E-03	6.0E-13	5.0E-12
Thorium-230	18.00			1.2E-07	4.3E-04	1.1E-02	5.4E-11	5.8E-10
Uranium-234	1.70			5.7E-08	1.9E-05	4.8E-04	3.0E-11	3.0E-11
Ursnium-235+D	69.00			3.8E-05	5.2E-01	1.3E+01	2.4E-07	9.9E-06
Uranium-238+D	58.00			7.5E-06	8.7E-02	2.2E+00	3.6E-08	1.2E-06
Pathway sum=	7.90				6.2E-01	1.5E+01		1E-05
Sum of the Pathways=					6.7E-01	1.7E+01		1E-05

exposure assumptions

Ingestion Rate IR (g/day)	0.05	Ingestion Risk= SCx IRxEFx EDx RF
Exposure Frequency (EF) (day/yr)	25	Inhalation Risk = SC + IR x EF x ED x CF x l/PEF x RF
Exposure Duration (ED) (years)	25	External Radiation Risk = SC x ED x Te x (1-SF) x RF
Particulate emission factor (m^3/kg):	4.63E+09	
Worker inhalation rate (m^3/day):	20	
Conversion factor(1000 g/kg):	1,000	
Exposure Time (ET) (hr/day)	8	
Shielding factor (SF):	0	
Fraction of year exposed (Te):	0.2	Te = (ET x EF) / (8,400 HR/YR)

NOTES:
(a) Radionuclides shown with +D include short lived daughter products in risk calculations.
(b) Ingestion and inhalation dose factors were taken from Federal Guidance Report 11. "Limiting Values of Radionuclide Intake and Air Concentration and Dose Factors for Inhalation, Submersion, and Ingestion"(EPA-520/1-88-020). Dose after intake of parent radionuclide. External Radiation dose factors were taken from NUREG/CR-5512 "Residual Radioactive Contamination from Decommissioning, Technical Basis for Translating Contamination Levels to Annual Dose."
(c) Committed effective dose equivalent expressed as committed (50 yr) dose (mrem) due to one year of exposure(mrem/yr).
(d) Cancer risk factors taken from January1992 HEAST tables.

Table taken from Attachment 2-6 *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds, Solid Waste Management Units 2 and 3, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* DOE/OR/07-1141&D2 (KY/ER-32 & D2) September 1994 Revision 2.

Table F2.7. Cancer Risks Estimated for Domestic Use of Groundwater

Scenario: Future Potable Use of Groundwater
MW093 (RGA)

Chemical	Oral Slope Factor (mg/kg-day)-1	Concentration MW093 ug/L	Chronic Daily Intake mg/kg-day	Excess Lifetime Cancer Risk	Total Pathway Risk
INGESTION OF GROUNDWATER					
2,4-Dinitrotoluene	0.68	18.50	2.2E-04	1.5E-04	
N-Nitroso-di-npropylamine	7.0	22.00	2.6E-04	1.8E-03	
Pentachlorophenol	0.12	57.00	6.7E-04	8.0E-05	
Arsenic	1.75	3.35	3.9E-05	6.9E-05	
Sum=					2E-03

Ingestion: Intake (mg/kg-d)=(conc. in gw*IngR*CF* EF*ED)/(BW*AT)

exposure parameters	
IngR=Ingestion rate (L/day)	2
CF=Conversion factor (mg/ug)	0.001
EF=Exposure frequency (days/year)	350
ED=Exposure duration (year)	30
BW=Body weight (kg)	70
AT=Averaging time (days)	25,550

Table taken from Attachment 2-7 *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds, Solid Waste Management Units 2 and 3, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* DOE/OR/07-1141&D2 (KY/ER-32 & D2) September 1994 Revision 2.

Table F2.8. Cancer Risks Estimated for Domestic Use of Groundwater

Scenario: Future Potable Use of Groundwater
MW074 (UCRS)

Chemical	Oral Slope Factor (mg/kg-day)-1	Concentration MW074 ug/L	Chronic Daily Intake mg/kg-day	Excess Lifetime Cancer Risk	Total Pathway Risk
INGESTION OF GROUNDWATER					
Beryllium	4.3	15.8	1.9E-04	8.0E-04	8.0E-04
INHALATION OF VOLATILE COMPOUNDS DURING DOMESTIC USE OF GROUNDWATER					0.0E+00
Sum of Pathways=					8E-04

Ingestion: Intake (mg/kg-d)=(conc. in gw*IngR*CF* EF*ED)/(BW*AT)
Inhalation: Inh dose (mg/kg-d)=(conc. in gw*VF*InhR*EF*ED)/(BW*AT)
SFi=Unit Risk*(BW/InhR)*1000

exposure parameters

IngR=Ingestion rate (L/day)	2
CF=Conversion factor (mg/ug)	0.001
EF=Exposure frequency (days/year)	350
ED=Exposure duration (year)	30
BW=Body weight (kg)	70
AT=Averaging time (days)	25,550
InhR=Indoor Inhalation Rate (m^3/day)	15
VF=Volatilization Factor (L/m^3)	0.5

Table taken from Attachment 2-8 *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds, Solid Waste Management Units 2 and 3, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* DOE/OR/07-1141&D2 (KY/ER-32 & D2) September 1994 Revision 2.

Table F2.9. Hazard Index Estimates for Domestic Use of Groundwater

Scenario: Future Potable Use of Groundwater
MW074 (UCRS)

Chemical	Reference Dose (mg/kg-day)	Concentration MW074 ug/L	Chronic Daily Intake mg/kg-day	Hazard Quotient	Pathway Hazard Index
INGESTION OF GROUNDWATER					
Nickel	0.02	125.4	3.4E-03	0.172	
Barium	0.07	634	1.7E-02	0.248	
Zinc	0.3	343.3	9.4E-03	0.031	
Vanadium	0.007	410.1	1.1E-02	1.605	
Chromium	0.005	139.8	3.8E-03	0.766	
Cadmium	0.0005	4.6	1.3E-04	0.252	
Silver	0.003	42.1	1.2E-03	0.384	
Manganese	0.005	1,535.3	4.2E-02	8.413	
Copper	0.037	95.9	2.6E-03	0.000	
Beryllium	0.005	15.8	4.3E-04	0.087	
Uranium (soluble salts)	0.003	10.68	2.9E-04	0.098	
					12

Equations:

Ingestion: Intake (mg/kg-d)=(conc. in gw*IngR*CF* EF*ED)/(BW*AT)

exposure parameters

IngR=Ingestion rate (L/day)	2
CF=Conversion factor (mg/ug)	0.001
EF=Exposure frequency (days/year)	350
ED=Exposure duration (year)	30
BW=Body weight (kg)	70
AT=Averaging time (days)	10,950

Table taken from Attachment 2-9 *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds, Solid Waste Management Units 2 and 3, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* DOE/OR/07-1141&D2 (KY/ER-32 & D2) September 1994 Revision 2.

Table F2.10. Hazard Index Estimates for Domestic Use of Groundwater

Scenario: Future Potable Use of Groundwater
MW089 (RGA)

Chemical	Reference Dose (mg/kg-day)	Concentration MW074 ug/L	Chronic Daily Intake mg/kg-day	Hazard Quotient	Pathway Hazard Index
INGESTION OF GROUNDWATER					
Nickel	0.02	14.6	4.0E-04	0.020	
Barium	0.07	253	6.9E-03	0.099	
Zinc	0.3	34.3	9.4E-04	0.003	
Vanadium	0.007	7.6	2.1E-04	0.030	
Chromium	0.005	7.8	2.1E-04	0.043	
Cyanide	0.02	3	8.2E-05	0.004	
Thallium (Carbonate)	0.00008	0.9	2.5E-05	0.308	
Manganese	0.005	3,630	9.9E-02	19.890	
Copper	0.037	9	2.5E-04	0.000	
Arsenic	0.0003	3.9	1.1E-04	0.356	
					20.75
INHALATION OF VOLATILE COMPOUNDS DURING DOMESTIC USE OF GROUNDWATER					0.0
Sum of Pathways=					20.75

Equations:

Ingestion: Intake (mg/kg-d)=(conc. in gw*IngR*CF* EF*ED)/(BW*AT)

Inhalation: Inh dose (mg/kg-d)=(conc. in gw*VF*InhR*EF*ED)/(BW*AT)

exposure parameters

IngR=Ingestion rate (L/day)	2
CF=Conversion factor (mg/ug)	0.001
EF=Exposure frequency (days/year)	350
ED=Exposure duration (year)	30
BW=Body weight (kg)	70
AT=Averaging time (days)	10,950
InhR=Indoor Inhalation Rate (m^3/day)	15
VF=Volatilization Factor (L/m^3)	0.5

Table taken from Attachment 2-10 *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds, Solid Waste Management Units 2 and 3, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* DOE/OR/07-1141&D2 (KY/ER-32 & D2) September 1994 Revision 2.

Table F2.11. Risk of Cancer Incidence for Domestic Use of Groundwater

Scenario: Future Potable Use of Groundwater
MW154 (UCRS)

Radionuclide[a]	Groundwater Concentration (pCi/L)[b]	Annual Intake (pCi/yr)	Total Intake (pCi)	Ingestion Dose Conversion Factor[c] (mrem/pCi)	Committed Effective Dose Equivalent 1 Yr Intake (mrem/yr)[d]	Total Committed Effective Dose Equivalent (mrem)	Cancer Incidence Risk Factor (pCi)-1[e]	Risk of Cancer Incidence
Np-237	0.32	224.0	6720.0	4.4E-03	9.9E-01	3.0E+01	2.2E-10	1.5E-06
Pu-239	0.18	126.0	3780.0	3.7E-04	4.6E-02	1.4E+00	2.3E-10	6.7E-07
	1000	7.0E+05	2.1E+07	1.5E-06	1.0E+00	3.1E+01	1.3E-12	2.7E-05
Tc-99	3.6	2,520.0	75,600.0	2.8E-04	7.1E-01	2.1E+01	1.6E-11	1.2E-06
	0.14	98.0	2,940.0	2.7E-04	2.6E-02	7.8E-01	1.6E-11	4.7E-08
U-234	27	18,900.0	567,000.0	2.6E-04	4.8E+00	1.4E+02	2.8E-11	1.6E-05
U-235+D								
U-238+D								
Pathway totals=					7.6E+00	2.3E+02		5E-05

exposure assumptions

Ingestion Rate IR (g/day)	2	Ingestion Risk= WC x IR x EF x ED x RF
Exposure Frequency (EF) (day/yr)	350	
Exposure Duration (ED) (years)	30	

NOTES:
[a]Radionuclides shown with +D include short lived daughter products in risk calculations.
[b] Sample concentrations are actual values. Results are shown as calculated by the lab, even if they are less than the detection limit for this analysis. ND is shown if the actual value was negative.
[c] Ingestion and inhalation dose factors were taken from Federal Guidance Report 11. "Limiting Values of Radionuclide Intake and Air Concentration and Dose Factors for Inhalation, Submersion, and Ingestion"(EPA-520/1-88-020). Dose factors include the contribution to dose from ingrowth of decay products after intake of parent radionuclide.
[d] Committed effective dose equivalent expressed as committed (50 yr) dose (mrem) due to one year of exposure (mrem/yr).

[e] Cancer risk factors taken from January1992 HEAST tables.

Table taken from Attachment 2-11 *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds, Solid Waste Management Units 2 and 3, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* DOE/OR/07-1141&D2 (KY/ER-32 & D2) September 1994 Revision 2.

Table F2.12. Risk of Cancer Incidence for Domestic Use of Groundwater

Scenario: Future Potable Use of Groundwater
MW84 (RGA)

Radionuclide[a]	Groundwater Concentration (pCi/L)[b]	Annual Intake (pCi/yr)	Total Intake (pCi)	Ingestion Dose Conversion Factor[c] (mrem/pCi)	Committed Effective Dose Equivalent 1 Yr Intake (mrem/yr)[d]	Total Committed Effective Dose Equivalent (mrem)	Cancer Incidence Risk Factor (pCi)-1[e]	Risk of Cancer Incidence
Np-237	ND	0.0	0.0	4.4E-03	0.0E+00	0.0E+00	2.2E-10	0.0E+00
Pu-239	0.03	21.0	630.0	3.7E-04	7.7E-03	2.3E-01	2.3E-10	1.4E-07
	466	3.3E+05	9.8E+06	1.5E-06	4.8E-01	1.4E+01	1.3E-12	1.3E-05
Tc-99	0.14	98.0	2940.0	2.8E-04	2.8E-02	8.3E-01	1.6E-11	4.7E-08
	0.01	7.0	210.0	2.7E-04	1.9E-03	5.6E-02	1.6E-11	3.4E-09
	0.23	161.0	4,830.0	2.6E-04	4.1E-02	1.2E+00	2.8E-11	1.4E-07
U-234								
U-235+D								
U-238+D								
Totals					5.5E-01	1.7E+01		1E-05

exposure assumptions

Ingestion Rate IR (g/day)	2	Ingestion Risk= WC x IR x EF x ED x RF
Exposure Frequency (EF) (day/yr)	350	
Exposure Duration (ED) (years)	30	

NOTES:

[a]Radionuclides shown with +D include short lived daughter products in risk calculations.

[b] Sample concentrations are actual values. Results are shown as calculated by the lab, even if they are less than the detection limit for this analysis. ND is shown if the actual value was negative.

[c] Ingestion and inhalation dose factors were taken from Federal Guidance Report 11. "Limiting Values of Radionuclide Intake and Air Concentration and Dose Factors for Inhalation, Submersion, and Ingestion"(EPA-520/1-88-020). Dose factors include the contribution to dose from ingrowth of decay products after intake of parent radionuclide.

[d] Committed effective dose equivalent expressed as committed (50 yr) dose (mrem) due to one year of exposure (mrem/yr).

[e] Cancer risk factors taken from January1992 HEAST tables.

Table taken from Attachment 2-12 *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds, Solid Waste Management Units 2 and 3, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* DOE/OR/07-1141&D2 (KY/ER-32 & D2) September 1994 Revision 2.

Table F2.13. Summary of Human Health Risk Characterization for SWMU 4 Without Lead as a COPC

Receptor	Total ELCR	COCs	% Total ELCR	POCs	% Total ELCR	Total HI	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil)	5.4E-04	Beryllium Uranium-238	97 2	Dermal contact External exposure	97 2	3.62	Beryllium Chromium Iron Vanadium Barium	5 45 24 24 2	Dermal contact	99
Future industrial worker at current concentrations (soil)	5.4E-04	Beryllium Uranium-238	97 2	Dermal contact External exposure	97 2	3.62	Beryllium Chromium Iron Vanadium Barium	5 45 24 24 2	Dermal contact	99
Future industrial worker at current concentrations (RGA groundwater)	4.7E-04	Arsenic Beryllium 1,1-DCE Carbon tetrachloride Chloroform TCE Vinyl chloride	15 48 8 7 2 20 2	Incidental ingestion Dermal contact Inhalation while showering	72 18 10	32.6	Aluminum Arsenic Cadmium Chromium Iron Manganese Vanadium Carbon tetrachloride TCE	4 1 1 1 66 5 2 4 14	Ingestion Dermal contact Inhalation while showering	88 6 6
Future industrial worker at current concentrations (McNairy groundwater)	3.1E-03	Arsenic Beryllium	18 82	Ingestion Dermal contact	78 22	75.9	Aluminum Arsenic Barium Beryllium Cadmium Chromium Iron Manganese Vanadium	4 5 1 1 1 3 63 8 14	Ingestion Dermal contact	93 7
Future child rural resident at current concentrations (soil)	NA	NA	NA	NA	NA	98.2	Barium Beryllium Cadmium Chromium Iron Nickel Vanadium	2 2 2 24 60 2 9	Ingestion Dermal contact Ingestion of vegetables	1 21 78

Table F2.13. Summary of Human Health Risk Characterization for SWMU 4 Without Lead as a COPC (Continued)

Receptor	Total ELCR	COCs	% Total ELCR	POCs	% Total ELCR	Total HI	COCs	% Total HI	POCs	% Total HI
Future child rural resident at current concentrations (RGA groundwater)	NA	NA	NA	NA	NA	487	Aluminum Arsenic Boron Chromium Iron Manganese Vanadium Carbon tetrachloride Chloroform TCE *cis*-1,2-DCE	3 1 1 1 49 3 1 10 1 29 1	Ingestion Dermal contact Inhalation while showering/household Ingestion of vegetables	40 1 30 29
Future child rural resident at current concentrations (McNairy groundwater)	NA	NA	NA	NA	NA	798	Aluminum Arsenic Barium Beryllium Cadmium Chromium Iron Manganese Mercury Vanadium Zinc	4 5 1 1 1 3 66 6 1 12 1	Ingestion Dermal contact Ingestion of vegetables	60 2 39
Future adult rural resident at current concentrations (soil)	4.3E-03	Beryllium Total PCBs Uranium-234 Uranium-238	72 5 6 17	Dermal contact External exposure Ingestion of vegetables	6 2 1	28.4	Barium Beryllium Cadmium Chromium Iron Nickel Vanadium	2 2 2 22 63 2 8	Dermal contact Ingestion of vegetables	14 85
Future adult rural resident at current concentrations (RGA groundwater)	7.0E-03	Arsenic Beryllium 1,1-DCE Carbon tetrachloride Chloroform TCE Vinyl chloride Technetium-99	8 22 15 7 5 20 2 21	Ingestion Dermal contact Inhalation while showering/household Ingestion of vegetables	26 3 30 41	158	Aluminum Arsenic Boron Chromium Iron Manganese Vanadium Carbon tetrachloride TCE	3 1 1 1 57 4 1 7 22	Ingestion Dermal contact Inhalation of vapors/particles Ingestion of vegetables	51 2 19 28

Table F2.13. Summary of Human Health Risk Characterization for SWMU 4 Without Lead as a COPC (Continued)

Receptor	Total ELCR	COCs	% Total ELCR	POCs	% Total ELCR	Total HI	COCs	% Total HI	POCs	% Total HI
Future adult rural resident at current concentrations (McNairy groundwater)	> 1.0E-02*	Arsenic Beryllium Technetium-99	21 77 2	Ingestion Dermal contact Ingestion of vegetables	58 8 35	303	Aluminum Arsenic Barium Beryllium Cadmium Chromium Iron Manganese Vanadium Zinc	4 5 1 1 1 3 66 6 12 1	Ingestion Dermal contact Ingestion of vegetables	65 2 32
Future child recreational user at current concentrations (soil)	NA	NA	NA	NA	NA	< 1	–	–	–	–
Future teen recreational user at current concentrations (soil)	NA	NA	NA	NA	NA	< 1	–	–	–	–
Future adult recreational user at current concentrations (soil)	< 1.0E-06	–	–	–	–	< 1	–	–	–	–
Future excavation worker at current concentrations (soil and waste)	2.7E-03	Arsenic Beryllium Total dioxins/furans Total PCBs Radium-226 Total uranium Uranium-238	1 7 4 2 2 83 1	Ingestion Dermal contact External exposure	37 10 54	2.61	Aluminum Arsenic Barium Beryllium Cadmium Chromium Iron Manganese Vanadium	8 4 2 2 1 24 24 14 20	Ingestion Dermal contact	13 87

Table taken from *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1895&D1,July 2000.
NA = ECLR not applicable to child and teen cohorts. Values for adult include exposure as child and teen.
– = There are no COCs or POCs.

* = The ELCR is approximate because the linearized multistage model returns imprecise values at risks > 1.0E-02.

Table F2.14. Summary of Human Health Risk Characterization for SWMU 5 Without Lead as a COPC

Receptor	Total ELCR	COCs	% Total ELCR	POCs	% Total ELCR	Total HI	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil)	4.1E-04	Arsenic Beryllium Total PAHs	6 49 45	Ingestion Dermal contact	2 98	< 1	–	–	–	–
Future industrial worker at current concentrations (soil)	4.1E-04	Arsenic Beryllium Total PAHs	6 49 45	Ingestion Dermal contact	2 98	< 1	–	–	–	–
Future industrial worker at current concentrations (RGA groundwater)	5.4E-04	Beryllium 1,1-DCE Radium-226	35 1 64	Ingestion Dermal contact	90 9	26.8	Aluminum Barium Cadmium Chromium Iron Manganese Vanadium	4 1 1 2 73 16 2	Ingestion Dermal contact	96 4
Future industrial worker at current concentrations (McNairy groundwater)	1.2E-03	Beryllium Radium-226	42 58	Ingestion Dermal contact	89 11	63	Aluminum Cadmium Chromium Iron Manganese Vanadium	4 1 7 79 3 5	Ingestion Dermal contact	95 5
Future child rural resident at current concentrations (soil)	NA	NA	NA	NA	NA	46.2	Aluminum Arsenic Beryllium Chromium Nickel Zinc	24 53 1 17 3 1	Ingestion Dermal contact Ingestion of vegetables	1 12 87
Future child rural resident at current concentrations (RGA groundwater)	NA	NA	NA	NA	NA	283	Aluminum Barium Cadmium Chromium Iron Manganese Vanadium	4 1 1 2 77 12 1	Ingestion Dermal contact Ingestion of vegetables	61 1 37
Future child rural resident at current concentrations (McNairy groundwater)	NA	NA	NA	NA	NA	680	Aluminum Cadmium Chromium Iron Manganese Vanadium	4 1 6 81 3 4	Ingestion Dermal contact Ingestion of vegetables	60 1 39
Future adult rural resident at current concentrations (soil)	> 1.0E-02*	Arsenic Beryllium Total PAHs Total PCBs	21 9 68 2	Dermal contact Ingestion of vegetables	9 90	13.9	Aluminum Arsenic Beryllium Chromium Nickel Zinc	24 55 1 15 3 1	Dermal contact Ingestion of vegetables	8 92

Table F2.14. Summary of Human Health Risk Characterization for SWMU 5 Without Lead as a COPC (Continued)

Receptor	Total ELCR	COCs	% Total ELCR	POCs	% Total ELCR	Total HI	COCs	% Total HI	POCs	% Total HI
Future adult rural resident at current concentrations (RGA groundwater)	3.9E-03	Beryllium 1,1-DCE Radium-226 Technetium-99	33 4 57 5	Ingestion Dermal contact Inhalation while showering/household Ingestion of vegetables	56 3 4 37	107	Aluminum Barium Cadmium Chromium Iron Manganese Vanadium	4 1 1 2 76 13 1	Ingestion Dermal contact Ingestion of vegetables	67 2 31
Future adult rural resident at current concentrations (McNairy groundwater)	8.2E-03	Beryllium Radium-226	43 57	Ingestion Dermal contact Ingestion of vegetables	61 4 34	257	Aluminum Cadmium Chromium Iron Manganese Vanadium	4 1 6 81 3 4	Ingestion Dermal contact Ingestion of vegetables	65 2 33
Future child recreational user at current concentrations (soil)	NA	NA	NA	NA	NA	< 1	–	–	–	–
Future teen recreational user at current concentrations (soil)	NA	NA	NA	NA	NA	< 1	–	–	–	–
Future adult recreational user at current concentrations (soil)	1.0E-05	Arsenic Total PAHs Total PCBs	2 96 2	Ingestion of venison Ingestion of rabbit Ingestion of quail	16 63 21	< 1	–	–	–	–
Future excavation worker at current concentrations (soil and waste)	2.9E-04	Arsenic Beryllium Total PAHs Total PCBs	8 62 28 1	Ingestion Dermal contact	13 87	2.16	Aluminum Arsenic Barium Beryllium Chromium Iron Manganese	9 7 2 3 18 38 22	Ingestion Dermal contact	18 82

Table taken from *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1895&D1,July 2000.
NA = ECLR not applicable to child and teen cohorts. Values for adult include exposure as child and teen.
– = There are no COCs or POCs.
* = The ELCR is approximate because the linearized multistage model returns imprecise values at risks > 1.0E-02.

Table F2.15. Summary of Human Health Risk Characterization for SWMU 6 Without Lead as a COPC

Receptor	Total ELCR	COCs	% Total ELCR	POCs	% Total ELCR	Total HI	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil)	2.4E-04	Beryllium Total PAHs	90 10	Dermal contact	99	< 1	–	–	–	–
Future industrial worker at current concentrations (soil)	2.4E-04	Beryllium Total PAHs	90 10	Dermal contact	99	< 1	–	–	–	–
Future industrial worker at current concentrations (RGA groundwater)	2.3E-04	Arsenic Beryllium TCE	15 74 11	Ingestion Dermal contact Inhalation while showering	76 22 2	19.1	Aluminum Arsenic Barium Cadmium Chromium Iron Manganese Vanadium TCE	3 1 1 2 2 61 20 3 6	Ingestion Dermal contact Inhalation while showering	92 6 2
Future industrial worker at current concentrations (McNairy groundwater)	7.8E-04	Arsenic Beryllium	24 76	Ingestion Dermal contact	79 21	41.7	Aluminum Arsenic Barium Cadmium Chromium Iron Manganese Vanadium	5 3 1 1 6 74 3 5	Ingestion Dermal contact	95 5
Future child rural resident at current concentrations (soil)	NA	NA	NA	NA	NA	9.38	Beryllium Chromium Nickel Zinc	8 72 15 5	Dermal contact Ingestion of vegetables	34 65
Future child rural resident at current concentrations (RGA groundwater)	NA	NA	NA	NA	NA	223	Aluminum Arsenic Barium Cadmium Chromium Iron Manganese Vanadium TCE	3 1 1 1 2 58 14 2 17	Ingestion Dermal contact Inhalation while showering/household Ingestion of vegetables	54 1 12 33
Future child rural resident at current concentrations (McNairy groundwater)	NA	NA	NA	NA	NA	451	Aluminum Arsenic Barium Cadmium Chromium Iron Manganese Vanadium	5 3 1 1 6 76 2 5	Ingestion Dermal contact Ingestion of vegetables	59 1 39

Table F2.15. Summary of Human Health Risk Characterization for SWMU 6 Without Lead as a COPC (Continued)

Receptor	Total ELCR	COCs	% Total ELCR	POCs	% Total ELCR	Total HI	COCs	% Total HI	POCs	% Total HI
Future adult rural resident at current concentrations (soil)	2.4E-03	Beryllium Total PAHs	54 46	Dermal contact Ingestion of vegetables	30 69	2.57	Beryllium Chromium Nickel Zinc	7 70 17 6	Dermal contact Ingestion of vegetables	24 75
Future adult rural resident at current concentrations (RGA groundwater)	2.3E-03	Arsenic Beryllium TCE Technetium-99	12 51 16 21	Ingestion Dermal contact Inhalation while showering/household Ingestion of vegetables	41 6 8 46	79.9	Aluminum Arsenic Barium Cadmium Chromium Iron Manganese Vanadium TCE	3 1 1 1 2 61 15 2 12	Ingestion Dermal contact Inhalation while showering/household Ingestion of vegetables	62 2 7 29
Future adult rural resident at current concentrations (McNairy groundwater)	5.7E-03	Arsenic Beryllium	28 72	Ingestion Dermal contact Ingestion of vegetables	59 7 34	170	Aluminum Arsenic Barium Cadmium Chromium Iron Manganese Vanadium	5 3 1 1 6 76 2 5	Ingestion Dermal contact Ingestion of vegetables	65 2 33
Future child recreational user at current concentrations (soil)	NA	NA	NA	NA	NA	< 1	–	–	–	–
Future teen recreational user at current concentrations (soil)	NA	NA	NA	NA	NA	< 1	–	–	–	–
Future adult recreational user at current concentrations (soil)	< 1.0E-06	–	–	–	–	< 1	–	–	–	–
Future excavation worker at current concentrations (soil and waste)	2.3E-04	Beryllium Total PAHs	90 9	Ingestion Dermal contact	5 95	2.44	Aluminum Barium Beryllium Chromium Iron Manganese Vanadium	8 2 3 15 32 15 26	Ingestion Dermal contact	12 88

Table taken from *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1895&D1,July 2000.
NA = ECLR not applicable to child and teen cohorts. Values for adult include exposure as child and teen.
– = There are no COCs or POCs.

Table F2.16. Summary of Human Health Risk Characterization for SWMU 7 Without Lead as a COPC

Receptor	Total ELCR	ELCR COCs	% Total ELCR	ELCR POCs	% Total ELCR	Total HI[a]	Systematic Toxicity COCs	% Total HI	Systematic Toxicity POCs	% Total HI
Current industrial worker at current concentrations	4×10^{-3}	Arsenic	<1	Ingestion of soil	<1	5	Aluminum	4.1	Ingestion of soil	3.6
		Beryllium	97.4	Dermal contact with soil	97.4		Antimony	4.4	Dermal contact with soil	96.4
		Benz(a)anthracene	<1	External exposure to soil	2.5		Arsenic	2.6		
		Benzo(a)pyrene	<1				Beryllium	9.6		
		Benzo(b)fluoroanthene	<1				Chromium	13.6		
		Indeno(1,2,3-cd)pyrene	<1				Iron	20.7		
		^{237}Np	<1				Manganese	10.7		
		^{234}U	<1				Uranium	13.7		
		^{235}U	<1				Vanadium	17.7		
		$^{235/236}U$	<1							
		^{238}U	<1							
Future industrial worker at current concentrations	6×10^{-3}	Arsenic	12.0	Ingestion of groundwater	25.5	62	Aluminum	2.3	Ingestion of groundwater	63.7
		Beryllium	70.9	Dermal contact with groundwater	2.9		Antimony	1.0	Dermal contact with groundwater	27.2
		1,1-DCE	<1				Arsenic	6.7		
		PCB-1248	<1	Inhalation while showering	3.5		Barium	<1	Ingestion of soil	<1
		PCB-1254	1.3				Beryllium	<1	Dermal contact with soil	7.8
		Benz(a)anthracene	<1	Ingestion of soil	<1		Cadmium	<1		
		Benzo(a)pyrene	<1	Dermal contact with soil	67.3		Chromium	2.9		
		Benzo(b)fluoroanthene	<1	External exposure to soil	1.7		Iron	8.4		
		Carbon tetrachloride	<1				Manganese	8.8		
		Dibenzo(a,h)anthracene	<1				Nickel	<1		
		Indeno(1,2,3-cd)pyrene	<1				Uranium	1.2		
		TCE	2.4				Vanadium	3.2		
		Vinyl chloride	4.9				1,2-*cis*-DCE	<1		
		^{237}Np	1.7				1,2- DCE (total)	13.8		
		^{239}Pu	<1				2,4-Dimethylphenol	<1		
		^{222}Rn	2.5				4-Methylphenol	<1		
		^{99}Tc	<1				PCB-1254	40.0		
		^{230}Th	<1				Carbon tetrachloride	<1		
		^{234}U	<1				TCE	7.0		
		^{235}U	<1							
		$^{235/236}U$	<1							
		^{238}U	2.4							
Future child recreational user at current concentrations	NA	NA	NA	NA	NA	0.07	NE	NE	NE	NE
Future teen recreational user at current concentrations	NA	NA	NA	NA	NA	0.06	NE	NE	NE	NE
Future adult recreational user at current concentrations	1×10^{-5}	PCB-1260	18.2	Ingestion of deer	10.0	0.07	NE	NE	NE	NE
		Benzo(a)pyrene	9.1	Ingestion of rabbit	70.9					
		Dibenzo(a,h)anthracene	41.8	Ingestion of quail	21.8					
		^{238}U	16.4							

Table F2.16. Summary of Human Health Risk Characterization for SWMU 7 Without Lead as a COPC (Continued)

Receptor	Total ELCR	ELCR COCs	% Total ELCR	ELCR POCs	% Total ELCR	Total HI[a]	Systematic Toxicity COCs	% Total HI	Systematic Toxicity POCs	% Total HI
Future child rural resident at current concentrations	NA	NA	NA	NA	NA	1320	Aluminum	1.8	Ingestion of groundwater	20.7
							Antimony	<1	Dermal contact with groundwater	3.5
							Arsenic	5.2		
							Barium	<1	Inhalation while showering	<1
							Beryllium	<1		
							Cadmium	<1	Inhalation from household use	<1
							Chromium	1.6		47.6
							Cobalt	<1	Ingestion of vegetables from groundwater	
							Copper	<1		<1
							Fluoride	<1	Ingestion of soil	2.2
							Iron	8.9	Dermal contact with soil	25.5
							Manganese	3.9	Ingestion of vegetables from soil	
							Mercury	<1		
							Molybdenum	<1		
							Nickel	<1		
							Nitrate-nitrite	<1		
							Selenium	<1		
							Silver	<1		
							Tin	<1		
							Uranium	16.4		
							Vanadium	1.4		
							Zinc	<1		
							1,2-*cis*-DCE	<1		
							1,2- DCE (total)	40.8		
							2,4-Dimethylphenol	<1		
							2-Methylphenol	<1		
							4-Methylphenol	<1		
							Acetone	<1		
							PCB-1254	12.4		
							Benzene	<1		
							Carbon tetrachloride	<1		
							TCE	4.0		

Table F2.16. Summary of Human Health Risk Characterization for SWMU 7 Without Lead as a COPC (Continued)

Receptor	Total ELCR	ELCR COCs	% Total ELCR	ELCR POCs	% Total ELCR	Total HI[a]	Systematic Toxicity COCs	% Total HI	Systematic Toxicity POCs	% Total HI
Future adult rural resident at current concentrations	5×10^{-2}	Arsenic	14.6	Ingestion of groundwater	13.1	446	Aluminum	1.8	Ingestion of groundwater	25.1
		Beryllium	42.6	Dermal contact with groundwater	<1		Antimony	<1	Dermal contact with groundwater	5.3
		1,1,2-TCA	<1				Arsenic	5.4		
		1,1-DCE	<1	Inhalation while showering	<1		Barium	<1	Inhalation from household use	<1
		1,2-DCE	<1				Beryllium	<1		
		PCB-1248	<1	Inhalation from household use	3.5		Cadmium	<1	Ingestion of vegetables from groundwater	44.2
		PCB-1254	1.5				Chromium	1.6		
		PCB-1260	<1	Ingestion of vegetables from groundwater	20.3		Cobalt	<1	Ingestion of soil	<1
		Benzene	<1				Copper	<1	Dermal contact with soil	1.2
		Benz(a)anthracene	<1	Ingestion of soil	<1		Fluoride	<1	Ingestion of vegetables from soil	23.8
		Benzo(a)pyrene	1.0	Dermal contact with soil	20.3		Iron	8.8		
		Benzo(b)fluoroanthene	<1	External exposure to soil	1.2		Manganese	4.3		
		Bis(2ethylhexyl)phthalate	<1	Ingestion of vegetables from soil	38.9		Mercury	<1		
		Carbon tetrachloride	<1				Molybdenum	<1		
		Chloroform	<1				Nickel	<1		
		Chloromethane	<1				Nitrate-nitrite	<1		
		Dibenzo(a,h)anthracene	1.2				Uranium	15.0		
		Indeno(1,2,3-cd)pyrene	<1				Vanadium	<1		
		Tetrachloroethene	<1				Zinc	<1		
		TCE	3.3				1,2-*cis*-DCE	<1		
		Vinyl chloride	10.2				1,2- DCE (total)	39.0		
		^{241}Am	<1				2,4-Dimethylphenol	<1		
		^{237}Np	1.2				2-Methylphenol	<1		
		^{239}Pu	<1				4-Methylphenol	<1		
		^{222}Rn	<1				Acetone	<1		
		^{99}Tc	7.4				PCB-1254	14.8		
		^{230}Th	<1				Carbon tetrachloride	<1		
		^{234}U	2.2				TCE	4.3		
		^{235}U	<1							
		$^{235/236}U$	<1							
		^{238}U	11.5							
Future excavation worker at current concentrations	2×10^{-3}	Arsenic	1.8	Ingestion of soil	25.6	5	Aluminum	5.0	Ingestion of soil	18.4
		Beryllium	42.5	Dermal contact with soil	43.8		Antimony	11.3	Dermal contact with soil	81.5
		Benzo(a)pyrene	<1	External exposure to soil	32.5		Arsenic	3.4		
		Dibenzo(a,h)anthracene	1.7				Chromium	17.6		
		^{237}Np	<1				Copper	2.9		
		^{239}Pu	<1				Iron	21.3		
		^{234}U	3.4				Manganese	11.0		
		^{235}U	9.4				Nickel	3.9		
		$^{235/236}U$	<1				Uranium	7.5		
		^{238}U	41.3				Vanadium	10.9		

Table taken from Executive Summary *Remedial Investigation Report for Solid Waste Management Units 7 and 30 of Waste Area Grouping 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* DOE/OR/07-1604/V2&D1 July 1997
NA = ELCR not applicable to child and teen cohorts. Values for adult include exposure as child and teen.
NE = Land use scenario no evaluated or not of concern. Total ELCR and total HI columns reflect values from Tables 1.59 to 1.70 of DOE 1997 without lead included.
[a] %Total HI for COCs and PCBs values do not include lead as a COC. Tables 1.59 to 1.70 of DOE 1997 present the systemic toxicity with lead included.

Table F2.17. Summary of Human Health Risk Characterization for SWMU 30 Without Lead as a COPC

Receptor	Total ELCR	ELCR COCs	% Total ELCR	ELCR POCs	% Total ELCR	Total HI[a]	Systematic Toxicity COCs	% Total HI	Systematic Toxicity POCs	% Total HI
Current industrial worker at current concentrations	4×10^{-3}	Arsenic Beryllium PCB-1260 Benz(a)anthracene Benzo(a)pyrene Benzo(b)fluoroanthene Indeno(1,2,3-cd)pyrene ^{237}Np ^{234}U ^{235}U $^{235/236}U$ ^{238}U	<1 97.3 <1 <1 <1 <1 <1 <1 <1 <1 <1 <1 1.4	Ingestion of soil Dermal contact with soil External exposure to soil	<1 97.3 1.7	4	Aluminum Antimony Arsenic Beryllium Cadmium Chromium Iron Manganese Uranium Vanadium	5.1 3.7 2.7 10.7 3.5 13.5 19.8 11.3 9.0 17.6	Ingestion of soil Dermal contact with soil	2.9 97.0
Future industrial worker at current concentrations	4×10^{-3}	Arsenic Beryllium 1,1-DCE PCB-1260 Benz(a)anthracene Benzo(a)pyrene Benzo(b)fluoroanthene Bis(2ethylhexyl)phthalate Carbon tetrachloride Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene Tetrachloroethene TCE Vinyl chloride ^{241}Am ^{237}Np ^{239}Pu ^{222}Rn ^{99}Tc ^{234}U ^{235}U $^{235/236}U$ ^{238}U	1.3 90.0 <1 <1 <1 <1 <1 <1 <1 <1 <1 <1 3.0 <1 <1 <1 <1 2.5 <1 <1 <1 <1 1.4	Ingestion of groundwater Dermal contact with groundwater Inhalation while showering Ingestion of soil Dermal contact with soil External exposure to soil	4.0 <1 3.0 <1 90.0 1.6	12	Aluminum Antimony Arsenic Beryllium Cadmium Chromium Iron Manganese Nitrate Uranium Vanadium Carbon tetrachloride Di-n-octylphthalate TCE	2.0 1.4 2.7 4.0 1.3 6.5 7.7 4.3 1.9 3.7 7.1 1.3 19.0 34.2	Ingestion of groundwater Dermal contact with groundwater Ingestion of soil Dermal contact with soil	33.1 28.8 1.1 36.3
Future child recreational user at current concentrations	NA	NA	NA	NA	NA	0.04	NE	NE	NE	NE
Future teen recreational user at current concentrations	NA	NA	NA	NA	NA	0.04	NE	NE	NE	NE

Table F2.17. Summary of Human Health Risk Characterization for SWMU 30 Without Lead as a COPC (Continued)

Receptor	Total ELCR	ELCR COCs	% Total ELCR	ELCR POCs	% Total ELCR	Total HI[a]	Systematic Toxicity COCs	% Total HI	Systematic Toxicity POCs	% Total HI
Future adult recreational user at current concentrations	2×10^{-5}	PCB-1260 Benzo(a)pyrene Dibenzo(a,h)anthracene	48.0 12.7 20.7	Ingestion of deer Ingestion of rabbit Ingestion of quail	8.7 80.0 11.3	0.04	NE	NE	NE	NE
Future child rural resident at current concentrations	NA	NA	NA	NA	NA	334	Aluminum Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Fluoride Chromium VI Iron Manganese Mercury Nickel Nitrate Nitrate as nitrogen Selenium Uranium Vanadium Zinc 1,2- DCE (total) PCB-1254 Bis(2ethylhexyl)phthalate Carbon tetrachloride Di-n-octylphthalate TCE	3.3 <1 6.6 <1 1.4 1.7 3.0 <1 <1 <1 18.0 2.0 <1 <1 <1 <1 <1 37.1 2.5 <1 <1 2.0 <1 1.7 1.8 14.4	Ingestion of groundwater Dermal contact with groundwater Inhalation while showering Inhalation from household use Ingestion of vegetables from groundwater Ingestion of soil Dermal contact with soil Ingestion of vegetables from soil	8.0 2.7 <1 1.3 8.7 1.0 7.4 70.7

Table F2.17. Summary of Human Health Risk Characterization for SWMU 30 Without Lead as a COPC (Continued)

Receptor	Total ELCR	ELCR COCs	% Total ELCR	ELCR POCs	% Total ELCR	Total HI[a]	Systematic Toxicity COCs	% Total HI	Systematic Toxicity POCs	% Total HI
Future adult rural resident at current concentrations	4×10^{-2}	Arsenic	5.5	Ingestion of groundwater	1.8	105	Aluminum	3.1	Ingestion of groundwater	10.4
		Beryllium	47.7		<1		Antimony	<1		4.6
		1,1,2-TCA	<1	Dermal contact with groundwater	<1		Arsenic	6.7	Dermal contact with groundwater	<1
		1,1-DCE	<1				Barium	<1		
		PCB-1254	<1	Inhalation while showering	2.1		Beryllium	1.1	Inhalation from household use	8.8
		PCB-1260	1.3				Cadmium	1.7		
		Benz(a)anthracene	<1	Inhalation from household use	22.7		Chromium	2.8	Ingestion of vegetables from groundwater	<1
		Benzo(a)pyrene	3.2				Copper	<1		4.6
		Benzo(b)fluoroanthene	<1	Ingestion of vegetables from groundwater	<1		Iron	17.3	Ingestion of soil	70.4
		Benzo(k)fluoroanthene	<1		25.0		Manganese	1.6		
		Bis(2ethylhexyl)phthalate	<1	Ingestion of soil	<1		Mercury	<1	Dermal contact with soil	
		Carbon tetrachloride	<1	Dermal contact with soil	45.5		Nickel	<1		
		Chloroform	<1				Nitrate	<1	Ingestion of vegetables from soil	
		Chrysene	<1	External exposure to soil			Uranium	35.9		
		Dibenzo(a,h)anthracene	1.3				Vanadium	2.0		
		Indeno(1,2,3-cd)pyrene	<1	Ingestion of vegetables from soil			Zinc	<1		
		Tetrachloroethene	<1				1,2- DCE (total)	<1		
		TCE	3.9				PCB-1254	2.0		
		^{241}Am	<1				Carbon tetrachloride	1.3		
		^{237}Np	<1				Di-n-octylphthalate	3.0		
		^{239}Pu	<1				TCE	16.9		
		^{226}Ra	<1							
		^{222}Rn	<1							
		^{99}Tc	21.4							
		^{230}Th	3.2							
		^{234}U	<1							
		^{235}U	<1							
		$^{235/236}U$	8.4							
		^{238}U								

Table F2.17. Summary of Human Health Risk Characterization for SWMU 30 Without Lead as a COPC (Continued)

Receptor	Total ELCR	ELCR COCs	% Total ELCR	ELCR POCs	% Total ELCR	Total HI[a]	Systematic Toxicity COCs	% Total HI	Systematic Toxicity POCs	% Total HI
Future excavation worker at current concentrations	1×10^{-3}	Arsenic	2.0	Ingestion of soil	6.3	4	Aluminum	5.0	Ingestion of soil	20.0
		Beryllium	91.7	Dermal contact with soil	91.7		Antimony	6.8	Dermal contact with soil	80.0
		PCB-1248	<1		3.3		Arsenic	3.6		
		Benz(a)anthracene	<1	External exposure to soil			Beryllium	3.4		
		Benzo(a)pyrene	<1				Cadmium	3.2		
		Benzo(b)fluoroanthene	<1				Chromium	11.1		
		Dibenzo(a,h)anthracene	<1				Iron	21.5		
		Indeno(1,2,3-cd)pyrene	<1				Manganese	15.6		
		^{237}Np	<1				Uranium	13.3		
		^{239}Pu	<1				Vanadium	13.8		
		^{234}U	<1							
		^{235}U	<1							
		$^{235/236}U$	<1							
		^{238}U	4.1							

Table taken from Executive Summary *Remedial Investigation Report for Solid Waste Management Units 7 and 30 of Waste Area Grouping 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* DOE/OR/07-1604/V2&D1 July 1997

NA = ELCR not applicable to child and teen cohorts. Values for adult include exposure as child and teen.

NE = Land use scenario no evaluated or not of concern. Total ELCR and total HI columns reflect values from Tables 1.59 to 1.70 of DOE 1997 without lead included.

[a] %Total HI for COCs and PCBs values do not include lead as a COC. Tables 1.59 to 1.70 of DOE 1997 present the systemic toxicity with lead included.

Table F2.18. Summary of Human Health Risk Characterization for the North Ditch Without Lead as a COPC

Receptor	Total ELCR	ELCR COCs	% Total ELCR	ELCR POCs	% Total ELCR	Total HI[a]	Systematic Toxicity COCs	% Total HI	Systematic Toxicity POCs	% Total HI
Current industrial worker at current concentrations	4×10^{-4}	Arsenic Beryllium PCB-1260 $^{235/236}U$ ^{238}U	7.6 84.2 <1 4.5	Ingestion of soil Dermal contact with soil External exposure to soil	1.0 92.1 5.0	5	Aluminum Antimony Arsenic Chromium Iron Manganese Uranium Vanadium	6.6 5.7 3.7 14.4 24.9 15.3 3.2 22.5	Dermal contact with soil	98.8
Future industrial worker at current concentrations	4×10^{-4}	Arsenic Beryllium PCB-1260 $^{235/236}U$ ^{238}U	7.6 84.2 1.2 8.2 4.5	Ingestion of soil Dermal contact with soil External exposure to soil	1.0 92.1 5.0	5	Aluminum Antimony Arsenic Chromium Iron Manganese Uranium Vanadium	6.6 5.7 3.7 14.4 24.9 15.3 3.2 22.5	Dermal contact with soil	98.8
Future child recreational user at current concentrations	NA	NA	NA	NA	NA	0.004	NE	NE	NE	NE
Future teen recreational user at current concentrations	NA	NA	NA	NA	NA	0.003	NE	NE	NE	NE
Future adult recreational user at current concentrations	1×10^{-6}	NE	NE	NE	NE	0.004	NE	NE	NE	NE
Future child rural resident at current concentrations	NA	NA	NA	NA	NA	229	Aluminum Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Iron Manganese Nickel Uranium Vanadium Zinc	7.0 1.9 14.1 1.1 <1 <1 4.4 <1 36.2 4.3 <1 23.4 4.7 <1	Ingestion of soil Dermal contact with soil Ingestion of vegetables from soil	1.3 12.3 86.4

Table F2.18. Summary of Human Health Risk Characterization for the North Ditch Without Lead as a COPC (Continued)

Receptor	Total ELCR	ELCR COCs	% Total ELCR	ELCR POCs	% Total ELCR	Total HI[a]	Systematic Toxicity COCs	% Total HI	Systematic Toxicity POCs	% Total HI
Future adult rural resident at current concentrations	9×10^{-3}	Arsenic Beryllium PCB-1260 ^{237}Np ^{234}U $^{235/236}U$ ^{238}U	37.8 21.1 9.7 <1 5.0 1.1 24.4	Ingestion of soil Dermal contact with soil External exposure to soil Ingestion of vegetables from soil	<1 11.1 2.6 84.4	68	Aluminum Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Iron Manganese Nickel Uranium Vanadium Zinc	7.0 1.6 14.6 1.1 <1 <1 4.0 <1 37.3 3.8 1.0 23.8 3.8 <1	Ingestion of soil Dermal contact with soil Ingestion of vegetables from soil	<1 7.9 91.6
Future excavation worker at current concentrations	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

Table taken from Executive Summary *Remedial Investigation Report for Solid Waste Management Units 7 and 30 of Waste Area Grouping 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* DOE/OR/07-1604/V2&D1 July 1997

NA = ELCR not applicable to child and teen cohorts. Values for adult include exposure as child and teen.

NE = Land use scenario no evaluated or not of concern. Total ELCR and total HI columns reflect values from Tables 1.59 to 1.70 of DOE 1997 without lead included.

[a] %Total HI for COCs and PCBs values do not include lead as a COC. Tables 1.59 to 1.70 of DOE 1997 present the systemic toxicity with lead included.

Table F2.19. Summary of Human Health Risk Characterization for the South Ditch Without Lead as a COPC

Receptor	Total ELCR	ELCR COCs	% Total ELCR	ELCR POCs	% Total ELCR	Total HI[a]	Systematic Toxicity COCs	% Total HI	Systematic Toxicity POCs	% Total HI
Current industrial worker at current concentrations	4×10^{-4}	Arsenic Beryllium PCB-1260 Benz(a)anthracene Benzo(a)pyrene Benzo(b)fluoroanthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np $^{235/236}U$ ^{238}U	4.7 58.3 1.9 1.3 16.9 3.1 2.3 1.0 <1 2.2 6.9	Ingestion of soil Dermal contact with soil External exposure to soil	1.7 88.9 9.2	5	Aluminum Antimony Arsenic Cadmium Chromium Iron Manganese Nickel Uranium Vanadium	6.9 16.0 2.1 2.4 10.7 17.3 9.8 4.6 9.2 17.6	Dermal contact with soil	98.2
Future industrial worker at current concentrations	4×10^{-4}	Arsenic Beryllium PCB-1260 Benz(a)anthracene Benzo(a)pyrene Benzo(b)fluoroanthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np $^{235/236}U$ ^{238}U	4.7 58.3 1.9 1.3 16.9 3.1 2.3 1.0 <1 2.2 6.9	Ingestion of soil Dermal contact with soil External exposure to soil	1.7 88.9 9.2	5	Aluminum Antimony Arsenic Cadmium Chromium Iron Manganese Nickel Uranium Vanadium	6.9 16.0 2.1 2.4 10.7 17.3 9.8 4.6 9.2 17.6	Dermal contact with soil	98.2
Future child recreational user at current concentrations	NA	NA	NA	NA	NA	0.005	NE	NE	NE	NE
Future teen recreational user at current concentrations	NA	NA	NA	NA	NA	0.005	NE	NE	NE	NE
Future adult recreational user at current concentrations	2×10^{-6}	PCB-1260	66.7	Ingestion of rabbit	83.3	0.006	NE	NE	NE	NE

Table F2.19. Summary of Human Health Risk Characterization for the South Ditch Without Lead as a COPC (Continued)

Receptor	Total ELCR	ELCR COCs	% Total ELCR	ELCR POCs	% Total ELCR	Total HI[a]	Systematic Toxicity COCs	% Total HI	Systematic Toxicity POCs	% Total HI
Future child rural resident at current concentrations	NA	NA	NA	NA	NA	334	Aluminum Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Iron Manganese Nickel Uranium Vanadium Zinc PCB-1260	4.9 3.5 5.6 <1 <1 1.4 2.3 1.6 17.9 1.9 <1 9.5 46.4 2.7 <1	Ingestion of soil Dermal contact with soil Ingestion of vegetables from soil	1.3 8.5 90.1
Future adult rural resident at current concentrations	1×10^{-2}	Arsenic Beryllium PCB-1016 PCB-1260 Benz(a)anthracene Benzo(a)pyrene Benzo(b)fluoroanthene Benzo(k)fluoroanthene Bis(2ethylhexyl)-phthalate Chrysene Dibenzo(a,h)anthra-cene Indeno(1,2,3-cd)pyrene ^{237}Np ^{234}U $^{235/236}U$ ^{238}U	14.2 8.6 <1 10.0 1.6 20.7 3.8 <1 <1 <1 2.8 1.2 1.1 8.57 1.8 23.6	Ingestion of soil Dermal contact with soil External exposure to soil Ingestion of vegetables from soil	<1 6.7 2.9 85.7	101	Aluminum Antimony Arsenic Barium Cadmium Chromium Copper Iron Manganese Mercury Nickel Uranium Vanadium Zinc PCB-1016	5.0 3.1 5.8 <1 1.3 2.0 1.6 17.8 1.6 <1 9.8 47.2 2.2 1.4 <1	Ingestion of soil Dermal contact with soil Ingestion of vegetables from soil	<1 5.5 94.2
Future excavation worker at current concentrations	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

Table taken from Executive Summary *Remedial Investigation Report for Solid Waste Management Units 7 and 30 of Waste Area Grouping 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* DOE/OR/07-1604/V2&D1 July 1997

NA = ELCR not applicable to child and teen cohorts. Values for adult include exposure as child and teen.

NE = Land use scenario no evaluated or not of concern. Total ELCR and total HI columns reflect values from Tables 1.59 to 1.70 of DOE 1997 without lead included.

[a] %Total HI for COCs and PCBs values do not include lead as a COC. Tables 1.59 to 1.70 of DOE 1997 present the systemic toxicity with lead included.

Table F2.20. Summary Human Health Risk Characterization for Future Risk at Future Modeled Concentrations for SWMUs 7 and 30 and Associated Ditches

Receptor	Total ELCR	ELCR COCs	% Total ELCR	ELCR POCs	% Total ELCR	Total HI	Systematic Toxicity COCs	% Total HI	Systematic Toxicity POCs	% Total HI
Future child rural resident at future modeled concentrations – 30 years	NA	NA	NA	NA	NA	0.08	NE	NE	NE	NE
Future child rural resident at future modeled concentrations – 100 years	NA	NA	NA	NA	NA	0.3	NE	NE	NE	NE
Future adult rural resident at future modeled concentrations – 30 years	5×10^{-5}	Vinyl chloride ^{99}Tc	7.5 91.7	Ingestion of groundwater Inhalation from household use	95.8 3.75	0.03	NE	NE	NE	NE
Future adult rural resident at future modeled concentrations – 100 years	2×10^{-4}	Vinyl chloride ^{99}Tc	7.0 90.0	Ingestion of groundwater Inhalation from household use	95.0 2.75	0.1	NE	NE	NE	NE

Table taken from Executive Summary *Remedial Investigation Report for Solid Waste Management Units 7 and 30 of Waste Area Grouping 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* DOE/OR/07-1604/V2&D1 July 1997
NA = ELCR not applicable to child and teen cohorts. Values for adult include exposure as child and teen.
NE = Land use scenario no evaluated or not of concern. Total ELCR and total HI columns reflect values from Tables 1.59 to 1.70 of DOE 1997 without lead included.

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APPENDIX G

REVIEW OF ECOLOGICAL RISK ASSESSMENTS

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CONTENTS

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FIGURES

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TABLES

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ACRONYMS

BGOU	Burial Grounds Operable Unit
bgs	below ground surface
BRA	baseline risk assessment
COPC	contaminant of potential concern
CSM	conceptual site model
DNAPL	dense nonaqueous phase liquid
DOE	U.S. Department of Energy
EPC	exposure point concentration
ERA	ecological risk assessment
HQ	hazard quotient
HI	hazard index
NFA	no further action
NOAEL	No Observed Adverse Effects Level
PAH	polyaromatic hydrocarbon
PCB	polychlorinated biphenyl
PGDP	Paducah Gaseous Diffusion Plant
RCRA	Resource Conservation and Recovery Act
RGA	Regional Gravel Aquifer
RI	remedial investigation
RGO	remedial goal option
SFF	site foraging factor
SI	site investigation
SVOC	semivolatile organic compound
SWOU	surface water operable unit
SWMU	solid waste management unit
^{99}Tc	technetium-99
TCE	trichloroethene
UCL	upper confidence limit
VOC	volatile organic compound
WAG	waste area group
WKWMA	West Kentucky Wildlife Management Area

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G.1. INTRODUCTION

G.1.1 SITE LOCATION

This appendix provides summaries of the results of ecological risk assessments (ERAs) previously completed for Solid Waste Management Units (SWMUs) 2, 4, 5, 6, 7, and 30 within the Burial Grounds Operable Unit (BGOU) of Paducah Gaseous Diffusion Plant (PGDP) (Figure G.1). SWMUs 3 and 145 are not included because SWMU 3 is covered by a RCRA cap and SWMU 145 is sited on 44 acres that now lie beneath the C-746-S&T Landfills. SWMUs 2, 3, 4, 5, 6, 7, and 30 are located within the developed area of the PGDP facility. SWMUs 2, 3, and 4 are in the west-central area of the plant inside the security fence-lined area. SWMU 4 is bounded on all sides by plant roads and an active railroad spur (see Section 1.3 of the main text). SWMUs 5, 6, 7, and 30 are in the northwestern section of the PGDP secured area. 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.

G.1.2 SITE HISTORY

All the SWMUs considered in the ERAs originally were burial pits or landfills for process wastes from PGDP. The individual waste streams, burial practices, and operating time frames for each SWMU are described in-depth in Section 1.3 of this Remedial Investigation (RI) Report, and that material is briefly summarized here.

SWMU 2 was used primarily for the disposal of uranium metal pieces, uranium oxides, oils [that may have contained polychlorinated biphenyls (PCBs)], trichloroethene (TCE), and uranyl fluoride. Some technetium-99 (^{99}Tc) also may be present at this SWMU associated with the uranium wastes. SWMU 3 was an aboveground earth and clay surface impoundment with an overflow weir that subsequently was converted for disposal of solid uranium-contaminated wastes (uranium metal, uranium oxides, smelter furnace liners, and radioactively contaminated trash). SWMU 3 also includes an adjacent ditch that carried leachate from the surface impoundment. The landfill ceased operation in 1986 and was covered with a Resource Conservation and Recovery Act (RCRA) multilayered cap. SWMU 4 is an open vegetated field that was used to bury wastes in designated burial cells. This SWMU may have received uranium- and ^{99}Tc-contaminated sludge as well as TCE. SWMU 4 was covered in 1982 with 2 to 3 ft of soil material and a 6-inch clay cap. SWMU 5 contained disposal cells laid out in a grid pattern. Slag from nickel and aluminum smelters was disposed of here along with radioisotopes. Waste cells in SWMU 5 were covered with 2 to 3 ft of soil after they were filled. SWMU 6 also was divided into discrete burial cells: two for magnesium scrap, one for exhaust fan hoods contaminated with perchloric acid (see Section 2.5.4 of the main text for further discussion of the instability of perchloric acid), one for contaminated aluminum scrap, and one area for a single contaminated modine trap. SWMU 7 contains burial pits that were used for disposal of noncombustible, uranium-contaminated and uncontaminated trash, material, and equipment. SWMU 30 contained an area used for burning combustible trash that may have contained uranium contamination. The ash and debris from the incineration were buried below ground in a pit at SWMU 30. SWMU 145 contains landfills used to discard scrap and waste materials, including construction debris.

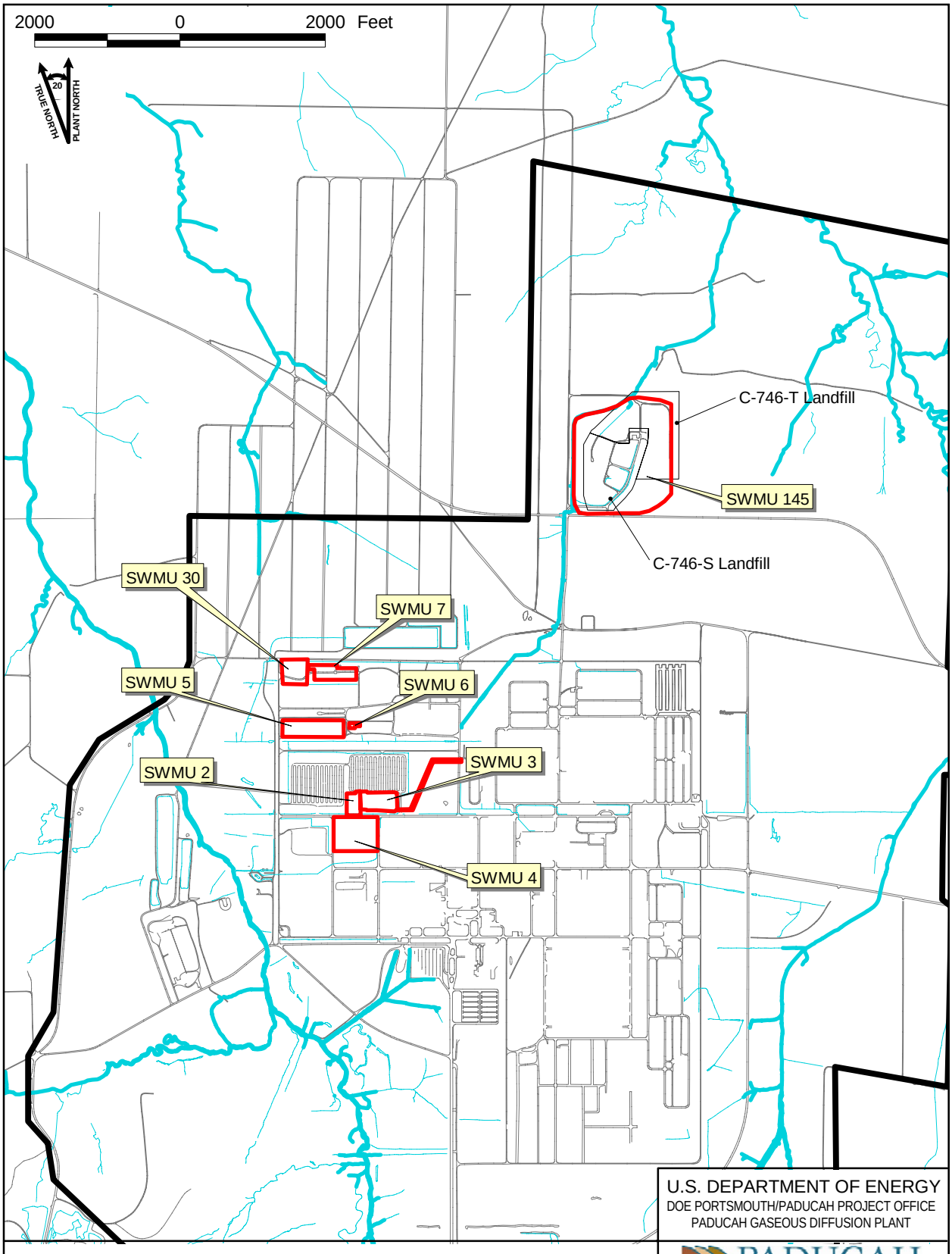

Figure G.1. Location of the BGOU SWMUs

Figure No. \BGOU\RI.apr
DATE 08-02-07

Trends in TCE concentration in soil and groundwater suggest dense nonaqueous-phase liquid (DNAPL) is present at SWMUs 4 and the area joining SWMUs 7 and 30. Some of the burial ground SWMUs ceased operation in the 1950s, but others were in use as late as the 1980s. After each unit ceased to be used for waste burial, it was covered with a soil cap. SWMU 3 was closed with the addition of a RCRA cap in 1987. Previous sampling identified a groundwater plume of dissolved phase TCE in the subsurface under most of these SWMUs.

G.2. PROBLEM FORMULATION

The first step in an ERA 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. The problem formulation presented here is consistent with those presented in the original ERAs that are summarized in this appendix.

G.2.1 PRELIMINARY CONCEPTUAL SITE MODEL

The preliminary CSM includes a description of the environmental setting, known site contaminants, and a figure representing the potential exposure pathways. This preliminary CSM is used as the basis for selection of benchmark values used to screen the site for potential ecological risk.

G.2.1.1 Site Environmental Setting and Habitat Descriptions

The SWMUs included in this ERA are generally similar in topography and process history. All the SWMUs, except SWMU 3 originally served as burial grounds or landfills for process wastes from PGDP operations. Once the pits within the burial grounds no longer were being used, they were topped with soil covers and most sites were revegetated. SWMU 3, however, was covered with a RCRA cap. 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. Figures G.2 to G.9 show the surface conditions at the SWMUs considered in this report.

The terrestrial ecosystems occurring in the area of these SWMUs are described more fully in the work plan for the BGOU (DOE 2006).This section presents a brief summary of the ecosystem relevant to defining the CSM and exposure pathways. The primary ecosystem in the area outside the industrial area around the SWMUs is upland grassland interspersed with developed industrial areas. The vegetation over these SWMUs is maintained with routine mowing (see section 3.1) approximately eight times per year. Most of the SWMUs also are surrounded by fencing and/or roads. 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, as well as hawks and owls, are found in this area. There also are amphibians, reptiles (primarily lizards and turtles), and bats. Table G.1 lists species observed in the nonindustrial areas of the PGDP and at the adjacent WKWMA.

Figure G.2. Surface of SWMU 2

Figure G.3. Surface of SWMU 3

Figure G.4. Surface of SWMU 4 (Area Behind Fence)

Figure G.5. Surface of SWMU 5 (Behind Fence)

Figure G.6. Surface of SWMU 6

Figure G.7. Surface of SWMU 7 (Field with Tree Surrounded by Road)

Figure G.8. SWMU 30 (Foreground, SWMU 7 is in Upper Left)

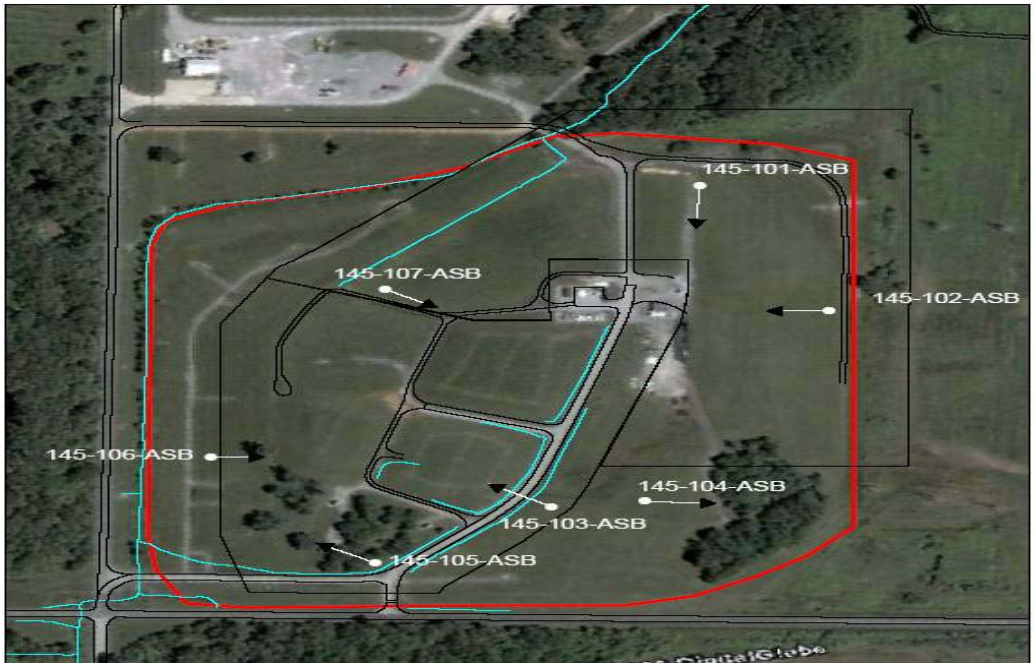

Figure G.9. Aerial View of Landfills at SWMU 145

Table G.1. Wildlife Species Present or Potentially Present at the PGDP Site[a]

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	*Sialis sialus*
Eastern kingbird	*Tyrannus tyrannus*
Eastern meadowlark	*Sturnella magna*
Eastern phoebe	*Sayornis phoebe*

Table G.1. Wildlife Species Present or Potentially Present at the PGDP Site[a] (Continued)

Common Name	Scientific Name
Bird (Continued)	
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*

Table G.1. Wildlife Species Present or Potentially Present at the PGDP Site (Continued)

Common Name	Scientific Name
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 sodalist*
Mice	Various species
Moles	Various species
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*

[a] The listed species are from the Surface Water Operable Unit Report (DOE 2008) and the WKWMA species information website (http://fw.ky.gov/kfwis/arcims/WmaSpecies.asp?strID=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 the SWMUs. These species are listed in Table G.2 of this document. As noted in the footnote to Table G.2, none of the species listed in the table have been reported as sighted on the U.S. Department of Energy (DOE) Reservation.

Table G.2. Federally Listed, Proposed, and Candidate Species Potentially Occurring within the Paducah Site Study Area[a]

Common Name	Scientific Name	Animal Type	Endangered Species Act Status
Indiana bat[b]	Myotis sodalist	Mammal	Listed endangered
Interior least tern	Sterna antillarum athalassos	Bird	Listed endangered
Pink mucket	Lampsilis abrupta	Mussel	Listed endangered
Ring pink	Obovaria retusa	Mussel	Listed endangered
Orangefoot pimpleback	Plethobasus cooperianus	Mussel	Listed endangered
Fat pocketbook	Potamilus capax	Mussel	Listed endangered

[a] All of the listed species are discussed in *Environmental Investigations at the Paducah Gaseous Diffusion Plant and Surrounding Area, McCracken County, Kentucky, Volume III*, COE Nashville District, May 1994. Note that the area evaluated in the referenced report encompasses 11,719 acres and extends to include the Ohio River, which is over three miles north of the DOE Reservation. None of these species have been reported as sighted on the DOE Reservation, although potential summer habitat exists there for the Indiana bat. No critical habitat for any of these species has been designated anywhere in the area.

[b] Specimens of the Indiana bat were collected from WKWMA property in 1991 and 1999.

G.2.1.2 Existing Data

The dataset for surface soils used in the ERAs summarized in this appendix is described in the remedial investigation documents containing the original assessments (DOE 1994; DOE 1997; DOE 1998; and DOE 2000). No new surface soil samples have been collected since the original assessments were done except at SWMUs 3 and 7. The uncertainty section discusses the results and potential impact of new surface soil samples

G.2.1.3 Site Contaminants

Only surface soil contaminants at the SWMUs were considered in the ERAs summarized in this appendix. Site contaminants at all SWMUs included inorganic chemicals, organic chemicals, and radionuclides.

G.2.1.4 Fate and Transport Mechanisms

Potential migration pathways for contaminants from waste and soil at the BGOU 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. The surface soils at most of the BGOU SWMUs considered here are held in place by vegetation or, for SWMU 3, by the presence of a RCRA cap with a vegetative cover. Transport of surface soil off-site is likely to be minimal. Migration of contaminants to subsurface soil and through subsurface soil to groundwater is likely to occur. Contaminants in groundwater may be discharged to surface water at areas away from the BGOU SWMUs. 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.

G.2.2 POTENTIALLY COMPLETE EXPOSURE PATHWAYS

Only surface samples (0–1 ft) were included in the assessments summarized in this appendix. Subsurface contamination may be accessible to burrowing ecological receptors. The subsurface interval of interest for this type of exposure would be in the 1–5 ft bgs depth. Insufficient analytical data are available in this depth range at these SWMUs to conduct a quantitative screening of potential exposure to burrowing animals. Burrowing animals also could encounter buried waste, but insufficient characterization is available for the waste to conduct a screening for exposure to materials in waste. Potential ecological risk from exposure to subsurface soil and waste to burrowing animals therefore is addressed qualitatively in the uncertainty section of this appendix. Significant contaminant transport through runoff directly to surface water is unlikely because most of the sites have vegetated surfaces. 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 representative of the CSMs from the past assessments and reflective of current site conditions is shown in Figure G.10.

G.2.3 POTENTIALLY CONTAMINATED MEDIA

Potential sources within the pits in the burial grounds may have contaminated both surface and subsurface soil. Only surface samples (0-1 ft) were included in the assessments described here. Subsurface contamination and buried waste are addressed qualitatively in the uncertainty section.

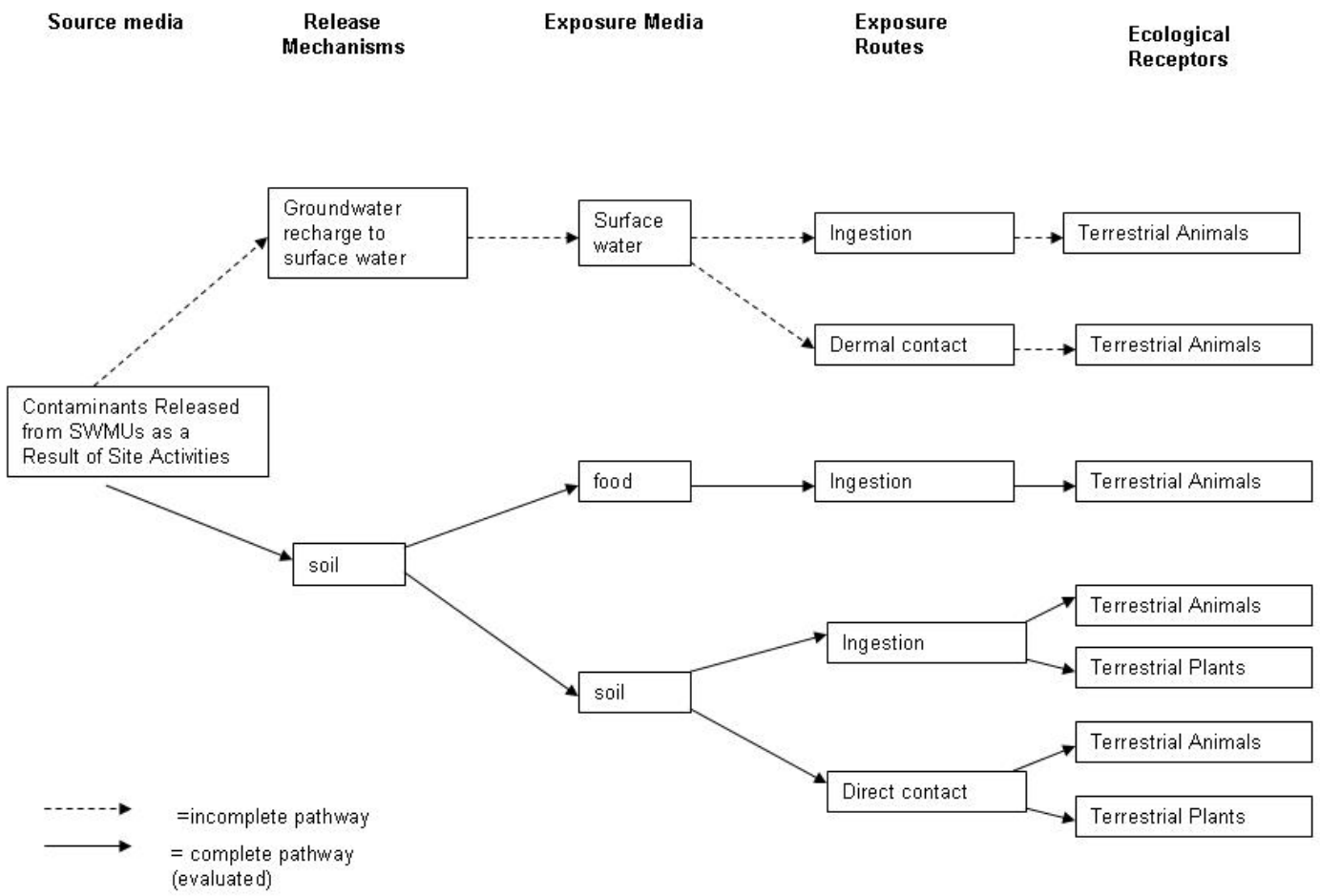

Figure G.10. Preliminary Conceptual Site Model for BGOU SWMUs

G.3. SCREENING-LEVEL EFFECTS EVALUATION

The ERAs summarized in this appendix all were completed prior to the development of the no further action (NFA) levels provided in Appendix A of the PGDP Ecological Risk Assessment methods document (DOE 2001). For SWMU 2, the maximum detected concentration of each potential contaminant was used as the exposure point concentration (EPC) and compared to a single ecological screening level selected from the literature. For SWMUs 4, 5, 6, 7, and 30, maximum detected concentrations of potential contaminants were used as the EPC and compared to screening levels developed for plant and soil receptors. For wildlife receptors, which are more mobile, the upper confidence limit (UCL) concentrations of potential contaminants were used as the EPC and compared to screening levels for each of those receptors unless the UCL exceeded the maximum detected concentration; in this case, the maximum detected concentration was used.

G.4. SUMMARY OF PREVIOUSLY CONDUCTED ERAS

For the ecological risk characterization for soil, the results of the previous ERAs are summarized here. For most of the SWMUs, no new surface data have been collected since the previous risk assessments were performed. In addition, the soils at some or all of the units are outside the scope of the BGOU RI as defined in the approved work plan (DOE 2006); therefore, a new quantitative risk assessment was not performed for soils. Previous ERAs were conducted for SWMUs 2, 4, 5, 6, 7, and 30 at PGDP. SWMU 3 is covered with a RCRA cap, and SWMU 145 lies beneath a landfill closed under RCRA; therefore, surface soil risks at these two units do not require further evaluation for ecological risk.

Screening levels for some classes of compounds [PCBs and polyaromatic hydrocarbons (PAHs)] were also used in the previous risk assessments. The PAH class was not a contaminant of potential concern (COPC) for any SWMU in the BGOU RI. The maximum detected concentration for each detected PCB was summed to develop a value for the PCB class. If no PCBs were detected at a SWMU, there was no evaluation in the ERA of the PCB class for that SWMU.

A summary of the results of the comparison in previous assessments of the site data to the ecological screening levels is provided in Table G.3. This table lists the number of COPCs in each suite retained for each site and the medium for further consideration. As shown, all BGOU SWMUs with an ERA had one or more COPCs, and the majority of COPCs retained at the BGOU SWMUs are metals.

Table G.3. Summary of Suite of COPCs Retained in Surface Soil

Area	Media	Metal	Rad	PCB	SVOC	VOC
SWMU 2	Soil	6	----	---	----	----
SWMU 3	Soil	NE	NE	NE	NE	NE
SWMU 4	Soil	5	----	1	----	----
SWMU 5	Soil	5	----	1	3	----
SWMU 6	Soil	2	----	----	1	----
SWMU 7	Soil	19	Total*	1	----	----
SWMU 30	Soil	17	Total*	1	-----	----
SWMU 145	Soil	NE	NE	NE	NE	NE

----: no COPCs
NE: SWMU did not undergo an ecological evaluation
*Radionuclide risk was assessed based on a total dose benchmark for all radionuclides
SVOC=semivolatile organic compound
VOC=volatile organic compound

G.4.1 SWMU 2

The waste area grouping (WAG) 22 RI addendum for SWMUs 2 and 3 contained only a preliminary identification of COPCs for ecological risk (DOE 1994). The subsequent data summary and interpretation report (DOE 1997) was completed for SWMU 2 and contains a comparison of surface soil concentrations to ecological preliminary remediation goals. That comparison was conducted for sediment in the ditch, surface soil (from 0 to 1 ft bgs), and the deeper Regional Gravel Aquifer (RGA) and McNairy soil. The ecological PRGs used for the comparison were the Oak Ridge values from Efroymson *et al.* (1996). Comparisons for deeper soil may be relevant for burrowing animals and are presented in Section 5 of the data summary and interpretation report. Only the results from the data summary and interpretation report for surface soil are summarized in Table G.4; further evaluation of ditch sediment in this area of the facility is provided in the *Surface Water Operable Unit (On-Site) Site Investigation and Baseline Risk Assessment Report at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* [Surface Water Operable Unit (SWOU) Site Investigation (SI) and Baseline Risk Assessment (BRA)] (DOE 2008). Only the surface soil COPCs exceeding their screening criteria based on the maximum detected concentration are provided in Table G.4; the comparison of all COPCs can be found in Table 5.15 of the data summary and interpretation report.

Table G.4. Summary of COPCs Retained in Surface Soil for SWMU 2

Analyte	Frequency of Detection	Max Detected Concentration (mg/kg)	EcoPRG (mg/kg)	Hazard Quotient (HQ)
Arsenic	3/3	24.6	2.66	9.3
Chromium	3/3	11.3	0.4	28
Manganese	3/3	655	100	6.5
Nickel	3/3	28.6	24.0	1.2
Silver	3/3	6.3	2.0	3.1
Vanadium	3/3	18.9	2.0	9.5

Based on the data summary and interpretation report (DOE 1997)

G.4.2 SWMU 4

The WAG 3 RI report (DOE 2000) included an ecological risk assessment for surface soil at SWMU 4. This assessment included a comparison to both No Observed Adverse Effects Level (NOAEL)-based benchmark screening levels for the receptors listed in the table and to the background values for surface soil. Tables G.5 and G.6 include only chemicals exceeding both benchmark and background values. Table G.5 presents the frequency of detection and the concentrations used as EPCs for each analyte. The hazard quotient (HQ) for each receptor using those EPCs is provided in Table G.6. Blank cells in Table G.6 indicate the HQ was one or less; a dash indicates that no screening level was available for that receptor/COPC combination. All HQs listed in Table G.6 are compared to NOAEL-based HQs. NOAEL-based benchmarks for plants and soil invertebrates are from Efroymson *et al.* (1997a; 1997b). NOAEL-based benchmarks for wildlife are derived from the literature sources shown in Exhibits 2.1 and 2.14 of the original document and following the methods in Sample, Opresko, and Suter II (1996).

Table G.5. COPCs Retained in Surface Soil for SWMU 4

Analyte	Frequency of Detection	Max detected concentration (EPC for soil receptors) mg/kg	UCL (EPC for wildlife) mg/kg
Chromium	13/13	14,300	10,539.31
Copper	13/13	30.1	14.7
Nickel	11/13	153	32.12
Vanadium	13/13	47.8	28.63
Zinc	12/13	72.5	48.43
PCBs (total)	4/11	0.494	0.49

Based on the WAG 3 RI report (DOE 2000)

Table G.6. HQs for COPCs Retained in Surface Soil for SWMU 4

Analyte	Plant HQ	Soil Invertebrates HQ	Meadow vole HQ	Long-tailed weasel HQ	White-footed mouse HQ	Short-tailed shrew HQ	American Woodcock HQ
Chromium	296	740	1.63			4.41	
Nickel	5.1						
Vanadium	23.9	-----	2.99			9.15	
Zinc	1.45						4.22
PCBs (total)		-----				2.83	1.27

Blank cells indicate the HQ was one or less; a dash indicates that no screening level was available for that receptor/COPC combination.
Based on the WAG 3 RI report (DOE 2000).

G.4.3. SWMU 5

The WAG 3 RI report (DOE 2000) included an ecological risk assessment for surface soil at SWMU 5. This assessment included a comparison to both NOAEL-based benchmark screening levels for the receptors listed in the table and to the background values for surface soil. Tables G.7 and G.8 include only chemicals exceeding both benchmark and background values. Table G.7 presents the frequency of detection and the concentrations used as EPCs for each analyte. The HQ for each receptor using those EPCs is provided in Table G.8. Blank cells in Table G.8 indicate the HQ was one or less; a dash indicates that no screening level was available for that receptor/COPC combination. All HQs listed in Table G.8 are compared to NOAEL-based HQs. NOAEL-based benchmarks for plants and soil invertebrates are from Efroymson *et al.* (1997a; 1997b). NOAEL-based benchmarks for wildlife are derived from the literature sources shown in Exhibits 2.13 and 2.14 of the original document and following the methods in Sample, Opresko, and Suter II (1996).

Table G.7. COPCs Retained in Surface Soil for SWMU 5

Analyte	Frequency of Detection	Max detected concentration (EPC for soil receptors) mg/kg	UCL (EPC for wildlife) mg/kg
Aluminum	13/13	13,800	10,761.77
arsenic	5/13	12.2	7.55
Chromium	13/13	20.5	15.01
Nickel	12/13	119	24.11
Zinc	13/13	163	84.34
Fluoranthene	7/13	53.3	3.85
Phenanthrene	7/13	34.6	2.63
di-n-butyl phthalate	3/13	1.7	0.91
PCBs (total)	5/13	0.618	0.55

Based the WAG 3 RI report (DOE 2000)

Table G.8. HQs for COPCs Retained in Surface Soil for SWMU 5

Analyte	Plant HQ	Soil Invertebrates HQ	Meadow vole HQ	Long-tailed weasel HQ	White-footed mouse HQ	Short-tailed shrew HQ	American Woodcock HQ
Aluminum	276	-----	159	42.5	24.3	49.4	10.6
Arsenic	1.22		3.08			7.39	
Chromium	20.5	51.25					
Nickel	3.97						
Zinc	3.26	1.63					6.8
Fluoranthene	-----	1.57					
Phenanthrene	-----	1.02					
di-n-butyl phthalate							1.8
PCBs (total)		-----				3.64	1.64

Blank cells indicate the HQ was one or less; a dash indicates that no screening level was available for that receptor/COPC combination.
Based on the WAG 3 RI report (DOE 2000).

G.4.4 SWMU 6

The WAG 3 RI report (DOE 2000) included an ecological risk assessment for surface soil at SWMU 6. This assessment included a comparison to both NOAEL-based benchmark screening levels for the receptors listed in the table and to the background values for surface soil. Tables G.9 and G.10 include only chemicals exceeding both benchmark and background values. Table G.9 presents the frequency of detection and the concentrations used as EPCs for each analyte. The HQ for each receptor using those EPCs is provided in Table G.10. Blank cells in Table G.10 indicate the HQ was one or less; a dash indicates that no screening level was available for that receptor/COPC combination. All HQs listed in Table G.10 are compared to NOAEL-based HQs. NOAEL-based benchmarks for plants and soil invertebrates are from Efroymson *et al*. (1997a; 1997b). NOAEL-based benchmarks for wildlife are derived from the literature sources shown in Exhibits 2.13 and 2.14 of the original document and following the methods in Sample, Opresko, and Suter II (1996).

Table G.9. COPCs Retained in Surface Soil for SWMU 6

Analyte	Frequency of Detection	Max detected concentration (EPC for soil receptors) mg/kg	UCL (EPC for wildlife) mg/kg
Nickel	5/7	43.2	24.84
Zinc	7/7	128	78.44
di-n-butyl phthalate	2/7	1.7	0.99

Based on the WAG 3 RI report (DOE 2000)

Table G.10. HQs for COPCs Retained in Surface Soil for SWMU 6

Analyte	Plant HQ	Soil Invertebrates HQ	Meadow vole HQ	Long-tailed weasel HQ	White-footed mouse HQ	Short-tailed shrew HQ	American Woodcock HQ
Nickel	1.44						
Zinc	2.56	1.28					5.58
di-n-butyl phthalate							1.80

Blank cells indicate the HQ was one or less; a dash indicates that no screening level was available for that receptor/COPC combination.
Based on the WAG 3 RI report (DOE 2000).

G.4.5 SWMU 7

The WAG 22 RI report (DOE 1998), which contains the ecological risk assessment for SWMU 7, was completed prior to development of the NFA levels in the PGDP risk methods document in 2001; therefore, the document developed NOAEL-based benchmarks for each of six ecological receptors. Three of the receptors (plants, soil invertebrates, and soil microbes) were relatively nonmobile and were screened by comparison of the benchmarks to maximum detected values. Three of the receptors (white-tailed deer, white-footed mouse, and short-tailed shrew) were considered relatively mobile and were screened by comparison of the benchmarks to the UCL (if the UCL exceeded the maximum detected concentration, then the maximum detected concentration was used). Table 1.11 in Appendix A of the WAG 22 RI report presents the summary of COPCs for SWMU 7. Table G.11 summarizes the EPCs for COPCs for the two classes of receptors for SWMU 7. Only analytes exceeding their screening levels are summarized in Table G.11.The full comparison of all analytes to screening levels is shown in Appendix A of the WAG 22 RI report.

Table G.11. COPCs Retained in Surface Soil for SWMU 7

Analyte	Frequency of Detection	Max detected concentration (EPC for soil receptors) mg/kg	UCL (EPC for wildlife) mg/kg
Aluminum	13/13	14,800	9,670
Arsenic	13/13	16.0	7.21
Barium	13/13	120	75.5
Beryllium	12/13	24.0	11.4
Cadmium	9/13	3.0	1.87
Chromium	13/13	44.0	32.2
Cobalt	13/13	29.0	12.0
Copper	13/13	99.0	34.1
Fluoride	6/6	32.0	24.7
Iron	13/13	30,000	21,900
Lead	13/13	120	33.0
Manganese	13/13	1,160	472
Mercury	11/13	0.1	.0961
Nickel	13/13	55.0	26.4
Selenium	9/13	0.88	0.524
Thallium	12/13	2.0	1.28
Uranium	7/7	1,400	701
Vanadium	13/13	52.0	29.5
Zinc	13/13	200	97.5
Aroclor-1260	6/13	1.8	0.295

Based on the WAG 22 RI report (DOE 1998)

Table 2.4 in Appendix A of the WAG 22 RI report presents the screening levels developed for three receptors: plants, soil microbes, and earthworms. Table 2.5 in Appendix A of the WAG 22 RI presents the screening levels developed for three wildlife receptors: white-tailed deer, white-footed mouse, and the short-tailed shrew. The wildlife benchmarks are all NOAEL-based levels.

Hazard quotients for analytes with HQs exceeding 1 for any of the receptors as well as the total hazard index (HI) (the sum of all the HQs for a receptor) for SWMU 7 are listed in Table G.12. The HQs for all analytes are provided in Tables 2.6 and 2.7 of Appendix A of the WAG 22 RI.

A separate dose-based analysis was done to assess risk to ecological receptors from radionuclides and is presented in Table 2.9 of Appendix A of the WAG 22 RI. The dose contributions were less than the benchmark dose of 100 mrad per day for all the receptors listed in Table G.12, except that the HQ for plants was 1.09. The isotopes U-234 and U-235 were the main contributors to the total dose for plants.

Table G.12. HQs for COPCs Retained in Surface Soil for SWMU 7

Analyte	Plants HQ	Soil microbes HQ	Earthworm HQ	White-tailed deer HQ	White-footed mouse HQ	Short-tailed shrew HQ
Aluminum	296	24.7	-----	40.6	59.8	620
Arsenic	1.6				3.54	27.1
Barium			-----			1.11
Beryllium	2.4	-----	-----			6.17
Cadmium						3.45
Chromium	44	4.4	110		3.19	22.6
Cobalt	1.45		-----			
Copper			1.98			
Fluoride		1.07	-----	-----	-----	-----
Iron	-----	150	-----			
Lead	2.4					
Manganese	2.32	11.6	-----			
Mercury						3.76
Nickel	1.83					1.06
Selenium						1.09
Thallium	2.0	-----	-----			6.09
Uranium	280	-----	-----		1.41	22.6
Vanadium	26.0	2.6	-----	1.56	1.12	9.02
Zinc	4.0	2.0				1.10
Aroclor-1260	-----	-----	-----		4.66	33.2

Blank cells indicate the HQ was one or less; a dash indicates that no screening level was available for that receptor/COPC combination.
Based on the WAG 22 RI report (DOE 1998)

G.4.6 SWMU 30

The WAG 22 RI report (DOE 1998), which also contains the ecological risk assessment for SWMU 30, was completed prior to development of the NFA levels in the PGDP risk methods document in 2001; therefore, the document developed NOAEL-based benchmarks for each of six ecological receptors. Three of the receptors (plants, soil invertebrates, and soil microbes) were relatively nonmobile and were screened by comparison to maximum detected values. Three of the receptors (white-tailed deer, white-footed mouse, and short-tailed shrew) were considered relatively mobile and were screened by comparison to the UCL (if the UCL exceeded the maximum detected concentration, then the maximum detected concentration was used). Table 1.11 in Appendix A of the WAG 22 RI report presents the summary of COPCs for SWMU 30. Table G.13 summarizes the EPCs for COPCs for the two classes of receptors for SWMU 30. Only analytes exceeding their NFA level are summarized in the table. The full comparison of all analytes to NFA levels is shown in Appendix A of the WAG 22 RI report.

Table G.13. COPCs Retained in Surface Soil for SWMU 30

Analyte	Frequency of Detection	Max detected concentration (EPC for soil receptors) mg/kg	UCL (EPC for wildlife) mg/kg
Aluminum	14/14	15,000	10,500
Arsenic	14/14	9.0	6.19
Barium	14/14	161	104
Beryllium	14/14	24.0	11.1
Cadmium	13/14	9.0	3.58
Chromium	14/14	38.0	27.9
Cobalt	14/14	12.0	8.08
Copper	14/14	89.0	50.0
Iron	14/14	29,600	18,000
Manganese	14/14	624	434
Mercury	14/14	2.0	0.272
Nickel	14/14	66.0	39.6
Silver	9/14	4.0	2.09
Thallium	12/14	1.2	0.578
Uranium	2/4	450	394
Vanadium	14/14	34.0	25.5
Zinc	14/14	155	76.7
Aroclor-1260	7/17	150	1.32

Based on the WAG 22 RI report (DOE 1998)

Table 2.4 in Appendix A of the WAG 22 RI report presents the screening levels developed for three receptors: plants, soil microbes, and earthworms. Table 2.5 in Appendix A of the WAG 22 RI report presents the screening levels developed for three wildlife receptors: white-tailed deer, white-footed mouse, and the short-tailed shrew. The wildlife benchmarks are all NOAEL-based levels.

Analytes with HQs exceeding 1 for any of the receptors as well as the total HI for SWMU 30 are listed in Table G.14. The HQs for all analytes are provided in Tables 2.6 and 2.7 of Appendix A of the WAG 22 RI report.

A separate dose-based analysis was done to assess risk to ecological receptors from radionuclides and is presented in Table 2.9 of Appendix A of the WAG 22 RI. The dose contributions were less than the benchmark dose of 100 mrad per day for all the receptors listed in Table G.14, except that the HQ for plants was 1.32. The isotopes U-234 and U-235 were the main contributors to the total dose for plants.

Table G.14. HQs for COPCs Retained in Surface Soil for SWMU 30

Analyte	Plant HQ	Soil microbe HQ	Earthworm HQ	White-tailed deer HQ	White-footed mouse HQ	Short-tailed shrew HQ
Aluminum	300	25	-----	44.0	65.1	678
Arsenic					3.04	23.3
Barium			-----			1.54
Beryllium	2.4		-----			6.01
Cadmium	3.0				1.08	6.65
Chromium	38.0	3.8	95.0		2.78	19.7
Copper			1.78			
Iron	-----	148	-----	-----	-----	-----
Manganese	1.25	6.24	-----			
Mercury	6.67		20.0		1.50	10.6
Nickel	2.20					1.60
Silver	2.0		-----			
.Thallium	1.20	-----	-----			2.75
Uranium	90.0	-----	-----			12.7
Vanadium	17.0	1.70	-----	1.35		7.78
Zinc	3.10	1.55				
Aroclor-1260	-----	-----	-----		20.9	148

Blank cells indicate the HQ was one or less; a dash indicates that no screening level was available for that receptor/COPC combination.
Based on the WAG 22 RI report (DOE 1998)

G.5. FOOD WEB MODELING FOR PCBS

The ecological evaluations done as part of the previous RI reports include comparisons to screening levels designed to be protective of adverse effects from direct exposure to the media (direct contact and ingestion of soil). For contaminants that bioaccumulate through the food chain, such as PCBs, additional risks may be present because of the additional dose ingested through the food chain. The ERAs in the previous RIs did not include a food web model assessment' however, the assessment conducted as part of the screening ERA in the SWOU SI and BRA (DOE 2008) assessed the bioaccumulation potential for several species of mammalian and avian receptors. The receptor species evaluated for soil (short-tailed shrew, meadow vole, American kestrel, American woodcock, and American robin) also are appropriate receptors for the SWMUs within the BGOU.

The approach used for the food web model is described in Section E.3.2 of the SWOU SI and BRA (DOE 2008). Food web modeling for total PCBs involved calculation of the potential dose ingested per kg body weight per day to the toxicity reference benchmarks developed in *Toxicological Benchmarks for Wildlife: 1996 Revision* (Sample, Opresko, and Suter II 1996). The toxicity reference benchmarks are provided in Table E.3 of the SWOU SI and BRA and the HQs for the food web model appear in Section E.5.2 of the same document. This document covers different sites than the BGOU RI, but the modeling results can be used directly because the dose of PCBs (and therefore the HQ) for each receptor are directly proportional to the soil concentration. Table E.3.2 and Table E.3 of the SWOU SI and BRA show the NOAEL-based HQs for total PCBs for each species. The ratio of these soil concentrations to HQs is valid for the BGOU units as well as long as they are calculated for a site foraging factor (SFF) of 1.0. The SFF is 1.0 for the short-tailed shrew, the meadow vole, the American robin and the bobwhite quail; therefore, the HQs for these receptors were used to evaluate the total PCB results of the BGOU RI units. The ratios used to convert the total PCB value into an equivalent food web model HQ are shown in Table G.15. The conversion factors are the same for both high and low concentrations (except for rounding differences); the larger value was used if a slight difference existed between the two values.

Table G.15 Factors for Converting Soil Concentrations into Food Web Model HQs

Receptor Species	Soil Concentration in SWOU Appendix E	NOAEL HQ in SWOU Appendix E	Soil-to-HQ Conversion Factor
Short-tailed Shrew	0.4	10.2	25.5
Meadow vole	0.4	0.035	0.0875
American robin	0.4	1.2	3.0
Bobwhite Quail	0.4	0.014	0.035
Short-tailed Shrew	20	511	25.6
Meadow vole	20	1.7	0.085
American robin	20	57.5	2.9
Bobwhite Quail	20	0.69	0.035

Table G.16 shows the HQs associated with the maximum total PCBs detected at each SWMU in the BGOU SWMU soil. These HQs are >1 for the short-tailed shrew and for the American robin at SWMUs 2, 4, 5, and 7. At SWMU 30, HQs are greater than 1 for all mammal species evaluated and the American robin.

Table G.16 HQs Associated with the Maximum Total PCBs at Each SWMU[1]

	Conversion Factor	SWMU 2 HQ	SWMU 4 HQ	SWMU 5 HQ	SWMU 6 HQ	SWMU 7 HQ	SWMU 30 HQ
Total PCBs (mg/kg)		0.39	0.494	0.618	NA	1.99	17.1
Short-tailed Shrew	25.5	9.9	13	16	NA	51	436
Meadow vole	0.0875	0.034	0.043	0.054	NA	0.17	1.5
American robin	3.0	1.2	1.5	1.9	NA	6.0	51
Bobwhite Quail	0.035	0.014	0.017	0.022	NA	0.07	0.60

[1] SWMU 3 surface soil was never evaluated except in combination with SWMU 2 surface soil. SWMU 145 was not evaluated because of the presence of a cap on the site.
NA: PCBs not detected.

G.6. UNCERTAINTIES

There are a number of uncertainties that impact the potential usefulness of the results of the previously conducted ERAs. At SWMU 7, additional surface soil samples were collected at two sampling locations after completion of the previous ecological risk assessment. The maximum detected concentration of metals, organics, and radionuclides for these new SWMU 7 samples appear in Attachment F1 of Appendix F (the human health risk assessment). For all metals and most radionuclides, the maximum detected concentration associated with the new samples is well below the maximum detected concentration used in the previous ecological risk assessment for SWMU 7 and therefore would not alter the results of that assessment. The maximum detected concentration of Total PCBs (14.8 mg/L) in the new surface samples exceeds the value used in the risk assessment, but PCBs already were retained as a COPC for SWMU 7. The new samples contained a detection of di-n-butyl phthalate, but the detected concentration of 0.94 would have an HQ of 1.0 using the di-n-butyl phthalate benchmark from the WAG 3 RI report. Uranium -234, uranium-235, and uranium-236 also were detected at higher maximum concentrations in the new surface soil samples at SWMU 7. Radionuclides already were retained for SWMU 7 based on dose to plants from uranium; the new data therefore do not substantially impact the results of the assessment already conducted and summarized in this appendix. The screening evaluations summarized here included the surface soil interval. Sufficient sampling results were not available for subsurface soil in the depth range of interest (0-5 ft bgs) to which burrowing animals may be exposed to conduct a quantitative screen of the subsurface soil. In addition, characterization of the buried waste was not adequate to quantitatively assess potential exposure for burrowing animals. Because the screening for surface soil indicated that additional evaluation of all the BGOU SWMUs was necessary, the uncertainties relating to exposures of burrowing animals will be addressed as part of that future evaluation, which will resolve the uncertainties related to these potential exposure pathways.

Another 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 the surrounding industrial area may limit the extent to which ecological receptors use these areas.

The exposure parameters used for the wildlife receptors in the previous ERAs were assembled from literature values. These general values are representative of the population as a whole or may come from a population in a different area of the United States than the facility. Exposure parameter values for

populations of these receptors in western Kentucky may differ from those used in the assessment, which could result in an over- or underestimate of dose and the resulting risk or hazard.

The food web modeling for PCBs is based on bioaccumulation and transfer of contaminants through the food chain, sometimes for several levels of the food chain. Uncertainty in the values for bioaccumulation factors used to estimate the concentration in food items for the food web model generally leads to an overestimation of potential risk, because of conservatism in the bioaccumulation factors available in the literature.

These uncertainties, combined with the results of the ERAs, indicate the need for further evaluation of these sites. Risk managers may determine that sites do 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 sites to better define the potential ecological risk indicated by the results of the previous ERAs. Alternatively, the benchmarks used in the screenings presented here and in the NFA levels in the PGDP risk ecological risk methods documents (DOE 2001 and the 2008 draft revision of the same document) may be used as the ecologically-based remedial goal options (RGOs).

G.7. CONCLUSIONS

Each of the sites evaluated in the ERAs summarized in this section retained a number of COPCs. Some metals at concentrations above background were retained as COCs for ecological risk at each SWMU. Total PCBs were retained as COPCs for all SWMUs, except SWMU 6. This is based on direct risk from soil as well as risks to some wildlife receptors from bioaccumulation through the food chain. The only other COPCs retained are three SVOCs (fluorene, phenanthrene, and di-n-butyl phthalate) at SWMU 5 and di-n-butyl phthalate at SWMU 6.

The current plan is to conduct additional ecological risk assessment in future RI activities. In the absence of these future activities, the benchmarks used in the screenings presented here and in the NFA levels in the PGDP risk ecological Risk Methods Documents (DOE 2001 and the 2008 draft revision of the same document) will be used to develop ecologically-based RGOs.

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APPENDIX H

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND TO BE CONSIDERED GUIDANCE

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ACRONYMS

ALARA	as low as reasonably achievable
ARAR	applicable or relevant and appropriate requirement
BGOU	Burial Grounds Operable Unit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
COE	U.S. Army Corps of Engineers
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FR	*Federal Register*
FS	feasibility study
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NWP	Nationwide Permit
OSHA	Occupational Safety and Health Association
PGDP	Paducah Gaseous Diffusion Plant
RI	remedial investigation
SWMU	solid waste management unit
TBC	To Be Considered
USC	*United States Code*

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H.1 INTRODUCTION

Congress specified in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) § 121 (42 *USC* 9621) that remedial actions for the cleanup of hazardous substances must require a level or standard of control that attains those requirements, criteria, standards, or limitations under federal or more stringent state environmental laws that are legally applicable or relevant and appropriate (ARAR) to the hazardous substances or circumstances at a site (unless an ARAR is waived).

This appendix supplies a preliminary list of available federal and state ARARs that may be associated with potential remedial actions at the Burial Grounds Operable Unit (BGOU) at the Paducah Gaseous Diffusion Plant (PGDP). The process of ARAR identification is an iterative one that is continually changing as the remedial investigation/feasibility study (RI/FS) progresses; therefore, the ARARs that are identified represent a compilation of potential ARARs that are subject to change as site-specific contamination at the BGOU is further characterized and alternatives are further evaluated. Site-specific ARARs will be identified further during the remedial action selection for the FS. The U.S. Environmental Protection Agency (EPA) differentiates ARARs as either "applicable" or "relevant and appropriate" to a site. The terms and conditions of these categories are as follows:

- *Applicable requirements* are "those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site" (40 *CFR* § 300.5); and

- *Relevant and appropriate requirements* are "those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site" (40 *CFR* § 300.5).

The EPA also categorizes ARARs based on whether they are specific to the chemical(s) present at the site (chemical-specific), the remedial action being evaluated (action-specific), or the location of the site (location-specific). The EPA designated these categories to assist in the identification of ARARs; however, they are not necessarily precise [53 *FR* 51437 (1988)]. Some ARARs may fit into more than one category, while others may not definitively fit into any one category. Terms and conditions relevant to this categorization are included in the list that follows:

- *Chemical-specific ARARs* usually are "health- or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of numerical values" [53 *FR* 51437 (1988)]. These values establish the acceptable amount or concentration of a chemical that may remain in, or be discharged to, the ambient environment.

- *Action-specific ARARs* usually are "technology- or activity-based requirements or limitations placed on actions taken with respect to hazardous wastes, or requirements to conduct certain actions to address particular circumstances at a site" [53 *FR* 51437 (1988)]. Selection of a particular remedial action at a site will trigger action-specific ARARs that specify appropriate technologies and performance standards.

- *Location-specific ARARs* "generally are restrictions placed upon the concentration of hazardous substances or the conduct of activities solely because they are in special locations" [53 *FR* 51437

(1988)]. Some examples of special locations include floodplains, wetlands, historic places, and sensitive ecosystems or habitats.

Pursuant to CERCLA § 121(e) [42 *USC* 9621(e)(1)], response actions, or portions of response actions conducted entirely on-site, as defined in 40 *CFR* 300.5, must comply with the substantive portions of ARARs, but not the procedural or administrative requirements. Additionally, CERCLA § 121(d)(4) [42 *USC* 9621(d)(4)] provides six ARAR waiver options that may be invoked, provided that human health and the environment are protected.

Published, unpromulgated information that does not necessarily meet the definition of an ARAR may be necessary, under certain circumstances, to determine what is protective of human health and the environment. This type of information is known as To Be Considered (TBC) guidance and also may be useful in developing CERCLA remedies. Because ARARs do not exist for every chemical or circumstance that may be found at a CERCLA site, the EPA believes that it may be necessary, when determining cleanup requirements or designing a remedy, to consult reliable information that otherwise would not be considered a potential ARAR. Criteria or guidance developed by the EPA, other federal agencies, or states may assist in determining, for example, health-based levels for a particular contaminant or the appropriate method for conducting an action for which there are no ARARs. The TBC guidance generally falls within four categories: (1) health effects information; (2) technical information on how to perform or evaluate investigations or response actions; (3) policy; and (4) proposed regulations, if the proposed regulation is noncontroversial and likely to be promulgated as drafted.

The EPA requires compliance with Occupational Safety and Health Association (OSHA) standards through § 300.150 of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), not through the ARARs process. Worker health and safety requirements typically are not addressed as ARARs. The regulations at 29 *CFR* 1910.120 are designed to protect workers involved in cleanup operations at uncontrolled hazardous waste sites and to provide for worker protection during initial site characterization and analysis, monitoring activities, materials handling activities, training, and emergency response.

As mentioned above, ARARs identification is an iterative process that continually changes as the RI/FS progresses. There are no chemical-specific ARARs for this action. The action-specific ARARs will be identified as part of the FS, based upon the remedial alternatives under consideration; therefore, the ARARs discussed are focused on location-specific ARARs. The final set of ARARs will be included as part of the Record of Decision based on the selected remedy.

H.2 LOCATION-SPECIFIC APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

No threatened or endangered species or their potential habitats, critical habitats, 100-year floodplains, wetlands, prime farmland, or cultural resources have been identified in the boundaries of the BGOU solid waste management units (SWMUs); however, a 100-year floodplain has been identified near SWMU 4 and wetlands have been identified in the ditches south of SWMU 4 and across a roadway to the north. Wetlands also have been identified south of SWMUs 5 and 6 on the other side of a roadway (CDM 1994; COE 1994; LMES 1996). ARARs discussed in this section will be met by avoidance of the resource to the extent practicable. If impacts become apparent, measures to mitigate adverse effects will be taken.

Construction activities must avoid or minimize adverse impacts on wetlands and act to preserve and enhance their natural and beneficial values (10 *CFR* 1022).If the action involves the discharge of dredged

or fill material into waters of the United States, the response action will comply with the substantive requirements of Nationwide Permit (NWP) 38 (Cleanup of Hazardous and Toxic Waste), however, the specific requirement of notification is not required for CERCLA actions under this NWP. Consequently, although wetlands should be delineated and avoided to the extent possible, the delineation does not have to be sent to the U.S. Army Corps of Engineers (COE), and the COE does not have to be notified for this action [61 *FR* 65905-65906 (1996)].

No federally listed or candidate species or their habitats are known to occur in the vicinity of the project area. The Commonwealth of Kentucky has no threatened and endangered species regulations promulgated at this time.

H.3 ACTION-SPECIFIC APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Action-specific ARARs will be developed, as appropriate, in the FS.

H.4 CHEMICAL-SPECIFIC APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

There are no chemical-specific ARARs for this action.

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