Department of Energy

Portsmouth/Paducah Project Office
1017 Majestic Drive, Suite 200
Lexington, Kentucky 40513
(859) 219-4000

FEB 08 2013

Mr. Wm. Turpin Ballard
Remedial Project Manager
U.S. Environmental Protection Agency, Region 4
61 Forsyth Street
Atlanta, Georgia 30303

PPPO-02-1815290-13B

Mr. Todd Mullins, FFA Manager
Kentucky Department for Environmental Protection
Division of Waste Management
200 Fair Oaks Lane, 2nd Floor
Frankfort, Kentucky 40601

Dear Mr. Ballard and Mr. Mullins:

TRANSMITTAL OF THE FEASIBILITY STUDY FOR SOLID WASTE MANAGEMENT UNITS 5 AND 6 OF THE BURIAL GROUNDS OPERABLE UNIT AT THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY, DOE/LX/07-0130a&D2/R3

References:

1. Letter from J. Woodard to Wm. T. Ballard and T. Mullins, Paducah Federal Facility Agreement – Transmittal of Resolution Agreement of Informal Dispute for the D2/R2 Feasibility Study for Solid Waste Management Units 5 and 6 of the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/LX/07-0130a&D2/R2)," dated December 19, 2012
2. E-mail from T. Mullins to J. Woodard, Untitled (Subject: Dispute SWMU 5&6 ARARs), dated October 19, 2012
3. Letter from B. Schneider for A. Webb to R. Blumenfeld, "Feasibility Study for Solid Waste Management Units 5 and 6 of the Burial Grounds Operable Unit (DOE/LX/07-0130a&D2/R2)," dated September 26, 2012
4. Letter from Wm. T. Ballard to R. Blumenfeld, Untitled [Subject: Clarification of EPA's Nonconcurrence of the Feasibility Study for Solid Waste Management Units (SWMU) 5 and 6 of the Burial Ground Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/LX/07-0130a&D2/R2)], dated September 25, 2012
5. Letter from Wm. T. Ballard to R. Blumenfeld, Untitled [Subject: EPA's Nonconcurrence of the Feasibility Study for Solid Waste Management Units (SWMU) 5 and 6 of the Burial Ground Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/LX/07-0130a&D2/R2)], dated September 18, 2012

Enclosed is the *Feasibility Study for Solid Waste Management Units 5 and 6 of the Burial Grounds Operable Unit, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0130a&D2/R3, which incorporates the terms of the signed *Memorandum of Agreement of Resolution of Informal Dispute for the D2/R2 Feasibility Study for Solid Waste Management Units 5 and 6 of the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0130a&D2/R2, dated December 19, 2012, and clarifications received during recent comment resolution meetings. In addition, a redline version of the document is provided to assist with your review.

The U.S. Department of Energy (DOE) is very appreciative of the hard work, time commitment, and overall level of cooperation provided by the Kentucky Department for Environmental Protection and the U.S. Environmental Protection Agency to work through resolution and finalization of the subject document. DOE looks forward to the agencies' final approval of the feasibility study.

If you have any questions or require additional information, please contact Lisa Santoro at (270) 441-6804.

Sincerely,

Rachel H. Blumenfeld
Acting Paducah Site Lead
Portsmouth/Paducah Project Office

Enclosures:

1. Feasibility Study for Solid Waste Management Units 5 and 6 of the Burial Grounds Operable Unit, Paducah Gaseous Diffusion Plant, Paducah, Kentucky, DOE/LX/07-0130a&D2/R3
2. Redline Feasibility Study for Solid Waste Management Units 5 and 6 of the Burial Grounds Operable Unit, Paducah Gaseous Diffusion Plant, Paducah, Kentucky, DOE/LX/07-0130a&D2/R3

e-copy w/enclosures:
ballard.turpin@epa.gov, EPA/Atlanta
brandy.mitchell@lataky.com, LATA/Kevil
bruce.ford@lataky.com, LATA/Kevil
christie.lamb@lataky.com, LATA/Kevil
craig.jones@lataky.com, LATA/Kevil
edward.johnstone@lataky.com, LATA/Kevil
gaye.brewer@ky.gov, KDEP/PAD
jennifer.woodard@lex.doe.gov, PPPO/PAD
leo.williamson@ky.gov, KDEP/Frankfort
lisa.santoro@lex.doe.gov, PPPO/PAD
mark.duff@lataky.com, LATA/Kevil
myrna.redfield@lataky.com, LATA/Kevil
pad.dmc@swiftstaley.com, SST/Kevil
rachel.blumenfeld@lex.doe.gov, PPPO/PAD
reinhard.knerr@lex.doe.gov, PPPO/PAD
rob.seifert@lex.doe.gov, PPPO/PAD
stephaniec.brock@ky.gov, KYRHB/Frankfort
todd.mullins@ky.gov, KDEP/Frankfort
tufts.jennifer@epa.gov, EPA/Atlanta

CERTIFICATION

Document Identification: ***Feasibility Study for Solid Waste Management Units 5 and 6 of the Burial Grounds Operable Unit, Paducah Gaseous Diffusion Plant, Paducah, Kentucky,*** **DOE/LX/07-0130a&D2/R3**

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

LATA Environmental Services of Kentucky, LLC

Mark J. Duff, Paducah Project Manager — 2-8-13 Date Signed

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

U.S. Department of Energy (DOE)

Rachel H. Blumenfeld, Acting Paducah Site Lead
Portsmouth/Paducah Project Office — 2-8-13 Date Signed

DOE/LX/07-0130a&D2/R3
Primary Document

Feasibility Study for Solid Waste Management Units 5 and 6 of the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

CLEARED FOR PUBLIC RELEASE

DOE/LX/07-0130a&D2/R3
Primary Document

Feasibility Study for Solid Waste Management Units 5 and 6 of the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—February 2013

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
LATA Environmental Services of Kentucky, LLC
managing the
Environmental Remediation Activities at the
Paducah Gaseous Diffusion Plant
under contract DE-AC30-10CC40020

CLEARED FOR PUBLIC RELEASE

THIS PAGE INTENTIONALLY LEFT BLANK

PREFACE

This *Feasibility Study for Solid Waste Management Units 5 and 6 of the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0130a&D2/R3, was prepared to evaluate remedial alternatives to support remedy selection under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) at the U.S. Department of Energy's Paducah Gaseous Diffusion Plant (PGDP). This document follows the *Feasibility Study for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0130&D2, (DOE 2010a) submitted in December 2010. As a result of review and discussion by the Federal Facility Agreement (FFA) parties, the D2 version of the feasibility study was separated into smaller documents focused on fewer solid waste management units (SWMUs) (DOE 2010a). This document, DOE/LX/07-0130a&D2/R3, presents only information about SWMUs 5 and 6. Information for the rest of the Burial Grounds Operable Unit landfills and burial grounds is presented in separate documents. This work was prepared in accordance with the requirements of the *Federal Facility Agreement for the Paducah Gaseous Diffusion Plant* (EPA 1998). In accordance with Section IV of the FFA, this integrated technical document was developed to satisfy applicable requirements of CERCLA (42 *USC* § 9601 *et seq.*) and the Resource Conservation and Recovery Act (42 *USC* § 6901 *et seq.*). As such, the phases of the investigation process are referenced by CERCLA terminology within this document to reduce the potential for confusion.

THIS PAGE INTENTIONALLY LEFT BLANK

CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

ACRONYMS

amsl	above mean sea level
ARAR	applicable or relevant and appropriate requirement
AT123D	Analytical Transient 1-,2-,3-Dimensional
BHHRA	baseline human health risk assessment
BGOU	Burial Grounds Operable Unit
bgs	below ground surface
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
CRMP	Cultural Resources Management Plan
CSM	conceptual site model
DNAPL	dense nonaqueous-phase liquid
DOE	U.S. Department of Energy
DPE	dual-phase extraction
ELCR	excess lifetime cancer risk
E/PP	excavation/penetration permit
EPA	U.S. Environmental Protection Agency
ERH	electrical resistance heating
FFA	Federal Facility Agreement
FR	*Federal Register*
FS	feasibility study
GAC	granular-activated carbon
GRA	general response action
HDPE	high-density polyethylene
HI	hazard index
HQ	hazard quotient
HU	hydrogeologic unit
ISCO	*in situ* chemical oxidation
KAR	*Kentucky Administrative Regulations*
KDEP	Kentucky Department for Environmental Protection
KEEC	Kentucky Energy and Environment Cabinet
KOW	Kentucky Ordnance Works
KPDES	Kentucky Pollutant Discharge Elimination System
KY	Commonwealth of Kentucky
LCD	Lower Continental Deposits
LDA	large diameter auger
LLW	low-level waste
LUC	Land Use Control
LUCIP	land use control implementation plan
MCL	maximum contaminant level
MLLW	mixed low-level waste
MNA	monitored natural attenuation
MW	monitoring well
NAL	no action level
NAPL	nonaqueous-phase liquid

NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act of 1969
NHPA	National Historic Preservation Act
NNSS	Nevada Nuclear Security Site
NPL	National Priorities List
NRCS	Natural Resources Conservation Service
NRDA	Natural Resource Damage Assessment
O&M	operation & maintenance
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PGDP	Paducah Gaseous Diffusion Plant
POE	point of exposure
PRB	permeable reactive barrier
PTW	principal threat waste
RAO	remedial action objective
RAWP	Remedial Action Work Plan
RCRA	Resource Conservation and Recovery Act
RDWP	Remedial Design Work Plan
RG	remediation goal
RGA	Regional Gravel Aquifer
RI	remedial investigation
ROD	Record of Decision
RPO	representative process option
SADA	Spatial Analysis and Decision Assistance
SERA	screening ecological risk assessment
SESOIL	Seasonal Soil Compartment Model
SMP	Site Management Plan
SPH	six-phase heating
SVE	soil vapor extraction
SVOA	semivolatile organic analytes
SVOC	semivolatile organic compound
SWMU	solid waste management unit
T&E	threatened and endangered
TBC	to be considered
Tc-99	technetium-99
TCE	trichloroethene
TCH	thermal conduction heating
TSCA	Toxic Substances Control Act
TVA	Tennessee Valley Authority
UCD	Upper Continental Deposits
UCRS	Upper Continental Recharge System
USC	*United States Code*
USFWS	U. S. Fish and Wildlife Service
VOA	volatile organic analytes
VOC	volatile organic compound
WAC	waste acceptance criteria
WAG	waste area grouping
WKWMA	West Kentucky Wildlife Management Area
ZVI	zero-valent iron

EXECUTIVE SUMMARY

This *Feasibility Study for Solid Waste Management Units 5 and 6 of the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0130a&D2/R3 (FS), was prepared to evaluate remedial alternatives for Solid Waste Management Units (SWMUs) 5 and 6 of the Burial Grounds Operable Unit (BGOU) in support of remedy selection under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) at the Paducah Gaseous Diffusion Plant (PGDP). This work was prepared in accordance with the requirements of the *Federal Facility Agreement for the Paducah Gaseous Diffusion Plant* (FFA) (EPA 1998).

Under a work plan approved by U.S. Environmental Protection Agency (EPA) and the Commonwealth of Kentucky (KY) (DOE 2006), the U. S. Department of Energy (DOE) conducted a Remedial Investigation (RI), which was the continuation of earlier investigative activities, to evaluate source areas of contamination associated with PGDP's landfills and burial grounds. Results of the RI were reported in the *Remedial Investigation Report for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0030&D2/R1 (DOE 2010b). A baseline human health risk assessment (BHHRA) also was conducted that evaluated the full range of risks to human health under a range of exposure scenarios associated with current and future land use, some of which are unlikely or hypothetical. A screening ecological risk assessment (SERA) also evaluated impacts to the environment.

Following approval of the RI, an FS was prepared, with the latest version being the *Feasibility Study for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0130&D2, submitted in December 2010 (DOE 2010b). As a result of review and discussion by the FFA parties, the D2 version of the FS has been subdivided into focused groupings. This document presents an FS for SWMUs 5 and 6 that develops and evaluates remedial alternatives to address residual risks from and uncertainties about these SWMUs. Information for the rest of the BGOU landfills and burial grounds will be presented in separate documents.

The RI identified risks to human health and the environment from potential exposure to contaminants of concern (COCs) remaining in surface and subsurface soils at SWMUs 5 and 6 under some current and future use scenarios. This FS summarizes additional evaluation of these risks and determines that there is no SWMU-related direct contact risk under reasonably anticipated future use. Additionally, there are no leaching risks from soils that need to be addressed as part of this FS. The source term information for wastes buried at SWMUs 5 and 6 is limited to historical records. The waste has not been sampled. Though the nature of disposed materials does not suggest a significant potential risk, the impact to human health from direct contact with buried wastes is identified as an uncertainty and will be addressed through the developed alternatives. Likewise, process knowledge does not indicate potential for substantial surface soil contamination associated with SWMUs 5 and 6 activities; however, the degree of impact to human health and the environment remains uncertain. This FS develops and evaluates a range of remedial alternatives to prevent direct contact with surface soils and buried wastes and for monitoring Regional Gravel Aquifer (RGA) groundwater beneath these SWMUs to document no unacceptable impacts to RGA groundwater. The FS also develops and evaluates alternatives to monitor surface water to document no unacceptable impacts.

SCOPE OF THE BGOU

The BGOU at PGDP is one of five media-specific, sitewide operable units (OUs) associated with pre-shutdown efforts to evaluate and implement remedial actions. A final Comprehensive Site OU evaluation will be conducted following plant shutdown and completion of pre- and post-shutdown actions to ensure long-term protectiveness of human health and the environment. The five media-specific, strategic cleanup initiatives that have been agreed upon by DOE, EPA, and the KY, as documented in the current Site Management Plan (SMP) (DOE 2012), are as follows:

- Groundwater OU Strategic Initiative
- Burial Grounds OU Strategic Initiative
- Surface Water OU Strategic Initiative
- Soils OU Strategic Initiative
- Decontamination and Decommissioning OU Strategic Initiative

The BGOU consists of contamination associated with PGDP's landfills and burial grounds as listed in Table ES.1. In general, the contents of the burial grounds, upon excavation and characterization for disposal, may include RCRA hazardous waste, PCB waste, and low-level radioactive waste (LLW). Some of the materials in the PGDP burial grounds are considered to be principal threat waste (PTW). Based upon disposal records, SWMUs 5 and 6 contain industrial wastes, some of which are LLW. Without more definitive waste characterization (i.e., sampling and analysis), it is not possible to state whether or not PCBs or RCRA hazardous wastes are also present at SWMUs 5 and 6. Based upon the waste inventory, the buried wastes at SWMUs 5 and 6 (including low-level radioactive waste) are considered low level threat waste consistent with EPA guidance.

The scope of the BGOU FS includes evaluating risks from the waste units and evaluating alternatives as necessary for protection of human health and the environment, including addressing releases or potential releases from these source areas that may affect RGA) groundwater and/or the surface water drainageways. Remedial decisions for sediments located adjacent to the BGOU SWMUs fall primarily within the scope of the Surface Water OU. The Groundwater OU will address dissolved-phase groundwater contamination in the RGA.

Table ES.1. BGOU Source Areas and Solid Waste Management Units

SWMU No.	Description
2	C-749 Uranium Burial Grounds
3	C-404 Low-Level Radioactive Waste Burial Grounds
4	C-747 Contaminated Burial Yard and C-748-B Burial Area
5	C-746-F Burial Yard
6	C-747-B Burial Grounds
7 and 30	C-747-A Burial Grounds and Burn Area
145 (9 and 10)	Area P and C-746-S and C-746-T Landfills

PREVIOUS INVESTIGATIONS AND OTHER INFORMATION USED FOR THIS FS

Table ES.2 identifies the previously completed reports and/or investigations related to SWMUs 5 and 6 used in the development of this FS. Additionally, information obtained after completion of these previous investigations has been included where that information has been deemed relevant to the development of remedial alternatives. In particular, *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Volume 1: Human Health*, DOE/OR/07-1506&D2/R0/V1, dated December 2001, has been superseded by *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Volume 1: Human Health,* DOE/LX-07-0107&D2/R1/V1, dated February 2011 (DOE 2011b).

SOURCE AREAS AND NATURE AND EXTENT OF CONTAMINATION

The SWMUs comprising the BGOU consist primarily of landfills and belowground burial cells in which various PGDP wastes have been placed. SWMUs 5 and 6 are located in the northwestern section of the PGDP industrial area. SWMU 5 (~4.5 acres) operated from 1965 to 1987. Disposal cells at SWMU 5 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. SWMU 6 (~0.3 acres) operated from 1960 to 1976. Wastes disposed in SWMU 6 include magnesium and aluminum scrap metal and larger metal waste (exhaust fans, modine trap). Historical information on these sources does not indicate PCBs or solvents were disposed of in these areas, and this information is consistent with the site characterization data. Waste areas in both SWMUs are covered with more than two ft of soil.

Table ES.2. Summary of Previous Investigations of BGOU

Dates	Title	SWMU 5	SWMU 6
1990–1992	Phase II Site Investigation (CH2M HILL 1992)	✓	✓
1998–2001	WAG 3 RI/FS (DOE 1998)	✓	✓
1999–2001	Data Gaps Investigation (DOE 2000a)	✓	
2002–2003	Scrap Yards Site Characterization (Paducah OREIS)	✓	✓
2006	Burial Grounds RI/FS Work Plan (DOE 2006)	✓	✓
2007	Burial Grounds Remedial Investigation (DOE 2010b)	✓	✓

Table ES.2 is based on Table 1.4 of the BGOU RI (DOE 2010b).
Blank cells indicate the investigation is not applicable to the SWMU.
Paducah OREIS = Paducah site information contained in the Oak Ridge Environmental Information System database
SWMU = solid waste management unit
WAG = waste area grouping

The waste materials in SWMUs 5 and 6 have limited mobility. Nevertheless, the potential for materials to migrate to groundwater was evaluated in the RI (DOE 2010b). If contaminants were mobilized, they have the potential to migrate downward through the Upper Continental Recharge System (UCRS) soils and reach the RGA. Some lateral movement of contaminants could occur in the UCRS, but these pathways are known to be limited. There also is a limited pathway for groundwater to migrate through the cover material to the surface of SWMU 5. These periodic circumstances, should they occur, would create a route for SWMU 5 contaminants to migrate to the surface and could contaminate adjacent surface soils and/or expose workers to potential contamination in seep water. These circumstances could result in an unacceptable level of risk. Based on this conceptual model, any contamination resulting from buried waste found at these SWMUs would be expected to be found concentrated in the soils and groundwater of the UCRS immediately within and under the burial cells, with little lateral dispersion of contamination in the UCRS from the cells and immediately adjacent soils. The RI Report 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. Consistent with the BGOU FS scope, the source areas, contamination in secondary sources impacted by releases from the waste, and potential for future migration from the wastes were the basis for evaluation of remedial alternatives.

MIGRATION PATHWAYS AND RISK SUMMARY

The RI identified unacceptable risks to human health and the environment from SWMUs 5 and 6 under some future use scenarios. The potential risks evaluated include the following:

- Direct contact with buried wastes;
- Direct contact with surface soils;

- Direct contact with subsurface soils; and
- Migration of COCs to groundwater and/or surface water.

As stated, the source terms at SWMUs 5 and 6 were not sampled. The impact to human health from direct contact with buried wastes was not identified quantitatively in the BHHRA, and no specific COCs were identified. Hazards associated from contact with waste are identified as an uncertainty and the potential threat will be addressed through the developed alternatives in this FS. The BHHRA identified COCs in surface and subsurface soils and evaluated and reported the hazards and risks for the current and future uses, some of which are unlikely or hypothetical. PGDP is an industrial facility and is expected to remain an industrial facility. The current access controls for SWMUs 5 and 6 (as well as all the burial grounds) are expected to continue into the foreseeable future. Thus, the future use scenario considered reasonable for SWMUs 5 and 6 is that of industrial.

Several COCs were identified in the BHHRA that potentially would limit future residential use of RGA groundwater or pose a potential unacceptable risk to future industrial and future outdoor workers who may contact contaminated soil. (Note that future outdoor worker was defined as excavation worker in the RI.) The COCs, as identified in the BHHRA, are summarized in this section. Several modifying factors were considered, as potential remediation goals (RGs) were being identified for this FS. This includes whether the waste unit was the source of the impact, updates to the toxicity assessment, and additional review indicating many of the naturally occurring metals were at or below background concentrations. See Appendices A and B for this evaluation.

The potential for releases from the waste to limit residential use of groundwater were evaluated in the risk assessment at the SWMU boundary and downgradient potential points of exposure. The COCs identified in the BHHRA for residential use of RGA groundwater at the SWMU boundary included:

- SWMU 5: Arsenic, technetium-99, uranium, manganese, and naphthalene
- SWMU 6: No COCs

The BHHRA identified COCs for contact with contaminants in soil. The COCs identified for the future industrial worker (surface soils) and future outdoor worker (soils depths from 0–16 ft bgs) were the focus of this FS (Table ES.3). The future land use is expected to remain industrial (DOE 2012).

Although Total polycyclic aromatic hydrocarbon (PAH) is identified as a COC for both SWMUs 5 and 6, the data indicate that the waste units are not the source of PAH impacts to the adjacent drainageways. No complete migration pathway from the source areas to these drainageways was identified, although there is a limited migration route at SWMU 5 for groundwater to reach the surface. The conceptual model for the BGOU is that contaminants released from the waste to infiltrating water will exit from the bottom of the burial cells and migrate vertically downward through the UCRS and into the RGA. The potential for lateral migration through the UCRS was investigated in 2011(Johnstone 2011). No seeps and no evidence of lateral migration were observed in ditches adjacent to SWMUs 5 and 6 during observation made on April 27, 2011, after a 500-year rainfall event for the 60-day period leading up to the observation. In 1997, water observed at three points along the southern edge of the SWMU 5 waste cell cover material was reported to be the result of seeps (Mullins 1997). The reported seeps never again have been observed and there is little data and much uncertainty about the reported seeps. The distribution of PAH detects in surface soil samples and the location of elevated detects, as seen in Figure B.1 of this document, provide no indication that the reported seeps have contributed to PAH contamination. In addition, PAHs were not detected in any subsurface soil samples beneath the waste units suggesting these have not been released from these source areas.

Table ES.3. Summary of COCs Identified for Future Industrial Worker (0–1 ft bgs) and Outdoor Worker (0–16 ft bgs)

	SWMU 5	SWMU 6
Carcinogenic COCs (ELCR > 1E-06)	Arsenic Beryllium Total PAH *Total PCB*	Beryllium Total PAH
Non-cancer Hazard COCs (HQ > 0.1)	*Aluminum* *Arsenic* *Barium* *Beryllium* *Chromium* *Iron* *Manganese*	*Aluminum* *Barium* *Beryllium* *Chromium* *Iron* *Manganese* *Vanadium*

Table ES.3 is from the BGOU RI (DOE 2010b).
Analytes shown in italics only identified as COCs for outdoor worker scenario.
Analytes not italicized are COCs for future industrial and outdoor worker scenarios.
bgs = below ground surface
COC = contaminant of concern
ELCR = excess lifetime cancer risk
HQ = hazard quotient
PCB = polychlorinated biphenyl
PAH = polycyclic aromatic hydrocarbon
SWMU = solid waste management unit

The SERA was summarized in the BGOU RI. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. Direct toxic effects on wildlife populations are low when screened against benchmarks due to the industrial nature and small scale of the SWMUs. The cumulative effects of small losses or contamination of terrestrial habitat will be assessed facility-wide (or watershed-wide) in the PGDP baseline ecological risk assessment for the Surface Water OU. For SWMUs 5 and 6, metals were the more frequently identified chemicals exceeding benchmarks, but typically were below background concentrations. PAHs and PCBs also were chemicals of potential concern for SWMU 5, but predominantly were in samples collected from soils or sediments adjacent to the disposal areas not related to releases from the wastes.

IDENTIFICATION OF REMEDIAL ACTION OBJECTIVES AND DEVELOPMENT OF REMEDIATION GOALS

Remedial action objectives (RAOs) are goals for protection of human health and the environment. RAOs provide a general description of what a CERCLA cleanup is designed to accomplish. The BGOU FS evaluates taking actions as necessary to protect human health and the environment from the BGOU waste units and addressing potential releases from these source areas that may impact RGA groundwater or adjacent drainageways. The following general RAOs were developed.

(1) Contribute to the protection of groundwater by eliminating, reducing, or controlling sources of groundwater contamination; and

(2) Prevent exposure to waste and contaminated soils that present an unacceptable risk from direct contact.

The BGOU waste areas are located within the industrial area of the PGDP facility, and reasonable future use of this area is expected to remain industrial. At SWMUs 5 and 6, buried waste consisting of radionuclide-contaminated metal debris and other materials is not sufficiently characterized to determine whether there would be an unacceptable threat. Only limited soil data are available to characterize the contamination in the surface soils at SWMU 5, creating an uncertainty when evaluating potential risks for direct contact.

To address this uncertainty this FS evaluates alternatives designed to eliminate direct contact with wastes to ensure no risk to future outdoor workers.

The following are SWMU-specific RAOs for SWMUs 5 and 6.

SWMU-specific RAO 1. Contribute to the protection of groundwater by eliminating, reducing, or controlling sources of groundwater contamination that will result in an exceedance of the maximum contaminant level (MCL) or risk-based concentration for residential use of groundwater in the absence of an MCL in RGA groundwater.

SWMU-specific RAO 2. Prevent exposure to waste or waste-related contaminated soils that exceed target cumulative excess lifetime cancer risks (ELCRs) and cumulative noncancer hazard indices (HIs) for the future industrial and future outdoor worker receptors. The acceptable cumulative risk levels for this RAO are defined as follows:

- Surface Soil: cumulative ELCR < 1E-05 and cumulative HI ≤ 1 for a future industrial worker
- Subsurface Soil: cumulative ELCR < 1E-04 and cumulative HI ≤ 1 for an future outdoor worker

For subsurface soils (1–16 ft bgs), the RAO was defined to be protective of the future outdoor worker. Using current background and toxicity values, none of the subsurface soil samples at SWMUs 5 and 6 pose a noncancer hazard; that is, each sample had an HI less than 1. Arsenic, PAHs, and PCBs were carcinogens identified as contributing to the ELCR (beryllium is not evaluated as a carcinogen in this FS) in SWMU 5 and Total PAHs in SWMU 6. Arsenic was below background concentrations in all subsurface soil samples, and neither PAHs nor PCBs were detected in any subsurface soils; therefore, there are no COCs to be addressed in this FS to meet the RAO for subsurface soils.

For surface soils, the RAO was defined to be protective of the future industrial worker. The HI for the future industrial worker was less than 1 at both SWMUs 5 and 6; therefore, no COCs to address noncancer hazards in surface soils were identified in the BHHRA. Arsenic was identified as contributing to the ELCR at SWMU 5, but is at background concentrations. It exceeded the background concentration of 12 mg/kg in only one sample, with a concentration of 12.2 mg/kg. This was in a drainageway sample not associated with the waste disposal areas.

Total PAHs was the other COC identified as contributing to the ELCR in both SWMUs. Total PAHs were found only in surface soils/sediments in drainageways adjacent to the SWMUs and the impact at these locations is being addressed within the surface water OU.

Potential migration of contaminants from the waste that may pose an ongoing source to RGA groundwater was evaluated in the BHHRA. The concentrations in groundwater at the SWMU boundary were modeled based on the soil concentrations. For this FS, the groundwater cleanup levels are MCLs or risk-based concentrations for residential use of groundwater in the absence of an MCL.

In SWMU 6, no COCs were identified in the BHHRA for residential use of groundwater at the SWMU boundary for protection of groundwater. A review of the COCs identified for SWMU 5 suggests that none would exceed the MCL in RGA groundwater, are below background, or are not detected in subsurface soils. For example, arsenic and technetium-99 were identified as contributing to an unacceptable ELCR;

however, modeled concentrations in the RGA were below the MCLs and subsurface soil concentrations are below background. For noncancer hazards, uranium was identified as a primary COC associated with the migration of contamination from buried waste to groundwater; however, no releases to soils were identified (all subsurface soil results below background) and concentrations are below screening levels protective of RGA groundwater at the MCL of 0.03 mg/L. Following the review of these data, it was determined that there are no soil COCs to be addressed in this FS for protection of RGA groundwater.

SWMU-specific RAOs were used for screening general response actions (GRAs) and developing and evaluating remedial alternatives. The evaluation of the candidate alternatives to address wastes is based on the waste descriptions/volumes determined for the source characterization. No chemical specific numerical criteria are identified for evaluation of these wastes. Because no soil COCs were identified to be addressed in this FS for protection of the future industrial worker (surface soil), future outdoor worker (subsurface soils), or protection of groundwater, no RGs were developed for protection of human health.

No source or complete migration pathway to the drainage ditches was identified for the PAHs identified in sediments adjacent to the SWMUs; therefore, the surface water OU RAOs/RGs are applicable for these PAHs, and any actions to address these will be completed within the scope of that OU. In addition, no RGs were developed specific to protection of ecological receptors. Risks to terrestrial receptors are not expected at SWMU 6 from current or future exposures. For SWMU 5 risk characterization for terrestrial receptors is uncertain due to the limited soils data used in the screening ecological risk assessment. Given the industrial nature of this habitat, no specific actions were identified for these areas. Most of the impacts identified in the SERAs for these SWMUs were for drainageway or surface soil samples adjacent to the burial ground areas that did not result from migration from the waste. Actions to address human health within the SWMU boundaries will reduce exposures to these receptors. The COCs identified will be investigated further during the sitewide baseline ecological risk assessment where cumulative effects to ecological receptors will be evaluated.

There are no soil COCs at SWMUs 5 or 6 to be addressed in this FS to protect groundwater (RAO 1). There are no COCs to be addressed in this FS to protect future industrial or outdoor workers direct contact with contaminants in soils (RAO 2). PAHs, a COC for the future industrial worker, did not result from a release from the waste unit, and their presence in the drainageways is being evaluated as part of the surface water OU.

In summary, potential contact with buried wastes in SWMUs 5 and 6 and with surface soils at SWMU 5 are the only risks/uncertainties that will be addressed by FS alternatives.

SCOPE OF THE D2/R3 FS REMEDIAL ALTERNATIVES EVALUATION

An objective of this FS is to identify a range of remedial alternatives that addresses the potential threat from direct contact with the waste buried in SWMUs 5 and 6. EPA guidance (EPA/540/G-89/004 at pages 4-7) states that alternatives for source control actions should range from one that would eliminate, to the extent feasible, long-term management to one that would use treatment as a primary component to address principal threats. The guidance also requires inclusion of one or more alternatives that involve containment of the waste with little or no treatment, as well as a No Action alternative. The selected final remedy must comply with applicable or relevant and appropriate requirements (ARARs), unless waived, and must protect human health and the environment.

This FS acknowledges Kentucky's requirement to assess an 1E-06 or *de minimis* risk-based cleanup against the nine CERCLA criteria by the inclusion of Alternative 6, Excavation and Disposal.

Alternative 6 meets the intention of the Kentucky requirement by removing and disposing of waste and impacted soil to meet 1E-04 risk levels followed by at least 2 ft of backfill.

For SWMUs 5 and 6, the following remedial alternatives are brought forward for detailed evaluation.

Alternative 1 – No Action. No action is included as required by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

Alternative 5 – Kentucky Subtitle D Cap, LUCs, and Monitoring. This cap eliminates direct contact with surface soils and prevents water infiltration. LUCs also maintain restrictions on direct contact with the waste and soils in close proximity to the waste by controlling access and excavation in applicable areas. LUCs will be designed and implemented through a LUCIP to ensure protectiveness, should DOE convey ownership of the property. Monitoring will be conducted to verify there is no unacceptable threat to surface water or groundwater because waste is left in place Installation of a Kentucky Subtitle D Cap at SWMUs 5 and 6, which includes multilayers that are distinctly different to the natural subsoils, provides greater depth to the buried waste. These aspects (thickness and distinct properties) of the cap are expected to provide protection of individuals from inadvertent intrusion by alerting them that this is a man-made engineered cover over something that is potentially hazardous to human health and by making it more difficult to expose the buried waste. Based upon the waste inventory, the buried wastes at SWMUs 5 and 6 (including LLW) are considered low level threat waste consistent with EPA guidance.

Alternative 6 – Excavation and Disposal of Waste Materials and Affected Soils. Waste materials in the burial cell and surrounding affected soil will be excavated and removed and replaced with clean backfill.

Those alternatives brought forward underwent both detailed and comparative analysis. Following is a summary of comparative analysis of retained alternatives.

SUMMARY OF COMPARATIVE ANALYSIS (SWMUs 5 AND 6)

Alternatives 5, 6, and 6a meet the threshold criteria. The cap included in Alternative 5 includes sufficient soil to mitigate the potential for direct contact with waste. It also includes a low-permeable layer that severely limits infiltration. By limiting infiltration, potential risks to groundwater and the potential for seep formation are mitigated. Alternative 5 also includes long-term groundwater monitoring.

Alternatives 6 and 6a take the most aggressive action to mitigate source term uncertainty by removing the source term and disposing of it either off-site or at an on-site disposal facility, if one is available. Because all source term material would be removed, there is no need for continued long-term groundwater monitoring or site maintenance.

None of the alternatives would reduce the toxicity, mobility, or volume of contamination through treatment, except that Alternatives 6 and 6a would do so as required to meet disposal facility waste acceptance criteria. Alternative 5 is consistent with EPA's expectation concerning low-level threat waste.

1. INTRODUCTION

This *Feasibility Study for Solid Waste Management Units 5 and 6 of the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0130a&D2/R3 (FS), was prepared to evaluate remedial alternatives for Solid Waste Management Units (SWMUs) 5 and 6 of the Burial Grounds Operable Unit (BGOU) in support of remedy selection under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) at the Paducah Gaseous Diffusion Plant (PGDP). This work was prepared in accordance with the requirements of the *Federal Facility Agreement for the Paducah Gaseous Diffusion Plant* (FFA) (EPA 1998). Only SWMUs 5 and 6 are addressed in this D2/R3 FS. Other SWMUs and source areas within the BGOU are addressed in separate documents.

This introduction explains the BGOU and the purpose and organization of the report. It provides background information and the regulatory framework for this FS. Site and area-specific descriptions are provided, including land use, demographics, climate, air quality, noise, ecological resources, and cultural resources. An overview also is provided of the topography, surface water hydrology, geology, and hydrogeology of the region and the study area. Previous investigations of the BGOU are discussed, as are a conceptual site model (CSM) summarizing the nature and extent of contamination and fate and transport modeling of selected contaminants of concern (COCs). Additional sections in this FS address the potential threat from direct contact with the waste buried within SWMUs 5 and 6, as well as a range of remedial alternatives that are protective of the public and future workers.

1.1 SCOPE OF THE BGOU

The BGOU at PGDP is one of five media-specific, sitewide operable units (OUs) associated with pre-shutdown efforts to evaluate and implement remedial actions. A final Comprehensive Site OU evaluation will be conducted following plant shutdown and completion of pre- and post-shutdown actions to ensure long-term protectiveness of human health and the environment. The five media-specific, strategic cleanup initiatives that have been agreed upon by the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the Commonwealth of Kentucky (KY), as documented in the current Site Management Plan (SMP) (DOE 2012), are as follows:

- Groundwater OU Strategic Initiative
- Burial Grounds OU Strategic Initiative
- Surface Water OU Strategic Initiative
- Soils OU Strategic Initiative
- Decontamination and Decommissioning OU Strategic Initiative

The BGOU consists of contamination associated with PGDP's landfills and burial grounds as listed in Table 1.1. The CERCLA remedial process is employed at the BGOU. In general, the contents of the burial grounds, upon excavation and characterization for disposal, may include Resource Conservation and Recovery Act (RCRA) hazardous waste, polychlorinated biphenyl (PCB) waste, and low-level waste (LLW). Some of the materials in the PGDP burial grounds are considered to be principal threat waste (PTW).

Based upon disposal records, SWMUs 5 and 6 contain industrial wastes, some of which are LLW. Industrial wastes in burial grounds at the PGDP are known to contain waste that could be contaminated with PCBs or RCRA hazardous wastes. Without more definitive waste characterization (i.e., sampling and analysis), it is not possible to state whether or not PCBs or RCRA hazardous wastes are also present at SWMUs 5 and 6. Based upon the waste inventory, the buried wastes at SWMUs 5 and 6 (including low-level radioactive waste) are considered low-level threat waste consistent with EPA guidance.

The scope of the BGOU FS includes evaluating actions as necessary for protection of human health and the environment from the waste units and addressing potential releases from these source areas that may impact Regional Gravel Aquifer (RGA) groundwater or adjacent drainageways. Remedial decisions for sediments within the BGOU SWMUs fall primarily within the scope of the Surface water OU. The Groundwater OU will address dissolved-phase groundwater contamination in the RGA.

Table 1.1. BGOU Source Areas and Solid Waste Management Units

SWMU No.	Description
2	C-749 Uranium Burial Grounds
3	C-404 Low-Level Radioactive Waste Burial Grounds
4	C-747 Contaminated Burial Yard and C-748-B Burial Area
5	C-746-F Burial Yard
6	C-747-B Burial Grounds
7 and 30	C-747-A Burial Grounds and Burn Area
145 (9 and 10)	Area P and C-746-S and C-746-T Landfills

1.2 PURPOSE AND ORGANIZATION OF REPORT

Under a work plan (DOE 2006) approved by EPA and KY, DOE conducted a Remedial Investigation (RI), which was the continuation of earlier investigative activities, to evaluate source areas of contamination associated with PGDP's landfills and burial grounds. Results of the RI were reported in the *Remedial Investigation Report for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0030&D2/R1 (DOE 2010b). This report included a baseline human health risk assessment (BHHRA) that evaluated the full range of BGOU-related risks to human health, and a screening ecological risk assessment (SERA) evaluated impacts to the environment under a range of potential exposure scenarios associated with current and future land use.

Following approval of the RI, an FS was prepared with the latest version being *Feasibility Study for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0130&D2, submitted in December 2010 (DOE 2010a). Following review and discussion of that document by the FFA parties, this document, DOE/LX/07-0130a&D2/R3, follows that D2 version and evaluates alternatives only for SWMUs 5 and 6.

This FS was prepared in accordance with the requirements of the FFA (EPA 1998). In accordance with Section IV of the FFA, this integrated technical document was developed to satisfy applicable requirements of CERCLA (42 *USC* § 9601 *et seq.*) and RCRA (42 *USC* § 6901 *et seq.*). In addition to the EPA requirements, National Environmental Policy Act of 1969 (NEPA) values, consistent with the DOE's Secretarial Policy Statement on NEPA in June 1994 (DOE 1994), are evaluated and documented in this FS. In consideration of the U.S. Department of the Interior's Natural Resource Damage Assessment (NRDA) and Restoration Program, the BGOU FS will be provided to trustee agencies for their review. The NRDA is a process whereby a natural resource trustee may pursue compensation on behalf of the public for injury to natural resources resulting from releases of hazardous substances. It is DOE's policy to integrate natural resource concerns early into the investigation and remedy selection process to minimize unnecessary resource injury.

This FS also has been prepared in accordance with the Integrated FS/Corrective Measures Study Report outline prescribed in Appendix D of the FFA for PGDP, except for a few format changes. As such, this FS is considered a primary document. Primary documents may be described generally as those documents that the DOE is required to issue to EPA and the Kentucky Energy and Environment Cabinet (KEEC) to fulfill the obligations of the FFA (EPA 1998). All subsections contained in the referenced outline have been included for completeness. Additional subsections have been added to the outline, as appropriate, to provide clarity and enhance the organization of the document.

The initial sections of this FS highlight sitewide information, the approach used to evaluate the SWMUs, and key findings. The SWMU-specific sections of this report i.e., Sections 5.1 and 5.2 provide a more comprehensive presentation of the current understanding of the sources, nature and extent of contaminants, migration pathways, and risks.

1.3 BACKGROUND INFORMATION

The following subsections present background information concerning the site and regulatory setting at PGDP. They also provide a description of the PGDP region and source areas, as well as highlight key factors of the process history, nature and extent of contamination, migration potential, and risks associated with the source areas that provide the basis for screening technologies and remedial alternatives for SWMUs 5 and 6.

Additional SWMUs 5 and 6 details are included in Sections 5.1 and 5.2, respectively.

1.3.1 PGDP Site Description

PGDP is located approximately 10 miles west of Paducah, KY, and 3.5 miles south of the Ohio River in the western part of McCracken County (Figure 1.1). The PGDP industrial area occupies approximately 650 acres of the DOE site and is surrounded by an additional 800-acre buffer zone. DOE licenses most of the remaining acreage to KY as part of the West Kentucky Wildlife Management Area (WKWMA). Tennessee Valley Authority's (TVA's) Shawnee Fossil Plant borders the DOE site to the northeast, between the plant and the Ohio River (Figure 1.2).

Before the PGDP was built, a munitions-production facility, the Kentucky Ordnance Works (KOW), was operated at the current PGDP location and in adjoining areas southwest of the site. Munitions, including trinitrotoluene, were manufactured in an area southwest of PGDP and stored at the KOW between 1942 and 1945. The KOW was shut down immediately after World War II. Construction of PGDP was initiated in 1951 and the plant began operations in 1952. Construction was completed in 1955 and PGDP became fully operational in 1955, supplying enriched uranium for commercial reactors and military defense reactors.

PGDP was operated by Union Carbide Corporation until 1984, when Martin Marietta Energy Systems, Inc., (which later became Lockheed Martin Energy Systems, Inc.) was contracted to operate the plant for DOE. On July 1, 1993, DOE leased the plant production/operations facilities to the United States Enrichment Corporation; however, DOE maintains ownership of the plant and is responsible for environmental restoration. On April 1, 1998, Bechtel Jacobs Company LLC, replaced Lockheed Martin Energy Systems, Inc., in implementing the Environmental Management Program at PGDP. On April 23, 2006, Paducah Remediation Services, LLC, replaced Bechtel Jacobs Company LLC, in implementing the Environmental Management Program at PGDP. On July 26, 2010, LATA Environmental Services of Kentucky, LLC, replaced Paducah Remediation Services, LLC, in implementing the Environmental Management Program at PGDP.

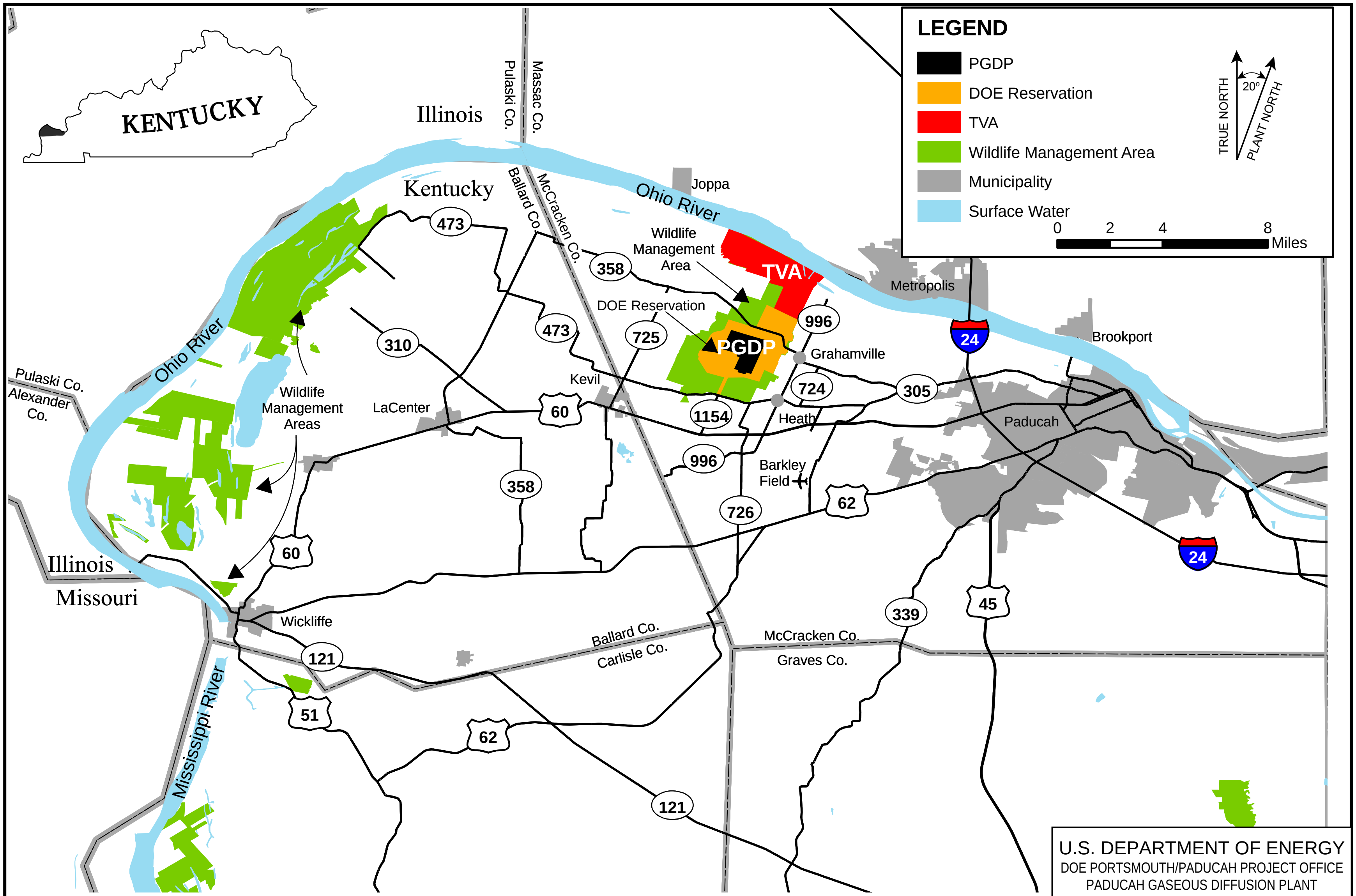
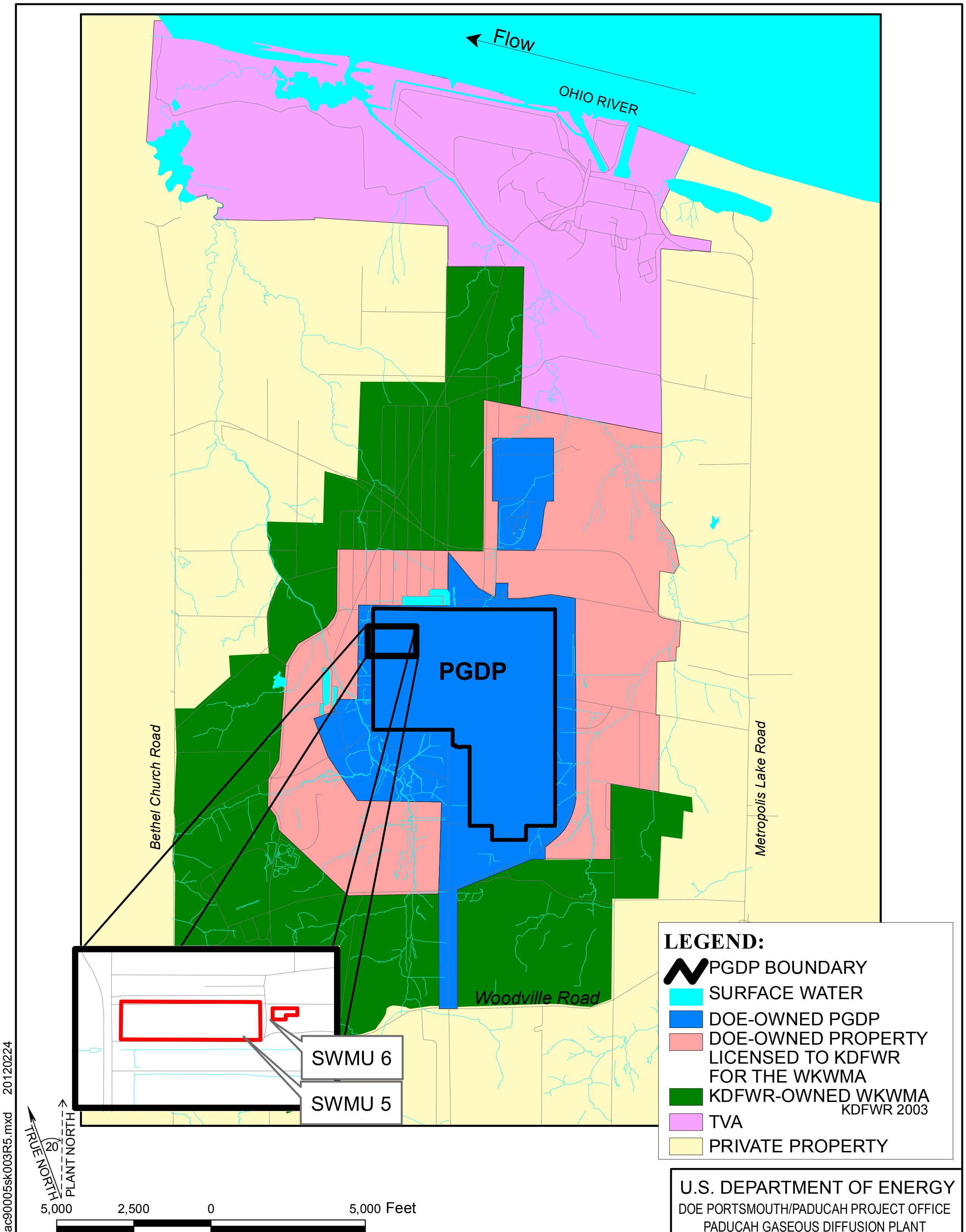


Figure 1.1. PGDP Site Location

LATA Environmental Services of Kentucky, LLC



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

Figure 1.2. PGDP Land Ownership Map

LATA Environmental Services of Kentucky, LLC

Figure No. C5AC90005sk003r5.mxd
DATE 02-24-2012

Contamination as a result of PGDP operations has resulted in three dissolved-phase trichloroethene (TCE) plumes that are migrating from PGDP toward the Ohio River. These groundwater plumes are the Northwest Groundwater Plume (SWMU 201), the Northeast Groundwater Plume (SWMU 202), and the Southwest Plume (SWMU 210) (Figure 1.3). There is also a technetium-99 (Tc-99) plume that is consistent with the footprint of the TCE Northwest Groundwater Plume, but the high concentration Tc-99 plume is contained within the fenced area of the site. Neither SWMU 5 nor SWMU 6 is a source for these plumes.

1.3.1.1 Regulatory setting

This section summarizes the regulatory framework for environmental restoration at PGDP, including the major statutes and accompanying regulations driving response actions, such as the CERCLA, RCRA, and NEPA. It also describes environmental programs and the documents controlling response actions, such as the FFA and the SMP (DOE 2011a). The scope of this action within the overall response strategy for PGDP is described.

1.3.1.1.1 Major statutes, regulations, and controlling documents

Section 105(a)(8)(B) of CERCLA, as amended by the Superfund Amendments and Reauthorization Act, requires EPA to promulgate a list of national priorities among the known or threatened releases of hazardous substances, pollutants, or contaminants throughout the United States. On June 30, 1994, EPA placed PGDP on the National Priorities List (NPL) [59 *Federal Register* (*FR*) 27989 (May 31, 1994)]. The NPL lists sites that are designated by EPA as high priority sites for remediation under CERCLA in accordance with CERCLA's National Contingency Plan (NCP). As the lead agency under CERCLA, DOE is responsible for conducting cleanup activities at PGDP in compliance with NCP. CERCLA is not the only driver for cleanup at PGDP. RCRA requires corrective action for releases of hazardous constituents from SWMUs.

Section 120 of CERCLA requires federal facilities listed on the NPL to enter into an FFA. The FFA coordinates the CERCLA remedial action and RCRA corrective action process into a set of comprehensive requirements for site remediation. Section XII of the PGDP FFA addresses FSs and includes the following requirement.

At a minimum, an evaluation of alternative remedies (i.e., an FS) to address any release shall be conducted when the circumstances listed below are present:

- The Baseline Risk Assessment shows that the cumulative carcinogenic risk for an individual exposed to a given Release, based on a reasonable maximum exposure for both current and future land use, is greater than 1×10^{-6};

- The Baseline Risk Assessment shows that the noncarcinogenic hazard quotient (HQ) for an individual exposed to a given Release, based on a reasonable maximum exposure for both current and future land use, is greater than 1;

- The Release has caused adverse environmental impacts;

- Maximum Contaminant Levels, non-zero Maximum Contaminant Level Goals, or other Chemical-Specific applicable or relevant and appropriate requirements (ARARs) are exceeded; or

- Other site-specific or Release-specific circumstances warranting an evaluation of alternatives.

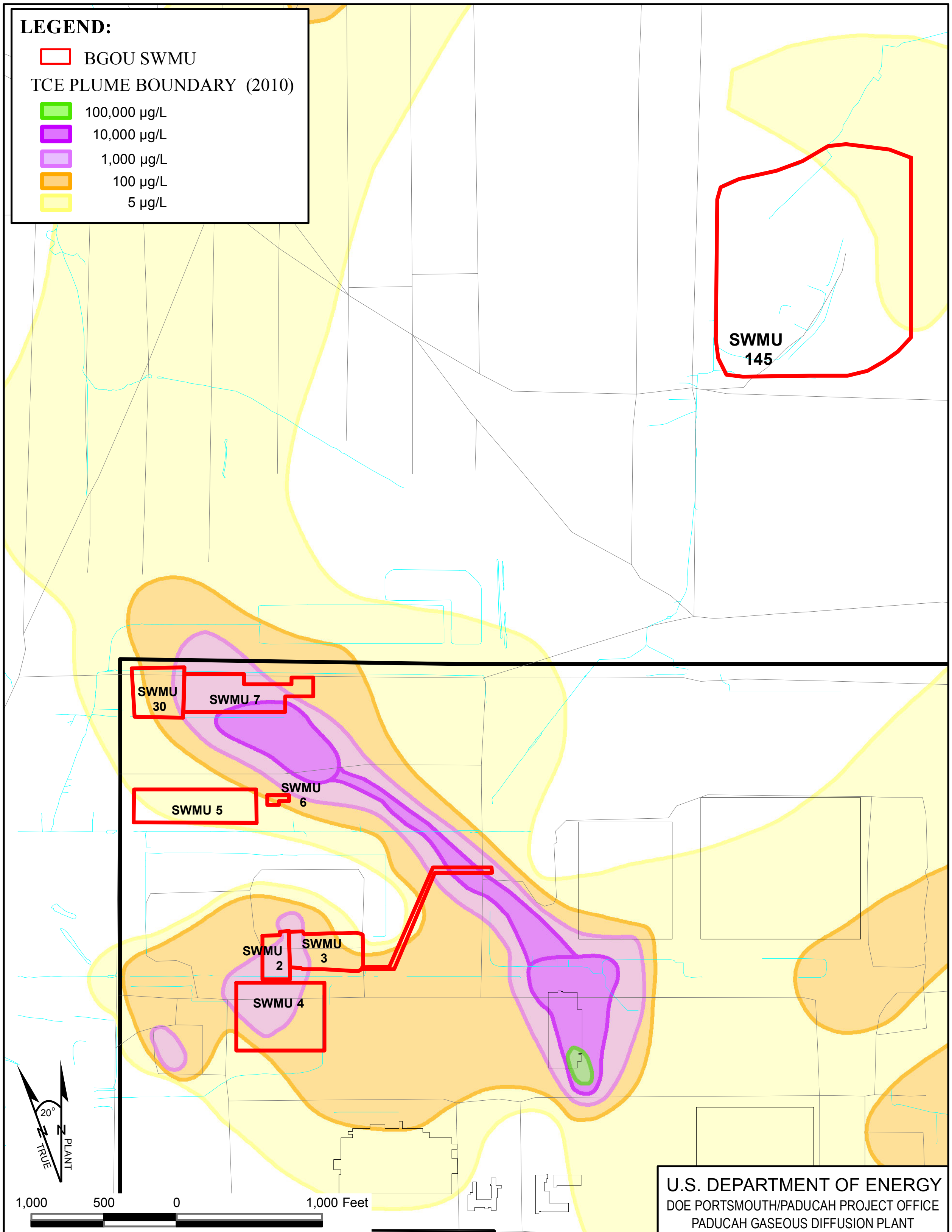


Figure 1.3 BGOU SWMUs in Relation to PGDP Groundwater Plume

Figure No. BGOU FS...SWMU_plumeR4.mxd
DATE 09-16-11

The FFA requires that DOE develop and submit an annual SMP to EPA and KEEC. The SMP outlines the programmatic framework for implementing the FFA.

1.3.1.1.2 Environmental programs

Environmental sampling at PGDP is a multimedia (air, water, soil, sediment, direct radiation, and biota) program of chemical, radiological, and ecological monitoring. Environmental monitoring consists of two activities: effluent monitoring and environmental surveillance. As part of the ongoing environmental activities, SWMUs and areas of concern have been identified. Characterization and/or remediation of these sites will continue pursuant to CERCLA and Hazardous and Solid Waste Amendments corrective action conditions of the RCRA Permit.

1.3.1.1.3 National Environmental Policy Act

The intent of NEPA is to promote a decision-making process that results in minimization of adverse impacts to human health and the environment. On June 13, 1994, the Secretary of Energy issued a Secretarial Policy (Policy) on NEPA that addresses NEPA requirements for actions taken under CERCLA. Section II.E of the Policy indicates that DOE CERCLA documents will incorporate NEPA values, to the extent practicable, such as analysis of cumulative, off-site, ecological, cultural, and socioeconomic impacts.

1.3.1.2 Land use, demographics, surface features, and environment

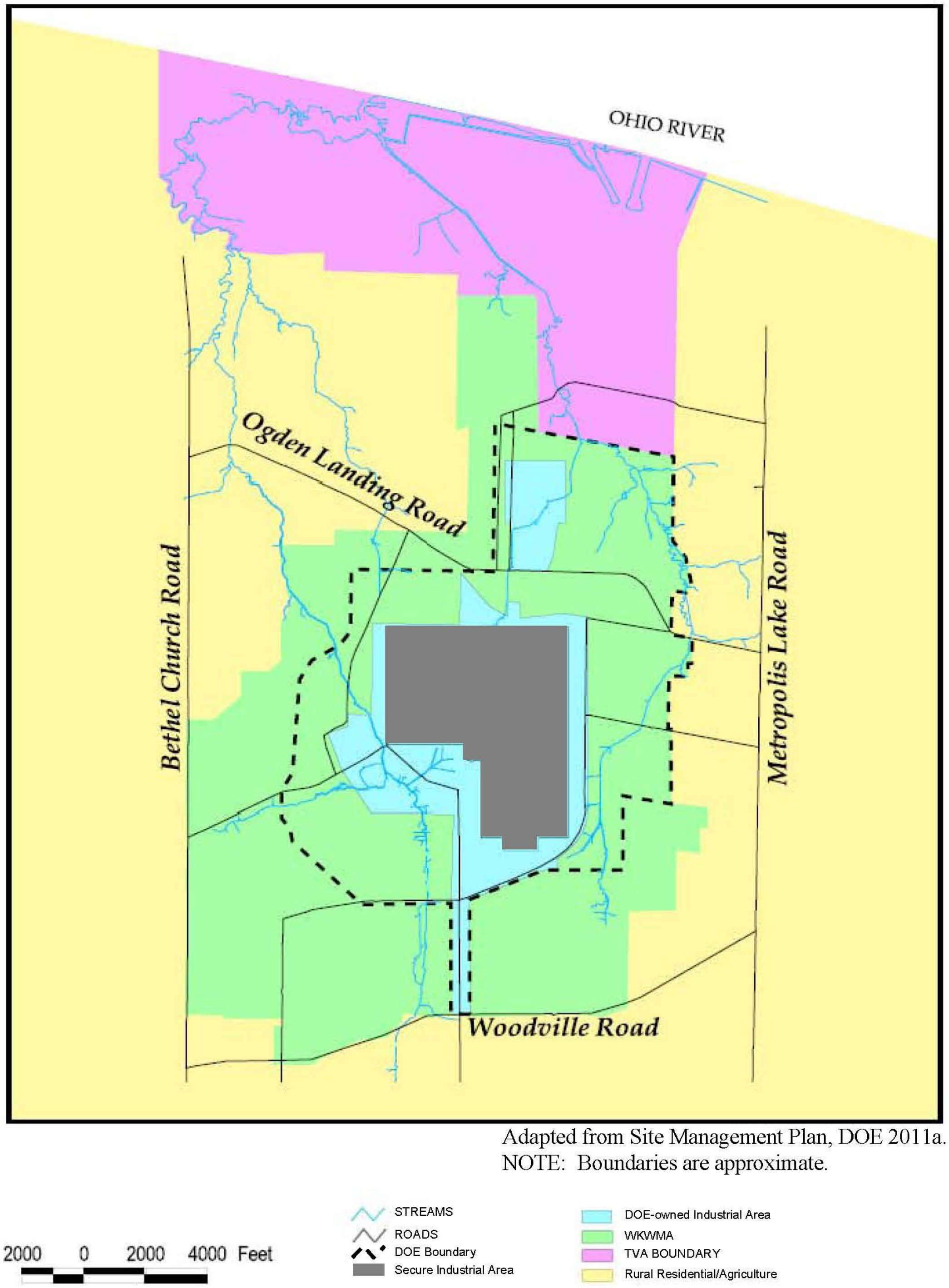
1.3.1.2.1 Land use

The area of PGDP that includes SWMUs 5 and 6, is heavily industrialized. The area immediately beyond the secured industrial area is mostly agricultural and open land, with some forested areas (see Figure 1.4). TVA's Shawnee Fossil Plant, adjacent to the northeast border of the DOE Reservation, is the only other major industrial facility in the immediate area. The PGDP is posted government property and trespassing is prohibited. Access to the PGDP site is controlled by guarded checkpoints, a perimeter/security fence, and vehicle barriers and is subject to routine armed patrol and visual inspection by plant protective forces. The PGDP site includes 1,986 acres licensed to the Kentucky Department of Fish and Wildlife Resources. PGDP is an industrial facility. The future use scenario considered reasonable for SWMUs 5 and 6 is that of industrial (DOE 2012).

This area is part of the WKWMA and borders PGDP to the north, west, and south. The WKWMA is an important recreational resource for western Kentucky and is used by more than 10,000 people each year. Major recreational activities include hunting, field trials for dogs and horses, trail riding, fishing, and skeet shooting.

1.3.1.2.2 Demographics

Approximately 89,000 people live within the three counties that are included in the 10-mile radius of PGDP. The estimated population of Paducah, Kentucky, for 2009 was approximately 25,700. Metropolis, Illinois, had an estimated population in 2009 of approximately 6,500 (U.S. Census Bureau 2009). The closest communities to PGDP are the unincorporated towns of Grahamville [about 1.6 kilometers (1 mile) to the east] and Heath [about 1.6 kilometers (1 mile) southeast]. Current and anticipated future land use for PGDP and surrounding areas is depicted in Figure 1.5 and represents the future land use scenario from the PGDP SMP (DOE 2012). SWMUs 5 and 6 are located inside the PGDP boundary. The future land use is anticipated to be industrial.

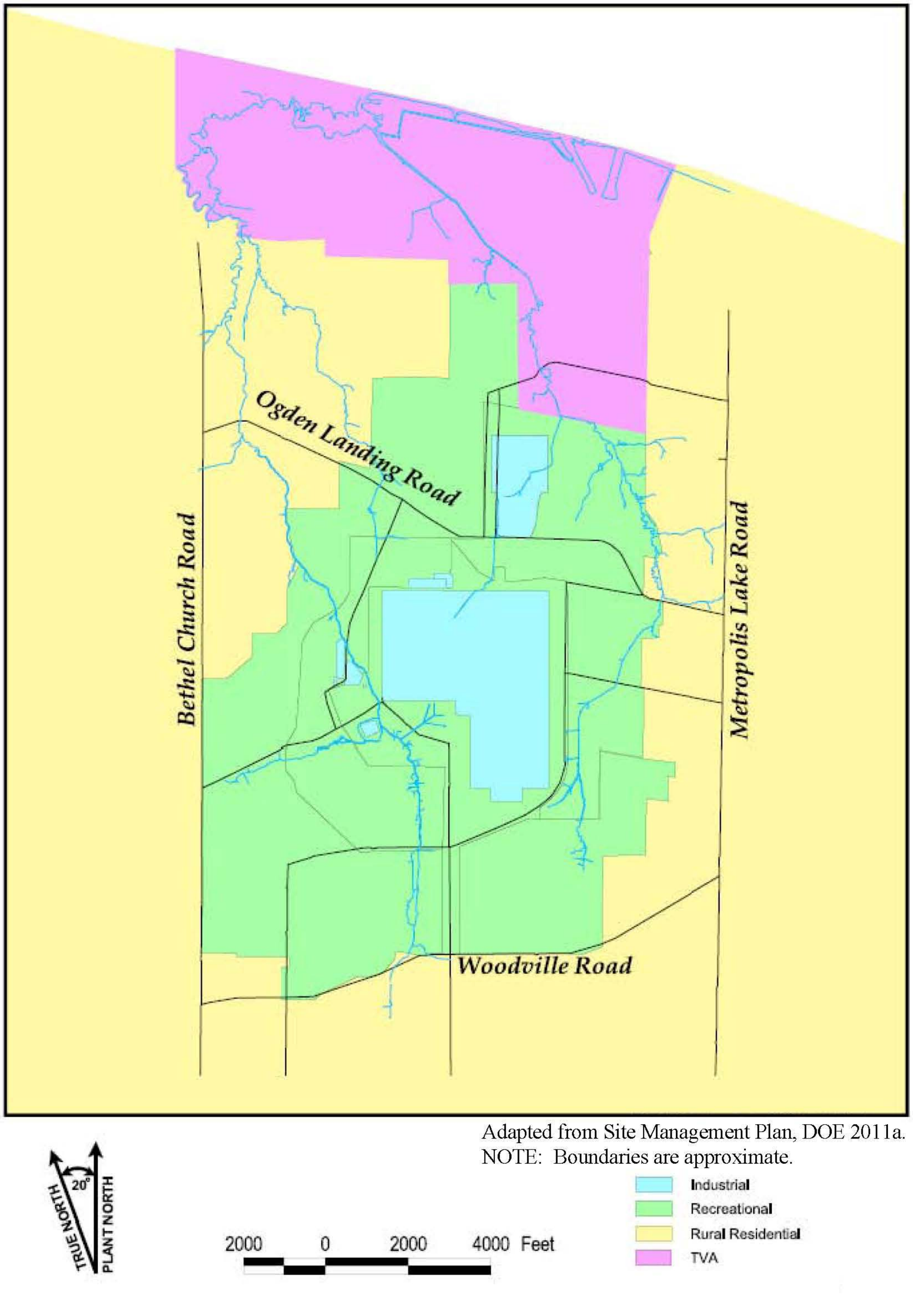


Adapted from Site Management Plan, DOE 2011a.
NOTE: Boundaries are approximate.

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

Figure 1.4. Current Land Use in Proximity to PGDP

LATA Environmental Services of Kentucky, LLC



Adapted from Site Management Plan, DOE 2011a.
NOTE: Boundaries are approximate.

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

Figure 1.5. Anticipated Future Land Use

LATA Environmental Services of Kentucky, LLC

Major employers in the area of PGDP include the United States Enrichment Corporation (approximately 1,200 employees), Babcock & Wilcox Conversion Services, LLC (approximately 140 employees), DOE Environmental Management contractors (approximately 500 employees), and TVA's Shawnee Fossil Plant (approximately 260 employees).

1.3.1.2.3 Surface features and topography

PGDP lies in the Jackson Purchase Region of western Kentucky between the Tennessee and Mississippi Rivers, bounded on the north by the Ohio River. The confluence of the Ohio and Mississippi Rivers is approximately 35 miles downstream (southwest) from the site. The confluence of the Ohio and Tennessee Rivers is approximately 15 miles upstream (east) from the site.

Local elevations range from 290 ft above mean sea level (amsl) along the Ohio River to 450 ft amsl southwest of PGDP near Bethel Church Road. Generally, the topography in the PGDP area slopes toward the Ohio River at an approximate 27-ft/mile gradient (CH2M Hill 1992). Within the plant boundaries where most of the BGOU SWMUs are located, ground surface elevations vary from 360 to 390 ft amsl.

The terrain in the vicinity of the plant is slightly modified by the dendritic drainage systems associated with the two principal streams in the area, Bayou Creek and Little Bayou Creek. These streams have eroded small valleys, which are about 20 ft below the adjacent plain.

SWMU 5 is a burial area in the northwest quadrant of the plant (Figure 1.2). 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 Kentucky Pollutant Discharge Elimination System (KPDES) Outfall 001. The ground surface is grass-covered with no significant surface structures. Approximately five ft of topographic relief exists between the highest point in 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 1.2) 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 to KPDES Outfall 001. PGDP maintains the area as a grassed field with occasional shrubs.

1.3.1.2.4 Climate

The climate of the region may be broadly classified as humid-continental. The term "humid" refers to the surplus of precipitation versus evapotranspiration that normally is experienced throughout the year. The 30-year average monthly precipitation for the period 1961 through 1990 is 4.11 inches,[2] 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).

The "continental" nature of the local climate refers to the dominating influence of the North American landmass. Continental climates typically experience large temperature changes between seasons. The 22-year average monthly temperature is 58.0°F, with the coldest month being January with an average temperature of 35°F and the warmest month being July with an average temperature of 79°F. The average

---

[2] For the 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).

mean prevailing wind speed is 10 miles per hour. Historically, stronger winds are recorded when the winds are from the southwest.

1.3.1.2.5 Air quality

PGDP is located in the Paducah-Cairo Interstate Air Quality Control Region of Kentucky, which includes McCracken County and 16 other counties in western Kentucky. Data from the state's air monitors are used to assess the region's ambient air quality for the criteria pollutants (ozone, nitrogen oxides, carbon monoxide, particulates, lead, and sulfur dioxide) and to designate nonattainment areas (i.e., those areas for which one or more of the National Ambient Air Quality Standards are not met). McCracken County is classified as an attainment area for all six criteria pollutants [*Fiscal Year 2008 Annual Report* (KDAQ 2008)]. Ten ambient air sampling stations are operated by the Kentucky Radiation Health Branch to monitor airborne radionuclides from PGDP.

1.3.1.2.6 Noise

Noises associated with plant activities generally are restricted to areas inside buildings located on-site. Currently, noise levels beyond the security fence are limited to wildlife, hunting, traffic moving through the area, and operation and maintenance activities associated with outside waste storage areas located close to the security fence.

1.3.1.3 Ecological, cultural, archeological, and historical resources

The following sections give a brief overview of the soils, terrestrial and aquatic systems, wetlands, and cultural resources at PGDP. A more detailed description, including an identification and discussion of sensitive habitats and threatened and endangered (T&E) species, is contained in the *Investigation of Sensitive Ecological Resources Inside the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (CDM 1994) and the *Environmental Investigations at the Paducah Gaseous Diffusion Plant and Surrounding Area, McCracken County, Kentucky* (COE 1994).

1.3.1.3.1 Soils and prime farmland

Six soil types are associated with PGDP as mapped by the Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (USDA 1976). These are Calloway silt loam, Grenada silt loam, Loring silt loam, Falaya-Collins silt loam, Vicksburg silt loam, and Henry silt loam.

The dominant soil types, the Calloway and Henry silt loams, consist of nearly level, somewhat poorly drained to poorly drained soils that formed in deposits of loess and alluvium. These soils tend to have low organic content, low buffering capacity, and acidic hydrogen-ion concentration (pH) ranging from 4.5 to 5.5. The Henry and Calloway series have a fragipan horizon, a compact and brittle silty clay loam layer that extends from 26 inches below ground surface (bgs) to a depth of 50 inches or more. The fragipan reduces the vertical movement of water and causes a seasonally perched water table in some areas at PGDP. In areas within the PGDP where past construction activities have disturbed the fragipan layer, the soils are best classified as "urban."

The area of SWMUs 5 and 6 is mapped as Henry Silt Loam with fragipans common from 1.5–7 ft (USDA 1976). Grading operations during the construction of the plant largely disturbed the soils; nearby ditching dissected the fragipan. Moreover, subsequent diggings, fills, and cover in the burial areas of SWMUs 5 and 6 would have destroyed the fragipan. The cover for both SWMUs 5 and 6 is likely a mixture of Henry silt loam and the underlying silt unit (loess).

Prime farmland, as defined by the NRCS, is land that is best suited for food, feed, forage, fiber, and oilseed productions, excluding "urban built-up land or water" [7 *CFR* § 657 and 658]. The NRCS determines prime farmland based on soil types found to exhibit soil properties best suited for growing crops. These characteristics include suitable moisture and temperature regimes, pH, drainage class, permeability, erodibility factor, and other properties needed to produce sustained high yields of crops in an economical manner. Prime farmland is located north of the PGDP plant area. The prime farmland north of the plant is predominantly located in areas having soil types of Calloway, Grenada, and Waverly.

1.3.1.3.2 Terrestrial systems

The terrestrial component of the PGDP ecosystem includes the plants and animals that use the upland habitats for food, reproduction, and protection. The upland vegetative communities 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 PGDP has been cleared of vegetation at some time, and much of the grassland habitat currently is mowed by PGDP personnel. The Kentucky Division 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. These areas have the greatest potential for restoration and for establishment of a sizeable prairie preserve in the Jackson Purchase area (KSNPC 1991).

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.

Typical birds of the area include 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 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).

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).

1.3.1.3.3 Aquatic systems

The aquatic communities in and around PGDP area that could be contaminated by plant discharges include two perennial streams (Bayou Creek and Little Bayou Creek), the North-South Diversion Ditch (a former ditch for the discharge of plant effluents to Little Bayou Creek), a marsh located at the confluence of Bayou Creek and Little Bayou Creek, and other 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 dominated by bluegill, green and longear sunfish, and stonerollers.

1.3.1.3.4 Threatened and endangered species

Potential habitat for federally listed T&E species was evaluated for the area surrounding PGDP during the 1994 U.S. Army Corps of Engineers (COE) environmental investigation of PGDP (COE 1994) and inside the fence of the PGDP during the 1994 investigation of sensitive resources at the PGDP (CDM 1994). Investigation inside the PGDP security fence did not detect any T&E species or their preferred habitats, and the U.S. Fish and Wildlife Service (USFWS) has not designated critical habitat for any species within DOE property; however, a 2007 USFWS investigation determined that most of the PGDP is within a maternity circle for Indiana bat (listed endangered). Subsequently, the USFWS has conducted a biological assessment of Indiana bat in support of the draft Indiana Bat Recovery Plan (USFWS 2007). The assessment indicates that PGDP is designated within the Mississippi River Recovery and Mitigation Focus Area where Indiana bat minimization and mitigation efforts will be undertaken or attempted.

Under the Indiana Bat Mitigation Guidance for the Commonwealth of Kentucky, a suitable summer habitat would be a tree 5 inches in diameter or greater with certain type of bark, crevices, or cracks. No such habitat exists at either SWMUs 5 or 6.

1.3.1.3.5 Cultural, archaeological, and historic resources

In accordance with the National Historic Preservation Act (NHPA), a Programmatic Agreement among the DOE Paducah Site Office, the Kentucky State Historic Preservation Officer, and the Advisory Council on Historic Preservation Concerning Management of Historical Properties, was signed in January 2004. DOE developed the *Cultural Resources Management Plan for the Paducah Gaseous Diffusion Plant, Paducah Gaseous Diffusion Plant, McCracken County, Kentucky* (CRMP) (BJC 2006) to define the preservation strategy for PGDP and direct efficient compliance with the NHPA and federal archaeological protection legislation at PGDP. PGDP facilities are documented with survey forms and photographs in the *Cultural Resources Survey for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, BJC/PAD–688/R1. No archaeological resources have been identified within the vicinity of the BGOU facilities.

1.3.1.4 Surface water hydrology, wetlands, and floodplains

1.3.1.4.1 Surface water hydrology

PGDP is located in the western portion of the Ohio River drainage basin, approximately 15 miles downstream of the confluence of the Ohio River with the Tennessee River and approximately 35 miles upstream of the confluence of the Ohio River with the Mississippi River. Locally, PGDP is within the drainage areas of the Ohio River, Bayou Creek, and Little Bayou Creek.

The plant is situated on the divide between the two creeks. Surface flow is east-northeast toward Little Bayou Creek and west-northwest toward Bayou Creek. 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. The Little Bayou Creek's intermittent drainage originates within WKWMA and extends northward and joins Bayou Creek near the Ohio River along a 6.5-mile course.

Most of the flow within Bayou and Little Bayou Creeks is from process effluents or surface water runoff from PGDP. Plant discharges are monitored at the KPDES outfalls prior to discharge into the creeks.

1.3.1.4.2 Wetlands

The 1994 COE environmental investigations identified 1,083 separate wetland areas and grouped them into 16 vegetative cover types encompassing forested, scrub/shrub, and emergent wetlands (COE 1994). 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.

Five acres of potential wetlands were identified inside the fence at PGDP (COE 1995). The COE made the determination that these areas are jurisdictional wetlands. Wetlands inside the plant security fence are confined to portions of drainage ditches traversing the site. These areas provide some groundwater recharge, floodwater retention, and sediment retention. While the opportunity for these functions and values is high, the effectiveness is low due to water exiting the area quickly through the drainage system. Other functions and values (e.g., wildlife benefits, recreation, diversity, etc.) are very low.

1.3.1.4.3 Floodplains

Floodplains were evaluated during the 1994 COE environmental investigation of PGDP (COE 1994). This evaluation used the Hydrologic Engineering Center Computer Program-2 model to estimate 100- and 500-year flood elevations. Flood boundaries from the Hydrologic Engineering Center Computer Program-2 model were delineated on topographic maps of the PGDP area to determine areal extent of the flood waters associated with these events.

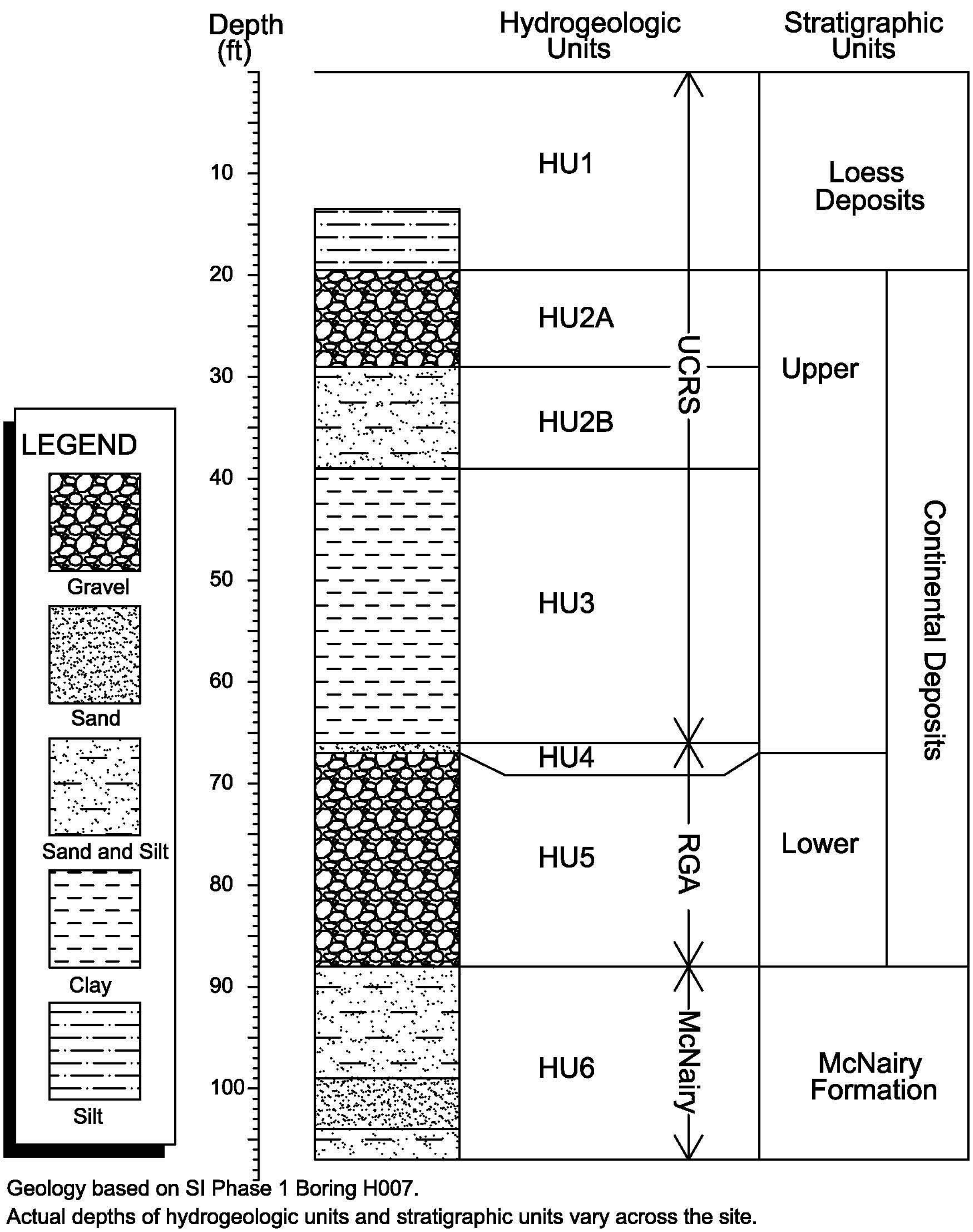
Flooding is associated with the Ohio River, Bayou Creek, and Little Bayou Creek. The majority of overland flooding at PGDP is associated with storm water runoff and flooding from Bayou and Little Bayou Creeks. A floodplain analysis performed by COE (COE 1994) found that much of the built-up portions of the plant lie outside the 100- and 500-year floodplains of these streams. Drainage ditches inside the PGDP security fence can contain nearly all of the expected 100- and 500-year flood discharges (COE 1994). 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 Atlas 14 (National Oceanic and Atmospheric Administration 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 assumed the plant ditches still will contain the 100- and 500-year discharges. The BGOU SWMUs are not located within the floodplain.

1.3.1.5 Regional and study area geology and hydrogeology

1.3.1.5.1 Regional geology

PGDP is located in 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 1.6 summarizes the geologic and hydrogeologic systems of the PGDP region.

Within the Jackson Purchase Region, strata deposited above the Precambrian basement rock attain a maximum thickness of 12,000–15,000 ft. Exposed strata in the region range in age from Devonian to Holocene. The Devonian stratum crops out along the western shore of Kentucky Lake. Mississippian carbonates form the nearest outcrop of bedrock and are exposed approximately 9 miles northwest of Mississippian carbonate bedrock and consist of the following: the Tuscaloosa Formation; the sand and



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

Figure 1.6. Example Stratigraphic and Hydrogeologic Units

LATA Environmental Services of Kentucky, LLC

clays of the Clayton/McNairy Formations; the Porters Creek Clay; and the Eocene sand and clay deposits (undivided Jackson, Claiborne, and Wilcox Formations). Continental Deposits unconformably overlie the Coastal Plain deposits, which are, in turn, covered by loess and/or alluvium.

Relative to the shallow groundwater flow system in the vicinity of PGDP, the Continental Deposits and the overlying loess and alluvium are of key importance. The Continental Deposits resemble a large low-gradient alluvial fan that covered much of the region and eventually buried the erosional topography. A principal geologic feature in the PGDP area is the Porters Creek Clay Terrace, a subsurface terrace that trends approximately east to west across the southern portion of the plant. The Porters Creek Clay Terrace represents the southern limit of erosion or scouring of the ancestral Tennessee River. Thicker sequences of Continental Deposits, as found underlying PGDP, represent valley fill deposits and can be informally divided into a lower unit (gravel facies) and an upper unit (clay facies). The Lower Continental Deposits (LCD) is the gravel facies consisting of chert gravel in a matrix of poorly sorted sand and silt that rests on an erosional surface representing the beginning of the valley fill sequence. In total, the gravel units average an approximate 30-ft thickness, but some thicker deposits (as much as 50 ft) exist in deeper scour channels. The Upper Continental Deposits (UCD) is primarily a sequence of fine-grained, clastic facies varying in thickness from 15–60 ft that consist of clayey silts with lenses of sand and occasional gravel.

The BGOU area lies within the buried valley of the ancestral Tennessee River in which Pleistocene Continental Deposits (the fill deposits of the ancestral Tennessee River Basin) rest unconformably on Cretaceous marine sediments. Pliocene through Paleocene formations in the BGOU area have been removed by erosion from the ancestral Tennessee River Basin. In this area, the upper McNairy Formation consists of 60–70 ft of interbedded units of silt and fine sand and underlies the Continental Deposits. Total thickness of the McNairy Formation is approximately 225 ft.

The surface deposits found in the vicinity of PGDP consist of loess and alluvium. Both units are composed of clayey silt or silty clay and range in color from yellowish-brown to brownish-gray or tan, making field differentiation difficult.

1.3.1.5.3 Regional 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.

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.

Upper Continental Recharge System (UCRS). The upper stratum, where infiltration of water from the surface occurs and where the uppermost zone of saturation exists in the UCD (beneath PGDP and the contiguous land to the north) is called the UCRS. Groundwater flow is primarily downward in the Upper Continental Deposits. Vertical hydraulic gradients generally range from 0.5–1 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 screened 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. Hydrographs of UCRS monitoring wells (MWs) on-site indicate fluctuations of only a few ft over the past 10 years. 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 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 creates mounding of hydraulic head in the RGA that can affect contaminant transport. Because the hydraulic conductivity in the RGA on-site is relatively large, the mounding is only slight (often less than 1 ft) and difficult to measure.

Regional Gravel Aquifer. Vertically infiltrating water from the UCRS moves downward into a basal sand member of the UCD and the Pleistocene gravel member of the LCD 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 is Class IIa groundwater (current source of drinking water), although it is not currently being used at or downgradient of the site.

Hydraulic potential in the RGA declines toward the Ohio River, which is the control of base level of the region's surface water and groundwater systems. The RGA potentiometric surface gradient beneath PGDP is commonly 10^{-4} ft/ft, but increases by an order of magnitude near the Ohio River. (Vertical gradients are not well documented, but small.) The hydraulic conductivity of the RGA varies spatially. Pumping tests have documented the hydraulic conductivity of the RGA ranges from 53 ft/day to 5,700 ft/day. East-to-west flow of the ancestral Tennessee River, which laid down the Pleistocene Continental Deposits gravel member, tended to orient permeable gravel and sand lenses east-west. Thus, with the hydraulic head in the RGA generally decreasing northward toward the Ohio River, groundwater flow trends to the northeast and northwest from PGDP in response to the anisotropy of the hydraulic conductivity as well as the anthropogenic recharge, which is greatest in the industrial portion of the plant. Anthropogenic recharge from waterline leaks, lagoons, cooling tower basins, and other sources provides the primary driving force in moving groundwater in northeastern and northwestern flow directions from the industrial plant area.

Ambient groundwater flow rates in the more permeable pathways of the RGA commonly range from 1–3 ft/day.

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 and parallels the Ohio River near the northern DOE property boundary (LMES 1996).]

The contact between the LCD 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.

1.3.1.5.4 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 1.6). 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 HU 2 interval consists of an upper sand and gravel member (HU 2A) and a lower sand and gravel member (HU 2B) 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 HU 3 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.

1.3.1.6 DOE plant controls

Current DOE plant controls for the PGDP are described below.

- The SWMUs are within areas protected from trespassing under the 1954 Atomic Energy Act as amended (referred to as the 229 Line). These areas are posted as "no trespassing" and trespassers are subject to arrest and prosecution. Physical access to the PGDP is prohibited by security fencing, and armed guards patrol the DOE property 24 hours per day to restrict workers entry and prevent uncontrolled access by the public/site visitors.

- Vehicle access to SWMUs 5 and 6 is restricted by passage through Security Post 57 and by the plant vehicle protection barrier.

- SWMUs 5 and 6 are in areas that are subject to routine patrol and visual inspection by plant protective forces, at a minimum once per shift.

- Protection of the current PGDP industrial workers is addressed under DOE's Integrated Safety Management System/Environmental Management System program and 29 *CFR* § 1910. Interim work area access controls that may be used under these programs during implementation of a remedy include warning and informational signage, temporary fencing and/or barricades, and visitor sign-in controls.

These existing access controls are maintained due to the nature and security needs of the facility or implemented for protection of worker safety and health and are being maintained outside of the requirements of CERCLA; nonetheless, the existing controls serve to protect against unacceptable/uncontrolled exposures.

Additionally, Section XLII of the FFA requires that the sale or transfer of the PGDP comply with Section 120(h) of CERCLA. In the event DOE determines to enter into any contract for the sale or transfer of any of PGDP, DOE will comply with the applicable requirements of Section 120(h) in effecting that sale or transfer, including all notice requirements. In addition, DOE will notify EPA and KY of any such sale or transfer at least 90 days prior to such sale or transfer.

1.3.2 SWMUs 5 and 6 History

The disposal of solid waste began with construction of the plant in 1951. Scrap and wastes have been buried in a minimum of 22 different locations, and scrap has been stored in at least five storage yards. These known areas have been identified as SWMUs or areas of concern (Union Carbide 1978).

Table 1.2 identifies the previously completed reports and/or investigations primarily used as information for SWMUs 5 and 6. Reference information for these investigations can be found in Section 7. In addition to the reports of previous investigations, the following documents provide important information on the content and volume of SWMUs 5 and 6:

- *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).

Historical information that is known about these SWMUs is compiled in Table 1.3. Based upon disposal records, SWMUs 5 and 6 contain industrial wastes, some of which are LLW. Industrial wastes in burial grounds at the PGDP are known to contain waste that could be contaminated with PCBs or RCRA hazardous wastes. Without more definitive waste characterization (i.e., sampling and analysis), it is not possible to state whether or not PCBs or RCRA hazardous wastes are also present at SWMUs 5 and 6. Based upon the waste inventory, the buried wastes at SWMUs 5 and 6 (including low-level radioactive waste) are considered low level threat waste consistent with EPA guidance.

Table 1.2. Summary of Investigations for SWMUs 5 and 6

Dates	Title	SWMU 5	SWMU 6
1990–1992	Phase II Site Investigation (CH2M HILL 1992)	✓	✓
1998–2001	WAG 3 RI/FS (DOE 1998)	✓	✓
1999–2001	Data Gaps Investigation (DOE 2000a)	✓	
2002–2003	Scrap Yards Site Characterization (Paducah OREIS)	✓	✓
2006	Burial Grounds RI/FS Work Plan (DOE 2006)	✓	✓
2007	Burial Grounds Remedial Investigation (DOE 2010b)	✓	✓

Table 1.2 is based on Table 1.4 of the BGOU RI (DOE 2010b).
Paducah OREIS = Paducah site information contained in the Oak Ridge Environmental Information System database.
Blank cells indicate the investigation is not applicable to the SWMU.
SWMU = solid waste management unit
WAG = waste area group

Table 1.3. Summary of Historical Information for BGOU SWMUs 5 and 6

<table>
<tr><th>Sub Unit</th><th>Dates of Operation</th><th>Area of Waste</th><th>Cover[a]</th><th>Volume of Contaminated Media to be Addressed by the Remedial Action[b]</th><th>Known or Expected Contents (Special Hazards)</th></tr>
<tr><td colspan="6">SWMU 5 C-746-F Burial Yard</td></tr>
<tr><td></td><td>1965–1987</td><td>197,400 ft^2 (6–15 ft deep)</td><td>2–3 ft soil</td><td>113,555 cubic yards</td><td>Radionuclide-contaminated scrap metal, slag from nickel and aluminum smelters</td></tr>
<tr><td colspan="6">SWMU 6 C-747-B Burial Ground</td></tr>
<tr><td>Area H</td><td>1971</td><td>180 ft^2 (6 ft deep)</td><td>3 ft soil</td><td rowspan="5">6,215 cubic yards</td><td>Magnesium scrap</td></tr>
<tr><td>Area I (including Area I-2)</td><td>1966</td><td>316 ft^2 (8 ft deep)</td><td>5 ft soil</td><td>Exhaust fans (contaminated with perchloric acid)</td></tr>
<tr><td>Area J</td><td>Early 1960s</td><td>4,000 ft^2 (6 ft deep)</td><td>3 ft soil</td><td>Contaminated aluminum</td></tr>
<tr><td>Area K</td><td>1968–1969</td><td>180 ft^2 (6 ft deep)</td><td>3 ft soil</td><td>Magnesium scrap</td></tr>
<tr><td>Area L</td><td>1969</td><td>600 ft^2 (6 ft deep)</td><td>3 ft soil</td><td>Modine trap</td></tr>
</table>

Table 1.3 is based on Table 1.3 of the BGOU RI (DOE 2010b).
[a] The source material used for cover is unknown.
[b] Volume of waste is assumed to approximate the volume of the burial cell. Volumes calculated using information from the RI report and FS Section 5.4.3, as summarized in Table 5.3.

1.3.3 Nature and Extent of Contamination

The current understanding of the nature and extent of contamination in surface and subsurface soils was derived from historical investigations (Section 1.3.2). Soil samples were collected from angled borings beneath the wastes to establish if releases had occurred from the waste and, if so, their magnitude in the secondary media. The wastes in both SWMUs 5 and 6 were covered with soil, and surface soil data were collected within the SWMU boundary.

The BGOU data set includes soil and sediment samples collected from locations outside the SWMU boundary that are not affected by releases from the wastes and will be addressed by other strategic initiatives. Several organic chemicals were detected only in locations adjacent to the SWMUs. Inorganic constituents rarely exceeded background. Several of these (uranium, Tc-99, aluminum, arsenic, and chromium) exceeded background concentrations only (or primarily) in surface soil samples.

SWMU-specific sections for SWMUs 5 and 6 and Appendices A and B provide additional details and maps showing the sampling locations and distribution of selected COCs. The key observations include the following.

- Consistent with the information on the wastes, the data suggest organic contaminants have not migrated from these sources. Polycyclic aromatic hydrocarbons (PAHs) and PCBs were not detected in subsurface soils.

- The detected metals concentrations were within the background range, with few results exceeding the concentration used for screening against background, and were not in a distribution indicative of migration from the wastes.

- Tc-99 was considered potentially present in wastes at SWMU 5. It was detected above background in 1 of 64 subsurface soil samples.

1.3.4 Conceptual Site Model

The waste materials in SWMUs 5 and 6 have limited mobility. To the extent these materials are mobile, the most likely pathway of the contaminants released from wastes would be downward migration through the UCRS soils, ultimately reaching the RGA (Figure 1.7). Based on this conceptual model, any contamination resulting from buried waste found at these SWMUs would be expected to be found concentrated in the soils and groundwater of the UCRS immediately within and under the burial cells, with little lateral dispersion of contamination in the UCRS from the cells and immediately adjacent soils. Consistent with the BGOU goals, the source areas, contamination in secondary sources impacted by releases from the waste, and potential for future migration from the wastes were the focus of the investigations and basis for evaluation of remedial alternatives.

The potential for contamination to be released from soil and waste to surface water is believed to be limited at SWMUs 5 and 6. There are no known lateral pathways of groundwater migration through the UCRS. There may be a limited pathway for groundwater to migrate laterally through the cover material overlaying UCRS of SWMU 5.

On April 27, 2011, after heavy rainfall (i.e., a 500-year rainfall event for the 60-day period leading up to April 27), ditches adjacent to the BGOU SWMUs were inspected for groundwater seeps. A seep was observed in the ditch north of SWMU 30, but there were no seeps observed at either SWMU 5 or SWMU 6. Follow-up research into the nature of the SWMU 30 seep was conducted (Johnstone 2011). This research included comparing the Phase II Site Investigation (DOE 1992) geophysical maps and topography maps with the location of the seep. The research concluded that the seep was present at SWMU 30, because a portion of the native material (UCRS HU 1) that normally is present in the sidewalls of BGOU waste cells had been removed (i.e., the northern edge of the burial cell at SWMU 30 coincided with the ditch). The uppermost portion of HU 1 has been replaced by a relatively permeable cover material that allows water that infiltrates into the waste cell to migrate through the cover material and into the adjacent ditch. By comparison, no such seeps were observed in the ditches adjacent to SWMUs 5 and 6 where HU 1 is present in the sidewalls of the waste cells, because the location of ditches at SWMUs 5 and 6 do not coincide with the waste cells SWMU 5, as shown in Figures 5.1 and 6.1 of this document. The conclusion drawn from these observations is that HU 1, when present, prevents lateral migration of fluids that periodically may collect in the waste cells. The sidewalls of the waste cells at SWMU 5 and 6 are composed of HU 1 and are expected to prevent migration to nearby ditches. This conclusion is supported by the low yield of groundwater from HU 1 wells and temporary sampling points installed at PGDP. In summary, there is no route for SWMU 5 and SWMU 6 waste cell contaminants to migrate through the UCRS into the ditches.

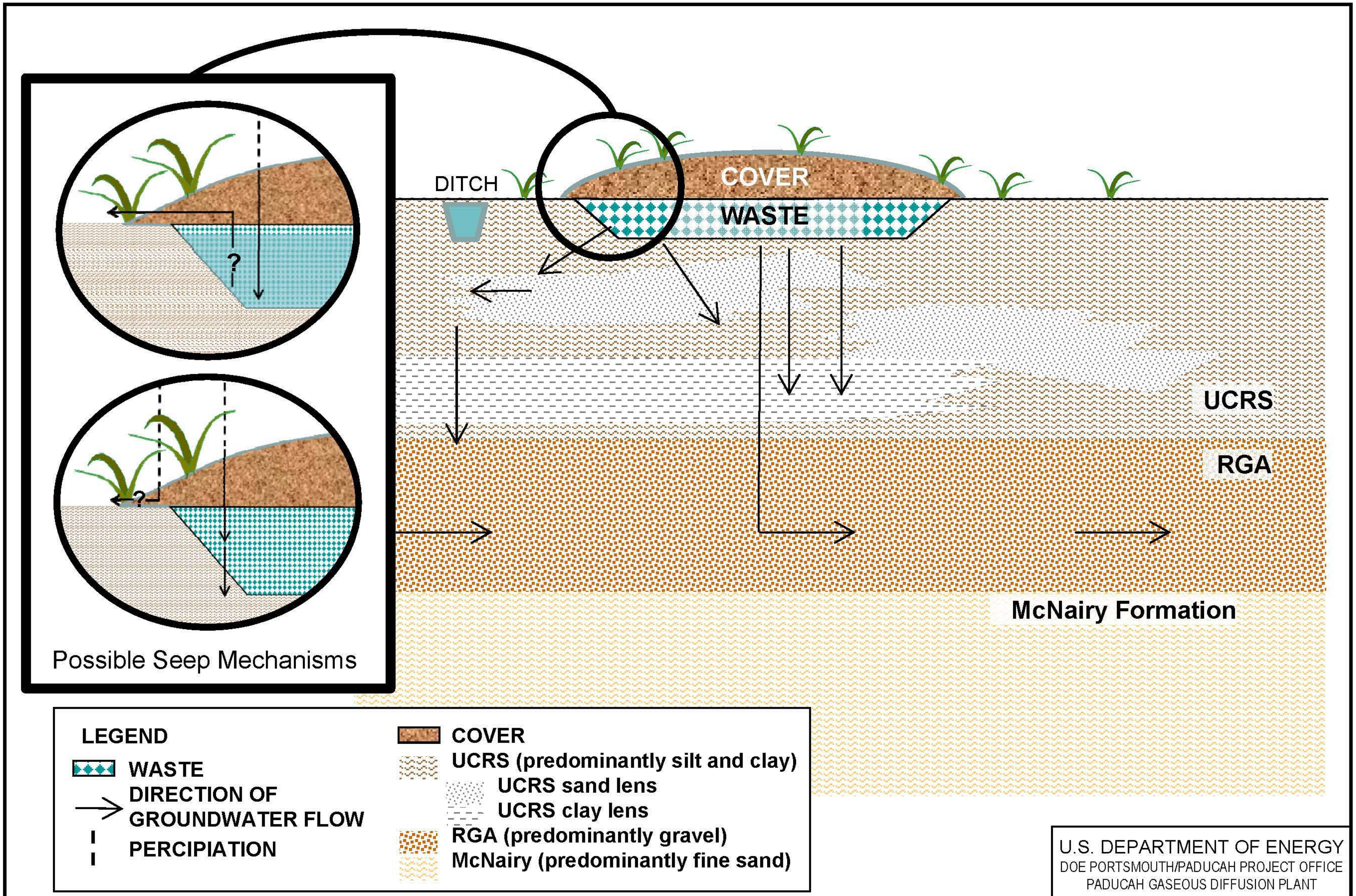


Figure 1.7. Pictorial Conceptual Model of the BGOU

LATA Environmental Services of Kentucky, LLC

On March 6, 1997, water was observed at three points along the southern edge of the waste cell cover material at SWMU 5; the water was documented in field notes as seeps (Mullins 1997). These seeps never again have been observed, and there is little data and much uncertainty associated with the seeps Assuming the surface water observed in 1997 was the result of groundwater flowing to the surface, rather than the result of "ponding" or pooling of the 5.5 inches of rain that had fallen in the 5-day period leading up to the observation, two postulated explanations for seeps have been developed. First, waste cells may fill with infiltration water and then spill over the HU 1, creating a seep at the interface of the UCRS and the cover soils that lie over the disposal cell. A second possibility for seep formation is that precipitation percolating through relatively permeable material used to cover the waste migrated downward until reaching HU 1, then migrated laterally to the terminal edge of the cover material. These postulated groundwater migration routes are included in the CSM, as shown in Figure 1.7 These periodic circumstances, should they occur, would create a route for SWMU 5 contaminants to migrate to the surface and could contaminate adjacent surface soils and/or expose workers to potential contamination in seep water. These circumstances could result in an unacceptable level of risk.

1.3.5 Contaminant Fate and Transport

1.3.5.1 Contaminant fate

Some contaminants may be transformed to new constituents in the environment; organic compounds may decompose or be transformed by various processes including hydrolysis, oxidation/reduction, photolysis, or biological processes, and radioisotopes may decay by nuclear reactions. All transformations produce new constituents or daughter products, some of which may also have hazardous or toxic effects. Transformations of organic compounds are governed by environmental conditions, pH or oxidation reduction potential levels, and the presence of bacteria and electron donors. Transformations of radionuclides are dependent on the decay constant of the isotope alone.

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 or may be stable nuclides. Natural uranium consists of three primary isotopes: uranium-234, uranium-235, and uranium-238. Decay products of uranium isotopes also are radioactive, with unique decay chains. Half-lives for radioisotope decay for the radioactive contaminants at PGDP are listed in the PGDP Risk Methods Documents (DOE 2011b).

1.3.5.2 Contaminant transport

The transport of contaminants from the BGOU SWMUs will occur primarily in the dissolved phase, due to partitioning from the solid or adsorbed phase to infiltration from rainfall or to groundwater where waste is saturated, which is a common condition in the BGOU. The dissolution of contaminants will be controlled by the rate of water infiltrating through soil and waste at the waste units, the solubility of the contaminants, and equilibrium partitioning between the liquid phase and the soil, described by a partitioning coefficient: K_d. For volatile compounds, partitioning to the soil gas phase, described by a Henry's Law constant, also may be an important transport pathway. The K_d for organic compounds is a function of the organic carbon coefficient (K_{oc}) and fraction of organic carbon in the soil (f_{oc}).

The mobility of metals is dependent on a range of factors, including, but not limited to, soil pH, cation exchange capacity of the soils, redox of the disposal cell and soils below the cell, and the heterogeneity the HUs. The range of K_d for inorganic COCs is very large and some metals are expected to be relatively mobile and some are expected to be immobile. The high clay content and neutral pH of the UCRS is expected to limit migration of metals at these SWMUs. The potential for acidic leachate at SWMU 6 was

Table 1.7. Summary of Remedial Investigation Report Uncertainties

SWMU No.	Uncertainty	Response and Citation of Discussion in FS
Global	Whether process knowledge and existing data sufficiently characterize the contents of waste cells and allow for management of uncertainties.	In this FS, uncertainties related to data gaps are discussed in the context of remedial alternatives development for each SWMU. Remedial alternatives are designed to provide a degree of protection greater than that necessary to protect against the maximum observed concentrations of COCs, and to mitigate uncertainties in available data.
	Whether the expected industrial land use will continue in perpetuity.	This uncertainty is addressed throughout the FS document, which develops remedial alternatives according to CERCLA guidance and will support remediation under CERCLA when executed. The remedial alternatives include the necessary postremediation sampling, long-term monitoring, costs, and land use controls appropriate for each SWMU. Alternatives that include long-term monitoring, or leave waste in place, will require five-year reviews under CERCLA. Consistent with guidance, five-year reviews would consider the effects of any changes in land-use on the protectiveness of the selected remedy.
Global	Whether the lateral extent of the burial cell is adequately delineated. Acidic leachate, oxidation/reduction conditions, and degree of waste saturation. Nature, extent and volume of the source zone (burial cell). Limited groundwater monitoring around the BGOU SWMUs. Potential for leachate from burial areas to impact adjacent surface water ditches. Nature and extent of contaminants in surface soil at selected SWMUs.	Remedial design includes the opportunity to collect engineering data to support technology sizing, design and optimization. These are the features or attributes of the alternatives evaluated for the BGOU. Geophysical evaluations of these SWMUs provide a high degree of confidence that the areal extents of these SWMUs have been determined to a precision sufficient to support FS decision making. For excavation: • Criterion to remove visible waste. • Postremediation sampling. • Removal of contaminant source. For cover: • A cover will be engineered to manage runoff. • Elimination of direct contact exposure pathway. • Long-term surface water and groundwater monitoring. • Cover maintenance to maintain elimination of direct contact. For cap or containment: • A cap will be engineered to manage runoff. • Elimination of direct contact exposure pathway. • Long-term surface and groundwater monitoring. • Leachate collection and treatment. • Cap maintenance to maintain elimination of direct contact. Remediation will not be considered complete until verified by postremediation sampling or long-term monitoring, or both. Appendix C contains area and volume assumptions for remediation and cost estimates, including postremediation sampling. An FS cost estimate assumes -30/+50%. accuracy to account for some degree of site uncertainty.

evaluated because of perchloric acid contamination on the exhaust fans; however, soil and UCRS groundwater do not indicate any impacts from acid, and any acid that was present would be expected to be rapidly neutralized in these soils (see Section 5).

Tc-99 has a relatively low K_d, suggesting releases of this radionuclide from waste to subsurface soils have higher potential to reach the RGA than other radionuclides. However, the distribution of Tc-99 at SWMU 5 does not support the assumptions for its theoretical mobility at this site given that all but one exceedance of background concentrations remained in surface soils.

1.3.5.3 Groundwater fate and transport modeling

Modeling for the BGOU RI used the Spatial Analysis and Decision Assistance (SADA), Seasonal Soil Compartment Model (SESOIL), and Analytical Transient 1-,2-,3-Dimensional (AT123D) models, consistent with Tier 3 of the modeling matrix in the PGDP Risk Methods Document (DOE 2011b). 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 points of exposure (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, 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 the BGOU RI (DOE 2010b). The fate and transport modeling for the BGOU RI incorporates the sampling results of the 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.

Table 1.4 presents the results of the deterministic modeling effort for the BGOU RI for the SWMU boundary, plant boundary and off-site POEs for the analytes determined to be COCs. None of the constituents except uranium was modeled (using assumptions and modeling parameters that predict migration likely much greater than that occurring than that actually occurring at present time) to have a maximum groundwater concentration that exceeds the respective maximum contaminant level (MCL).

As discussed in Appendix A, although these constituents were modeled in the RI, these were not all constituents to be addressed in the FS based on factors including background, risk/MCL comparisons, and travel times.

1.3.6 Human Health Risk Summary

The RI determined that there were several COCs at SWMUs 5 and 6. Because these COCs are present, there could be unacceptable threats to human health and the environment from SWMUs 5 and 6 under some future use scenarios, particularly if there were any of the following:

- Direct contact with buried wastes;
- Direct contact with surface soils;
- Direct contact with subsurface soils; and
- Migration of COCs to groundwater and/or surface water.

Table 1.4. Concentrations of the Analytes in Groundwater Predicted in SESOIL and AT123D Modeling of the BGOU SWMUs

Predicted Maximum Groundwater Concentration[a]						
Analyte	**SWMU Boundary**	**Plant Boundary**	**Property Boundary**	**Little Bayou Seeps**	**Ohio River**	**MCL**
SWMU 5						
Arsenic (mg/L)	9.25E-03	1.78E-03	1.27E-04	N/A	0.00E+00	0.01
Manganese (mg/L)	1.01E+00	8.69E-02	2.30E-11	N/A	0.00E+00	[b]
Naphthalene (mg/L)	5.55E-03	9.82E-04	3.72E-04	N/A	1.08E-04	[b]
Technetium-99 (pCi/L)	1.27E+02	4.99E+01	2.64E+01	N/A	8.72E+00	4 mrem/yr[c]
Uranium (mg/L)	***4.60E-01***	***3.32E-02***	4.65E-11	N/A	0.00E+00	0.03[d]
SWMU 6						
None						

Table 1.4 is based on Tables 5.2 and 5.3 of the BGOU RI (DOE 2010b).
[a] Values in bold, italic font with highlight exceed the analyte's MCL.
[b] MCLs not available for these contaminants.
[c] MCL for beta and photon emitters.
N/A = The point of exposure is not applicable. Groundwater flow pathways do not reach the specific discharge point from this SWMU as demonstrated in the BGOU RI (DOE 2010b).
[d] Derived based on toxicity (hazard) of uranium soluble salts.

The impact to human health from direct contact with buried wastes was not characterized quantitatively in the BHHRA, and no specific COCs were identified. The BHHRA also concluded that, although much of the scrap metal waste known to be disposed at these SWMUs is not expected to pose significant hazards if contacted by workers in the future, potential risks are uncertain because the scrap metals may be contaminated with radionuclides. Hazards associated with contact with waste are identified as an uncertainty, and the potential threat will be addressed through the developed alternatives in this FS.

A BHHRA was conducted as part of the RI. The BHHRA reported the hazards and risks for current and future uses, some of which are unlikely or hypothetical. The risk characterization summary for all scenarios evaluated in the RI for these SWMUs is included in Appendix B. The risk characterization for direct contact scenarios was reported in the WAG 3 RI (DOE 2000b), so additional review of these COCs was conducted (e.g., background comparisons, toxicity assumptions for beryllium) to better support management decisions based on current understanding of the risks/hazards. The emphasis in the BGOU RI was to better characterize potential releases from the wastes to subsurface soils and potential impacts to the RGA and to update the risk assessment for use of RGA groundwater at the SWMU boundary and downgradient POEs.

The land use is expected to remain industrial; therefore, the emphasis of the review of the BHHRA in development of the FS, was the future industrial and outdoor worker scenarios. Exposure parameters for both scenarios were selected to ensure risks were characterized considering reasonable maximum exposure (per RAGS Part B and the RMD). (The future outdoor worker was defined as the excavation worker in the BHHRA.) The COCs identified in the BHHRA for these receptors are summarized in Table 1.5. The results of the review of the risk characterization in the BHHRA, along with uncertainties related to the nature and extent of contamination, triggered the evaluation of alternatives in the FS, consistent with Section XII of the FFA.

Potential migration of contaminants from the waste that may pose an ongoing source to RGA groundwater was evaluated in the BHHRA (at the SWMU boundary) and COCs were identified. For SWMU 6, there were no COCs. For SWMU 5, arsenic and Tc-99 were identified as contributing to the cancer risk and manganese, uranium, and naphthalene to the noncancer hazard.

Table 1.5 Summary of COCs Identified for Future Industrial Worker (0–1 ft bgs) and Outdoor Worker (0–16 ft bgs)

	SWMU 5	SWMU 6
Carcinogenic COCs (ELCR > 1E-06)	Arsenic Beryllium Total PAH *Total PCB*	Beryllium Total PAH
Non-cancer Hazard COCs (HQ > 0.1)	*Aluminum* *Arsenic* *Barium* *Beryllium* *Chromium* *Iron* *Manganese*	*Aluminum* *Barium* *Beryllium* *Chromium* *Iron* *Manganese* *Vanadium*

Table 1.5 is taken from the BGOU RI (DOE 2010b).
Analytes shown in italics only identified as COCs for outdoor worker scenario. Others are COCs for future industrial and outdoor worker scenarios.
ELCR = excess lifetime cancer risk
HQ = hazard quotient

To meet the remedial action objectives (RAOs) for these SWMUs, the COCs identified based on assumptions that do not limit residential use of RGA groundwater at the SWMU boundary (Appendix A) and direct contact with contaminants in soil (Appendix B) were reviewed to identify potential remediation goals (RGs) for soils.

Dermal contact with soil has been a driving exposure pathway 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 (DOE 2010b). In such circumstances, risk estimates from the dermal exposure route may be unrealistic and exceed the real risk posed by this route of exposure.

The exposure point concentration used to estimate risk is an estimate of the average chemical concentration of the soils. The risk assessment used default exposure durations and exposure frequencies for risk estimates for likely future industrial workers and outdoor workers. Exposure parameters for general site maintenance (16 days/yr for 25 years) estimated for other locations at PGDP are more representative for future maintenance of the BGOU SWMUs than the assumptions of 250 days/year for 25 years assumed for a more unrestricted industrial land use assumptions (DOE 2011b). The future outdoor worker risk estimates assume 185 days/year for 25 years for the exposure frequency and exposure duration (DOE 2011b). This would exceed the exposures for an excavation land use scenario for a soil removal action associated with construction of a foundation or excavation of contaminated soil. A site-specific duration for the number of days and years to complete an excavation was estimated in the WAG 3 risk assessment to evaluate this uncertainty, suggesting the ELCR for the future outdoor worker would decrease by a factor of 8 for SWMU 5 and a factor of 67 for SWMU 6.

1.3.7 Screening Ecological Risk Assessment

The SERA was summarized in the BGOU RI, and it concluded that risks to terrestrial receptors are not expected at SWMU 6 from current or future exposures; at SWMU 5, exceedances of benchmarks were limited in extent.

A summary of the results of the comparison in previous assessments of the site data to the ecological screening levels is provided in Table 1.6. This table lists the number of chemicals of potential concern

(COPCs) in each suite retained for each site and the medium for further consideration. Radionuclides were eliminated as COPCs for SWMUs 5 and 6.

Table 1.6. Summary of Suite of Ecological COPCs Retained in Surface Soil

Area	Media	Metal	Rad	Pesticide/PCB	SVOC	VOC
SWMU 5	Soil	5	----	1	3	----
SWMU 6	Soil	2	----	----	1	----

Table 1.6 is taken from Table 6.16 of the BGOU RI (DOE 2010b).
----: no ecological COPCs
PCB = polychlorinated biphenyl
SVOC = semivolatile organic compound
SWMU = solid waste management unit
VOC = volatile organic compound

The SERA concluded that the BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. Because the SWMU source units are small and PGDP is industrial, the use of screening against benchmarks to assess direct toxic effects on wildlife populations is conservative. The cumulative effects to terrestrial habitat will be assessed facility-wide (or watershed-wide) in the PGDP baseline ecological risk assessment for the surface water OU. For SWMUs 5 and 6, metals were the more frequently identified chemicals exceeding benchmarks, but typically were below background concentrations. PAHs and PCBs also were COPCs for SWMU 5, but were predominantly in samples collected from soils or sediments adjacent to the disposal areas and are not attributed to releases from buried waste (see Sections 5 and 6 for additional discussion).

1.4 SUMMARY AND CONCLUSIONS FROM THE BGOU RI

This section lists the major findings from the BGOU RI, updated based upon the RI review conducted as part of this FS.

1.4.1 Major Findings from the BGOU RI

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

- The primary residual threats from SWMUs 5 and 6 are associated with direct contact with buried wastes; however, the RI also acknowledges the uncertainties related to the nature and extent of contaminants in surface soil at selected SWMUs. The RI also states that the FS will manage this uncertainty by evaluating remedial alternatives that address the uncertainty.

- Total PAHs were identified as contributing to potential cancer risks at SWMUs 5 and 6. These were present in surface soils/drainageway samples not derived from the waste units and will be addressed within the decision process of the surface water OU.

- The reasonable anticipated future use of these SWMUs is continued industrial use,. The risk assessment included future industrial and outdoor worker scenarios for contact with surface and subsurface soils. Excluding PAHs, there are no soil COCs to protect future industrial or outdoor workers.

- Contaminants are not expected to migrate through groundwater from SWMUs 5 and 6 to locations at the SWMU boundary, the plant boundary, property boundary, and near the Ohio River, at levels that limit hypothetical residential groundwater use.

- The SERA concluded that risks to terrestrial receptors are not expected at SWMU 6 from current or future exposures, and, at SWMU 5, exceedances of benchmarks were limited in extent. This disturbed industrial area does not support any unique or significant ecological resources. The COPCs identified are not associated with releases from the waste. These will be considered further in future sitewide risk assessments.

1.4.2 Uncertainties Identified in the RI Report

The BGOU Work Plan identified data gaps for individual SWMUs that were necessary to be filled in order to move forward with the FS. The Work Plan was implemented to reduce 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 this FS. These uncertainties are documented in the RI Report (DOE 2010b) and include the following relative to SWMUs 5 and 6.

- The lateral extent of source zones (burial areas) is well-documented. The magnitude of the potential threat from contact with waste is uncertain; therefore, the FS will ensure alternatives are developed to manage threats associated with direct contact with buried waste materials.

- The potential for acidic leachate, changing oxidation/reduction conditions, and the degree of waste saturation were identified as uncertainties; however, these uncertainties do not appear to present a significant risk based on the historical and current data. For those alternatives that leave waste in place, a monitoring program will incorporate methods to address these uncertainties.

- Limited groundwater monitoring around the BGOU SWMUs was identified as an uncertainty. The FS will manage this uncertainty by incorporating additional groundwater monitoring where appropriate, for alternatives where waste is left in place.

- The potential for releases from SWMU 5 burial areas to impact adjacent surface water ditches was identified as an uncertainty. Conclusions drawn from the 2011 field investigation, described in Section 1.3.4 of this document, suggest that there is no completed pathway through the UCRS to surface water ditches (Johnstone 2011); however, a 1997 report of surface seeps at SWMU 5 leaves open the possibility that groundwater could migrate to the surface through the relatively impermeable material used to cover the waste (Mullin 1997). The FS will evaluate alternatives that include monitoring and mitigation measures related to shallow groundwater and surface water to address the uncertainties associated with the reported seeps.

- The nature and extent of contaminants in surface soils at SWMU 5 remain uncertain. This FS considers how exposure to surface soils within SWMU 5 will be managed under the BGOU.

The uncertainties associated with SWMUs 5 and 6, the approach taken to address the uncertainties, and the locations in the FS where the uncertainties are addressed are summarized in Table 1.7 and discussed in the following sections.

1.4.2.1 Nature of the source zone

The BGOU RI did not conduct intrusive sampling in the existing waste management units. As a result, specific waste characterization data are limited. Historical records and data, past observations, and waste disposal documentation referenced in the BGOU RI Report were used to supplement the RI data to establish the basis for selecting remedial alternatives and preparing cost estimates for those alternatives (DOE 2010b). A key project assumption for the FS is that the available historical documentation and soil

Table 1.7. Summary of Remedial Investigation Report Uncertainties (Continued)

SWMU No.	Uncertainty	Response and Citation of Discussion in FS
Global	Whether waste has been completely or partially released from buried drums.	No drums of liquids have been reported to have been disposed of at SWMU 5 or SWMU 6. Drums of solid materials, if disposed of, are no longer expected to be intact. In addition, solid materials are not expected to migrate in the environment.
	Whether arsenic and other metals are COCs for future residential groundwater users and whether their concentrations might exceed regulatory limits in the RGA.	The BGOU is a source removal action, not a groundwater action. MCLs and risk-based concentrations in groundwater are used only to develop groundwater protective soil RGs, as described in Section 2 and Appendix B. Arsenic and other metals in the BGOU were determined not to pose a threat to groundwater. The uncertainty related to arsenic and other metals on screening of metals and radionuclides in soil is addressed in Appendix A and Appendix B.
5	Sampling information for soil at SWMU 5 is limited; therefore, any remediation alternative that leaves waste in place would have to include the following components: (1) focus on the removal of direct exposure pathways; (2) incorporate long-term groundwater monitoring; (3) provision to review the decision during five-year reviews or as appropriate, if new information becomes available.	The uncertainty associated with the data set at SWMU 5 is addressed in the alternatives presented in Section 5. For removal of direct exposure pathways, alternatives range from LUCs and long-term monitoring, to a soil cover with LUCs and long-term monitoring, to excavation of the waste and soil in close proximity to the waste. Costs for 5-year reviews are included in Appendix C.
	Whether conditions are different than presented in the RI Report.	Uncertainties related to COCs for this SWMU are described in the RI Report. The list of COCs was identified through the assessments of all media and scenarios of interest. Appendices A and B and Section 5 further discuss the refinement of the COC list based on background comparisons, updated toxicity information, and clarification of chemical concentration patterns. The features of the various types of alternatives that address this uncertainty are listed under nature and extent.
	Whether surface soil PAH concentrations warranting action exist within the SWMU.	PAHs are deferred to Surface Water OU. Individual PAH compounds were detected only at isolated locations at some SWMUs. The PAH compounds that were detected were determined not to come from SWMU 5. See Section 5 and Appendix B.
	Whether arsenic is a COC because of its detection at 12.2 mg/kg in one sample, which is above the background concentration for surface soils (12 mg/kg).	Arsenic was determined not to be a COC. Appendix B and Section 5 further discuss the refinement of the COC list based on background comparisons, updated toxicity information, and clarification of chemical concentration patterns.
6	Whether leachate acidified by perchloric acid leaching from contaminated exhaust fans has affected the mobility of some contaminants.	Because any perchloric acid present was disposed of over 20 years ago, it is likely that any perchloric acid present has been neutralized by the buffering capacity of native materials and, therefore, is not affecting the mobility of any contaminants that might be present.
	Whether current geophysical data accounts for a portion of the SWMU where equipment was in the way during the original survey.	Once the alternative has been selected, the original surveys will be reviewed to verify that the geophysical data are sufficient to support the implementation. As necessary, additional geophysics will be performed as part of remedial design.
	Whether PAHs detected in surface soil near a road are part of the BGOU.	The PAHs detected in the vicinity of SWMU 6 are not part of the BGOU. This uncertainty is addressed in Section 5 and Appendix B.

Table 1.7. Summary of Remedial Investigation Report Uncertainties (Continued)

SWMU No.	Uncertainty	Response and Citation of Discussion in FS
6	Whether metals in subsurface soil are COCs that warrant action based on dermal contact parameters for the outdoor worker scenario and consideration of site background levels.	Review of these data support the conclusion that metals in the subsurface are not COCs based on screening and additional background comparisons. Identification of COCs in subsurface soil at SWMU 6 is discussed in Section 5 and Appendices A and B.
	Whether buried water lines would interfere with an excavation or have affected contaminant migration from SWMU 6.	The uncertainty of the presence of buried water lines could impact the placement of monitoring wells at SWMU 6. This will have to be considered in remedial design.

BGOU = Burial Grounds Operable Unit
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
COC = contaminant of concern
PAH = polycyclic aromatic hydrocarbon
RG = remediation goal
RGA = Regional Gravel Aquifer
SWMU = solid waste management unit

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, to develop effective alternatives, and to conduct a detailed alternative analysis. While the 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). Based upon disposal records, SWMUs 5 and 6 contain industrial wastes, some of which are LLW. Industrial wastes in burial grounds at the PGDP are known to contain waste that could be contaminated with PCBs or RCRA hazardous wastes. Without more definitive waste characterization (i.e., sampling and analysis), it is not possible to state whether or not PCBs or RCRA hazardous wastes are also present at SWMUs 5 and 6. Based upon the waste inventory, the buried wastes at SWMUs 5 and 6 (including low-level radioactive waste) are considered low level threat waste consistent with EPA guidance. A related uncertainty is that the RI was unable to sample to the middle SWMU 5; therefore, there are some uncertainties in the nature of the contaminant source that need to be managed during the decision-making process. The principal issue related to this uncertainty is that direct contact with buried wastes must be controlled to ensure protectiveness of human health and the environment.

SWMUs 5 and 6 have been investigated previously (Section 1.3.2). The BGOU RI used a combination of historical and current sample results of soil and groundwater from the area of each SWMU. The results of previous investigations, as well as the recent RI sampling, document the presence or absence of metals, organic compounds, and radionuclides in the Burial Grounds. The associated samples were collected and analyzed over several previous and continuing investigations, as well as in the BGOU RI, using several methods. Changes to analytical methods and variations in detection limits restrict a rigorous comparison of data (e.g., laboratory reporting limits have varied over time). During development of the BGOU RI Work Plan, it was decided to limit the historical sample analyses used in the RI to groundwater samples collected in January 1995 and later and soil samples collected in June 1996 and later to minimize the potential for "age" to bias the analysis of the data. This approach maximized 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 many of the SWMUs that would allow analyses of seasonal variations and analyte trending, but temporary borings provide a snapshot of the conditions where groundwater samples could be obtained.

1.4.2.1.1 Maximum COC concentrations may not be known

Because only limited source-term data are available, it is possible that the maximum concentration of the COCs present at the SWMUs have not been established; however, sufficient data exist to determine if an action is needed at each unit as long as this action incorporates control over direct contact with buried waste. If wastes are left in place, postremediation sampling and groundwater monitoring will be performed in conjunction with implementation of individual remedies to address this uncertainty. Screening of technologies and development of alternatives considered this uncertainty. In consideration of this uncertainty, the screening of technologies and development of alternatives included best engineering judgment to ensure that alternatives were developed to provide protection of human health and the environment.

1.4.2.1.2 Approach for addressing the limited source term data in the FS

The RGs for the BGOU were developed to address potential risks posed by contaminants in surface or subsurface soils (secondary media) impacted by releases from the waste, usually a reliable indicator of releases from the source (s). Because the primary mode of migration in the UCRS is vertical, some uncertainty about the nature of the source term remains, particularly for SWMU 5, given the larger waste disposal area. The available data provide a basis for estimating potential actions needed at these SWMUs.

1.4.2.2 Acidic leachate, oxidation/reduction conditions, and degree of waste saturation

Historically, DOE finds no evidence of acidic leaching from the BGOU SWMUs; however, the potential for acidic leachate at each SWMU is uncertain due to the lack of disposal records and the amount of time elapsed since disposal. It is unlikely that any acid moieties remain. For example, although exhaust fans with perchloric acid were disposed of at SWMU 6, the perchloric acid is no longer expected to be present because such a strong acid would have become neutralized by the site soils. It should be noted that angled borings beneath SWMU 6 found no evidence of acidic leachate, either from subsurface metal concentrations or groundwater pH. Moreover, over 30 years have elapsed since the burial of exhaust fans at SWMU 6; it is likely that all of the perchloric acid has been neutralized. Any change from this baseline condition would be detected by long-term monitoring and addressed as part of the Five-Year Review.

Uncertainty exists with regard to the dissolved oxygen concentration in the UCRS at SWMU 6 due to a lack of data. The majority of dissolved oxygen measurements from UCRS wells ranges from near zero to 4 mg/L and the oxidation/reduction potential commonly ranges from -100 to 300 microVolts, with the majority of measurements greater than zero. Data from all BGOU SWMUs combined demonstrate the trends of dissolved oxygen (517 measurements) and oxidation/reduction potential (136 measurements) in the UCRS at the BGOU SWMUs. The relative abundance of measurements for these SWMUs where measurements were taken demonstrates a trend that appears to be representative of conditions across the BGOU; therefore, the oxidation/reduction potential in the UCRS at SWMU 6 will be assumed to be similar to that in the UCRS at other BGOU SWMUs.

Although there is some potential for some wastes to be intermittently present in saturated conditions, this condition does not materially affect the alternative evaluation. The selected alternatives will need to include technologies that take into account any groundwater that is encountered by removing, isolating, or containing the waste, or providing a mechanism to dewater the waste.

The historical waste disposal record does not indicate any burial of drummed waste at SWMUs 5 or 6. For SWMU 6, where the last disposal occurred more than 30 years ago in 1976, however, it is reasonable to assume most, if not all, drums would have failed (an Oak Ridge National Laboratory researcher estimated that drum failure would be expected to occur within 18 to 36 years). Additionally, at SWMU 5, where the last disposal occurred in 1987, it is reasonable to assume some drums, if present, still may be intact. 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. The risk assessment concluded that these uncertainties related to the source zone were not estimated to have a large effect on the risk characterization.

1.4.2.3 Extent and volume of the source zone

There remains some uncertainty with regard to the boundaries of some BGOU SWMUs; however, geophysical surveys have been completed at SWMUs 5 and 6. Engineering drawings and currently assumed burial cell extent were used as the basis for FS assumptions; however, to manage this uncertainty, a geophysical survey may be needed and specified in the Remedial Design Work Plan (RDWP) to optimize planning/implementing the selected alternative.

1.4.2.3.1 Assumptions used for area, depth, and volume of contaminant source areas

Assumptions are made regarding the area, depth, and volumes of contaminated source areas based on available RI data. To address these issues, engineering data collection to support technology sizing, design, and optimization will be included as a component for remedial alternatives where additional information regarding the source term is needed to support the detailed design of the alternative. These assumptions are discussed below.

1.4.2.3.2 Removal of COCs from soil and waste layers

For alternatives that involve excavation, it is assumed that excavation will extend from the surface to approximately 1–20 ft below grade to remove visible waste. Based on evaluation of RI data, the COC concentrations present in Layers 4–7 (20–64 ft bgs) are representative of residual values that are below RGs, and RAOs should be met for radioactive and inorganic COCs.

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 in the RI Report for the BGOU SWMUs at the plant boundary, property boundary, surface seeps at Little Bayou Creek, and near the Ohio River.

1.4.2.3.3 Use of postremediation sampling to reduce uncertainties

During the FS, RGs are established that are protective of the groundwater exposure pathway, or direct contact if more restrictive. The data are sufficient for selection of appropriate remedies to mitigate those risks to acceptable levels. If removal is selected as a remedy, residual uncertainty can be managed by specifying postremediation sampling and groundwater monitoring as appropriate during implementation of the selected remedy to verify that cleanup levels are met. No additional analyses for characterization are required, except to support waste management if needed.

1.4.2.3.4 Estimation of waste volumes for remediation

As part of the excavation alternative, it was assumed that selected SWMUs will require excavation. In general, the volume of waste to be excavated was estimated based on the areal footprint of the SWMU and an assumed excavation depth not to exceed 20 ft bgs. This depth is several ft deeper than the greatest disposal depth reported for any of the SWMUs and corresponds to the bottom of SADA modeling Layer 3 (See BGOU RI). If documentation was available indicating that only a portion of the SWMU was used for waste disposal, the volume of waste material was reduced by an estimated percentage corresponding to the volume of soil that is not likely to have been impacted by contact with wastes. This was accomplished by evaluating the historical layout figures for each SWMU and estimating the volume of the SWMU likely to be in contact with waste, based on the size and position of disposal cells within the SWMU.

If an alternative that includes application of a surface barrier or cap to the SWMU was considered, the reported surface area of the SWMU, plus an additional buffer, was assumed for development of an estimate for installing a cover.

1.4.2.4 Limited groundwater monitoring around the BGOU SWMUs

The assumption carried forward from the BGOU RI is that all of the materials disposed in SWMUs 5 and 6 potentially contained radioactive materials. The conceptual model applicable to all of the BGOU SWMUs is that releases from the SWMUs have impacted soils below or immediately adjacent to the source zones and, through vertical infiltration in the soil, have the potential to contaminate the groundwater underlying these sources.

While the transport modeling conducted for the RI necessarily made simplifying assumptions, the data were adequate to identify the COCs, determine their contribution to risks to human health, and develop RGs for evaluating alternatives. To the extent practicable, the modeling approach simulated actual PGDP site conditions using, as an example, K_ds for metals in soils based on acidic soils with a low cation exchange capacity, consistent with known site conditions. Subsurface soil results do not suggest a release to subsurface soils has occurred from the waste.

1.4.2.5 Potential for leachate from burial areas to impact adjacent surface water ditches

No seeps have been observed as associated with SWMU 6. Section 5.1.1.3.2 addresses this uncertainty as it relates to SWMU 5.

1.4.2.6 Delineation uncertainties for contaminants in surface soil at selected SWMUs

RGs established in the FS are protective of both the direct contact and groundwater exposure pathways. Alternatives will address containment, removal or treatment of soils to meet the RGs, as applicable. Uncertainties regarding the extent of contamination above the RGs will be managed by excavation guided by postremediation sampling until the effectiveness of excavation is demonstrated or by long-term groundwater monitoring where cleanup levels cannot be met in the subsurface soils or media.

Animals that burrow to 5 ft bgs would be expected to encounter ecological COPCs located in Layers 1 and 2, which extend to 10 ft bgs. Because these soils are the only media that would affect ecological receptors and are addressed in the FS by removing Layers 1 through 3 at the SWMUs during waste excavation or, if waste is left in place, selecting an alternative that places a surface barrier over the soils of interest to prevent contact with residuals also could prevent exposure by ecological receptors.

1.4.2.7 Cost estimate between -30% and +50%

The unknowns associated with source, volume, and characterization information related to waste types and volumes for treatment and/or disposal add uncertainty to the development of remedial cost estimates. Assumptions for these parameters were used to develop costs. Cost estimates are provided in Appendix C.

THIS PAGE INTENTIONALLY LEFT BLANK

2. IDENTIFICATION AND SCREENING OF TECHNOLOGIES

A primary objective of this FS is to identify remedial technologies and process options that potentially meet the RAOs for this action and then combine them into a range of remedial alternatives. RAOs and RGs for potential remedial actions are introduced and developed in this section. In addition, technology types and process options that may be applicable for remediation of SWMUs 5 and 6 are identified, screened, and evaluated in this section. The potential remedial technologies are evaluated for implementability, effectiveness, and relative cost in eliminating, reducing, or controlling risks to human health and the environment. The criteria for identifying, screening, and evaluating potentially applicable technologies are provided in EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988) and the NCP.

CERCLA requires development and evaluation of a range of responses, including a No Action alternative, to ensure that an appropriate remedy is selected. The selected final remedy must comply with ARARs, unless waived, and must protect human health and the environment. The technology screening process consists of a series of steps that include the following:

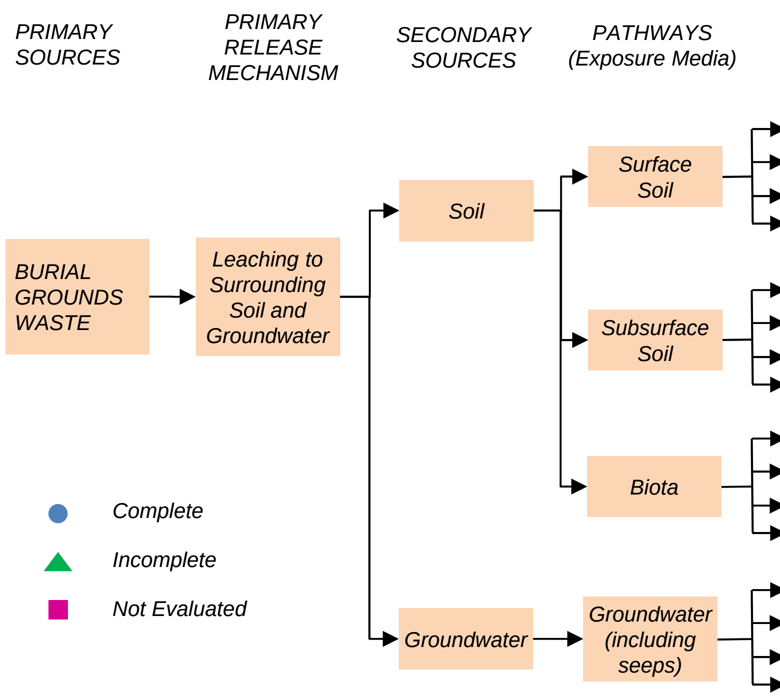
- Identifying general response actions (GRAs) that will meet RAOs, either individually or in combination with other GRAs;
- Identifying a volume or area of media to which the GRA will be applied (see Table 1.3);
- Identifying, screening, and evaluating remedial technology types for each GRA; and
- Selecting one or more representative process options (RPOs) for each technology type.

Following the technology screening and identification of the RPOs in this section, RPOs are assembled into remedial alternatives that are evaluated further in the detailed and comparative analyses of alternatives found in Section 3.

2.1 INTRODUCTION

Previous PGDP investigations and reports used to develop the CSM and to identify and screen remedial technologies are listed in Section 1. Other sources used in technology identification and screening, including EPA, DOE, peer-reviewed databases and reports, and journal publications, are cited in this section and the references are provided in Section 6.

Technologies are identified and evaluated in this FS based on their effectiveness in eliminating direct contact with surface soil, waste, and soils in close proximity to the waste and mitigating uncertainty associated with the waste. Technologies also are identified and evaluated for their effectiveness in eliminating or mitigating the exposure pathways, as shown in the CSM of the BGOU source areas (Figure 2.1). Finally, RPOs are developed from the appropriate technology types necessary to address the physical and chemical nature of the contamination at each SWMU. In Section 3, alternatives will be developed by combining the appropriate RPOs in a manner sufficient to remediate the full scope of contamination at each SWMU.



PATHWAYS (Exposure Media)	EXPOSURE ROUTE	RECEPTORS: Current Industrial Worker	Future Industrial Worker	Future Outdoor Worker	Future Recreational User	Future Rural Resident
Surface Soil	Ingestion	●	●	●	●	●
	Inhalation	●	●	●	●	●
	Dermal	●	●	●	●	●
	External (Radiation)	●	●	●	●	●
Subsurface Soil	Ingestion	▲	▲	●	▲	▲
	Inhalation	▲	▲	●	▲	▲
	Dermal	▲	▲	●	▲	▲
	External (Radiation)	▲	▲	●	▲	▲
Biota	Ingestion	▲	▲	▲	●	■
	Inhalation	▲	▲	▲	▲	■
	Dermal	▲	▲	▲	▲	■
	External (Radiation)	▲	▲	▲	▲	■
Groundwater (including seeps)	Ingestion	▲	▲	▲	▲	●
	Inhalation	▲	▲	▲	▲	●
	Dermal	▲	▲	▲	▲	●
	External (Radiation)	▲	▲	▲	▲	▲

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

Figure 2.1 Conceptual Site Model for BGOU

LATA Environmental Services of Kentucky, LLC

Figure 2.1 is based on Figure F.1 of the *Remedial Investigation Report for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0030&D2/R1, February (DOE 2010).

2.2 DEVELOPMENT OF RAOs

The RAOs for the BGOU FS, developed in accordance with NCP requirements, consist of site-specific goals for protecting human health and the environment (EPA 1988) and meeting ARARs (in the absence of a CERCLA waiver). The RAOs were developed from the CSM and the BHHRA results by identifying the COCs and their sources, as well as the contaminant migration pathways and exposure scenarios that the action will address.

2.2.1 ARARs

ARARs include federal or more stringent state environmental or facility laws/regulations that are applicable or relevant and appropriate to the hazardous substances or circumstances at a site unless a CERCLA waiver is granted. ARARs do not include occupational safety or worker protection requirements. Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state environmental or facility siting law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site (40 *CFR* § 300.5). Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state environmental or facility siting law 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). In addition to ARARs, there are advisories, criteria, or guidance to be considered (TBC) for a particular release that were developed by other federal agencies or states that may be useful in developing CERCLA remedies. These are not potential ARARs, but are TBC guidance [40 *CFR* § 300.400(g)(3)]. CERCLA § 121(d)(4) provides several ARAR waiver options that may be invoked, provided that human health and the environment are protected. Additional ARAR discussion is presented in Appendix D.

ARARs typically are divided into three categories: (1) chemical-specific, (2) location-specific, and (3) action-specific. "Chemical-specific ARARs usually are health-or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values" [(53 *FR* 51394, 51437 (December 21, 1988)]. (In the absence of chemical-specific ARARs, cleanup criteria are based upon risk calculations consistent with those used to complete the BHHRA for the BGOU SWMUs.) 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* 51394, 51437 (December 21, 1988)]. Action-specific ARARs usually are technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes or requirements to conduct certain actions to address particular circumstances at a site [53 *FR* 51394, 51437 (December 21, 1988)].

There are no chemical-specific ARARs for remediation of the contaminated soils at the source areas with identified COCs; however, soil RGs, including RGs for radionuclides, were developed based on both direct exposure and migration from soil to groundwater. The Kentucky drinking water standard MCLs were used to back calculate soil RGs (see 401 *KAR* 8:250 for inorganic compounds, 8:420 for VOCs, and 8:550 for radionuclides), but are not ARARs for this source action.

2.2.2 RAOs

RAOs are goals for protection of human health and the environment. RAOs provide a general description of what a CERCLA cleanup is designed to accomplish. The BGOU FS evaluates taking actions as necessary to protect human health and the environment from the BGOU waste units and addressing potential releases from these source areas that may impact RGA groundwater or adjacent drainageways. The following general RAOs were developed.

(1) Contribute to the protection of groundwater by eliminating, reducing, or controlling sources of groundwater contamination; and

(2) Prevent exposure to waste and contaminated soils that present an unacceptable risk from direct contact.

The BGOU waste areas are located within the industrial area of the PGDP facility, and reasonable future use of this area is expected to remain industrial (DOE 2012). At SWMUs 5 and 6, buried waste consisting of radionuclide-contaminated metal debris and other materials is not sufficiently characterized to determine whether there would be an unacceptable threat. To address this uncertainty, this FS evaluates alternatives designed to eliminate direct contact with wastes to ensure no risk to future outdoor workers.

For each of these general RAOs, a SWMU-specific RAO is defined. These SWMU-specific RAOs are as follows:

SWMU-specific RAO 1. Contribute to the protection of groundwater by eliminating, reducing, or controlling sources of groundwater contamination that will result in an exceedance of the MCL or risk-based concentration for residential use of groundwater in the absence of an MCL in RGA groundwater.

SWMU-specific RAO 2. Prevent exposure to waste or waste-related contaminated soils that exceed target cumulative excess lifetime cancer risks (ELCRs) and cumulative noncancer hazard indices (HIs) for the future industrial and future outdoor worker receptors. The acceptable cumulative risk levels for this RAO are defined as follows:

- Surface Soil: cumulative ELCR < 1E-05 and cumulative HI ≤ 1 for a future industrial worker
- Subsurface Soil: cumulative ELCR < 1E-04 and cumulative HI ≤ 1 for an future outdoor worker

The SWMU-specific RAO may not fully address the general RAO for those direct contact risks that are more appropriately addressed in other programs and are not within the scope of the BGOU. Specifically, no RGs will be identified in this FS to address potential ecological impacts.

The sitewide baseline ecological risk assessment is where cumulative effects to ecological receptors will be evaluated. COPCs identified in the SERA will be incorporated into that evaluation. Most of the impacts identified in the SERAs for these SWMUs were for drainageway or surface soil samples adjacent to the burial ground areas that did not result from migration from the waste. No significant ecological risks were identified at these SWMUs. The area within the SWMU boundary does not support any unique or significant ecological resources. Based on the existing data, risks to terrestrial receptors are not expected at SWMU 6 from current or future exposures. For SWMU 5 risk characterization for terrestrial receptors is uncertain due to the limited soils data used in the screening ecological risk assessment. In addition, addressing human health risks within the SWMU boundaries would be expected to also reduce exposures to these receptors. Since the SERA did not identify specific short-term hazards, alternatives will consider the benefits of reducing exposures within the SWMU boundaries, deferring derivation of RGs for a final sitewide remedy to address residual risks posed to ecological receptors.

2.2.3 Remediation Goals

Consistent with Office of Solid Waste and Emergency Response Directive 9355.7-04, *Land Use in the CERCLA Remedy Selection Process*, DOE, EPA, and KY have determined that the reasonably anticipated future use for the area of the PGDP that includes the burial grounds is industrial. This future use is consistent with continued use of these SWMUs as burial grounds. Nevertheless, the BHHRA for these SWMUs evaluated a full range of potential future uses including residential to ensure that the FS would evaluate methods to control threats that exceed risk levels acceptable for unrestricted future residential use. To address threats associated with future uses more restrictive than industrial, land use controls (LUCs) will be instituted as part of any alternative that leaves waste in place or where source area-related contamination remains after active remediation at levels that preclude unrestricted use and unlimited exposure. The purpose of the LUCs will be to prevent exposure to future receptors that could result in unacceptable risk to them. The LUC program for the BGOU is discussed in Section 2.4.1.1.

The preliminary RGs are media-specific goals that serve as the basis for identifying and screening the treatment processes or mass removal and containment efficiencies required for the alternatives developed in Section 3. RGs for chemicals that have the potential to impact RGA groundwater are derived differently than those to protect workers from exposure to contaminants in soil. An overview of the RG development process is shown in Figure 2.2.

The COCs identified in the BHHRA are the constituents for which RGs are to be potentially developed. Evaluation of potential alternatives to meet the RAOs and corresponding development of soil RGs protective for future workers or groundwater have the following additional considerations.

- RGs will not be developed for COCs that are at/below background concentrations.

- The direct contact COCs for the future industrial and outdoor worker were identified in the WAG 3 Investigation (DOE 2000b). For cases where updated toxicity information indicates the chemical would not be a COC using current assumptions, no RG would be required for that chemical for the remedy to be protective and meet the RAO.

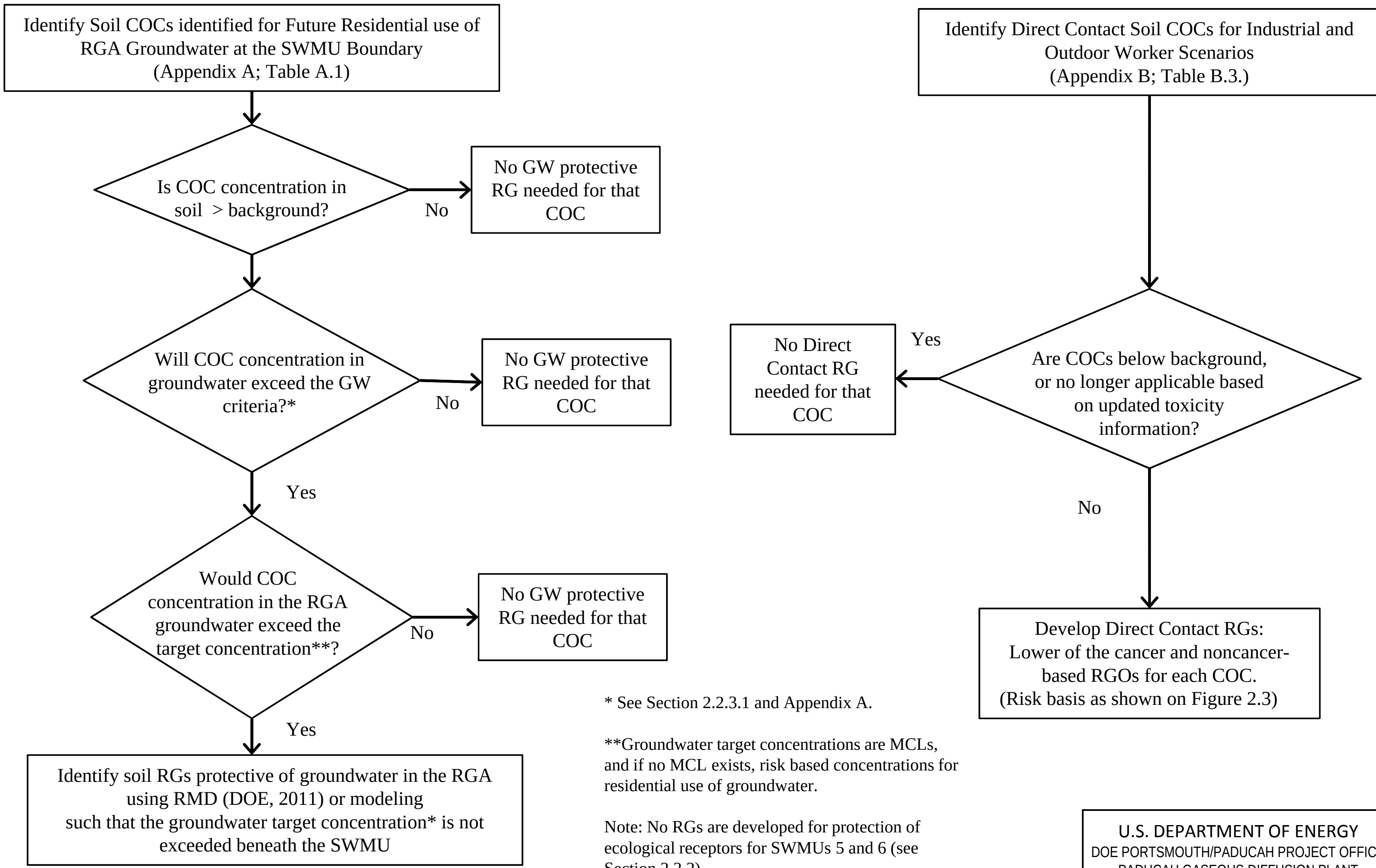
- The BHHRA identified risks to the outdoor worker based on contact with contaminants in surface and subsurface soils (0–16 ft). Consistent with the RAO, the risk-based RG for direct contact with surface soil are the lesser of those developed for the future industrial worker and outdoor worker scenarios. If the risk-based RG for direct contact with the COC in surface soil is less than surface soil background, then the final RG for surface soil would be background. For subsurface soils, the risk-based RG for direct contact with subsurface soil is that developed for the outdoor worker scenario. Again, if the risk-based RG for direct contact with the COC in subsurface soil is less than subsurface soil background, then the final RG for subsurface soil would be background.

- Chemicals identified as COCs for the future workers that are present only in the drainageways are beyond the bounds of SWMUs 5 and 6 and are not a result of releases from the waste units. As such, they are not addressed by this FS and will be considered by the Surface Water OU.

The RG derivation as well as the technologies/alternatives to address the potential risks from exposure pathways are considered independently in this FS; however, the final remedy will address both pathways to meet the RAOs. Figure 2.3 highlights the potentially applicable RGs and the implications for evaluating the depth to which these apply.

Section 2.2.3.1 provides a summary of the derivation of RGs for protection of groundwater, which is presented in greater detail in Appendix A. Section 2.2.3.2 summarizes the RGs for protection of workers from direct contact exposures, which are discussed in detail in Appendix B. The primary risk associated with direct contact is associated with direct contact with buried wastes.

Alternatives must meet the RAOs for Direct Contact and Protection of Groundwater



* See Section 2.2.3.1 and Appendix A.

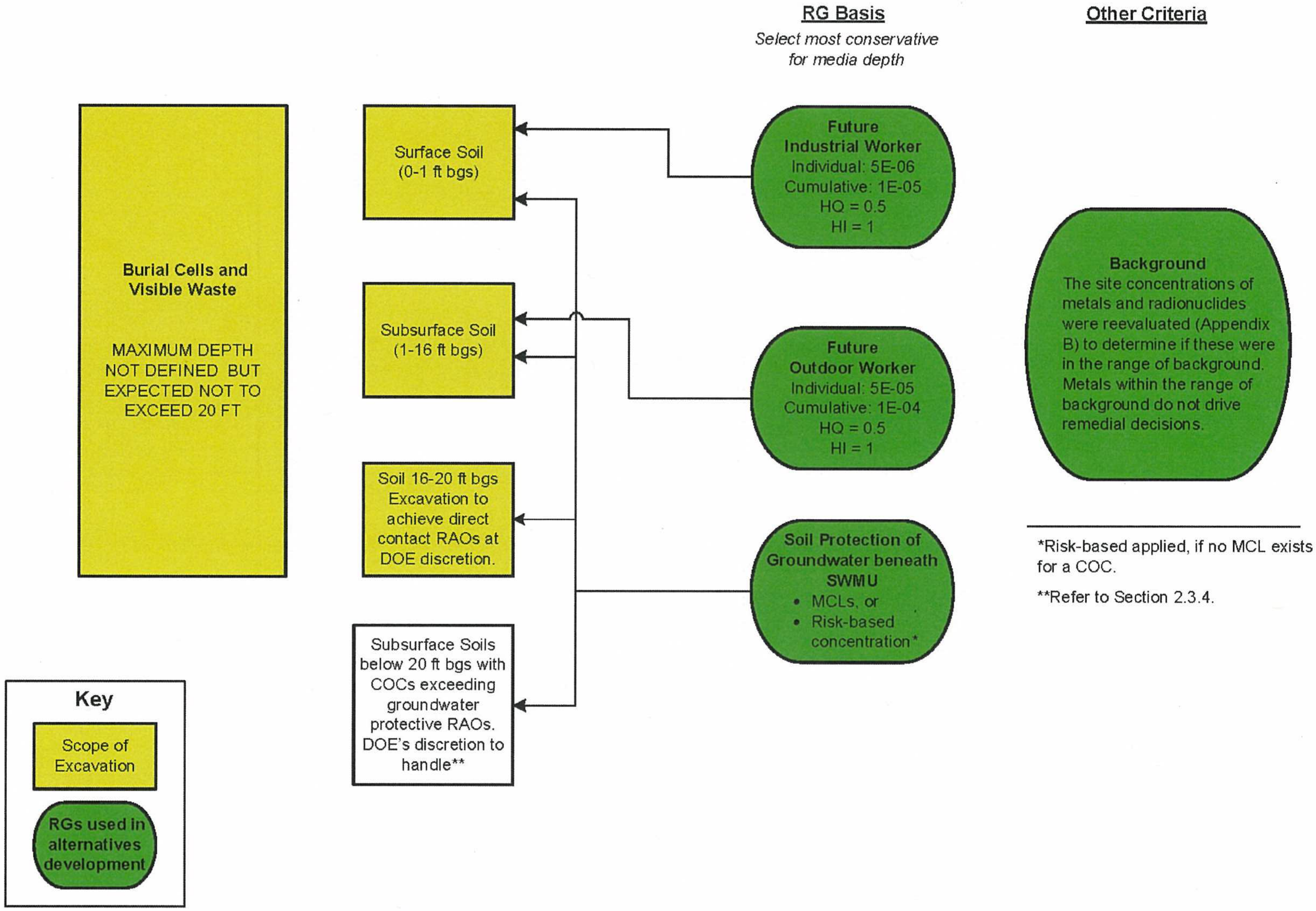
**Groundwater target concentrations are MCLs, and if no MCL exists, risk based concentrations for residential use of groundwater.

Note: No RGs are developed for protection of ecological receptors for SWMUs 5 and 6 (see Section 2.2.2).

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

Figure 2.2. RG Development

LATA Environmental Services of Kentucky, LLC



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

Figure 2.3. BGOU Excavation Extent and Applicable RGs

LATA Environmental Services of Kentucky, LLC

The approach for establishing preliminary soil RGs that are protective of the groundwater exposure pathway was to assume that the COC might leach from either surface or subsurface soil and reach the RGA groundwater beneath the SWMU in concentrations that might exceed the MCL established by the Safe Drinking Water Act. The preliminary RGs were developed to be protective of the RGA directly beneath each SWMU through a comparison to drinking water standards (MCLs).

2.2.3.1 Soil RGs for groundwater protection

The BHHRA identified COCs for use of RGA groundwater based on risks for modeled concentrations in the RGA at the SWMU boundary (see Table 1.4). These COCs were reviewed consistent with the process identified on Figure 2.2 to determine which of these COCs requires development of an RG to be protective of groundwater at SWMUs 5 and 6. The evaluation of these data is detailed in Appendix A.

Establishing soil RGs protective of the groundwater exposure pathway assumes that the COC might leach from either surface or subsurface soil and reach the RGA groundwater beneath the SWMU in concentrations that might exceed the MCL established by the Safe Drinking Water Act or risk-based concentrations for COCs that do not have a MCL.

In SWMU 6, no soil COCs were identified for protection of groundwater. Although manganese was modeled, no unacceptable noncancer hazard for potable use of RGA groundwater was identified (HI ≤ 1 as summarized on Table B.2).

Following the review of the data for SWMU 5, it was determined that there are no soil COCs to be addressed in this FS for protection of RGA groundwater (See Appendix A, Section 5, for more detailed discussion). These results are highlighted below.

- Arsenic and manganese are at background concentrations. In addition, for arsenic, the MCL was not exceeded in RGA groundwater.

- Tc-99 was identified as contributing to an unacceptable ELCR; however, modeled concentrations in the RGA were below the MCLs, the soil screening levels for protection of RGA groundwater (DOE 2011b, Table A.11) were not exceeded, and subsurface soil concentrations are below background.

- For noncancer hazards, uranium was identified as a primary COC; however, no releases to soils were identified (all subsurface soil results are below background), concentrations are below screening levels protective of RGA groundwater at the MCL of 0.03 mg/L, and because of limited mobility, no loading to the RGA groundwater would be expected within the 1,000 year travel time.

- The naphthalene-modeled concentration contributed a limited amount to the noncancer hazard; however, review of modeling assumptions suggests this compound would attenuate and not exceed the groundwater criteria in the RGA groundwater. This is further supported by the fact that naphthalene was not detected in any subsurface soil samples and was not detected in RGA groundwater.

The more detailed evaluation of these as discussed in Appendix B confirms that no releases of chemicals from SWMUs 5 or 6 are identified. No RGs need to be developed to meet the SWMU-specific RAOs for protection of RGA groundwater.

2.2.3.2 RGs for direct exposure to COCs in soil

The BGOU BHHRA identified several COCs for protection of future industrial or outdoor workers as summarized in Section 1.3.6. To meet the SWMU-specific RAO for direct contact, the cumulative risk and hazard target criteria for future industrial worker direct contact to surface soil is to be below E-05 (ELCR) and 1 (HI) and for subsurface soil (1–16 ft bgs) below E-04 (ELCR) and 1 (HI) for the outdoor worker. These targets are within EPA's generally accepted risk range.

The HI for the future industrial worker was less than 1 at both SWMUs 5 and 6; therefore, there are no COCs to be addressed in surface soils to meet the SWMU-specific RAO for noncancer hazard. The only noncancer hazards were identified for the outdoor worker, with the estimated HIs reported in the BHHRA less than 3. The SWMU-specific RAO protective of the outdoor worker requires the HI be less than 1 for subsurface soils (1–16 ft bgs). The BHHRA HI was relatively low, and most of the metals identified as COCs in the BHHRA were below background. Using current background and toxicity values, none of the subsurface soil samples at SWMUs 5 and 6 pose a noncancer hazard; that is, each subsurface soil sample had a hazard index (HI) less than 1. Since subsurface soils do not pose an unacceptable hazard to the outdoor worker, the SWMU-specific RAO is met, and no RGs need to be developed for this receptor and endpoint.

For carcinogenic COCs in subsurface soils, the cumulative ELCR must be less than 1E-4 for the outdoor worker. As summarized below, there are no COCs to be addressed in this FS to meet the SWMU-specific RAO for carcinogenic COCs in subsurface soils.

Arsenic, Total PAHs and PCBs were carcinogens identified as contributing to the ELCR in SWMU 5 for the outdoor worker.[3] Arsenic was below background concentrations in all subsurface soil samples, and PAHs or PCBs were not detected in any subsurface soils.

Total PAHs were carcinogens identified as contributing to the ELCR in SWMU 6. PAHs were not detected in any subsurface soil samples.

For carcinogenic COCs in surface soils, the cumulative ELCR must be less than 1E-5 for the future industrial worker. Total PAHs were carcinogenic COCs identified as contributing to the ELCR at both SWMUs 5 and 6. In SWMU 5, arsenic also was identified as contributing to the ELCR, but is at background concentrations. It exceeded the background concentration of 12 mg/kg in only one sample, with a concentration of 12.2 mg/kg. This was in a drainageway sample not associated with the waste disposal areas.

Total PAHs were found only in surface soils/sediments in drainageways adjacent to the SWMUs and the impact at these locations is being addressed within the Surface Water OU. More importantly, the data indicate that the waste units are not the source of these impacts, and no complete migration pathway from the source areas to these drainageways was identified. The conceptual model for the BGOU is that contaminants released from the waste to infiltrating water will exit from the bottom of the burial cells and migrate vertically downward through the UCRS and into the RGA. The potential for lateral migration through the UCRS was investigated in 2011 (Johnstone 2011). No seeps and no evidence of lateral migration were observed in ditches adjacent to SWMUs 5 and 6 during observation made on April 27, 2011, after a 500-year rainfall event for the 60-day period leading up to the observation. In 1997, water observed at three points along the southern edge of the SWMU 5 waste cell cover material was reported to be the result of seeps (Mullins 1997). The reported seeps never again have been observed and there is little data and much uncertainty about the reported seeps. The distribution of PAH detects in surface soil

---

[3] Beryllium is not evaluated as a carcinogen in this FS.

samples and the location of elevated detects, as seen in Figure B.1 of Appendix B, provide no indication that the reported seeps have contributed to PAH contamination. In addition, PAHs were not detected in any subsurface soil samples beneath the waste units, suggesting these have not been released from these source areas.

The general RAO "Prevent exposure to waste and contaminated soils that present an unacceptable risk from direct contact" is addressed in this FS as follows:

- The SWMU-specific RAO for soils to be used in screening technologies and developing and evaluating remedial alternatives in this FS for soils are met; no RGs are required for evaluating impacts in soils.

- To meet the general RAO, impacts in drainageways are to be evaluated and addressed within the Surface Water OU, and COPCs identified in the SERA will be incorporated into the sitewide baseline ecological risk assessment.

2.2.3.3 Threats from direct contact with wastes and affected soils

The evaluation of subsurface soil data indicated very limited impact to these secondary media as result of releases from the waste; however, subsurface soil data are limited, leaving an uncertainty that must be managed.

SWMUs 5 and 6 waste has not been sampled, also leaving an uncertainty to be managed. 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 wastes contained in the five discrete burial areas within SWMU 6 are well understood and include magnesium scrap, exhaust hood blowers contaminated with perchloric acid (expected to be degraded; see Section 1.4.2.2), radio logically contaminated aluminum scrap, and a radiologically contaminated modine cold trap. Scoping for the BGOU RI/FS Work Plan determined that organic contaminants likely were not associated with the buried materials at either SWMU 5 or 6 (DOE 2006).

Based upon disposal records, SWMUs 5 and 6 contain industrial wastes, some of which are LLW. Industrial wastes in burial grounds at the PGDP are known to contain waste that could be contaminated with PCBs or RCRA hazardous wastes. Without more definitive waste characterization (i.e., sampling and analysis), it is not possible to state whether or not PCBs or RCRA hazardous wastes are also present at SWMUs 5 and 6. Based upon the waste inventory, the buried wastes at SWMUs 5 and 6 (including low-level radioactive waste) are considered low level threat waste consistent with EPA guidance.

While uncertain, but based on process knowledge, the waste disposed of at SWMUs 5 and 6 likely present a direct contact threat.

2.2.4 Basis for BGOU Technology Identification and Screening

The BGOU RI did not conduct intrusive sampling in the waste management units. As a result, specific waste characterization data are limited. Historical records and data, past observations, and waste disposal documentation referenced in the BGOU RI Report (DOE 2010b) were used to supplement the RI data to establish the basis for selecting remedial alternatives and preparing cost estimates for those alternatives. It also was necessary to make some assumptions regarding the nature, extent, and quantities of waste and waste-related contamination within the BGOU SWMUs that would require remediation. The FS will develop alternatives to address the potential threat from direct contact with wastes or affected soils at

SWMUs 5 and 6. Although there is little evidence of migration to groundwater or surface water of constituents at levels that could pose an unacceptable threat, monitoring will be employed for SWMUs where waste is left in place to confirm this evaluation.

2.3 GENERAL RESPONSE ACTIONS

GRAs describe those actions that will satisfy the RAOs. This section develops GRAs that may be implemented individually or in combination to meet the SWMUs 5 and 6 RAOs.

GRAs developed for SWMUs 5 and 6 FS include LUCs, surface controls, monitoring, containment, removal, treatment, and disposal.

Table 2.1 lists the GRAs, as well as the technology types and process options contained within each GRA. Identification was based on demonstrated process efficiencies, engineering judgment, and existing policies or procedures. Further discussion of technologies and process options for each GRA is found in Section 2.4.

2.3.1 Land Use Controls

LUCs for the CERCLA sites at the PGDP BGOU as described in Section 2.4.1.1 are needed only for those alternatives that leave waste in place at concentrations that would not allow for unrestricted use and unlimited exposure.

2.3.2 Surface Controls

Surface controls are those technologies, and associated process options with the primary purpose of providing a physical barrier that will prevent direct contact exposure to surface soil contamination. These technologies, soil covers, and associated process options provide a physical means of preventing direct contact with contaminated soils without inclusion of a low-permeable layer.

2.3.3 Monitoring

Monitoring for SWMUs 5 and 6 include both monitoring the progress of cleanup by determining the extent of contamination remaining and long-term monitoring for potential migration of wastes left in place. Monitoring alone does not meet the RAOs, but can be used in combination with other GRAs to form a remedial action.

There is no evidence of groundwater contamination from SWMUs 5 or 6; however, any alternatives that leave waste in place will incorporate monitoring to confirm that there is no unacceptable threat to groundwater or surface water from migration from SWMUs 5 and 6.

2.3.4 Monitored Natural Attenuation

Monitored natural attenuation (MNA) relies on natural processes to achieve site-specific remedial objectives. Processes may include physical, chemical, or biological processes that reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil and groundwater. Monitoring of contaminant concentrations and process-specific parameters to ensure protection of human health and the environment during implementation is a critical element of MNA.

Table 2.1. BGOU SWMUs 5 and 6 GRA Technology and Process Option Screening

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
Land Use Controls	Institutional controls/Physical Controls	E/PP program/warning signs	E/PP program requires review and approval of any proposed intrusive activities to protect workers and remedy integrity. Warning signs notify site workers of potential hazards and restrict access.	Available	Technically implementable. Retained for possible alternative development.
	Institutional Controls	Property Record Notice, CERCLA Section 120(h)	Property notice that waste left in place and survey plat of its location filed at McCracken County Clerk's office. CERCLA Section 120(h) is a covenant required for transfer of federally owned property notifying anyone that hazardous substance was stored or released and remedial actions are complete.	Available	Technically implementable. Retained for possible alternative development.
		Deed and/or lease restrictions	Deed and/or lease restrictions prohibiting residential development or agricultural development within the BGOU source area will be put in place contingent upon the property transfer.	Available	Technically implementable. Retained for possible alternative development.
Surface Controls	Surface Barriers	Soil cover	Monolayered cover used for surface soil contamination.	Commercially available	Technically implementable. Retained for possible alternative development.
Monitoring	Soil Monitoring	Conventional sample collection and analysis	Conventional collection and analysis of soil samples for physical/chemical parameters yields data that verify effectiveness of remedial action. Samples are usually collected with spade, trowel, scoop, hand auger, flight auger, trier, or split-spoon (shallow sample depths assumed so that no mechanized equipment is needed).	Commercially available	Technically implementable. This technology is screened from further evaluation as a primary technology, but its use is incidental to other GRAs such as removal.

Table 2.1. BGOU SWMUs 5 and 6 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
	Groundwater Monitoring	Monitoring well installation, sample collection and analysis	Groundwater samples can be obtained from wells completed in saturated zone using pumps, bailers, or passive samplers. Depending on the zone from which the sample is collected, analytical results can be utilized to monitor potential migration to the aquifer or to the surface. Analysis can be performed on-site using field instrumentation or off-site at fixed-base laboratories.	Commercially available	This technology is retained for possible alternative development. May also be used as a secondary technology to other GRAs such as containment or treatment.
	Surface Water Monitoring	Field inspections, water sample collection and analysis	Surface water samples can be obtained from seeps or surface water ditches and analysis can be performed on-site using field instrumentation or off-site at fixed-base laboratories.	Commercially available	This technology is retained for possible alternative development; also may be used as a secondary technology to other GRAs such as containment or treatment.
Monitored Natural Attenuation	Monitoring and natural processes	Soil and groundwater monitoring; abiotic and biological processes	Natural processes including dilution, diffusion, dispersion, sorption, biodegradation, combined with monitoring.	Commercially available	This GRA is screened from further evaluation because there are no additional steps that would be effective to enhance the natural processes.

Table 2.1. BGOU SWMUs 5 and 6 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
Removal	Excavators	Backhoes, trackhoes	Tracked excavators with 45-ft arms limited to approximately 30 ft bgs.	Commercially available	Technically implementable. Retained for possible alternative development.
		Vacuum excavation, remote excavator	Commercial vacuum excavators used for digging small exploratory holes to assess conditions, radioactive waste cleanup.	Commercially available	Technically implementable. Retained for possible alternative development.
		Crane and clamshell	Excavation at depths greater than 100 ft bgs possible.	Commercially available	Technically implementable. Retained for possible alternative development.
		Large diameter auger	Large diameter augers (~2–4) are used to remove soils from a vertical column. Borings can be cased to avoid sidewall collapse. Augers are capable of drilling to depths of 100 ft bgs.	Commercially available	This process option is screened from further evaluation at SWMUs 5 and 6 because the buried metallic waste could damage the auger or prevent advancement.
Containment	Hydraulic containment	N/A	Hydraulic containment involves implementing process options that either limit the potential for water to migrate through the waste or contaminated soil or limit the potential for contaminated water to enter the RGA without use of a barrier. Two common process options for this technology are recharge controls such as limiting storm water run-on and groundwater extraction.	Commercially available	Specific process options such as groundwater extraction are technically implementable, while others, such as recharge controls, are not implementable given site topography. Groundwater extraction is not applicable given lack of COCs requiring calculation of RGs at SWMUs 5 and 6. This technology is screened from further evaluation development.
	Capping	Subtitle C cover	Multilayered cover incorporating compacted clay and geosynthetics used for RCRA hazardous waste landfill closures.	Commercially available	Technically implementable. Retained for possible alternative development.

Table 2.1. BGOU SWMUs 5 and 6 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
Containment (Continued)	Capping (Continued)	Subtitle D cover	Multilayered cover used for RCRA nonhazardous waste landfill closures. This process option complies with KDEP requirement that are more stringent than the EPA's subtitle D landfill cover requirements.	Commercially available	Technically implementable. Retained for possible alternative development.
		Evapotranspiration cover	Soil cover system using one or more vegetated soil layers to retain water until it is either transpired through vegetation or evaporated from the soil surface.	Commercially available	Process option not technically implementable as a stand-alone installation due to local climate conditions, but could be combined with other technologies. Retained for possible alternative development.
		Concrete-based cover	Concrete cover systems may consist of a single layer of concrete pavement over a prepared subgrade to isolate contaminated soils, reduce infiltration, and provide a trafficable surface.	Commercially available	Technically implementable. Retained for possible alternative development.
		Conventional asphalt cover	Asphalt cover systems may consist of a single layer of bituminous pavement over a prepared subgrade to isolate contaminated soils, reduce infiltration, and provide a trafficable surface. Must be sealed and/or combined with a low-permeability membrane to reduce permeability effectively.	Commercially available	Technically implementable. Retained for possible alternative development.
		MatCon™ asphalt	MatCon™ asphalt has been used for RCRA Subtitle C-equivalent closures of landfills and soil contamination sites. MatCon™ is produced using a mixture of a proprietary binder and a specified aggregate in a conventional hot-mix asphalt plant.	Commercially available	Technically implementable. Retained for possible alternative development.

Table 2.1. BGOU SWMUs 5 and 6 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
Containment (Continued)	Subsurface horizontal barriers	Flexible membrane	Single layers of relatively impermeable polymeric plastic (HDPE and others) laid out in rolls or panels and welded together. The resulting membrane cover essentially is impermeable to transmission of water unless breached. Flexible membranes can be sealed around surface infrastructure using waterproof sealants. Must be combined with protective soil layers.	Commercially available	Technically implementable. Retained for possible alternative development.
		N/A	Subsurface horizontal barriers potentially may limit downward migration of contaminants in infiltrating water by formation of a physical barrier to flow. Subsurface vertical barrier technologies can be used to isolate areas of soil contamination and to restrict groundwater flow into the contaminated area or underlying zones. Process option examples within this technology include freeze walls, jet grouting, and permeation grouting.	Commercially available	Technically implementable. Retained for possible alternative development.
		Freeze walls	Constructed by artificially freezing the soil pore water, resulting in decreased permeability and formation of a low-permeability barrier. The frozen soil remains relatively impermeable and migration of contaminants is thereby reduced. A horizontal barrier would be constructed by installing freeze pipes through wells drilled at a 45 degree angle along the sides of an area to be contained.	Commercially available	Technically implementable, but less practical as a permanent barrier. Eliminated from alternative development.

Table 2.1. BGOU SWMUs 5 and 6 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
Containment (Continued)	Subsurface horizontal barriers (Continued)	Jet grouting	Grouts are injected through drill rods to reduce infiltration of water. The jetted grout mixes with the soil to form a column or panel.	Commercially available	The effectiveness of jet grouting as a vertical barrier remains uncertain with no means to verify *in situ* results. Eliminated from possible alternative development.
		Permeation grouting	Low-viscosity grout is injected vertically or directionally into soil at multiple locations. Establishing and verifying a continuous, effective subsurface barrier is difficult or impossible in heterogeneous and/or low-permeability soils or in the presence of subsurface infrastructure.	Commercially available	Uncertain effectiveness. Retained for possible alternative development.
	Subsurface Vertical Barriers	Freeze walls	Constructed by artificially freezing the soil pore water, resulting in decreased permeability and formation of a low-permeability barrier. The frozen soil remains relatively impermeable and migration of contaminants is thereby reduced.	Commercially available	Technically implementable, but typically used to construct a temporary vertical hydraulic barrier during construction projects. Technology less practical as a permanent barrier. Retained for possible alternative development.
		Slurry walls	Vertically excavated trenches that are kept open are backfilled with a slurry, generally bentonite and water. Soil (often excavated material) then is mixed with bentonite and water to create a low-permeability soil-bentonite backfill.	Commercially available	Technically implementable. Retained for possible alternative development.

Table 2.1. BGOU SWMUs 5 and 6 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
Containment (Continued)	Subsurface Vertical Barriers (Continued)	Sheet pilings	Long (e.g., 60 ft) structural steel sections with a vertical interlocking system that are driven into the ground to create a continuous subsurface wall. After the sheet piles have been driven to the required depth, they are cut off at the surface. The subsurface soils must be relatively homogenous (i.e., no boulders) to allow for a uniform installation.	Commercially available	Technically implementable. Retained for possible alternative development.
		Jet grouting	This system breaks up the soil structure completely and performs deep soil mixing to create a homogeneous soil, which, in turn, solidifies. The jet grouting technique can be used regardless of soil, permeability, or grain size distribution. It is possible to apply jet grouting to most soils, from soft clays and silts to sands and gravels. Although it is possible to inject any binder, water-cement-bentonite mixtures typically are used when an impermeable vertical barrier is to be created.	Commercially available	Technically implementable. Retained for possible alternative development.
Treatment	Biological	*In Situ* Process Options—Enhanced biodegradation and phytoremediation *Ex Situ* Process Options—Bioreactors and constructed wetlands	Bioremediation techniques are destruction techniques directed toward stimulating the microorganisms to grow and use the contaminants as a food and energy source by creating a favorable environment for the microorganisms.	Commercially available	There are no COCs requiring RGs that are amenable to this technology. This technology also does not mitigate risk from contact with buried waste. This technology type is screened from further consideration.

Table 2.1. BGOU SWMUs 5 and 6 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
Treatment (Continued)	Physical/chemical	Soil Vapor Extraction—*In Situ*	Removal of unsaturated zone air and vapor by applying vacuum.	Commercially available	There are no COCs requiring RGs that are amenable to this process option. This process option also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.
		Dual-phase Extraction—*In Situ*	Enhancement of SVE that includes extraction of groundwater and soil vapor.	Commercially available	There are no COCs requiring RGs that are amenable to this process option. This process option also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.
		Air Sparging—*In Situ*	Promotes volatilization of VOCs in saturated zone by injecting air. Can be combined with SVE. Can be used in conjunction with actions that lower water table such as ERH.	Commercially available	There are no COCs requiring RGs that are amenable to this process option. This process option also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.
		Soil Flushing—*In Situ*	Promotes dissolution or desorption of VOCs in soil, may mobilize NAPLs by reducing interfacial tension. Can be applied *in situ* or *ex situ*.	Commercially available	There are no COCs requiring RGs that are amenable to this process option. This process option also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.

Table 2.1. BGOU SWMUs 5 and 6 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
Treatment (Continued)	Physical/chemical (Continued)	Electrokinetics—*In Situ*	Applied *in situ* as Lasagna™ process.	Commercially available	There are no COCs requiring RGs that are amenable to this process option. This process option also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.
		Soil Fracturing—*In Situ*	Highly pressurized gas (nitrogen or air) is injected into soil via borings to extend existing fractures and create a secondary network of subsurface channels. Hydraulic fracturing (hydrofracturing) uses water or slurry instead of gas. Soil fracturing can extend the range of treatment when combined with other technologies such as bioremediation, chemical oxidation/reduction, or soil vapor extraction. Potential adjunct technology for some *in situ* treatment, containment, or removal technologies.	Commercially available	There are no COCs requiring RGs that are amenable to this process option. This process option also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.
		Liquid Atomized Injection—*In Situ*	A proprietary delivery mechanism that injects a reagent into the subsurface in an aerosolized state. Pneumatically fractures low permeability formations.	Commercially available	There are no COCs requiring RGs that are amenable to this process option. This process option also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.

Table 2.1. BGOU SWMUs 5 and 6 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
Treatment (Continued)	Physical/chemical (Continued)	Permeable Reactive Barrier—*In Situ*	PRBs are designed and constructed to permit the passage of water while immobilizing or destroying contaminants through the use of various reactive agents. PRBs may be constructed to depths of 60 ft bgs, but complexity and cost increase with depth.	Commercially available	There are no COCs requiring RGs that are amenable to this process option. This process option also does not mitigate risk from contact with buried waste. Also, this process option is not technically implementable because hydraulic gradients in the UCRS primarily are downward and the construction depths required in the RGA exceed the current practical limit of the technology. This process option is screened from further consideration.
		Air Stripping—*Ex Situ*	Applied *ex situ* for secondary waste treatment.	Commercially available	There are no COCs requiring RGs that are amenable to this process option. This process option also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.
		Ion exchange—*Ex Situ*	Treatment technologies may destroy, immobilize, or render contaminants less toxic. Treatment technologies may be implemented *in situ*, *ex situ*, or both. Ion exchange removes ions from the aqueous phase by exchanging cations or anions between contaminants and the exchange media. Media are typically resins made from synthetic organic materials, inorganic materials, or natural polymeric materials.	Commercially available	There are no COCs requiring RGs that are amenable to this process option. This process option also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.

Table 2.1. BGOU SWMUs 5 and 6 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
Treatment (Continued)	Physical/chemical (Continued)	Granular activated carbon (GAC)	GAC is used for VOC removal from aqueous streams. Dissolved contaminants are removed by adsorption onto activated carbon grains.	Commercially available	There are no COCs requiring RGs that are amenable to this process option. This process option also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.
		Vapor Condensation	Applied *ex situ* for secondary waste off-gas treatment.	Commercially available	There are no COCs requiring RGs that are amenable to this process option. This process option also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.
		Deep Soil Mixing—*In Situ*	Potential adjunct technology for some *in situ* treatment, containment, or removal technologies.	Commercially available	There are no COCs requiring RGs that are amenable to this process option. This process option also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.
		Cement and Grouting—*In Situ*	Stabilization/solidification agents are injected at high pressure through conventional boreholes to form a grouted mass.	Commercially available	Technically implementable. Retained for possible alternative development.
		Jet Grouting—*In Situ*	Stabilization/solidification agents are injected at high pressure through a rotating stylus as the stylus is moved vertically through the soil. The high pressure injectant mixes with the surrounding soil matrix to form a solid vertical column.	Commercially available	Technically implementable. Retained for possible alternative development.

Table 2.1. BGOU SWMUs 5 and 6 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
Treatment (Continued)	Thermal	Electrical Resistance Heating—*In Situ*	Saturated or unsaturated soils are heated by applying current in subsurface, resulting in *in situ* steam stripping. VOCs and steam are recovered by dual phase extraction wells and treated. Can be implemented as three-phase or six-phase heating.	Commercially available	There are no COCs requiring RGs that are amenable to this process option. This process option also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.
		Thermal Conduction Heating—*In Situ*	Saturated or unsaturated soils are heated via thermal conduction by placing heating elements in wells. VOCs and steam are recovered by dual phase extraction wells and treated.	Commercially available	There are no COCs requiring RGs that are amenable to this process option. This process option also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.
		Catalytic Oxidation—*Ex Situ*	Applied *ex situ* for secondary vapor treatment.	Commercially available	There are no COCs requiring RGs that are amenable to this process option. This process option also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.
		Thermal Desorption—*Ex Situ*	Soils are heated to volatilize VOCs, which then are treated. Applied *ex situ* for excavated waste treatment.	Commercially available	There are no COCs requiring RGs that are amenable to this process option. This process option also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.

Table 2.1. BGOU SWMUs 5 and 6 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
Treatment (Continued)	Thermal (Continued)	Vitrification	Extremely high heat is used either *in situ* or *ex situ* to melt and glassify the contaminated media.	Limited Commercial availability	Vitrification would reduce the uncertainties associated with SWMUs 5 and 6 as it would reduce potential contaminant mobility and direct contact with waste.
	Chemical	Permanganate Fenton's reagent ZVI Ozonation Persulfate Redox manipulation Surfactant-enhanced *in situ* chemical oxidation (ISCO)	*In situ* chemical oxidation processes involve injection of chemical compounds to oxidize organic contaminants in the subsurface.	Commercially available	There are no COCs requiring RGs that are amenable to this technology type. This technology type also does not mitigate risk from contact with buried waste. This technology is screened from further consideration.
Disposal	Land disposal	Off-site permitted disposal facility	Shallow land burial site for LLW, MLLW, and HW disposal option.	Commercially available	Technically implementable. Retained for possible alternative development.
		Potential on-site disposal unit	Planned radioactive and mixed waste on-site disposal unit.	Under consideration	Technically implementable. Retained for possible alternative development.
		PGDP C-746-U Landfill	Existing on-site nonhazardous nonradioactive waste landfill.	Available	Technically implementable. Retained for possible alternative development.
	Discharge of wastewater	Wastewater treatment demonstrating compliance with ARARS	Allowed under CERCLA after treatment.	Available	Technically implementable. Retained for possible alternative development.

Gray shading indicates the technology was screened out as not applicable or not technically implementable.
ARAR = applicable or relevant and appropriate requirement; BGOU = Burial Grounds Operable Unit; bgs = below ground surface; E/PP = excavation/penetration permit; CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act; COC = contaminant of concern; GRA = general response action; HDPE = high density polyethylene; HW = hazardous waste; LLW = low-level waste; MLLW = mixed low-level waste; N/A = not applicable; NAPLs = nonaqueous-phase liquids; PGDP = Paducah Gaseous Diffusion Plant; PRB = permeable reactive barriers; RCRA = Resource Conservation and Recovery Act; SWMU = solid waste management unit; UCRS = Upper Continental Recharge System; VOC = volatile organic compound

EPA technical brief, "Depleted Uranium" states that, "...the use of monitored natural attenuation (MNA) may be applied as an optional process, which should be evaluated with other applicable remedies (including innovative technologies) for restoring contaminated groundwater, preventing migration of contaminant plumes, and protecting groundwater and other environmental resources" (EPA 2006a).

As the waste disposal records show that SWMUs 5 and 6 contain uranium contaminated scrap, MNA may contribute to meeting RAOs at SWMUs 5 and 6.

2.3.5 Removal

The removal GRA involves removal of all or some buried waste and soils in close proximity to the waste. Removal would generate secondary wastes potentially requiring *ex situ* treatment and disposal or discharge. Removal can meet RAOs. An excavation alternative would be conducted to the visible limits of buried wastes (assumed to be 16 ft bgs). Additional soil may be removed if the confirmation sampling at the margins of the excavation indicates residual contamination present above RGs. or deeper if visible contamination continues to be observed. For cost estimating purposes, the excavation depth was assumed to be 20 ft bgs. If COCs are still present above their cleanup levels below 20 ft bgs, DOE would evaluate whether additional excavation would be warranted and would consult regulatory agencies. However, the decision about whether to conduct additional excavation below 20 ft will remain at DOE's discretion, as presented in Figure 2.3.

Additional excavation may be performed in pursuit of source contaminants exposed directly to area soils and/or groundwater based on the added environmental benefits of the continued action. In this instance, additional discussion of such discretionary expansion of proposed remedial action boundaries would be undertaken with the regulators.

2.3.6 Containment

Containment isolates contaminated media from release mechanisms, transport pathways, and exposure routes using surface and/or subsurface barriers, thereby reducing contaminant flux and reducing or eliminating exposures to receptors. Containment can meet RAO 2. While it cannot directly meet RAO 1, because there are no COCs that merit calculation of RGs, it can help mitigate the uncertainties identified in Section 1.4.1.

2.3.7 Treatment

Treatment reduces the toxicity, mobility, or volume of contaminants or contaminated media. Contaminant sources may be reduced or eliminated, and contaminant migration pathways and exposure routes may be eliminated. *In situ* methods treat contaminants and media in place without removal. *Ex situ* methods treat contaminants or media after removal. Treatment may contribute to meeting RAO 2. For example, groundwater or contact water may require treatment prior to discharge.

2.3.8 Disposal

Disposal may include land disposal of solid wastes or discharge of liquid or vapor phase effluents generated during waste treatment processes. Waste disposal for solids may include use of permitted commercial off-site disposal facilities, off-site DOE disposal facilities, or on-site facilities as available. These facilities may have regulated waste acceptance criteria (WAC). Disposal can meet General RAOs 1 and 2 if combined with removal.

2.4 IDENTIFICATION AND SCREENING OF TECHNOLOGY TYPES AND PROCESS OPTIONS

This section identifies remedial technologies and process options for the GRAs that potentially meet the RAOs. The technologies and associated process options are described in Section 2.4.1, as are their potential technical implementability. Evaluated technologies and process options that cannot be effectively implemented are screened and eliminated from further consideration. In Section 2.4.2, the retained process option's effectiveness is evaluated. Finally, RPOs that will be used to develop the remedial alternatives are identified in Section 2.4.3.

2.4.1 Identification and Screening of Technologies and RPOs

The technology types and process options for each GRA are discussed in the following subsections 2.4.1.1 through 2.4.1.7. Table 2.2 summarizes the narrative discussion that follows.

In this FS, technologies and process options are evaluated in the context that there are no COCs at either SWMU that require the calculation of an RG; however, technologies and process options are evaluated as to how they may address the identified uncertainties at both SWMUs. For example, there are no RGs that would drive removal of the waste, but removal would mitigate the uncertainties. Generally, technologies and process options are retained that are implementable to mitigate the uncertainties associated with a broad range of COCs. Those technologies and process options that focus on specific categories of COCs, such as soil vapor extraction, are not retained.

Additionally, certain technologies or process options may not be implemented effectively as a primary remedial action and one would expect that they would be screened from further evaluation. Some technologies and process options are retained as a temporary, complementary action subordinate to another action and are retained. For example, freezing is not effectively implementable as a long-term action, but it is further evaluation as a means to stabilize an excavation sidewall.

LUCs will be implemented at BGOU SWMUs where waste is left in place or source area-related contamination remains after active remediation that precludes unrestricted use and unlimited exposure. In such cases, DOE will implement and maintain a LUC program that is protective based on current reasonably anticipated future land use as described in the following subsections. LUCs will include institutional controls such as property record notices, the excavation/penetration permit (E/PP) Program, and physical controls (warning signs). Upon transfer of the property, DOE will comply with Section 120(h) of CERCLA and will implement deed restrictions as described in Section 2.4.1.1.

The LUC implementation actions, including inspections, monitoring, and continued maintenance, will be provided in a Land Use Control Implementation Plan (LUCIP) that will be prepared by DOE and submitted as a component of the remedial design.

In addition to LUCs selected and implemented as part of the BGOU remedy selection process, other existing DOE plant controls currently are on-going and are discussed further in Section 1.3.1.6. Accordingly, PGDP is a federal facility with restricted access by the general public. Physical access to PGDP is prohibited by security fencing, and armed guards patrol the DOE property 24 hours per day to restrict worker entry and prevent uncontrolled access by the public/site visitors. These existing access controls are being maintained outside of the requirements of CERCLA due to the nature and security needs of the facility; nonetheless, the existing controls serve to protect against unacceptable/uncontrolled exposures.

Table 2.2. Evaluation of SWMUs 5 and 6 Technologies and Process Options

General Response Action	Technology Type	Process Option	Effectiveness			Implementability		Relative Cost	
			Long-term Effectiveness	Short-term Effectiveness	Demonstrated Effectiveness and Reliability	Technical	Administrative	Capital	O&M
Land use controls	Institutional controls	E/PP program	Moderate—Only effective for duration of plant operations	High—effective at preventing worker exposure	High—already implemented	High—already implemented	High—already implemented	Low	Low
		Property record notice	Moderate—relies on continued future implementation	High—effective for preventing groundwater and property use	High to moderate	High	High	Low	Low
		CERCLA § 120(h)	Moderate—relies on continued future implement-ation	High—effective for preventing groundwater and property use	High to moderate	High	High	Low	Low
		Deed and/or lease restrictions	Moderate—relies on continued future implement-ation	High—effective for preventing groundwater and property use	High to moderate	High	High	Low	Low
	Physical controls	Warning signs	Moderate—prevent and controls access; does not reduce contaminant levels	High—effective at preventing worker exposure	High—already implemented; requires inspections and maintenance	High—already implemented	High—already implemented	Low	Low

Table 2.2. Evaluation of SWMUs 5 and 6 Technologies and Process Options (Continued)

General Response Action	Technology Type	Process Option	Effectiveness			Implementability		Relative Cost	
			Long-term Effectiveness	Short-term Effectiveness	Demonstrated Effectiveness and Reliability	Technical	Administrative	Capital	O&M
Surface Controls	Surface Barriers	Soil cover	Moderate	High	Moderate—Can be subject to erosion or rutting if not maintained.	High	High	Moderate	Moderate
Monitoring	Groundwater monitoring	Monitoring well installation, sample collection and analysis	High—sampling an continue many years	High—can be installed quickly	High	High	High	Moderate	Low
	Surface Water Monitoring	Field inspections, water sample collection and analysis	High—sampling can continue many years	High— no installation required	High	High	High	Low	Low
Removal	Excavators	Backhoes, trackhoes	High—remove source to 15–20 ft bgs with conventional equipment. Deeper excavations possible, but with added complexity	Moderate—risks to workers in excavation	High	High	High	Low	Low

Table 2.2. Evaluation of SWMUs 5 and 6 Technologies and Process Options (Continued)

General Response Action	Technology Type	Process Option	Effectiveness			Implementability		Relative Cost	
			Long-term Effectiveness	Short-term Effectiveness	Demonstrated Effectiveness and Reliability	Technical	Administrative	Capital	O&M
Removal (Continued)	Excavators (Continued)	Vacuum excavation, remote excavator	High—remove source to 9.14 to 12.2 m (30–40 ft) bgs	Low—work may be hampered by metal debris or other large pieces.	Low—because of the scrap and metal debris found at these SWMUs	Low—because of the scrap and metal debris found at these SWMUs	High	Moderate	Moderate
		Crane and clamshell	High—remove source to > 30 m (100 ft) bgs	Moderate—more technically complex; hoisting and rigging concerns	High	Moderate	Moderate	High	High
Containment	Capping	Subtitle C cover	Moderate	High	High	Moderate	High	High—complex construction	Moderate—ongoing maintenance &monitoring required
		Subtitle D cover	Moderate	High	High	Moderate	High	High	Moderate
		Evapotranspiration Cover	Moderate	High	High	High	High	Moderate	Moderate
		Concrete-based cover	Low—prone to cracking	High	Low—prone to cracking	Moderate	High	High	High
		Conventional asphalt cover	Low—relatively permeable	High	Low—relatively permeable	High	High	Low	Moderate
		MatCon™ asphalt cover	Moderate	High	Moderate	Moderate—proprietary vendor technology	High	Moderate	Moderate

Table 2.2. Evaluation of SWMUs 5 and 6 Technologies and Process Options (Continued)

General Response Action	Technology Type	Process Option	Effectiveness			Implementability		Relative Cost	
			Long-term Effectiveness	Short-term Effectiveness	Demonstrated Effectiveness and Reliability	Technical	Administrative	Capital	O&M
		Flexible membrane	Moderate	High	Moderate–must be protected from damage	Moderate	High	Moderate	Moderate—ongoing maintenance and monitoring required
	Subsurface horizontal barriers	Permeation grouting	Low to moderate	Low to moderate	Low	Low—poor performance in heterogeneous and low conductivity soils	Low	High	Low
Containment (Continued)	Subsurface vertical barriers	Freeze walls	Low for permanent installation	High	Low—few long-term applications, but effectively used as a temporary measure in construction industry to stabilize excavation sidewalls	Low	High	High	High—energy and refrigerant costs
		Slurry walls	Potentially high	Low—intrusive and requires adequate space to implement	Moderate	Low	High	High	Moderate

Table 2.2. Evaluation of SWMUs 5 and 6 Technologies and Process Options (Continued)

General Response Action	Technology Type	Process Option	Effectiveness			Implementability		Relative Cost	
			Long-term Effectiveness	Short-term Effectiveness	Demonstrated Effectiveness and Reliability	Technical	Administrative	Capital	O&M
Containment (Continued)	Subsurface vertical barriers (Continued)	Sheet pile	High	Moderate to high—installation may contact waste depending upon placement	High	High	High	High	None
		Jet grouting	Potentially high	Moderate—installation may contact waste and generate some residuals for management	Moderate	Moderate	Low	High	Low
Treatment	Physical/ chemical	Cement and chemical grouting	High	High	Moderate	Moderate	High	Moderate	None
		Jet grouting	High	High	Moderate	Moderate	High	Moderate	None
	Thermal	Vitrification	High	High	Moderate	Moderate	Low	High	None
Disposal	Land disposal	Off-site permitted commercial disposal facility	High	Moderate—long-distance transportation required	High	High	High	High	None
		Potential on-site disposal unit	High	High	High	Moderate	Moderate	Low	None
		On-site C-746-U Landfill	High	High	High	High	High	Low	None—long-term monitoring & maintenance not paid by program
		Soils to excavation as backfill after treatment	High	Uncertain	High	High	High	Low	None

Table 2.2. Evaluation of SWMUs 5 and 6 Technologies and Process Options (Continued)

General Response Action	Technology Type	Process Option	Effectiveness			Implementability		Relative Cost	
			Long-term Effectiveness	Short-term Effectiveness	Demonstrated Effectiveness and Reliability	Technical	Administrative	Capital	O&M
	Discharge of wastewater	Wastewater treatment demonstrating compliance with ARARS	High	Moderate	High	High	Moderate	Moderate	Moderate—monitoring required

Gray shading indicates the technology was screened out during evaluation.
ARARs = applicable or relevant and appropriate requirements
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
E/PP = excavation/penetration permit
GAC = granular activated carbon
KY = Commonwealth of Kentucky
O&M = operation and maintenance

2.4.1.1 LUCs

LUCs are not remedial technologies, but will be evaluated along with technologies for purposes of the remedial alternative development.

The E/PP program is a LUC administered by DOE's contractors at PGDP. It currently includes a specific permitting procedure (PAD-ENG-0026 or equivalent) designed to provide a common sitewide system to identify and control potential personnel hazards related to trenching, excavation, and penetration greater than 6 inches into the surface of the earth, concrete, pavement or walls, floors, and ceilings of buildings. The E/PP permits are issued by the Paducah Site's DOE Prime Contractor. The primary objective of the E/PP procedure is to provide notice of existing underground utility lines and/or other structures to the organization requesting a permit and to ensure that any E/PP activity is conducted safely and in accordance with all environmental requirements pertinent to the area (DOE 2008).

The E/PP procedure does the following:

- Requires formal authorization (i.e., internal permits/approvals) before beginning any intrusive activities at PGDP;

- Is reviewed annually; and

- Is implemented by trained personnel knowledgeable in its requirements.

An initial draft of an E/PP is reviewed by project support groups to ensure that the latest updates in engineering drawings and utility drawings are considered prior to the issuance of an E/PP.

This technology is technically implementable; however, it is maintained outside of the CERCLA process. The substantive requirements of this program must be incorporated into any LUC program to ensure controls are maintained under future land uses.

Warning Signs. Warning signs are a physical control that will be placed at the source areas at the beginning of the remedial action to provide warning of potential contaminant exposure, will continue to be posted pending a final decision under the Comprehensive Site OU, or until such time as contaminant levels have been reduced that would allow for unrestricted use and unlimited exposure.

Property Record Notice. In the event contamination and/or waste is left in place that will preclude unrestricted use and unlimited exposure, a Property Record Notice (Notice) will be filed at the McCracken County Clerk's Office, in accordance with state and federal law, within 120 days of regulatory approval of the LUCIP and will remain in effect until DOE, KEEC, and EPA approve a request to modify or delete it. The Notice will include the purpose of the Notice, a brief summary of the main COCs and location of any waste remaining in-place, along with a description of the CERCLA remedial action and a DOE program contact. The Notice also will include a survey plat, accomplished by a registered land surveyor (under the direction and approval of a DOE official and consistent with applicable security requirements), that depicts the contamination and the area subject to LUCs. DOE will file both the Notice and survey plat in the register of deeds (e.g., Real Estate Office) of the McCracken County Clerk. The Notice also will inform the reader that, upon title transfer of the property, the deed will include applicable land use restrictions and information required by CERCLA Section 120(h)(3).

Deed and/or Lease Restriction. For alternatives with waste remaining in place, DOE will implement and maintain a LUC program that includes the use of deed and/or lease restrictions that prohibit residential development or agricultural development with the BGOU source area and will be put in place contingent upon the property transfer. A LUCIP will be developed during the remedial design process that provides the requirements for implementation, maintenance, monitoring, and enforcement of LUCs. The frequency of monitoring, sampling, inspection, etc., will be defined in the LUCIP.

CERCLA Section 120(h). In the event that DOE should enter into any contract for the sale or transfer of any of the site property, DOE will comply with the provisions found in CERCLA 120(h) and Section XLII of the PGDP FFA. Pursuant to Section 120(h) of CERCLA, each deed entered into for the transfer of real property is required to contain the following items to the extent such information is available:

- Notice of the type and quantities of hazardous substances;
- Notice of the time at which such storage, release, or disposal took place;
- Description of the remedial action taken, if any; and
- A covenant warranting that

  — All remedial actions necessary to protect human health and the environment with respect to any such substance remaining on the property has been taken before the date of such transfer, and

  — Any additional remedial action found to be necessary after the date of such transfer shall be conducted by the United States.

This technology is technically implementable and is retained for possible alternative development.

2.4.1.2 Surface controls technologies

Surface controls are those technologies, and associated process options with the primary purpose of providing a physical barrier that will prevent direct contact exposure to surface soil contamination. These technologies, soil covers, and associated process options provide a physical means of preventing direct contact with contaminated soils without inclusion of a low-permeable layer. A technology evaluated in this FS is surface barriers.

2.4.1.2.1 Surface barriers

Soil Cover— Soil covers are intended to prevent direct contact only and promote runoff, but not provide hydraulic containment. Both a 1-ft soil cover and a 2-ft soil cover (18 inches compacted local soil and 6 inches topsoil) were selected for inclusion as process options in this FS.

Both a 1-ft soil cover and a 2-ft soil cover will provide a physical barrier to existing surface soil, and enhance the existing cover already present, and serve to limit direct contact with contaminated soils. Soil covers, as described in this FS, will be designed and constructed in a manner that limits direct contact with contaminated soils to control the risk from direct contact exposure. Soil covers will be designed and installed to provide adequate site drainage, but are not constructed with a defined low-permeable layer. This type of cover potentially is effective, technically implementable, commercially available, and is retained for further consideration.

2.4.1.3 Monitoring technologies

Monitoring may be used in combination with other technologies to meet RAOs. Monitoring for the BGOU could include determination of soil and groundwater contaminant concentrations during remedial action as well as long-term groundwater monitoring. This technology is retained for further evaluation of process options.

2.4.1.3.1 Soil monitoring

Soil monitoring may be used before, during, and after remediation to determine extent and concentration of COCs. Conventional collection of soil samples for laboratory analysis for physical/chemical parameters yields data that may be used to support remedial design and verify effectiveness of remedial action.

This technology is screened from further evaluation as a primary technology; however, it is acknowledged that its use is incidental to removal responses.

2.4.1.3.2 Groundwater monitoring

Groundwater monitoring may be used in the UCRS and/or RGA saturated zones before, during, and after remediation to determine extent and concentrations of COCs. Conventional groundwater sampling consists of withdrawing a representative sample of groundwater from a well or drive point, using a variety of pump types or bailers, and analyzing the contents in a laboratory. Overall, groundwater monitoring is widely used for compliance monitoring and is effective, technically implementable, and commercially available. Monitoring of groundwater downgradient of the BGOU SWMUs is not a significant challenge; however, monitoring contribution of contaminants from individual SWMUs (which are adjacent to or contiguous) can be a challenge. Any monitoring systems selected would need to take into account comingled releases from adjacent units and upgradient sources. The design of any such unit would be addressed during remedial design.

This technology is retained for further evaluation; however, no process options beyond the conventional use of monitoring wells are evaluated.

Note that the ability to implement a successful groundwater monitoring program may depend on the design and installation of additional MWs at PGDP. MW needs would be addressed during the remedial design process for the selected remedial alternative. The need for additional monitoring wells is accounted for in the remedial alternative cost estimates.

2.4.1.3.3 Surface water monitoring

Surface water monitoring may be used during and after remediation to determine if COCs have migrated or are migrating along the surface water pathway. Conventional surface water grab sample methods, using standard sampling tools, can be used for collection of a representative sample for field or fixed-based laboratory analysis. Surface water monitoring is widely used for compliance monitoring and is effective, technically implementable, and commercially available. This technology is retained for further evaluation; however, no process options beyond conventional sampling are evaluated.

2.4.1.4 MNA/enhanced attenuation

Natural attenuation encompasses the naturally occurring soil and groundwater processes such as sorption, abiotic or biological degradation, and dilution, which immobilize, transform, or reduce concentrations of pollutants. Each natural attenuation process occurs under a range of conditions that must be extensively characterized and monitored over time to determine the effectiveness of the remedy. Although some natural attenuation processes may contribute to the protectiveness of the remedy, there are no additional steps that would be effective to enhance these natural processes. The sorption processes already have been estimated as part of the modeling of the impacts to groundwater. Thus, this technology is not technically implementable and is screened from further evaluation.

2.4.1.5 Removal technologies

Removal, in the context of this FS, means the excavation of source materials disposed in the BGOU, as well as UCRS soils containing COCs above RGs. The technical complexity of conventional excavation increases greatly with depths greater than about 20 ft (6 m) (Terzaghi et al. 1996), and several factors to be considered include slope stability, control of seepage, worker safety, management of excavated soil, shoring requirements, and potential for mobilization of COCs. Other removal methods could be considered in light of the potential impact of these factors.

This technology involves the use of commercially available heavy equipment to remove waste and contaminated soil. The selection of specific equipment is site specific and must consider items such as vertical and lateral extent of excavation, soil and groundwater conditions, specific hazards associated with the buried waste, site permit conditions, and potential interferences with existing utilities, infrastructure or buildings. When using conventional excavation equipment, deep excavations may require extensive terracing or elaborate shoring. Piping of groundwater and entry of heaving sands into the excavation can occur as excavation proceeds below the water table, and must also be considered. Several types of excavation equipment that potentially could be used at the BGOU SWMUs are discussed later in this section.

Excavation can have a large capital cost, but low operation and maintenance costs (O&M), and may have the largest probability of achieving over 99% COC removal at smaller sites with contamination restricted to the upper 12.2 m (40 ft) of the soil (AFCEE 2000). Overall, experience has shown that excavation works best and is most cost-competitive at sites where confining layers are shallow, soil permeabilities are low, the volume of source materials is less than 5,000 m^3 (176,600 ft^3), and the contaminants do not require complex treatment or disposal (NRC 2004).

Removal technologies are generally paired with other GRAs such as treatment or disposal to meet RAOs. In some cases, RAOs may be met by combining selective, or hot spot, excavation with disposal, treatment, or containment GRAs.

This technology is technically implementable at SWMUs 5 and 6, and is commercially available and is retained for further evaluation.

2.4.1.5.1 Backhoes, trackhoes, and front-end loaders

Conventional excavation equipment such as backhoes, trackhoes, front-end loaders, and skid steer loaders can do an effective job of removing contaminated soil and overburden. Practical considerations regarding equipment limitations and sidewall stability can restrict the depth of excavation to a maximum of about 20 ft in a single lift. Where source zone contamination lies at greater depth, excavation can require a series of progressively deeper lifts or terraces accessed by ramps. This technique can extend the maximum depth of excavation in unconsolidated soil to over 40 ft; however, the unit cost of soil excavation increases rapidly with increasing depth of excavation. Additionally, implementation of methods to control or prevent the movement of groundwater into the excavation may be required if source removal extends below the water table. These methods are expensive and can require placement of caissons or driven sheet piling and dewatering (AFCEE 2000).

This process option is technically implementable at SWMUs 5 and 6, and is commercially available and is retained for further evaluation.

2.4.1.5.2 Vacuum excavation

Vacuum excavation can be used to remove contaminated soil to depths of about 30 ft in congested areas where access, obstructions, and buried utilities prevent safe operation of conventional excavators. A combination of high-pressure air (or water) is used to break up the soil, while a high flow vacuum removes the soil and deposits it in the vacuum truck collector body. Vacuum trucks are commercially available with capacities up to 15 yd^3. Additionally, contaminated soil and sludge can be placed directly in vacuum roll-off boxes (20 or 25 yd^3) or bags for disposal without having to decontaminate the vacuum truck.

Effective excavation can be performed as far as 300 ft from the vacuum truck, allowing work inside buildings and in highly congested areas. The high flow vacuum eliminates the need for additional dust control measures typically required during conventional excavation activities. This technology would not be effective at handling debris; thus, it would not be suitable for some of the wastes disposed of at SWMUs 5 and 6, but it could be used to remove soil from around the debris to expose the debris for further inspection or removal by other means.

This process option is technically implementable at SWMUs 5 and 6, and is retained for further evaluation.

2.4.1.5.3 Cranes and clamshells

Cranes and clamshells are often are used in deep excavations (e.g., excavation of piers, dredging, and mining). Excavation to depths of over 100 ft is achievable. Deep excavations may require elaborate shoring to prevent sidewall collapse, otherwise a bentonite slurry or biopolymer is needed to fill the excavation.

This process option is technically implementable at SWMUs 5 and 6 and is commercially available and is retained for further evaluation.

2.4.1.5.4 Large diameter auger

Large diameter augers (LDAs) can be used to effectively remove contaminated soil using a drill rig equipped with a large diameter (3 ft–10 ft) solid stem auger. LDAs can be used either cased or uncased. Casing prevents water infiltration and prevents sidewalls from sloughing to the excavation. LDA borings can reach depths of 27.4 m (90 ft) depending on the lithology and drill rig. Following excavation, holes typically are filled with flowable fill material. Conventionally, LDAs are used for source removal where standard heavy equipment is not feasible (e.g., heavily industrialized sites and/or deep contamination). Densely located subsurface utilities potentially could impact the boring spacing, and, therefore, the removal efficiency of this technology. The effectiveness of this technology partially depends on the location and spacing of the borings. The boring overlap pattern can be designed to achieve 100% removal; however, due to the amount of fill material excavated by overlapping the borings, the cost of excavation increases with the percentage of boring overlap.

This process option is of questionable technical implementability. Large debris contained in SWMUs 5 and 6 could cause the auger flights to bind, could cause auger refusal, and could cause equipment damage; consequently, this process option is screened from further evaluation.

2.4.1.6 Containment technologies

Containment technologies can hydraulically isolate source areas, reduce infiltration, and minimize contaminant migration to the RGA. Containment technologies also can isolates contaminated media from release mechanisms, transport pathways, and exposure routes using surface and/or subsurface barriers, thereby reducing contaminant flux and reducing or eliminating exposures to receptors.

2.4.1.6.1 Hydraulic containment

Hydraulic containment involves implementing process options that either limit the potential for water to migrate through the waste or contaminated soil or limit the potential for contaminated water to enter the RGA using methods that do not include installation of a physical barrier. These methods include process options such as limiting or eliminating rainwater and process water run-on to a site. Hydraulic containment also includes groundwater extraction.

Because there are no sources of run-on to SWMUs 5 and 6 other than precipitation and because there are no COCs associated with migration to groundwater that merit calculation of above RGs at either SWMUs 5 or 6, hydraulic containment is not a practicable means to mitigate SWMU uncertainty. This technology is screened from further evaluation.

2.4.1.6.2 Capping

The capping technology contains those process options that are designed to both prevent direct contact and significantly reduce infiltration into buried wastes through either an impermeable layer (RCRA Subtitle C and D landfill final covers, concrete based covers, conventional asphalt covers, MatCon™ asphalt, and flexible membranes) or through soil mass and vegetation (evapotranspiration cover). Capping including RCRA Subtitle C and Kentucky Subtitle D landfill covers with the specified impermeable layer, will prevent infiltration of water into the buried waste.

Of the capping process options listed below, all are intended to and will be designed to reduce recharge of precipitation through the use of a low permeable layer, except the evapotranspirative cover and soil cover. The evapotranspirative cover will limit infiltration, but does so by relying on the capacity of the cover to retain moisture and then release it back to the environment through evapotranspiration.

This technology is implementable and is retained for further evaluation.

EPA (2008) identifies the following advantages and limitations of containment of source areas.

- Advantages of containment
  - It is a simple and robust technology.
  - Containment typically is inexpensive compared to treatment, especially for large source areas.
  - A well-constructed containment system almost completely eliminates contaminant transport to other areas and thus prevents both direct and indirect exposures.
  - In unconsolidated soils, containment systems substantially reduce mass flux and source migration potential.

— Containment systems can be combined with *in situ* treatment and, in some cases, might allow the use of treatments that would constitute too great a risk with respect to migration of either contaminants or reagents in an uncontrolled setting.

- Limitations of containment

— Containment does not reduce source zone mass, concentration, or toxicity unless it is used in combination with treatment technologies.

— Data are not yet available concerning the long-term integrity of the different types of physical containment systems.

— Long-term monitoring of the containment system is essential for ensuring that contaminants are not migrating.

— Covers and alternative soil cover systems that seek to control infiltration must address the potential for freeze/thaw damage, commonly by burying the low hydraulic conductivity layer or capillary barrier under an adequately thick (predicted by frost depth of the area) surface layer of soil.

This technology is retained for further evaluation. Specific process options are described below.

Subtitle C Cover. This type of cover is designed to meet performance objectives for RCRA Subtitle C landfill closures under 40 *CFR* § 265.310. EPA guidance recommends a cover consisting of (top to bottom) an upper vegetated soil layer, a sand drainage layer, and a flexible membrane liner overlying a compacted clay barrier (EPA 1987). A gas collection layer may be included if gas-generating wastes are capped. Nominal thickness of this type of cover is 4.9 ft, and addition of grading fill would increase the thickness at the crest. A biotic layer also can be added to prevent the intrusion of roots or burrowing animals and would also deter human intrusion.

This type of cover is designed to be less permeable than the bottom liner of a RCRA Subtitle C landfill and meets the requirements of 40 *CFR* § 265.310. Neither SWMU 5 nor SWMU 6 has engineered bottom liners and therefore would be more permeable than a Subtitle C landfill cover. Other types of covers may be used if equivalent performance can be demonstrated through numerical modeling and/or site-specific large scale lysimeter studies.

This type of cover is potentially effective, technically implementable, commercially available, and is retained for further consideration.

Subtitle D Cover. Kentucky Subtitle D requirements are for nonhazardous waste landfills. This type of cover is designed to meet performance objectives for a Kentucky Subtitle D Contained Landfill under 401 *KAR* 48:080. These KDEP regulations for contained landfills cap systems provide relevant and appropriate requirements for a final cover of a landfill with industrial waste and are listed in Table D.2. The design of a landfill cover for a Subtitle D facility is generally a function of the bottom liner system or natural subsoils present. The cover will include the following components.

The components, listed from bottom to top, include the following:

- Filter fabric or other approved material;

- 12-inch sand gas venting system with a minimum hydraulic permeability of 1E-03;

- Filter fabric or other approved material;
- 18-inch clay layer with a maximum permeability of 1E-07 cm/sec;
- 12-inch drainage layer with a minimum permeability of 1E-03 cm/sec for areas of the final cap with a slope of less than 15%; and
- 36-inch vegetative soil layer.

Alternative specifications may be used if approved by KDEP and EPA through the CERCLA process provided the alternative results in similar performance with respect to safety, stability, and environmental protection. For example, a gas venting layer may not be an appropriate design feature for installations involving inorganic waste that will not generate methane as it decomposes. Also, an alternative design may substitute a synthetic liner of 40 mil for the 18-inch clay layer.

Installation of a Kentucky Subtitle D Cap at SWMUs 5 and 6, which includes multilayers that are distinctly different to the natural subsoils, provides greater depth to the buried waste. These aspects (thickness and distinct properties) of the cap are expected to provide protection of individuals from inadvertent intrusion by alerting them that this is a man-made engineered cover over something that is potentially hazardous to human health and by making it more difficult to expose the buried waste. Based upon the waste inventory, the buried wastes at SWMUs 5 and 6 (including LLW) are considered low level threat waste consistent with EPA guidance.

This type of cover is potentially effective, technically implementable, commercially available, and is retained for further consideration.

Evapotranspiration Cover. Soil cover systems use one or more vegetated soil layers to retain water until it is either transpired through vegetation or evaporated from the soil surface. These cover systems rely on the water storage capacity of the soil layer, rather than low hydraulic conductivity materials, to minimize percolation. Alternative earthen cover system designs are based on using the hydrological processes (water balance components) at a site, which include the water storage capacity of the soil, precipitation, surface runoff, evapotranspiration, and infiltration. The greater the storage capacity and evapotranspirative properties, the lower the potential for percolation through the cover system.

This type of cover is potentially effective, technically implementable, commercially available, and is retained for further consideration.

Concrete and Asphalt-based Covers. Concrete and asphalt covering systems may consist of a single layer of bituminous or concrete pavement over a prepared subgrade to isolate contaminated soils, reduce infiltration, and provide a trafficable surface. The asphalt surface can be sealed around infrastructure using adhesive sealants and flexible boots; however, constructability is improved by absence of surface infrastructure.

This process option is technically implementable and is retained for further evaluation.

MatCon™. MatCon™ asphalt has been used for RCRA Subtitle C-equivalent closures of landfills and soil contamination sites. MatCon™ is produced using a mixture of a proprietary binder and a specified aggregate in a conventional hot-mix asphalt plant. The EPA Superfund Innovative Technology Evaluation program evaluated MatCon™ in 2003 with respect to permeability, flexural strength, durability, and cost (EPA 2003). EPA determined that the as-built permeability of < 1E-07 cm/s was retained for at least 10 years with only minor maintenance, and MatCon™ had superior mechanical strength properties and durability.

This process option is effective, technically implementable, commercially available, and is retained for further evaluation.

Flexible Membranes. Flexible membranes are single layers of relatively impermeable polymeric plastic [high-density polyethylene (HDPE) and others]. Flexible membranes are a component of a RCRA Subtitle C cover, potentially other types of covers, and also may be used alone. Flexible membranes are laid out in rolls or panels and welded together. The resulting membrane cover essentially is impermeable to transmission of water unless breached. Flexible membranes can be sealed around infrastructure using adhesive sealants and flexible boots; however, constructability is improved by absence of surface infrastructure.

Flexible membranes must be protected from damage to remain impermeable. Flexible membranes are subject to damage and/or leakage due to puncturing or abrasion, exposure to excessive heat, freezing, temperature cycling, poor welds, tearing, shearing, ultraviolet or other radiation exposure, and chemical incompatibilities.

This technology is effective, technically implementable, commercially available, and is retained for further evaluation.

2.4.1.6.3 Subsurface horizontal barriers

Subsurface horizontal barriers potentially may limit downward migration of contaminants in infiltrating water by formation of a physical barrier to flow. Surface barriers must be implemented with subsurface barriers to avoid “bathtubbing” (i.e., infiltrating water spilling over the sides). Several types of subsurface barriers are discussed below. This technology is implementable and is retained.

Freeze Walls. Frozen barrier walls, also called cryogenic barriers or freeze walls, are constructed by artificially freezing the soil pore water, resulting in decreased permeability and formation of a low permeability barrier. The frozen soil remains relatively impermeable and migration of contaminants thereby is reduced. This technology has been used for groundwater control and soil stabilization in the construction industry and for strengthening walls at excavation sites for many years. This technology also has been identified for contamination and dust control during excavation of buried wastes.

Implementation of this technology requires installing pipes called thermoprobes into the ground and circulating refrigerant through them. As the refrigerant moves through the system, it removes heat from the soil and freezes the pore water. Implementation in arid regions requires injecting water to provide the moisture necessary to form the barrier or to repair the frozen wall. Systems can be operated actively or passively depending on air temperatures (EPA 1999).

The thermoprobes can be placed at 45-degree angles along the sides of the area to be contained to form a V-shaped or conical barrier to provide subsurface containment. This technology is considered innovative and emerging for remediation, but is commercially available through the geotechnical construction industry.

Freeze wall containment potentially could eliminate vertical COC flux as long as the soil remains frozen and would be effective only as a temporary containment measure. The technology is not practical as a permanent hydraulic barrier system and therefore is screened from further consideration.

Jet Grouting. Grout mixtures injected at high pressures and velocities into the pore spaces of the soil or rock have been used in civil construction for many years to stabilize subgrades and reduce infiltration of water. More recently, jet grouting has been tested as a potential means of creating a subsurface horizontal barrier, without disturbing overlying soils. Grouts typically are injected through drill rods. The jetted grout mixes with the soil to form a column or panel. Jet grouting can be used in soil types ranging from gravel to clay, but the soil type can alter the diameter of the grout column. Soil properties also are related to the efficiency. For instance, jet grouting in clay is less efficient than in sand (EPA 1999).

V-shaped jet-grouted composite barriers were demonstrated at Brookhaven and the Hanford sites (Dwyer 1994) and at Fernald in 1992 (Pettit et al. 1996) in attempts to completely isolate contaminated soils in field trials. At Hanford and Brookhaven, V-shaped grouted barriers were created by injecting grout through the drill strings of rotary/percussion directional drilling rigs. Next, a waterproofing polymer (AC 400) was placed as a liner between the waste form and the cement v-trough, forming a composite barrier. Technologies to determine the continuity and impermeability of the completed barrier are unavailable; therefore, the effectiveness of the completed barriers is uncertain. This technology is screened from further consideration as a subsurface horizontal barrier.

Permeation Grout Barriers. Permeation grouting has been used extensively in construction and mining to stabilize soils and control movement of water. Low-viscosity grout is injected vertically or directionally at multiple locations into soil at sufficiently low pressure to avoid hydrofracturing while filling soil voids. Soil permeability may be reduced with minimal increase in soil volume using this method (EPA 1999).

The extent of grout permeation is a function of the grout viscosity, grout particle size, and soil particle size distribution. A variety of materials can be used in permeation grouting, and it is essential to select a grout that is compatible with the soil matrix. Particulate grouts are applicable when the soil permeability is greater than 1E-01 cm/s. Chemical grouts can be used with soil permeabilities greater than 1E-03 cm/s (EPA 1999). Permeation grouting has been tested at pilot scale, resulting in formation of subsurface layers of inconsistent coverage, thickness, and permeability.

Viscous liquid barriers are a variant of permeation grouting using low-viscosity liquids that gel after injection, forming an inert impermeable barrier. Field tests have resulted in formation of subsurface layers of inconsistent coverage, thickness, and permeability.

Permeation grouting is limited to soil formations with moderate to high permeabilities. Establishing and verifying a continuous, effective subsurface barrier is difficult or impossible in heterogeneous soils or in the presence of subsurface infrastructure. But because this process option is technically implementable, it is retained for further consideration.

2.4.1.6.4 Subsurface vertical barriers

Vertical barrier technologies can be used to isolate areas of soil contamination and to restrict groundwater flow into the contaminated area or underlying zones. Subsurface vertical barriers may be used to contain or divert contaminated groundwater flow. Subsurface vertical barrier technologies must be “keyed” into an underlying low permeability layer to avoid leakage around the barrier if complete containment is required (Deuren et al. 2002).

Given that flow is predominantly downward through the UCRS in the BGOU and that no continuous low permeability layer exists between the COC source areas and the RGA, vertical barriers are likely effective only as adjunct technologies for other primary technologies (e.g., removal). The following is a discussion of several different types of subsurface vertical barriers. This technology is retained for further consideration.

Freeze Walls. This technology previously was evaluated as a subsurface horizontal barrier. The same principles apply as a subsurface vertical barrier, only the thermoprobes are installed vertically instead of on a 45 degree angle to prevent/contain the lateral flow of groundwater. Freeze wall containment potentially could eliminate lateral COC flux as long as the soil remains frozen and, therefore, would be effective only as a temporary containment measure. The technology is used in the construction industry to prevent the influx of groundwater into and/or stabilize the sidewalls of deep excavations. Although impractical as a permanent hydraulic barrier and therefore screened, this process option is potentially effective as an adjunct process option during excavation, is technically implementable, commercially available, and is retained for further evaluation.

Slurry Walls. Slurry walls are an established and commercially available technology. Slurry walls consist of vertically excavated trenches that are kept open by filling the trench with a low permeability slurry, generally bentonite and water. The slurry forms a very thin layer of fully hydrated bentonite that is impermeable. Soil (often excavated material) then is mixed with bentonite and water to create a soil bentonite backfill with a hydraulic conductivity of approximately 1E-07 cm/s, which is used to backfill the trench, displacing the slurry. Trench excavation is commonly completed by a backhoe with a modified boom at depths of up to 60 ft. A drag line or clam shell may be used for excavations greater than 60 ft.

Alternatively, a cement, bentonite, and water slurry that is left in the trench to harden may be used. Concrete slurry walls may have a greater hydraulic conductivity than traditional slurry walls and the excavated soil that is not used as a backfill must be disposed of properly. This technology is technically implementable, commercially available, and is retained for further evaluation.

Sheet Pilings. Sheet pilings are an established and readily available technology. Sheet pilings are long structural steel sections with a vertical interlocking system that are driven into the ground to create a continuous subsurface wall. After the sheet piles have been driven to the required depth, they are cut off at the surface. Sheet pilings are commonly used in excavations for shoring and to reduce groundwater flow into the excavation and, therefore, are a potentially useful adjunct technology for soil removal. This technology is effective, technically implementable, commercially available, and is retained for further evaluation.

Jet Grouting. Although not considered an effective horizontal subsurface barrier, jet grouting is effective as a vertical subsurface barrier. Jet grouting can be used regardless of soil type, permeability, grain size distribution, etc. In theory, it is possible to stabilize most soils from soft clays and silts to sands and gravel. Although it is possible to inject any type of binder, in practice, water/cement mixtures normally are used. Where it is required that the soil be impermeable, water/cement/bentonite mixes are typically utilized.

A subsurface slurry wall can be formed by sequentially jet grouting adjoining columns of soil. An advantage of jet grouting over other slurry wall techniques is, it can be used to stabilize a wide range of soils ranging from gravel to heavy clays. A secondary advantage is that large diameter columns or panels can be created from relatively small diameter boreholes (http://www.recon-net.com/jet-grouting.html#jetgrouting). Waste soil and other material requiring management and disposal are less for jet grouting than for a conventional slurry wall and, therefore, jet grouting will be retained for consideration as a vertical subsurface barrier process option. This process option could be used as a secondary technology to removal to stabilize the sidewalls of an excavation.

2.4.1.7 Treatment technologies

Treatment technologies may destroy, immobilize, or render contaminants less toxic. Treatment technologies may be implemented *in situ, ex situ,* or both.

In situ treatments destroy, remove, or immobilize COCs without removing or extracting contaminated media. *In situ* treatment technologies may involve distributing fluids or gaseous amendments; applying thermal, pressure, or electrical potential gradients; manipulating subsurface conditions to promote biotic or abiotic contaminant degradation; or applying physical mixing in combination with other treatments. *Ex situ* treatments destroy, remove, or immobilize COCs after the contaminated media has been removed through excavation or extraction.

The following treatment technologies are evaluated for potential implementability at BGOU SWMUs 5 and 6: biological, physical/chemical, thermal, and chemical. Process options are described for each retained technology, with *in situ* process options being discussed prior to *ex situ* process options being discussed. Process options are not discussed for those technologies screened from further evaluation.

2.4.1.7.1 Biological technologies

Bioremediation techniques are destruction techniques directed toward stimulating the microorganisms to grow and use the contaminants as a food and energy source by creating a favorable environment for the microorganisms. Generally, this means providing some combination of oxygen, nutrients, and moisture, and controlling the temperature and pH. Sometimes, microorganisms adapted for degradation of the specific contaminants are applied to enhance the process (FRTR 2008). Bioremediation techniques can be applied either *in situ* or *ex situ*.

Biological processes typically are implemented at low cost. Contaminants can be destroyed, and often little to no residual treatment is required. The process does require more time, and, in the case of *in situ* applications, it is difficult to determine whether contaminants have been destroyed. Biological treatment of PAHs leaves less degradable PAHs (cPAHs) behind. These higher molecular weight cPAHs are classified as carcinogens. Also, an increase in chlorine concentration leads to a decrease in biodegradability. Some compounds, however, may be broken down into more toxic by-products during the bioremediation process (e.g., TCE to vinyl chloride). For *in situ* applications, these by-products may be mobilized to groundwater or contacted directly if no control techniques are used. This type of treatment scheme requires soil, aquifer, and contaminant characterization, and may require extracted groundwater treatment. Groundwater with low-level contamination sometimes may be recirculated through the treatment area to supply water to the treatment area (FRTR 2008).

There are no COCs requiring calculated RGs that are amenable to this technology. This technology also does not mitigate risk from contact with buried waste. This technology type is screened from further consideration.

2.4.1.7.2 Physical/chemical technologies

Physical/chemical treatment uses the physical properties of the contaminants or the contaminated medium to destroy (i.e., chemically convert) or separate the contamination. For example, passive treatment walls separate and destroy the contaminant from *in situ* groundwater, air sparging, dual-phase extraction, fluid/vapor extraction and air stripping are separation techniques. Physical/chemical technologies also include stabilization/solidification process options.

Many physical/chemical process options primarily address groundwater either as a stand-alone remedy or as a component of a process train. Several are described below, and they are screened from further consideration for SWMU 5 and SWMU 6 as primary technologies because neither SWMU 5 nor SWMU 6 contains COCs for which RGs are calculated, and these process options do not mitigate the uncertainties associated with the SWMU wastes This technology is retained for further evaluation because it contains cement and chemical grouting and jet grouting that could be implemented at SWMUs 5 and 6.

Soil Vapor Extraction—In Situ. Soil vapor extraction (SVE) applies a vacuum to unsaturated soils to induce the controlled flow of air through contaminated intervals, thereby removing volatile and some semivolatile contaminants from the soil. SVE can increase the rate of volatilization from dense nonaqueous-phase liquid (DNAPL), aqueous, and sorbed VOC phases by maintaining a high concentration gradient between these phases and the air filled soil porosity.

The gas leaving the soil may be treated to recover or destroy the contaminants, depending on local and state air discharge regulations. Vertical extraction wells typically are used at depths of 5 ft or greater and have been successfully applied as deep as 300 ft. Horizontal extraction vents installed in trenches or horizontal borings can be used as warranted by contaminant zone geometry, drill rig access, or other site-specific factors. SVE is defined by EPA as a presumptive remedy for VOCs in soil (EPA 2007).

This process option is not applicable for implementation at either SWMU 5 or SWMU 6 because there is no evidence that either contains COCs above RGs. This process option also would not effectively mitigate the risk associated with each SWMU's waste (see Section 1.3.6). It is therefore screened from further evaluation.

Dual-phase Extraction—In Situ. Dual-phase extraction (DPE), also known as multi-phase extraction, uses a high-vacuum system to remove both contaminated groundwater and soil vapor. In DPE systems, a high-vacuum extraction well is installed with its screened section in the zone of contaminated soils and groundwater. Fluid/vapor extraction systems depress the water table and water flows faster to the extraction well. Impermeable covers often are placed over the soil surface during operations to prevent short circuiting of air flow and to increase the radius of influence of the wells. Groundwater depression pumps may be used to reduce groundwater upwelling induced by the vacuum or to increase the depth of the vadose zone. DPE was evaluated and recommended by Hightower et al. (2001) as potentially effective and implementable for remediation of DNAPL TCE in saturated conditions in the UCRS at PGDP. Potential adjunct technologies to improve performance, including fracturing, active or passive air injection, air sparging, and ozone injection, are discussed separately.

This process option is not applicable for implementation at either SWMU 5 or SWMU 6 because there is no evidence that either contains COCs requiring calculated RGs. This process option also would not effectively mitigate the risk associated with each SWMU's waste (see Section 1.3.6). It is therefore screened from further evaluation.

Air Sparging—In Situ. Air sparging injects air into a contaminated aquifer. Injected air traverses horizontally and vertically in channels through the soil column, creating an underground stripper that removes contaminants by volatilization. This injected air helps to volatilize the contaminants up into the unsaturated zone, where they typically are removed by an SVE system. This technology is designed to operate at high flow rates to maintain increased contact between groundwater and soil and strip more groundwater by sparging. Air sparging can act on aqueous DNAPL and sorbed phase VOCs by promoting volatilization of VOCs into an air phase, although air sparging may not effectively treat DNAPL when present in amounts significantly above residual saturation (COE 2008).

Oxygen added to contaminated groundwater and vadose zone soils also can enhance biodegradation of contaminants below and above the water table. Ozone may be generated on-site and added to air injection or sparging systems to oxidize contaminants *in situ*. This application of sparging was recommended for evaluation by Hightower et al. (2001) for remediation of TCE sources in the UCRS unsaturated zone at PGDP.

This process option is not applicable for implementation at either SWMU 5 or SWMU 6 because there is no evidence that either contains COCs requiring calculated RGs. This process option also would not effectively mitigate the risk associated with each SWMU's waste (see Section 1.3.6). It is therefore screened from further evaluation.

Soil Flushing—In Situ. Soil flushing is the extraction of contaminants from soil with water or other suitable aqueous solutions. Soil flushing is accomplished by passing the extraction fluid through in-place soils using an injection or infiltration process. Extraction fluids are recovered from the underlying aquifer and, when possible, they are recycled. Many soil flushing techniques are adapted from enhanced oil recovery methods used by the petroleum industry for many years.

This process option is not applicable for implementation at either SWMU 5 or SWMU 6 because there is no evidence that either contains COCs requiring calculated RGs. This process option also would not effectively mitigate the risk associated with each SWMU's waste (see Section 1.3.6). It is therefore screened from further evaluation.

Electrokinetics—In Situ. The principle of electrokinetic remediation relies upon application of a low-intensity direct current through the soil between ceramic electrodes that are divided into a cathode array and an anode array. This mobilizes charged species, causing ions and water to move toward the electrodes. Metal ions, ammonium ions, and positively charged organic compounds move toward the cathode. Anions such as chloride, cyanide, fluoride, nitrate, and negatively charged organic compounds move toward the anode. The current creates an acid front at the anode and a base front at the cathode.

Two primary mechanisms, electromigration and electroosmosis, transport contaminants through the soil toward one or the other electrodes. In electromigration, charged particles are transported through the stationary soil moisture. In contrast, electroosmosis is the movement of the soil moisture containing ions relative to a stationary charged surface. The direction and rate of movement of an ionic species will depend on its charge, both in magnitude and polarity, as well as the magnitude of the electroosmosis-induced flow velocity. Non-ionic species, both inorganic and organic, also will be transported along with the electroosmosis-induced water flow. Electrokinetics can act on aqueous, DNAPL, and sorbed-phase VOCs. Electroosmosis has been used for years in the construction industry to dewater low-permeability soils.

While this process option has been demonstrated at PGDP to be effective, technically implementable, and commercially available for remediation of VOCs in soil, it is not suitable for implementation at either SWMU 5 or SWMU 6. It is therefore screened from further evaluation.

Soil Fracturing—In Situ. Soil fracturing may be accomplished either pneumatically, using air, or hydraulically, using liquids. Pneumatic fracturing involves the injection of highly pressurized gas (nitrogen or air) into the soil via borings to extend existing fractures and create a secondary network of subsurface channels. Hydraulic fracturing (hydrofracturing) uses water or slurry instead of gas. Soil fracturing can extend the range of treatment when combined with other primary technologies such as bioremediation, chemical oxidation/reduction, or soil vapor extraction. Soil fracturing for these uses is discussed as a secondary technology in the discussion of the primary technology such as the introduction of a chemical reagent.

This process option is not applicable for implementation at either SWMU 5 or SWMU 6 because there is no evidence that either contains COCs requiring calculated RGs. This process option also would not effectively mitigate the risk associated with each SWMU's waste (see Section 1.3.6). It is therefore screened from further evaluation.

Liquid Atomized Injection—In Situ. For liquid atomized injection, a proprietary delivery mechanism is used to inject a reagent into the subsurface in an aerosolized state. It will pneumatically fracture low permeability formations.

This process option is not applicable for implementation at either SWMU 5 or SWMU 6 because there is no evidence that either contains COCs requiring calculated RGs. This process option also would not effectively mitigate the risk associated with each SWMU's waste (see Section 1.3.6). It is therefore screened from further evaluation.

Permeable Reactive Barrier—In Situ. Permeable reactive barriers (PRBs) are designed and constructed to permit the passage of water while immobilizing or destroying contaminants through the use of various reactive agents. PRBs often are used in conjunction with subsurface vertical barriers such as sheet piling to form a funnel and gate system that directs the groundwater flow through the PRB.

This process option is not applicable for implementation at either SWMU 5 or SWMU 6 because there is no evidence that either contains COCs requiring calculated RGs. This process option also would not effectively mitigate the risk associated with each SWMU's waste (see Section 1.3.6). It is therefore screened from further evaluation.

Air Stripping—Ex Situ. Air stripping removes volatile organics from extracted groundwater by greatly increasing the surface area of the contaminated water exposed to air. Air stripping is a presumptive technology for treatment of VOCs in extracted groundwater (EPA 1996).

Types of aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration. Packed tower air strippers typically include a spray nozzle at the top of the tower to distribute contaminated water over the packing in the column, a fan to force air countercurrent to the water flow, and a sump at the bottom of the tower to collect decontaminated water. Tray aerators stack a number of perforated trays vertically in an enclosure. Air is blown upward through the perforations as water cascades downward through the trays. Aeration tanks strip volatile compounds by bubbling air into a tank through which contaminated water flows. A forced air blower and a distribution manifold are designed to ensure air-water contact.

This process option is not applicable for implementation at either SWMU 5 or SWMU 6 because there is no evidence that either contains COCs requiring calculated RGs. This process option also would not effectively mitigate the risk associated with each SWMU's waste (see Section 1.3.6). It is therefore screened from further evaluation.

Ion Exchange—Ex Situ. Ion exchange removes ions from the aqueous phase by exchanging cations or anions between the contaminants and the exchange medium. Ion exchange materials may consist of resins made from synthetic organic materials that contain ionic functional groups to which exchangeable ions are attached. Resins also may be inorganic and natural polymeric materials. After the resin capacity has been exhausted, resins can be regenerated (off-site by the vendor) for reuse.

This process option is not applicable for primary implementation at either SWMU 5 or SWMU 6 because there is no evidence that either contains COCs requiring calculated RGs. This process option also would not effectively mitigate the risk associated with each SWMU's waste (see Section 1.3.6). It is therefore screened from further evaluation.

Granular-Activated Carbon (Vapor Phase and Liquid Phase)—Ex Situ. Vapor-phase carbon adsorption removes pollutants including VOCs removed from extracted air by physical adsorption onto activated carbon grains. Carbon is "activated" for this purpose by processing the carbon to create porous particles with a large internal surface area (300 to 2,500 m^2 or 3,200 to 27,000 ft^2 per gram of carbon) that attracts and adsorbs organic molecules as well as certain metal and inorganic molecules.

Commercial grades of activated carbon are available for specific use in vapor-phase applications. The granular form of activated carbon typically is used in packed beds through which the contaminated air flows until the concentration of contaminants in the effluent from the carbon bed exceeds an acceptable level. Granular-activated carbon (GAC) systems typically consist of one or more vessels filled with carbon connected in series and/or parallel operating under atmospheric, negative, or positive pressure. The carbon then can be regenerated in place, regenerated at an off-site regeneration facility, or disposed of depending upon economic considerations.

Liquid phase GAC also is widely used for removal of VOCs including VOCs from aqueous streams, including pump-and treat systems. Liquid-phase carbon adsorption removes dissolved pollutants by physical adsorption onto activated carbon grains, similar to gas-phase absorption as described previously. Sizing of the GAC bed is based on effluent flow rate, face velocity, and residence time. Most GAC systems include a multiple bed configuration to optimize carbon utilization. GAC currently is used as a polishing step after air stripping at the PGDP Northwest Plume Pump-and-Treat Facility.

This process option is not applicable for implementation at either SWMU 5 or SWMU 6 because there is no evidence that either contains COCs requiring calculated RGs. This process option also would not effectively mitigate the risk associated with each SWMU's waste (see Section 1.3.6). It is therefore screened from further evaluation.

Vapor Condensation. TCE and other VOCs in contaminated vapor streams can be cooled to condense the contaminants (EPA 2006b). The contaminant-laden vapor stream is cooled below the dew point of the contaminants, e.g., below about 37.2°C (99°F) for TCE, and the condensate can be collected for recycling or disposal. Methods used to cool the vapor stream may include the use of liquid nitrogen, mechanical chilling, or a combination of the two.

Condensation systems are most often used when the vapor stream contains concentrations of contaminants greater than 5,000 ppm or when it is economically desirable to recover the organic contaminant contained in the vapor stream for reuse or recycling. Other configurations of vapor condensation include adsorbing or otherwise concentrating compounds from low-concentration vapors using another technology (e.g., GAC) and then performing condensation for recovery for disposal or recycling.

This process option is not applicable for implementation at either SWMU 5 or SWMU 6 because there is no evidence that either contains COCs requiring calculated RGs. This process option also would not effectively mitigate the risk associated with each SWMU's waste (see Section 1.3.6). It is therefore screened from further evaluation.

Deep Soil Mixing. Deep soil mixing is a stabilization/solidification technique in which regents, generally cement, are injected into a soil matrix and mixed *in situ*. Several types of deep soil mixing systems are commercially available, including single- and dual-auger systems. Dual-auger soil mixing involves the controlled injection and blending of reagents into soil through dual overlapping auger mixing assemblies, consisting of alternate sections of auger flights and mixing blades that rotate in opposite directions to pulverize the soil and blend in the appropriate volumes of treatment reagents. Each auger mixing assembly is connected to a separate, hollow shaft (Kelly-bar) that conveys the treatment reagents to the mixing area, where the reagents are injected through nozzles located adjacent to the auger cutting edge. The mix proportions, volume, and injection pressures of the reagents are continuously controlled and monitored by an electronic instrumentation system.

Deep soil mixing is not implementable at SWMU 5 or SWMU 6 because of the debris known to exist at these SWMUs. This debris would interfere with the auger flights and could cause auger flights to bind, could cause auger refusal, or could cause equipment damage. Regardless, the debris likely would prevent complete mixing. This technology is screened from further consideration.

Cement and Chemical Grouting—In Situ. Cement grouting, also known as slurry grouting or high mobility grouting, is a grouting technique that fills pores in granular soil or voids in rock or soil with flowable particulate grouts. Depending on the application, Portland cement or microfine cement grout is injected under pressure at strategic locations either through single port or multiple port pipes. The grout particle size and soil/rock void size must be properly matched to permit the grout to enter the pores or voids. The grouted mass has an increased strength and stiffness, and reduced permeability.

Chemical grouting is a grouting technique that transforms granular soils into sandstone-like masses, by permeation with a low viscosity grout. Typically, a sleeve port pipe first is grouted into a predrilled hole. The grout is injected under pressure through the ports on the pipe. The grout permeates the soil and solidifies it into a sandstone-like mass. The grouted soil has increased strength and stiffness and reduced permeability.

In situ grouting of the SWMU 5 and SWMU 6 wastes would reduce the uncertainty associated with the wastes by reducing mobility. It is commercially available and technically implementable. This process option is retained for further evaluation.

Jet Grouting—In Situ. Jet grouting is a grouting technique that creates *in situ* geometries of soilcrete (grouted soil), using a grouting monitor attached to the end of a drill stem. The jet grout monitor is advanced to the maximum treatment depth, at which time high velocity grout jets (and sometimes water and air) are initiated from ports in the side of the monitor. The jets erode and mix the *in situ* soil as the drill stem and jet grout monitor are rotated and raised.

Jet grouting is effective across the widest range of soil types of any grouting system, including silts and most clays, although cohesionless soils typically are more erodible by jet grouting than cohesive soils.

In situ stabilization, treatment, and amendment methods are available for immobilizing uranium contamination in soils and groundwater. The addition of amendments (e.g., apatite or phosphase solutions) stabilizes uranium in soils and groundwater through the formation of relatively insoluble uranium-phosphate solids. Stabilization leaves the contamination in place. Precipitation of uranium to the phosphate form leaves uranium highly insoluble and essentially inert chemically. Even ingestion would not result in much uranium retention in the body.

Jet grouting the wastes at SWMU 5 and SWMU 6 would reduce the uncertainty associated with the wastes by reducing mobility. This option is commercially available and is technically implementable. This process option is retained for further evaluation.

2.4.1.7.3 Thermal technologies

Thermal processes burn, decompose, or detonate contaminants (destruction); melt the contaminants (immobilization); or use heat to increase volatility of contaminants (separation). Destruction technologies include incineration, open burn/open detonation, and pyrolysis. Vitrification immobilizes inorganics and destroys some organics. Separation technologies include thermal desorption and hot gas decontamination.

Thermal treatments offer quick cleanup times, but typically are the most costly treatment group. This difference, however, is less in *ex situ* applications than *in situ* applications. Cost is driven by energy and equipment costs and is both capital- and O&M-intensive.

This technology is technically implementable and is retained for further evaluation.

Electrical Resistance Heating—In Situ. Electrical resistance heating (ERH) uses electrical resistance heaters or electromagnetic/fiber optic/radio frequency heating to increase the volatilization rate of semivolatiles and facilitate vapor extraction. The vapor extraction component of ERH requires heat-resistant extraction wells, but is otherwise similar to SVE.

Contaminants in low-permeability soils such as clays and fine-grained sediments can be vaporized and recovered by vacuum extraction using this method. Electrodes are placed directly into the soil matrix and energized so that electrical current passes through the soil, creating a resistance that then heats the soil. The heat may dry out the soil causing it to fracture. These fractures make the soil more permeable, allowing the use of SVE to remove the contaminants.

The heat created by ERH also forces trapped liquids, including DNAPLs, to vaporize and move to the steam zone for removal by SVE. ERH applies low-frequency electrical energy in circular arrays of three (three-phase) or six (six-phase) electrodes to heat soils. The temperature of the soil and contaminant is increased, thereby increasing the contaminant's vapor pressure and its removal rate. ERH also creates an *in situ* source of steam to strip contaminants from soil. Heating via ERH also can improve air flow in high moisture soils by evaporating water, thereby improving SVE performance. ERH can act on aqueous, DNAPL, and sorbed phase VOCs.

Six-phase heating (SPH) was evaluated and recommended by Hightower et al. (2001) for TCE DNAPL contamination in the saturated and unsaturated zones of the UCRS. A pilot study using SPH subsequently was conducted at PGDP between February and September of 2003. The heating array was 30 ft in diameter and reached a depth of 99 ft bgs. Baseline sampling results showed an average reduction in soil contamination of 98% and groundwater contamination of 99% (DOE 2003).

ERH was implemented as the C-400 IRA remedy to remove VOC contamination, primarily TCE, from subsurface soils in the vicinity of the C-400 Cleaning Building. This decision was documented in a Record of Decision (ROD) signed in August 2005.

Phase I construction began in December 2008 and was substantially complete in December 2009; at that time, start up and shakedown testing began. Testing was complete and operations commenced at the end of March 2010. Heating operations ceased (soil vapor extraction continued) at the end of October 2010, and all system operations ended on December 4, 2010.

Phase I performance assessment results support the conclusion that RAOs, as documented in the ROD, were achieved for the UCRS and upper RGA in the Phase I treatment areas.

Postoperational soil sample results show average percent reductions in TCE concentrations of 95% and 99% in the Phase I east and southwest treatment areas. Groundwater analytical results from postoperational samples show average reductions of 76% and 99% in the east and southwest areas, respectively.

Target temperatures were attained in treatment areas and depths targeted for VOC removal, indicating that the ERH design was adequate for thermal treatment of UCRS soils.

There are no COCs requiring calculated RGs that are amenable to this process option. This technology also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.

Thermal Conduction Heating—In Situ. Thermal conduction heating (TCH) is similar to ERH in that the physical processes of contaminant removal and collection are similar, but the two processes use different methods to heat the subsurface. TCH uses an array of heating elements placed in heater wells to raise the temperature of the subsurface by thermal conduction. Unlike ERH, it does not pass a current through the subsurface or rely on the electrical resistance of the soil to facilitate the heating process. TCH can generate subsurface temperatures above 100°C and is therefore effective at removing semivolatile organic compounds (SVOCs) such as PAHs, PCBs, pesticides, and dioxins. The maximum soil temperature achievable with ERH is 100°C and its application typically is limited to treatment of VOCs. Unlike ERH, buried metal objects are not a significant limitation to the implementation of TCH as long as the buried materials do not interfere with the construction of heater and heater/vacuum wells.

There are no COCs requiring calculated RGs at SWMU 5 and SWMU 6 that are amenable to this process option. This technology also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.

Steam Stripping—In Situ. Hot air or steam is injected below the contaminated zone to heat contaminated soil and thereby enhance the release of VOCs and some VOCs from the soil matrix. Desorbed or volatilized VOCs are removed through SVE (FRTR 2008). Steam injection has been used to enhance oil recovery for many years and was investigated for environmental remediation beginning in the 1980s. Approximately 10 applications of this technology for recovery of fuels, solvents, and creosote are reported in EPA 2005, with varied results.

There are no COCs requiring calculated RGs at SWMUs 5 and 6 that are amenable to this process option. This technology also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.

Catalytic Oxidation—Ex Situ. Oxidation equipment (thermal or catalytic) can be used for destroying contaminants in the exhaust gas from air strippers and SVE systems. Thermal oxidation units typically are single chamber, refractory-lined oxidizers equipped with a propane or natural gas burner and a stack. Lightweight ceramic blanket refractory is used because many of these units are mounted on skids or trailers. Flame arrestors are installed between the vapor source and the thermal oxidizer. Burner capacities in the combustion chamber range from 0.5 to 2 million BTUs per hour. Operating temperatures range from 760° to 870°C (1,400°F to 1,600°F), and gas residence times typically are one second or less.

Catalytic oxidation units are widely used for the destruction of VOCs and numerous vendors are available; however, there are no COCs requiring calculated RGs that are amenable to this process option at SWMUs 5 and 6. This technology also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.

Thermal Desorption—Ex Situ. Thermal desorption heats wastes *ex situ* to volatilize water and organic contaminants. A carrier gas or vacuum system transports volatilized water and organics to a gas treatment system where they are collected or oxidized to CO_2 and water (FRTR 2008).

Two common thermal desorption designs are the rotary dryer and thermal screw. Rotary dryers are horizontal cylinders that can be indirect- or direct-fired. The dryer is normally inclined and rotated. Thermal screw units transport the medium through an enclosed trough using screw conveyors or hollow augers. Hot oil or steam circulates through the auger to indirectly heat the medium. Thermal desorption systems typically require treatment of the off-gas to remove particulates and destroy contaminants. Particulates are removed by conventional particulate removal equipment such as wet scrubbers or fabric filters. Contaminants may be removed through condensation followed by carbon adsorption or destroyed in a secondary combustion chamber or a catalytic oxidizer.

Most of the hardware components for thermal desorption systems are readily available off the shelf. Most *ex situ* soil thermal treatment systems employ similar feed systems consisting of a screening device to separate and remove materials greater than five centimeters (2 inches), a belt conveyor to move the screened soil from the screen to the first thermal treatment chamber, and a weight belt to measure soil mass. Occasionally, augers are used rather than belt conveyors, but either type of system requires daily maintenance and is subject to failures that can shut down the system.

There are no COCs requiring calculated RGs that are amenable to this process option. This technology also does not mitigate risk from contact with buried waste. This process option is screened from further consideration.

Vitrification. Of all the common solidification methods, vitrification offers the greatest degree of containment. Most (but not all) of the resultant solids have an extremely low leach rate; however, the high energy demand and requirements for specialized equipment and trained personnel greatly limit the use of this method. Exposure to contaminants to the vitrification process results in several desirable results: (1) destruction of hazardous organics by pyrolytic decomposition and/or oxidation, and (2) removal (partial or fully) of low-solubility, high-volatility, and high-solubility inorganics in the residual glass product, through chemical incorporation and/or encapsulation.

In the *ex situ* method, the waste, together with other chemicals that produce the glassy product, are mixed and melted within a special furnace. Waste and glass- (or slag-) forming constituents are introduced into the heated zone of the furnace. These react to produce a molten mass while organic materials are decomposed or volatilized into a suitable scrubber system. The fused mass of insoluble materials can be cast into blocks or removed in a granular form depending on composition and intended disposal requirements.

In situ vitrification is another *in situ* process that uses an electric current to melt soil or other earthen materials at extremely high temperatures (1,600 to 2,000°C or 2,900 to 3,650°F) and thereby immobilize most inorganics and destroy organic pollutants by pyrolysis. Inorganic pollutants are incorporated within the vitrified glass and crystalline mass. Water vapor and organic pyrolysis combustion products are captured in a hood, which draws the contaminants into an off-gas treatment system that removes particulates and other pollutants from the gas. The vitrification product is a chemically stable, leach-resistant, glass and crystalline material similar to obsidian or basalt rock. The process destroys and/or removes organic materials. Radionuclides and heavy metals are retained within the molten soil (FRTR 2008).

In situ vitrification would mitigate the uncertainties associated with the SWMU 5 and SWMU 6 wastes by reducing mobility. It is therefore retained for further evaluation.

2.4.1.7.4 Chemical technologies

In situ chemical oxidation (ISCO) processes are *in situ* treatments whereby chemical compounds are injected to oxidize organic contaminants in the subsurface. Commercially available chemical oxidation technologies include the following:

- Permanganate
- Fenton's reagent
- Zero-valent iron (ZVI)
- Ozonation
- Persulfate
- Redox manipulation
- Surfactant-enhanced ISCO

ISCO has been used at many sites, and oxidants are available from a variety of vendors. Water-based oxidants can react directly only with the dissolved-phase of nonaqueous-phase liquid (NAPL) contaminants because the two will not mix. This property limits their activity to the oxidant solution/DNAPL interface; however, significant mass reduction has been reported for application of ISCO at sites with dissolved-phase VOCs and DNAPL residual ganglia (EPA 2008). Off-gas control is often important during implementation of chemical oxidation technologies.

Neither SWMU 5 nor SWMU 6 is known to contain COCs requiring calculated RGs amenable to chemical treatment. Additionally, chemical treatment would not be an effective means to mitigate the uncertainties associated with the SWMU wastes; therefore, the chemical treatment technology process options are screened from further evaluation.

2.4.1.8 Disposal technologies

Disposal technologies for wastes and soil produced during excavation are discussed.

2.4.1.8.1 Land disposal

Land disposal of buried waste and soils generated from excavation at the SWMUs will require disposal facilities to accept the waste types generated during the action. Historical records indicate that only LLW and nonhazardous solid waste will be generated at SWMU 5 and SWMU 6. It is acknowledged that once excavation begins, sampling of uncovered buried waste would be used to definitively determine waste types and to confirm the waste meets WAC of the receiving facility if one must be used. The following discussion presents potential on-site and off-site options for land disposal of waste materials generated during remediation of SWMUs 5 and 6.

On-Site Disposal. DOE has existing and available capacity for on-site disposal of nonhazardous solid wastes. The C-746-U Landfill at PGDP on DOE-owned property would be used to dispose of the nonhazardous solid wastes generated from SWMUs 5 and 6.

On-site disposal of waste also may be possible for additional waste types depending upon the remedy selected from a waste disposal alternatives evaluation DOE is conducting for CERCLA-derived wastes. One alternative being considered in that evaluation is the siting, design, construction, operation, closure, and postclosure of a new on-site waste disposal facility. This potential facility would be designed and operated to accept LLW, RCRA, Toxic Substances Control Act (TSCA), and mixed low-level waste (MLLW) and also may be designed to accept classified wastes. The CERCLA waste disposal alternative evaluation is currently in progress (an RI/FS is under development); therefore, a decision is not yet available. If a new on-site facility were selected in a ROD, then CERCLA wastes that meet the facility's WAC could be disposed of on-site when the facility is open and ready for disposal operations. Cost for disposal of waste in a potential on-site disposal unit are included in the estimate in Appendix C. Additionally, operations at the potential on-site waste disposal facility anticipate the incorporation of concrete and metal recycling. Any applicable waste generated through excavation would be evaluated for recycle value and potential for waste minimization.

This process option is technically implementable and retained for possible alternative development.

Off-Site Disposal. Off-site disposal currently is used by DOE for land disposal of wastes that do not meet the WAC of the on-site PGDP C-746-U Landfill. DOE has existing contracts with off-site commercial disposal facilities (Energy*Solutions* in Clive, UT, is most frequently used) as well as access to disposal at the Nevada National Security Site (NNSS) in Mercury, NV. DOE also has established methods for packaging and transportation of waste off-site. Energy*Solutions* can be reached either by rail or truck; NNSS-bound waste can be shipped only by truck. Other off-site disposal facilities that become available in the future would be considered for off-site disposal as a method to validate and maintain cost efficiency. One such facility is Waste Control Specialists in Andrews County, TX.

Off-site disposal costs for the FS are based on current contract rates that DOE has in place with the primary disposal facilities discussed. The main cost elements associated with off-site disposal include the cost of the containers (either purchased or rentals), transportation costs, and disposal fees. The costs also are dependent on the waste type (regulatory classification) and form (i.e., soil, debris) of the waste.

This process option is technically implementable and retained for possible alternative development.

2.4.1.8.2 Discharge of wastewater

Water collected as incidental to the implementation of an excavation alternative will be sent to a temporary water treatment unit to be installed as part of the remedial action. Based on the COCs found at SWMU 5 and the historical disposal records, it is anticipated that the temporary wastewater treatment unit will consist of media appropriate to remove solids and radionuclides. The used filter media would be sent to a land disposal facility or regenerated, as appropriate.

Water would be discharged from the water treatment unit to existing ditches and would exit PGDP through an existing KPDES-permitted outfall.

As noted in the introduction to Section 2.4.1, Table 2.2 lists and summarizes the narrative discussion in Sections 2.4.1.1 through 2.4.1.7. The gray shading in some rows of Table 2.2 indicates the technology was screened out as not applicable or not technically implementable.

It is reasonably expected that BGOU project effluent will meet all ambient water quality criteria in the receiving stream if the concentration of pollutants is at or below the Kentucky numeric water quality criteria for fish consumption specified in Table I of 401 *KAR* 10:031 Section 6(1). There are no waste load allocations approved by EPA pursuant to 40 *CFR* § 130.7 for the receiving stream (Bayou Creek) that would impact effluent limits based on the numeric water quality criteria for fish consumption specified in Table I of 401 *KAR* 10:031 Section 6(1).

2.4.2 Evaluation and Screening of Representative Technologies

Technologies retained following the initial screening in Section 2.4.1 are evaluated with respect to effectiveness, implementability, and cost in Table 2.2. The objective of this evaluation is to provide sufficient information for subsequent selection of RPOs in Section 2.4.3.

Effectiveness is the most important criterion at this evaluation stage. The evaluation of effectiveness was based primarily on the following:

- The potential effectiveness of process options in handling the estimated areas or volumes of contaminated media and meeting the RAO;

- The potential impacts to worker safety, human health, and the environment during construction and implementation; and
- The degree to which the processes are proven and reliable with respect to the contaminants and conditions at the site.

The evaluation of implementability includes consideration of the following:

- The availability of necessary resources, skilled workers, and equipment to implement the technology;
- Site accessibility and interfering infrastructure;
- Potential public concerns regarding implementation of the technology; and
- The time and cost-effectiveness of implementing the technology in the physical setting associated with the waste unit.

A relative cost evaluation is provided in Table 2.2 for comparison among technologies. Relative capital and O&M costs are described as high, medium, or low. Capital costs for the technologies evaluated tend to increase with increasing complexity and number of process unit operations. O&M costs are estimated to be lower when an alternative may meet RGs and reduce or eliminate the need for long-term monitoring.

While it is understood that monitoring will be needed for as long as there is a potential for a completed exposure pathway between COPCs and receptors, a technology that leaves waste in place is assumed for estimating purposes to have a 30-year long-term monitoring program that is moderate in cost. A technology such as a cap that incorporates a long-term monitoring program and cap maintenance is estimated to have higher O&M costs. These costs are based on references applicable to the particular process option, prior estimates, previous experience, and engineering judgment. The costs are not intended for budgeting purposes. Additionally, a LUC program will be implemented to assure that a containment remedy controls direct contact over the long-term protection of human health and the environment.

2.4.3 Representative Process Options

Table 2.3 shows the RPOs that were selected to be included in alternative development based on the implementability screening and effectiveness evaluation performed in Sections 2.4.1 and 2.4.2, respectively. The selected RPOs were determined to be the most potentially effective and implementable of the process options considered for each technology type. The RPOs were selected as needed to formulate the remedial alternatives that are appropriate for each SWMU, as presented in Section 3. Not all technologies or process options were developed into components of remedial alternatives.

In some cases, more than one representative process option was selected for a technology type; this was done, for example, when two or more process options were considered to be sufficiently different in their performance such that one would not adequately represent the other.

Table 2.3. Selection of Representative Process Options

General Response Actions	Technology Type	Representative Process Options	Basis for Selection
Land Use Controls	Institutional controls	Engineering, legal, or administrative controls intended to prevent or limit exposure to hazardous substances	Effective and implementable. Low costs.
Surface Controls	Soil Cover	Soil cover (including covers of varying thicknesses)	Effective and implementable. Prevents direct contact with contamination that cannot be effectively removed or destroyed by other means. Moderate cost.
Monitoring	Groundwater monitoring	Conventional sampling and analysis from monitoring wells. Potential exists for installation of additional monitoring wells	Effective and implementable for monitoring; moderate cost.
	Surface Water Monitoring	Conventional grab sample and analysis from surface water	Effective and implementable for monitoring; low cost.
Removal	Excavators	Backhoes, trackhoes	Demonstrated effectiveness to depths of 20 ft bgs; technically implementable at BGOU source areas. Moderate costs.
Containment	Capping	Kentucky Subtitle D Landfill Cap	Effective and implementable. Prevents direct contact and migration of residual contamination that cannot be effectively removed or destroyed by other means. Includes impermeable layer Moderate cost.
Containment	Subsurface horizontal barriers	Permeation grouting	Implementable and will provide some protection to groundwater if paired with a surface barrier to prevent infiltration.
Containment	Subsurface vertical barriers	Sheet pile	Sheet pile is selected as a complementary process option to excavation, not as a permanent installation.
Treatment	Physical/Chemical	Cement and chemical grouting	Implementable and will provide some protection to groundwater if paired with a surface barrier to prevent infiltration.

Table 2.3. Selection of Representative Process Options (Continued)

General Response Actions	Technology Type	Representative Process Options	Basis for Selection
Disposal	Land disposal	Off-site disposal	Effective and implementable as an adjunct technology for soil removal. High costs.
		Potential on-site disposal unit	Effective as an adjunct technology for soil removal. Not currently implementable. High costs.
		C-746-U on-site landfill	Effective and implementable for nonhazardous nonradioactive wastes, currently available. Wastes must meet WAC, including for PCBs. Moderate costs.
Disposal	Discharge of wastewater	Wastewater treatment demonstrating compliance with ARARs	Effective and implementable for treated groundwater. Moderate costs.

ARARs = applicable or relevant and appropriate requirements
BGOU = Burial Grounds Operable Unit
PCBs = polychlorinated biphenyls
WAC = waste acceptance criteria

THIS PAGE INTENTIONALLY LEFT BLANK

3. DEVELOPMENT AND SCREENING OF ALTERNATIVES

Remedial alternatives for SWMUs 5 and 6 are developed and screened in this section. The RPOs selected in Section 2 were combined to formulate a range of remedial alternatives to satisfy the RAOs, mitigate uncertainties for SWMUs 5 and 6, and address the source areas that are reported to be present at the individual SWMUs.

3.1 CRITERIA FOR THE DEVELOPMENT OF REMEDIAL ALTERNATIVES

The purpose of the FS and the overall remedy selection process is to identify remedial actions that eliminate, reduce, or control risks to human health and the environment and meet ARARs. The national program goal of the FS process, as defined in the NCP, is to select remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste. The NCP defines certain expectations for developing remedial action alternatives to achieve these goals.

Formulation of a No Action alternative is required by the NCP [40 *CFR* § 300.430(e)(6)]. The No Action alternative serves as a baseline for evaluating other remedial action alternatives and generally is retained throughout the FS process. No action implies that no remediation will be implemented to alter the existing site conditions. As defined in CERCLA guidance (EPA 1988), no action may include environmental monitoring; however, actions taken to reduce exposure, such as institutional controls including, but not limited to, administrative and legal controls, and physical controls such as fences and signage, are not included as a component of a No Action alternative.

3.2 DEVELOPMENT OF ALTERNATIVES

The remedial alternatives presented in this section were developed by applying professional judgment to the process of combining the RPOs identified in Section 2.4 into a range of remedial actions to meet the RAOs. Effectiveness, implementability, and cost criteria also were used to guide the development and screening of alternatives. The alternatives were formulated to create responses that vary in their extent of attainment of RAOs, implementability, and cost.

SWMUs 5 and 6 contain waste that poses a relatively low long-term threat (See Section 1.4.2.1). The developed alternatives are consistent with EPA's expectation that we use engineering controls, such as containment, for such waste; therefore, no alternatives were developed in which treatment is a principal element.

The primary elements that comprise each remedial alternative are summarized in Table 3.1. All alternatives that leave waste in place include LUCs to mitigate the identified uncertainties associated with SWMUs 5 and 6, as discussed in Section 2.4.1.1, and monitoring to ensure that the remedy remains protective. LUCs, in combination with engineering controls, ensure that the selected remedy provides long-term protection of human health.

In order to develop remedial costs for each alternative, assumptions were made about the area, depth, and volume of the contaminant source areas. These assumptions were based on the available characterization data and site history as described in Section 1, Table 1.3, and in the SWMU-specific sections. Containment remedies were estimated assuming the placement of a combined remedy over both SWMUs 5 and 6.

Table 3.1. Alternative Formulation for BGOU SWMUs 5 and 6

Alternative	Name	Description
1	No Action	• No action
2	Limited Action	• Long-term groundwater monitoring • LUCs
3	Soil Cover, LUCs, Monitoring	• Soil Cover (1 ft new soil) • Long-term groundwater monitoring • LUCs
4	18/6 Cover, LUCs, Monitoring	• 18/6 Soil Cover (18 inches of new native compacted soil topped with 6 inches of new topsoil) • Long-term groundwater monitoring • LUCs
5	Kentucky Subtitle D Cap, LUCs, Monitoring	• Kentucky Subtitle D cap • Long-term groundwater monitoring • LUCs
6	Excavation and Disposal	• Excavation of buried waste materials and affected soils • Treatment or disposal of residual groundwater, as indicated by sampling • Postremediation sampling and analysis • WAC sampling and analysis • Physical/chemical waste treatment, if necessary • Transportation of waste materials to disposal facility (on-site or off-site as available and deemed appropriate) • Backfill of excavated areas with clean soil

BGOU = Burial Grounds Operable Unit
LUCs = land use controls
SWMU = solid waste management unit
WAC = waste acceptance criteria

3.3 REMEDIAL ALTERNATIVES FOR SWMUs 5 AND 6

3.3.1 Alternative 1—No Action

Formulation of a No Action alternative is required by the NCP [40 *CFR* § 300.430(e)(6)]. The No Action alternative serves as a baseline for evaluation of other remedial action alternatives and is generally retained throughout the FS process. As defined in CERCLA guidance (EPA 1988), a No Action alternative may include environmental monitoring; however, actions taken to reduce exposure, such as site fencing, are not included as a component of the No Action alternative. As evaluated, Alternative 1 is a true No Action alternative and does not include environmental monitoring. Alternative 1 includes no actions and no costs.

3.3.2 Alternative 2—Limited Action

The limited action alternative includes LUCs and long-term monitoring. LUCs maintain restrictions on direct contact with the waste and soils in close proximity to the waste by controlling access and excavation in applicable areas. LUCs will be designed and implemented a LUCIP to ensure protectiveness, should DOE convey ownership of the property. Monitoring will be conducted to verify that there is no unacceptable threat to surface water or groundwater because waste is left in place.

This alternative will consist of the following, as necessary:

- Perform remedial design;
- Install monitoring wells, and conduct long-term RGA groundwater monitoring; and
- Implement LUCs.

3.3.2.1 Remedial design

A detailed remedial design will be performed for this remedial alternative. Existing geophysical data will be reviewed, and augmented as necessary, to define the limits of waste placement. It is necessary to determine these limits in order to accurately develop the extent of LUCs. Additionally, MW placement will be considered in the context of satisfying the long-term needs of the BGOU, as well as optimizing placement for other site needs as applicable.

3.3.2.2 Long-term groundwater and surface water monitoring

The long-term groundwater monitoring program will incorporate sampling of strategically placed upgradient and downgradient wells, screened in the RGA, and analyses for a broad suite of SWMU-related analytes. For estimating purposes, it is assumed that wells will be sampled quarterly for two years, with additional semiannual monitoring through 10 years. Sampling and analysis will continue biannually for years 11 through 30. Existing PGDP monitoring wells would be used where practicable with new wells added as needed. SWMU-specific monitoring details will be developed in the remedial design, which would be provided for regulatory review and approval. For estimating purposes, it is assumed that one upgradient well and three downgradient wells would be required at each SWMU.

Long-term surface water monitoring will mitigate the potential for leachate from SWMUs 5 and 6 to impact adjacent surface water ditches. If a periodic seep is observed in ditches adjacent to SWMUs 5 and 6, it will be sampled for a broad range of analytes. SWMU-specific monitoring details will be developed in the remedial design, which would be provided for regulatory review and approval.

3.3.2.3 LUCs

LUCs as described in Section 2.4.1.1 would be implemented for units where waste remains in place that precludes unrestricted use and unlimited exposure.

3.3.3 Alternative 3—Soil Cover, LUCs, Monitoring

Use of a 1-ft, clean topsoil cover will address uncertainty regarding risk from surface soil contamination by providing a direct contact barrier to any contaminated soils and waste. LUCs maintain restrictions on direct contact with the waste and soils in close proximity to the waste by controlling access and excavation in applicable areas. LUCs will be designed and implemented through a LUCIP to ensure protectiveness, should DOE convey ownership of the property. Monitoring will be conducted to verify that there is no unacceptable threat to surface water or groundwater because waste is left in place.

The specific design details would depend on the SWMU. If the alternative is selected in the ROD, a remedial design will be developed, which would be provided for regulatory review and approval.

This alternative will consist of the following, as necessary:

- Perform remedial design,
- Install soil cover,
- Install monitoring wells and conduct long-term RGA groundwater monitoring, and
- Implement LUCs.

3.3.3.1 Remedial design

Detailed remedial design will be performed for this remedial alternative. Engineering data will be collected as necessary to support and optimize sizing and design. The data collection would be based on an approach to be developed in the RDWP.

The remedial design will include updating the geophysical survey to ensure that the bounds of the waste area are well understood. The remedial design will include a topographic survey to document site elevation and current drainage patterns. Any cover design will take into consideration the existing drainage so that surface water has an appropriate pathway within the confines of existing sitewide discharge requirements.

The clean soil used in the cover is not intended to retard surface water infiltration. As such, a permeability specification will not be developed for the material during the remedial design. It is anticipated that soil will be imported from local sources. Because of the thin lift to be placed, local topsoil will be specified.

3.3.3.2 Soil cover construction

A surface soil cover will be constructed over the unit. For evaluation and cost estimating purposes, it is assumed the cover will consist of 1 ft of clean soil placed within the existing SWMU boundaries. The cover will be graded to drain, mulched, and seeded to prevent erosion. Armoring (riprap) may be installed at sharp transition points or where erosion may occur with native plant species.

3.3.3.3 Long-term groundwater monitoring

A long-term groundwater monitoring program comparable to that described under Alternative 2 would be implemented.

3.3.3.4 LUCs

LUCs as described in Section 2.4.1.1 would be implemented for units where waste remains in place that precludes unrestricted use and unlimited exposure.

3.3.4 Alternative 4—18/6 Cover, LUCs, Monitoring

Use of a more substantial soil cover (consisting of 18 inches of compacted local soil and 6 inches of topsoil) provides a direct contact barrier to any contaminated soils and waste using locally available materials. LUCs maintain restrictions on direct contact with the waste and soils in close proximity to the waste by controlling access and excavation in applicable areas. LUCs will be designed and implemented through a LUCIP to ensure protectiveness, should DOE convey ownership of the property. Monitoring will be conducted to verify that there is no unacceptable threat to surface water or groundwater because waste is left in place.

If the alternative is selected in the ROD, a detailed design will be developed, which would be provided for regulatory review and approval through the CERCLA process.

This alternative will consist of the following, as necessary:

- Perform remedial design,
- Install soil cover,

- Install monitoring wells and conduct long-term RGA groundwater monitoring, and
- Implement LUCs.

3.3.4.1 Remedial design

Detailed remedial design will be performed for this alternative. Engineering data will be collected as necessary to support and optimize sizing and design. The data collection would be based on an approach to be developed in the RDWP.

The remedial design will include updating the geophysical survey to ensure that the bounds of the waste area are well understood. The remedial design will include a topographic survey to document site elevation and current drainage patterns.

The clean soil used in the cover is not intended to retard surface water infiltration. As such, a permeability specification will not be developed for either material during the remedial design. It is anticipated that soil will be imported from local sources.

3.3.4.2 18/6 Soil Cover Construction

A surface soil cover will be constructed over the unit. For evaluation and cost estimating purposes, it is assumed the cover will consist of 18 inches of compacted clean native soil topped by 6 inches of clean topsoil. The cover will be compacted, graded to drain, mulched and seeded to prevent erosion. Armoring (riprap) may be installed at sharp transition points or where erosion may occur with native plants species.

3.3.4.3 Long-term groundwater monitoring

A long-term RGA groundwater monitoring program comparable to that described under Alternative 2 would be implemented.

3.3.4.4 LUCs

LUCs as described in Section 2.4.1.1 would be implemented for units where waste remains in place that precludes unrestricted use and unlimited exposure.

3.3.5 Alternative 5—Kentucky Subtitle D Cap, LUCs, Monitoring

This cap eliminates direct contact with surface soils and buried waste. The cap also will provide hydraulic containment to prevent the type of spillage that has occurred in the past at SWMU 5. Installation of a Kentucky Subtitle D Cap at SWMUs 5 and 6, which includes multilayers that are distinctly different to the natural subsoils, provides greater depth to the buried waste. These aspects (thickness and distinct properties) of the cap are expected to provide protection of individuals from inadvertent intrusion by alerting them that this is a man-made engineered cover over something that is potentially hazardous to human health and by making it more difficult to expose the buried waste. Based upon the waste inventory, the buried wastes at SWMUs 5 and 6 (including LLW) are considered low level threat waste consistent with EPA guidance. As discussed in Section 2.4.1.1 LUCs maintain restrictions on direct contact with the waste and soils in close proximity to the waste by controlling access and excavation in applicable areas. LUCs will be designed and implemented through a LUCIP to ensure protectiveness, should DOE convey ownership of the property. Monitoring will be conducted to verify that there is no unacceptable threat to surface water or groundwater because waste is left in place. The specific design details would depend on the SWMU. If the alternative is selected in the ROD, a detailed remedial design will be developed, which would be provided for regulatory review and approval.

This alternative will consist of the following activities as necessary:

- Conduct remedial design,
- Place grade fill to achieve adequate drainage,
- Install Kentucky Subtitle D cap,
- Install monitoring wells and conduct long-term RGA groundwater monitoring, and
- Implement LUCs.

3.3.5.1 Remedial design

Detailed remedial design will be performed for this remedial alternative. Engineering data collection to support cover sizing, design and optimization would be performed as necessary during the remedial design. The data collection would be based on an approach to be developed in the RDWP.

The remedial design will include updating the geophysical survey to ensure that the bounds of the waste area are well understood. The remedial design may include a topographic survey to document site elevation and current drainage patterns.

This alternative does not anticipate taking credit for the existing cover as a barrier to accessing the waste.

Once field measurements are completed, an ARAR-compliant remedial design will be completed.

3.3.5.2 Place grade fill to achieve adequate drainage

Prior to cap installation, general grade fill will be placed and compacted to achieve the desired grade to ensure proper drainage. It is anticipated that existing topsoil and root mass will be left in place and not removed. Clearing and grubbing activities will be limited to concrete, structures, or other installations that would impede cap placement. This subgrade will be compacted, tested and proof-rolled per specification.

3.3.5.3 Install Kentucky Subtitle D cap

This type of cover is designed to meet performance objectives for a Subtitle D landfill (i.e., Contained Landfill under 401 *KAR* 48:080) and will prevent direct exposure to the waste and cover areas where surface water could penetrate and leach COCs, causing them to be transported into lower soil layers and groundwater. The capping activity will include contouring of surface soils, as needed, to support the structural cap per established requirement, and placement of the capping materials in accordance with ARARs. The cover will include the components.

- A filter fabric or other approved material

- A 12-inch sand gas venting system with a minimum hydraulic permeability of 1E-03

- A filter fabric or other approved material

- An 18-inch clay layer with a maximum permeability of 1E-07 cm/sec

- A 12-inch drainage layer with a minimum permeability of 1E-03 cm/sec for areas of the final cap with a slope of less than 15%

- A 36-inch vegetative soil layer

Alternative specifications may be used if approved by KDEP and EPA through the CERCLA process, provided the alternative results in similar performance with respect to safety, stability, and environmental protection. For example, a gas venting layer may not be an appropriate design feature for installations involving inorganic wastes that will not generate methane as they decompose. Also, an alternative design may substitute a synthetic liner of 40 mil for the 18-inch clay layer.

3.3.5.4 Install monitoring wells and conduct long-term groundwater monitoring

A long-term groundwater monitoring program comparable to that described under Alternative 2 would be implemented.

3.3.5.5 Implement LUCs

LUCs as described in Section 2.4.1.1 would be implemented for units where waste remains in place that precludes unrestricted use and unlimited exposure.

3.3.6 Alternative 6—Excavation and Disposal of Waste Materials and Affected Soil

Waste materials in the burial cell and surrounding affected soil will be excavated and removed and replaced with clean backfill.

This alternative will consist of the following activities as necessary:

- Remedial design;
- Excavation of waste and source area contaminated soils;
- Treatment or disposal of residual groundwater, if necessary, as indicated by sampling results;
- Sampling to confirm soils at the excavation margins are below RGs (as defined in the ROD);
- WAC sampling and analysis;
- Treatment of the waste and soil, if necessary, for transportation and/or disposal;
- Transportation and disposal of waste; and
- Backfill with clean soil.

This alternative would address or eliminate long-term risks to the environment and could be conducted in accordance with ARARs; therefore, long-term groundwater monitoring and LUCs associated with this alternative are not necessary as long as the excavation removes affected soils to levels below RGs.

3.3.6.1 Remedial design

Detailed remedial design will be performed for this remedial alternative. Engineering data collection to support technology sizing, design, and optimization would be performed as necessary during the remedial design. The data collection would be based on an approach to be developed in the RDWP.

The remedial design will include updating the geophysical survey to ensure that the bounds of the waste area are well understood.

3.3.6.2 Excavation of waste materials and affected soils

Waste and soil containing COCs above their cleanup levels will be removed from the SWMU to a maximum depth of 20 ft. The specific equipment, techniques and approach implemented under this alternative will be detailed in the remedial design. A number of factors and variables will be considered including, but not limited to, field lighting; site controls and monitoring; controls for fugitive emissions; weather protection; combustibles monitoring; and fire suppression. Potential methods are listed below.

- The waste material will be excavated with mechanized equipment such as loaders and trackhoes.

- Depending on how the material is to be characterized to meet the disposal facility WAC, the waste and soil either will be temporarily staged at the PGDP or loaded directly into waste containers. If the waste and soil meets the WAC of the C746-U Landfill or the potential on-site disposal unit (if available), then it may be directly loaded into trucks for transportation and disposal.

- The material will be segregated based on physical, chemical, and radioactive characteristics, as determined by field observation, testing, and monitoring.

- The waste and soil will be treated, if necessary, to meet WAC requirements. Waste may be temporarily stored for the purpose of treatment in containers such as 208-liter (55-gal) drums; 1,325-liter (350-gal polyliners); 1,585-kg (3,500-lb) steel boxes; or 10-m^3 (25-yd^3) roll-off containers. The wastes will be stored in compliance with ARARs. Temporary storage would occur only as long as needed to get the waste through the treatment process and sent directly to disposal.

- If the material is determined by analytical testing to be nonhazardous, does not exceed the cleanup levels, and meets PGDP guidance for clean backfill (PRS 2010), it will be set aside and considered for use as backfill. This procedure will be documented in the remedial action work plan (RAWP).

The excavation alternative includes the removal of all visible waste, with no prescribed restriction on excavation depth, although the cost estimates assume that no visible waste would be encountered below 20 ft. Excavation will progress until visible wastes have been removed and the appropriate cleanup levels are met. It is anticipated that cleanup levels would be met before reaching a depth of approximately 16 ft, a depth that also corresponds with typical maximum depths for utility installations at PGDP (and therefore protective of industrial and outdoor worker). Excavations may be advanced to 20 ft, if necessary, in an effort to meet groundwater protective RGs. In the absence of visible waste, excavation below 20 ft to meet groundwater protective RGs will be at DOE's discretion and communicated to the regulators. The bottom and sidewalls of an excavation would be characterized and the conditions documented.

Postremediation samples will be collected to determine the effectiveness of remediation and to ascertain when excavation is complete. The eventual evaluation of soil COC concentrations will be based on a cumulative ELCR and cumulative HI calculation using postremediation sampling results. If these cumulative targets are met at all sampling locations, no additional monitoring will be necessary.

3.3.6.3 Treatment or disposal of residual groundwater

An on-site wastewater treatment unit will be used as required to treat wastewater generated from dewatering as needed based on sample analysis results. Water will come from both precipitation contacting waste as well as groundwater seeping from sidewalls. A wastewater treatment unit will be designed as part of the remedial action to treat the COCs. Wastewater treatment will demonstrate compliance with ARARs. A temporary confinement structure or existing decontamination pad will provide a controlled environment for performing treatment operations, as necessary.

3.3.6.4 Sampling and analysis

Several types of sampling and analysis efforts will be performed during the excavation phase. As required, one set of samples will be collected to characterize the excavated material to meet the disposal facility WAC requirements. Periodic sampling and analysis will occur throughout the course of excavating the SWMU to confirm clean margins. Excavation will continue to the desired depth or until material above RGs no longer is encountered. A final set of samples will be collected from the bottom and sides of the excavation to confirm that the material above the RGs has been removed. The excavation will be backfilled after this is confirmed.

3.3.6.5 Transportation and disposal of waste

The exact mode of transportation will be chosen based on material characteristics and disposal facility requirements. The shipping container requirements and transportation method(s) will be described in detail in the RDWP. The transportation requirements will be more accurately determined after the SWMU wastes are characterized.

If waste is shipped off-site for disposal, it is anticipated that the wastes will be transported either by rail cars in appropriate containers or by truck utilizing closed containers such as intermodals or roll-offs. Waste of sufficiently high radioactivity may require transport in steel drums or B-25 boxes. The waste may require the addition of absorbent material prior to being transported in order to meet transportation requirements or receiving facility WAC.

If waste is disposed of on-site at the C-746-U Landfill or potential on-site disposal facility (if available), wastes will be transported to the facilities as bulk truckload shipments or via truck in appropriate shipping containers.

3.3.6.5.1 Off-Site shipment to an appropriate receiving facility

This option assumes that the waste would be shipped off-site to an existing federal or commercial receiving facility. Shipments would require manifesting and would occur in accordance with local, state, and federal regulations. The excavated waste would undergo treatment at an off-site treatment facility, if necessary, to meet the WAC of the disposal facility.

Any radioactively or chemically contaminated solid waste generated during remedial actions would be collected and placed in containers acceptable for transportation or combined with bulk contaminated soils for shipment off-site. The rail cars or trucks used to haul contaminated materials would undergo safety inspection before use. All containers would be checked for surface contamination and decontaminated, if necessary, before being loaded onto the rail cars or trucks. Containers would be manifested according to the applicable requirements for shipments of radioactive and chemically hazardous waste materials. As required, predesignated routes would be traveled and an emergency response program would be developed for responding to any accidents. Off-site transportation of radioactively and chemically contaminated materials would comply with all applicable state and federal regulations.

3.3.6.5.2 PGDP disposal facilities

An evaluation of the feasibility of constructing an on-site disposal facility for CERCLA waste is underway. Should such a facility be constructed and available within a reasonable time frame for use, it would provide the option for cost-effective implementation of this alternative. The costs of completing Alternative 6, while using an on-site disposal facility for CERCLA wastes also have been developed and are shown as Alternative 6a. Waste also will be evaluated against the WAC of the C-746-U Landfill for potential disposal at that facility, as appropriate.

3.3.6.6 Backfill with clean soil

Upon completion of excavation and receipt of acceptable postremediation sample results, clean or uncontaminated fill material will be placed in the excavation. The fill material will be placed in the excavation in lifts and compacted as described in the RDWP. The excavation will be backfilled and graded to return the location to its original condition. If confirmed clean, soil from the upper layer of each SWMU that has been set aside will be combined with soil from elsewhere on the facility. All backfill material used will be confirmed clean prior to placement, in accordance with DOE protocol (PRS 2010). The cost estimate for this alternative assumes clean soil is obtained from off-site sources to be used for backfill. Backfill options may be evaluated to consider potential creation of wetlands.

3.3.6.7 Metal recovery (optional for SWMU 5)

Metal recovery provides an opportunity to recycle commodity metals. Metal recovery is an option for SWMU 5 only because SWMU 5 contains potentially recoverable metals. Should an appropriate facility be available at the time, it will be evaluated for its cost effectiveness should excavation be implemented.

3.4 SCREENING OF ALTERNATIVES

Alternatives are screened using the process described in EPA (1988) and the NCP to reduce the number of alternatives carried forward to detailed analysis. Defined alternatives are evaluated against the short- and long-term aspects of three broad criteria: effectiveness, implementability, and cost. Because the purpose of the screening evaluation is to reduce the number of alternatives that will undergo a more thorough and extensive analysis, alternatives are evaluated more generally in this phase than during the detailed analysis.

The evaluation of effectiveness considers reductions in toxicity, mobility, or volume of COCs. The long-term aspect evaluates effectiveness and permanence of the alternative, while the short-term aspect evaluates alternatives with respect to their effects on human health and the environment during construction and implementation of the remedial action. The evaluation of implementability considers technical feasibility criteria, including the ability to construct, operate, and maintain the remedy, as well as administrative feasibility criteria, including the availability of treatment, storage, and disposal capacity. Evaluation of cost for the alternatives is based on the capital and O&M costs for the primary technologies utilized. Alternatives with the best combinations of effectiveness and implementability and the lowest costs are retained for detailed analysis and comparative analysis. The screening evaluation for SWMUs 5 and 6 along with detailed and comparative analyses of alternatives for each BGOU SWMU is presented in the SWMU-specific sections of Sections 5.4 and 5.5, respectively.

4. DETAILED AND COMPARATIVE ANALYSES OF ALTERNATIVES

Remedial alternatives were developed in Section 3. A determination about whether to retain each alternative for detailed analysis occurs in Section 5. The purpose and approach for performing the detailed analysis are discussed here in Section 4. Results of the detailed analysis form the basis for comparing alternatives. The general approach for performing the comparative analysis also is presented here in Section 4. The SWMUs-specific comparative analyses of each alternative retained for consideration is presented in Section 5. The results of the detailed and comparative analyses ultimately will be used for preparing the Proposed Plan for BGOU SWMUs 5 and 6.

4.1 DETAILED ANALYSIS

4.1.1 Approach to the Detailed Analysis

The remedial action alternatives developed in Section 3 and retained after screening are analyzed in detail against the nine CERCLA threshold, balancing, and modifying criteria outlined in 40 *CFR* § 300.430(e)(9)(iii). This analysis forms the basis for selecting a final remedial action. The intent of this analysis is to present sufficient information for selection of an appropriate remedy.

4.1.2 Overview of the CERCLA Evaluation Criteria

The CERCLA evaluation criteria include technical, administrative, and cost considerations; compliance with specific statutory requirements; and state and community acceptance. Overall protection of human health and the environment and compliance with ARARs (in the absence of a CERCLA waiver) are categorized as threshold criteria that any viable alternative must meet. The balancing criteria upon which the detailed analysis is primarily based include long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost. Both state acceptance and community acceptance are considered modifying criteria and are evaluated following a public comment period on the Proposed Plan, as well as when a final decision is made and the ROD is prepared. Each criterion is described below.

4.1.2.1 Overall protection of human health and the environment (threshold criterion)

Alternatives will be assessed to determine whether they can adequately protect human health and the environment in both the short and long term. Alternatives must protect human health and the environment from unacceptable risks posed by contaminants present at the BGOU source areas by eliminating, reducing, or controlling exposures as established during the development of RAOs consistent with 40 *CFR* § 300.430(e)(2)(I). Overall protection of human health and the environment draws on the assessments of the other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs (in the absence of a CERCLA waiver).

4.1.2.2 Compliance with ARARs (threshold criterion)

ARARs include substantive federal or more stringent state environmental or facility siting laws/regulations. They do not include occupational safety or worker radiation protection requirements. Additionally, per 40 *CFR* § 300.400(g)(3), other advisories, criteria, or guidance may be considered in determining remedies (TBC category). CERCLA § 121(d)(4) provides several ARAR waiver options that may be invoked, provided that human health and the environment are protected. Activities conducted on-site must comply with the substantive, but not administrative, requirements. Administrative requirements include applying for permits, recordkeeping, consultation, and reporting. Activities conducted off-site must comply with both the substantive and administrative requirements of applicable laws. Measures required to meet ARARs will be incorporated into the design phase and implemented during the construction and operation phases of the remedial action.

ARARs typically are divided into three categories: (1) chemical-specific, (2) location-specific, and (3) action-specific. Chemical-specific ARARs provide health- or risk-based concentration limits or discharge limitations in various environmental media (i.e., surface water, groundwater, soil, or air) for specific hazardous substances, pollutants, or contaminants. Location-specific ARARs establish restrictions on permissible concentrations of hazardous substances or establish requirements for how activities will be conducted because they are in special locations (e.g., floodplains or historic districts). Action-specific ARARs include operation, performance, and design of the preferred alternative based on waste types and/or media to be addressed and removal/remedial activities to be implemented.

Alternatives are assessed to determine whether they meet ARARs identified for each alternative. If ARARs will not be met at the end of an action, an evaluation will occur to determine when a basis exists for invoking one of the ARAR waivers cited in 40 *CFR* § 300.430(f)(l)(ii)(c) that are listed as follows:

(1) The alternative is an interim measure and will become part of a total remedial action that will attain the federal or state ARARs.

(2) Compliance with the requirement will result in greater risk to human health and the environment than other alternatives.

(3) Compliance with the requirement is technically impracticable from an engineering perspective.

(4) The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method or approach.

(5) With respect to a state requirement, the state has not consistently applied, or demonstrated the intention to consistently apply, the promulgated requirement in similar circumstances at other remedial actions within the state.

An alternative must meet this threshold criterion (or obtain a CERCLA waiver) to be eligible for selection. The ARARs in this FS are tailored to the scope of the FS, which does not include groundwater or surface water remediation. ARARs for each of the remedial alternatives retained for detailed and comparative analysis at one or more of the SWMUs are listed in Appendix D.

4.1.2.3 Long-term effectiveness and permanence (balancing criterion)

Long-term effectiveness and permanence are an assessment of the risk remaining at the site after RAOs have been met and the effectiveness and reliability of controls required to manage the risk posed by untreated waste or treatment residuals. Alternatives will be assessed for the long-term effectiveness and permanence they afford, along with the degree of certainty that the alternative will prove successful. These are factors that may be considered in this assessment:

- The magnitude of residual risk from untreated waste or treatment residuals remaining at the conclusion of the remedial activities, including their volume, toxicity, and mobility.

- The adequacy and reliability of controls such as containment systems necessary to manage treatment residuals and untreated waste. For example, this factor addresses uncertainties associated with land disposal for providing long-term protection from residuals; the assessment of the potential need to replace technical components of the alternative, such as a cover or treatment system; and the potential exposure pathways and risks posed should the remedial action need replacement.

- The ability of controls to prevent treatment residuals and untreated waste from serving as a continuing source of contamination to groundwater, such that groundwater quality cannot be restored throughout the plume.

4.1.2.4 Reduction of toxicity, mobility, or volume through treatment (balancing criterion)

The degree to which the alternatives employ treatment or recycling that reduces toxicity, mobility, or volume will be assessed, including how the treatment is used to address the principal threats posed by the release sites. Factors that will be considered, as appropriate, include these:

- Treatment or recycling processes that the alternatives employ and the materials that they will treat;

- The amount of hazardous substances, pollutants, or contaminants that will be destroyed or recycled;

- The degree of expected reduction in toxicity, mobility, or volume of the waste because of the treatment or recycling and the specification of which reductions are occurring;

- The degree to which the treatment is irreversible;

- The type and quantity of residuals that will remain following treatment, taking into consideration the persistence, toxicity, mobility, and propensity to bioaccumulate such hazardous substances and their constituents; and

- The degree to which treatment reduces the inherent hazards posed by the principal threats at the release sites.

4.1.2.5 Short-term effectiveness (balancing criterion)

Short-term effects during implementation of the remedial action will be assessed, including the following:

- Short-term risks that might be posed to the community;
- Potential risks or hazards to workers and the effectiveness and reliability of protective measures;
- Potential environmental effects and the effectiveness and reliability of mitigative measures; and
- Time until RAOs are achieved.

4.1.2.6 Implementability (balancing criterion)

The ease or difficulty of implementing the alternatives will be assessed by considering the following types of factors, as appropriate:

- Technical feasibility, including the technical difficulties and unknowns associated with constructing and operating the technology, reliability of the technology, ease of undertaking additional remedial actions, and ability to monitor the effectiveness of the remedy;

- Administrative feasibility, including the availability of treatment, storage, and disposal capacity; and
- Availability of required materials and services.

4.1.2.7 Cost (balancing criterion)

Supporting calculations for conceptual designs including cost estimates are provided in Appendix C. These are the types of costs assessed:

- Remedial design and construction documentation costs, including remedial design, construction management and oversight, remedial design and remedial action document preparation, project/program management and oversight, and reporting costs;
- Construction costs, including capital equipment, general and administrative costs, and construction subcontract fees;
- Operating and maintenance costs;
- Equipment replacement costs; and
- Surveillance and monitoring costs.

EPA guidance distinguishes between scope contingency and bid contingency costs (EPA 2000). Scope contingency costs represent risks associated with incomplete design and include contributing factors such as limited experience with technologies, additional requirements because of regulatory or policy changes, and inaccuracies in defining quantities or characteristics. Bid contingency costs are unknown costs at the time of estimate preparation that become known as remedial action construction proceeds. They represent reserves for quantity overruns, modifications, change orders, and claims during construction. Although EPA guidance allows for contingency based on the complexity and size of the project and the inherent uncertainties related to the remedial technologies, scope contingency was applied to the excavation alternative cost estimates prepared for this FS.

Life-cycle costs are presented as Net Present Worth, and in escalated dollars, for capital, O&M, and periodic costs for each alternative. Escalation was applied as directed by DOE Order 430.1A, "Life Cycle Asset Management." Guidance was provided by U.S. Department of Energy, Office of Project Assessment, "FY 2011 Field Budget Call: Escalation Rates."

Detailed total costs for implementing each alternative at the appropriate BGOU source areas are presented in Appendix C. Summary costs for implementing each alternative at the individual source areas are presented in the sections for the individual SWMUs that follow.

The alternative cost estimates are for comparison purposes only and are not intended for budgetary, planning, or funding purposes. Estimates were prepared to meet the -30% to +50% range of accuracy recommended in CERCLA guidance EPA (1988).

4.1.2.8 State acceptance (modifying criterion)

This assessment evaluates the technical and administrative issues and concerns Kentucky Department for Environmental Protection (KDEP) may have regarding each of the alternatives. This criterion will be addressed in the Proposed Plan and ROD after KDEP comments on the FS are received.

4.1.2.9 Community acceptance (modifying criterion)

This assessment evaluates the issues and concerns the public may have regarding each of the alternatives. This criterion will be addressed in the ROD after public comments on the Proposed Plan are received.

4.1.3 Federal Facility Agreement and NEPA

Additional requirements considered in this FS include the specific requirements of the FFA and NEPA, consistent with the DOE's Secretarial Policy Statement on NEPA in June of 1994 (DOE 1994).

4.1.3.1 Otherwise required permits under the FFA

When DOE proposes a response action, Section XXI of the FFA further requires that DOE identify each state and federal permit that otherwise would have been required in the absence of CERCLA Section 121(e)(1) and the NCP. DOE identifies the permits that otherwise would be required, the standards, requirements, criteria, or limitations necessary to obtain such permits and provide an explanation of how the proposed action will meet the standards, requirements, criteria, or limitations identified.

An evaluation of alternatives presented in the FS determined that the otherwise required permits may include the KPDES permit; the RCRA Treatment, Storage, and Disposal Facility permit; and the Solid Waste Landfill permit. Jurisdictional wetlands have been identified on PGDP and will be delineated, as necessary, prior to a remedial action.

PGDP currently operates under KPDES Permit No. KY0004049, Hazardous Waste Facility Operating Permit No. KY8-890-008-982, and Solid Waste Permit No. 07300045. The substantive requirements of the otherwise required permits are identified in the ARARs provided for each alternative. A list of ARARs is provided in Appendix D.

4.1.3.2 NEPA values

The following NEPA values also are considered in this FS to the extent practicable, consistent with DOE policy.

- Land use
- Air quality and noise
- Geologic resources and soils
- Water resources
- Wetlands and floodplains
- Ecological resources
- T&E species
- Migratory birds
- Cultural and archeological resources
- Socioeconomics, including environmental justice and transportation

Alternatives selected for detailed analysis would have no identified short-term or long-term impacts on geological resources, migratory birds, cultural resources, or socioeconomics. Upon final selection of the alternative, the absence of any short- and long-term impacts to these values will be verified.

No long-term impacts to air quality or noise would result from implementation of the remedial action alternatives evaluated. Remedial actions should not result in generation of air pollutants above regulatory limits, and noise levels should be similar to current background levels.

None of the remedial alternatives would have any impacts on geologic resources, and construction activities would only have short-term impacts on soils. Site clearing, excavation, grading, and contouring would alter the topography of the construction area, but the geologic formations underlying those sites should not be affected. Construction would disturb existing soils, and some topsoil might be removed in the process. Soil erosion impacts during construction would be mitigated through the use of best management practices control measures (e.g., covers and silt fences). No conversion of prime farmland soils is expected to occur. Surface soil quality may improve for all alternatives except for No Action and Limited Action. Any alternative that would create disturbances also would include restoration to these areas.

None of the activities associated with the remedial alternatives would be conducted within a floodplain. Wetlands were identified during the 1994 COE environmental investigation for the area surrounding PGDP. This investigation identified five acres of potential wetlands inside the fence at PGDP (COE 1994). The COE made the determination that these areas are jurisdictional wetlands (COE 1995).

As stated in the regulations, construction activities must avoid or minimize adverse impacts on wetlands and act to preserve and enhance their natural and beneficial values [Executive Order 11990 and 10 *CFR* § 1022]. These applicable requirements include avoiding construction in wetlands, avoiding (to the extent practicable) long- and short-term adverse impacts to floodplains and wetlands, avoiding degradation or destruction of wetlands, and avoiding discharge of dredge and fill material into wetlands. In addition, the protection of wetlands shall be incorporated into all planning documents and decision making as required by 10 *CFR* § 1022.3.

No long- or short-term impacts have been identified to archeological or cultural resources. DOE developed the CRMP (BJC 2006) to define the preservation strategy for PGDP and direct efficient compliance with the NHPA and federal archaeological protection legislation at PGDP. No archaeological or historical resources have been identified within the vicinity of the BGOU SWMUs; however, should portions of the project remove soils that previously have been undisturbed, an archaeological survey will be conducted in accordance with the CRMP. If archaeological properties are located that will be affected adversely, then appropriate mitigation measures will be employed.

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations," requires agencies to identify and address disproportionately high and adverse human health or environmental effects their activities may have on minority and low-income populations. There is a disproportionately high percentage of minority and low-income populations within 50 miles of the PGDP site (DOE 2004), but since there are no potential impacts from these alternatives, there would be no disproportionate or adverse environmental justice impacts to these populations associated with these alternatives.

No long- or short-term adverse transportation impacts are expected to result from implementation of remedial alternatives. During construction activities there would be a slight increase in the volume of truck traffic in the vicinity of the BGOU SWMUs, but the affected roads are capable of handling the additional truck traffic. Any wastes transferred off-site or transported in commerce along public rights-of-way will meet the packaging, labeling, marking, manifesting, and placarding requirements for hazardous materials at 49 *CFR* Parts 107, 171-174, and 178; however, transport of wastes along roads within the PGDP site that are not accessible to the public would not be considered "in commerce."

In addition, CERCLA § 121(d)(3) provides that the off-site transfer of any hazardous substance, pollutant, or contaminant generated during CERCLA response actions be sent to a treatment, storage, or disposal facility that complies with applicable federal and state laws and has been approved by the EPA for acceptance of CERCLA waste. Accordingly, DOE will verify with the appropriate EPA regional contact that any needed off-site facility is acceptable for receipt of CERCLA wastes before transfer.

4.1.3.3 Natural Resources Damage Assessment

The alternatives evaluated are acceptable because they are anticipated to have beneficial impact, and they are not expected to cause any further injury to a natural resource through their implementation than already might exist. Each alternative requires time to attain the CERCLA remediation cleanup criteria, with some alternatives requiring a longer period to reach the criteria.

4.2 COMPARATIVE ANALYSIS

The SWMUs 5 and 6 remedial action alternatives are subjected to comparative analysis to identify the relative advantages and disadvantages of each so that the key tradeoffs that risk managers must balance can be identified. The comparative analysis provides a measure of the relative performance of the alternatives against each evaluation criterion.

Alternatives are compared based on two of the three CERCLA categories including threshold criteria and primary balancing criteria. The third category, modifying criteria, including state and community acceptance, will not be addressed until the Proposed Plan has been issued for public review. These modifying criteria will be addressed in the responsiveness summary and the ROD, which will be prepared following the public comment period.

Threshold criteria are of greatest importance in the comparative analysis because they reflect the key statutory mandates of CERCLA, as amended. The threshold criteria that any viable alternative must meet are as follows:

- Overall protection of human health and the environment, and
- Compliance with ARARs (in the absence of a CERCLA waiver).

The primary balancing criteria to which relative advantages and disadvantages of the alternatives are compared include the following:

- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, or volume through treatment;
- Short-term effectiveness;
- Implementability; and
- Cost.

The first and second balancing criteria address the statutory preference for treatment as a principal element of the remedy and the bias against off-site land disposal of untreated material. Together with the third and fourth criteria, they form the basis for determining the general feasibility of each potential remedy. The final criterion addresses whether the costs associated with a potential remedy are proportional to its overall effectiveness, considering both the cleanup period and O&M requirements during and following cleanup, relative to other alternatives. Key tradeoffs among alternatives most frequently will relate to one or more of the balancing criteria.

The comparative analyses for remedial alternatives are presented in the SWMU-specific sections that follow.

THIS PAGE INTENTIONALLY LEFT BLANK

5. SWMUS 5 AND 6

Previous sections of this document presented sitewide information, the approach to addressing the BGOU SWMUs, and key findings as the basis for technology screening and development of alternatives. This section documents specific background information required in an FS to support a remedial decision for a consolidated remedial action at SWMUs 5 and 6, consolidating the current understanding of the burial ground, nature and extent of contamination, and potential for migration and risks.

5.1 SWMU 5

5.1.1 History and Background

The following sections provide site history and background information specific to SWMU 5.

5.1.1.1 Historical Information, Site Description, and History

The C-746-F Burial Yard (SWMU 5) is located in the northwestern section of the PGDP secured area. The SWMU, which covers an area of approximately 197,400 ft^2, is located adjacent to the C-746-P/P1 scrap yard to the north and SWMU 6 to the east. Unnamed gravel roads parallel the north, south, and east sides, while a paved road lies to the west. The ground surface is covered with short grasses and various flowering herbaceous plants (DOE 1998). Shallow drainage swales bordering the SWMU direct surface runoff to KPDES Outfall 001. The ground surface has no significant surface structures. Approximately 5 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.

SWMU 5 was in operation from 1965 to 1987. The burial cells 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. 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. Waste placed in the yard disposal cells was covered with 2–3 ft of soil.

Disposal cells 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 6–15 ft bgs. Figure 5.1 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.

Based upon disposal records, SWMUs 5 and 6 contain industrial wastes, some of which are LLW. Industrial wastes in burial grounds at the PGDP are known to contain waste that could be contaminated with PCBs or RCRA hazardous wastes. Without more definitive waste characterization (i.e., sampling and analysis), it is not possible to state whether or not PCBs or RCRA hazardous wastes are also present at SWMUs 5 and 6. Based upon the waste inventory, the buried wastes at SWMUs 5 and 6 (including low-level radioactive waste) are considered low level threat waste consistent with EPA guidance.

5.1.1.2 Nature and Extent of Contamination

Characterization of SWMU 5 included analysis of metals, radionuclides, and organic constituents [PCBs, volatile organic analytes (VOAs) and semivolatile organic analytes (SVOAs)] in surface and subsurface

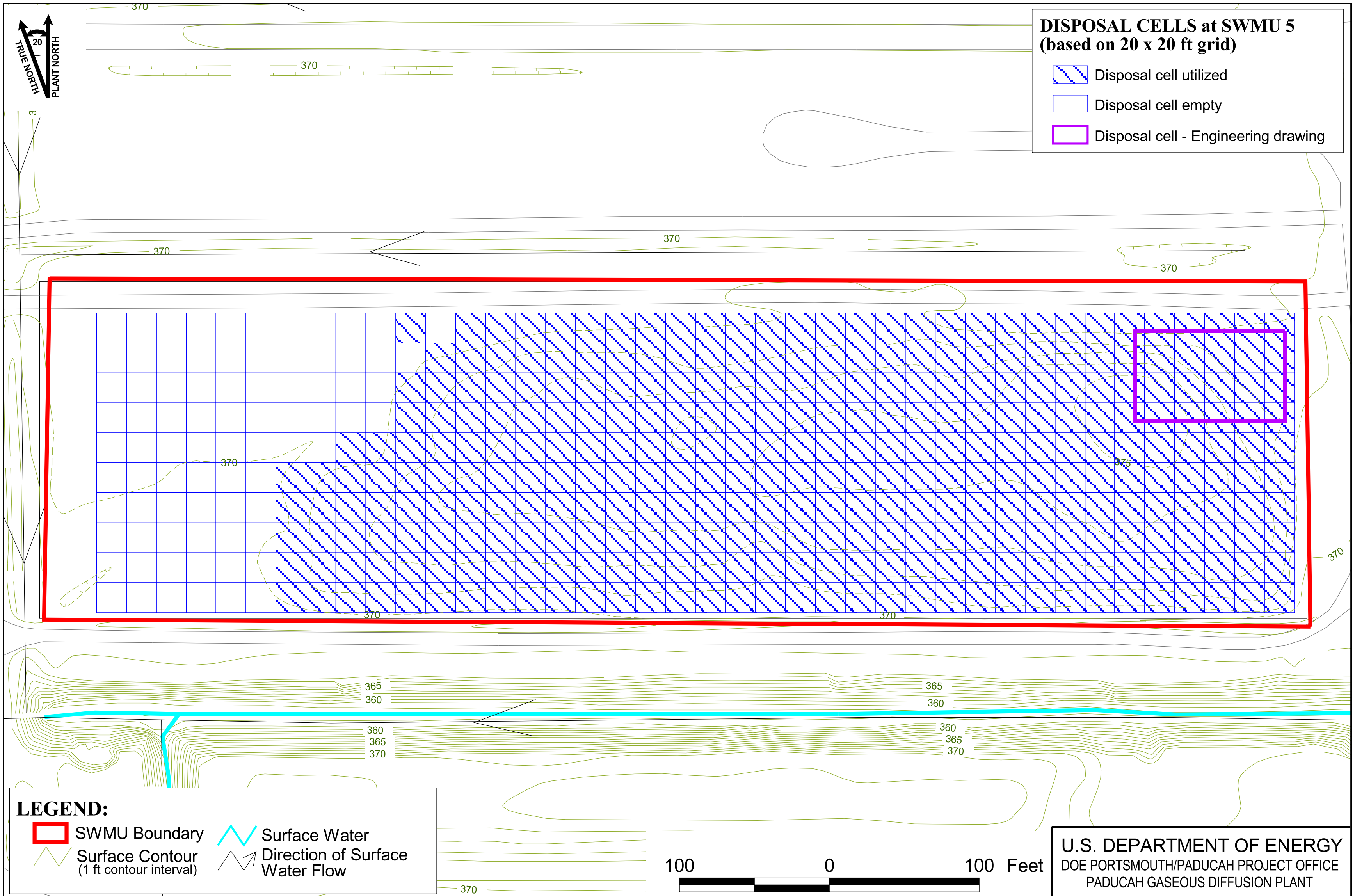


Figure 5.1. SWMU 5 Historical Layout

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

LATA Environmental Services of Kentucky, LLC

soils (Figure 5.2). There were several surface soil/sediment sampling locations in the drainageways adjacent to the waste disposal areas and limited sampling of the soil cover.

Metals and radionuclides were the primary potential contaminants of interest at SWMU 5 because the majority of items believed to be buried there include some radionuclide-contaminated scrap metal and slag from PGDP nickel and aluminum smelters. The concentrations of metals in the soils were reviewed based on comparisons with background and patterns indicative of releases from the wastes. The metals analyses rarely exceed screening criteria [both background and no action levels (NALs), where applicable) (Appendix B)]. In the 1–20 ft interval bgs, background concentrations were not exceeded for most metals (aluminum, arsenic, barium, chromium, copper, iron, manganese, nickel, and uranium). There was one vanadium sample above background in this interval. In the interval from 20–85 ft bgs, the infrequent background exceedances were distributed across 8 of the 12 stations, typically in only one depth interval, and several of these locations were adjacent to and not beneath the waste.[4] Metals that exceeded background and the outdoor worker NAL in 40 samples collected in this interval include chromium (2), iron (4) and vanadium (3). These data suggest variability in soil properties with depth, rather than migration from the waste, as the source(s) of these constituents.

Surface soil samples showed infrequent exceedances. Arsenic background of 12 mg/kg was exceeded at one location (005-006 in the drainageway on the west of the SWMU, adjacent to unused burial cells). More importantly, there were no exceedances of background in the 62 subsurface soil samples collected beneath the waste.

The results of the subsurface soils do not indicate any releases of uranium from the waste. Uranium was analyzed in seventeen subsurface soil samples collected in spring of 2007. The analysis was by SW846-6020 with a detection limit slightly below 1 mg/kg. Uranium was detected in 3 of these samples, none above the background level of 4.6 mg/kg. The maximum concentration was 1.24 mg/kg.

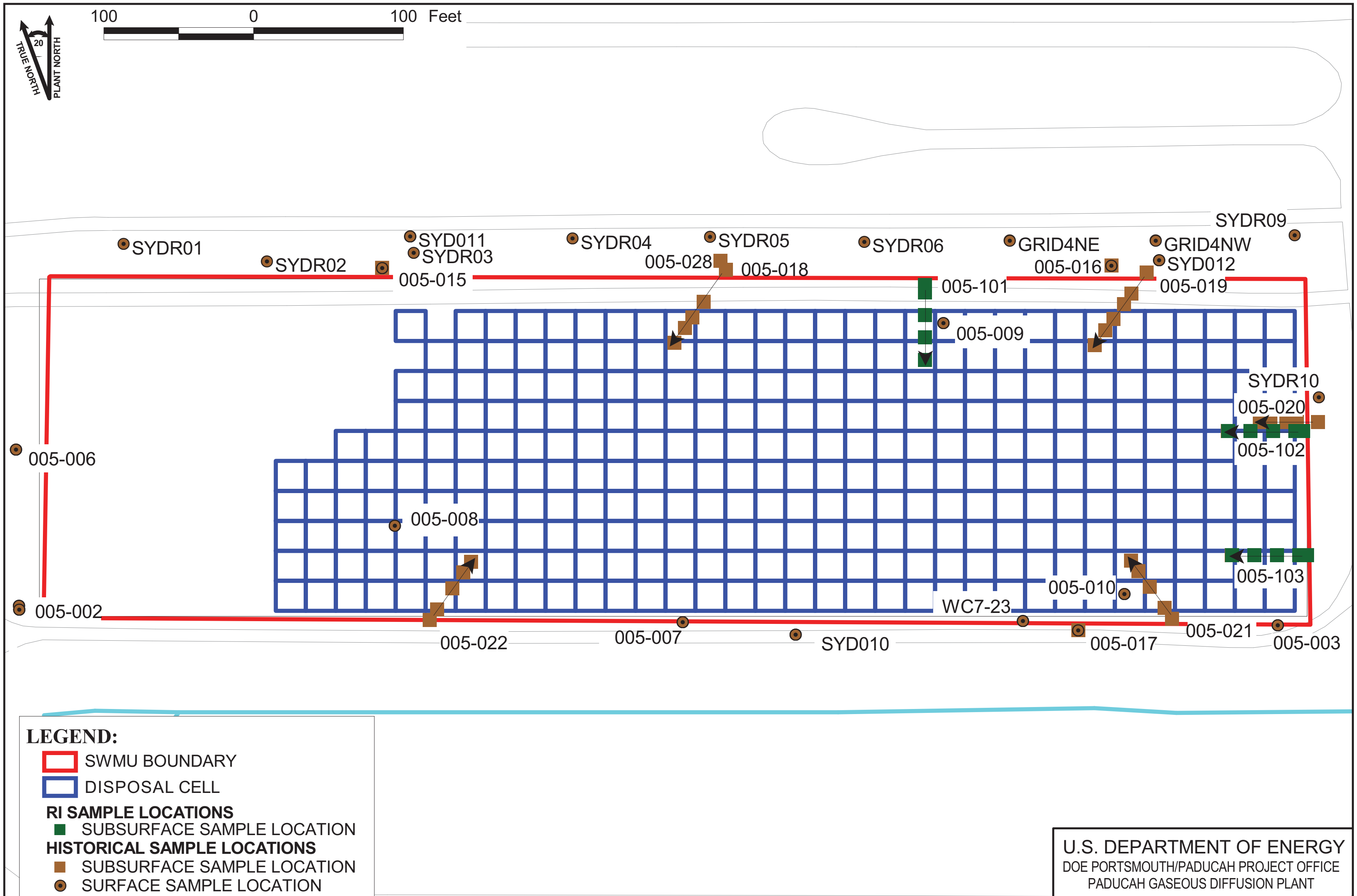
The surface soil results suggest uranium was detected above background in 1 of 7 samples; however, these surface samples adjacent to the waste areas do not reflect releases from the source. More importantly, these data are considered unreliable for drawing conclusions on the presence and concentrations of uranium. These samples were collected in the fall of 2001, analyzed by SW-846-6010A, with a detection limit of 200 mg/kg. This detection limit is well above background. The single detected concentration of 279 JX mg/kg is less than 40% above the detection limit. It also is not considered reliable based on comparisons with the concentrations of uranium-238 in these samples.

Tc-99 exceeded background concentrations in only 1 of 64 subsurface soil samples; however, it was detected above background in 9 of 26 surface soil samples. This distribution is not indicative or any release from the waste unit, nor does it reflect the assumed mobility of this radionuclide.

Organic constituents were detected infrequently and not at levels of concern in samples beneath the waste; however, organic constituents were reported in surface samples.

- No PCBs were detected in 51 subsurface soil samples, but were detected in 6 of 26 surface soil samples, all but one adjacent to the site. This is consistent with information on the dispositioned wastes, and does not suggest TSCA regulated materials are being released from the wastes.

[4] Beryllium is excluded from this comparison. The maximum concentration was 2.59 mg/kg, below the noncancer NAL. A comparison across all BGOU SWMUs suggest that analytical method differences influence this result, and all exceedances of background in SWMUs 5 and 6 were associated with samples analyzed by SW-846-6010A. All results were near detection limits.



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

Figure 5.2. Soil Sample Locations at SWMU 5

LATA Environmental Services of Kentucky, LLC

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

- Similarly, no Total PAHs were detected 39 subsurface soil samples, but were detected in 6 of 25 surface soil samples. Naphthalene was detected in 2 surface samples at locations with elevated Total PAHs.

5.1.1.3 Contaminant Migration

Section 1 provided an overview of the hydrogeologic conditions at SWMUs 5 and 6, with the conceptual model shown in Figure 1.7. This discussion highlights the results of the two pathways evaluated in the transport modeling analyses in the BGOU RI (dissolved-phase transport through the aquifer and vapor transport to a residential basement) and also the potential for migration from the source to adjacent drainageways, which has been identified as a potentially complete pathway to be considered in the FS.

5.1.1.3.1 Migration of Contaminants to the RGA

The source of contamination to the RGA evaluated in the RI is the waste disposal area. Data were evaluated to determine if releases from 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. For SWMU 5, arsenic, manganese, naphthalene, Tc-99, and uranium were modeled in the RI to predict the maximum groundwater concentration in the RGA.

Following further review of these data, it was concluded that no releases of these chemicals from the waste are identified as potentially impacting the RGA (Appendix A). Naturally occurring metals like arsenic and manganese are conservatively modeled, with results below background posing potential hazards to the RGA. At SWMU 5, arsenic exceeded background in 1 of 95 samples at a surface location, while manganese was above background in only 2 of 95 samples. Naphthalene was detected only in surface soil samples not related to releases from the waste. This is not a persistent organic, and consistent with that, has never been detected in RGA groundwater. Uranium exceeded background concentrations in only one surface soil sample and is considered immobile.

Tc-99 was one of the more mobile constituents potentially thought to be present in the waste; however, no strong evidence of a release from the waste was identified. The locations above background were primarily surface samples. This was not anticipated because of the likely high mobility of this radionuclide. The only background exceedance in subsurface samples was at a depth of 85 ft. The concentration predicted at the SWMU boundary was below the MCL.

5.1.1.3.2 Potential Migration of Contaminants to Drainageways

The potential for contamination to be released from soil and waste to surface water is believed to be limited at SWMUs 5 and 6, yet uncertainty remains because of the lack of source term data. There are no known lateral pathways of groundwater migration through the UCRS. There may be a limited pathway for groundwater to migrate laterally through the cover material overlaying UCRS of SWMU 5.

On April 27, 2011, after heavy rainfall (i.e., a 500-year rainfall event for the 60-day period leading up to April 27), ditches adjacent to the BGOU SWMUs were inspected for groundwater seeps. A seep was observed in the ditch north of SWMU 30, but there were no seeps observed at either SWMU 5 or SWMU 6. Follow-up research into the nature of the SWMU 30 seep was conducted (Johnstone 2011). This research included comparing the Phase II Site Investigation (DOE 1992) geophysical maps and topography maps with the location of the seep. The research concluded that the seep was present at SWMU 30, because a portion of the native material (UCRS HU 1) that normally is present in the sidewalls of BGOU waste cells had been removed (i.e., the northern edge of the burial cell at SWMU 30 coincided with the ditch). The uppermost portion of HU 1 has been replaced by a relatively permeable cover material that allows water that infiltrates into the waste cell to migrate through the cover material and into the adjacent ditch. By comparison, no such seeps were observed in the ditches adjacent to SWMU 5 where HU 1 is present in the sidewalls of the waste cells, because the location of ditches at SWMU 5 do not coincide with the waste cells at SWMU 5, as shown in Figure 5.1 of this document. The conclusion drawn from these observations is that HU 1, when present, prevents lateral migration of fluids that periodically may collect in the waste cells. The sidewalls of the waste cells at SWMU 5 are composed of HU 1 and are expected to prevent migration to nearby ditches. This conclusion is supported by the low yield of groundwater from HU 1 wells and temporary sampling points installed at PGDP. In summary, there is no route for SWMU 5 waste cell contaminants to migrate through the UCRS into the ditches.

On March 6, 1997, water was observed at three points along the southern edge of the waste cell cover material; the water was documented in field notes as seeps (Mullins 1997). These seeps never again have been observed, and there is little data and much uncertainty associated with the seeps. Assuming the surface water observed in 1997 was the result of groundwater flowing to the surface, rather than the result of "ponding" or pooling of the 5.5 inches of rain that had fallen in the 5-day period leading up to the observation, two postulated explanations for seeps have been developed. First, waste cells may fill with infiltration water and then spill over the HU 1, creating a seep at the interface of the UCRS and the cover soils that lie over the disposal cell. A second possibility for seep formation is that precipitation percolating through relatively permeable material used to cover the waste migrated downward until reaching HU 1, then migrated laterally to the terminal edge of the cover material. These periodic circumstances, should they occur, would create a route for SWMU 5 contaminants to migrate to the surface and could contaminate adjacent surface soils and/or expose workers to potential contamination in seep water. These circumstances could result in an unacceptable level of risk. These postulated groundwater migration routes are included in the CSM, as shown in Figure 1.7.

The more widespread exceedances of screening values in the drainageways were Total PAHs. In addition to the fact that no evidence of releases of PAHs from the waste were indicated by the subsurface soil data, these were predominantly located north of the site where migration from the waste would not occur.

5.1.2 Risk Characterization and Identification of COCs

A BHHRA was conducted as part of the RI. The BHHRA reported the hazards and risks for current and future uses, some of which are unlikely or hypothetical. The risk characterization summary for all scenarios evaluated in the RI for SWMU 5 is included in Appendix B. The risk characterization for direct contact scenarios was reported in the WAG 3 RI (DOE 2000b), so additional review of these COCs was conducted (e.g., background comparisons, toxicity assumptions for beryllium) to better support management decisions based on current understanding of the risks/hazards.

The source term data for wastes are limited. The impact to human health from direct contact with buried wastes was not characterized quantitatively in the BHHRA, and no specific COCs were identified. The BHHRA also concluded that, although much of the scrap metal waste may not pose significant hazards if contacted by workers in the future, potential risks are uncertain because wastes may be contaminated with radionuclides. Hazards associated with contact with waste are identified as an uncertainty, and the potential threat will be addressed through the developed alternatives in this FS.

The emphasis in the BGOU RI was to better characterize potential releases from the wastes to subsurface soils and potential impacts to the RGA and to update the risk assessment for use of RGA groundwater at the SWMU boundary and downgradient POEs. Only limited soil data are available to characterize the contamination in the soil cover, creating an uncertainty when evaluating potential risks for direct contact to surface soils.

For the leaching pathway, five constituents were identified as COCs for the future on-site rural resident based on exposure to groundwater in the BHHRA. These included arsenic, Tc-99, uranium, manganese, and naphthalene. Additional review of these COCs suggests several are below background, the RGA groundwater concentrations were below MCLs, and/or not detected in subsurface soils (Appendix A).

Residential land use is not a reasonably anticipated future use. Soil data within the SWMU boundary are limited, but show risks/hazards above the acceptable risk range for this scenario. Based on available surface soil data, COCs were identified in the BHHRA for future residential exposures to surface soils. These included some metals below background concentrations that contribute to the HI; 99% of the HI is from dermal absorption and ingestion of vegetables. The COC list for the future resident was not refined in this FS, recognizing this is not a likely future scenario, and given uncertainties in the available data. There were no COCs identified for future child or teen recreational users.

The land use is expected to remain industrial, and the emphasis of the review of the BHHRA was focused on the future industrial worker and the outdoor worker. Arsenic, beryllium, and Total PAHs were identified as COCs contributing to unacceptable risk estimates for both the future industrial worker and future outdoor worker. Beryllium, a major contributor to the ELCR (49-62%) is not currently evaluated as a carcinogen by the oral route of exposure. For the outdoor worker, Total PCBs were an additional carcinogen contributing (1%) to the ELCR. Total PCBs were detected only in surface soils.

No COCs were identified for the industrial worker for noncancer hazards. Several naturally occurring metals (aluminum, arsenic, barium, beryllium, chromium, iron, and manganese) contributed to the HI of 2.16 for the outdoor worker, with 82% of the hazard from dermal absorption.

These risks are summarized in Appendix B, including additional review of soil background concentrations and toxicity assumptions as the basis for identifying those COCs for which remediation goals will be developed in this FS.

A SERA for SWMU 5 concluded potential risks to terrestrial receptors are limited in extent. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. The metal COCs were below or near background concentrations at nearly all locations, and the PAH compounds were above benchmarks at only one location. PCBs were at concentrations below the lowest observed adverse effect level for wildlife. The results do not suggest any emergency response is needed, and narrows the potential scope of future ecological risk assessments. Analytes retained as COPCs may require further study to determine if effects are likely, and these analytes will be investigated further in the PGDP baseline ecological risk assessment for the Surface Water OU where cumulative effects will be evaluated.

Uncertainty remains regarding hazards associated with contact with buried wastes. Soil samples were not collected from within waste cells and risks from exposure to wastes were not evaluated. The risks from some scrap metals at this site that are not contaminated with radionuclides do not typically pose hazards to people who handle objects containing the metal in everyday use. SWMU 5, however, is assumed to contain a range of materials that may pose hazards.

5.1.3 SWMU-Specific RAOs

The stated problem at SWMU 5 for this FS is that buried waste materials containing radionuclides and metals present a potential direct contact risk to future outdoor and industrial workers. Based on waste descriptions and data collected during the RI, no PTW materials were identified for this source area.

The BHHRA identified potential for direct contact risks/hazards for future industrial workers and future outdoor workers contacting contaminants in soil. The process for review of these risks/hazards to identify the COCs and remediation goals was presented in Section 2.2.3, and the results of this process as it applies to SWMU 5 are presented in Section 5.4. The SWMU-specific RAOs for SWMU 5 include the following:

(1) Contribute to the protection of groundwater by eliminating, reducing, or controlling sources of groundwater contamination that will result in an exceedance of the MCL or risk-based concentration for residential use of groundwater in the absence of an MCL in RGA groundwater.

(2) Prevent exposure to waste or waste-related contaminated soils that exceed target cumulative ELCRs and cumulative noncancer HIs for the future industrial and future outdoor worker receptors. The acceptable cumulative risk levels for this RAO are defined as follows:

- Surface Soil: cumulative ELCR < 1E-05 and cumulative HI ≤ 1 for a future industrial worker
- Subsurface Soil: cumulative ELCR < 1E-04 and cumulative HI ≤ 1 for a future outdoor worker

Although the SERA identified some COPCs, no significant ecological threat from contact with surface soil was identified at SWMU 5 based on the limited data set, so no specific RAO was developed to address these exposures. Actions at SWMU 5 based on human health may reduce potential ecological impacts, and the COPCs will be considered in the future sitewide ecological risk assessment.

5.1.4 Soil RGs

No COCs requiring RGs for surface or subsurface soils were identified for SWMU 5. That is, there are no contaminants in surface or subsurface soils that would result in an unacceptable risk to future industrial or future outdoor workers as defined by the SWMU-specific RAO. In addition, no soil impacts were identified that would limit future residential use of RGA groundwater.

The review of the COCs identified for groundwater protection are presented in Appendix A, and COCs identified as contributing to potential unacceptable direct contact risks for future workers are presented in Appendix B. The following information highlights the current understanding of site risks and the basis for determining that no soil RGs are required and that the SWMU-specific RAOs are met.

No RGs are needed to meet the SWMU-specific RAO for protection of RGA groundwater.

- Arsenic and manganese are at background concentrations. In addition, for arsenic, the MCL was not exceeded in RGA groundwater.

- Tc-99 was identified as contributing to an unacceptable ELCR, however, modeled concentrations in the RGA were below the MCLs, the soil screening level for protection of RGA groundwater (DOE 2011b, Table A.11) were not exceeded, and subsurface soil concentrations are below background.

- For noncancer hazards, uranium was identified as a primary COC; however, no releases to soils were identified (all subsurface soil results are below background), concentrations are below screening levels protective of RGA groundwater at the MCL of 0.03 mg/L, and because of limited mobility, no loading to the RGA groundwater would be expected within the 1,000-year travel time.

- In the RI modeling, naphthalene was assumed not to degrade/attenuate during transport. The resulting estimated RGA concentration contributed a limited amount to the noncancer hazard. As discussed in Appendix B, naphthalene is known to attenuate and even at assumed degradation rates toward the upper end of those expected, degradations rates would not exceed the groundwater criteria in the RGA groundwater. This is further supported by the fact that naphthalene is not detected in any subsurface soil samples and is not detected in RGA groundwater.

No RGs are needed to meet the SWMU-specific RAO for protection of future outdoor workers from contact with contaminants in subsurface soils.

- For carcinogenic COCs in subsurface soils, the cumulative ELCR must be less than 1E-4 for the outdoor worker. Arsenic, Total PAHs and Total PCBs were carcinogens identified as contributing to the ELCR in SWMU 5 for the outdoor worker. Arsenic was below background concentrations in all subsurface soil samples, and PAHs and PCBs were not detected in any subsurface soils.

- Seven metals were identified as COCs contributing to the noncancer hazard (HI = 2.16). Based on review of these data (Appendix B), these metals are infrequently detected, typically below background and or risk based concentrations. None of the subsurface soil samples are estimated to have an HI > 1. Since subsurface soils do not pose an unacceptable hazard to the outdoor worker, the SWMU-specific RAO is met, and no RGs need to be developed for this receptor and endpoint.

No RGs are needed to meet the SWMU-specific RAO for protection of future industrial workers from contact with contaminants in surface soils.

- The HI for the future industrial worker was less than 1; therefore, there are no surface soil COCs to be addressed to meet the SWMU-specific RAO for noncancer hazards.

- Arsenic and beryllium were identified as COCs for the future industrial worker. Beryllium is not evaluated as a carcinogen in this FS; concentrations are near background and below screening values for noncancer hazards. Arsenic is at background levels.

- Total PAHs also were identified as COCs for the future industrial worker; however, these were not associated with releases from the waste unit. The scope of the BGOU includes potential contaminant migration pathways from the burial grounds to surface water, but does not include additional characterization or evaluation of the ditches bounding the burial grounds. These ditches are components of the Surface Water OU.

The PAHs detected at SWMU 5 are not associated with releases from the wastes and are present in surface samples adjacent to the SWMU, possibly influenced by the road on the north side of the site. These are part of the drainage features surrounding the waste disposal area. The DOE *Action Memorandum for Contaminated Sediment Associated with the Surface Water Operable Unit (On-Site) at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2009) concluded Total PAHs are unlikely to migrate off-site at concentrations above risk-based screening levels. The Action Memorandum also concluded that cancer risks in this area of the site would be appropriately based on the current industrial worker (14 days/year) for decision making at the Surface Water OU at the ELCR of 5E-6, such that the cumulative risks would remain below the target risk of 1E-5. For PAHs, this is 2.7 mg/kg. This Action Memorandum also states the following:

> There are no known primary sources of PAHs at the site, and their presence is believed to be attributed to ongoing activities associated with routine industrial activities (e.g., motorized vehicles, asphalt paving, etc.). As a result, PAHs are not good candidates to verify cleanup as part of this interim action. For this interim action, other primary contaminants of concern (COCs) such as polychlorinated biphenyls (PCBs) and uranium will be used to verify cleanup. It is anticipated that removal of hotspots for these primary

COCs will provide opportunities to achieve significant human and ecological risk reduction associated with PAHs.

The RGs for PAHs in this area will be coordinated with the approach for the Surface Water OU.

Uncertainty remains regarding hazards associated with contact with buried wastes. The wastes were not typically sampled, and no identification of COCs or quantitative estimates of risks were developed; therefore, although no RGs are developed, the FS evaluates alternatives to address the source areas to meet RAO to prevent direct contact with waste. Given limited surface soil sampling within the SWMU boundary to confirm the characterization of contamination in the existing soil cover, there is an uncertainty recognized that must be considered in evaluating remedy alternatives.

5.2 SWMU 6

5.2.1 History and Background

The following sections provide site history and background information specific to SWMU 6.

5.2.1.1 Historical Information, Site Description and History

The C-747-B Burial Ground, located in the northwestern section of the plant area east of SWMU 5, was in operation from 1960–1976. The SWMU 6 administrative boundary covers an area of approximately 8,400 ft^2, which is divided into five separate burial cells (Figure 5.3). Each cell and its contents were identified in the WAG 3 RI Report (DOE 2000b). The following are the dimensions and description of waste placed in each of the cells.

- 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 is buried during midsummer 1971. 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—Exhaust Fan Burial Area. Eight exhaust hood blowers removed from C-710 were discarded to this area. 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. In 1976, additional exhaust fans from C-710 were buried in cell I-2. This discard cell is approximately 8 ft by 35 ft and is about 8 ft deep. The waste was covered with about 5 ft of soil. A smaller cell located near the northwest corner of Area I, designated I-2 on Figure 5.4, is approximately 6 ft by 6 ft.

- 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. 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—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. 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.

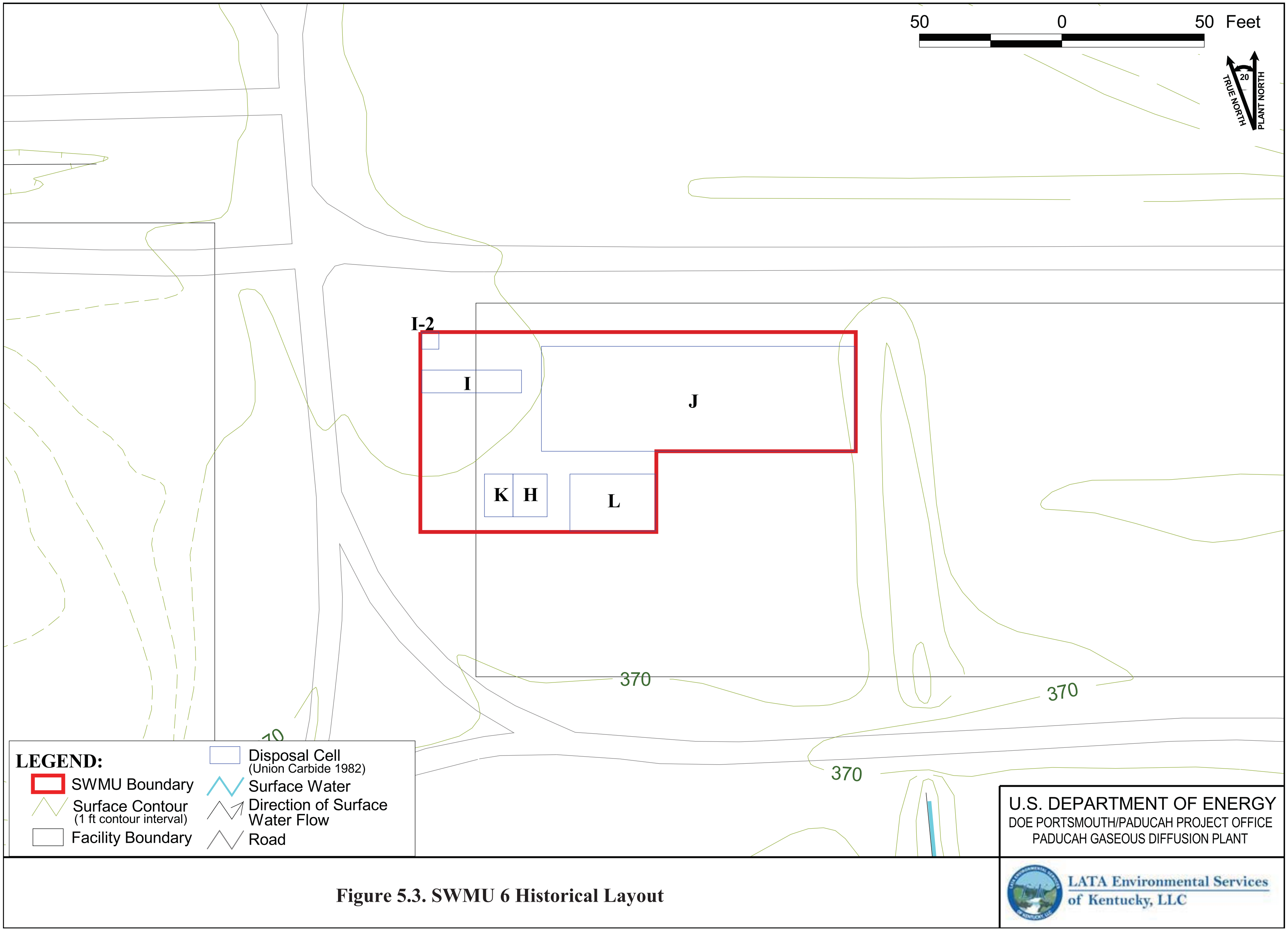


Figure 5.3. SWMU 6 Historical Layout

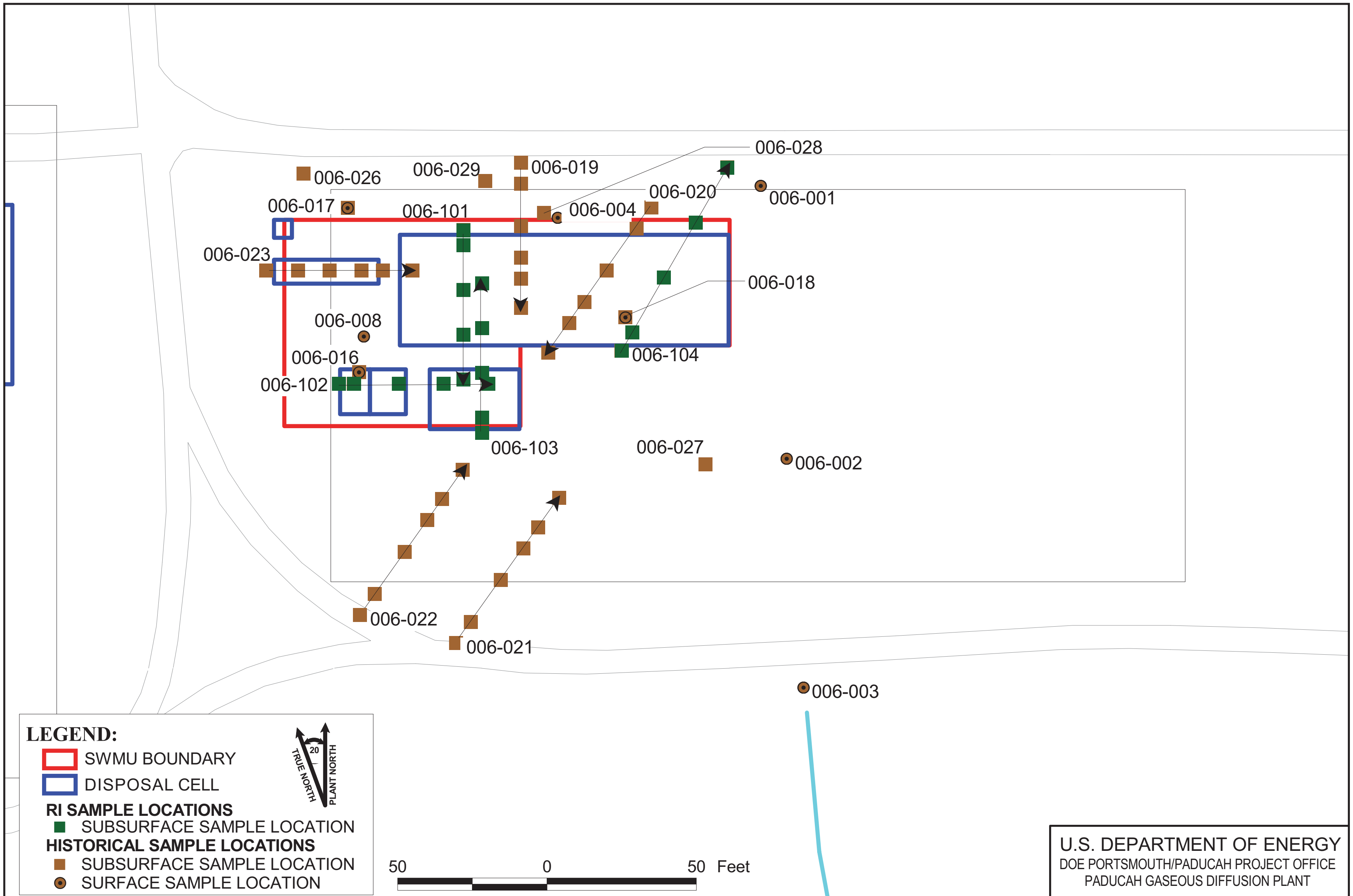


Figure 5.4. Soil Sample Locations at SWMU 6

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

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

SWMU 6 (Figure 5.3) is 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.

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). No disposal of solvents or PCBs was documented.

Based upon disposal records, SWMUs 5 and 6 contain industrial wastes, some of which are LLW. Industrial wastes in burial grounds at the PGDP are known to contain waste that could be contaminated with PCBs or RCRA hazardous wastes. Without more definitive waste characterization (i.e., sampling and analysis), it is not possible to state whether or not PCBs or RCRA hazardous wastes are also present at SWMUs 5 and 6. Based upon the waste inventory, the buried wastes at SWMUs 5 and 6 (including low-level radioactive waste) are considered low level threat waste consistent with EPA guidance.

5.2.1.2 Nature and Extent of Contamination

Characterization of SWMU 6 included analysis of metals, radionuclides, and organic constituents (PCBs, VOAs and SVOAs) in surface and subsurface soils (Figure 5.4). Samples 006-001,006-002, and 006-003 were collected from the drainage ditch located east of the burial areas. This drainage feature receives surface runoff during periods of heavy rainfall.

The BGOU RI did not identify any radionuclides as potential contaminants for SWMU 6. Organic constituents were infrequently detected in soils as highlighted below:

- No PCBs were identified in 83 soil samples. This is consistent with information on the disposed wastes, and do not suggest TSCA regulated materials are a source at this site.

- Traces of TCE (0.0011-0.0101 mg/kg) were detected in 5 of 102 samples. These were from two angled borings south of the SWMU (006-021 and 006-022), and not under or very close to any burial cells. SWMU 6 is located above the Northwest Plume. In addition to the soil results, TCE was not detected in UCRS groundwater from SWMU 6 suggesting that TCE in RGA groundwater beneath the SWMU is the result of upgradient sources. There is no indication that solvents (DNAPL or significant source of these mobile constituents) are present at the SWMU.

- Total PAHs were detected in 2 of 64 samples as shown in Appendix B, Figure B.1. These samples were collected from the drainage ditch/swale located east of the site. Sample 006-001 is located near a road north of the SWMU, and sample 006-003 is over 100 ft from the nearest disposal cell to the south and outside of the SWMU boundary.

Metals analyses of subsurface soil samples from SWMU 6 rarely exceed screening criteria (both background and NALs, where applicable) for identifying contamination (See Appendix B). The distributions of metals that exceed background concentrations appear to reflect variability in soils, not indicative of releases from the source areas.

5.2.1.3 Contaminant Migration

Section 1 provided an overview of the hydrogeologic conditions at SWMUs 5 and 6, with the conceptual model shown in Figure 1.7. This discussion highlights the results of the two pathways evaluated in the transport modeling analyses in the BGOU RI (dissolved-phase transport through the aquifer and vapor transport to a residential basement) and also potential for migration from the source to adjacent drainageways that have been identified as a potentially complete pathway to be considered in the FS.

5.2.1.3.1 Migration of contaminants to the RGA groundwater

In the BGOU RI, soil data were reviewed to identify analytes with potential to impact RGA groundwater. The fate and transport modeling predicted the maximum concentration of these analytes in RGA groundwater at the SWMU boundary, plant boundary, property boundary, and Ohio River. These concentrations then were used in the BHHRA to evaluate if there is evidence of potential sources that may limit residential use of RGA groundwater in the future. The manganese concentration in the SWMU boundary at SWMU 6 was estimated to exceed the NAL for the rural resident groundwater user, though manganese exceeded background in only 1 of 85 soil samples and is not indicative of a release from the waste. More importantly, the risk assessment established no unacceptable cumulative noncancer hazards (HI ≤ 1) or risks at any of the POEs, including the SWMU boundary.

No releases from the wastes to subsurface soil were identified that indicate a potential to impact RGA groundwater.

The waste metals in SWMU 6 are not expected to be highly mobile. Migration potential from the source would be further limited by the presence of clays and water/soils with near neutral pH (UCRS groundwater pH values ranged from 5.04 to 6.75 S.U., soil pH measurements ranged from 6.6 to 7.99 S.U.). The fact that no pattern of release of metals was identified in subsurface soils is consistent with this physical setting.

The potential for acidic leachate was identified for SWMU 6 because of exhaust fans with perchloric acid. Angled borings beneath SWMU 6 found no evidence of acidic leachate, from either subsurface metal concentrations or groundwater pH. This suggests minimal perchloric acid residue on the exhaust fans that has attenuated over time. This acid is highly water soluble, these wastes have been present at the site for over 30 years with only a soil cover, and this type of strong acid would be rapidly neutralized by these soils.

5.2.1.3.2 Potential migration of contaminants to drainageways

The potential for releases of contaminants in waste to migrate laterally to adjacent drainageways was not a focus of previous studies. SWMU 6 is an area of about l/3 acre that is relatively flat with a 5-ft wide by 4-ft-deep drainage ditch to the east that drains into Ditch 001. The ditch is very intermittent with water present only during extensive rain events. Migration in the unsaturated zone and UCRS is predominantly vertical. SWMU 6 has a 3-ft cover, and the bottom of the ditch is four ft. As illustrated on Figure 5.4, potential migration to the ditch to the east of SWMU 6 would be limited to a localized area at the east edge of burial cell J, assuming there are no conduits through the HU 1 unit.

There are no known lateral pathways of groundwater migration through the UCRS at SWMU 6.

On March 6, 1997, water was observed at three points along the southern edge of the waste cell cover material at SWMU 5; the water was documented in field notes as seeps (Mullins 1997). No such seeps have been reported at SWMU 6.

5.2.2 Risk Characterization and Identification of COCs

A BHHRA was conducted as part of the RI. The BHHRA reported the hazards and risks for current and future uses, some of which are unlikely or hypothetical. The risk characterization summary for all scenarios evaluated in the RI for SWMU 6 is included in Appendix B. The risk characterization for direct contact scenarios was reported in the WAG 3 RI (DOE 2000), so additional review of these COCs was conducted (e.g., background comparisons, toxicity assumptions for beryllium) to better support management decisions based on current understanding of the risks/hazards.

The impact to human health from direct contact with buried wastes was not characterized quantitatively in the BHHRA, and no specific COCs were identified. The BHHRA also concluded that, although much of the scrap metal waste known to be disposed of at SWMU 6 is not expected to pose significant hazards if contacted by workers in the future, potential risks are uncertain because the scrap metals may be contaminated with radionuclides. Hazards associated with contact with waste are identified as an uncertainty, and the potential threat will be addressed through the developed alternatives in this FS.

The emphasis in the BGOU RI was to better characterize potential releases from the wastes to subsurface soils and potential impacts to the RGA, and to update the risk assessment for use of RGA groundwater at the SWMU boundary and downgradient POEs. For SWMU 6, no COCs were identified for RGA groundwater at the SWMU boundary (ELCR < 1E-6, HI ≤1).

The land use is expected to remain industrial, and the emphasis of the review of the BHHRA was focused on the future industrial worker and the outdoor worker. Beryllium and Total PAHs were identified as COCs contributing to unacceptable risk estimates for both the future industrial worker and future outdoor worker. The major contributor to the ELCR (90%) was attributed to beryllium, which currently is not evaluated as a carcinogen by the oral route of exposure.

Several naturally occurring metals (aluminum, barium, beryllium, chromium, iron, manganese, and vanadium) were identified as COCs contributing to the noncancer hazard for the outdoor worker. The HI was 2.44, with dermal absorption (88% of the HI) the primary route of exposure.

These risks are summarized in Appendix B, including additional review of soil background concentrations and toxicity assumptions as the basis for identifying those COCs for which RGs will be developed in this FS.

5.2.3 SWMU-Specific RAOs

The stated problem at SWMU 6 for this FS is that buried waste materials present a potential direct contact risk to the future outdoor worker. Waste materials are buried to a maximum of 8 ft and covered with 3–5 ft of soil. Based on waste descriptions and data collected during the RI, no PTW materials were identified for this source area.

The BHHRA identified potential for direct contact risks/hazards for future industrial workers and future outdoor workers contacting contaminants in soil. The process for review of these risks/hazards to identify the COCs and remediation goals was presented in Section 2.2.3, and the results of this process as it applies to SWMU 6 are presented in Section 5.2.4.

It remains a general RAO for BGOU SWMUs to prevent releases from the waste unit that may impact RGA groundwater or adjacent drainageways; however, no migration of contaminants from the waste to subsurface soils, groundwater or drainageways was identified for this SWMU.

The following are the SWMU-specific RAOs identified for SWMU 6.

(1) Contribute to the protection of groundwater by eliminating, reducing, or controlling sources of groundwater contamination that will result in an exceedance of the MCL or risk-based concentration for residential use of groundwater in the absence of an MCL in RGA groundwater.

(2) Prevent exposure to waste or waste-related contaminated soils that exceed target cumulative ELCRs and cumulative noncancer HIs for the future industrial and future outdoor worker receptors. The acceptable cumulative risk levels for this RAO are defined as follows:

- Surface Soil: cumulative ELCR < 1E-05 and cumulative HI ≤ 1 for a future industrial worker
- Subsurface Soil: cumulative ELCR < 1E-04 and cumulative HI ≤ 1 for a future outdoor worker

Although the SERA identified some COPCs, no significant ecological threat from contact with surface soils was identified at SWMU 6 based on the available data set, so no specific RAO was developed to address these exposures. Actions at SWMU 6 based on human health may reduce potential ecological impacts, and the COPCs will be considered in the future sitewide ecological risk assessment.

5.2.4 Soil RGs

No COCs requiring RGs for surface or subsurface soils were identified for SWMU 6. That is, there are no contaminants in surface or subsurface soils that would result in an unacceptable risk to future industrial or future outdoor workers as defined by the SWMU-specific RAO. In addition, no soil impacts identified would limit future residential use of RGA groundwater. The following information highlights the current understanding of site risks and the basis for this conclusion.

No sources of groundwater contamination were identified for SWMU 6. No COCs were identified for the future on-site rural resident based on exposure to RGA groundwater.

PGDP is an industrial facility and future land use is expected to remain industrial. The SWMU-specific RAO defined to be protective for direct contact to contaminants in soil. The COCs in the BGOU RI for the default industrial and outdoor worker scenarios were reviewed, and it was concluded no actions to address chemicals in soils are needed to meet the target risk/hazards.

- Surface soils—protection of the future industrial worker

  - The HI for the future industrial worker was less than 1; therefore, there are no surface soil COCs to be addressed to meet the SWMU-specific RAO for noncancer hazards.

  - Beryllium and Total PAHs were identifies as contributing to the ELCR. Beryllium is not evaluated as a carcinogen in this FS; it is near background concentrations and well below screening values for noncancer hazards. Removing beryllium as a COC for carcinogenic effects reduces the ELCR for future workers to within the EPA acceptable risk range (below 1E-4), with risks attributed to Total PAHs (in drainageway samples, not from migration from the waste). The scope of the BGOU includes potential contaminant migration pathways from the burial grounds to surface water, but does not include additional characterization or evaluation of the ditches bounding the burial grounds. These ditches are components of the Surface Water OU; therefore, there are no COCs in soils adjacent to or beneath with wastes of SWMU 6 to be addressed in this FS.

- Subsurface soils—protection of the future outdoor worker

- For the outdoor worker, seven metals were identified as COCs contributing to the noncancer hazard (2.44). Based on review of these data (Appendix B), these metals are infrequently detected, typically below background and or risk based concentrations. None of the subsurface soil samples are estimated to have an HI > 1. Since subsurface soils do not pose an unacceptable hazard to the outdoor worker, the SWMU-specific RAO is met, and no RGs need to be developed for this receptor and endpoint.

- Total PAHs were identified as COCs for the outdoor worker; however, Total PAHs were not detected in any subsurface soil samples.

A SERA for SWMU 6 concluded risks to terrestrial receptors are not expected from current or future exposures. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. Lowest observed effects levels were exceeded only for nickel and zinc, but soil concentrations were below background at all stations except 006-001 (drainageway sample). In addition, it is inappropriate to assess direct toxic effects on wildlife populations for source units due to the industrial nature and small scale of the SWMUs. The cumulative effects to terrestrial habitat will be assessed facility-wide (or watershed-wide) in the PGDP baseline ecological risk assessment for the Surface Water OU.

5.3 SCREENING OF ALTERNATIVES

Alternatives are usually screened in this section of an FS using the process described in EPA (1988) and the NCP, with some alternatives being screened from further evaluation while others are carried forward to detailed analysis.

There are potential threats at SWMUs 5 and 6 from the buried waste, and there is uncertainty associated with the surface soil at SWMU 5 due to the limited sampling data. Alternatives were evaluated to address these potential threats. Because there are no waste-related COCs above RGs present that are amenable to treatment, there is no alternative that includes treatment (a treatment alternative is usually prescribed by the EPA guidance).

Alternatives are evaluated with respect to effectiveness, implementability, and cost. The evaluation of effectiveness considers reductions in toxicity, mobility, or volume of COCs. The evaluation of implementability considers technical feasibility criteria, including the ability to construct, operate, and maintain the remedy, and administrative feasibility criteria, including the availability of treatment, storage, and disposal capacity. Evaluation of cost for the alternatives is based on the relative capital and O&M costs for the primary technologies utilized. Alternatives with the best combinations of effectiveness and implementability and the lowest costs usually are retained for comparative analysis.

5.3.1 Alternatives Eliminated from Detailed Analysis for SWMUs 5 and 6 Source Areas

Table 5.1 summarizes the results of alternative screening for SWMUs 5 and 6.

Alternative 2 was screened out and does not move to the detailed analysis based on its lack of effectiveness because it does not mitigate the significant uncertainty due to the lack of surface soil characterization and would not meet the threshold criterion of protection of human health and the environment.

Table 5.1. Remedial Alternative Screening Summary for SWMUs 5 and 6

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Screening Criteria	**No Action**	**Limited Action**	**Soil Cover, Long-Term Monitoring, LUCs**	**18/6 Soil Cover, Long Term Monitoring, LUCs**	**KY Subtitle D Cap, Long-Term Monitoring, LUCs**	**Excavation and Disposal of Waste Materials and Affected Soils**
Overall Effectiveness	Low	Low	Moderate	Moderate	Moderate	Moderate
Short-term	High	High	High	High	High	Moderate
Long-term	Low	Low	Low	Low	Moderate	High
Overall Implementability	High	High	High	High	High	Low to Moderate
Technical	High	High	High	High	Moderate	Moderate
Administrative	Low	High	High	High	High	Moderate
Overall Cost	Low	Low	Moderate	Moderate	Moderate	High
Capital	Low	Low	Low	Low	Moderate	High
Operation and maintenance	Low	Moderate	Moderate	Moderate	Moderate	None

Alternatives shaded gray were screened out at this step.
LUCs = land use controls
SWMU = solid waste management unit

Alternatives 3 and 4 are both soil covers, but do not contain a low-permeable layer. These alternatives are screened from detailed analysis because they are ineffective at minimizing infiltration of precipitation through the buried LLW.

5.3.2 Summary of Alternatives Retained for Detailed Analysis

The following alternatives are carried forward for detailed analysis.

- Alternative 1: No Action
- Alternative 5: Kentucky Subtitle D cap, Long-Term Monitoring, LUCs
- Alternative 6: Excavation and Disposal of Waste Materials and Affected Soils

Comparative analyses are performed after the detailed analyses are complete.

5.4 DETAILED ANALYSIS OF ALTERNATIVES

This section analyzes the alternatives carried forward from Section 5.3.2. The detailed analysis provides further definition of the alternatives, as needed, to address SWMU-specific conditions. The detailed analysis also provides an assessment of each alternative against the nine evaluation criteria. A table that summarizes the discussion and identifies specific criteria evaluation factors used in the analysis follows the detailed analysis of alternatives.

5.4.1 Alternative 1—No Action

The No Action alternative is defined in accordance with CERCLA and provides a baseline to which other alternatives can be compared. Under this alternative, no action would be taken to implement remedial activities for SWMUs 5 and 6 or to reduce the potential hazard to human or ecological receptors.

5.4.1.1 Overall protection of human health and the environment

No additional controls would be implemented to protect site workers and the public. None of the chemicals detected in soil have been identified as a threat to groundwater, so the No Action alternative is protective of groundwater. The No Action alternative, however, is not protective of human health and the environment. It does not acknowledge the existing site controls maintained outside of CERCLA that currently prevent contact with the buried waste will continue into the foreseeable future. If these current controls were not in place, there would be no means to prevent future exposure.

5.4.1.2 Compliance with ARARs

No ARARs have been identified for Alternative 1, the No Action alternative.

5.4.1.3 Long-term effectiveness and permanence

The No Action alternative does not provide any long-term effectiveness or permanence. Alternative 1 would leave the chemicals detected in the soil at the current levels at this SWMU. SWMU-related COCs do not merit the calculation of RGs; however, this alternative does not provide any long-term controls to manage residual uncertainties at this SWMU.

5.4.1.4 Reduction of toxicity, mobility, or volume through treatment

The No Action alternative would not result in any reduction in toxicity, mobility, or volume through treatment.

5.4.1.5 Short-term effectiveness

No actions would be implemented under Alternative 1; therefore, no additional risks to workers, the public, or the environment would be incurred.

5.4.1.6 Implementability

The No Action alternative is considered implementable. If future remedial action is necessary, this alternative would not impede implementation of such action.

The ongoing public awareness program would require regular coordination with DOE, KY, and possibly with other governmental agencies.

5.4.1.7 Cost

The net present worth cost, capital cost, and O&M costs of Alternative 1 are estimated to be $0 because there would be no action.

5.4.2 Alternative 5—Kentucky Subtitle D Cap, Long-Term Monitoring, LUCs

This alternative combines the design and installation of a Kentucky Subtitle D cap with continued long-term groundwater monitoring and LUCs. The components of the cap are detailed in Section 2.4. This cap eliminates direct contact with surface soils. LUCs maintain restrictions on direct contact with the waste and soils in close proximity to the waste by controlling access and excavation in applicable areas. This alternative includes a specified low permeable layer that will prevent rainwater infiltration, thus eliminating the potential for future seep generation. LUCs will be designed and implemented through a LUCIP to ensure protectiveness. Monitoring will be conducted to verify that there is no unacceptable threat to surface water or groundwater because waste is left in place. For estimating purposes, this alternative assumes that one contiguous cap would be placed over SWMUs 5 and 6.

5.4.2.1 Overall protection of human health and the environment

Alternative 5 would meet this threshold criterion for SWMUs 5 and 6. A cap provides a physical barrier between receptors and contaminated surface soils, thus preventing direct contact and the associated risk. Installation of a Kentucky Subtitle D Cap at SWMUs 5 and 6, which includes multilayers that are distinctly different to the natural subsoils, provides greater depth to the buried waste. These aspects (thickness and distinct properties) of the cap are expected to provide protection of individuals from inadvertent intrusion by alerting them that this is a man-made engineered cover over something that is potentially hazardous to human health and by making it more difficult to expose the buried waste. Based upon the waste inventory, the buried wastes at SWMUs 5 and 6 (including LLW) are considered low level threat waste consistent with EPA guidance. A cap provides a direct reduction in mobility of surface contamination and a reduction in migration of subsurface vadose zone contamination by preventing infiltration. It does reduce the potential for future seep occurrence and therefore reduces uncertainty. Also, a cap further reduces the possibility of unacceptable risk in groundwater; however, no groundwater impacts are anticipated from either SWMU 5 or 6 based upon fate and transport modeling in the RI. LUCs maintain restrictions on direct contact with the waste and soils in close proximity to the waste by controlling access and excavation in applicable areas.

5.4.2.2 Compliance with ARARs

Alternative 5 will meet this threshold criterion by complying with potential action-specific ARARs. ARARs for this alternative are summarized in Appendix D.

5.4.2.3 Long-term effectiveness and permanence

Alternative 5 would be moderately effective in regard to long-term effectiveness and permanence. It would limit exposure to surface soil, waste, and soil in close proximity to the waste. It also would mitigate the uncertainty of contribution of contaminants to the RGA; however, waste and associated risk would remain at the unit. LUCs would protect current and future site workers and the public; however, this alternative relies on either a continued DOE presence at the site to enforce current controls or that a future site owner maintains the LUCs. The degree of long-term effectiveness and permanence is dependent upon maintaining the cap's ability to eliminate direct contact; appropriate materials and maintenance activities would be selected as part of the remedial design activities. Long-term O&M of the groundwater monitoring system and surface cover would be required.

5.4.2.4 Reduction of toxicity, mobility, or volume through treatment

Alternative 5 does not include any treatment technologies; therefore, a reduction in toxicity, mobility, or volume through treatment would not be achieved.

5.4.2.5 Short-term effectiveness

Implementation of Alternative 5 would not have any detrimental impact on the community.

Implementation of Alternative 5 includes the potential for worker exposure to contaminated surface soils and groundwater during environmental sampling and construction. Potential exposure pathways include inhalation of dust containing surface soils, dermal contact with surface soils, and dermal contact with contaminated groundwater. PGDP worker protection programs will make worker exposure unlikely.

No adverse ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. Final soil covers and vegetation would be an improvement over the current site conditions. No known archaeological or historical sites or T&E species would be impacted by this alternative.

At the time that implementation of each component of Alternative 5 is completed, all RAOs will have been achieved. Tentatively, implementation of Alternative 5 may take several months.

5.4.2.6 Implementability

Any cap placed over SWMUs 5 and 6 will need to cover the lateral extent of SWMUs 5 and 6 to both cover the waste and resolve uncertainties associated with the surface soil. Surface soil uncertainty at SWMU 5 could also be resolved through additional surface soil sampling. The extent of waste will be confirmed by geophysical survey during the remedial design; however, a drainage ditch lies approximately 100 ft to the south of SWMU 5 and runs in an east-west direction. The interaction of the ditch would need to be considered in the remedial design. KY regulations require the cap slope be constant across the cap layers and be between 5 and 25%. While a flatter slope may be desirable to prevent erosion, it may extend the cap over the existing ditch. The interaction of the slope to the ditches will be considered during the remedial design. To the west, historical records and previous geophysical investigations indicate that SWMU 5 waste placement did not extend far enough to cause interference. Waste placement to the west will be verified during the remedial design.

Cap installation would be accomplished using standard construction methods, materials, and equipment that are available from vendors and contractors. Implementation of Alternative 5 also includes continuation/expansion of existing environmental media monitoring to track contaminant migration because wastes are left in place.

5.4.2.7 Cost

The 30-year net present worth cost of Alternative 5 is estimated to be $10,006,000, with a capital cost of $8,092,000 and an average annual O&M cost of $63,784. The capital cost is primarily for installation of a Subtitle D Cap and an MW network. The average annual O&M cost is primarily for the monitoring program, cap maintenance, and 5-year reviews of the remedy. See Appendix C for estimate details.

5.4.3 Alternative 6—Excavation and Disposal

Waste materials in the burial cell and surrounding affected soil will be excavated and removed and replaced with clean backfill. Alternative 6 incorporates the following:

- Install sheet piles around the perimeter of each waste unit
- Excavate all buried materials and surrounding contaminated soils

- Dispose of cover soil and waste disposal characterization sampling
- Dewater excavation
- Segregate, bulk, and consolidate compatible waste groups
- Dispose of waste materials and affected soils

NOTE: For cost estimating purposes, Alternative 6a was added, which assumes waste disposal at an on-site waste disposal unit. Additionally, operations at the potential on-site waste disposal facility anticipate the incorporation of concrete and metal recycling. Any applicable waste generated through excavation would be evaluated for recycle value and potential for waste minimization. Refer to Appendix C.

Alternative 6 and Alternative 6a assume that removal would take place as a combined effort for both SWMUs. That is, one set of design and planning documents would be completed for both SWMUs and the excavation would proceed under one mobilization effort.

Alternative 6 for SWMU 5 assumes that 78% of the total SWMU area would be excavated. This is an area equal to 210 ft wide by 730 ft long. Excavation and disposal quantities are based on removal of soil down to 20 ft bgs. This will generate approximately 114,000 yd^3 (in place) of waste materials and soil. The loose volume of this excavated waste is approximately 137,000 yd^3, which accounts for 20% expansion of the soil volume upon removal and addition of sorbent (0.054%). Waste dispositioning assumptions are summarized in Table 5.2. Nonhazardous solid waste generated from excavation would be disposed of at the C-746-U Landfill (approximate 54,000 yd^3). The LLW generated from excavation (approximate 83,000 yd^3) would be disposed of either at the NNSS in Mercury, NV, or a potential on-site disposal unit, if available.

Table 5.2. SWMU 5 Waste Disposition Estimate

Area (ft^2)	Excavation Layer (bgs)	Quantity (bcy)	Quantity (lcy)	Quantity (lcy) w/ sorbent	% Off-site Disposal	Off-site Disposal (lcy)	On-site Disposal (lcy)
153,300	0–3 ft	17,033	20,440	20,550	0	0	20,550
153,300	3–6 ft	17,033	20,440	20,550	25	5,138	15,413
153,300	6–12 ft	34,067	40,880	41,101	90	36,991	4,110
153,300	12–20 ft	45,422	54,507	54,801	75	41,101	13,700
				Total	(rounded)	83,000	54,000

bcy = bulk cubic yds
lcy = loose cubic yds

As in any excavation remedy, waste dispositioning is a large cost driver and it is appropriate to evaluate waste volumes against disposal volumes. As stated in Section 5.1.1, the total quantity of wastes buried at the yard could be up to 33,185 yd^3. After applying the equivalent swell factor and accounting for sorbent quantity, the loose volume of the waste could be up to 41,972 yd^3. The difference between the waste volume and estimated off-site disposal volume accounts the additional soil that will require excavation in order to meet RGs.

The application of Alternative 6 at SWMU 6 assumes excavation of the SWMU within the administrative boundary (8,390 SF) to a depth of 20 ft bgs. This will generate approximately 6,215 BCY of waste for disposal. For estimating purposes, it is assumed that waste generated from within a specific disposal area to a depth of one-foot below the reported burial depth will require off-site disposal (or disposal at the on-site disposal cell if available). This volume is estimated to be 22% of the waste or 1,371 BCY. It is assumed that the remaining 78% of the excavated material, 4,844 BCY, will meet the 746-U landfill WAC and be disposed of there.

Table 5.3 summarizes the estimated waste volumes and disposition pathways for both SWMUs 5 and 6.

Table 5.3. SWMUs 5 and 6 Waste Disposition Estimate

Area (ft^2)	Quantity (bcy)	Quantity (lcy)	Quantity (lcy) w/ sorbent	% Off-site Disposal	On-site Disposal	Off-site Disposal (lcy) (Rounded)	On-site Disposal (lcy) (Rounded)
SWMU 5	113,555	136,267	137,002	61%	39%	83,000	54,000
SWMU 6	6,215	7,458	7,498	22%	78%	1,600	5,800
		Total	(rounded)	59%	41%	84,600	59,800

Additional assumptions for excavation, transportation, disposal, treatment, excavation dewatering, etc., for SWMUs 5 and 6 can be found in Appendix C.

5.4.3.1 Overall protection of human health and the environment

Alternative 6 would meet the threshold criterion for protection of human health and the environment. Potential short-term risks to remediation workers due to direct contact with the waste material and inhalation hazards are much larger than for any of the other alternatives evaluated in this FS. In addition, potential risks to the public and the environment, as a result of potential shipping and handling concerns, should be considered for off-site shipments. These concerns are greatly reduced for disposal in a potential on-site waste disposal facility.

Waste and contaminated soil will be physically removed from the SWMUs and disposed of in one or more appropriate disposal facilities, including a potential on-site disposal unit, thus meeting all RAOs for waste in the former burial cells.

5.4.3.2 Compliance with ARARs

Alternative 6 would meet this threshold criterion. ARARs for this alternative are summarized in Appendix D.

5.4.3.3 Long-term effectiveness and permanence

Complete excavation offers maximum control of contaminant migration because no wastes or associated contaminated soils would remain in the SWMUs; therefore, this alternative offers a high degree of risk reduction, long-term effectiveness, and permanence.

5.4.3.4 Reduction of toxicity, mobility, or volume through treatment

Alternative 6 reduces or eliminates the mobility and volume of contaminants from the SWMUs. The toxicity of the treatment residuals also would be drastically reduced and/or eliminated; however, this does not occur through treatment. Treatment is used for secondary waste such as removed groundwater during excavation. The removal and disposition of waste from an unlined burial cell containing COCs to an appropriate disposal facility prevents those contaminants from migrating to the groundwater.

5.4.3.5 Short-term effectiveness

Short-term risks to the community resulting from excavation activities at the SWMUs would not be expected. Alternative 6, however, includes a potential risk to the public from transportation of the LLW or hazardous wastes/liquids to off-site disposal and/or treatment facilities. This risk would be greatly reduced by disposing of waste in a potential on-site disposal unit.

Short-term exposures of workers to COCs during implementation of Alternative 6 could occur. Potential exposure pathways include direct contact with soil (ingestion, inhalation) and exposure to external penetrating radiation. Worker risks are not expected to exceed acceptable limits because exposure frequency and duration are less than those evaluated in the BHHRA. Typically, risks from handling waste/contaminated soils would be minimized through adherence to health and safety protocols. To protect workers, personal protective equipment, ambient conditions monitoring, and decontamination protocols would be used in accordance with an approved, site-specific health and safety plan.

The RAOs would be achieved immediately following excavation. Excavation and disposal would be conducted by trained personnel in accordance with standard radiological, engineering, and operational procedures, safety analysis, health and safety plans, and safe work practices to maintain a work environment that minimizes injury or exposure to risks to human health or the environment.

No ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. Final backfill, cover soils, and vegetation are anticipated to be improvements on existing conditions. No known archaeological or historical sites or T&E species would be impacted by this alternative.

5.4.3.6 Implementability

Alternative 6 is considered to be technically and administratively feasible and implementable. The equipment and technologies associated with implementation of this alternative have been proven and are available from contractors or vendors. Likewise, sampling, analysis, transportation, and disposal at an approved location are routinely performed and, if properly implemented, are proven to be safe. Excavated waste materials are expected to be radioactive. Treatment of wastes (i.e., solidification) may be necessary to make the waste suitable for transportation and/or land disposal. On-site treatment processes will comply with ARARs.

An option for disposal of waste and residuals at a potential on-site disposal unit is considered under Alternative 6. The primary difference would be the elimination of waste leaving PGDP, related off-site transportation issues, and the cost for disposal. At this time, no capacity exists for disposal of these wastes at PGDP.

5.4.3.7 Cost

The 30-year net present worth cost of Alternative 6 is estimated to be $240,408,000 with a capital cost of $240,203,000 and an average annual O&M cost of $6,844. The capital cost is primarily for excavation and packaging of the buried material and affected soil followed by appropriate disposition. This estimate assumes off-site disposition for 60% (83,000 yd^3) of the excavated material and affected soils, with the remaining 40% (54,000 yd^3) eligible for disposition in the existing PGDP C-746-U contained landfill. The estimated 30-year net present worth cost is reduced to $72,919,000, with a capital cost of $72,714,000 under an assumption that there will be an on-site waste disposal facility available for disposition of the excavated waste and affected soils (Alternative 6a). The annual O&M cost is primarily for the 5-year reviews of the remedy. See Appendix C for estimate details.

5.4.4 Summary of Detailed Analysis of Alternatives

Table 5.4 summarizes the discussion above and identifies specific criteria evaluation factors.

5.5 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section provides a comparative analysis for source area alternatives for SWMUs 5 and 6.

5.5.1 Threshold Criteria

SWMUs 5 and 6 remedial alternatives are compared with respect to the threshold criteria in the following sections.

5.5.1.1 Overall protection of human health and the environment

Alternative 1 does not meet the threshold criterion of overall protection of human health and the environment. It does not acknowledge the existing site controls maintained outside of CERCLA that currently prevent contact with the buried waste will continue into the foreseeable future.

Alternatives 5, 6, and 6a meet the threshold criterion of overall protection of human health and the environment. Based upon fate and transport modeling in the RI, contaminants at SWMU 5 or 6 should not pose a threat to groundwater, yet uncertainty remains because of the lack of source term data. Alternative 5 includes a groundwater monitoring component that would monitor the effectiveness of the remedy because waste is left in place Alternative 5 also includes LUCs because waste will remain in place.

5.5.1.2 Compliance with ARARs

No ARARs have been identified for Alternative 1. Alternatives 5, 6, and 6a would comply with ARARs.

5.5.2 Balancing Criteria

Remedial alternatives are compared with respect to the balancing criteria in the following sections.

5.5.2.1 Long-term effectiveness and permanence

Alternative 1 does not offer an acceptable degree of long-term effectiveness because no action is taken to mitigate surface soil uncertainties and uncertainties associated with the source term and surrounding soils. Alternatives 6, and 6a offers a higher degree of long term effectiveness and permanence than Alternative 5 as the excavation alternatives provide for waste to be excavated and removed from the SWMUs. None of the chemicals detected at SWMUs 5 or 6 pose a threat to groundwater. Alternative 5 includes long-term groundwater monitoring to ensure that the protectiveness of the remedy is maintained. Alternative 5 also include LUCs because waste will remain in place. Alternative 5 also includes an engineered low permeable layer that will severely reduce infiltration.

With respect to long-term effectiveness and permanence, Alternative 1 is ranked low because it does not offer an acceptable degree of long-term effectiveness and because no action is taken to mitigate surface soil and source term uncertainties. Alternative 5 is rated moderate to high. Its soil cover thickness will prevent direct contact with surface soil and waste. It mitigates the uncertainty of the impact of the source term to groundwater by preventing water infiltration into the waste. As with any containment alternative, the source term remains in place and the alternative depends upon continued actions such as LUCs, cap maintenance, and monitoring. Alternatives 6 and 6a are ranked high for long-term effectiveness and

Table 5.4. Detailed Analysis Summary for SWMUs 5 and 6

Criteria	Alternative 1 No Action	Alternative 5 Kentucky Subtitle D Cap, LUCs, and Monitoring	Alternative 6 Excavation and Removal of All Waste Materials	Alternative 6a Excavation and Removal of All Waste Materials (at Proposed On-site Disposal Unit)
Overall Protection of Human Health and the Environment	Does not meet the threshold criterion. No reduction in risk; action does not adequately mitigate uncertainty associated with surface soil contact and does not mitigate potential for future seeps.	Meets the threshold criterion. Action mitigates direct contact risk through a soil cap and LUCs. Uncertainty associated with potential for future seeps is mitigated by the low permeability layer component of the cap.	Meets the threshold criterion. Action mitigates direct contact risk, and other uncertainties mitigated through removal of waste and impacted soils to meet RGs.	Meets the threshold criterion. Action mitigates direct contact risk, and other uncertainties mitigated through removal of waste and impacted soils to meet RGs.
Compliance with ARARs	No ARARs identified.	Meets the threshold criterion.	Meets the threshold criterion.	Meets the threshold criterion.
• Action-Specific ARARs	None	Alternative can meet all ARARs.	Alternative can meet all ARARs.	Alternative can meet all ARARs.
• Chemical-Specific ARARs	None	None identified	None identified	None identified
• Location-Specific ARARs	None	Wetland survey will be performed, but wetlands unlikely to be found. If found, ARARs will be met.	Wetland survey will be performed, but wetlands unlikely to be found. If found, ARARs will be met.	Wetland survey will be performed, but wetlands unlikely to be found. If found, ARARs will be met.
Long-term Effectiveness and Permanence	Low	Moderate to High	High	High

Table 5.4. Detailed Analysis Summary for SWMUs 5 and 6 (Continued)

	Alternative 1	Alternative 5	Alternative 6	Alternative 6a
Criteria	**No Action**	**Kentucky Subtitle D Cap, LUCs, and Monitoring**	**Excavation and Removal of All Waste Materials**	**Excavation and Removal of All Waste Materials (at Proposed On-site Disposal Unit)**
• Magnitude of Residual Risk	No action is taken; therefore, no change in residual risk.	Direct contact risk uncertainty will be mitigated by LUCs and Kentucky Subtitle D cap, which is approximately 4-ft to 7.5-ft thick. Uncertainties associated with seeps and future potential groundwater impacts are mitigated through installation of low-permeable layer incorporated into the cap that will eliminate water infiltration. Monitoring provides information that helps understand uncertainties associated with groundwater and surface water impacts.	Residual risk and associated uncertainty should be fully resolved through removal of wastes and associated soils from the site.	Residual risk and associated uncertainty should be fully resolved through removal of wastes and associated soils from the site.

Table 5.4. Detailed Analysis Summary for SWMUs 5 and 6 (Continued)

	Alternative 1	Alternative 5	Alternative 6	Alternative 6a
Criteria	**No Action**	**Kentucky Subtitle D Cap, LUCs, and Monitoring**	**Excavation and Removal of All Waste Materials**	**Excavation and Removal of All Waste Materials (at Proposed On-site Disposal Unit)**
• Need for 5-Year Review	None	5-year review needed	5-year review may be needed. If hazardous substances remain at the site above levels that allow for unlimited use and unrestricted exposure, then a CERCLA 5-Year Review would be required.	5-year review may be needed. If hazardous substances remain at the site above levels that allow for unlimited use and unrestricted exposure, then a CERCLA 5-Year Review would be required.
• Adequacy and Reliability of Controls	None	Relies on continuation of LUCs selected as part of the CERCLA remedy.	Continued controls not required.	Continued controls not required.
Reduction of Toxicity, Mobility, or Volume through Treatment	None	None	No reduction through treatment other than incidental to treatment of collected waste to meet disposal facility WAC. Water collected as incidental to excavation will be treated and discharged to existing ditches.	No reduction through treatment other than incidental to treatment of collected waste to meet disposal facility WAC. Water collected as incidental to excavation will be treated and discharged to existing ditches
• PTW	None	None	None	None

Table 5.4. Detailed Analysis Summary for SWMUs 5 and 6 (Continued)

Criteria	Alternative 1 No Action	Alternative 5 Kentucky Subtitle D Cap, LUCs, and Monitoring	Alternative 6 Excavation and Removal of All Waste Materials	Alternative 6a Excavation and Removal of All Waste Materials (at Proposed On-site Disposal Unit)
Short-term Effectiveness	High	High	Moderate	Moderate
• Protection of Community During Remedial Actions	None	Minimal impact to community due to possible increase in truck traffic hauling soil.	Impact to the community due to transport of waste to disposal facility. Additional impact of fugitive dust and emissions from excavation site mitigated through ARARs.	Impact to the community due to transport of waste to disposal facility. Additional impact of fugitive dust and emissions from excavation site mitigated through ARARs.
• Protection of Workers During Remedial Actions	None	Risk to workers largely due to heavy equipment operations associated with monitoring well installation and cover construction. Risk can be mitigated through work control practices such as training, administrative controls, physical controls, and PPE.	Excavation requires significant contact with waste and impacted soils. Risks can be mitigated though work control practices such as training, administrative controls, physical controls, and PPE.	Excavation requires significant contact with waste and impacted soils. Risks can be mitigated though work control practices such as training, administrative controls, physical controls, and PPE.
• Environmental Impacts	None	Placement of an impermeable cap covered with topsoil will support a healthy vegetative cover to prevent erosion.	Excavation of waste and associated soil should fully resolve uncertainties at SWMU 5.	Excavation of waste and associated soil should fully resolve uncertainties at SWMU 5.

Table 5.4. Detailed Analysis Summary for SWMUs 5 and 6 (Continued)

Criteria	Alternative 1 No Action	Alternative 5 Kentucky Subtitle D Cap, LUCs, and Monitoring	Alternative 6 Excavation and Removal of All Waste Materials	Alternative 6a Excavation and Removal of All Waste Materials (at Proposed On-site Disposal Unit)
Implementability	High	High	High	High (applicable only if an on-site disposal cell is available).
• Ability to Construct and Operate Technology:	N/A	All construction means and methods are proven technologies and routinely used at other DOE sites as well as in private industry.	All construction means and methods are proven technologies and routinely used at other DOE sites as well as in private industry.	All construction means and methods are proven technologies and routinely used at other DOE sites as well as in private industry.
• Reliability of Technology:	N/A	Technologies implemented are highly reliable and in common use.	Technologies implemented are highly reliable and in common use.	Technologies implemented are highly reliable and in common use.
• Ease of Undertaking Additional Remediation:	N/A	Additional remediation may be aided or complicated by installed Kentucky Subtitle D landfill cover depending upon future remedy.	Additional excavation likely can be accomplished should RGs not be met by excavation.	Additional excavation likely can be accomplished should RGs not be met by excavation.
• Monitoring Considerations:	N/A	There are no impediments to monitoring implementation.	Monitoring during excavation will follow proven industrial hygiene and environmental monitoring practices. Remedy will require no post remedy monitoring, as RGs will be met.	Monitoring during excavation will follow proven industrial hygiene and environmental monitoring practices. Remedy will require no post remedy monitoring, as RGs will be met.

Table 5.4. Detailed Analysis Summary for SWMUs 5 and 6 (Continued)

Criteria	Alternative 1 No Action	Alternative 5 Kentucky Subtitle D Cap, LUCs, and Monitoring	Alternative 6 Excavation and Removal of All Waste Materials	Alternative 6a Excavation and Removal of All Waste Materials (at Proposed On-site Disposal Unit)
• Coordination With Other Agencies	Agency coordination will follow FFA. No new agencies involved.	Agency coordination will follow FFA. No new agencies involved.	Agency coordination will follow FFA. No new agencies involved.	Agency coordination will follow FFA. No new agencies involved.
• Availability of Equipment and Specialists	N/A	All equipment and specialists are readily available.	All equipment and specialists are readily available.	All equipment and specialists are readily available.
Cost	Low	Moderate	High	Moderate to High
• Capital Cost	$0	$8,092,000	$240,203,000	$72,714,000
• Average Annual O&M Cost	$0	$63,784	$6,844	$6,844
• Net Present Worth Cost	$0	$10,006,000	$240,408,000	$72,919,000

permanence because they eliminate all surface soil and source term uncertainties (residual risk) through removal and disposal.

5.5.2.2 Reduction of toxicity, mobility, or volume through treatment

None of the alternatives reduce the toxicity, mobility, or volume through treatment of COCs in waste or soil at the SWMUs; however, SWMU-related COCs in soil do not merit calculation of RGs. Alternative 5 is consistent with EPA's expectation concerning low-level threat waste.

5.5.2.3 Short-term effectiveness

The short-term effectiveness of Alternative 1 is high because there are no actions implemented, and thus there is no threat to workers or the public. In addition, the in-place plant controls (maintained outside CERCLA) are protective against direct contact with buried waste in the short-term.

Alternative 5 also is ranked high for short-term effectiveness because, while there are field actions associated with the alternative, the work—civil construction—is well understood, and risks associated with the work can be mitigated through work practices. Additionally, the potential impact to the community is limited to a possible increase of truck traffic on public roads.

The short-term effectiveness of Alternatives 6 and 6a is moderate because of the increased field work, as compared to Alternative 5, required to implement these alternatives. Significantly more resources are required to excavate, package, and transport waste. Excavation also exposes workers to the uncertainties associated with the waste.

5.5.2.4 Implementability

Alternatives 1 and 5 are highly implementable. Alternative 1 is implementable because no action is taken. Alternative 5 is highly implementable because it relies on proven construction means and methods.

Alternative 6 may be less implementable than Alternatives 1 and 5, because of uncertainties associated with the wastes. Alternatives 1 and 5 do not include intrusive activities into the waste. As such, the absolute and relative implementability of these alternatives is well understood. Alternative 6a is implementable only if an on-site disposal cell is available during the time of remediation.

5.5.2.5 Cost

There are no costs associated with Alternative 1 because no action is taken. The Alternative 5 total net present worth cost of $10,006,000 is significantly lower than the excavation Alternatives 6 and 6a. Alternative 6 total net present value costs are $240,408,000 and assumes that waste is disposed of off-site. Alternative 6a total net present value costs are $72,919,000 and assumes that wastes can be disposed of at an on-site waste disposal facility that does not currently exist but would be constructed prior to excavation of SWMUs 5 and 6. Alternative 5 has higher average annual O&M costs than Alternative 6 ($63,784 versus $6,844) due to the need for monitoring of the remedy associated with Alternative 5 that leaves waste in place. Additional estimate detail for all alternatives brought forward for detailed analysis are included in Appendix C of this FS.

5.5.3 Summary of Comparative Analysis of Alternatives

Alternatives 5, 6, and 6a all meet the threshold criteria.

Alternative 5 provides for direct contact avoidance with surface soils and waste by the construction of a substantial soil cap over the waste. Alternative 5 also includes a low-permeable layer that mitigates potential risks to groundwater by severely limiting infiltration. Because waste is left in place, Alternative 5 also includes long-term groundwater monitoring.

Alternatives 6 and 6a take the most aggressive action to mitigate source term uncertainty by removing the source term and disposing of it either off-site or at an on-site disposal facility, if one is available. Because all source term material is removed, there is no need for continued long-term groundwater monitoring or site maintenance.

None of the alternatives would reduce the toxicity, mobility, or volume of contamination through treatment, except that Alternatives 6 and 6a would do so as required to meet landfill WAC. Alternative 5 is consistent with EPA's expectation concerning low-level threat waste.

THIS PAGE INTENTIONALLY LEFT BLANK

6. REFERENCES

AFCEE 2000. "Remediation of Chlorinated Solvent Contamination on Industrial and Airfield Sites," Air Force Center for Environmental Excellence, 2000, U.S. Air Force Environmental Restoration Program.

BJC 2006. *Cultural Resources Survey for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, BJC/PAD–688/R1, Bechtel Jacobs Company LLC, Bechtel Jacobs Company, LLC, Paducah, KY, March.

CDM 1994. *Investigation of Sensitive Ecological Resources Inside the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, Doc. No. 716-003-*FR*-BBRY, Paducah, KY, August 19.

CH2M HILL 1992. *Results of the Site Investigation, Phase II, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, KY/SUB/13B-97777CP-03/1991/1, April.

COE (U.S. Army Corps of Engineers) 1994. *Environmental Investigations at the Paducah Gaseous Diffusion Plant and Surrounding Area, McCracken County, Kentucky,* Volumes 1-5, United States Army Corps of Engineers, Nashville, TN, May.

COE 1995. U.S. Army Corps of Engineers, Louisville District, Louisville, KY, letter from Ronny J. Sadri, Project Manager, to Jimmie C. Hodges, Site Manager, U.S. Department of Energy, Paducah, KY, December 14.

COE 2008. *Engineering and Design, In Situ Air Sparging*, EM 1110-1-4005, January 31.

Deuren, J. V., T. Lloyd, S. Chherty, R. Liou, and J. Peck 2002. Remediation Technologies Screening Matrix and Reference Guide, 4th Edition, United States Army Environmental Center, SFIM-AEC-ET-CR-97053, January.

DOE (U.S. Department of Energy) 1994. *Secretarial Policy on the National Environmental Policy Act,* U.S. Department of Energy, June.

DOE 1998. *Work Plan for Waste Area Grouping 3 Remedial Investigation/Feasibility Study at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1649&D2, U.S. Department of Energy, Paducah, KY, July.

DOE 2000a. *Data Report for the Site-Wide Remedial Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-1845&D1, U.S. Department of Energy, Paducah, KY, January.

DOE 2000b. *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, September.

DOE 2003. Final Report, Six-Phase Heating Treatability Study at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, DOE/OR/07-2113&D1, Secondary Document, U.S. Department of Energy, Paducah, KY, December.

DOE 2004. *Final Environmental Impact Statement for Construction of a Depleted UF_6 Conversion Facility at Paducah Kentucky Site*, DOE-0359, U.S. Department of Energy, June.

DOE 2006. *Work Plan for the Burial Grounds Operable Unit Remedial Investigation/Feasibility Study at Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2179&D2/R1, U.S. Department of Energy, Paducah, KY, August.

DOE 2008. Class 2 Permit Modification Request for the Hazardous Waste Facility Permit KY8-890-008-982, Agency Interest No. 3059, Letter from William Murphie to Anthony Hatton, KDWM, Paducah, KY, May.

DOE 2009. *Action Memorandum for Contaminated Sediment Associated with the Surface Water Operable Unit (On-Site) at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0119&D2, U.S. Department of Energy, Paducah, KY, March.

DOE 2010a. *Feasibility Study for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0130&D2, U.S. Department of Energy, Paducah, KY, December.

DOE 2010b. *Remedial Investigation Report for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0030&D2/R1, U.S. Department of Energy, Paducah, KY, April.

DOE 2011b *Methods for Conducting Risk Assessment and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Volume 1: Human Health* DOE/LX-07-0107&D2/R1/V1, U. S. Department of Energy, Paducah, KY, February.

DOE 2012. *Site Management Plan, Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Annual Revision-FY 2012*, DOE/LX/07-1264&D2, U.S. Department of Energy, Paducah, KY, February.

Dwyer, B. P. 2003. "Feasibility of Permeation Grouting for Constructing Subsurface Barriers," SAND94-0786, Sandia National Laboratories, April.

EPA (U.S. Environmental Protection Agency) 1987. *Design, Construction and Maintenance of Covers Systems for Hazardous Waste, An Engineering Guidance Document,* EPA/600/2-87/039, NTIS PB 87-191656, U.S. Environmental Protection Agency, May.

EPA 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, EPA/540/G-89/004, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC, October.

EPA 1996. Presumptive Response Strategy and Ex Situ Treatment Technologies for Contaminated Groundwater at CERCLA Sites, Final Guidance, EPA/540/R-96/023, U.S. Environmental Protection Agency, October.

EPA 1998. *Federal Facility Agreement for the Paducah Gaseous Diffusion Plant*, DOE/OR/07-1707, U.S. Environmental Protection Agency, Region 4, Atlanta, GA, February 13.

EPA 1999. *Cancer Risk Coefficients for Environmental Exposure to Radionuclides, Federal Guidance Report No. 13*, EPA 402-R-99-001, Air and Remediation, U. S. Environmental Protection Agency, September.

EPA 2000. "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study," U.S. Environmental Protection Agency, OSWER 9355.0-75, July. Accessed at http://www.epa.gov/superfund/policy/remedy/sfremedy/rifs/costest.htm.

EPA 2003. "Site Technology Capsule: MatCon Modified Asphalt for Waste Containment," EPA/540/R-03/505A, U.S. Environmental Protection Agency, June.

EPA 2006a. "Depleted Uranium Technical Brief," EPA-402-R-06-011, U.S. Environmental Protection Agency, December.

EPA 2006b. Off-Gas Treatment Technologies for Soil Vapor Extraction Systems: State of the Practice, EPA-542-R-05-028, Office of Superfund Remediation and Technology Innovation, Office of Solid Waste and Emergency Response, March.

EPA 2007. Presumptive Remedies: Policy and Procedures, U.S. Environmental Protection Agency, last updated on Tuesday, July 17, 2007. Accessed 07/14/08, at 177Hhttp://www.epa.gov/superfund/policy/remedy/presump/pol.htm.

EPA 2008. "Contaminant Focus: DNAPLs," Accessed at http://www.clu-in.org/contaminantfocus/default.focus/sec/Dense_Nonaqueous_Phase_Liquids_(DNAPLs)/cat/Treatment_Technologies/p/5.

FRTR 2008. *Remediation Technologies Screening Matrix and Reference Guide*, Version 4.0, Federal Remediation Technologies Roundtable, accessed at http://www.frtr.gov/matrix2/top_page.html.

Hightower, et al. 2001. Innovative Treatment and Remediation Demonstration, Paducah Groundwater Project Innovative Technology Review, March.

Johnstone, F. 2011. PowerPoint Slide Presentation, "BGOU 'Seeps" Investigation," Data Assessment Codes, and OREIS data report, prepared for Burial Grounds Operable Unit Field Investigation Conclusion, set of 31 slides, transmitted in e-mail to G. Brewer et al., October 24.

Jowitt, P. W. and Chengchao Xu 1990. "Optimal Value Control in Water-Distribution Networks," *Journal of Water Resources Planning and Management*, 116(4):455.

KDAQ (Kentucky Division of Air Quality) 2008. *Fiscal Year 2008 Annual Report*, Kentucky Division for Air Quality, Frankfort, KY.

KSNPC 1991. *Biological Inventory of the Jackson Purchase Region*, Kentucky State Nature Preserves Commission, Frankfort, KY.

LMES 1996. *Aquifer Test Analysis of the Northwest Plume, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, KY/EM-145, Lockheed Martin Energy Systems, Inc., Paducah, KY, June.

Mullins, G. Todd 1997. "Seeps at SWMUs 5 and 30," excerpted from field records on individual seeps March 6 and March 17, 1997, transmitted in e-mail to G. Brewer, September 30, 2011.

NRC (National Research Council) 2004. "Contaminants in the Subsurface, Source Zone Assessment and Remediation," National Research Council of the National Academies, National Academies Press, Washington, DC.

PRS (Paducah Remediation Services, LLC) 2010. *Paducah Gaseous Diffusion Plant Fill and Cover Material Verification Guidance*, RS-ENR-0036, Paducah Remediation Services, LLC, February.

Pettit, P. J., D. E. Ridenour, D. Harris, and J. Jalovec 1996. "Success in Horizontal Barrier Developments," FEMP-2491, CONF-960212-92, U.S. Department of Energy, Fernald Environmental Management Project, Presented at Waste Management 1996, Tucson, AZ, February 25-29.

Terzaghi, K. T, R. B. Peck, and G. Mesri 1996. *Soil Mechanics in Engineering Practice*, Third Edition, John Wiley & Sons, Inc., New York, NY.

Thornthwaite, C. W. and J. R. Mather 1957. "Instructions and Tables for Computing Potential Evapotranspiration and the Water Balance," *Publications in Climatology* 10 (1957): 183-311.

Union Carbide 1973. *The Discard of Scrap Materials by Burial at the Paducah Plant,* Union Carbide Corporation, Paducah, KY, October.

Union Carbide 1978. *The Disposal of Solid Waste at the Paducah Gaseous Diffusion Plant,* Union Carbide Corporation, Paducah, KY, December.

U.S. Census Bureau 2009. Population Finder, City of Paducah, Kentucky. Accessed at http://factfinder.census.gov/servlet/SAFFPopulation, July 17, 2009.

USDA (U.S. Department of Agriculture) 1976. *Soil Survey of Ballard and McCracken Counties, Kentucky*, USDA Soil Conservation Service and Kentucky Agricultural Experiment Station.

USFWS (U.S. Fish and Wildlife Service) 2007. *Indiana Bat (Myotis sodalis) Draft Recovery Plan*: First Revision, U.S. Fish and Wildlife Service, Fort Snelling, MN.

APPENDIX A

DEVELOPMENT OF PRELIMINARY SOIL REMEDIATION GOALS FOR PROTECTION OF GROUNDWATER

THIS PAGE INTENTIONALLY LEFT BLANK

CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

TABLES

FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

ACRONYMS

BGOU	Burial Grounds Operable Unit
BHHRA	baseline human health risk assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminant of concern
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
Foc	fraction of organic carbon
FS	feasibility study
HI	hazard index
K_d	distribution coefficient
MCL	maximum contaminant level
NAL	no action level
PGDP	Paducah Gaseous Diffusion Plant
RAO	remedial action objective
RESRAD	computer model used to estimate radiation doses from RESidual RADioactive material
RG	remediation goal
RGA	Regional Gravel Aquifer
RI	remedial investigation
SESOIL	Seasonal Soil Compartment Model
SSL	soil screening level
SWMU	solid waste management unit
UCRS	Upper Continental Recharge System

THIS PAGE INTENTIONALLY LEFT BLANK

A.1. INTRODUCTION

This appendix accompanies the *Feasibility Study for Solid Waste Management Units 5 and 6 of the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0130a&D2/R3 (FS), which has been prepared to evaluate remedial alternatives for Solid Waste Management Units (SWMUs) 5 and 6 of the Burial Grounds Operable Unit (BGOU) at the Paducah Gaseous Diffusion Plant (PGDP). This appendix of the FS provides a discussion of development of remediation goals (RGs) to address the following remedial action objective (RAO):

- Contribute to the protection of groundwater by eliminating, reducing, or controlling sources of groundwater contamination.

A.2. COCs AND GROUNDWATER CONCENTRATIONS USED TO CALCULATE GROUNDWATER-PROTECTIVE RGs FOR SOIL

The BGOU Remedial Investigation (RI) baseline human health risk assessment (BHHRA) identified contaminants of concern (COCs) for use of Regional Gravel Aquifer (RGA) groundwater, based on risks for modeled concentrations in the RGA at the SWMU boundary. For this FS, the groundwater target concentrations are maximum contaminant levels (MCLs), or in the absence of an MCL, a risk-based concentration for residential use of groundwater. Guidance for use of MCL values at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites is provided by the U.S. Environmental Protection Agency (EPA) (EPA 1988).

As highlighted in Table A.1, several of the COCs had modeled groundwater concentrations that did not exceed MCLs at the SWMU boundary, the point of compliance for containment alternatives. These COCs were evaluated further and presented here because the point of compliance for excavation scenarios is the RGA groundwater concentrations beneath the SWMU.

Table A.1. RI Model-Predicted Concentrations of the Analytes Identified as COCs in RGA Groundwater at the BGOU SWMUs 5 and 6 Boundaries

Analyte	Predicted Maximum Groundwater Concentration (mg/L or pCi/L)[a]	MCL (mg/L or pCi/L)
SWMU 5		
Arsenic (mg/L)	9.25E-03	0.01
Manganese (mg/L)	1.01E+00	[b]
Naphthalene (mg/L)	5.55E-03	[b]
Technetium-99 (pCi/L)	1.27E+02	4 mrem/yr[c]
Uranium (mg/L)	***4.60E-01***	0.03[d]
SWMU 6—No COCs		

http://water.epa.gov/drink/contaminants/index.cfm#List
[a] Values in bold, italic font with highlight exceed the analyte's MCL.
[b] MCLs not available for these contaminants.
[c] MCL for beta and photon emitters.
[d] Derived based on the toxicity (hazard) of uranium-soluble salts.

A.3. TARGET COCs FOR FS ALTERNATIVE EVALUATION

In this section, the list of COCs identified in the BHHRA (Table A.1) is reduced by comparison of predicted groundwater concentration with the MCLs, comparing measured soil concentrations to background concentrations and examining and considering the frequency of detection, migration time through the Upper Continental Recharge System (UCRS), and the effects of biodegradation.

A.3.1 COCs REFINED BASED ON BACKGROUND EVALUATION

A.3.1.1 Manganese

Manganese was identified as a COC for residential use of groundwater at most BGOU SWMUs, with soil concentrations infrequently exceeding background. It was not a COC for SWMU 6 [the hazard index (HI) for residential use of RGA groundwater at the SWMU boundary was less than 1]. As highlighted in Table A.2, manganese concentrations exceeded background in only 3 of 158 analyses at SWMUs 5 and 6 and in a pattern that is inconsistent with release from the wastes. The potential release from the soil matrix and potential migration to RGA groundwater is controlled by a number of factors, including localized geochemical conditions. Based on the finding that there are few above-background detections of manganese and the fact that the presence and migration of manganese is controlled by site geochemical conditions, manganese is eliminated as a COC for leaching to groundwater at SWMUs 5 and 6.

Table A.2. Summary of Manganese Soil Concentrations

SWMU	Depth	Detected Concentrations (mg/kg)			Frequency of	
		Minimum	Maximum	Average	Detection	Exceeding Background
5	Surface	135	599	390	14/14	0/14
5	Subsurface	6.89	***1,750***	196	59/59	2/59
6	Surface	221	664	370	15/15	0/15
6	Subsurface	19.7	***1,550***	189	70/70	1/70

Background: 1,500 mg/kg surface soil; 820 mg/kg subsurface soil from Table A.12 of the Risk Methods Document (DOE 2011).
Bold, Italics**:** exceeds background.

A.3.1.2 Arsenic

As modeled in the BGOU RI, arsenic is a risk driver for groundwater at SWMU 5 though the modeled concentration at the SWMU boundary is below the MCL. Closer examination shows that despite arsenic's being present at SWMU 5, only 1 out of 74 surface and subsurface samples had a value above background (Table A.3). The exceedance occurred in a surface soil sample located in a ditch west of the site and is not associated with releases from the waste (Figure A.1). Based on the infrequency of detections above background and estimated concentration below the MCL, arsenic is eliminated as a COC to be addressed for migration to groundwater at SWMU 5 in this FS.

Arsenic never has been detected above background at SWMU 6 (Table A.3).

A.3.2 COC LIST REFINED BASED ON TRANSPORT

UCRS groundwater contamination migrates vertically to the RGA. Along the migration pathway, contaminants are subjected to the effects of retardation (which, as the name implies, increases travel times

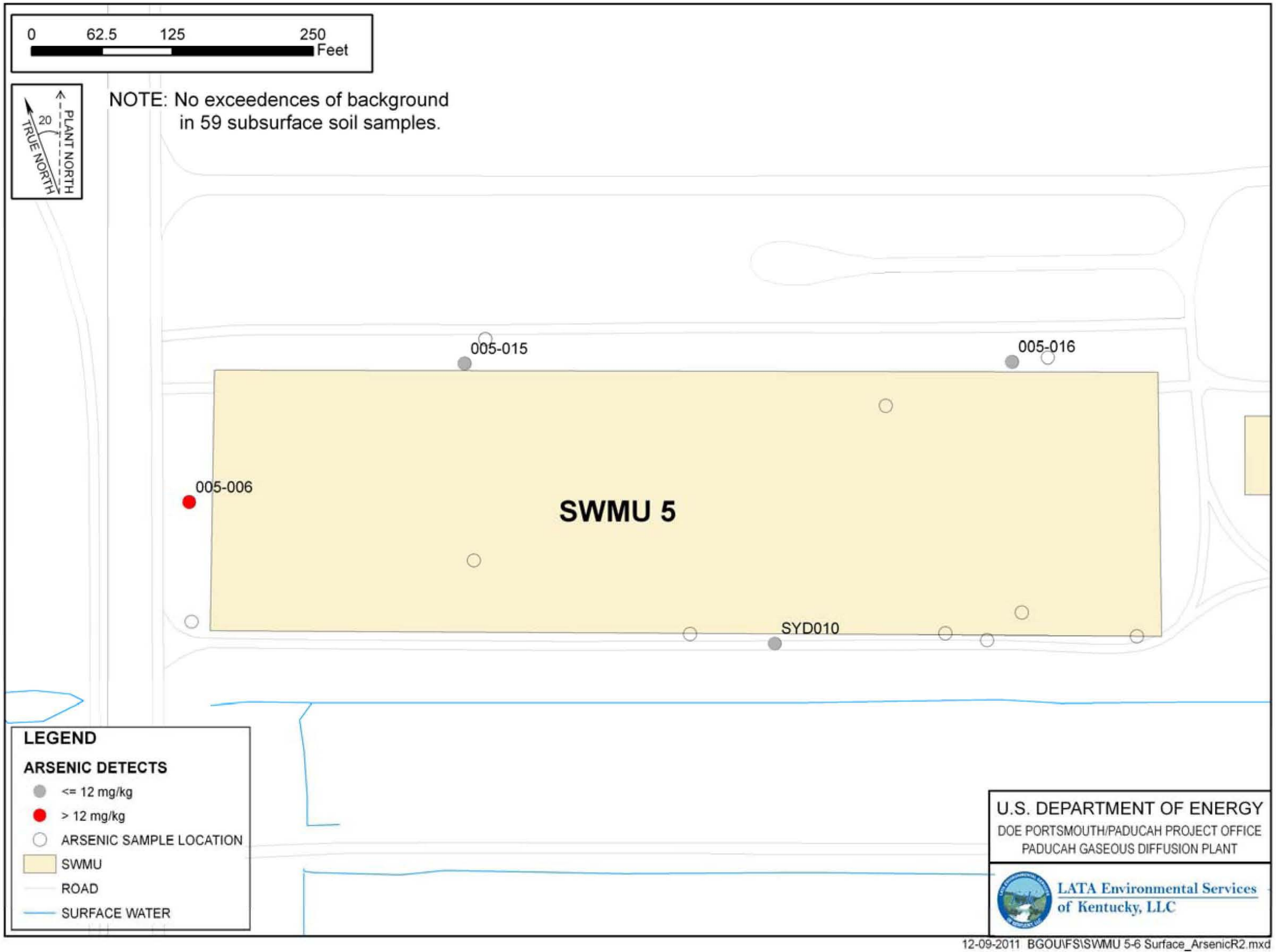


Figure A.1. Arsenic in Surface Soil at SWMU 5

Table A.3. Summary of Arsenic Soil Concentrations

SWMU	Depth	Detected Concentrations (mg/kg)			Frequency of	
		Minimum	Maximum	Average	Detection	Exceeding Background
5	Surface	5.21	***12.2***	8. 49	4/15	1/15
5	Subsurface	1.04	6.77	2.93	17/59	0/59
6	Surface	5.13	6.38	5.76	2/15	0/15
6	Subsurface	1.1	6.19	2.85	23/70	0/70

Background: 12 mg/kg surface soil; 7.9 mg/kg subsurface soil from Table A.12 of the Risk Methods Document (DOE 2011).
Bold, Italics**:** exceeds background.

to the RGA) and biodegradation (which reduces concentrations along the migration pathway). Retardation is quantified by the distribution coefficient (K_d). Retardation does not reduce groundwater concentration along the migration pathway, it only delays the peak concentration arrival time. Consistent with the modeling approach in the RI, if the peak concentration arrival time is greater than 1,000 years, the contaminant is assumed to be immobile, and Seasonal Soil Compartment Model (SESOIL) modeling is not warranted.

Defining chemicals as immobile (no loading to the RGA in 1,000 year travel time) is consistent with findings in the literature. Scientific evidence suggests that some chemicals become more resistant to desorption from soil as contact time increases (Loehr and Webster 1996; Alexander 1995; Pavlostathis and Mathavan 1992). Chemicals that have relatively low transport potential due to their high soil adsorption coefficients may, over time, become irreversibly adsorbed to soil and therefore immobile under normal conditions (Alexander 1995). This time period for reduced desorption to occur has been reported to be on the order of weeks or months for several chemicals, and a 100-year time period has been used to identify immobile chemicals. For this FS, it is assumed that these chemicals do not pose a threat to groundwater if an adequate zone of clean soil exists between the contamination and the groundwater such that the travel time is conservatively less than 1,000 years.

Figure A.2 shows the relationship between K_d and travel times to the RGA from the UCRS. In general, as simulated by SESOIL, the BGOU source zone depths extend from approximately 10 ft–40 ft bgs. When retardation is minimal, as characterized by small K_d values, approximately 25 years is required for UCRS contamination to reach the water table. K_d values greater than 12 result in contaminant travel times in excess of 1,000 years. Thus, chemicals with K_d greater than 12 do not require SESOIL modeling.

The effects of biodegradation on expected RGA groundwater concentrations are evaluated by using the chemical-specific K_d value and Figure A.2 to determine the expected travel time from the UCRS source zones to the RGA for a chemical of interest. That travel time is used, along with the chemical-specific biological half-life, in the following equation to predict expected RGA concentrations.

$$M(t) = M_0 \times e^{-kt}$$

Where:

M_0 = initial concentration
$M(t)$ = concentration at the time of interest
e = 2.71828183
k = ln(2)/biodegradation half-life
t = migration time through the UCRS

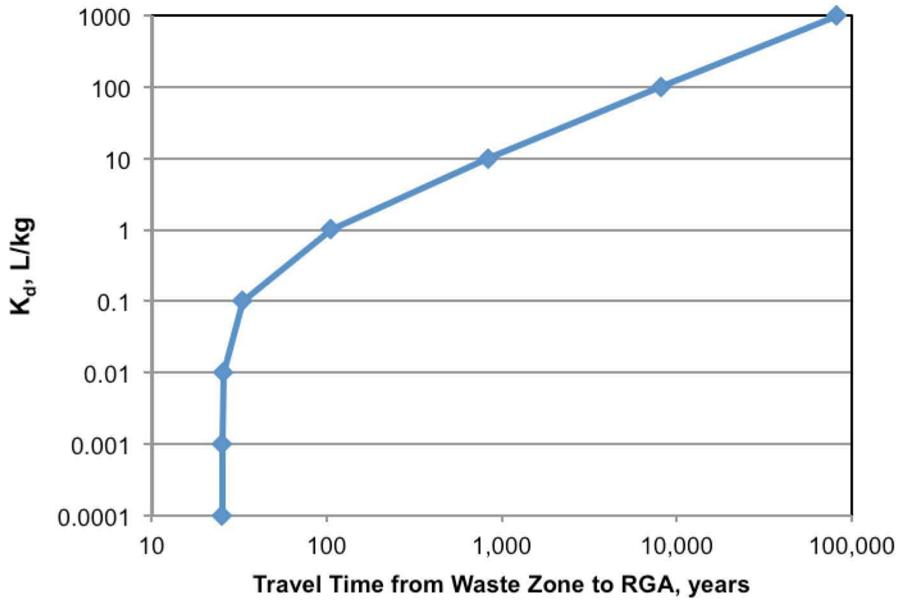


Figure A.2. Relationship of K_d to Travel Time to RGA

For conservatism, the individual constituent solubility is used as the initial concentration. If the predicted RGA chemical concentration is below the MCL or risk based standard, then additional SESOIL modeling is not required.

A.3.2.1 Naphthalene

The potential for naphthalene to result in impacts to the RGA was evaluated further in this FS. Naphthalene has not been detected in 168 RGA groundwater samples analyzed from 1995-2010. It was detected in 3 of 25 surface soil samples collected in SWMU 5 (Figure A.3) and not detected in any of 39 subsurface soil samples analyzed for PAHs.

Each of these 3 detects in surface soil samples occurred when high molecular weight polycyclic aromatic hydrocarbons were present, suggesting the presence of a mixture that will limit dissolution of naphthalene. Biodegradation of naphthalene released into soils in the dissolved phase has been demonstrated to occur under both aerobic and anaerobic conditions, with rates that are more rapid under aerobic conditions. Howard et al. (1991) reports naphthalene half-lives in soil from 16.6 to 48 days based upon a soil-die away test, and in groundwater from 24 hours (aerobic) to 258 days (anaerobic).

Naphthalene has a K_d of 0.953 [calculated from the soil organic carbon/water partition coefficient K_{oc} of 1191 L/kg and the fraction of organic carbon (foc) of 0.0008 used in the SESOIL modeling for the BGOU RI]. Based on a K_d value of approximately 1, the travel time of dissolved naphthalene from the UCRS waste zone to the RGA is approximately 100 years (Figure A.2). The biological half-life of 257 days (SESOIL chemical database) is consistent with the slower rate of degradation expected in the UCRS. Using a starting concentration of 31 mg/L (the solubility of naphthalene), 100 years of biodegradation will reduce the naphthalene concentration to < 0.00001 mg/L before it reaches the RGA, and the concentration would be below the groundwater no action level (NAL) of 0.176 µg/L in fewer than 13 years (DOE 2011). The maximum dissolved naphthalene concentration will be much less than the solubility limit; thus, the dissolved concentration prediction for water at the point of migration to the RGA as presented here is conservative.

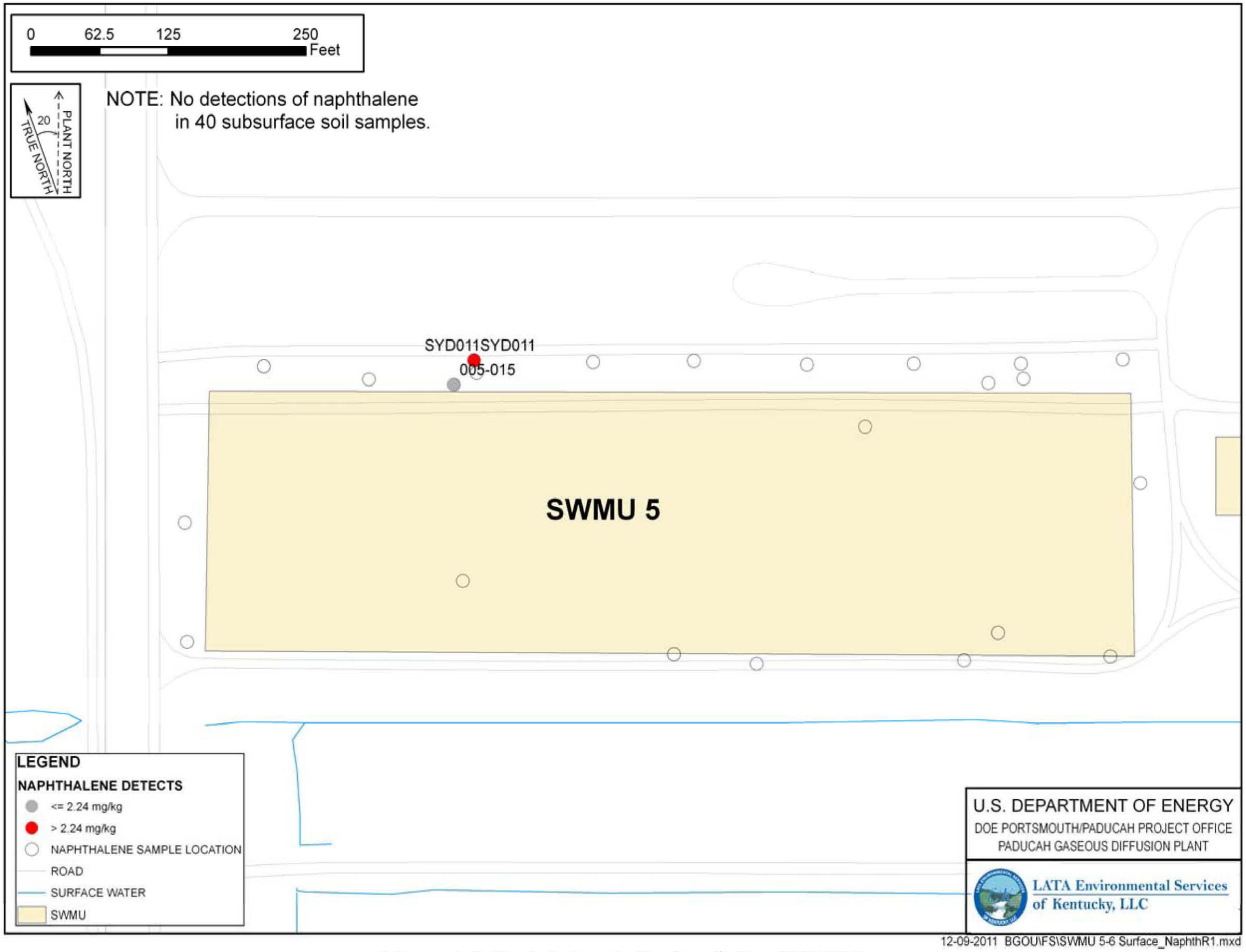


Figure A.3. Naphthalene in Surface Soil at SWMU 5

In summary, naphthalene has not been detected in RGA groundwater or any subsurface soil samples. This is consistent with predicted attenuation during the 100-year travel time to the RGA reducing concentrations such that no exceedances of the groundwater NAL would be expected. Were releases to the RGA to occur, rapid attenuation in this aerobic groundwater would be expected.

A.3.2.2 Uranium

Uranium was the only COC that had a modeled concentration at the SWMU boundary that was above the MCL. It was identified in the RI as a COC at SWMU 5. Before discussing the limited mobility of uranium, the concentrations and distribution of uranium reported in these samples were considered.

The results of the subsurface soils do not indicate any releases of uranium from the waste. Specifically, uranium was analyzed in 17 subsurface soil samples collected in spring of 2007. The analysis was by SW-846-6020 with a detection limit slightly below 1 mg/kg. Uranium was detected in 3 of these samples, none above the background level of 4.6 mg/kg. The maximum concentration was 1.24 mg/kg.

The site data do not suggest uranium has migrated from the waste to the underlying soils. Uranium, if present in the waste, also is considered to have limited mobility; another factor that suggests migration of uranium to RGA groundwater is not likely. The following discussion highlights factors that limit the potential migration of uranium.

The fate and transport modeling for the RI was completed to minimize the potential of eliminating COCs, so these may be further evaluated in the FS. The uranium K_d of 66.8 mL/g applicable for the sand and gravel units of the RGA was used in the RI modeling. The magnitude of the UCRS K_d values ranges from 253 to 93,900 mL/g, with the value of 3640 mL/g for clays more applicable for transport through the UCRS.

Using the uranium K_d of 3,640 ml/g for the BGOU modeling, uranium will not reach the RGA within 1,000 years (Figure A.2). EPA published a technical brief that discusses the mobility of depleted uranium and states the following:

> Uranium transport generally occurs in oxidizing surface water and groundwater as the uranyl ion, UO_2^{2+}, or as uranyl fluoride or carbonate complexes. UO_2^{2+} and uranyl fluoride complexes dominate in acidic oxidizing acidic waters, whereas the carbonate complexes dominate in near-neutral and alkaline oxidizing waters, respectively. In contrast, the uranous ion, U^{4+}, is essentially insoluble. An important point in considering uranium migration in soils is that when UO_2^{2+} is reduced to U^{4+} by humus, peat, or other organic matter or anaerobic conditions, it is essentially immobilized (EPA 2006).

While uranium in the waste zone may include more mobile forms or metallic uranium that may oxidize when released from the source zone, properties of UCRS would limit further migration. Anaerobic conditions are known to occur locally in the UCRS as evidenced by anaerobic degradation products of chlorinated solvents (DOE 2010). The low redox potential in the UCRS favors reduction to U^{4+}, which is not likely to be eluted. K_d values for uranium may be influenced by other factors, including sorption to clays and pH (Table A.4). The K_d value of 66.8 used in the RI modeling reflected a value applicable for sands, and conditions in the UCRS that would further limit migration.

The uncertainty associated with the 1,000-year time horizon used in the groundwater modeling effort and the ingrowth of uranium-238 daughters after 1,000 years was discussed in the RI Report (Appendix E, DOE 2010). The ingrowth of uranium-238 daughters is slow, such that the contributions of uranium-238 daughters and their related radiation doses to an exposed worker are not expected to be significant over

Table A.4. K_d Values for Uranium as a Function of pH

pH	Minimum	Maximum
3	< 1	32
4	0.4	5,000
5	25	160,000
6	100	1,000,000
7	63	630,000
8	0.4	250,000
9	< 1	7,900
10	< 1	5

(EPA 2006)

the next 100,000 years. Uranium at PGDP had been chemically separated from its decay daughters prior to processing at PGDP. The daughters that were present at secular equilibrium with the uranium in the ore body remained with tailings at the uranium mill where it was extracted. The following calculations refer to ingrowth of radium-226 and other daughters as secular equilibrium has begun to reestablish at PGDP.

The uranium-238 decay series is shown below in Table A.5.

Table A.5. Uranium-238 Decay Series

Parent	Half Life (T1/2)	Decay Mode	Branching Fraction	Daughter	Branching Fraction	Daughter
U-238	4.47E+09 yr	SF α	1.00E+00	Th-234		
Th-234	24.1 days	β-	1.00E+00	Pa-234m	2.00E-03	Pa-234
Pa-234m	1.17 min	β-IT	1.30E-03	Pa-234	1.00E+00	U-234
Pa-234	6.70 hr	β-	1.00E+00	U-234		
U-234	2.44E+05 yr	α	1.00E+00	Th-230		
Th-230	7.70E+04 yr	α	1.00E+00	Ra-226		
Ra-226	1.60E+03 yr	α	1.00E+00	Rn-222		
Rn-222	3.82 days	α	1.00E+00	Po-218		
Po-218	3.05 min	α β-	1.00E+00	Pb-214		
Pb-214	26.8 min	β-	1.00E+00	At-218		
At-218	2.00 sec	α	1.00E+00	Bi-214		
Bi-214	19.9 min	β-	1.00E+00	Po-214		
Po-214	1.64E+02 μsec	α	1.00E+00	Pb-210		
Pb-210	22.3 yr	β-	1.00E+00	Bi-210		
Bi-210	5.01 days	β-	1.00E+00	Po-210		
Po-210	1.38E+02 days	α				

SF = spontaneous fission, α = alpha decay, β- = beta decay, IT = internal transformation

The rate of ingrowth of uranium-238 series daughters is controlled by the half lives of uranium-238 and the slowest decaying daughters (uranium-234, thorium-230, radium-226, and lead-210).

The ingrowth of all of the daughters of a complex decay series of such as the uranium-238 series is described rigorously by the Bateman equations as applied in software based on radionuclide decay data (ORNL 2006). By making the assumption that the activities of all daughters is zero at time = 0, the software can be used to calculate the relative activity of each daughter at any subsequent time.

The ingrowth of uranium-238 daughters is shown in Table A.6.

Table A.6. Calculated Future Radionuclide Concentrations at the BGOU per 1 pCi/g Uranium-238 with No Daughters Present at Time = 0

Nuclide	1,000 years		10,000 years		100,000 years		3.5E+06 years	
	Activity (pCi/g)	% Total Activity	Activity (pCi/g)	% Total Activity	Activity (pCi/g)	% Total Activity	Activity (pCi/g)	% Total Activity
U-238+D	3.00E+00	9.99E+01	3.00E+00	9.88E+01	3.00E+00	7.33E+01	3.00E+00	2.14E+01
U-234	2.84E-03	9.44E-02	2.80E-02	9.22E-01	2.47E-01	6.04E+00	1.00E+00	7.14E+00
Th-230	1.27E-05	4.24E-04	1.23E-03	4.05E-02	8.77E-02	2.14E+00	1.00E+00	7.14E+00
Ra-226+D	1.45E-05	4.82E-04	7.14E-03	2.35E-01	7.59E-01	1.85E+01	8.99E+00	6.43E+01
Total	3.00E+00	1.00E+02	3.04E+00	1.00E+02	4.10E+00	1.00E+02	1.40E+01	1.00E+02

The activity concentration of uranium-234 and its daughters will remain less than the activity of uranium-238 and daughters (uranium-238+D) through 100,000 years, when uranium-238 will represent over 73% of total activity. The concentrations of uranium-234 and its daughters will exceed uranium-238+D activity at some time after 1 million years. By approximating uranium-238 and uranium-234 as a series in transient equilibrium, it can be estimated that the maximum uranium-234 activity will occur at approximately 3.5 million years (Cember 1989). After that time, the activity of all uranium-238 daughters will decrease at the rate of uranium-238 decay.

The radiotoxicity of members of the uranium-238 series described by dose coefficients is provided by the EPA and the International Commission on Radiological Protection. These dose coefficients are implemented in the ORNL (2006) software.

The relative radiotoxicity of members of the uranium-238 series at 1,000 years is shown in Table A.7.

Table A.7. Calculated Radiological Dose at 1,000 Years per 1 pCi/g Uranium-238

Nuclide	Activity		Radiation Dose (Sv)				
	(pCi/g)	% Total	Ingestion	Inhalation	External (Sv/yr)	Total	% Total Dose
U-238+D	3.00E+00	9.99E+01	6.81E-08 Bone	8.63E-07 Bone	1.87E-10	9.31E-07	9.49E+01
U-234	2.84E-03	9.44E-02	2.02E-10	2.71E-09	2.71E-17	2.92E-09	2.97E-01
Th-230	1.27E-05	4.24E-04	6.23E-12	7.85E-10	3.25E-17	7.91E-10	8.06E-02
Ra-226+D	1.45E-05	4.82E-04	3.39E-12	7.21E-12	4.67E-08 Skin	4.67E-08	4.76E+00
Total	3.00E+00	1.00E+02	6.83E-08	8.66E-07	4.69E-08	9.82E-07	1.00E+02

These radiological dose estimates are based on industrial worker exposure parameters for the ingestion and inhalation pathways, as described in the ORNL (2006) software. These estimates indicate that at 1,000 years, the radiation dose is absorbed predominantly by bone surface tissue of radiation emitted by uranium-238 and its daughters (thorium-234 and protactinium-234). As daughter ingrowth increases, the predominant radiation dose still is estimated for bone tissue, but the dose delivered by thorium-230 exceeds the uranium-238+D dose after approximately 100,000 years. During this time, the radiation dose from radium-226+D nuclides also is delivered primarily to bone surface tissue, but remains less than that of the uranium and thorium isotopes even after 1 million years. The predominant role of dose absorbed by bone tissue results from the assumption that inhaled or ingested uranium-238 and daughters is rapidly transported from the lung or gastrointestinal tract and deposited in bone tissue where it is strongly incorporated into bone tissue.

It is important to note that the decay and ingrowth of uranium-238 daughters is independent of whether the uranium-238 atom is associated with soil or water. The rates of decay and daughter ingrowth are unchanged by the surrounding matrix.

The uncertainty associated with the ingrowth of uranium-238 daughters is characterized by slowly increasing radiation doses estimated for thorium-230, which is expected to become greater than the dose delivered by uranium-238, thorium-234, and protactinium-234 after approximately 100,000 years. Radiation doses associated with uranium-234 and radium-226+D nuclides remain secondary until the time of maximum daughter ingrowth net secular equilibrium is estimated at 3.5 million years. The predominant radiation dose is absorbed bone tissue, based on the assumption of fast absorption and translocation of inhaled or ingested nuclides. As with nonradioactive COCs, remediation alternatives are developed to prevent exposure to all of the radionuclide COCs.

A.3.3 TECHNETIUM-99

Technetium-99 was identified as a COC for SWMU 5 in the BHHRA (risk contribution less than 3E-6); however, the predicted concentration at the SWMU boundary of 127 pCi/L was below the MCL of 900 pCi/L. In addition, none of the soil samples exceeded 38.5 pCi/L, the dose-based soil screening level (SSL) to protect RGA groundwater for a resident adult at the MCL of 4 mrem/yr (DOE 2011), RMD Table A.11). This SSL was estimated using the RESRAD code version 6.0 and PGDP-specific assumptions.

As discussed further in Section 5, the distribution of technetium-99 in soils do not indicate releases from SWMU 5 to subsurface soils have occurred, exceeding background concentrations in only 1 of 64 subsurface soil samples.

A.4. CONCLUSIONS

The COCs identified in the BHHRA included several constituents whose predicted RGA groundwater concentrations are below their MCLs, which are the target groundwater concentrations used to evaluate potential actions in this FS. Other factors, including consideration of background, transport and distribution, indicate none of these COCs require development of specific alternatives.

No COCs are identified that require development of preliminary RGs to meet the RAO.

A.5. REFERENCES

Alexander, M. 1995. "How Toxic are Chemicals in Soil?" *Environmental Science and Technology*, published by the American Chemical Society, 29(11), 2713-2717.

Cember, H. 1989. *Introduction to Health Physics.* Pergamon Press, New York.

DOE (U.S. Department of Energy) 2010. *Remedial Investigation Report for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0030&D2, U.S. Department of Energy, Paducah, KY, April.

DOE 2011. *Methods for Conducting Risk Assessment and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Volume 1: Human Health*, DOE/LX-07-0107&D2/R1/V1, February.

EPA (U.S. Environmental Protection Agency) 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, EPA540/G-89/004, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC, October.

EPA 2006. *Depleted Uranium: Technical Brief.* EPA 402-R-06-011, December, http://www.epa.gov/radiation/docs/cleanup/402-r-06-011.pdf.

Howard, P. H., R. S. Boethling, W. F. Jarvis, W. M. Meylan, and E. M. Michalenko 1991. *Handbook of Environmental Degradation Rates.* Lewis Publishers, Chelsea, MI.

Loehr, R. C. and M. T. Webster 1996. "Behavior of Fresh vs. Aged Chemicals in Soil." *J. Soil Contamination.* 5(4), 361-383.

ORNL (Oak Ridge National Laboratory) 2006. *User's Guide to the DCAL System,* ORNL/TM-2001/190, Dist. Category UC-407. August. Available at http://www.epa.gov/radiation/docs/assessment/dcal-manual.pdf.

Pavlostathis, S. G. and Mathavan, G. N. 1992. "Desorption Kinetics of Selected Volatile Organic Compounds from Field Contaminated Soils," *Environmental Science and Technology*, published by the American Chemical Society, 26(3), 532-538.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX B

DEVELOPMENT OF PRELIMINARY REMEDIATION GOALS FOR SOIL THAT ENSURE PROTECTION OF INDUSTRIAL AND OUTDOOR WORKERS

THIS PAGE INTENTIONALLY LEFT BLANK

CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

TABLES

FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

ACRONYMS

BGOU	Burial Grounds Operable Unit
bgs	below ground surface
BHHRA	baseline human health risk assessment
COC	contaminant of concern
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
FS	feasibility study
HI	hazard index
HQ	hazard quotient
NA	not applicable
NAL	no action level
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyls
PGDP	Paducah Gaseous Diffusion Plant
POC	point of contact
RAO	remedial action objective
RG	remediation goal
RGA	Regional Gravel Aquifer
RI	remedial investigation
RSL	Regional Screening Level
SWMU	solid waste management unit
Tc-99	technetium 99
WAG	Waste Area Grouping

THIS PAGE INTENTIONALLY LEFT BLANK

B.1. DEVELOPMENT OF REMEDIATION GOALS FOR SOIL THAT ENSURE PROTECTION OF INDUSTRIAL AND OUTDOOR WORKERS

This appendix accompanies the *Feasibility Study for Solid Waste Management Units 5 and 6 of the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0130a&D2/R3 (FS), which has been prepared to evaluate remedial alternatives for Solid Waste Management Units (SWMUs) 5 and 6 of the Burial Grounds Operable Unit (BGOU) at the Paducah Gaseous Diffusion Plant (PGDP). The FS will support remedy selection for SWMUs 5 and 6 in accordance with regulatory guidance and consistent with the scope of the BGOU FS. Appendix B details the approach taken to address the following general remedial action objective (RAO) for SWMUs 5 and 6:

- Prevent exposure to waste and contaminated soils that present an unacceptable risk from direct contact.

The scope of the BGOU FS includes evaluating risks from exposure to contaminants of concern (COCs) in soils and waste at SWMUs 5 and 6 and taking actions, as necessary, to protect human health and the environment. As discussed in Sections 5 and 6, it is uncertain if the surface and subsurface soil sample results available to the remedial investigation (RI) and baseline health risk assessment (BHHRA) completely characterized the nature and extent of contamination. Additionally, the characterization of the waste was uncertain and relied on samples from adjacent and underlying subsurface soil. These uncertainties are recognized in the BHHRA as having a small to moderate impact on the reported risks (i.e., risk results could vary by up to 2 orders of magnitude).

Releases from wastes and contaminated soils to groundwater and surface water and the risks and hazards associated with these releases also are within the scope of the FS. Because the RI for SWMUs 5 and 6 did not ascertain the integrity of the existing soil cover at these SWMUs, the impact of this soil cover from any contamination present on releases to surface water or on contaminant migration from these and underlying subsurface soils and waste also is uncertain.

Contamination in sediments in ditches adjacent to the BGOU SWMUs fall primarily within the scope of the Surface Water Operable Unit (OU) Strategic Initiative. Thus, these ditches will be addressed as part of the post-gaseous diffusion plant shutdown activities for the Surface Water OU.

Given the uncertainties mentioned above, the risk evaluation in this FS assumes that surface soils possibly contain contamination leading to unacceptable risks and that releases from the soils and wastes are possible. Exposure of future workers can be reduced by lowering the concentration of COCs in soil or waste, or by reducing the worker's potential for exposure to contaminated soil and waste, or a combination of both. Particularly, for this FS, due to the uncertainty in the waste source term, administrative or engineering controls are considered to limit or eliminate direct contact with waste. No chemical-specific remediation goals (RGs) are developed for contact with waste.

Identifying soil RGs is one method that supports an evaluation of achieving the RAO because the RGs identify concentrations of COCs in soil that does not pose unacceptable risk under defined exposure scenarios. In addition, an RG can be used to support treatment and/or removal alternatives by establishing where treatment/removal would be required. For this FS, achieving the SWMU-specific RAO for which RGs will be developed is based on meeting the following target cumulative excess lifetime cancer risks (ELCRs) and cumulative noncancer hazard indices (HIs) for the industrial and outdoor worker (Note that the future outdoor worker was referred to as an excavation worker in the RI.) receptors who may contact contaminants in soil in the future.

- Surface Soil: cumulative ELCR < 1E-05 and cumulative HI ≤ 1 for a future industrial worker
- Subsurface Soil: cumulative ELCR < 1E-04 and cumulative HI ≤ 1 for an outdoor worker

This appendix describes the development of RGs that are protective of industrial workers from direct contact with surface soil and outdoor workers from direct contact with subsurface soil at SWMUs 5 and 6. The COCs identified in the BHHRA for these receptors are the constituents for which RGs potentially are to be developed. Evaluation of potential alternatives to meet this RAO and corresponding development of soil RGs protective for future workers have the following additional considerations.

- RGs will not be developed for COCs that are at/below background concentrations.

- The direct contact COCs for the future industrial and outdoor workers were identified in the Waste Area Group 3 Investigation (DOE 2000). Where updated toxicity information indicates the chemical would not be a COC using current assumptions, no RG would be required for that chemical for the remedy to be protective and meet the RAO.

- The BHHRA identified risks to the outdoor worker based on contact with contaminants in surface and subsurface soils (0–16 ft). To meet the RAO as stated, the RGs for the outdoor worker would be derived only for those COCs present in the subsurface soil (1–16 ft bgs). RGs for surface soil are to be based on the future industrial worker, which given the target cumulative ELCR 1E-5, would be the lower target concentration.

- Chemicals identified as COCs for the future workers that are present only in the drainageways and are not a result of releases from the waste units are being addressed in the Surface Water OU, guided by the applicable RAOs and RGs for that operable unit. Evaluating alternatives to address these COCs is not within the scope of the BGOU FS (the RAO for this FS is not the appropriate basis for identifying RGs for the SWOU); therefore, no RGs are developed for these COCs.

RGs are to be developed for the COCs that are not eliminated by the previous considerations. These soil contaminants present above the RGs must be addressed by remedial alternatives developed in the FS. During the FS process, remedial actions are examined in the context of their effectiveness in meeting the RAO.

B.1.1 SUMMARY OF COCs FROM BASELINE HUMAN HEALTH RISK ASSESSMENT

The BGOU RI included a BHHRA, which evaluated a variety of exposure scenarios for the COCs identified in the RI. Tables B.1 and B.2 (taken from the RI) summarize the results of the risk assessment (DOE 2010). The findings of the risk assessment form the basis for identification of the COCs to be evaluated and addressed by the remedial alternatives presented in the FS.

The reasonably anticipated current and future land use of PGDP is industrial. Additionally, no current or future use of affected groundwater drawn from the Regional Gravel Aquifer (RGA) at the SWMUs 5 and 6 source areas is anticipated. Although the risk assessment prudently examined a range of potential land uses and receptors in order to estimate future risks, which was consistent with regulatory guidance and the approved BGOU RI Work Plan (DOE 2006), the future PGDP land use will be maintained as industrial.

Table B.1. Summary of Risk Characterization for SWMU 5

Receptor	Total ELCR[a]	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI[a]	COCs	% Total HI	Routes of Exposure	% 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	8.15E+01	Uranium Arsenic Manganese Naphthalene	90.3 3.6 2.6 3.4	Ingestion Dermal Inhalation while showering Household inhalation	96.4 0.2 0.4 3.0
Future adult rural resident at current concentrations (RGA groundwater only)	2.52E-04	Arsenic Tc-99	97.2 2.8	Ingestion Dermal	99.7 0.3	2.31E+01	Uranium Arsenic Manganese Naphthalene	91.0 3.7 2.7 2.6	Ingestion Dermal Inhalation while showering Household inhalation	97.1 0.3 0.3 2.3
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	6.56E+00	Uranium Arsenic Manganese Naphthalene	81 9 27.5	Ingestion Household inhalation	92.4 6.6
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	4.99E-05	Arsenic Tc-99	94.5 5.5	Ingestion	99.7	1.84E+00	Uranium Arsenic Naphthalene Manganese	82.4 8.9 5.8 2.1	Ingestion Household inhalation	93.9 5.1

Table B.1. Summary of Risk Characterization for SWMU 5 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI[a]	COCs	% Total HI	Routes of Exposure	% 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 Tc-99	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

Table B.1 is taken from Table 6.9 of the BGOU RI (DOE 2010). (Note that excavation worker as referenced in the RI is now outdoor worker.)
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 routes of exposure.
[a] Total ELCR and total HI represent total risk or hazard summed across all routes of exposure for all COCs.
[b] WAG 3 RI (DOE 2000), Table 1.56. In this table, lead has been excluded as a COC.

COC = contaminant of concern
ELCR = excess lifetime cancer risk
HI = hazard index
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
POC = point of contact
RGA = Regional Gravel Aquifer
WAG = waste area group

Table B.2. Summary of Risk Characterization for SWMU 6

Receptor	Total ELCR[a]	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI[a]	COCs	% Total HI	Routes of Exposure	% 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		1.77E-01	Manganese	100	Ingestion of water Dermal	97.9 2.1
Future adult rural resident at current concentrations (RGA groundwater only)		*No COCs		*No COCs		5.18E-02	Manganese	100	Ingestion of water Dermal	95.7 4.3
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 B.2. Summary of Risk Characterization for SWMU 6 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	Routes of Exposure	% Total ELCR	Total HI[a]	COCs	% Total HI	Routes of Exposure	% 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

Table B.2 is taken from Table 6.10 of the BGOU RI (DOE 2010). (Note that excavation worker as referenced in the RI is now outdoor worker.)
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 routes of exposure.
[a] Total ELCR and total HI represent total risk or hazard summed across all routes of exposure for all COCs.
[b] WAG 3 RI (DOE 2000), Table 1.57. In this table, lead has been excluded as a COC.
COC = contaminant of concern
ELCR = excess lifetime cancer risk
HI = hazard index
PAH = polycyclic aromatic hydrocarbon
POC = point of contact
RGA = Regional Gravel Aquifer
WAG = waste area group

The COCs carried forward for evaluation in this FS are those identified in the risk assessment for the future industrial worker [potential exposure to surface soil from 0–1 ft below ground surface (bgs)]. As summarized above, the BHHRA also evaluated the exposure for a future outdoor worker (potential exposure to surface and subsurface soils and waste from 0–16 ft bgs) and identified COCs that may require controls to ensure protection of human health. The COCs identified in the BHHRA for SWMUs 5 and 6 for these workers are summarized in Table B.3.

Table B.3. Summary of COCs Identified for Future Industrial Worker and Outdoor Worker at BGOU SWMUs 5 and 6

	SWMU 5	SWMU 6
Carcinogenic COCs (ELCR > 1E-06)	Arsenic Beryllium Total PAH *Total PCB*	Beryllium Total PAH
Noncancer Hazard COCs (HQ > 0.1)	*Aluminum* *Arsenic* *Barium* *Beryllium* *Chromium* *Iron* *Manganese*	*Aluminum* *Barium* *Beryllium* *Chromium* *Iron* *Manganese* *Vanadium*

Reference: BGOU RI (DOE 2010)
Analytes in italics identified as COCs only for outdoor worker scenario.
Analytes not italicized are COCs.
for both future industrial and outdoor worker scenarios.
COC = contaminant of concern
ELCR = excess lifetime cancer risk
HQ = hazard quotient
PCB = polychlorinated biphenyl
PAH = polycyclic aromatic hydrocarbon
SWMU = solid waste management unit

B.1.2 REFINEMENT OF COC LIST

Refinement of the COC list begins with an evaluation of the COCs identified in the RI for future industrial or outdoor workers, as summarized in Table B.3. This list has been refined based on additional comparisons to background, updated toxicity and exposure parameter information, additional screening criteria, and/or clarification of the chemical concentration patterns. While some refinements may be SWMU-specific, a number of the COCs are evaluated based on overall patterns across the BGOU. The full list of COCs has been refined using the following considerations.

- Review of Naturally Occurring Metals: To facilitate understanding the patterns in the results for naturally occurring metals, a summary of the frequency of detection of the naturally occurring metals was reviewed (Table B.4). As explained later in this section, this review demonstrated that none of the naturally occurring metals were retained as COCs because their extents were explained by the range of natural occurrence.

Table B.4. Review of COCs Contributing to the Noncancer Hazards to Outdoor Worker at SWMU 5 and SWMU 6

Analysis	SWMU	Depth	Avg mg/kg	Max mg/kg	Background mg/kg[1]	Frequency of Exceeding Background	Comments
Aluminum	5	Surface	8,400	13,800	13,000	**2/14**	• Infrequent exceedance; maximum concentration near background • No exceedance of the outdoor worker NAL (18,700 mg/kg)
		Subsurface	7,980	10,200	12,000	0/11	
	6	Surface	8,390	11,200	13,000	0/15	
		Subsurface	8,470	10,500	12,000	0/25	
Arsenic	5	Surface	8.49	12.2	12	**1/15**	• Only 1/26 samples at SWMU 5 slightly above background. Surface soil ditch sample west of the SWMU • Not a COC for SWMU 6
		Subsurface	2.13	3.07	7.9	0/11	
	6	Surface	5.76	6.38	12	0/15	
		Subsurface	2.64	5.94	7.9	0/25	
Barium	5	Surface	88.4	125	200	0/15	• No exceedance of background • No exceedance of outdoor worker NAL
		Subsurface	76.8	141	170	0/11	
	6	Surface	80.2	99.2	200	0/15	
		Subsurface	74.8	119	170	0/25	
Beryllium	5	Surface	0.63	0.74	0.67	**2/14**	• Concentrations near minimum detection limits • Concentrations below the outdoor worker NAL for noncancer effects (5.32 mg/kg) • All concentrations well below EPA RSL (160 mg/kg for residential soil)
		Subsurface	0.81	0.93	0.69	**2/11**	
	6	Surface	0.585	0.73	0.67	**1/15**	
		Subsurface	0.94	2.62	0.69	**3/25**	
Chromium	5	Surface	11.9	20.5	16	**2/15**	• 2/26 samples at SWMU 5 above background • none exceed the outdoor worker NAL (40.8 mg/kg)
		Subsurface	12.1	18.1	43	0/11	
	6	Surface	10.1	14.4	16	0/15	
		Subsurface	12.5	20.5	43	0/25	
Iron	5	Surface	13,800	26,900	28,000	0/14	• 2/40 samples at SWMU 6 exceeded background; average concentrations across the BGOU are comparable • Outdoor worker NAL is below background • All concentrations are below the EPA RSL (72,000 mg/kg; HI = 0.1)
		Subsurface	10,500	18,000	28,000	0/11	
	6	Surface	11,600	19,600	28,000	0/15	
		Subsurface	12,600	54,200	28,000	**2/25**	

Table B.4. Review of COCs Contributing to the Noncancer Hazards to Outdoor Worker at SWMU 5 and SWMU 6 (Continued)

Analysis	SWMU	Depth	Avg mg/kg	Max mg/kg	Background mg/kg[1]	Frequency of Exceeding Background	Comments
Manganese	5	Surface	390	599	1,500	0/14	• Single exceedance; pattern comparable across the BGOU • No exceedance of the outdoor worker NAL (1,960 mg/kg)
		Subsurface	274	690	820	0/11	
	6	Surface	370	664	1,500	0/15	
		Subsurface	270	1,550	820	**1/25**	
Vanadium	5	Surface	21.6	35.4	38	0/14	• Two exceedances in SWMU 6 • Not a COC for SWMU 5 • All concentrations below the EPA RSL (520 mg/kg; HI = 0.1 for industrial soil)
		Subsurface	21.3	33.3	37	0/11	
	6	Surface	19.4	24.8	38	0/15	
		Subsurface	22.4	65.6	37	**2/25**	

[1] Background values are surface and subsurface concentrations taken from Table A.12 of the Risk Methods Document (DOE 2011).
BGOU = Burial Grounds Operable Unit
COC = contaminant of concern
EPA RSL = Regional Screening Levels of June 2011 (EPA 2011)—(EPA Region 4/Kentucky screening values for comparison)
HI = hazard index
NAL = no action level
SWMU = solid waste management unit
Subsurface soils include samples collected between 1 and 16 ft bgs.

At the time the Waste Area Grouping (WAG) 3 RI reports were developed,, beryllium was evaluated as a carcinogen through the oral route of exposure. Since the completion of those BHHRAs, the oral 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 performed in EPA Region 4. The maximum beryllium concentration at the BGOU SWMUs (3.07 mg/kg) is below the noncancer no action levels (NALs) for beryllium for the industrial worker and outdoor workers (4.29 mg/kg and 5.32 mg/kg). In addition, as summarized in the RI (DOE 2010), although beryllium is a carcinogen by the inhalation route of exposure, it would be screened from evaluation as a COC because the highest risk at any SWMU was three orders of magnitude less than 1E-6.

- Use of Updated EPA Risk Assessment Guidance: Historically, a conservative dermal absorption factor was used to ensure that the ELCR and HI were not underestimated. The historical risk assessments included in the RI identified dermal exposure to metals as a significant contributor to the HI for SWMUs 5 and 6 for the future outdoor worker scenario; however, EPA issued the *Final Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (EPA 2004), which contained updated absorption factors for metals. Using these updated factors decreased the HI for dermal exposure to soil by a factor of about 100 and eliminated dermal exposure as a pathway of unacceptable risk.

B.1.2.1 Evaluation of Carcinogenic COCs

Carcinogenic compounds are the primary drivers for remedial action decisions at each of the BGOU SWMUs. As noted above, beryllium has been removed as a COC for the BGOU based upon an updated toxicity assessment. Arsenic concentrations at BGOU SWMUs were evaluated and found to be comparable to background. Arsenic background was not exceeded in any soil sample at SWMU 6 and in only 1 of 26 soil samples from SWMU 5 at depths to 16 ft bgs. The sample above background had an arsenic concentration of 12.2 mg/kg that slightly exceeded the established background of 12 mg/kg at a location in the drainage ditch west of the disposal area (see Section 5). Thus, arsenic was removed as a COC for SWMUs 5 and 6. Once beryllium and arsenic are removed, the COC list for carcinogenic compounds is as shown in Table B.5.

Table B.5. Summary of Carcinogenic COCs and Adjusted Risk Levels

	Adjusted Risk Estimate*		
	Industrial Worker	**Outdoor Worker**	**COCs**
SWMU 5	1.8E-04	8.4E-05	Total PAH, Total PCBs
SWMU 6	2.4E-05	2.1E-05	Total PAH

* Adjusted risk estimate with removal of beryllium (SWMUs 5 and 6) and arsenic (SWMU 5).
COC = contaminant of concern
PCB = polychlorinated biphenyl
PAH = polycyclic aromatic hydrocarbon
SWMU = solid waste management unit

The primary impact of removing beryllium and arsenic from the risk estimates as previously calculated in the RI is that the outdoor worker risks for SWMUs 5 and 6 are now within EPA's acceptable risk range of E-6 to E-4.

There is some uncertainty with respect to the source(s) of polycyclic aromatic hydrocarbons (PAHs) and total polychlorinated biphenyls (PCBs); however, the fact that the PAHs and PCBs were detected only in surface soils/sediments at SWMUs 5 and/or 6 suggests that these COCs are not related to releases from wastes at these SWMUs. Figures B.1–B.3 highlight the surface locations. Contaminants at those locations will be addressed as part of the SWOU.

- PAHs. No PAHs were detected in approximately 80 subsurface soil samples collected to identify potential releases from the wastes at SWMUs 5 and 6. The two surface soil samples with PAHs above screening levels at SWMU 6 are adjacent to, but not part of, SWMU 6 and did not result from migration from the waste, and data were incorporated into the evaluation of the SWOU. Similarly, SWMU 5 samples typically are located adjacent to roads located on the perimeter of the SWMU and did not result from migration from the waste (see Sections 5 and 6).

- PCBs. No PCBs were detected in 51 subsurface soil samples analyzed in SWMU 5. There were 6 detections of PCBs in surface soil samples, most adjacent to the SWMU boundary and below the industrial worker NAL. The maximum PCB concentration of 0.306 mg/kg is well below the SWOU RG of 16 mg/kg and the BGOU SWMU risk management level for the RG of 10 mg/kg. PCBs were not a COC for the industrial worker exposures to surface soils. PCBs were a COC for the outdoor worker; however, PCBs were not detected in subsurface soils. PCBs were not detected and not identified as a COC at SWMU 6.

B.1.2.2 Noncancer Hazards

The HI is less than 1 for the industrial worker, so no COCs are identified for surface soils for this receptor. The noncancer hazard for the outdoor worker at SWMUs 5 and 6 was greater than 1, but hazard indices were relatively low, ranging from 2.16 to 2.44. Seven metals were identified as contributing to the

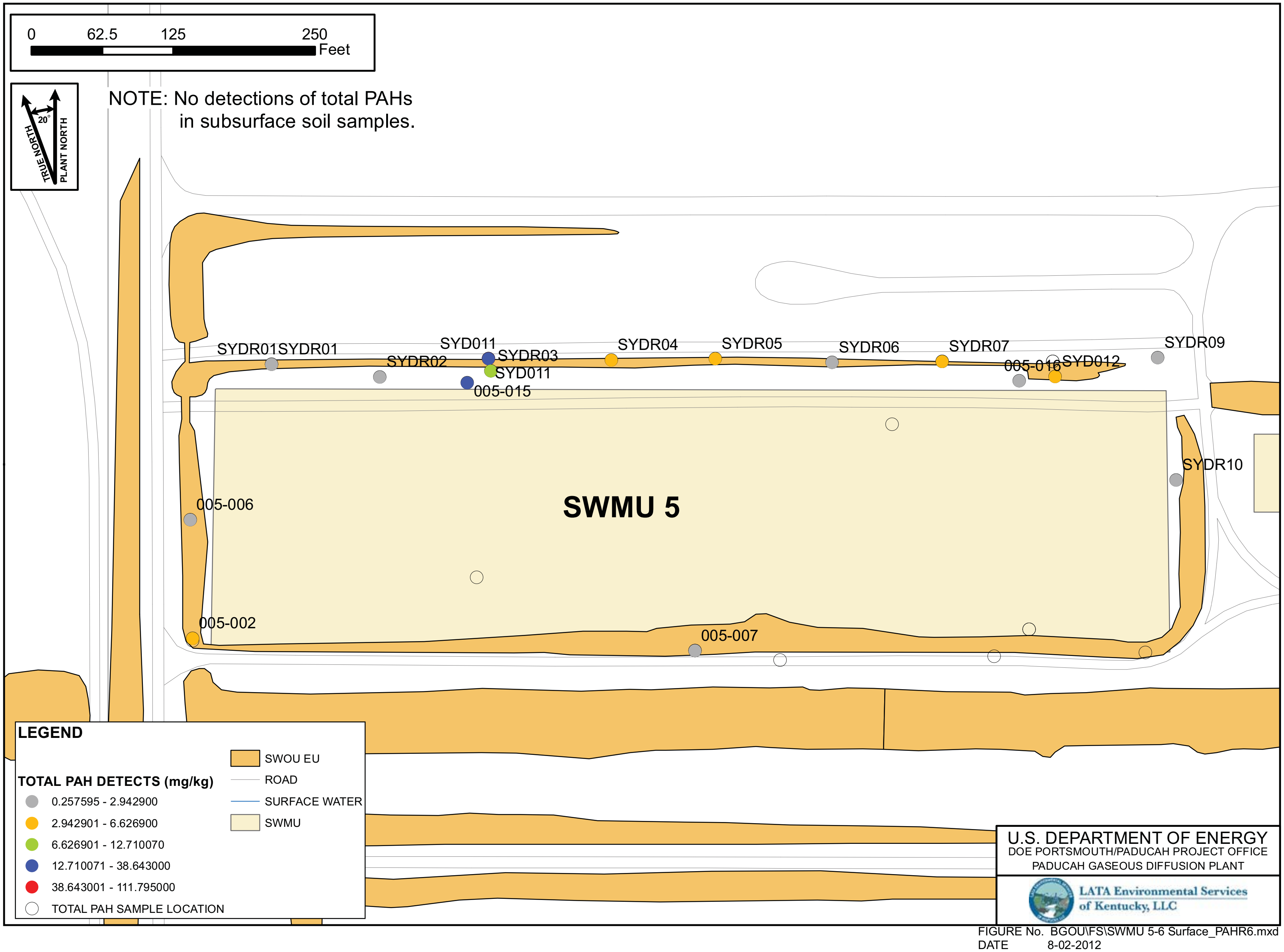


Figure B.1. Total PAHs in Surface Soils at SWMU 5

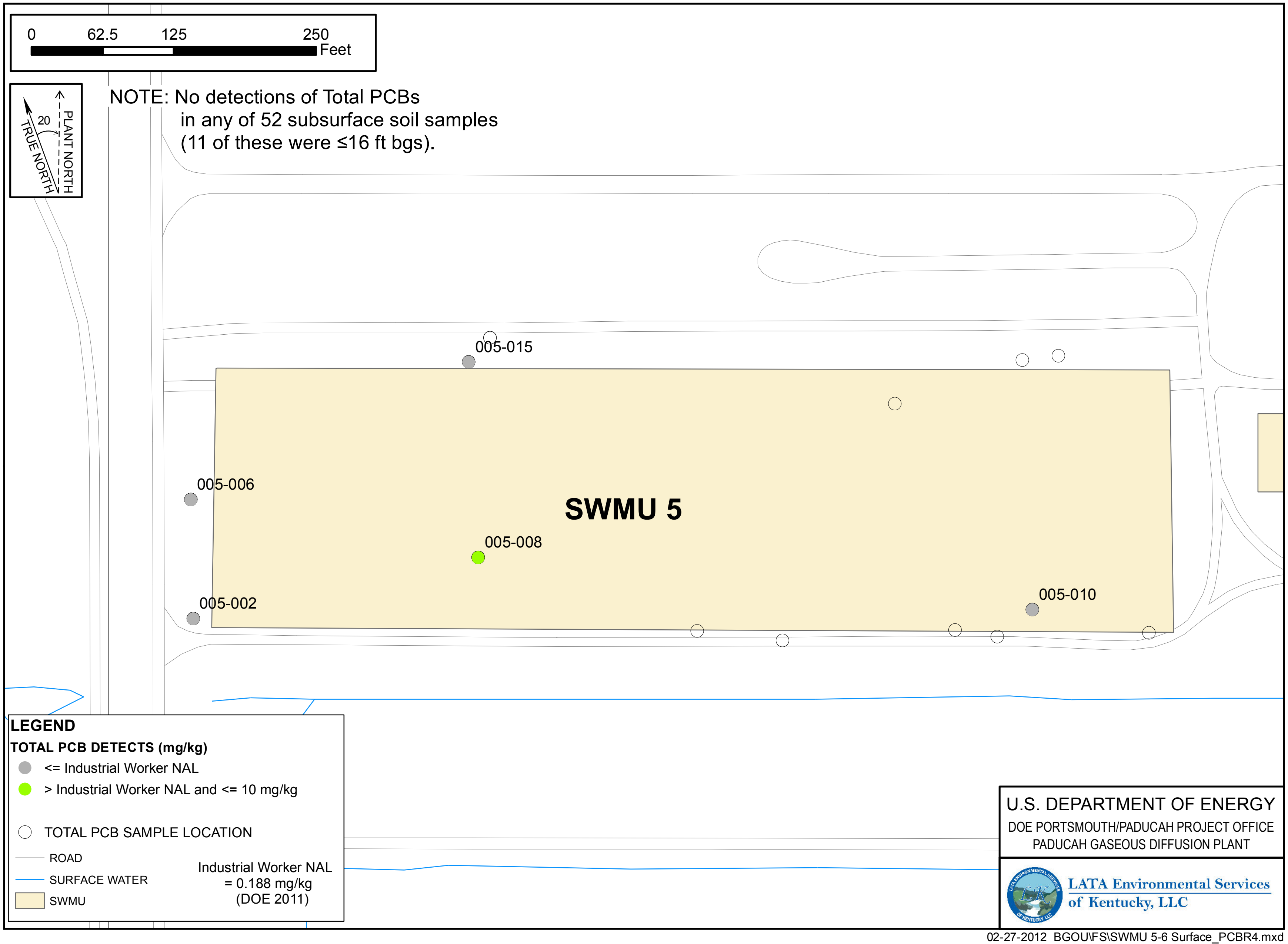


Figure B.2. Total PCBs in Surface Soils at SWMU 5

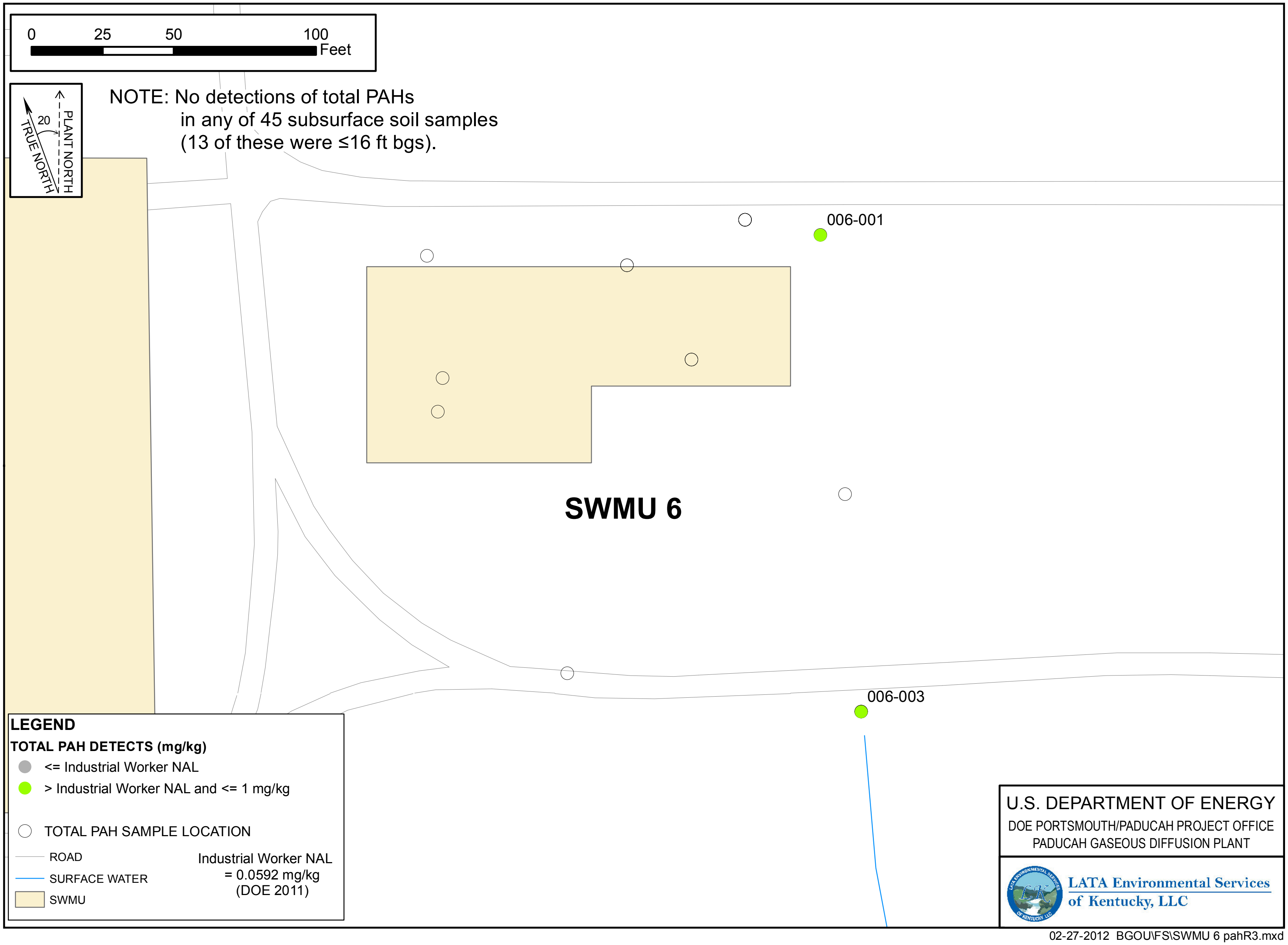


Figure B.3. Total PAHs in Surface Soils at SWMU 6

HI at each of these SWMUs. As summarized on Table B.4, these infrequently exceed background concentrations, in some cases, only in surface soil samples.

The potential contribution of these metals to the noncancer hazard was further reviewed based on the frequencies of these constituents exceeding outdoor worker NALs. Hazards to the outdoor worker were estimated based on concentrations from 0–16 ft bgs, and results are compared separately for surface and subsurface soils. COCs with a concentration below the NAL (HI = 0.1) are not identified as a COC for further risk analysis using the current assumptions for these worker scenarios.

As shown on Table B.4, several of the COCs identified for the outdoor worker in the WAG 3 RI do not exceed background, outdoor worker NALs (HI = 0.1) and/or EPA RSLs (EPA 2011). Removing the contribution of metals below background and NALs reduces the HI. Dermal absorption accounts for 82–88% of the total HI; thus, this evaluation overestimates the intake for most of these metals.

Most importantly, the data were reviewed by comparison of detected results at each sample location with the outdoor worker NAL to estimate a sample-specific HI. No samples (0–16 ft bgs) at SWMUs 5 or 6 had an HI > 1 with the exception of the two samples, with vanadium detected above background at SWMU 6.

Although these COCs were not retained for industrial or outdoor worker scenarios, several of the metals shown on Table B.4 also contributed to the HI > 1 for unrestricted residential exposures. Most of the hazard is attributed to ingestion of vegetables and dermal absorption. Residential exposure is not considered a reasonable exposure path.

None of the COCs identified in the BHHRA that contribute to the non-cancer hazard for the outdoor worker are carried forward as hazards to be addressed in the FS:

- Several metals were identified as COCs contributing to the noncancer hazard for the outdoor worker; however, most were typically below background and/or outdoor worker NALs.

- HIs are considered conservative for these metals, with 82–88% of the risk attributed to dermal absorption.

- Exceedances of background are sporadic and, for most metals, comparable to patterns across the BGOU.

- No subsurface soil samples at either site exceed an HI of 1 (vanadium detected in two subsurface soil samples screened based on toxicity factors applicable for vanadium compounds).

B.1.3 DIRECT CONTACT THREATS TO BE ADDRESSED IN THE FS

The RAO for SWMUs 5 and 6 addressed in this appendix is "Prevent exposure to waste and contaminated soils that presents an unacceptable risk from direct contact." No unacceptable risks/hazards are identified for the current workers maintaining the site. Achieving the RAO for soils is more conservatively based on meeting the following target cumulative ELCRs and cumulative noncancer HIs for the industrial and outdoor worker receptors.

- Surface Soil: cumulative ELCR < 1E-05 and cumulative HI ≤ 1 for a future industrial worker
- Subsurface Soil: cumulative ELCR < 1E-04 and cumulative HI ≤ 1 for an outdoor worker

In addition, the scope of the BGOU FS includes addressing releases or potential releases from the source areas; however, remedial decisions for sediments adjacent to the SWMUs are to be addressed in the SWOU.

In this appendix, the BHHRA results were evaluated specifically to determine the threats to be addressed in the FS. That is, identify COCs that may result in exceeding the target cumulative ELCRs and HIs that are related to releases from the waste units.

The COCs for direct contact exposures to contaminants in soil presented in the BHHRA were those identified in the WAG 3 RI Report (DOE 2000). The COCs identified for the industrial worker and outdoor worker were further reviewed considering background concentrations, updated toxicity information, and potential relationship to releases from the waste unit.

Based on the previous discussions, no COCs are identified for which RGs are to be developed for this FS to meet the RAO for contaminants in soil.

- Subsurface Soils—Outdoor Worker
  - All carcinogenic chemicals identified as COCs for the outdoor worker were below background (arsenic) or not detected (PCBs and PAHs) in any of the subsurface soils. Therefore, there are no COCs to be addressed in the FS to meet the target ELCR for subsurface soils (1–16 ft bgs).[1]
  - For the outdoor worker, there are no subsurface soil samples (0–16 ft bgs) in SWMUs 5 or 6 with an HI > 1.2.
- Surface Soils—Industrial Worker
  - No unacceptable noncancer hazards were identified for the future industrial worker in the BHHRA (surface soil target HI is met).
  - PCBs, detected only in surface soils/adjacent sediments, were not a COC for the industrial worker, were not associated with releases from the waste, and the maximum concentration 0.306 mg/kg well below the SWOU RG for PCBs of 16 mg/kg.
  - PAHs were detected in surface soil/sediments adjacent to the waste units. Data indicate these were not associated with releases from the waste and therefore, not within the scope of the BGOU. These impacts are addressed within the SWOU, consistent with the remediation goals established for these areas.

The key data gaps identified to be addressed in the BGOU RI focused on evidence of releases of waste constituents to underlying soils. Based on a review of these data, no releases were identified; however, limitations in the number of soil borings relative to the size of the SWMU are recognized. Assuming a soil cover/cap will be a component of a remedy, collection of surface soil data within the SWMU boundary to characterize the soil cover was not an objective, and surface impacts were evaluated using data primarily around the perimeter of the SWMU with direct contact risks presented, as summarized in previous risks assessments. Based upon review of data presented here, the COCs identified for future industrial scenarios are not present at levels above the target ELCR/HI levels identified in the RAOs. Recognizing these levels primarily represent soil results adjacent to the SWMU, the protectiveness of the

[1] Based on current toxicity factors, beryllium is not included as a carcinogen.
[2] Vanadium was slightly above background in 2 samples; using toxicity factors for "vanadium and compounds," these would not be identified as chemicals of potential concern.

cover has not been established. Since no specific COCs are identified, the primary threat to be addressed in the FS is direct contact with buried wastes. Uncertainty related to surface soil data will be considered during FS alternative development and analysis.

B.2. REFERENCES

DOE (U.S. Department of Energy) 2000. *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, September.

DOE 2006. *Work Plan for the Burial Grounds Operable Unit Remedial Investigation/Feasibility Study at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-2179&D2/R1, U.S. Department of Energy, Paducah, KY, August.

DOE 2010. *Remedial Investigation Report for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0030&D2/R1, U.S. Department of Energy, Paducah, KY, January.

DOE 2011. *Methods for Conducting Risk Assessment and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Volume 1: Human Health*, DOE/LX-07-0107&D2/R1/V1, U.S. Department of Energy, Paducah, KY, February.

EPA (U.S. Environmental Protection Agency) 1999. *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents*, EPA 540-R-98-031, Office of Solid Waste and Emergency Response, July.

EPA 2004. *Final Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)*, EPA/540/R/99/005 OSWER 9285.7-02EP PB99-963312, Office of Superfund Remediation and Technology Innovation, U.S. Environmental Protection Agency, Washington, DC, July.

EPA 2011. *United States Environmental Protection Agency Regions 3, 6, and 9, Regional Screening Levels for Chemical Contaminants at Superfund Sites*. Available at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm.

APPENDIX C

COST ESTIMATES

THIS PAGE INTENTIONALLY LEFT BLANK

Appendix C—Cost Estimates

This appendix contains cost estimates for the remedial alternatives for SWMUs 5 and 6 presented in this document. This appendix includes the following components:

- Remedial Alternatives Cost Estimate Summary for SMWUs 5 and 6

Estimate Basis for SWMU 5

- Estimate Basis for SMWU 6

- Alternative 5—KY Subtitle D Cap, Long-Term Monitoring, LUCs
  - Conceptual Design Calculations
  - Cost Estimate Spreadsheet

- Alternative 6— Excavation and Removal of all Waste Materials
  - Conceptual Design Calculations
  - Cost Estimate Spreadsheet

- Alternative 6a—Excavation with on-site disposal (at Proposed on-site Disposal Unit)
  - Conceptual Design Calculations
  - Cost Estimate Spreadsheet

Remedial Alternatives Cost Estimate Summary for SWMUs 5 and 6

			PRESENT WORTH [1]		ESCALATED	
Alternative Description	**Annual Time Period, yrs**	**Capital $ (2011 Constant Dollars)**	**Total Annual $**	**Total $ (Capital & Annual)**	**Total Annual $**	**Total $ (Capital & Annual)**
SWMU 5						
Alternative 1—No Action	0	$0	$0	$0	$0	$0
		,,				
Alternative 5—KY Subtitle D Cap, Long-Term Monitoring, LUCs	30	$8,092,000	$1,914,000	$10,006,000	$4,647,000	$13,215,000
Alternative 6—Excavation and Removal of all Waste Materials	0	$240,203,000	$205,000	$240,408,000	$540,000	$254,876,000
Alternative 6a—Excavation with on-site disposal (at Proposed on-site Disposal Unit)	0	$72,714,000	$205,000	$72,919,000	$540,000	$77,532,000

Note:

(1) Not used for budgeting or planning purposes because value is based on investing funds for out-year expenditures.

ESTIMATE BASIS
SWMU 5 (C-746-F Burial Yard)

A. SWMU Dimensions

Disposal pits on square grid ranged from 10 x 10 feet to 20 x 20 feet cells
Disposal cells excavated to a depth of 6 to 15 feet bgs (avg 10 ft).
Waste placed in the disposal pits was covered with 2 to 3 feet of soil.
Burial cells being excavated are expected to encompass 70 percent of SWMU area.

SWMU Area =	197,400	sf
Fraction of the SWMU area comprised of burial cells =	0.78	
Estimated Area containing Burial Cells =	153,300	sf

Approximate Area of Waste Cells

Width =	210	ft
Length =	730	ft
Area =	153,300	sf

B. Unquantifiable Disposal Items

Disposal of some radionuclide-contaminated scrap metal and slag from the nickel and aluminum smelters.
Chemically unstable or incompatible compound/wastes are thought to have been disposed here.
Approx. 320 waste disposal cells with an estimated average of 2800 cubic feet (33,185 bcy).

C. Excavation and Disposal

Assumptions:
Waste buried 6-15 ft, assume average depth to bottom of waste is 12 ft bgs.
Excavate to a maximum depth of 20 feet bgs.
Excavation increases soil volume by a factor of 20 percent during handling (bank to loose).
Soil density is 100 pounds per cubic foot.
All excavated soil will require addition of sorbent to reduce moisture content.
Density of sorbent will increase soil volume by 0.54 percent. Assume 0.54 lbs sorbent added to 100 lbs soil

Excavated Soil Volume Calculation

Area (SF)	Beginning Depth (feet bgs)	End Depth (feet bgs)	Quantity (BCY)	Quantity (LCY)	Quantity (LCY) w/sorbent	% Off-Site Disposal	Off-Site (CY)	On-Site (CY)
153,300	0	3	17,033	20,440	20,550	0	0	20,550
153,300	3	6	17,033	20,440	20,550	25	5,138	15,413
153,300	6	12	34,067	40,880	41,101	90	36,991	4,110
153,300	12	20	45,422	54,507	54,801	75	41,101	13,700
						Total (rounded)	83,000	54,000
							61%	39%

Disposal assumption: off-site to Nevada Nuclear Security Site (NNSS) and on-site to U Landfill.

D. Dewatering Estimate for Excavation

Sheet pile installed around perimeter of excavation =	1600	lf
Assumed depth to groundwater (DOE, 2010) =	5	ft
Assumed bottom of Excavation below grade =	20	ft
Groundwater Thickness =	15	ft
Assumed Average Site Soil Porosity =	0.2	
Area to be Dewatered =	153,300	sf

Initial Pore Volume = Area x Groundwater Thickness x Porosity

Estimate of Initial Pore Volume to Dewater

area (sf)	thickness (ft)	porosity	Volume (cubic ft)	Volume (gallon)
153,300	15	0.2	459,900	3,440,000

Assumed removal rate achieved for dewatering initial pore volume =	30	gpm
Dewatering rate after removal of initial pore volume (DOE, 1998, pg 17) =	7.9	gpm

E. References

DOE, 2010, BGOU Remedial Investigation Report

ESTIMATE BASIS
SWMU 6 (C-747-B Burial Yard)

A. SWMU Dimensions and contents

SWMU 6 covers an area of approximately 8,390 ft^2 as derived by GIS calculation.
Burials were made in five discrete burial areas (H, I, J, K, L). Area I includes a sub-area designated I-2.

Area H
The disposal site is about 12 ft by 15 ft and is about 6 ft deep.
At total of about 10 drums of magnesium scrap was buried during midsummer 1971.
Area I
This discard cell is approximately 8 ft by 35 ft and is 8 ft deep.
Eight exhaust hood blowers removed from C-710 were discarded to this area.
Area I-2
This discard cell is approximately 6 ft by 6 ft. Is is assumed to also be 8 ft deep.
Additional exhaust fans from C-710 were buried in Area I-2.
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.
Area J contains about 100 to 150 drums of aluminum scrap in the form of nuts, bolts, plates, trimmings, etc.
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.
Area K contains a total of about 20 drums of scrap magnesium in various shapes.
A 3-ft cover of soil was placed on top of the buried drums
Area L
This area contains a single contaminated modine trap.
The burial area is about 20 ft by 30 ft and about 6 ft deep.
The dispositioned waste was covered with about 3 ft of soil.

B. Unquantifiable Disposal Items

The wastes at SWMU 6 are well quantified and the individual waste areas well inventoried.

C. Excavation and Disposal

Assumptions:
Excavation area will be limited to SWMU 6 administrative area (8,390 SF as derived through GIS means)
Excavate to a maximum depth of 20 feet bgs.
Excavation increases soil volume by a factor of 20 percent during handling (bank to loose).
Soil density is 100 pounds per cubic foot.
All excavated soil will require addition of sorbent to reduce moisture content.
Density of sorbent will increase soil volume by 0.54 percent. Assume 0.54 lbs sorbent added to 100 lbs soil
Off-site vs. On-site disposal, at the existing 746-U landfill, is applicable to Alternative 6.
Alternative 6a assumes all wastes disposed of on-site at either the existing 764-U landfill or the proposed on-site landfill.
Disposal assumption: off-site to Nevada Nuclear Security Site (NNSS) and on-site to existing 746-U Landfill.

D. Dewatering Estimate for Excavation

Assume sheet pile around administrative boundary perimeter

Sheet pile installed around perimeter of excavation =	470	lf
Assumed depth to groundwater (DOE, 2010) =	5	ft
Assumed bottom of Excavation below grade =	20	ft
Groundwater Thickness =	15	ft
Assumed Average Site Soil Porosity =	0.2	
Area to be Dewatered =	8,390	sf

ESTIMATE BASIS
SWMU 6 (C-747-B Burial Yard)

Initial Pore Volume = Area x Groundwater Thickness x Porosity

Estimate of Initial Pore Volume to Dewater				
area (sf)	thickness (ft)	porosity	Volume (cubic ft)	Volume (gallon)
8,390	15	0.2	25,170	188,000

Assumed removal rate achieved for dewatering initial pore volume =	30	gpm
Dewatering rate after removal of initial pore volume (DOE, 1998, pg 17) =	7.9	gpm

E. References

DOE, 2010, BGOU Remedial Investigation Report

CONCEPTUAL DESIGN CALCULATIONS

BGOU SWMU 5 and 6

Alternative 5 - KY Subtitle D Cap, Long Term Monitoring, LUCs

Parameter			Total	Units	Basis
Combined Cap Area					
		Estimated combined SWMU 5 and 6 area.	223,150	SF	See sketch below calculation sheet.
Soil Volume Calc (Each Layer Assumes 10% for waste except leveling layer)					
	Leveling Soil Volume (needed to bring existing subgrade to design grades.)				
		Leveling Soil Thickness	1	feet	Engr Est.
		Assumed Layer Area	223,150	SF	Engr Est.
		Leveling Soil Volume CF	223,150	LCF	calc
		Conversion	27	CF/CY	calc
		Leveling Soil Volume LCY	8,265	LCY	calc
	Gas Vent layer Volume				
		Sand Layer Thickness; minimum 10^{-3} cm/s hydraulic conductivity	1	feet	Engr Est
		Assumed Layer Area	229,126	SF	Engr Est
		Sand Layer Volume CF	229,126	LCF	calc
		Conversion	27	CF/CY	calc
		Sand Layer Volume LCY	8,486	LCY	calc
		Waste (10%)	849	LCY	Calc
		Sand Layer Volume Total	9,335	LCY	calc
	Clay Layer Volume				
		Clay Layer Thickness; maximum 10^{-7} cm/s hydraulic conductivity	1.5	feet	Engr Est
		Assumed layer Area	240,830	SF	Engr Est
		Clay Layer Volume CF	361,245	LCF	calc
		Conversion	27	CF/CY	calc
		Clay Layer Volume LCY	13,379	LCY	calc
		Waste (10%)	1,338	LCY	Calc
		Sand Layer Volume Total	14,717	LCY	calc
	Drainage Layer Volume				
		Sand Layer Thickness; minimum 10^{-3} cm/s hydraulic conductivity	1	feet	Engr Est
		Assumed Layer Area	246,778	SF	Engr Est
		Sand Layer Volume CF	246,778	LCF	calc
		Conversion	27	CF/CY	calc
		Sand Layer Volume LCY	9,140	LCY	calc
		Waste (10%)	914	LCY	Calc
		Sand Layer Volume Total	10,054	LCY	calc
	Vegetative Layer Volume				
		Vegetative Layer Thickness	3	feet	Engr Est
		Assumed layer Area	271,210	SF	Engr Est
		Vegetative Layer Volume CF	813,630	LCF	calc
		Conversion	27	CF/CY	calc
		Vegetative Layer Volume LCY	30,134	LCY	calc
		Waste (10%)	3,013	LCY	Calc
		Sand Layer Volume Total	33,148	LCY	calc
	Total Cap Volume				
		All Layers	75,519	LCY	calc
Cap Construction Duration					
		Cap Construction Rate	600	LCY/day	Engr Est.
		Cap Construction Duration	126	wdays	calc
		Conversion	10	hrs/wday	Engr Est.
		Conversion	4	wday/wks	Engr Est.
		Cap Construction Duration	1259	hrs	calc

CONCEPTUAL DESIGN CALCULATIONS

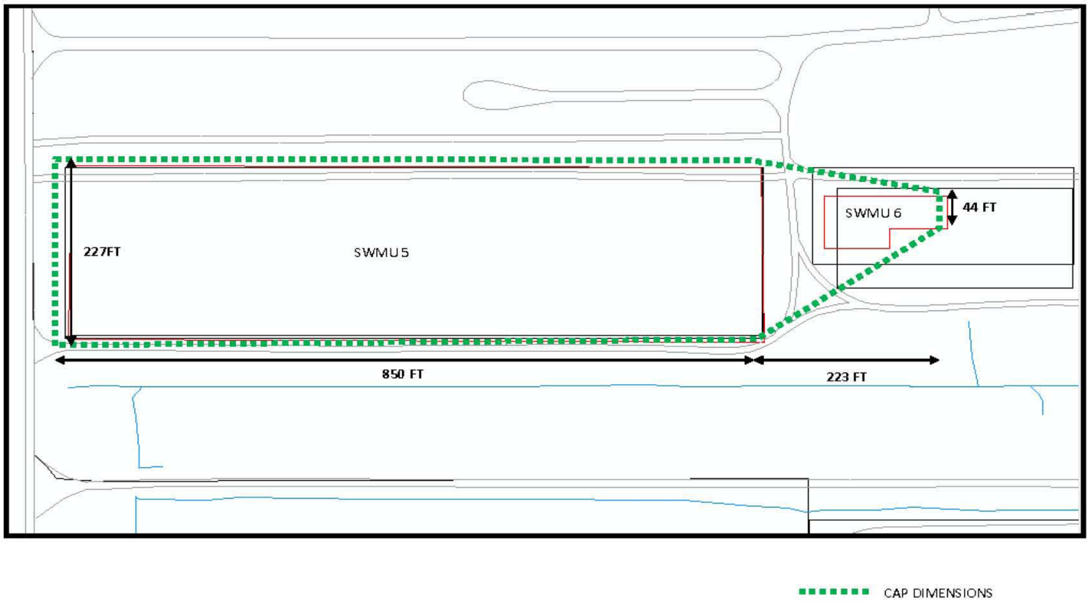
BGOU SWMU 5 and 6

Alternative 5 - KY Subtitle D Cap, Long Term Monitoring, LUCs

		Cap Construction Duration	31	wks	calc
		Cap Construction Duration	7	months	Engr Est.
Compaction Testing					
		Compaction Rate	10,000	SF/test	Engr Est
		Compaction Area	223,150	SF	calc
		Total Thickness	7.50	feet	Engr Est.
		Number of Lifts	8	lfts	calc
		Number of Compactions Tests	180	tests	calc

CONCEPTUAL DESIGN CALCULATIONS
BGOU SWMU 5 and 6
Alternative 5 - KY Subtitle D Cap, Long Term Monitoring, LUCs

Notes: For estimating purposes, it was assumed that one contiguous cap would be placed over both SWMUs.



For soil volume calculation, the irregular trapazoid with an estimated area to be capped of 223,150 SF was used.

For estimating purposes, it was assumed grade over the cap would be maintained above, but near the minimum slope of 5%. However, a grade break would be placed at the edge of waste and the shoulders would be graded to a 25% slope. These slopes are allowable under 401 KAR 48: 080.

References:

DOE, 2009, BGOU Remedial Investigation, April.
Lindeburg, 1990, Engineering Unit Conversions.
US Army, 1994, Field Manual No. 5-430-00-1, Planning and Design of Roads, Airfields, and Helioports in the Theater of Operations - Road Design.

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 5 - KY Subtitle D Cap, Long-Term Monitoring, LUCs

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
COST ESTIMATE SUMMARY									
Capital Cost									
1.0 Project Plans	1	LS	$140,000	$140,000					
2.0 Engineering Design	1	LS	$186,000	$186,000					
3.0 Work Package Prep./Readiness Review	1	LS	$157,000	$157,000					
4.0 Training	1	LS	$148,000	$148,000					
5.0 Mobilization	1	LS	$84,000	$84,000					
6.0 Site Preparation	1	LS	$310,000	$310,000					
7.0 Cover Construction	1	LS	$4,718,000	$4,718,000					
8.0 Well Installation and Site Restoration	1	LS	$329,000	$329,000					
9.0 O&M Manual and RACR	1	LS	$58,000	$58,000					
fee, management reserve, subproject management	1	LS	$1,961,600	$1,962,000					fee = 7%, mgt reserve = 15%, and Subproject Management = 10% (engineers estimate)
			SUBTOTAL CAPITAL COST	**$8,092,000**					
Annual Cost									
Annual Cap O&M (Years 1 - 30)	30	LS	$55,000	$1,650,000					
Quarterly Groundwater LTM (Years 1 - 2)	2	LS	$93,000	$186,000					
Annual Groundwater LTM (Years 3 - 5)	3	LS	$28,000	$84,000					
Biannual Groundwater LTM (Years 6-30)	25	LS	$16,000	$400,000					
Five Year Review Year 5	1	LS	$50,000	$50,000					
Five Year Review Year 10	1	LS	$50,000	$50,000					
Five Year Review Year 15	1	LS	$50,000	$50,000					
Five Year Review Year 20	1	LS	$50,000	$50,000					
Five Year Review Year 25	1	LS	$50,000	$50,000					
Five Year Review Year 30	1	LS	$50,000	$50,000					
			SUBTOTAL ANNUAL COST	**$2,620,000**					
			TOTAL	**$10,712,000**					
Present Worth Value									
	Quantity	Unit	Unit Cost	Total				**Present Worth**	
Total Capital Cost	1	LS	$8,092,000	$8,092,000				**$8,092,000**	
Annual Cap O&M (Years 1 - 30)	30	LS	$55,000	$1,650,000				**$1,182,473**	2.3% discount rate
Quarterly Groundwater LTM (Years 1 - 2)	2	LS	$93,000	$186,000				**$179,774**	2.3% discount rate
Annual Groundwater LTM (Years 3 - 5)	3	LS	$28,000	$84,000				**$76,710**	2.3% discount rate
Biannual Groundwater LTM (Years 6-30)	25	LS	$16,000	$400,000				**$269,229**	2.3% discount rate
Five Year Review Year 5	1	LS	$50,000	$50,000				**$44,626**	2.3% discount rate
Five Year Review Year 10	1	LS	$50,000	$50,000				**$39,830**	2.3% discount rate
Five Year Review Year 15	1	LS	$50,000	$50,000				**$35,550**	2.3% discount rate
Five Year Review Year 20	1	LS	$50,000	$50,000				**$31,729**	2.3% discount rate

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 5 - KY Subtitle D Cap, Long-Term Monitoring, LUCs

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
Five Year Review Year 25	1	LS	$50,000	$50,000				**$28,319**	2.3% discount rate
Five Year Review Year 30	1	LS	$50,000	$50,000				**$25,276**	2.3% discount rate
							Capital	**$8,092,000**	
						Present	**Annual**	**$1,913,516**	
						Worth	**Avg. Annual**	**$63,784**	
						Values	**Total**	**$10,006,000**	
This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost.									
Not used for budgeting or planning purposes because value is based on investing funds for out year expenditures.									
1.0 Project Plans									
Hazard Analysis Document	1	LS	$29,814	$29,814					Engineering Estimate
Health & Safety Plan	1	LS	$6,751	$6,751					Engineering Estimate
Remedial Design Work Plan	1	LS	$58,328	$58,328					Engineering Estimate
Security Plan	1	LS	$21,785	$21,785					Engineering Estimate
QA Plan	1	LS	$5,187	$5,187					Engineering Estimate
Sampling & Analysis Plan	1	LS	$8,687	$8,687					Engineering Estimate
Waste Management Plan	1	LS	$9,591	$9,591					Engineering Estimate
TASK TOTAL				**$140,143**			**$0**	**$140,000**	
2.0 Engineering Design									
Includes geophysical survey of the landfill.									
Civil Surveying	1	LS	$35,280	$35,280					Engineering Estimate
Geophysical Survey	1	LS	$32,793	$32,793					Engineering Estimate
Design	1	LS	$118,391	$118,391					Engineering Estimate
TASK TOTAL				**$186,464**			**$0**	**$186,000**	
3.0 Work Package Prep./Readiness Review									
Remedial Action Work Plan	1	LS	$119,152	$119,152					Engineering Estimate
Work Instructions	1	LS	$12,828	$12,828					Engineering Estimate
Training	1	LS	$847	$847					Engineering Estimate
USD/USQD	1	LS	$3,104	$3,104					Engineering Estimate
Lessons Learned	1	LS	$260	$260					Engineering Estimate
Procedures	1	LS	$1,445	$1,445					Engineering Estimate
AHA	1	LS	$846	$846					Engineering Estimate
Work Authorization	1	LS	$475	$475					Engineering Estimate
Excavation/Penetration Permits	1	LS	$9,733	$9,733					Engineering Estimate
Team Meeting Documentation	1	LS	$333	$333					Engineering Estimate
Emergency Response Plan	1	LS	$4,890	$4,890					Engineering Estimate
Transportation Plan	1	LS	$2,510	$2,510					Engineering Estimate
Project Org. Chart	1	LS	$950	$950					Engineering Estimate
TASK TOTALS				**$157,373**			**$0**	**$157,000**	
4.0 Training									
Assumptions: Training Specialist and training courses funded through other funding. 100% Q-cleared local work crew.									
Labor					1560		$90,230		Engineering Estimate
Subcontractor	1	LS	$57,600	$57,600					Engineering Estimate
TASK TOTALS				**$57,600**			**$90,230**	**$148,000**	
5.0 Mobilization									
Duration: Assume two weeks for mobilization.									
Labor					880		$53,287		Engineering Estimate

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 5 - KY Subtitle D Cap, Long-Term Monitoring, LUCs

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
Equipment									
Pickup	1	LS	$1,291	$1,291					Engineering Estimate
construction trailer	1	LS	$448	$448					Engineering Estimate
change trailer	1	LS	$448	$448					Engineering Estimate
100 KW generator	1	LS	$6,880	$6,880					Engineering Estimate
bulldozer	1	LS	$3,889	$3,889					Engineering Estimate
loader/crawler	1	LS	$2,864	$2,864					Engineering Estimate
water tank trailer	1	LS	$860	$860					Engineering Estimate
compactor sheepsfoot	1	LS	$2,679	$2,679					Engineering Estimate
compactor smooth drum	1	LS	$2,331	$2,331					Engineering Estimate
Materials									
PPE	1	LS	$1,517	$1,517					Engineering Estimate
laundry	1	LS	$2,240	$2,240					Engineering Estimate
misc materials	1	LS	$4,926	$4,926					Engineering Estimate
TASK TOTALS				**$30,373**			**$53,287**	**$84,000**	
6.0 Site Preparation									
Duration four weeks. Includes 2 weeks for removal of existing fence. Q-cleared and local labor									
Also install stormwater control measures including cleaning ditches, repairing culverts and drains, and diverting water from the project areas.									
Additionally, a fence contractor is included to construct new fence around perimeter.									
Labor					**2,000**		**$118,603**		Engineering Estimate
Equipment									
Pickup	1	LS	$2,582	$2,582					Engineering Estimate
construction trailer	1	LS	$896	$896					Engineering Estimate
change trailer	1	LS	$896	$896					Engineering Estimate
100 KW generator	1	LS	$13,760	$13,760					Engineering Estimate
bulldozer	1	LS	$3,889	$3,889					Engineering Estimate
loader/crawler	1	LS	$5,728	$5,728					Engineering Estimate
water tank trailer	1	LS	$860	$860					Engineering Estimate
compactor sheepsfoot	1	LS	$2,679	$2,679					Engineering Estimate
compactor smooth drum	1	LS	$2,331	$2,331					Engineering Estimate
Materials									
PPE	1	LS	$2,275	$2,275					Engineering Estimate
laundry	1	LS	$3,360	$3,360					Engineering Estimate
misc materials	1	LS	$4,926	$4,926					Engineering Estimate
Subcontractor									
Fence subcontractor	1	LS	$147,259	$147,259					Engineering Estimate
TASK TOTALS				**$191,441**			**$118,603**	**$310,000**	
7.0 Cover Construction									
Duration 7 months. Install cap compliant with KY regulations for landfill cover. Subcontracted labor for cap installation.									
Q cleared and local labor for support.									
Labor					**17,864**		**$795,872**		
Equipment									
Pickup Truck, crew cab, F250	21	month	$1,300	$27,300					Engineering Estimate
Front End Loader	7	month	$4,150	$29,050					Engineering Estimate
Water Truck, 2000 gal	7	month	$1,850	$12,950					Engineering Estimate

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 5 - KY Subtitle D Cap, Long-Term Monitoring, LUCs

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
Dump Trailer, 16 cy	35	month	$1,100	$38,500					Engineering Estimate
Analytical Lab									
	1	LS	$33,804	$33,804					Engineering Estimate
Materials									
PPE	1	LS	$24,268	$24,268					Engineering Estimate
laundry	1	LS	$35,840	$35,840					Engineering Estimate
Misc. Materials	1	LS	$78,822	$78,822					Engineering Estimate
Geotextile	20000	SF	$1	$20,000					
Fuel and Equipment Maintenance	1	LS	$61,600	$61,600					
Subcontractors									
Install KY Subtitle D Cap									
Leveling Soil	8,265	CY	$33.78	$279,189					Engineering Estimate
Filter Fabric	245,400	SF	$1.50	$369,082					Engineering Estimate
Vent Layer	9,335	CY	$34.72	$324,087					Engineering Estimate
Gas Vent System	1	LS	$20,782	$20,782					Engineering Estimate
Filter Fabric	258,000	SF	$1.50	$388,032					Engineering Estimate
18" Clay layer	14,717	CY	$34.08	$501,531					Engineering Estimate
12" Drainage Layer	10,054	CY	$34.72	$349,049					Engineering Estimate
36" Vegetative Soil Layer	33,148	CY	$33.79	$1,119,921					Engineering Estimate
Revegetation	7	Acre	$1,503	$10,519					Engineering Estimate
Geotechnical Testing	1232	HR	$96.00	$118,272					Engineering Estimate
Fabricate and Install Corner monuments	4	EA	$20,000	$80,000					Engineering Estimate
TASK TOTALS				**$3,922,599**			**$795,872**	**$4,718,000**	
8.0 Well Installation and Site Restoration									
Duration: one month duration for 4 wells. Assumes IDW is nonhazardous and accepted by PGDP disposal facilities									
Q cleared and local labor									
Labor									
Well installation & restoration					2280		$157,163		Engineering Estimate
Reporting					295		$27,013		Engineering Estimate
					2575		$184,176		
Equipment									
Pickup Truck, crew cab, 4x4	1	LS	$1,291	$1,291					Engineering Estimate
skid steer	1	LS	$1,024	$1,024					Engineering Estimate
Materials									
55 gal steel drum	100	ea	$68	$6,800					Engineering Estimate
Misc supplies	1	LS	$28,426	$28,426					Engineering Estimate
Well Installation Subcontractor									
Mob/Demob	1	LS	$22,699	$22,699					Vendor Quote from Similar Contract
Well Installation	1	LS	$64,386	$64,386					Vendor Quote from Similar Contract
Hydroseeding	1	LS	$762	$762					Vendor Quote from Similar Contract
Contractors									
Analytical Lab	1	ls	$19,511	$19,511					Engineering Estimate
TASK TOTAL				**$144,899**	**2,575**		**$184,176**	**$329,000**	

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 5 - KY Subtitle D Cap, Long-Term Monitoring, LUCs

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
9.0 O&M Manual and RACR									
Labor									
document development					869		$58,328		Engineering Estimate
TASK TOTAL				**$0**	**0**		**$58,328**	**$58,000**	
					SUBTOTAL CAPITAL COST			**$6,130,000**	
Annual Cap O&M (Years 1 - 30)									
First year through 30 years. Annual inspection of cap. Q cleared and local labor									
Labor									
inspections					676		$37,942		Engineering Estimate
reporting					115		$10,696		Engineering Estimate
Equipment									
pickup	1	LS	$1,678	$1,678					Engineering Estimate
tractor mower	1	LS	$894	$894					Engineering Estimate
Material									
Misc materials	1	LS	$2,600	$2,600					Engineering Estimate
Travel									
	1	LS	$1,256	$1,256					Engineering Estimate
TASK TOTAL				$6,429			$48,638	**$55,000**	
Quarterly Groundwater LTM (years 1-2)									
Duration: first two years									
Assumptions: Quarterly monitoring well sampling. Sample time is 5 hours per well, 4 wells total, 4 times per year									
IDW is non-hazardous and acceptable to onsite disposal facilities									
Labor									
Monitoring					480		$31,123		Engineering Estimate
Reporting					170		$15,641		Engineering Estimate
					650		$46,764		
Equipment									
pickup	1	LS	$1,291	$1,291					Engineering Estimate
generator	1	LS	$459	$459					Engineering Estimate
sampling trailer	1	LS	$53	$53					Engineering Estimate
Materials									
55 gal drums	10	ea	$68	$680					Engineering Estimate
misc materials	1	LS	$7,274	$7,274					Engineering Estimate
Contractors									
Analytical Lab	1	LS	$36,876	$36,876					Engineering Estimate
			$46,021	$46,633					
TASK TOTAL								**$93,000**	
Annual Groundwater LTM (years 3-5)									
Duration: years three through five									
Assumptions: Annual monitoring well sampling. Sample time is 5 hours per well, 4 wells total, 1 time per year									
IDW is non-hazardous and acceptable to onsite disposal facilities									
Labor									
Monitoring					120		$7,780		Engineering Estimate
Reporting					90		$8,175		Engineering Estimate
					210		$15,955		
Equipment									
pickup	1	LS	$646	$646					Engineering Estimate

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 5 - KY Subtitle D Cap, Long-Term Monitoring, LUCs

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
generator	1	LS	$115	$115					Engineering Estimate
sampling trailer	1	LS	$13	$13					Engineering Estimate
Materials									
55 gal drums	10	ea	$68	$680					Engineering Estimate
misc materials	1	LS	$1,819	$1,819					Engineering Estimate
Contractors									
Analytical Lab	1	LS	$9,219	$9,219					Engineering Estimate
			$11,880	$12,492					
TASK TOTAL								**$28,000**	
Biannual Groundwater LTM (years 6-30)									
Duration: years six through thirty									
Assumptions: Annual monitoring well sampling. Sample time is 5 hours per well, 4 wells total, once every 2 years									
IDW is non-hazardous and acceptable to onsite disposal facilities									
Labor									
Monitoring					60		$3,890		Engineering Estimate
Reporting					70		$6,428		Engineering Estimate
					130		$10,318		
Equipment									
pickup	1	LS	$323	$323					Engineering Estimate
generator	1	LS	$57	$57					Engineering Estimate
sampling trailer	1	LS	$7	$7					Engineering Estimate
Materials									
55 gal drums	10	ea	$68	$680					Engineering Estimate
misc materials	1	LS	$910	$910					Engineering Estimate
Contractors									
Analytical Lab	1	LS	$3,951	$3,951					Engineering Estimate
			$5,316	$5,928					
TASK TOTAL								**$16,000**	
Five Year Review (Yrs 5, 10, 15, 20, 25, 30)									
Five Year Review	1	LS	$50,198	$50,198					Engineering Estimate
TASK TOTAL								**$50,000**	

SWMUs 5 and 6, Alternative 5
Escalated Costs

Date	Yr	escalation	escalation factor	Capital	Annual Cap O&M (Yrs 1 - 30)	Quarterly GW LTM (Yrs 1 - 5)	Semi-Annual GW LTM (Yrs 6 - 10)	Annual GW LTM (Yrs 11 - 30)	Five Year Reviews	TOTALS
2012		1	1.000	$8,092,000	$55,000	$93,000	$28,000	$16,000	$50,000	
2013		1.029	1.029							
2014	0	1.029	1.059	$8,568,141						$8,568,141
2015	1	1.029	1.090		$59,925	$101,328				$161,253
2016	2	1.029	1.121		$61,663	$104,266				$165,929
2017	3	1.029	1.154		$63,451	$107,290				$170,741
2018	4	1.029	1.187		$65,291	$110,402				$175,693
2019	5	1.029	1.222		$67,185	$113,603			$61,077	$241,865
2020	6	1.029	1.257		$69,133		$35,195			$104,328
2021	7	1.029	1.293		$71,138		$36,216			$107,354
2022	8	1.029	1.331		$73,201		$37,266			$110,467
2023	9	1.029	1.370		$75,324		$38,347			$113,670
2024	10	1.029	1.409		$77,508		$39,459		$70,462	$187,429
2025	11	1.029	1.450		$79,756			$23,202		$102,958
2026	12	1.029	1.492		$82,069			$23,875		$105,943
2027	13	1.029	1.535		$84,449			$24,567		$109,016
2028	14	1.029	1.580		$86,898			$25,279		$112,177
2029	15	1.029	1.626		$89,418			$26,012	$81,289	$196,719
2030	16	1.029	1.673		$92,011			$26,767		$118,778
2031	17	1.029	1.721		$94,679			$27,543		$122,222
2032	18	1.029	1.771		$97,425			$28,342		$125,767
2033	19	1.029	1.823		$100,250			$29,164		$129,414
2034	20	1.029	1.876		$103,158			$30,009	$93,780	$226,947
2035	21	1.029	1.930		$106,149			$30,880		$137,029
2036	21	1.029	1.986		$109,227			$31,775		$141,003
2037	23	1.029	2.044		$112,395			$32,697		$145,092
2038	24	1.029	2.103		$115,654			$33,645		$149,299
2039	25	1.029	2.164		$119,008			$34,621	$108,190	$261,819
2040	26	1.029	2.227		$122,460			$35,625		$158,084
2041	27	1.029	2.291		$97,425			$36,658		$134,083
2042	28	1.029	2.358		$129,665			$37,721		$167,386
2043	29	1.029	2.426		$133,426			$38,815		$172,240
2044	30	1.029	2.496		$137,295			$30,009	$124,814	$292,118
TOTAL				$8,568,141	$2,776,636	$536,889	$186,482	$607,205	$539,611	$13,214,963

For the ESCALATED values:

$4,647,000 Total Annual $
$13,215,000 Total $ (Capital & Annual)

CONCEPTUAL DESIGN CALCULATIONS

BGOU SWMUs 5 and 6

Alternative 6 - Excavation and Removal of All Wastes

SWMU 5

Parameter			Total	Units	Basis
SWMU Dimensions					
		Total Area	197,400	SF	Engr Est.
		Fraction of Area to be Excavated	0.78		from Est Basis
		Area to be Excavated	153,300	SF	Calc
		Excavation Depth	20	feet	Engr Est.
Waste Volume Calc					
		Waste Volume	113,560	BCY	calc
		Conversion	1.20	LCY/BCY	LATA Directive
		Excavated Waste Volume	137,000	LCY	calc
		U Landfill WAC Compliant Waste Fraction	0.39		Est Basis
		Assumed NNSS Compliant Fraction	0.61		Est Basis
		U Landfill WAC Compliant Volume	54,000	LCY	calc
		NNSS WAC Compliant Volume	83,000	LCY	calc
		Conversion	1.4	ton/LCY	Engr Est
		LLW Tonnage (NNSS)	116,200	ton	calc
Absorbents for Soil					
		Absorbent Rate	0.54	lb/CF	LATA
		Total Excavated Waste	137,000	LCY	calc
		Total Absorbent needed	2,000,000	lbs	calc
Excavation Duration					
		Excavation Rate	2,100	bcy/month/ crew	Engr Est., 100 bcy/day/crew 21 day work month
		No. of Crews	2	crews	Engr Est
		Time to Excavate U Landfill WAC Compliant	10	month	calc
		Time to Excavate NNSS WAC Compliant	16	month	calc
		Total Excavation Time	27	month	calc
		Total Excavation Time	2.3	years	calc
		Work day	10	hrs/wday	Engr Est.
		Work week	5	wdays/wk	Engr Est.
		Work days per year	252	wdays/yr	calc
		Work hours per year	2,520	whour/yr	calc
		Work days per month	21	wdays/mo	calc
Dewatering Calc					
		Initial Pore Volume	3,440,000	gal	calc from Est. Basis
		Dewatering Rate for Initial Pore Vol	30	gpm	Assumed
		Days to dewater initial pore volume	80	days	calc
		Dewatering Rate after removing initial pore vol.	7.9	gpm	DOE, 1998, pg 17
		Total Excavation Time	27	months	calc
		pore volume.	0.1	the time	Engr Est
		Dewater Volume during excavation	675,000	gal	calc
		Total Water for Trmt/Disposal during excavation	4,115,000	gal	calc
LLW Sludge Production from GW Treatment					
		Assumed Dewatering Rate	7,257	gal/day	calc
		Number of days operating	567	days	calc
		Dewatering total	4,115,000	gallons	Engr Est
		Est. Sludge fraction	0.01		Engr Est
		Est. Sludge production	41,150	gallons	calc
		Conversion	7.48	gal/cf	Lindeburg, 1990
		Conversion	27	cf/cy	Lindeburg, 1990
		Est. Sludge production	204	cy	calc
		Drum Volume	55	gal/drum	
		Sludge Drum Total	748	drums	calc

CONCEPTUAL DESIGN CALCULATIONS
BGOU SWMUs 5 and 6
Alternative 6 - Excavation and Removal of All Wastes
SWMU 5

Parameter			**Total**	**Units**	**Basis**
		Sludge Drums per truckload	60	drums/trucklo	Engr Est
		Sludge Truck trips	12	trips	calc
Transportation					
		Average D-Yard box volume	640	CF	Engr Est.
		Assumed volume of waste per box	600	CF	Engr Est.
		Total Volume to NNSS	83,000	CY	calc
		Conversion	27	cf/cy	
		Volume in CF	2,241,000	CF	calc
		Number of D-Yard Boxes	3,735	ea	calc
		Number of Trucks to NNSS	3,735	ea	calc
Disposal Samples					
		Sample Rate	300	LCY	Engr Est.
		Samples for U Landfill WAC Compliant + 10 percent QA/QC	200	samples	Engr Est.
		Samples for NNSS + 10 percent QA/QC	310	samples	Engr Est.
Sheet Pile Installation					
		Depth of installation	40	feet	DOE, 1998
		Perimeter	1,570	feet	calc
		Fence Perimeter	2,000	feet	calc
		Area	62,800	SF	calc
		Sheet pile density	38	psf	calc
		Tonnage	1200	tons	calc
Backfill					
		Volume of Excavated Soil, Debris, Waste	137,000	LCY	
		Conversion	1.41	CCY/LCY	US Army, 1994
		Volume of Backfill	193,170	calc	
		Conversion	1.4	ton/CY	Lindeburg, 1990
		Backfill Tonnage	270,000	ton	
		Backfill Rate	3,000	cy/day	Engr Est.
		Est. Time to Backfill	46	days	calc
		Working days per month	21	days	calc
		Est. Months to Backfill	2	months	calc
Compaction Testing					
		Compaction Rate	20,000	SF/test	Engr Est
		Compaction Area	197,400	SF	Engr Est.
		Lift Thickness	2	feet	Engr Est.
		Number of Lifts	10	lifts	calc
		Number of Compactions Tests	100	tests	calc
Top Soil & Hydroseeding					
		Excavation Area	153,300	SF	Engr Est.
		Disturbed Area Factor	1.25		Engr Est.
		Conversion	43,560	SF/acre	Lindeburg, 1990
		Disturbed Area	191,625	SF	calc
		Conversion	1,000	SF/MSF	
		Disturbed Area	200	MSF	calc
		Top Soil Thickness	0.5	feet	Engr Est.
		Conversion	27	CF/CY	Lindeburg, 1990
		Conversion	1.3	ton/CY	Engr Est.
		Top Soil tonnage	4,600	ton	calc
Trucking to existing U Landfill at PGDP					
		Dump Capacity	14	ton	Engr Est
		Dump Capacity	10	lcy	Engr Est
		Dump Trips for U Landfill WAC Compliant	5,400	trips	calc
		Truck Liners	5,400	liners	calc
PPE LLW Drums					
		Drums filled per day with PPE LLW Waste	1	drum/day	Engr Est

CONCEPTUAL DESIGN CALCULATIONS

BGOU SWMUs 5 and 6

Alternative 6 - Excavation and Removal of All Wastes

SWMU 5

Parameter			**Total**	**Units**	**Basis**
		No. of drums used during project	567	drums	calc
		Drums per Truckload	60	drums/trucklo	Engr Est
		Truck Trips	9	trips	calc
		Drum Volume	55	gal/drum	Engr Est
		Conversion	7.48	gal/cf	Lindeburg, 1990
		Conversion	27	cf/cy	Lindeburg, 1990
		Total Volume of PPE	150	cy	calc

References:

DOE, 1998, Feasibility Study for Final Action at SWMU 2 of WAG 22 at the Paducah GDP, KY, Sept.
Glover, 1995, Pocket Ref, 2nd Edition.
Lindeburg, 1990, Engineering Unit Conversions
US Army, 1994, Field Manual No. 5-430-00-1, Planning and Design of Roads, Airfields, and Helioports in the Theater of Operations - Road Design.

CONCEPTUAL DESIGN CALCULATIONS

BGOU SWMUs 5 and 6

Alternative 6 - Excavation and Removal of All Wastes

SWMU 6

Parameter			**Total**	**Units**	**Basis**
SWMU Dimensions					
		Total Area	8,390	SF	Engr Est.
		Fraction of Area to be Excavated	1.00		from Est Basis
		Area to be Excavated	8,390	SF	Calc
		Excavation Depth	20	feet	Engr Est.
Waste Volume Calc					
		Total Waste Volume	6,215	BCY	calc
		Area H (180 ft^2 x 7 ft deep)	47	BCY	calc
		Area I (280 ft^2 x 7 ft deep)	73	BCY	calc
		Area I-2 (36 ft^2 x 9 ft deep)	12	BCY	calc
		Area J (4,000 ft^2 x 7 ft deep)	1,037	BCY	calc
		Area K (180 ft^2 x 7 ft deep)	47	BCY	calc
		Area L (600 ft^2 x 7 ft deep)	156	BCY	calc
		Remaining Excavation Volume	4,844	BCY	calc
Disposal Calculations					
		Conversion	1.20	LCY/BCY	LATA Directive
		Excavated Waste Volume	7,458	LCY	Total BCY x 1.2
		U Landfill WAC Compliant Waste Fraction	0.78		Estimate assumes that waste outside the specified waste cells can be disposed of at the U landfill
		Assumed NNSS WAC Compliant Fraction	0.22		Estimate assumes that waste generated from areas H-L will be disposed of off-site
		U Landfill WAC Compliant Volume	5,813	LCY	calc
		NNSS WAC Compliant Volume	1,645	LCY	calc
		Conversion	1.4	ton/LCY	Engr Est
		LLW Tonnage (NNSS)	2,302	ton	calc
Absorbents for Soil					
		Absorbent Rate	0.54	lb/CF	LATA
		Total Excavated Waste	7,458	LCY	calc
		Total Absorbent needed	100,000	lbs	calc
Excavation Duration					
		Excavation Rate	2,100	bcy/month/crew	100 bcy/day/crew 21 day work month
		No. of Crews	2	crews	Engr Est
		Time to Excavate U Landfill WAC Compliant	1.2	month	calc
		Time to Excavate NNSS WAC Compliant	0.3	month	calc
		Total Excavation Time	2.0	Months	calc
		Total Excavation Time	0.2	years	calc
		Work day	10	hrs/wday	Engr Est.
		Work week	5	wdays/wk	Engr Est.
		Work days per year	252	wdays/yr	calc
		Work hours per year	2,520	whour/yr	calc
		Work days per month	21	wdays/mo	calc
Dewatering Calc					

CONCEPTUAL DESIGN CALCULATIONS

BGOU SWMUs 5 and 6

Alternative 6 - Excavation and Removal of All Wastes

SWMU 6

Parameter			**Total**	**Units**	**Basis**
		Initial Pore Volume	188,000	gal	calc from Est. Basis
		Dewatering Rate for Initial Pore Vol	30	gpm	Assumed
		Days to dewater initial pore volume	4	days	calc
		Dewatering Rate after removing initial pore vol.	7.9	gpm	DOE, 1998, pg 17
		Total Excavation Time	2.0	months	calc
		Fraction of time pumping occurs after removal of initial pore volume.	0.1	fraction of the time	Engr Est
		Dewater Volume during excavation	50,000	gal	calc
		Total Water for Trmt/Disposal during excavation	238,000	gal	calc
LLW Sludge Production from GW Treatment					
		Assumed Dewatering Rate	5,667	gal/day	calc
		Number of days operating	42	days	calc
		Dewatering total	238,000	gallons	Engr Est
		Est. Sludge fraction	0.01		Engr Est
		Est. Sludge production	2,380	gallons	calc
		Conversion	7.48	gal/cf	Lindeburg, 1990
		Conversion	27	cf/cy	Lindeburg, 1990
		Est. Sludge production	12	cy	calc
		Drum Volume	55	gal/drum	
		Sludge Drum Total	43	drums	calc
		Sludge Drums per truckload	60	drums/trucklo	Engr Est
		Sludge Truck trips	1	trips	calc
Transportation					
		Average D-Yard box volume	640	CF	Engr Est.
		Assumed volume of waste per box	600	CF	Engr Est.
		Total Volume to NNSS	1,645	CY	calc
		Conversion	27	cf/cy	
		Volume in CF	44,405	CF	calc
		Number of D-Yard Boxes	74	ea	calc
Disposal Samples					
		Sample Rate	300	LCY	Engr Est.
		Samples for U Landfill WAC Compliant + 10 percent QA/QC	30	samples	Engr Est.
		Samples for NNSS + 10 percent QA/QC	10	samples	Engr Est.
Sheet Pile Installation					
		Depth of installation	40	feet	DOE, 1998
		Perimeter	470	feet	calc
		Fence Perimeter	0	feet	calc
		Area	18,800	SF	calc
		Sheet pile density	38	psf	calc
		Tonnage	400	tons	calc
Backfill					
		Volume of Excavated Soil, Debris, Waste	7,458	LCY	
		Conversion	1.41	CCY/LCY	US Army, 1994
		Volume of Backfill	10,515	calc	
		Conversion	1.4	ton/CY	Lindeburg, 1990
		Backfill Tonnage	15,000	ton	
		Backfill Rate	3,000	cy/day	Engr Est.
		Est. Time to Backfill	2	days	calc
		Working days per month	21	days	calc

CONCEPTUAL DESIGN CALCULATIONS

BGOU SWMUs 5 and 6

Alternative 6 - Excavation and Removal of All Wastes

SWMU 6

Parameter			**Total**	**Units**	**Basis**
		Est. Months to Backfill	0.1	months	calc
Compaction Testing					
		Compaction Rate	20,000	SF/test	Engr Est
		Compaction Area	8,390	SF	Engr Est.
		Lift Thickness	2	feet	Engr Est.
		Number of Lifts	10	lifts	calc
		Number of Compactions Tests (one per lift)	10	tests	calc
Top Soil & Hydroseeding					
		Excavation Area	8,390	SF	Engr Est.
		Disturbed Area Factor	1.25		Engr Est.
		Conversion	43,560	SF/acre	Lindeburg, 1990
		Disturbed Area	10,488	SF	calc
		Conversion	1,000	SF/MSF	
		Disturbed Area	20	MSF	calc
		Top Soil Thickness	0.5	feet	Engr Est.
		Conversion	27	CF/CY	Lindeburg, 1990
		Conversion	1.3	ton/CY	Engr Est.
		Top Soil tonnage	300	ton	calc
Trucking to existing U Landfill at PGDP					
		Dump Capacity	14	ton	Engr Est
		Dump Capacity	10	lcy	Engr Est
		Dump Trips for U Landfill WAC Compliant	582	trips	calc
		Truck Liners	582	liners	calc
PPE LLW Drums					
		Drums filled per day with PPE LLW Waste	1	drum/day	Engr Est
		No. of drums used during project	42	drums	calc
		Drums per Truckload	60	drums/trucklo	Engr Est
		Truck Trips	1	trips	calc
		Drum Volume	55	gal/drum	Engr Est
		Conversion	7.48	gal/cf	Lindeburg, 1990
		Conversion	27	cf/cy	Lindeburg, 1990
		Total Volume of PPE	10	cy	calc

References:
DOE, 1998, Feasibility Study for Final Action at SWMU 2 of WAG 22 at the Paducah GDP, KY, Sept.
Glover, 1995, Pocket Ref, 2nd Edition.
Lindeburg, 1990, Engineering Unit Conversions
US Army, 1994, Field Manual No. 5-430-00-1, Planning and Design of Roads, Airfields, and Helioports in the Theater of Operations - Road Design.

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 6 - Excavation and Removal of All Waste Materials

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
COST ESTIMATE SUMMARY									
Capital Cost									
1.0 Project Plans	1	LS	$545,000	$545,000					
2.0 Engineering Design	1	LS	$359,000	$359,000					
3.0 Work Package Prep./Readiness Review	1	LS	$422,000	$422,000					
4.0 Training	1	LS	$299,000	$299,000					
5.0 Mobilization	1	LS	$446,000	$446,000					
6.0 Site Preparation	1	LS	$2,759,000	$2,759,000					
7.0 Excavation SWMU 5	1	LS	$67,569,000	$67,569,000					
7.1 Excavation SWMU 6	1	LS	$4,154,000	$4,154,000					
8.0 Waste Sorting, Transportation and Disposal	1	LS	$82,095,000	$82,095,000					
9.0 Backfill, Site Restoration and Equip Decon	1	LS	$5,477,000	$5,477,000					
10.0 O&M Manual and RACR	1	LS	$75,000	$75,000					
fee, management reserve, subproject management	1	LS	$44,334,000	$44,334,000					fee = 7%, mgt reserve = 15%, subproject management = 5%, engineers estimate)
contingency	1	LS	$31,669,200	$31,669,000					contingency on construction costs only = 20%
			SUBTOTAL CAPITAL COST	**$240,203,000**					
Annual Cost									
Five Year Review Year 5	1	LS	$50,000	$50,000					
Five Year Review Year 10	1	LS	$50,000	$50,000					
Five Year Review Year 15	1	LS	$50,000	$50,000					
Five Year Review Year 20	1	LS	$50,000	$50,000					
Five Year Review Year 25	1	LS	$50,000	$50,000					
Five Year Review Year 30	1	LS	$50,000	$50,000					
			SUBTOTAL ANNUAL COST	**$300,000**					
			TOTAL	**$240,503,000**					
Present Worth Value									
	Quantity	Unit	Unit Cost	Total				**Present Worth**	
Total Capital Cost	1	LS	$240,203,000	$240,203,000				**$240,203,000**	
Five Year Review Year 5	1	LS	$50,000	$50,000				**$44,626**	2.3% discount rate
Five Year Review Year 10	1	LS	$50,000	$50,000				**$39,830**	2.3% discount rate
Five Year Review Year 15	1	LS	$50,000	$50,000				**$35,550**	2.3% discount rate
Five Year Review Year 20	1	LS	$50,000	$50,000				**$31,729**	2.3% discount rate
Five Year Review Year 25	1	LS	$50,000	$50,000				**$28,319**	2.3% discount rate
Five Year Review Year 30	1	LS	$50,000	$50,000				**$25,276**	2.3% discount rate
							Capital	**$240,203,000**	
						Present	**Annual**	**$205,330**	
						Worth	**Avg. Annual**	**$6,844**	
						Values	**Total**	**$240,408,000**	
This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost.									
Not used for budgeting or planning purposes because value is based on investing funds for out year expenditures.									
1.0 Project Plans									

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 6 - Excavation and Removal of All Waste Materials

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
Hazard Analysis Document	1	LS	$147,330	$147,330					Engineering Estimate
Health & Safety Plan	1	LS	$20,688	$20,688					Engineering Estimate
Remedial Design Work Plan	1	LS	$247,773	$247,773					Engineering Estimate
Security Plan	1	LS	$43,570	$43,570					Engineering Estimate
QA Plan	1	LS	$10,374	$10,374					Engineering Estimate
Sampling & Analysis Plan	1	LS	$42,428	$42,428					Engineering Estimate
Waste Management Plan	1	LS	$32,791	$32,791					Engineering Estimate
TASK TOTAL				**$544,954**			**$0**	**$545,000**	
2.0 Engineering Design									
Includes geophysical survey of the landfill.									
Civil Surveying	1	LS	$35,280	$35,280					Engineering Estimate
Geophysical Survey	1	LS	$32,793	$32,793					Engineering Estimate
Design	1	LS	$290,925	$290,925					Engineering Estimate
TASK TOTAL				**$358,998**			**$0**	**$359,000**	
3.0 Work Package Prep./Readiness Review									
Remedial Action Work Plan	1	LS	$147,569	$147,569					Engineering Estimate
Work Instructions	1	LS	$134,730	$134,730					Engineering Estimate
Training	1	LS	$3,390	$3,390					Engineering Estimate
USD/USQD	1	LS	$19,915	$19,915					Engineering Estimate
Lessons Learned	1	LS	$5,206	$5,206					Engineering Estimate
Procedures	1	LS	$10,492	$10,492					Engineering Estimate
AHA	1	LS	$22,684	$22,684					Engineering Estimate
Work Authorization	1	LS	$475	$475					Engineering Estimate
Excavation/Penetration Permits	1	LS	$32,986	$32,986					Engineering Estimate
Team Meeting Documentation	1	LS	$1,333	$1,333					Engineering Estimate
Transportation Plan	1	LS	$13,867	$13,867					Engineering Estimate
Hoisting and Rigging Plan	1	LS	$12,469	$12,469					Engineering Estimate
Emergency Response Plan	1	LS	$15,847	$15,847					Engineering Estimate
Project Org. Chart	1	LS	$950	$950					Engineering Estimate
TASK TOTALS				**$421,913**			**$0**	**$422,000**	
4.0 Training									
Assumptions: Training Specialist and training courses funded through other funding. 100% Q-cleared local work crew.									
Labor					3120		$179,404		Engineering Estimate
Subcontractors	1	LS	$120,000	$120,000					Engineering Estimate
TASK TOTALS				**$120,000**			**$179,404**	**$299,000**	
5.0 Mobilization									
Duration: Assume one month for mobilization.									
Labor					4480		$268,184		Engineering Estimate
Equipment									
Pickup	1	LS	$5,165	$5,165					Engineering Estimate
construction trailer	1	LS	$896	$896					Engineering Estimate
change trailer	1	LS	$896	$896					Engineering Estimate
100 KW generator	1	LS	$13,760	$13,760					Engineering Estimate
dozer, 105 HP	1	LS	$15,555	$15,555					Engineering Estimate
skid steer loader	1	LS	$3,328	$3,328					Engineering Estimate
crane, 12 T truck mounted	1	LS	$13,680	$13,680					Engineering Estimate
water tank trailer, 5000 gal	1	LS	$3,440	$3,440					Engineering Estimate
portajohns/handwash stations	1	LS	$512	$512					Engineering Estimate

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 6 - Excavation and Removal of All Waste Materials

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
RAD screening system	1	LS	$80,000	$80,000					Engineering Estimate
Material									
PPE	1	LS	$8,342	$8,342					Engineering Estimate
Laundry	1	LS	$12,320	$12,320					Engineering Estimate
misc material	1	LS	$19,706	$19,706					Engineering Estimate
TASK TOTALS				**$177,600**			**$268,184**	**$446,000**	
6.0 Site Preparation									
Duration one month. Two work crews.									
Also install stormwater control measures including cleaning ditches, repairing culverts and drains, and diverting water from the project areas.									
Additionally, subcontractors to construct waste management building, weather enclosures, and fence.									
Labor					4,160		$251,727		Engineering Estimate
Equipment									
Pickup	1	LS	$5,165	$5,165					Engineering Estimate
construction trailer	1	LS	$896	$896					Engineering Estimate
change trailer	1	LS	$896	$896					Engineering Estimate
100 KW generator	1	LS	$13,760	$13,760					Engineering Estimate
dozer, 105 HP	1	LS	$15,555	$15,555					Engineering Estimate
skid steer loader	1	LS	$3,328	$3,328					Engineering Estimate
crane, 12 T truck mounted	1	LS	$13,680	$13,680					Engineering Estimate
water tank trailer, 5000 gal	1	LS	$3,440	$3,440					Engineering Estimate
portajohns/handwash stations	1	LS	$512	$512					Engineering Estimate
RAD screening system	1	LS	$80,000	$80,000					Engineering Estimate
Materials									
geotextile fabric	1	LS	$34,400	$34,400					Engineering Estimate
riprap	1	LS	$16,800	$16,800					Engineering Estimate
silt fence	1	LS	$325	$325					Engineering Estimate
crushed stone	1	LS	$9,000	$9,000					Engineering Estimate
hay/straw bales	1	LS	$2,400	$2,400					Engineering Estimate
PPE	1	LS	$8,342	$8,342					Engineering Estimate
laundry	1	LS	$12,320	$12,320					Engineering Estimate
misc. materials	1	LS	$9,853	$9,853					Engineering Estimate
Subcontracts									
Waste Management Bldg	1	LS	$1,000,000	$1,000,000					Engineering Estimate
Weather Enclosures (2)	1	LS	$1,200,000	$1,200,000					Engineering Estimate
Fence	1	LS	$76,950	$76,950					Engineering Estimate
TASK TOTALS				**$2,507,622**			**$251,727**	**$2,759,000**	
7.0 Excavation SWMU 5									
Two crews for 27 months for excavating, sorting, staging and sampling based on excavating MLLW and LLW at 100 BCY/day/crew.									
Sheet piling the excavation perimeter. Soil, debris, waste excavated to 300 cy stockpiles for waste profile sampling.									
Classified shipments will require shipping containers to be welded.									
The excavation will require dewatering; the resulting wastewater will be treated with a skid-mounted unit									
Q cleared and local labor in support.									
Labor					173,440		$10,179,169		Engineering Estimate

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 6 - Excavation and Removal of All Waste Materials

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
Equipment									
Pickup	1	LS	$108,461	$108,461					Engineering Estimate
dozer, 105 HP	1	LS	$326,659	$326,659					Engineering Estimate
skid steer loader	1	LS	$69,888	$69,888					Engineering Estimate
water tank trailer	1	LS	$72,240	$72,240					Engineering Estimate
construction trailer	1	LS	$18,816	$18,816					Engineering Estimate
change trailer	1	LS	$18,816	$18,816					Engineering Estimate
100 KW generator	1	LS	$288,960	$288,960					Engineering Estimate
vacuum truck 5,000 gal	1	LS	$193,939	$193,939					Engineering Estimate
gooseneck dump trailer, 18'	1	LS	$22,042	$22,042					Engineering Estimate
yard tractor	1	LS	$171,898	$171,898					Engineering Estimate
portajohns/hand wash sta	1	LS	$5,376	$5,376					Engineering Estimate
crane, 12T truck mounted	1	LS	$287,280	$287,280					Engineering Estimate
diaphragm dewatering pumps	1	LS	$21,000	$21,000					Engineering Estimate
portable HEPA filtration units	1	LS	$250,000	$250,000					Engineering Estimate
Rad screening system	1	LS	$2,608,200	$2,608,200					Engineering Estimate
flatbed trailer	1	LS	$78,758	$78,758					Engineering Estimate
rough terrain scissors lift	1	LS	$49,997	$49,997					Engineering Estimate
hydraulic excavator	1	LS	$408,643	$408,643					Engineering Estimate
65 T mobile crane	1	LS	$205,229	$205,229					Engineering Estimate
50,000 lb capacity forklift	1	LS	$104,261	$104,261					Engineering Estimate
rough terrain forklift	1	LS	$73,987	$73,987					Engineering Estimate
Analytical Lab									
	1	LS	$1,134,356	$1,134,356					Engineering Estimate
Materials									
D yard boxes	3735	EA	$9,575	$35,762,625					Engineering Estimate
55 gallon drums	1315	EA	$68	$89,420					Engineering Estimate
55 gallon drum liner	1315	EA	$7	$8,640					Engineering Estimate
drum overpacks	100	EA	$177	$17,747					Engineering Estimate
PPE (level C)	1	LS	$178,330	$178,330					Engineering Estimate
laundry	1	LS	$379,680	$379,680					Engineering Estimate
respirator cleaning	1	LS	$473,299	$473,299					Engineering Estimate
Misc. materials	1	LS	$266,026	$266,026					Engineering Estimate
Subcontractors									
wastewater treatment	1	LS	$11,895,000	$11,895,000					Engineering Estimate
sheet piling	1	LS	$1,800,000	$1,800,000					Engineering Estimate
TASK TOTALS				**$57,389,573**			**$10,179,169**	**$67,569,000**	
7.1 Excavation SWMU 6									
Two crews for 2 month for excavating, sorting, staging and sampling based on excavating MLLW and LLW at 100 BCY/day/crew.									
Sheet piling the excavation perimeter. Soil, debris, waste excavated to 300 cy stockpiles for waste profile sampling.									
The excavation will require dewatering; the resulting wastewater will be treated with a skid-mounted unit									
Q cleared and local labor in support.									
Labor					12,847		$1,508,025		Engineering Estimate
Equipment									
Pickup	1	LS	$8,034	$8,034					Engineering Estimate
dozer, 105 HP	1	LS	$24,197	$24,197					Engineering Estimate

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 6 - Excavation and Removal of All Waste Materials

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
skid steer loader	1	LS	$5,177	$5,177					Engineering Estimate
water tank trailer	1	LS	$5,351	$5,351					Engineering Estimate
construction trailer	1	LS	$1,394	$1,394					Engineering Estimate
change trailer	1	LS	$1,394	$1,394					Engineering Estimate
100 KW generator	1	LS	$21,404	$21,404					Engineering Estimate
vacuum truck 5,000 gal	1	LS	$14,366	$14,366					Engineering Estimate
gooseneck dump trailer, 18'	1	LS	$1,633	$1,633					Engineering Estimate
yard tractor	1	LS	$12,733	$12,733					Engineering Estimate
portajohns/hand wash sta	1	LS	$398	$398					Engineering Estimate
crane, 12T truck mounted	1	LS	$21,280	$21,280					Engineering Estimate
diaphragm dewatering pumps	1	LS	$1,556	$1,556					Engineering Estimate
portable HEPA filtration units	1	LS	$18,519	$18,519					Engineering Estimate
Rad screening system	1	LS	$193,200	$193,200					Engineering Estimate
flatbed trailer	1	LS	$5,834	$5,834					Engineering Estimate
rough terrain scissors lift	1	LS	$3,703	$3,703					Engineering Estimate
hydraulic excavator	1	LS	$30,270	$30,270					Engineering Estimate
65 T mobile crane	1	LS	$15,202	$15,202					Engineering Estimate
50,000 lb capacity forklift	1	LS	$7,723	$7,723					Engineering Estimate
rough terrain forklift	1	LS	$5,481	$5,481					Engineering Estimate
Analytical Lab									
	1	LS	$84,026	$84,026					Engineering Estimate
Materials									
D yard boxes	74	EA	$9,575	$708,550					Engineering Estimate
55 gallon drums	85	EA	$68	$5,780					Engineering Estimate
55 gallon drum liner	85	EA	$7	$558					Engineering Estimate
drum overpacks	6	EA	$177	$1,147					Engineering Estimate
PPE (level C)	1	LS	$13,210	$13,210					Engineering Estimate
laundry	1	LS	$28,124	$28,124					Engineering Estimate
respirator cleaning	1	LS	$35,059	$35,059					Engineering Estimate
Misc. materials	1	LS	$19,706	$19,706					Engineering Estimate
Subcontractors									
wastewater treatment	1	LS	$881,111	$881,111					Engineering Estimate
sheet piling	1	LS	$470,000	$470,000					Engineering Estimate
TASK TOTALS				**$2,646,120**			**$1,508,025**	**$4,154,000**	
8.0 Waste Sorting, Transportation and Disposal									
Assume work performed concurrent with excavation at a 1 month lag with two crews									
Includes transportation from staging area to the U-Landfill or NNSS.									
Assumes 83,000 LCY to NNSS and 54,000 LCY to the U-Landfill from SMWU 5.									
Assumes 1,645 LCY to NNSS and 5,813 LCY to the U-Landfill from SMWU 6									
Q cleared and local labor									
Labor					6000		$360,756		Engineering Estimate
Equipment									
Pickup Truck, crew cab, 4x4	1	LS	$5,165	$5,165					Engineering Estimate
water tank 5,000 gal	1	LS	$3,440	$3,440					Engineering Estimate
vacuum truck 5,000 gal	1	LS	$9,235	$9,235					Engineering Estimate
gooseneck dump trailer, 18'	1	LS	$1,050	$1,050					Engineering Estimate

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 6 - Excavation and Removal of All Waste Materials

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
yard tractor	1	LS	$8,186	$8,186					Engineering Estimate
generator 100 KW	1	LS	$13,760	$13,760					Engineering Estimate
portajohns/handwash sta	1	LS	$512	$512					Engineering Estimate
diaphragm dewatering pumps	1	LS	$1,000	$1,000					Engineering Estimate
truck crane 12 T	1	LS	$13,680	$13,680					Engineering Estimate
rad screening system	1	LS	$124,200	$124,200					Engineering Estimate
portable HEPA filtration system	1	LS	$250,000	$250,000					Engineering Estimate
Analytical Lab	1	LS	$1,445,187	$1,445,187					Engineering Estimate
Materials									
PPE (level C)	1	LS	$6,605	$6,605					Engineering Estimate
Laundry	1	LS	$14,560	$14,560					Engineering Estimate
Respirator cleaning	1	LS	$17,530	$17,530					Engineering Estimate
Absorbant	2,160,000	LB	$2	$3,996,000					Engineering Estimate
Misc. Materials	1	LS	$9,853	$9,853					Engineering Estimate
Transportation/Disposal									
NNSS, Transportation	3,809	EA	$10,622	$40,460,874					Vendor Quote from Similar Contract
NNSS, Disposal per CF	2,434,815	EA	$15	$35,353,514					
TASK TOTAL	2390400			**$81,734,351**			**$360,756**	**$82,095,000**	
9.0 Backfill, Site Restoration and Equip Decon									
Two months with two cleared work crews. Backfilling based on 3,000 cy/day									
Labor					7,547		$439,480		Engineering Estimate
Equipment									
pickup	1	LS	$10,950	$10,950					Engineering Estimate
dozer, 105 HP	1	LS	$16,488	$16,488					Engineering Estimate
crawler loader	1	LS	$12,143	$12,143					Engineering Estimate
compactor sheepsfoot	1	LS	$11,360	$11,360					Engineering Estimate
compactor smooth drum	1	LS	$9,885	$9,885					Engineering Estimate
water tank trailer, 5,000 gal	1	LS	$7,293	$7,293					Engineering Estimate
Materials									
PPE (level D)	1	LS	$16,078	$16,078					Engineering Estimate
laundry	1	LS	$23,744	$23,744					Engineering Estimate
Misc. materials	1	LS	$41,776	$41,776					Engineering Estimate
Contracts									
borrow material/top soil	207,234	CY	$23	$4,834,769					Engineering Estimate
Soil testing	1	LS	$5,300	$5,300					Engineering Estimate
geotechnical testing	1	LS	$25,440	$25,440					Engineering Estimate
hydroseeding	1	LS	$14,087	$14,087					Engineering Estimate
Analytical Lab	1	LS	$8,470	$8,470					Engineering Estimate
TASK TOTAL				**$5,037,783**			**$439,480**	**$5,477,000**	
10.0 O&M Manual and RACR									
Labor									
document development					1,089		$75,303		Engineering Estimate

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 6 - Excavation and Removal of All Waste Materials

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
TASK TOTAL				**$0**			**$75,303**	**$75,000**	
							SUBTOTAL CAPITAL COST	**$164,200,000**	
Five Year Review (Yrs 5, 10, 15, 20, 25, 30)									
Five Year Review	1	LS	$50,198	$50,198					Engineering Estimate
TASK TOTAL								**$50,000**	

SWMUs 5 and 6, Alternative 6
Escalated Costs

Date	Yr	escalation	escalation factor	Capital	Five Year Reviews	TOTALS
2012		1	1.000	$240,203,000	$50,000	
2013		1.029	1.029			
2014	0	1.029	1.059	$254,336,785		$254,336,785
2015	1	1.029	1.090			$0
2016	2	1.029	1.121			$0
2017	3	1.029	1.154			$0
2018	4	1.029	1.187			$0
2019	5	1.029	1.222		$61,077	$61,077
2020	6	1.029	1.257			$0
2021	7	1.029	1.293			$0
2022	8	1.029	1.331			$0
2023	9	1.029	1.370			$0
2024	10	1.029	1.409		$70,462	$70,462
2025	11	1.029	1.450			$0
2026	12	1.029	1.492			$0
2027	13	1.029	1.535			$0
2028	14	1.029	1.580			$0
2029	15	1.029	1.626		$81,289	$81,289
2030	16	1.029	1.673			$0
2031	17	1.029	1.721			$0
2032	18	1.029	1.771			$0
2033	19	1.029	1.823			$0
2034	20	1.029	1.876		$93,780	$93,780
2035	21	1.029	1.930			$0
2036	21	1.029	1.986			$0
2037	23	1.029	2.044			$0
2038	24	1.029	2.103			$0
2039	25	1.029	2.164		$108,190	$108,190
2040	26	1.029	2.227			$0
2041	27	1.029	2.291			$0
2042	28	1.029	2.358			$0
2043	29	1.029	2.426			$0
2044	30	1.029	2.496		$124,814	$124,814
TOTAL				$254,336,785	$539,611	$254,876,395

For the ESCALATED values:

$540,000 Total Annual $
$254,876,000 Total $ (Capital & Annual)

CONCEPTUAL DESIGN CALCULATIONS

BGOU SWMUs 5 and 6

Alternative 6a - Excavation with on-site disposal (at Proposed on-site Disposal Unit)

SWMU 5

Parameter			Total	Units	Basis
SWMU Dimensions					
		Total Area	197,400	SF	Engr Est.
		Fraction of Area to be Excavated	0.78		from Est Basis
		Area to be Excavated	153,300	SF	Calc
		Excavation Depth	20	feet	Engr Est.
Waste Volume Calc					
		Waste Volume	113,560	BCY	calc
		Conversion	1.20	LCY/BCY	LATA Directive
		Excavated Waste Volume	137,000	LCY	calc
		U Landfill WAC Compliant Fraction	0.39		Est Basis
		On-site Cell WAC Compliant Fraction	0.61		Est Basis
		U Landfill WAC Compliant Volume	54,000	LCY	calc
		On-site Cell WAC CompliantVolume	83,000	LCY	calc
		Conversion	1.4	ton/LCY	Engr Est
		LLW Tonnage	116,200	ton	calc
Absorbents for Soil					
		Absorbent Rate	0.54	lb/CF	LATA
		Total Excavated Waste	137,000	LCY	calc
		Total Absorbent needed	2,000,000	lbs	calc
Excavation Duration					
		Excavation Rate	2,100	bcy/month/ crew	Engr Est., 100 bcy/day/crew 21 day work month
		No. of Crews	2	crews	Engr Est
		Time to Excavate U Landfill WAC Compliant Vol	10	month	calc
		Time to Excavate On-site Cell WAC Compliant Vol	17	month	calc
		Total Excavation Time	27	month	calc
		Total Excavation Time	2.3	years	calc
		Work day	10	hrs/wday	Engr Est.
		Work week	5	wdays/wk	Engr Est.
		Work days per year	252	wdays/yr	calc
		Work hours per year	2,520	whour/yr	calc
		Work days per month	21	wdays/mo	calc
Dewatering Calc					
		Initial Pore Volume	3,440,000	gal	calc from Est. Basis
		Dewatering Rate for Initial Pore Vol	30	gpm	Assumed
		Days to dewater initial pore volume	80	days	calc
		Dewatering Rate after removing initial pore vol.	7.9	gpm	DOE, 1998, pg 17
		Total Excavation Time	27	months	calc
		Fraction of time pumping occurs after removal of initial pore volume.	0.1	fraction of the time	Engr Est
		Dewater Volume during excavation	675,000	gal	calc
		Total Water for Trmt/Disposal during excavation	4,115,000	gal	calc
LLW Sludge Production from GW Treatment					
		Assumed Dewatering Rate	7,257	gal/day	calc
		Number of days operating	567	days	calc
		Dewatering total	4,115,000	gallons	Engr Est
		Est. Sludge fraction	0.01		Engr Est
		Est. Sludge production	41,150	gallons	calc
		Conversion	7.48	gal/cf	Lindeburg, 1990
		Conversion	27	cf/cy	Lindeburg, 1990
		Est. Sludge production	204	cy	calc
		Drum Volume	55	gal/drum	
		Sludge Drum Total	748	drums	calc
		Sludge Drums per truckload	60	drums / truckload	Engr Est
		Sludge Truck trips	12	trips	calc

CONCEPTUAL DESIGN CALCULATIONS

BGOU SWMUs 5 and 6

Alternative 6a - Excavation with on-site disposal (at Proposed on-site Disposal Unit)

SWMU 5

Parameter			Total	Units	Basis
Disposal Samples					
		Sample Rate	300	LCY	Engr Est.
		Samples for U Landfill WAC Compliant + 10 percent QA/QC	200	samples	Engr Est.
		Samples for On-site Cell + 10 percent QA/QC	310	samples	Engr Est.
Sheet Pile Installation					
		Depth of installation	40	feet	DOE, 1998
		Perimeter	1,570	feet	calc
		Fence Perimeter	2,000	feet	calc
		Area	62,800	SF	calc
		Sheet pile density	38	psf	calc
		Tonnage	1200	tons	calc
Backfill					
		Volume of Excavated Soil, Debris, Waste	137,000	LCY	
		Conversion	1.41	CCY/LCY	US Army, 1994
		Volume of Backfill	193,170	calc	
		Conversion	1.4	ton/CY	Lindeburg, 1990
		Backfill Tonnage	270,000	ton	
		Backfill Rate	3,000	cy/day	Engr Est.
		Est. Time to Backfill	46	days	calc
		Working days per month	21	days	calc
		Est. Months to Backfill	2	months	calc
Compaction Testing					
		Compaction Rate	20,000	SF/test	Engr Est
		Compaction Area	197,400	SF	Engr Est.
		Lift Thickness	2	feet	Engr Est.
		Number of Lifts	10	lifts	calc
		Number of Compactions Tests	100	tests	calc
Top Soil & Hydroseeding					
		Excavation Area	153,300	SF	Engr Est.
		Disturbed Area Factor	1.25		Engr Est.
		Conversion	43,560	SF/acre	Lindeburg, 1990
		Disturbed Area	191,625	SF	calc
		Conversion	1,000	SF/MSF	
		Disturbed Area	200	MSF	calc
		Top Soil Thickness	0.5	feet	Engr Est.
		Conversion	27	CF/CY	Lindeburg, 1990
		Conversion	1.3	ton/CY	Engr Est.
		Top Soil tonnage	4,600	ton	calc
Trucking to existing U Landfill at PGDP					
		Dump Capacity	14	ton	Engr Est
		Dump Capacity	10	lcy	Engr Est
		Dump Trips for U Landfill WAC Compliant	5,400	trips	calc
		Truck Liners	5,400	liners	calc
Trucking to On-site Cell					
		Dump Capacity	14	ton	Engr Est
		Dump Capacity	10	lcy	Engr Est
		Dump Trips for Cercla Cell WAC Compliant	8,300	trips	calc
		Truck Liners	8,300	liners	calc
PPE LLW Drums					
		Drums filled per day with PPE LLW Waste	1	drum/day	Engr Est
		No. of drums used during project	567	drums	calc
		Drums per Truckload	60	drums / truckload	Engr Est
		Truck Trips	9	trips	calc
		Drum Volume	55	gal/drum	Engr Est
		Conversion	7.48	gal/cf	Lindeburg, 1990

CONCEPTUAL DESIGN CALCULATIONS

BGOU SWMUs 5 and 6

Alternative 6a - Excavation with on-site disposal (at Proposed on-site Disposal Unit)

SWMU 5

Parameter			Total	Units	Basis
		Conversion	27	cf/cy	Lindeburg, 1990
		Total Volume of PPE	150	cy	calc

References:

DOE, 1998, Feasibility Study for Final Action at SWMU 2 of WAG 22 at the Paducah GDP, KY, Sept.
Glover, 1995, Pocket Ref, 2nd Edition.
Lindeburg, 1990, Engineering Unit Conversions
US Army, 1994, Field Manual No. 5-430-00-1, Planning and Design of Roads, Airfields, and Helioports in the Theater of Operations - Road Design.

CONCEPTUAL DESIGN CALCULATIONS
BGOU SWMUs 5 and 6
Alternative 6a - Excavation with on-site disposal (at Proposed on-site Disposal Unit)
SWMU 6

Parameter			**Total**	**Units**	**Basis**
SWMU Dimensions					
		Total Area	8,390	SF	Engr Est.
		Fraction of Area to be Excavated	1.00		from Est Basis
		Area to be Excavated	8,390	SF	Calc
		Excavation Depth	20	feet	Engr Est.
Waste Volume Calc					
		Total Waste Volume	6,215	BCY	calc
		Area H (180 ft^2 x 7 ft deep)	47	BCY	calc
		Area I (280 ft^2 x 7 ft deep)	73	BCY	calc
		Area I-2 (36 ft^2 x 9 ft deep)	12	BCY	calc
		Area J (4,000 ft^2 x 7 ft deep)	1,037	BCY	calc
		Area K (180 ft^2 x 7 ft deep)	47	BCY	calc
		Area L (600 ft^2 x 7 ft deep)	156	BCY	calc
		Remaining Excavation Volume	4,844	BCY	calc
Disposal Calculations					
		Conversion	1.20	LCY/BCY	LATA Directive
		Excavated Waste Volume	7,458	LCY	Total BCY x 1.2
		U Landfill WAC Compliant Waste Fraction	0.78		Estimate assumes that waste outside the specified waste cells can be disposed of at the U landfill
		Assumed on-site disposal cell WAC Compliant Fraction	0.22		Estimate assumes that waste generated from areas H-L will be disposed of at on-site landfill
		U Landfill WAC Compliant Volume	5,813	LCY	calc
		On-site landfill WAC Compliant Volume	1,645	LCY	calc
		Conversion	1.4	ton/LCY	Engr Est
		LLW Tonnage (on-site disposal)	2,302	ton	calc
Absorbents for Soil					
		Absorbent Rate	0.54	lb/CF	LATA
		Total Excavated Waste	7,458	LCY	calc
		Total Absorbent needed	100,000	lbs	calc
Excavation Duration					
		Excavation Rate	2,100	bcy/month/crew	Engr Est., 100 bcy/day/crew 21 day work month
		No. of Crews	2	crews	Engr Est
		Time to Excavate U Landfill WAC Compliant	1.2	month	calc
		Time to Excavate On-site WAC Compliant	0.3	month	calc
		Total Excavation Time	2.0	Months	calc
		Total Excavation Time	0.2	years	calc
		Work day	10	hrs/wday	Engr Est.
		Work week	5	wdays/wk	Engr Est.
		Work days per year	252	wdays/yr	calc
		Work hours per year	2,520	whour/yr	calc
		Work days per month	21	wdays/mo	calc
Dewatering Calc					
		Initial Pore Volume	188,000	gal	calc from Est. Basis
		Dewatering Rate for Initial Pore Vol	30	gpm	Assumed
		Days to dewater initial pore volume	4	days	calc
		Dewatering Rate after removing initial pore vol.	7.9	gpm	DOE, 1998, pg 17
		Total Excavation Time	2.0	months	calc

CONCEPTUAL DESIGN CALCULATIONS

BGOU SWMUs 5 and 6

Alternative 6a - Excavation with on-site disposal (at Proposed on-site Disposal Unit)

SWMU 6

Parameter			**Total**	**Units**	**Basis**
		Fraction of time pumping occurs after removal of initial pore volume.	0.1	fraction of the time	Engr Est
		Dewater Volume during excavation	50,000	gal	calc
		Total Water for Trmt/Disposal during excavation	238,000	gal	calc
LLW Sludge Production from GW Treatment					
		Assumed Dewatering Rate	5,667	gal/day	calc
		Number of days operating	42	days	calc
		Dewatering total	238,000	gallons	Engr Est
		Est. Sludge fraction	0.01		Engr Est
		Est. Sludge production	2,380	gallons	calc
		Conversion	7.48	gal/cf	Lindeburg, 1990
		Conversion	27	cf/cy	Lindeburg, 1990
		Est. Sludge production	12	cy	calc
		Drum Volume	55	gal/drum	
		Sludge Drum Total	43	drums	calc
		Sludge Drums per truckload	60	drums/truckload	Engr Est
		Sludge Truck trips	1	trips	calc

CONCEPTUAL DESIGN CALCULATIONS

BGOU SWMUs 5 and 6

Alternative 6a - Excavation with on-site disposal (at Proposed on-site Disposal Unit)

SWMU 6

Parameter			**Total**	**Units**	**Basis**
Disposal Samples					
		Sample Rate	300	LCY	Engr Est.
		Samples for U Landfill WAC Compliant + 10 percent QA/QC	20	samples	Engr Est.
		Samples for On-Site Cell WAC Compliant + 10 percent QA/QC	20	samples	Engr Est.
Sheet Pile Installation					
		Depth of installation	40	feet	DOE, 1998
		Perimeter	470	feet	calc
		Fence Perimeter	0	feet	calc
		Area	18,800	SF	calc
		Sheet pile density	38	psf	calc
		Tonnage	400	tons	calc
Backfill					
		Volume of Excavated Soil, Debris, Waste	7,458	LCY	
		Conversion	1.41	CCY/LCY	US Army, 1994
		Volume of Backfill	10,515	calc	
		Conversion	1.4	ton/CY	Lindeburg, 1990
		Backfill Tonnage	15,000	ton	
		Backfill Rate	3,000	cy/day	Engr Est.
		Est. Time to Backfill	2	days	calc
		Working days per month	21	days	calc
		Est. Months to Backfill	0.1	months	calc
Compaction Testing					
		Compaction Rate	20,000	SF/test	Engr Est
		Compaction Area	8,390	SF	Engr Est.
		Lift Thickness	2	feet	Engr Est.
		Number of Lifts	10	lifts	calc
		Number of Compactions Tests (one per lift)	10	tests	calc
Top Soil & Hydroseeding					
		Excavation Area	8,390	SF	Engr Est.
		Disturbed Area Factor	1.25		Engr Est.
		Conversion	43,560	SF/acre	Lindeburg, 1990
		Disturbed Area	10,488	SF	calc
		Conversion	1,000	SF/MSF	
		Disturbed Area	20	MSF	calc
		Top Soil Thickness	0.5	feet	Engr Est.
		Conversion	27	CF/CY	Lindeburg, 1990
		Conversion	1.3	ton/CY	Engr Est.
		Top Soil tonnage	300	ton	calc
Trucking to existing U Landfill at PGDP					
		Dump Capacity	14	ton	Engr Est
		Dump Capacity	10	lcy	Engr Est
		Dump Trips for U Landfill WAC Compliant	581	trips	calc
		Truck Liners	581	liners	calc
Trucking to On-site Cell					
		Dump Capacity	14	ton	Engr Est
		Dump Capacity	10	lcy	Engr Est
		Dump Trips for On-Site Cell WAC Compliant	164	trips	calc
		Truck Liners	164	liners	calc

CONCEPTUAL DESIGN CALCULATIONS

BGOU SWMUs 5 and 6

Alternative 6a - Excavation with on-site disposal (at Proposed on-site Disposal Unit)

SWMU 6

Parameter			Total	Units	Basis
PPE LLW Drums					
		Drums filled per day with PPE LLW Waste	1	drum/day	Engr Est
		No. of drums used during project	42	drums	calc
		Drums per Truckload	60	drums/truckload	Engr Est
		Truck Trips	1	trips	calc
		Drum Volume	55	gal/drum	Engr Est
		Conversion	7.48	gal/cf	Lindeburg, 1990
		Conversion	27	cf/cy	Lindeburg, 1990
		Total Volume of PPE	10	cy	calc

References:
DOE, 1998, Feasibility Study for Final Action at SWMU 2 of WAG 22 at the Paducah GDP, KY, Sept.
Glover, 1995, Pocket Ref, 2nd Edition.
Lindeburg, 1990, Engineering Unit Conversions
US Army, 1994, Field Manual No. 5-430-00-1, Planning and Design of Roads, Airfields, and Helioports in the Theater of Operations - Road Design.

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 6a - Excavation With On-Site Disposal (At Proposed On-Site Disposal Unit)

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
COST ESTIMATE SUMMARY									
Capital Cost									
1.0 Project Plans	1	LS	$545,000	$545,000					
2.0 Engineering Design	1	LS	$359,000	$359,000					
3.0 Work Package Prep./Readiness Review	1	LS	$422,000	$422,000					
4.0 Training	1	LS	$299,000	$299,000					
5.0 Mobilization	1	LS	$446,000	$446,000					
6.0 Site Preperation	1	LS	$2,749,000	$2,749,000					
7.0 Excavation SWMU 5	1	LS	$30,773,000	$30,773,000					
7.1 Excavation SWMU 6	1	LS	$2,628,000	$2,628,000					
8.0 Waste Sorting, Transportation and Disposal	1	LS	$6,274,000	$6,274,000					
9.0 Backfill, Site Restoration and Equip Decon	1	LS	$5,484,000	$5,484,000					
10.0 O&M Manual and RACR	1	LS	$75,000	$75,000					
fee, management reserve, subproject management	1	LS	$13,514,580	$13,515,000					fee = 7%, mgt reserve = 15%, subproject management = 5%, (engineers estimate)
contingency	1	LS	$9,145,200	$9,145,000					contingency on construction costs only = 20%
			SUBTOTAL CAPITAL COST	**$72,714,000**					
Annual Cost									
Five Year Review Year 5	1	LS	$50,000	$50,000					
Five Year Review Year 10	1	LS	$50,000	$50,000					
Five Year Review Year 15	1	LS	$50,000	$50,000					
Five Year Review Year 20	1	LS	$50,000	$50,000					
Five Year Review Year 25	1	LS	$50,000	$50,000					
Five Year Review Year 30	1	LS	$50,000	$50,000					
			SUBTOTAL ANNUAL COST	**$300,000**					
			TOTAL	**$73,014,000**					
Present Worth Value									
	Quantity	Unit	Unit Cost	Total				**Present Worth**	
Total Capital Cost	1	LS	$72,714,000	$72,714,000				**$72,714,000**	
Five Year Review Year 5	1	LS	$50,000	$50,000				**$44,626**	2.3% discount rate
Five Year Review Year 10	1	LS	$50,000	$50,000				**$39,830**	2.3% discount rate
Five Year Review Year 15	1	LS	$50,000	$50,000				**$35,550**	2.3% discount rate
Five Year Review Year 20	1	LS	$50,000	$50,000				**$31,729**	2.3% discount rate
Five Year Review Year 25	1	LS	$50,000	$50,000				**$28,319**	2.3% discount rate
Five Year Review Year 30	1	LS	$50,000	$50,000				**$25,276**	2.3% discount rate
							Capital	**$72,714,000**	
						Present Worth Values	**Annual**	**$205,330**	
							Avg. Annual	**$6,844**	
							Total	**$72,919,000**	
This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost.									
Not used for budgeting or planning purposes because value is based on investing funds for out year expenditures.									
1.0 Project Plans									

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 6a - Excavation With On-Site Disposal (At Proposed On-Site Disposal Unit)

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
Hazard Analysis Document	1	LS	$147,330	$147,330					Engineering Estimate
Health & Safety Plan	1	LS	$20,688	$20,688					Engineering Estimate
Remedial Design Work Plan	1	LS	$247,773	$247,773					Engineering Estimate
Security Plan	1	LS	$43,570	$43,570					Engineering Estimate
QA Plan	1	LS	$10,374	$10,374					Engineering Estimate
Sampling & Analysis Plan	1	LS	$42,428	$42,428					Engineering Estimate
Waste Management Plan	1	LS	$32,791	$32,791					Engineering Estimate
TASK TOTAL				**$544,954**			**$0**	**$545,000**	
2.0 Engineering Design									
Includes geophysical survey of the landfill.									
Civil Surveying	1	LS	$35,280	$35,280					Engineering Estimate
Geophysical Survey	1	LS	$32,793	$32,793					Engineering Estimate
Design	1	LS	$290,925	$290,925					Engineering Estimate
TASK TOTAL				**$358,998**			**$0**	**$359,000**	
3.0 Work Package Prep./Readiness Review									
Remedial Action Work Plan	1	LS	$147,569	$147,569					Engineering Estimate
Work Instructions	1	LS	$134,730	$134,730					Engineering Estimate
Training	1	LS	$3,390	$3,390					Engineering Estimate
USD/USQD	1	LS	$19,915	$19,915					Engineering Estimate
Lessons Learned	1	LS	$5,206	$5,206					Engineering Estimate
Procedures	1	LS	$10,492	$10,492					Engineering Estimate
AHA	1	LS	$22,684	$22,684					Engineering Estimate
Work Authorization	1	LS	$475	$475					Engineering Estimate
Excavation/Penetration Permits	1	LS	$32,986	$32,986					Engineering Estimate
Team Meeting Documentation	1	LS	$1,333	$1,333					Engineering Estimate
Transportation Plan	1	LS	$13,867	$13,867					Engineering Estimate
Hoisting and Rigging Plan	1	LS	$12,469	$12,469					Engineering Estimate
Emergency Response Plan	1	LS	$15,847	$15,847					Engineering Estimate
Project Org. Chart	1	LS	$950	$950					Engineering Estimate
TASK TOTALS				**$421,913**			**$0**	**$422,000**	
4.0 Training									
Assumptions: Training Specialist and training courses funded through other funding. 100% Q-cleared local work crew.									
Labor									
					3120		$179,404		Engineering Estimate
Subcontractors	1	LS	$120,000	$120,000					Engineering Estimate
TASK TOTALS				**$120,000**			**$179,404**	**$299,000**	
5.0 Mobilization									
Duration: Assume one month for mobilization.									
Labor					4480		$287,890		Engineering Estimate
Equipment									
Pickup	1	LS	$5,165	$5,165					Engineering Estimate
construction trailer	1	LS	$896	$896					Engineering Estimate
change trailer	1	LS	$896	$896					Engineering Estimate
100 KW generator	1	LS	$13,760	$13,760					Engineering Estimate
dozer, 105 HP	1	LS	$15,555	$15,555					Engineering Estimate
skid steer loader	1	LS	$3,328	$3,328					Engineering Estimate
crane, 12 T truck mounted	1	LS	$13,680	$13,680					Engineering Estimate
water tank trailer, 5000 gal	1	LS	$3,440	$3,440					Engineering Estimate
portajohns/handwash stations	1	LS	$512	$512					Engineering Estimate

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 6a - Excavation With On-Site Disposal (At Proposed On-Site Disposal Unit)

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
RAD screening system	1	LS	$80,000	$80,000					Engineering Estimate
Materials									
PPE	1	LS	$8,342	$8,342					Engineering Estimate
Laundry	1	LS	$12,320	$12,320					Engineering Estimate
TASK TOTALS				**$157,894**			**$287,890**	**$446,000**	
6.0 Site Preperation									
Duration one month. Two work crews.									
Also install stormwater control measures including cleaning ditches, repairing culverts and drains, and diverting water from the project areas.									
Labor					4,160		$241,591		Engineering Estimate
Equipment									
Pickup	1	LS	$5,185	$5,185					Engineering Estimate
construction trailer	1	LS	$896	$896					Engineering Estimate
change trailer	1	LS	$896	$896					Engineering Estimate
100 KW generator	1	LS	$13,760	$13,760					Engineering Estimate
dozer, 105 HP	1	LS	$15,555	$15,555					Engineering Estimate
skid steer loader	1	LS	$3,328	$3,328					Engineering Estimate
crane, 12 T truck mounted	1	LS	$13,680	$13,680					Engineering Estimate
water tank trailer, 5000 gal	1	LS	$3,440	$3,440					Engineering Estimate
portajohns/handwash stations	1	LS	$512	$512					Engineering Estimate
RAD screening system	1	LS	$80,000	$80,000					Engineering Estimate
Materials									
geotextile fabric	1	LS	$34,400	$34,400					Engineering Estimate
riprap	1	LS	$16,800	$16,800					Engineering Estimate
silt fence	1	LS	$325	$325					Engineering Estimate
crushed stone	1	LS	$9,000	$9,000					Engineering Estimate
hay/straw bales	1	LS	$2,400	$2,400					Engineering Estimate
PPE	1	LS	$8,342	$8,342					Engineering Estimate
misc. materials	1	LS	$9,853	$9,853					Engineering Estimate
laundry	1	LS	$12,320	$12,320					Engineering Estimate
Subcontracts									
Waste Management Bldg	1	LS	$1,000,000	$1,000,000					Engineering Estimate
Weather Enclosures (2)	1	LS	$1,200,000	$1,200,000					Engineering Estimate
Fence	1	LS	$76,950	$76,950					Engineering Estimate
TASK TOTALS				**$2,507,642**			**$241,591**	**$2,749,000**	
7.0 Excavation SWMU 5									
Two crews for 27 months for excavating, staging, sorting, segregating, and sampling based on excavating MLLW and LLW at 100 BCY/day/crew.									
Sheet piling the excavation perimeter. Soil, debris, waste excavated to 300 cy stockpiles for waste profile sampling.									
The excavation will require dewatering; the resulting wastewater will be treated with a skid-mounted unit									
Q cleared and local labor in support.									
Labor					138,480		$8,157,793		Engineering Estimate
Equipment									
Pickup	1	LS	$108,461	$108,461					Engineering Estimate

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 6a - Excavation With On-Site Disposal (At Proposed On-Site Disposal Unit)

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
dozer, 105 HP	1	LS	$326,659	$326,659					Engineering Estimate
skid steer loader	1	LS	$69,888	$69,888					Engineering Estimate
water tank trailer	1	LS	$72,240	$72,240					Engineering Estimate
construction trailer	1	LS	$18,816	$18,816					Engineering Estimate
change trailer	1	LS	$18,816	$18,816					Engineering Estimate
100 KW generator	1	LS	$288,960	$288,960					Engineering Estimate
vacuum truck 5,000 gal	1	LS	$193,939	$193,939					Engineering Estimate
gooseneck dump trailer, 18'	1	LS	$22,042	$22,042					Engineering Estimate
yard tractor	1	LS	$171,898	$171,898					Engineering Estimate
portajohns/hand wash sta	1	LS	$5,376	$5,376					Engineering Estimate
crane, 12T truck mounted	1	LS	$287,280	$287,280					Engineering Estimate
diaphragm dewatering pumps	1	LS	$21,000	$21,000					Engineering Estimate
portable HEPA filtration units	1	LS	$250,000	$250,000					Engineering Estimate
Rad screening system	1	LS	$2,608,200	$2,608,200					Engineering Estimate
flatbed trailer	1	LS	$78,758	$78,758					Engineering Estimate
rough terrain scissors lift	1	LS	$49,997	$49,997					Engineering Estimate
hydraulic excavator	1	LS	$408,643	$408,643					Engineering Estimate
65 T mobile crane	1	LS	$205,229	$205,229					Engineering Estimate
50,000 lb capacity forklift	1	LS	$104,261	$104,261					Engineering Estimate
15 CY Dump Truck	1	LS	$199,670	$199,670					
rough terrain forklift	1	LS	$73,987	$73,987					Engineering Estimate
Analytical Lab									
	1	LS	$1,134,356	$1,134,356					Engineering Estimate
Materials									
dump truck liners	8300	EA	$95	$788,500					Engineering Estimate
55 gallon drums	1315	EA	$68	$89,420					Engineering Estimate
55 gallon drum liner	1315	EA	$7	$8,640					Engineering Estimate
drum overpacks	100	EA	$177	$17,747					Engineering Estimate
PPE (level C)	1	LS	$178,330	$178,330					Engineering Estimate
laundry	1	LS	$379,680	$379,680					Engineering Estimate
respirator cleaning	1	LS	$473,299	$473,299					Engineering Estimate
Misc. materials	1	LS	$266,026	$266,026					Engineering Estimate
Subcontractors									
wastewater treatment	1	LS	$11,895,000	$11,895,000					Engineering Estimate
sheet piling	1	LS	$1,800,000	$1,800,000					Engineering Estimate
TASK TOTALS				**$22,615,118**			**$8,157,793**	**$30,773,000**	
7.1 Excavation SWMU 6									
Two crews for 2 month for excavating, sorting, staging and sampling based on excavating MLLW and LLW at 100 BCY/day/crew.									
Sheet piling the excavation perimeter. Soil, debris, waste excavated to 300 cy stockpiles for waste profile sampling.									
The excavation will require dewatering; the resulting wastewater will be treated with a skid-mounted unit									
Q cleared and local labor in support.									
Labor					10,258		$604,281		Engineering Estimate
Equipment									
Pickup	1	LS	$8,034	$8,034					Engineering Estimate
dozer, 105 HP	1	LS	$24,197	$24,197					Engineering Estimate
skid steer loader	1	LS	$5,177	$5,177					Engineering Estimate
water tank trailer	1	LS	$5,351	$5,351					Engineering Estimate

C-43

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 6a - Excavation With On-Site Disposal (At Proposed On-Site Disposal Unit)

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
construction trailer	1	LS	$1,394	$1,394					Engineering Estimate
change trailer	1	LS	$1,394	$1,394					Engineering Estimate
100 KW generator	1	LS	$21,404	$21,404					Engineering Estimate
vacuum truck 5,000 gal	1	LS	$14,366	$14,366					Engineering Estimate
gooseneck dump trailer, 18'	1	LS	$1,633	$1,633					Engineering Estimate
yard tractor	1	LS	$12,733	$12,733					Engineering Estimate
portajohns/hand wash sta	1	LS	$398	$398					Engineering Estimate
crane, 12T truck mounted	1	LS	$21,280	$21,280					Engineering Estimate
diaphragm dewatering pumps	1	LS	$1,556	$1,556					Engineering Estimate
portable HEPA filtration units	1	LS	$18,519	$18,519					Engineering Estimate
Rad screening system	1	LS	$193,200	$193,200					Engineering Estimate
flatbed trailer	1	LS	$5,834	$5,834					Engineering Estimate
rough terrain scissors lift	1	LS	$3,703	$3,703					Engineering Estimate
hydraulic excavator	1	LS	$30,270	$30,270					Engineering Estimate
65 T mobile crane	1	LS	$15,202	$15,202					Engineering Estimate
50,000 lb capacity forklift	1	LS	$7,723	$7,723					Engineering Estimate
15 CY Dump Truck	1	LS	$14,790	$14,790					Engineering Estimate
rough terrain forklift	1	LS	$5,481	$5,481					
Analytical Lab									
	1	LS	$84,026	$84,026					Engineering Estimate
Materials									
dump truck liners	745	EA	$95	$70,775					
55 gallon drums	85	EA	$68	$5,780					Engineering Estimate
55 gallon drum liner	85	EA	$7	$558					Engineering Estimate
drum overpacks	8	EA	$177	$1,420					Engineering Estimate
PPE (level C)	1	LS	$13,210	$13,210					Engineering Estimate
laundry	1	LS	$28,124	$28,124					Engineering Estimate
respirator cleaning	1	LS	$35,059	$35,059					
Misc. materials	1	LS	$19,706	$19,706					Engineering Estimate
Subcontractors									
wastewater treatment	1	LS	$881,111	$881,111					Engineering Estimate
sheet piling	1	LS	$470,000	$470,000					
TASK TOTALS				**$2,023,408**			**$604,281**	**$2,628,000**	
8.0 Waste Sorting, Transportation and Disposal									
Assume work performed concurrent with excavation at a 1 month lag with two crews									
Includes transportation from staging area to final destination and treatment at final destination as needed.									
SWMU 5 is a Classified SWMU, therefore disposal at NNSS or on site. Assumes all classified, 90% of MLLW material meets WAC of on-site facility									
SWMU 6 waste will be loaded on dump trucks and taken to the OSWDF.									
Q cleared and local labor									
Labor									
packaging and shipping					5680		$339,431		Engineering Estimate
Equipment									
Pickup Truck, crew cab, 4x4	1	LS	$5,165	$5,165					Engineering Estimate
water tank 5,000 gal	1	LS	$3,440	$3,440					Engineering Estimate
vacuum truck 5,000 gal	1	LS	$9,235	$9,235					Engineering Estimate
gooseneck dump trailer, 18'	1	LS	$1,050	$1,050					Engineering Estimate

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 6a - Excavation With On-Site Disposal (At Proposed On-Site Disposal Unit)

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
yard tractor	1	LS	$8,186	$8,186					Engineering Estimate
generator 100 KW	1	LS	$13,760	$13,760					Engineering Estimate
portajohns/handwash sta	1	LS	$512	$512					Engineering Estimate
diaphragm dewatering pumps	1	LS	$1,000	$1,000					Engineering Estimate
truck crane 12 T	1	LS	$13,680	$13,680					Engineering Estimate
rad screening system	1	LS	$124,200	$124,200					Engineering Estimate
15 CY Dump Truck	1	LS	$14,790	$14,790					
portable HEPA filtration system	1	LS	$250,000	$250,000					Engineering Estimate
Analytical Lab	1	LS	$1,445,187	$1,445,187					Engineering Estimate
Materials									
PPE (level C)	1	LS	$6,605	$6,605					Engineering Estimate
Laundry	1	LS	$14,560	$14,560					Engineering Estimate
Respirator cleaning	1	LS	$17,530	$17,530					Engineering Estimate
Absorbant	2,160,000	LB	$2	$3,996,000					Engineering Estimate
Misc. materials	1	LS	$9,853	$9,853					Engineering Estimate
TASK TOTAL				**$5,934,753**			**$339,431**	**$6,274,000**	
9.0 Backfill, Site Restoration and Equip Decon									
Two months with two cleared work crews. Backfilling based on 3,000 cy/day									
Labor					7,547		$439,480		Engineering Estimate
Equipment									
pickup	1	LS	$10,950	$10,950					Engineering Estimate
dozer, 105 HP	1	LS	$16,488	$16,488					Engineering Estimate
crawler loader	1	LS	$12,143	$12,143					Engineering Estimate
compactor sheepsfoot	1	LS	$11,360	$11,360					Engineering Estimate
compactor smooth drum	1	LS	$9,885	$9,885					Engineering Estimate
water tank trailer, 5,000 gal	1	LS	$7,293	$7,293					Engineering Estimate
Materials									
PPE (level D)	1	LS	$16,078	$16,078					Engineering Estimate
laundry	1	LS	$23,744	$23,744					Engineering Estimate
Misc. materials	1	LS	$41,776	$41,776					Engineering Estimate
Contracts									
borrow material/top soil	207,534	CY	$23	$4,841,768					Engineering Estimate
Soil testing	1	LS	$5,300	$5,300					Engineering Estimate
geotechnical testing	1	LS	$25,440	$25,440					Engineering Estimate
hydroseeding	1	LS	$14,087	$14,087					Engineering Estimate
Analytical Lab	1	LS	$8,470	$8,470					Engineering Estimate
TASK TOTAL				**$5,044,782**			**$439,480**	**$5,484,000**	
10.0 O&M Manual and RACR									
Labor									
document development					1,089		$75,303		Engineering Estimate
TASK TOTAL				**$0**			**$75,303**	**$75,000**	

COST ESTIMATE
BGOU SWMUs 5 and 6
Alternative 6a - Excavation With On-Site Disposal (At Proposed On-Site Disposal Unit)

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
							SUBTOTAL CAPITAL COST	**$50,054,000**	
Five Year Review (Yrs 5, 10, 15, 20, 25, 30)									
Five Year Review	1	LS	$50,198	$50,198					Engineering Estimate
TASK TOTAL								**$50,000**	

SWMUs 5 and 6, Alternative 6a
Escalated Costs

Date	Yr	escalation	escalation factor	Capital	Five Year Reviews	TOTALS
2012		1	1.000	$72,714,000	$50,000	
2013		1.029	1.029			
2014	0	1.029	1.059	$76,992,564		$76,992,564
2015	1	1.029	1.090			$0
2016	2	1.029	1.121			$0
2017	3	1.029	1.154			$0
2018	4	1.029	1.187			$0
2019	5	1.029	1.222		$61,077	$61,077
2020	6	1.029	1.257			$0
2021	7	1.029	1.293			$0
2022	8	1.029	1.331			$0
2023	9	1.029	1.370			$0
2024	10	1.029	1.409		$70,462	$70,462
2025	11	1.029	1.450			$0
2026	12	1.029	1.492			$0
2027	13	1.029	1.535			$0
2028	14	1.029	1.580			$0
2029	15	1.029	1.626		$81,289	$81,289
2030	16	1.029	1.673			$0
2031	17	1.029	1.721			$0
2032	18	1.029	1.771			$0
2033	19	1.029	1.823			$0
2034	20	1.029	1.876		$93,780	$93,780
2035	21	1.029	1.930			$0
2036	21	1.029	1.986			$0
2037	23	1.029	2.044			$0
2038	24	1.029	2.103			$0
2039	25	1.029	2.164		$108,190	$108,190
2040	26	1.029	2.227			$0
2041	27	1.029	2.291			$0
2042	28	1.029	2.358			$0
2043	29	1.029	2.426			$0
2044	30	1.029	2.496		$124,814	$124,814
TOTAL				$76,992,564	$539,611	$77,532,175

For the ESCALATED values:

$540,000 Total Annual $
$77,532,000 Total $ (Capital & Annual)

APPENDIX D

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND TO BE CONSIDERED GUIDANCE

THIS PAGE INTENTIONALLY LEFT BLANK

CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

D.1. INTRODUCTION

Section 121(d) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and 40 *CFR* § 300.430(f)(1)(ii)(B) of the National Contingency Plan require that remedial actions at CERCLA sites attain legally applicable or relevant and appropriate requirements (ARARs) or provide grounds for invoking a CERCLA waiver. ARARs include the substantive requirements of federal or more stringent state environmental or facility siting laws/regulations. Additionally, per 40 *CFR* § 300.400(g)(3), other advisories, criteria, or guidance may be considered in determining remedies [to be considered (TBC) category]. CERCLA § 121(d)(4) provides several ARAR waiver options that may be invoked, provided that human health and the environment are protected. ARARs do not include occupational safety or worker protection requirements. On-site activities must comply with the substantive, but not administrative requirements. Administrative requirements include applying for permits, recordkeeping, consultation, and reporting. Activities conducted off-site must comply with both the substantive and administrative requirements of applicable laws.

ARARs typically are divided into three categories: (1) chemical-specific, (2) location-specific, and (3) action-specific. “Chemical-specific ARARs usually are health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values” [53 *FR* 51394, 51437 (December 21, 1988)]. (In the absence of chemical-specific ARARs, cleanup criteria are based upon risk calculations.) 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* 51394, 51437 (December 21, 1988)]. Action-specific ARARs usually are technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes or requirements to conduct certain actions to address particular circumstances at a site [53 *FR* 51394, 51437 (December 21, 1988)]. The three categories of ARARs are described in the subsections below. Tables D.1 and D.2 follow the narrative and contain ARARs and TBC guidance for the Burial Grounds Operable Unit (BGOU) Feasibility Study for Solid Waste Management Units (SWMUs) 5 and 6.

D.2. CHEMICAL-SPECIFIC ARARs/TBC GUIDANCE

Chemical-specific ARARs provide health- or risk-based concentration limits or discharge limitations in environmental media (i.e., surface water, groundwater, soil, or air) for specific hazardous substances, pollutants, or contaminants. There are no chemical-specific ARARs for remediation of the contaminated soils at the SWMUs 5 and 6 source areas. The Kentucky drinking water standard maximum contaminant levels (MCLs) do not apply to this project; however, they were used for consideration of soil remediation goals.

D.3. LOCATION-SPECIFIC ARARs/TBC GUIDANCE

Location-specific requirements establish restrictions on activities conducted within protected or environmentally sensitive areas. In addition, these requirements establish restrictions on permissible concentrations of hazardous substances within these areas.

A wetlands assessment would be performed prior to remedy implementation. Although it is not anticipated, if an action should involve discharge of dredge or fill material into waters of the United States, including jurisdictional wetlands, compliance with the substantive requirements of Nationwide Permit 38, General Conditions, would be required, as appropriate.

D.4. ACTION-SPECIFIC ARARs/TBC GUIDANCE

Action-specific ARARs include operation, performance, and design requirements or limitations based on waste type, media, and remedial activities. Component actions include groundwater monitoring, institutional controls, waste management, and transportation.

D.4.1 GENERAL CONSTRUCTION ACTIVITIES

General site preparation activities would trigger general requirements for storm water runoff and air emission control measures. ARARs for these common activities are discussed here.

D.4.2 STORM WATER RUNOFF

Storm water discharges from activities involving construction operations that result in the disturbance of land equal to or greater than one acre and less than five acres require implementation of good site planning and best management practices.

D.4.3 FUGITIVE EMISSIONS

Emission of airborne particulate concentrations may result from construction activities. Fugitive emissions are regulated by Kentucky through administrative rules at 401 *KAR* 63:010. An operator must take reasonable precautions to prevent particulate matter from becoming airborne.

Atmospheric radionuclide emissions, excluding radon-220 and radon-222, from U.S. Department of Energy (DOE) facilities are addressed in 40 *CFR* § 61, Subpart H. These regulations apply to airborne emissions during construction and operation activities. National Emissions Standards for Hazardous Air Pollutants limits ambient air radionuclide emissions from DOE facilities to levels that would prevent any individual from receiving an effective dose equivalent (EDE) of 10 mrem/year or more (40 *CFR* § 61.92). Nonpoint-source fugitive radionuclide emissions are estimated by plant monitoring stations.

D.4.4 WASTE WATER TREATMENT

Contaminated water, including decontamination fluid, collected storm water, and groundwater, shall be treated before discharge. Under Alternative 6, including 6A, a wastewater treatment facility may be constructed and designed to meet the substantive requirements of the Kentucky Pollutant Discharge Elimination System program for discharge of this water and the limits for radionuclides listed in Table II of 902 *KAR* 100:019 § 44 (7)(a).

D.4.5 WASTE MANAGEMENT

All primary waste (i.e., groundwater and contaminated soils) and secondary waste (i.e., contaminated personal protective equipment and decontamination wastewaters) generated during remedial activities will be characterized as either Resource Conservation and Recovery Act (RCRA) wastes (solid or hazardous), Toxic Substances Control Act (TSCA) waste, low-level radioactive waste(s), and/or mixed waste(s), as appropriate, and each must be managed in accordance with appropriate RCRA, TSCA, or DOE Order/Manual requirements. Wastes managed on-site must comply with the substantive requirements of the aforementioned ARARs.

D.4.6 TRANSPORTATION

Any remediation waste transferred off-site or transported in commerce along public rights-of-way must be conducted in compliance with all applicable laws and regulations. These transportation requirements include provisions for proper packaging, labeling, marking, manifesting, recordkeeping, licensing, and placarding that must be fully complied with for shipment. Before shipment of CERCLA wastes to any off-site facility, DOE must ensure the acceptance of the receiving site under the CERCLA Off-site Rule (40 *CFR* § 300.440 *et seq.*).

Table D.1. Location-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 Feasibility Study

Location-specific ARARs					
Location	**Requirement**	**Prerequisite**	**Citation**	**SWMU 5**	**SWMU 6**
Wetlands					
Presence of wetlands as defined in 10 *CFR* § 1022.4	Avoid, to the extent possible, the long- and short-term adverse effects associated with destruction, occupancy, and modification of wetlands.	DOE actions that involve potential impacts to, or take place within, wetlands—**applicable**.	10 *CFR* § 1022.3(a)	✓	✓
	Take action, to extent practicable, to minimize destruction, loss, or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands.		10 *CFR* § 1022.3(a) (7) and (8)	✓	✓
	Undertake a careful evaluation of the potential effects of any new construction in wetlands. Identify, evaluate, and, as appropriate, implement alternative actions that may avoid or mitigate adverse impacts on wetlands.		10 *CFR* § 1022.3(b) and (d)	✓	✓
	Measures that mitigate the adverse effects of actions in a wetland including, but not limited to, minimum grading requirements, runoff controls, design and construction constraints, and protection of ecologically-sensitive areas.		10 *CFR* § 1022.13(a) (3)	✓	✓
	If no practicable alternative to locating or conducting the action in the wetland is available, then before taking action design or modify the action in order to minimize potential harm to or within the wetland, consistent with the policies set forth in E.O. 11990.		10 *CFR* § 1022.14(a)	✓	✓
Location encompassing aquatic ecosystem as defined in 40 *CFR* § 230.3(c)	Except as provided under Section 404(b)(2), no discharge of dredged or fill material is permitted if there is a practicable alternative that would have less adverse impact on the aquatic ecosystem or if it will cause or contribute to significant degradation of the waters of the United States.	Action that involves the discharge of dredged or fill material into waters of the United States, including jurisdictional wetlands—**relevant and appropriate**.	40 *CFR* § 230.10(a) and (c)	✓	✓
	Except as provided under Section 404(b)(2), no discharge of dredged or fill material shall be permitted unless appropriate and practicable steps have been taken that will minimize potential adverse impacts of the discharge on the aquatic ecosystem; 40 *CFR* § 230.70 *et seq.* identifies such possible steps.		40 *CFR* § 230.10(d)	✓	✓
Nationwide Permit Program	Must comply with the substantive requirements of the NWP 38, General Conditions, as appropriate.	Discharge of dredged or fill material into waters of the United States, including jurisdictional wetlands—**relevant and appropriate**.	NWP 38, *Cleanup of Hazardous and Toxic Waste,* 33 *CFR* § 323.3(b)	✓	✓

CFR = *Code of Federal Regulations*
DOE = U.S. Department of Energy
E.O. = Executive Order
NWP = Nationwide Permit

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 Feasibility Study

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Activities causing fugitive dust emissions	No person shall cause, suffer, or allow any material to be handled, processed, transported, or stored; a building or its appurtenances to be constructed, altered, repaired, or demolished, or a road to be used without taking reasonable precaution to prevent particulate matter from becoming airborne. Such reasonable precautions shall include, when applicable, but not be limited to the following: • Use, where possible, of water or chemicals for control of dust in the demolition of existing buildings or structures, construction operations, the grading of roads or the clearing of land; • Application and maintenance of asphalt, oil, water, or suitable chemicals on roads, materials stockpiles, and other surfaces which can create airborne dusts; • Covering, at all times when in motion, open bodied trucks transporting materials likely to become airborne; • The maintenance of paved roadways in a clean condition; and • The prompt removal of earth or other material from a paved street which earth or other material has been transported thereto by trucking or earth moving equipment or erosion by water.	Fugitive emissions from land-disturbing activities (e.g., handling, processing, transporting, or storing of any material, demolition of structures, construction operations, grading of roads, or the clearing of land, etc.)—**applicable**.	401 *KAR* 63:010 § 3(1) and (1)(a), (b), (d), (e), and (f)	✓	✓
	No person shall cause or permit the discharge of visible fugitive dust emissions beyond the lot line of the property on which the emissions originate.		401 *KAR* 63:010 § 3(2)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Activities causing storm-water runoff (e.g., clearing, grading, excavation)	Implement good construction techniques to control pollutants in storm-water discharges during and after construction in accordance with substantive requirements provided by permits issued pursuant to 40 *CFR* § 122.26(c).	Storm water discharges associated with small construction activities as defined in 40 *CFR* § 122.26(b)(15) and 401 *KAR* 5:002 § 1 (157)—**applicable**.	40 *CFR* § 122.26(c)(1)(ii)(C) and (D) 401 *KAR* 5:060 § 8	✓	✓
	Storm water runoff associated with construction activities taking place at a facility with an existing Best Management Practices (BMP) Plan shall be addressed under the facility BMP and not under a storm water general permit.	Storm water discharges associated with small construction activities as defined in 40 *CFR* § 122.26(b)(15) and 401 *KAR* 5:002 § 1 (157)—**TBC**.	Fact Sheet for the KPDES General Permit For Storm water Discharges Associated with Construction Activities, June 2009	✓	✓
	Best management storm water controls will be implemented and may include, as appropriate, erosion and sedimentation control measures, structural practices (e.g., silt fences, straw bale barriers) and vegetative practices (e.g., seeding); storm water management (e.g., diversion); and maintenance of control measures in order to ensure compliance with the standards in Section C.5. Storm Water Discharge Quality.	Storm water runoff associated with construction activities taking place at a facility (PGDP) with an existing BMP Plan—**TBC**.	Appendix C of the PGDP BMP Plan (2007)—Examples of Storm water Controls	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Activities causing radionuclide emissions	Emissions of radionuclides to the ambient air from DOE facilities shall not exceed those amounts that would cause any member of the public to receive in any year an EDE of 10 mrem/yr.	Radionuclide emissions at a DOE facility—**applicable**.	40 *CFR* § 61.92 401 *KAR* 57:002	✓	✓
Activities causing toxic substances or potentially hazardous matter emissions	Persons responsible for a source from which hazardous matter or toxic substances may be emitted shall provide the utmost care and consideration in the handling of these materials to the potentially harmful effects of the emissions resulting from such activities. Shall not allow any affected facility to emit potentially hazardous matter or toxic substances in such quantities or duration as to be harmful to the health and welfare of humans, animals and plants.	Emissions of potentially hazardous matter or toxic substances as defined in 401 *KAR* 63:020 § 2 (2)—**applicable**.	401 *KAR* 63:020 § 3	✓	✓
Monitoring well installation	Permanent monitoring wells shall be constructed, modified, and abandoned in such a manner as to prevent the introduction or migration of contamination to a water-bearing zone or aquifer through the casing, drill hole, or annular materials.	Construction of monitoring well as defined in 401 *KAR* 6:001 § 1(18) for remedial action—**applicable**.	401 *KAR* 6:350 § 1(2)	✓	
Monitoring well installation	All permanent monitoring wells (including boreholes) shall be constructed to comply with the substantive requirements provided in the following Sections of 401 *KAR* 6:350: • Section 2. Design Factors; • Section 3. Monitoring Well Construction; • Section 7. Materials for Monitoring Wells; and • Section 8. Surface Completion.		401 *KAR* 6:350 § 2, 3, 7, and 8	✓	

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	If conditions exist or are believed to exist that preclude compliance with the requirements of 401 *KAR* 6:350, may request a variance prior to well construction or well abandonment. **NOTE:** Variance shall be made as part of the FFA CERCLA document review and approval process and shall include: • A justification for the variance; and • Proposed construction, modification, or abandonment procedures to be used in lieu of compliance with 401 *KAR* 6:350 and an explanation as to how the alternate well construction procedures ensure the protection of the quality of the groundwater and the protection of public health and safety.		401 *KAR* 6:350 § 6 (a)(6) and (7)	✓	
Development of monitoring well	Newly installed wells shall be developed until the column of water in the well is free of visible sediment. This well-development protocol shall not be used as a method for purging prior to water quality sampling.	Construction of monitoring well as defined in 401 *KAR* 6:001 § 1(18) for remedial action—**applicable**.	401 *KAR* 6:350 § 9	✓	
Direct Push monitoring well installation	Wells installed using direct push technology shall be constructed, modified, and abandoned in such a manner as to prevent the introduction or migration of contamination to a water-bearing zone or aquifer through the casing, drill hole, or annular materials.	Construction of direct push monitoring well as defined in 401 *KAR* 6:001 § 1(18) for remedial action—**applicable**.	401 *KAR* 6:350 § 5 (1)	✓	

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	Shall also comply with the following additional standards: (a) The outside diameter of the borehole shall be a minimum of 1 inch greater than the outside diameter of the well casing; (b) Premixed bentonite slurry or bentonite chips with a minimum of one-eighth (1/8) diameter shall be used in the sealed interval below the static water level; and (c) 1. Direct push wells shall not be constructed through more than one water-bearing formation unless the upper water bearing zone is isolated by temporary or permanent casing. 2. The direct push tool string may serve as the temporary casing.		401 *KAR* 6:350 § 5 (3)	✓	
Monitoring well abandonment	A monitoring well that has been damaged or is otherwise unsuitable for use as a monitoring well, shall be abandoned within 30 days from the last sampling date or 30 days from the date it is determined that the well is no longer suitable for its intended use.	Construction of monitoring well as defined in 401 *KAR* 6:001 § 1(18) for remedial action—**applicable**.	401 *KAR* 6:350 § 11 (1)	✓	
	Wells shall be abandoned in such a manner as to prevent the migration of surface water or contaminants to the subsurface and to prevent migration of contaminants among water bearing zones.		401 *KAR* 6:350 § 11 (1)(a)	✓	

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	Abandonment methods and sealing materials for all types of monitoring wells provided in subparagraphs (a)-(b) and (d)-(e) shall be followed.		401 *KAR* 6:350 § 11 (2)	✓	
Installation of an industrial solid waste landfill cover system	At a minimum, the final cap shall consist of a layered system. Each layer shall have the same slope of between 5 and 25 percent. The components, listed from bottom to top, are these: (1) A filter fabric or other material approved by the cabinet; (2) A 12-inch sand gas venting system with a minimum hydraulic permeability of 1 x 10^{-3}; (3) A filter fabric or other material approved by the cabinet; (4) An 18-inch clay layer with a maximum permeability of 1 x 10^{-7} centimeters per second; (5) For areas of the final cap with a slope of less than 15 percent, a 12-inch drainage layer with a minimum permeability of 1 x 10^{-3} centimeters per second; and (6) A 36-inch vegetative soil layer. Specifications for these required layers are provided in 401 *KAR* 48:080 § 9.	Closure of a contained landfill unit under 401 *KAR* 48:070 Section 15, including installation of final cap system —**relevant and appropriate**.	401 *KAR* 48:080 § 8 401 *KAR* 48:080 § 9	✓	
	A synthetic liner with a minimum thickness of forty (40) mils and a maximum coefficient of permeability of 1 x 10^{-12} centimeters per second may be substituted for the low-permeability soil cover.		401 *KAR* 48:080 § 9(5)	✓	
	Alternative specifications may be used that result in performance with regard to safety, stability, and environmental protection		401 *KAR* 48:080 § 11	✓	

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	equal to or better than that resulting from designs complying with the specifications of this administrative regulation. **NOTE:** Approval to use alternate specifications under 401 *KAR* 48:080, Section 11 will be obtained in an FFA CERCLA document (e.g., Remedial Design).				
Installation of a LLW near-surface disposal unit cover system	Covers shall be designed to minimize water infiltration, to direct percolating water or surface water away from the disposed waste, and to resist degradation by surface geologic processes and biotic activity.	Closure of a LLW near-surface disposal unit—**relevant and appropriate**.	902 *KAR* § 100:022 Section 23(4) 10 CFR § 61.51(a)(4)	✓	
	Surface features shall direct surface water drainage away from the disposal units at velocities and gradients that shall not result in erosion that shall require ongoing active maintenance in the future.		902 *KAR* § 100:022 Section 23(5) 10 CFR § 61.51(a)(5)	✓	
	Stability of the Disposal Site After Closure. The disposal facility shall be sited, designed, used, operated, and closed to achieve long-term stability of the disposal site and to eliminate to the extent practicable the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring, or minor custodial care are required. **NOTE:** For purposes of this remedy only, that portion of the regulation that is relevant and appropriate is as follows: "shall be closed to eliminate to the extent practicable		902 *KAR* 100:022 § 21	✓	

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring, or minor custodial care are required.”				
Marking boundaries of closed LLW near surface disposal unit	The boundaries and locations of each disposal unit shall be accurately located and mapped by means of a land survey. Near-surface disposal units shall be marked in a way that the boundaries of each unit can be easily defined. Three (3) permanent survey marker control points, referenced to United States Geological Survey (USGS) or National Geodetic Survey (NGS) survey control stations, shall be established on the site to facilitate surveys. The USGS or NGS control stations shall provide horizontal and vertical controls as checked against USGS or NGS record files. **NOTE:** For purpose of implementation of these ARARs the “disposal unit” is defined by the boundary of the cap.		902 *KAR* 100:022 § 24 (7) – (10)	✓	
Maintenance of a solid waste landfill cover	The operator of a contained solid waste landfill shall close each landfill unit and phase in a manner that minimizes the need for further maintenance and minimizes the closure care formation and release of leachate to the groundwater, or surface water to the extent necessary to protect human health and the environment.	Closure of a contained landfill unit under 401 *KAR* 48:070 Section 15, including installation of final cap system—**relevant and appropriate**.	401 *KAR* 48:070 § 15(1)	✓	
	The owner or operator of a contained solid waste landfill shall: • Maintain the site as necessary to prevent erosion or washing of the fill, and grade as necessary to drain rainwater from the		401 *KAR* 48:090 § 7(1)	✓	

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	fill area and to prevent standing water.				
	• Maintain the integrity and effectiveness of any final cap, including making repairs to the cap as necessary to correct the effects of settling, subsidence, erosion, or other events, and preventing run on and runoff from eroding or otherwise damaging the final cap. • Closure care use of the property shall not be allowed to disturb the integrity of the final cap, or any other components of the containment system, unless the activities shall not increase the potential threat to human health or the environment or the disturbance is necessary to reduce a threat to human health or the environment.		401 *KAR* 48:090 § 13(1)(a)(1) 401 *KAR* 48:090 § 13(2)(c)	✓	
Management of PCB waste	Any person storing or disposing of PCB waste must do so in accordance with 40 *CFR* § 761, Subpart D.	Storage or disposal of waste containing PCBs at concentrations ≥ 50 ppm—**applicable**.	40 *CFR* § 761.50(a)	✓	✓
Management of PCB remediation waste	Any person cleaning up and disposing of PCBs shall do so based on the concentration at which the PCBs are found.	Cleanup and disposal of PCB remediation waste as defined in 40 *CFR* § 761.3—**applicable**.	40 *CFR* § 761.61	✓	✓
Management of PCB/Radioactive waste	Any person storing such waste must do so taking into account both its PCB concentration and radioactive properties, except as provided in 40 *CFR* § 761.65(a)(1), (b)(1)(ii) and (c)(6)(i).	Generation of PCB/radioactive waste with ≥ 50 ppm PCBs for storage—**applicable**.	40 *CFR* § 761.50(b)(7)(i)	✓	✓
	Any person disposing of such waste must do so taking into account both its PCB concentration and its radioactive properties. If, taking into account only the PCB		40 *CFR* § 761.50(b)(7)(ii)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	properties in the waste (and not the radioactive properties of the waste), the waste meets the requirements for disposal in a facility permitted, licensed, or registered by a state as a municipal or nonmunicipal nonhazardous waste landfill [e.g., PCB bulk-product waste under 40 *CFR* § 761.62(b)(1)], then the person may dispose of PCB/radioactive waste, without regard to the PCBs, based on its radioactive properties in accordance with applicable requirements for the radioactive component of the waste.				
Characterization of solid waste	Must determine if solid waste is excluded from regulation under 40 *CFR* § 261.4.	Generation of solid waste as defined in 40 *CFR* § 261.2—**applicable**.	40 *CFR* § 262.11(a) 401 *KAR* 32:010 § 2	✓	✓
	Must determine if waste is listed as a hazardous waste in Subpart D of 40 *CFR* Part 261.	Generation of solid waste which is not excluded under 40 *CFR* § 261.4—**applicable**.	40 *CFR* § 262.11(b) 401 *KAR* 32:010 § 2	✓	✓
	Must determine whether the waste is characteristic waste (identified in Subpart C of 40 *CFR* Part 261) by using prescribed testing methods or applying generator knowledge based on information regarding material or processes used.	Generation of solid waste that is not listed in Subpart D of 40 *CFR* Part 261 and not excluded under 40 *CFR* § 261.4—**applicable**.	40 *CFR* § 262.11(c) 401 *KAR* 32:010 § 2	✓	✓
	Must refer to Parts 261, 262, 264, 265, 266, 268, and 273 of Chapter 40 for possible exclusions or restrictions pertaining to management of the specific waste.	Generation of solid waste which is determined to be hazardous waste—**applicable**.	40 *CFR* § 262.11(d) 401 *KAR* 32:010 § 2	✓	✓
Characterization of hazardous waste	Must obtain a detailed chemical and physical analysis on a representative sample of the waste(s), which at a minimum	Generation of RCRA-hazardous waste for storage, treatment or disposal—	40 *CFR* § 264.13(a)(1)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	contains all the information that must be known to treat, store, or dispose of the waste in accordance with pertinent sections of 40 *CFR* §§ 264 and 268.	**applicable**.	401 *KAR* 34:020 § 4		
Characterization of industrial wastewater	Industrial wastewater discharges that are point source discharges subject to regulation under § 402 of the Clean Water Act, as amended, are not solid wastes for the purpose of hazardous waste management. (Comment: This exclusion applies only to the actual point source discharge. It does not exclude industrial wastewaters while they are being collected, stored, or treated before discharge, nor does it exclude sludges that are generated by industrial wastewater treatment.) **NOTE:** For purpose of this exclusion, the CERCLA on-site treatment system for groundwater will be considered equivalent to a wastewater treatment unit and the point source discharges subject to regulation under CWA § 402, provided the effluent meets all identified CWA ARARs.	Generation of industrial wastewater and discharge into surface water—**applicable**.	40 *CFR* § 261.4(a)(2) 401 *KAR* 31:010 § 4	✓	✓
Determinations for management of hazardous waste	Must determine each EPA Hazardous Waste Number (Waste Code) to determine the applicable treatment standards under 40 *CFR* § 268.40 *et seq*. **NOTE:** This determination may be made concurrently with the hazardous waste determination required in 40 *CFR* § 262.11.	Generation of hazardous waste—**applicable**.	40 *CFR* § 268.9(a) 401 *KAR* 37:010 § 8	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	Must determine the underlying hazardous constituents [as defined in 40 *CFR* § 268.2(i)] in the characteristic waste.	Generation of RCRA characteristic hazardous waste (and is not D001 non-wastewaters treated by CMBST, RORGS, or POLYM of Section 268.42 Table 1) for storage, treatment, or disposal—**applicable**.	40 *CFR* § 268.9(a) 401 *KAR* 37:010 § 8	✓	✓
	Must determine if the hazardous waste meets the treatment standards in 40 *CFR* §§ 268.40, 268.45, or 268.49 by testing in accordance with prescribed methods or use of generator knowledge of waste. **NOTE:** This determination can be made concurrently with the hazardous waste determination required in 40 *CFR* § 262.11.	Generation of hazardous waste—**applicable**.	40 *CFR* § 268.7(a) 401 *KAR* 37:020 § 7	✓	✓
Characterization of LLW	Shall be characterized using direct or indirect methods and the characterization documented in sufficient detail to ensure safe management and compliance with the WAC of the receiving facility.	Generation of LLW for storage and disposal at a DOE facility—**TBC**.	DOE M 435.1-1(IV)(I)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	Characterization data shall, at a minimum, include the following information relevant to the management of the waste: • Physical and chemical characteristics; • Volume, including the waste and any stabilization or absorbent media; • Weight of the container and contents; • Identities, activities, and concentration of major radionuclides; • Characterization date; • Generating source; and • Any other information that may be needed to prepare and maintain the disposal facility performance assessment, or demonstrate compliance with performance objectives.		DOE M 435.1-1(IV)(I)(2)	✓	✓
Temporary on-site storage of hazardous waste in containers	A generator may accumulate hazardous waste at the facility provided that	Accumulation of RCRA hazardous waste on-site as defined in 40 *CFR* § 260.10—**applicable**.	40 *CFR* § 262.34(a) 401 *KAR* 32:030 § 5	✓	✓
	• Waste is placed in containers that comply with 40 *CFR* § 265.171-173;		40 *CFR* § 262.34(a)(1)(i) 401 *KAR* 32:030 § 5	✓	✓
	• The date upon which accumulation begins is clearly marked and visible for inspection on each container; and		40 *CFR* § 262.34(a)(2) 401 *KAR* 32:030 § 5	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	• Container is marked with the words "hazardous waste."		40 *CFR* § 262.34(a)(3) 401 *KAR* 32:030 § 5	✓	✓
	Container may be marked with other words that identify the contents.	Accumulation of 55 gal or less of RCRA hazardous waste or one quart of acutely hazardous waste listed in 261.33(e) at or near any point of generation—**applicable**.	40 *CFR* § 262.34(c)(1) 401 *KAR* 32:030 § 5	✓	✓
Use and management of containers holding hazardous waste	If container is not in good condition or if it begins to leak, must transfer waste into container in good condition.	Storage of RCRA hazardous waste in containers—**applicable**.	40 *CFR* § 265.171 401 *KAR* 35:180 § 2	✓	✓
	Use container made or lined with materials compatible with waste to be stored so that the ability of the container is not impaired.		40 *CFR* § 265.172 401 *KAR* 35:180 § 3	✓	✓
	Keep containers closed during storage, except to add/remove waste.		40 *CFR* § 265.173(a) 401 *KAR* 35:180 § 4	✓	✓
	Open, handle and store containers in a manner that will not cause containers to rupture or leak.		40 *CFR* § 265.173(b) 401 *KAR* 35:180 § 4	✓	✓
Storage of hazardous waste in container area	Area must have a containment system designed and operated in accordance with 40 *CFR* § 264.175(b).	Storage of RCRA hazardous waste in containers with free liquids—**applicable**.	40 *CFR* § 264.175(a) 401 *KAR* 34:180 § 6	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	Area must be sloped or otherwise designed and operated to drain liquid from precipitation, or Containers must be elevated or otherwise protected from contact with accumulated liquid.	Storage of RCRA hazardous waste in containers that do not contain free liquids (other than F020, F021, F022, F023,F026 and F027)—**applicable**.	40 *CFR* § 264.175(c) 401 *KAR* 34:180 § 6	✓	✓
Temporary tanks and container storage areas used to treat or store hazardous remediation wastes	EPA may replace the design, operating, or closure standards with alternate requirements that protect human health and the environment. **NOTE:** EPA approval of design, operating, or closure requirements for a temporary unit will be obtained by approval of a FFA CERCLA document.	Generation of RCRA remediation waste during remedial activities that require treatment or storage where they are located within the facility boundary and used only for treatment or storage of remediation wastes—**applicable**.	40 *CFR* § 264.553(a) and (b) 401 *KAR* 34:287	✓	✓
	Any temporary unit to which alternative requirements are applied in accordance with paragraph (a) of this section shall be: (1) Located within the facility boundary; and (2) Used only for treatment or storage of remediation wastes.		40 *CFR* § 264.553(b) 401 *KAR* 34:287	✓	✓
	In establishing standards to be applied to a temporary unit, the following factors shall be considered: • Length of time such unit will be in operation; • Type of unit; • Volumes of wastes to be managed; • Physical and chemical characteristics of the wastes to be managed in the unit;		40 *CFR* § 264.553(c) 401 *KAR* 34:287	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	• Potential for releases from the unit; • Hydrogeological and other relevant environmental conditions at the facility which may influence the migration of any potential releases; and • Potential for exposure of humans and environmental receptors if releases were to occur from the unit.				
Temporary on-site storage of remediation waste in staging piles (e.g., excavated soils/sediments, sludge)	May be temporarily stored (including mixing, sizing, blending, or other similar physical operations intended to prepare the wastes for subsequent management or treatment) at a facility if used only during remedial operations provided that the staging pile will be designed to	Accumulation of non-flowing hazardous remediation waste in staging pile (or remediation waste otherwise subject to land disposal restrictions)—**applicable**.	40 *CFR* § 264.554(a)(1) 401 *KAR* 34:287 § 5		✓
	• Facilitate a reliable, effective, and protective remedy;		40 *CFR* § 264.554(d)(1)(i) 401 *KAR* 34:287 § 5		✓
	• Prevent or minimize releases of hazardous wastes and constituents into the environment, and minimize or adequately control cross-media transfer as necessary to protect human health and the environment (e.g., use of liners, covers, runoff/run on controls, as appropriate).		40 *CFR* § 264.554(d)(1)(ii) 401 *KAR* 34:287 § 5		✓
	Must not place ignitable or reactive remediation waste in a staging pile unless the remediation waste has been treated, rendered, or mixed before placed in the staging pile so that	Storage of ignitable or reactive remediation waste in staging piles in—**applicable**.	40 *CFR* § 264.554(e) 401 *KAR* 34:287 § 5		✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	• The remediation waste no longer meets the definition of ignitable or reactive under 401 *KAR* 31:030 § 2 and § 4; and		40 *CFR* § 264.554(e)(1)(i) 401 *KAR* 34:287 § 5		✓
	• You have complied with 401 *KAR* 34:020 § 8, General Requirements for Ignitable, Reactive, or Incompatible Wastes.		40 *CFR* § 264.554(e)(1)(ii) 401 *KAR* 34:287 § 5		✓
	• Alternatively, instead of meeting the above requirements in 40 *CFR* 264.554(e)(1), the remediation waste may be managed to protect it from exposure to any material or condition that may cause it to ignite or react.		40 *CFR* § 264.554(e)(2) 401 *KAR* 34:287 § 5		✓
	Must not place in the same staging pile unless you have complied with 40 *CFR* § 264.17(b).	Storage of incompatible remediation waste in staging piles in—**applicable**.	40 *CFR* § 264.554(f)(1) 401 *KAR* 34:287 § 5		✓
	Must separate the incompatible materials or protect them from one another by using a dike, berm, wall, or other device.		40 *CFR* § 264.554(f)(2) 401 *KAR* 34:287 § 5		✓
	Must not pile remediation waste on the same base where incompatible wastes or materials were previously piled, unless the base has been decontaminated sufficiently to comply with 40 *CFR* § 264.17(b).		40 *CFR* § 264.554(f)(3) 401 *KAR* 34:287 § 5		✓
Storage of PCB waste and/or PCB/radioactive	Does not have to meet storage unit requirements in 40 *CFR* § 761.65(b)(1) provided the unit.	Storage of PCBs and PCB Items at concentrations ≥ 50 ppm designated for	40 *CFR* § 761.65(b)(2)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
waste in a RCRA-regulated container storage area		disposal—**applicable**.			
	• Is permitted by EPA under RCRA § 3004 to manage hazardous waste in containers and spills of PCBs cleaned up in accordance with Subpart G of 40 *CFR* § 761; or		40 *CFR* § 761.65(b)(2)(i)	✓	✓
	• Qualifies for interim status under RCRA § 3005 to manage hazardous waste in containers and spills of PCBs cleaned up in accordance with Subpart G of 40 *CFR* § 761; or		40 *CFR* § 761.65(b)(2)(ii)	✓	✓
	• Is permitted by an authorized state under RCRA § 3006 to manage hazardous waste in containers and spills of PCBs cleaned up in accordance with Subpart G of 40 *CFR* § 761.		40 *CFR* § 761.65(b)(2)(iii)	✓	✓
	NOTE: For purpose of this exclusion, CERCLA remediation waste, which is also considered PCB waste, can be stored on-site provided the area meets all of the identified RCRA container storage ARARs and spills of PCBs cleaned up in accordance with Subpart G of 40 *CFR* § 761.			✓	✓
Storage of PCB waste and/or PCB/radioactive waste in non-RCRA regulated unit	Except as provided in 40 *CFR* §§ 761.65 (b)(2), (c)(1), (c)(7), (c)(9), and (c)(10), after July 1, 1978, owners or operators of any facilities used for the storage of PCBs and PCB Items designated for disposal shall comply with the storage unit requirements in 40 *CFR* § 761.65(b)(1).	Storage of PCBs and PCB Items at concentrations ≥ 50 ppm designated for disposal—**applicable**.	40 *CFR* § 761.65(b)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	Storage facility shall meet the following criteria: • Adequate roof and walls to prevent rainwater from reaching stored PCBs and PCB items;		40 *CFR* § 761.65(b)(1) 40 *CFR* § 761.65(b)(1)(i)	✓	✓
	• Adequate floor that has continuous curbing with a minimum 6-inch high curb. Floor and curb must provide a containment volume equal to at least two times the internal volume of the largest PCB article or container or 25 percent of the internal volume of all articles or containers stored there, whichever is greater. **NOTE**: 6 inch minimum curbing not required for area storing PCB/radioactive waste;		40 *CFR* § 761.65(b)(1)(ii)	✓	✓
	• No drain valves, floor drains, expansion joints, sewer lines, or other openings that would permit liquids to flow from curbed area;		40 *CFR* § 761.65(b)(1)(iii)	✓	✓
	• Floors and curbing constructed of Portland cement, concrete, or a continuous, smooth, non-porous surface that prevents or minimizes penetration of PCBs; and		40 *CFR* § 761.65(b)(1)(iv)	✓	✓
	• Not located at a site that is below the 100-year flood water elevation.		40 *CFR* § 761.65(b)(1)(v)	✓	✓
	Storage area must be properly marked as required by 40 *CFR* § 761.40(a)(10).		40 *CFR* § 761.65(c)(3)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Risk-based storage of PCB remediation waste	May store PCB remediation waste in a manner other than prescribed in 40 *CFR* § 761.65(b) if approved in writing from EPA provided the method will not pose an unreasonable risk of injury to human health or the environment. **NOTE:** EPA approval of alternative storage method will be obtained by approval of the FFA CERCLA document.	Storage of waste containing PCBs in a manner other than prescribed in 40 *CFR* § 761.65(b) (see above) —**applicable**.	40 *CFR* § 761.61(c)	✓	✓
Temporary storage of PCB waste (e.g., PPE, rags) in a container(s)	Container(s) shall be marked as illustrated in 40 *CFR* § 761.45(a).	Storage of PCBs and PCB items at concentrations ≥ 50 ppm in containers for disposal—**applicable**.	40 *CFR* § 761.40(a)(1)	✓	✓
	Storage area must be properly marked as required by 40 *CFR* § 761.40(a)(10).		40 *CFR* § 761.65(c)(3)	✓	✓
	Any leaking PCB Items and their contents shall be transferred immediately to a properly marked nonleaking container(s).		40 *CFR* § 761.65(c)(5)		✓
	Container(s) shall be in accordance with requirements set forth in DOT HMR at 49 *CFR* §§ 171-180.		40 *CFR* § 761.65(c)(6)	✓	✓
Storage of PCB/radioactive waste in containers	For liquid wastes, containers must be nonleaking.	Storage of PCB/radioactive waste in containers other than those meeting DOT HMR performance standards —**applicable**.	40 *CFR* § 761.65(c)(6) (i)(A)	✓	✓
	For nonliquid wastes, containers must be designed to prevent buildup of liquids if such containers are stored in an area meeting the containment requirements of 40 *CFR* § 761.65(b)(1)(ii).		40 *CFR* § 761.65(c)(6) (i)(B)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	For both liquid and nonliquid wastes, containers must meet all substantive requirements pertaining to nuclear criticality safety. Acceptable container materials include polyethylene and stainless steel provided that the container material is chemically compatible with the waste being stored. Other containers may be used if the use of such containers is protective of health and the environment as well as public health and safety.		40 *CFR* § 761.65(c)(6) (i)(C)	✓	✓
Temporary storage of bulk PCB remediation waste or PCB bulk product waste in a waste pile	May be stored at the clean-up site or site of generation subject to the following conditions: • Waste must be placed in a pile designed and operated to control dispersal by wind, where necessary, by means other than wetting; and • Waste must not generate leachate through decomposition or other reactions.	Storage of PCB remediation waste or PCB bulk product waste in a waste pile—**applicable**.	40 *CFR* § 761.65(c)(9) (i) 40 *CFR* § 761.65(c)(9) (ii)		✓
	Storage site must have a liner designed, constructed, and installed to prevent any migration of wastes off or through liner into adjacent subsurface soil, groundwater or surface water at any time during the active life (including closure period) of the storage site.		40 *CFR* § 761.65(c)(9) (iii)(A)		✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	Liner must be: • Constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure because of pressure gradients, physical contact with waste or leachate to which they are exposed, climatic conditions, the stress of installation, and the stress of daily operation;		40 *CFR* § 761.65(c)(9) (iii)(A)(*1*)		✓
	• Placed on foundation or base capable of providing support to liner and resistance to pressure gradients above and below the liner to present failure because of settlement compression or uplift; and		40 *CFR* § 761.65(c)(9) (iii)(A)(*2*)		✓
	• Installed to cover all surrounding earth likely to be in contact with waste.		40 *CFR* § 761.65(c)(9) (iii)(A)(*3*)		✓
	Has a cover that meets the above requirements and installed to cover all of the stored waste likely to be contacted by precipitation, and is secured so as not to be functionally disabled by winds expected under normal weather conditions at the storage site; and	Storage of PCB remediation waste or PCB bulk product waste in a waste pile—**applicable**.	40 *CFR* § 761.65(c)(9) (iii)(B)		✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	Has a run on control system designed, constructed, operated and maintained such that: • It prevents flow on the stored waste during peak discharge from at least a 25-year storm; and • It collects and controls at least the water volume resulting from a 24-hour, 25-year storm. Collection and holding facilities (e.g., tanks or basins) must be emptied or otherwise managed expeditiously after storms to maintain design capacity of the system.		40 *CFR* § 761.65(c)(9)(iii)(C) 40 *CFR* § 761.65(c)(9)(iii)(C)(*1*) 40 *CFR* § 761.65(c)(9)(iii)(C)(*2*)		✓
	Requirements of 40 *CFR* § 761.65(c)(9) may be modified under the risk-based disposal option of 40 *CFR* § 761.61(c).		40 *CFR* § 761.65(c)(9)(iv)		✓
Staging of LLW	Shall be for the purpose of the accumulation of such quantities of wastes necessary to facilitate transportation, treatment, and disposal.	Staging of LLW at a DOE facility—**TBC**.	DOE M 435.1-1 (IV)(N)(7)	✓	✓
Temporary storage of LLW	Shall not be readily capable of detonation, explosive decomposition, reaction at anticipated pressures and temperatures, or explosive reaction with water.	Temporary storage of LLW at a DOE facility—**TBC**.	DOE M 435.1-1 (IV)(N)(1)	✓	✓
	Shall be stored in a location and manner that protects the integrity of waste for the expected time of storage.		DOE M 435.1-1 (IV)(N)(3)	✓	✓
	Shall be managed to identify and segregate LLW from mixed waste.		DOE M 435.1-1 (IV)(N)(6)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Packaging of LLW for storage	Shall be packaged in a manner that provides containment and protection for the duration of the anticipated storage period and until disposal is achieved or until the waste has been removed from the container.	Storage of LLW in containers at a DOE facility—**TBC**.	DOE M 435.1-1(IV)(L)(1)(a)	✓	✓
	Vents or other measures shall be provided if the potential exists for pressurizing or generating flammable or explosive concentrations of gases within the waste container.		DOE M 435.1-1(IV)(L)(1)(b)	✓	✓
	Containers shall be marked such that their contents can be identified.		DOE M 435.1-1(IV)(L)(1)(c)	✓	✓
Packaging of LLW for off-site disposal	Waste shall not be packaged for disposal in a cardboard or fiberboard box.	Packaging of LLW for off-site shipment of LLW to a commercial NRC or Agreement State licensed disposal facility—**relevant and appropriate**.	10 *CFR* § 61.56 902 *KAR* 100:021 § 7 (1)(b)	✓	✓
	Liquid waste shall be solidified or packaged in sufficient absorbent material to absorb twice the volume of the liquid.	Preparation of liquid LLW for off-site shipment of LLW to a commercial NRC or Agreement State licensed disposal facility—**relevant and appropriate**.	10 *CFR* § 61.56 902 *KAR* 100:021 § 7 (1)(c)	✓	✓
	Solid waste containing liquid shall contain as little freestanding and noncorrosive liquid as is reasonably achievable. The liquid shall not exceed one (1) percent of the volume.	Preparation of solid LLW containing liquid for off-site shipment of LLW to a commercial NRC or Agreement State licensed disposal facility—**relevant and appropriate**.	10 *CFR* § 61.56 902 *KAR* 100:021 § 7 (1)(d)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	Waste shall not be readily capable of • Detonation; • Explosive decomposition or reaction at normal pressures and temperatures; or • Explosive reaction with water.	Packaging of LLW for off-site shipment of LLW to a commercial NRC or Agreement State licensed disposal facility—**relevant and appropriate**.	10 *CFR* § 61.56 902 *KAR* 100:021 § 7 (1)(e)	✓	✓
	Waste shall not contain, or be capable of generating, quantities of toxic gases, vapors, or fumes harmful to a person transporting, handling, or disposing of the waste.	Packaging of LLW for off-site shipment of LLW to a commercial NRC or Agreement State licensed disposal facility—**relevant and appropriate**.	10 *CFR* § 61.56 902 *KAR* 100:021 § 7 (1)(f)	✓	✓
	Waste shall not be pyrophoric.	Packaging of pyrophoric LLW for off-site shipment of LLW to a commercial NRC or Agreement State licensed disposal facility—**relevant and appropriate**.	10 *CFR* § 61.56 902 *KAR* 100:021 § 7 (1)(g)	✓	✓
	Notwithstanding the provisions in 10 *CFR* § 61.56(a) (2) and (3), liquid wastes, or wastes containing liquid, must be converted into a form that contains as little free standing and noncorrosive liquid as is reasonably achievable, but in no case shall the liquid exceed 1 percent of the volume of the waste when the waste is in a disposal container designed to ensure stability, or 0.5 percent of the volume of the waste for waste processed to a stable form.	Preparation of LLW for off-site disposal of the waste container at a commercial NRC or Agreement State licensed disposal facility—**relevant and appropriate**.	10 *CFR* § 61.56(b)(2)	✓	✓
	Void spaces within the waste and between the waste and its package shall be reduced to the extent practical.	Preparation of LLW for off-site disposal of the waste container at a commercial NRC or Agreement State licensed disposal facility—**relevant and appropriate.**	10 *CFR* § 61.56(b)(3)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Transport or conveyance of collected RCRA wastewater to a WWTU located on the facility	Any dedicated tank systems, conveyance systems, and ancillary equipment used to treat, store or convey wastewater to an on-site KPDES-permitted wastewater treatment facility are exempt from the requirements of RCRA Subtitle C standards. **NOTE:** For purposes of this exclusion, any dedicated tank systems, conveyance systems, and ancillary equipment used to treat, store or convey CERCLA remediation wastewater to a CERCLA on-site wastewater treatment unit that meets all of the identified CWA ARARs for point source discharges from such a facility, are exempt from the requirements of RCRA Subtitle C standards.	On-site wastewater treatment unit (as defined in 40 *CFR* § 260.10) subject to regulation under § 402 or § 307(b) of the CWA (i.e., KPDES-permitted) that manages hazardous wastewaters—**applicable**.	40 *CFR* § 264.1(g)(6) 401 *KAR* 34:010 § 1		✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Release of property with residual radioactive material to an off-site commercial facility	Residual Radioactive Material. Property potentially containing residual radioactive material must not be cleared from DOE control unless either: A. The property is demonstrated not to contain residual radioactive material based on process and historical knowledge, radiological monitoring or surveys, or a combination of these; or B. The property is evaluated and appropriately monitored or surveyed to determine: 1. The types and quantities of residual radioactive material within the property; 2. The quantities of removable and total residual radioactive material on property surfaces (including residual radioactive material present on and under any coating); 3. That for property with potentially contaminated surfaces that are difficult to access for radiological monitoring or surveys, an evaluation of residual radioactive material on such surfaces is performed which is: a. Based on process and historical knowledge meeting the requirements of paragraph 4.k.(5) of this Order and monitoring and or surveys, to the extent feasible and;	Generation of DOE materials and equipment with residual radioactive material—**TBC**.	DOE O 458.1 § 4.k(3)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	b. Sufficient to demonstrate that applicable specific or pre-approved DOE Authorized Limits will not be exceeded; and 4. That any residual radioactive material within or on the property is in compliance with applicable specific or pre-approved DOE Authorized Limits.				
Treatment of LLW	Treatment to provide more stable waste forms and to improve the long-term performance of a LLW disposal facility shall be implemented as necessary to meet the performance objectives of the disposal facility.	Treatment of LLW for disposal at a LLW disposal facility—**TBC**.	DOE M 435.1-1(IV)(O)	✓	✓
Treatment of RCRA hazardous waste soil	Prior to land disposal, all “constituents subject to treatment” as defined in 40 *CFR* § 268.49(d) must be treated as follows.	Treatment of restricted hazardous waste soils—**applicable**.	40 *CFR* § 268.49(c)(1) 401 *KAR* 37:040 § 10	✓	✓
	For non-metals (except carbon disulfide, cyclohexanone, and methanol), treatment must achieve a 90 percent reduction in total constituent concentrations, except as provided in 40 *CFR* § 268.49(c)(1)(C).		40 *CFR* § 268.49(c)(1)(A) 401 *KAR* 37:040 § 10	✓	✓
	For metals and carbon disulfide, cyclohexanone, and methanol), treatment must achieve a 90 percent reduction in total constituent concentrations as measured in leachate from the treated media (tested according to TCLP) <u>or</u> 90 percent reduction in total constituent concentrations (when a metal removal technology is used), except as provided in 40 *CFR* § 268.49(c)(1)(C).		40 *CFR* § 268.49(c)(1)(B) 401 *KAR* 37:040 § 10	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	When treatment of any constituent subject to treatment to a 90 percent reduction standard would result in a concentration less than 10 times the Universal Treatment Standard for that constituent, treatment to achieve constituent concentrations less than 10 times the universal treatment standard is not required. [Universal Treatment Standards (UTS) are identified in 40 *CFR* § 268.48 Table UTS].		40 *CFR* § 268.49(c)(1)(C) 401 *KAR* 37:040 § 10	✓	✓
	In addition to the treatment requirement required by paragraph (c)(1) of 40 *CFR* § 268.49, soils must be treated to eliminate these characteristics.	Treatment of soils that exhibit the hazardous characteristic of ignitability, corrosivity, or reactivity—**applicable**.	40 *CFR* § 268.49(c)(2) 401 *KAR* 37:040 § 10	✓	✓
Disposal of prohibited RCRA hazardous waste in a land-based unit	May be land disposed if it meets the requirements in the table "Treatment Standards for Hazardous Waste" at 40 *CFR* § 268.40 before land disposal.	Land disposal, as defined in 40 *CFR* § 268.2, of prohibited RCRA waste—**applicable**.	40 *CFR* § 268.40(a) 401 *KAR* 37:040 § 2	✓	✓
	All underlying hazardous constituents [as defined in 40 *CFR* § 268.2(i)] must meet the UTS, found in 40 *CFR* § 268.48 Table UTS prior to land disposal.	Land disposal of restricted RCRA characteristic wastes (D001-D043) that are not managed in a wastewater treatment system that is regulated under the CWA, that is CWA equivalent, or that is injected into a Class I nonhazardous injection well—**applicable**.	40 *CFR* § 268.40(e) 401 *KAR* 37:040 § 2	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Disposal of RCRA characteristic wastewaters in an NPDES permitted wastewater treatment unit	Are not prohibited, if the wastes are managed in a treatment system which subsequently discharges to waters of the U.S. pursuant to a permit issued under 402 of the CWA (i.e., NPDES permitted) unless the wastes are subject to a specified method of treatment other than DEACT in 40 *CFR* § 268.40, or are D003 reactive cyanide. **NOTE:** For purposes of this exclusion, a CERCLA on-site wastewater treatment unit that meets all of the identified CWA ARARs for point source discharges from such a system, is considered a wastewater treatment system that is NPDES permitted.	Land disposal of hazardous wastewaters that are hazardous only because they exhibit a hazardous characteristic and are not otherwise prohibited under 40 *CFR* Part 268—**applicable**.	40 *CFR* § 268.1(c)(4)(i) 401 *KAR* 37:010 §2	✓	✓
Disposal of RCRA hazardous waste soil in a land-based unit	Must be treated according to the alternative treatment standards of 40 *CFR* § 268.49(c) <u>or</u> according to the UTSs specified in 40 *CFR* § 268.48 applicable to the listed and/or characteristic waste contaminating the soil prior to land disposal.	Land disposal, as defined in 40 *CFR* § 268.2, of restricted hazardous soils—**applicable**.	40 *CFR* § 268.49(b) 401 *KAR* 37:040 § 10	✓	✓
Disposal of RCRA hazardous debris in a land-based unit	Must be treated prior to land disposal as provided in 40 *CFR* § 268.45(a)(1)-(5) unless EPA determines under 40 *CFR* § 261.3(f)(2) that the debris no longer contaminated with hazardous waste <u>or</u> the debris is treated to the waste-specific treatment standard provided in 40 *CFR* § 268.40 for the waste contaminating the debris.	Land disposal, as defined in 40 *CFR* § 268.2, of RCRA-hazardous debris—**applicable**.	40 *CFR* § 268.45(a) 401 *KAR* 37:040 § 7		✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Disposal of treated hazardous debris	Debris treated by one of the specified extraction or destruction technologies on Table 1 of 40 *CFR* § 268.45 and which no longer exhibits a characteristic is not a hazardous waste and need not be managed in RCRA Subtitle C facility. Hazardous debris contaminated with listed waste that is treated by immobilization technology must be managed in a RCRA Subtitle C facility.	Treated debris contaminated with RCRA-listed or characteristic waste—**applicable**.	40 *CFR* § 268.45(c) 401 *KAR* 37:040 § 7		✓
Disposal of bulk PCB remediation waste off-site (self-implementing)	May be sent off-site for decontamination or disposal provided the waste either is dewatered on-site or transported off-site in containers meeting the requirements of DOT HMR at 49 *CFR* Parts 171-180.	Generation of bulk PCB remediation waste (as defined in 40 *CFR* § 761.3) for off-site disposal—**relevant and appropriate**.	40 *CFR* § 761.61(a)(5)(i)(B)	✓	✓
	Must provide written notice including the quantity to be shipped and highest concentration of PCBs [using extraction EPA Method 3500B/3540C or Method 3500B/3550B followed by chemical analysis using Method 8082 in SW-846 or methods validated under 40 *CFR* § 761.320-26 (Subpart Q)] before the first shipment of waste to each off-site facility where the waste is destined for an area not subject to a TSCA PCB Disposal Approval.	Bulk PCB remediation waste (as defined in 40 *CFR* § 761.3) destined for an off-site facility not subject to a TSCA PCB Disposal Approval—**relevant and appropriate**.	40 *CFR* § 761.61(a)(5)(i)(B)(2)*(iv)*	✓	✓
	Shall be disposed of in accordance with the provisions for cleanup wastes at 40 *CFR* § 761.61(a)(5)(v)(A).	Off-site disposal of dewatered bulk PCB remediation waste with a PCB concentration < 50 ppm—**relevant and appropriate**.	40 *CFR* § 761.61(a)(5)(i)(B)(2)*(ii)*	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	Shall be disposed of • In a hazardous waste landfill permitted by EPA under §3004 of RCRA; • In a hazardous waste landfill permitted by a State authorized under §3006 of RCRA; or • In a PCB disposal facility approved under 40 *CFR* § 761.60.	Off-site disposal of dewatered bulk PCB remediation waste with a PCB concentration ≥ 50 ppm—**relevant and appropriate**.	40 *CFR* § 761.61(a)(5)(i)(B)(2)*(iii)*	✓	✓
Disposal of PCB-contaminated nonporous surfaces on-site	• Decontamination procedures under 40 *CFR* § 761.79, • Technologies approved under 40 *CFR* § 761.60(e), or • Risk-based procedures/technologies under 40 *CFR* § 761.61(c).	PCB remediation waste porous surfaces as defined in 40 *CFR* § 761.3–**applicable.**	40 *CFR* § 761.61(a)(5)(ii)(A)		✓
Disposal of PCB-contaminated nonporous surfaces off-site	Shall be disposed of in accordance with 40 *CFR* § 761.61(a)(5)(i)(B)(3)(ii) [sic] 40 *CFR* § 761.61(a)(5)(i)(B)(2)(ii). Metal surfaces may be thermally decontaminated in accordance with 40 *CFR* § 761.79(c)(6)(i).	PCB remediation waste nonporous surfaces as defined in 40 *CFR* § 761.3 having surface concentrations < 100 µg/100 cm^2—**applicable**.	40 *CFR* § 761.61(a)(5)(ii)(B)(1)		✓
	Shall be disposed of in accordance with 40 *CFR* § 761.61(a)(5)(i)(B)(3)(iii) [sic] [40 *CFR* § 761.61(a)(5)(i)(B)(2)(iii)]. Metal surfaces may be thermally decontaminated in accordance with 40 *CFR* § 761.79(c)(6)(ii).	PCB remediation waste nonporous surfaces having surface concentrations ≥ 100 µg/100 cm^2—**applicable**.	40 *CFR* § 761.61(a)(5)(ii)(B)(2)		✓
Disposal of PCB-contaminated porous surfaces	Shall be disposed of on-site or off-site as bulk PCB-remediation waste, according to 40 *CFR* § 761.61(a)(5)(i) or decontaminated for use according to 40 *CFR* § 761.79(b)(4).	PCB remediation waste porous surfaces (as defined in 40 *CFR* § 761.3)—**applicable**.	40 *CFR* § 761.61(a)(5)(iii)		✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Disposal of liquid PCB remediation waste (self-implementing)	Shall either • Decontaminate the waste to the levels specified in 40 *CFR* § 761.79(b)(1) or (2); or	Liquid PCB remediation waste (as defined in 40 *CFR* § 761.3)—**applicable**.	40 *CFR* § 761.61(a)(5)(iv)(A)	✓	✓
	• Dispose of the waste in accordance with the performance-based requirements of 40 *CFR* § 761.61(b) or in accordance with a risk-based approval under 40 *CFR* § 761.61(c).		40 *CFR* § 761.61(a)(5)(iv)(B)	✓	✓
Disposal of PCB cleanup wastes (e.g., PPE, rags, non-liquid cleaning materials) (self-implementing)	Shall be either decontaminated in accordance with 40 *CFR* § 761.79((b) or (c), or disposed of in one of the following facilities: • A facility permitted, licensed or registered by a State to manage municipal solid waste under 40 *CFR* § 258; • A facility permitted, licensed, or registered by a State to manage non-municipal nonhazardous waste subject to 40 *CFR* § 257.5 thru 257.30, as applicable; or • A hazardous waste landfill RCRA permitted by EPA under Section 3004 of RCRA, or a state authorized under Section 3006 of RCRA; or • In a PCB disposal facility approved under 40 *CFR* § 761; or **NOTE:** or otherwise authorized under CERCLA.	Generation of non-liquid cleaning materials at any PCB concentration resulting from the cleanup of PCB remediation waste—**applicable**.	40 *CFR* § 761.61(a)(5)(v)(A)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Reuse of PCB cleaning solvents, abrasives and equipment	May be reused after decontamination under 40 *CFR* § 761.79.	Generation of PCB wastes from the cleanup of PCB remediation waste—**applicable**.	40 *CFR* § 761.61(a)(5)(v)(B)	✓	✓
Performance-based disposal of PCB remediation waste	May dispose by one of the following methods • In a high-temperature incinerator under 40 *CFR* § 761.70(b); • By an alternate disposal method under 40 *CFR* § 761.60(e); • In a chemical waste landfill under 40 *CFR* § 761.75; • In a facility under 40 *CFR* § 761.77; or	Disposal of non-liquid PCB remediation waste (as defined in 40 *CFR* § 761.3)—**applicable**.	40 *CFR* § 761.61(b)(2) 40 *CFR* § 761.61(b)(2)(i)	✓	✓
	• Through decontamination in accordance with 40 *CFR* § 761.79.		40 *CFR* § 761.61(b)(2)(ii)	✓	✓
	Shall be disposed according to 40 *CFR* § 761.60(a) or (e), or decontaminate in accordance with 40 *CFR* § 761.79.	Disposal of liquid PCB remediation waste—**applicable**.	40 *CFR* § 761.61(b)(1)	✓	✓
Risk-based disposal of PCB remediation waste	May dispose of in a manner other than prescribed in 40 *CFR* § 761.61(a) or (b) if approved in writing from EPA and method will not pose an unreasonable risk of injury to [sic] human health or the environment. **NOTE:** EPA approval of alternative disposal method will be obtained by approval of the FFA CERCLA document.	Disposal of PCB remediation waste—**applicable**.	40 *CFR* § 761.61(c)	✓	
Disposal of PCB decontamination waste and residues	Such waste shall be disposed of at their existing PCB concentration unless otherwise specified in 40 *CFR* § 761.79(g)(1-6).	PCB decontamination waste and residues—**applicable**.	40 *CFR* § 761.79(g)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Disposal of LLW	LLW shall be certified as meeting waste acceptance requirements before it is transferred to the receiving facility.	Disposal of LLW at a DOE facility—**TBC**.	DOE M 435.1-1(IV)(J)(2)	✓	✓
General duty to mitigate for discharge of wastewater from groundwater treatment system	Take all reasonable steps to minimize or prevent any discharge or sludge use or disposal in violation of effluent standards which has a reasonable likelihood of adversely affecting human health or the environment.	Discharge of pollutants to surface waters—**applicable**.	401 *KAR* 5:065 § 2(1) 40 *CFR* §122.41(d)		✓
Operation and maintenance of treatment system	Properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used to achieve compliance with the effluent standards. Proper operation and maintenance also includes adequate laboratory controls and appropriate quality assurance procedures.	Discharge of pollutants to surface waters—**relevant and appropriate**.	401 *KAR* 5:065 § 2(1) 40 *CFR* § 122.41(e)		✓
Technology-based treatment requirements for wastewater discharge	To the extent that EPA promulgated effluent limitations are inapplicable, shall develop on a case-by-case Best Professional Judgment (BPJ) basis under § 402(a)(1)(B) of the CWA, technology based effluent limitations by applying the factors listed in 40 *CFR* § 125.3(d) and shall consider: • The appropriate technology for this category or class of point sources, based upon all available information; and • Any unique factors relating to the discharger.	Discharge of pollutants to surface waters from other than a POTW—**applicable**.	40 *CFR* § 125.3(c)(2)		✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Water quality-based effluent limits for wastewater discharge	Must develop water quality based effluent limits that ensure that: • The level of water quality to be achieved by limits on point source(s) established under this paragraph is derived from, and complies with all applicable water quality standards; and • Effluent limits developed to protect narrative or numeric water quality criteria are consistent with the assumptions and any available waste load allocation for the discharge prepared by the State and approved by EPA pursuant to 40 *CFR* § 130.7.	Discharge of pollutants to surface waters that causes, or has reasonable potential to cause, or contributes to an instream excursion above a narrative or numeric criteria within a State water quality standard established under § 303 of the CWA—**applicable**.	40 *CFR* § 122.44(d)(1)(vii) 401 *KAR* 5:065 § 2(4)		✓
	Must attain or maintain a specified water quality through water quality related effluent limits established under § 302 of the CWA.	Discharge of pollutants to surface waters that causes, or has reasonable potential to cause, or contributes to an instream excursion above a narrative or numeric criteria within a State water quality standard—**applicable**.	40 *CFR* § 122.44(d)(2) 401 *KAR* 5:065 § 2(4)		✓
	If a discharge causes, has the reasonable potential to cause, or contribute to an in-stream excursion above the numeric criterion for whole effluent toxicity using the procedures in paragraph (d)(1)(ii), must develop effluent limits for whole effluent toxicity.	Discharge of wastewater that causes, has the reasonable potential to cause, or contributes to an in-stream excursion above the numeric criterion for whole effluent toxicity**—applicable**.	40 *CFR* § 122.44(d)(1)(iv) 401 *KAR* § 5:065 2(4)		✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Monitoring requirements for groundwater treatment system discharges	In addition to 40 *CFR* §122.48(a) and (b) and to assure compliance with effluent limitations, one must monitor, as provided in subsections (i) thru (iv) of 122.44(i)(1). **NOTE:** Monitoring parameters, including frequency of sampling, will be developed as part of the CERCLA process and included in a Remedial Design, RAWP, or other appropriate FFA CERCLA document.	Discharge of pollutants to surface waters—**applicable**.	40 *CFR* § 122.44(i)(1) 401 *KAR* § 5:065 2(4)		✓
	All effluent limitations, standards, and prohibitions shall be established for each outfall or discharge point, except as provided under § 122.44(k).		40 *CFR* § 122.45(a) 401 *KAR* § 5:065 2(5)		✓
	All effluent limitations, standards and prohibitions, including those necessary to achieve water quality standards, shall unless impracticable be stated as: • Maximum daily and average monthly discharge limitations for all discharges.	Continuous discharge of pollutants to surface waters—**applicable**.	40 *CFR* § 122.45(d)(1) 401 *KAR* § 5:065 2(5)		✓
Mixing zone requirements for discharge of pollutants to surface water	The relevant requirements provided in 401 *KAR* 10:029 § 4 shall apply to a mixing zone for a discharge of pollutants. **NOTE:** Determination of the appropriate mixing zone will, if necessary, involve consultation with KDEP and will be documented in the CERCLA Remedial Design or other appropriate FFA CERCLA document.	Discharge of pollutants to surface waters of the Commonwealth [*Bayou Creek*]—**applicable**.	401 *KAR* 10:029 § 4		✓
Surface Water Standards	Table 1 of 401 *KAR* 10:031 § 6(1) provides allowable instream concentrations of pollutants that may be found in surface waters or discharged into surface waters.	Discharge of pollutants to surface waters of the Commonwealth designated as *Warm Water Aquatic Life Habitat*—**applicable**.	401 *KAR* 10:031 § 6(1)		✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Discharge of radionuclides into surface water	Conduct radiological activities to ensure that radionuclides from DOE activities contained in liquid effluents do not cause private or public drinking water systems to exceed the drinking water maximum contamination limits in 40 *CFR* Part 141, *National Primary Drinking Water Regulations*.	Discharge of radioactive materials in liquid waste to surface water at a DOE facility—**TBC**.	DOE O 458.1 §4.g(7)		✓
Effluent limits for radionuclides in wastewater	Shall not exceed the limits for radionuclides listed on Table II—Effluent Limitations.	Discharge of wastewater with radionuclides from an NRC. Agreement State licensed facility into surface waters—**relevant and appropriate**.	902 *KAR* 100:019 § 44 (7)(a)		✓
	Conduct activities to ensure that liquid discharges containing radionuclides from DOE activities do not exceed an annual average (at the point of discharge) of either of the following: (a) 5 pCi (0.2 Bq) per gram above background of settleable solids for alpha-emitting radionuclides. (b) 50 pCi (2 Bq) per gram above background of settleable solids for beta-emitting radionuclides.	Discharge of radioactive concentrations in sediments to surface water from a DOE facility—**TBC**.	DOE O 458.1 §4.g(4)		✓
	(2) When actions taken to protect humans from radiation and radioactive materials are not adequate to protect biota, then evaluations must be done to demonstrate compliance with paragraph 4.j.(1) of this Order in one or more of the following ways:		DOE O 458.1 §4.j(2)		

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	(a) Use DOE-STD-1153-2002, *A Graded Approach for* Evaluating Radiation Doses to Aquatic and Terrestrial Biota. (b) Use an alternative approach to demonstrate that the dose rates to representative biota populations do not exceed the dose rate criteria in DOE-STD-1153-2002, Table 2.2. (c) Use an ecological risk assessment to demonstrate that radiation and radioactive material released from DOE operations will not adversely affect populations within the ecosystem.				
Decontamination of PCB-contaminated water	For discharge to a treatment works as defined in 40 *CFR* § 503.9 (aa), or discharge to navigable waters, meet standard of < 3 ppb PCBs; or	Water containing PCBs regulated for disposal—**applicable**.	40 *CFR* § 761.79 (b)(1)(ii)	✓	✓
	For unrestricted use, meet standard of 0.5 ppb PCBs.		40 *CFR* § 761.79(b)(1)(iii)	✓	✓
Decontamination of PCB-contaminated liquids	Meet standard of < 2 ppm PCBs.	Organic liquids and nonaqueous inorganic liquids containing PCBs—**applicable**.	40 *CFR* § 761.79(b)(2)	✓	✓
Decontamination of PCB containers (self-implementing option)	Must flush the internal surfaces of the container three times with a solvent containing < 50 ppm PCBs. Each rinse shall use a volume of the flushing solvent equal to approximately 10 percent of the PCB container capacity.	Decontaminating a PCB Container as defined in 40 *CFR* § 761.3—**applicable**.	40 *CFR* § 761.79(c)(1)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Decontamination of movable equipment contaminated by PCBs (self-implementing option)	May decontaminate by • Swabbing surfaces that have contacted PCBs with a solvent; • A double wash/rinse as defined in 40 *CFR* § 761.360-378; or • Another applicable decontamination procedure under 40 *CFR* § 761.79.	Decontaminating movable equipment contaminated by PCB, tools and sampling equipment—**applicable**.	40 *CFR* § 761.79(c)(2)	✓	✓
Decontamination of metal surfaces in contact with PCBs	For surfaces in contact with liquid or non-liquid PCBs < 500 ppm, may be decontaminated in an industrial furnace for purposes of disposal in accordance with 40 *CFR* § 761.72.	Use of thermal processes to decontaminate metal surfaces, as required by 40 *CFR* § 761.61 (a)(6) —**applicable**.	40 *CFR* § 761.79 (c)(6)(i)	✓	✓
	For surfaces in contact with liquid or non-liquid PCBs ≥ 500 ppm, may be smelted in an industrial furnace operating in accordance with 40 *CFR* § 761.72(b), but must first be decontaminated in accordance with 40 *CFR* § 761.72(a) or to a surface concentration of < 100 µg/100 cm^2.		40 *CFR* § 761.79 (c)(6)(ii)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Closure performance standard for RCRA container storage unit	Must close the facility (e.g., container storage unit) in a manner that: • Minimizes the need for further maintenance; • Controls minimizes or eliminates to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated runoff, or hazardous waste decomposition products to the ground or surface waters or the atmosphere; and • Complies with the closure requirements of part G, but not limited to, the requirements of 40 *CFR* § 264.178 for containers.	Storage of RCRA hazardous waste in containers —**applicable**.	40 *CFR* § 264.111 401 *KAR* 34:070 § 2	✓	✓
Closure of RCRA container storage unit	At closure, all hazardous waste and hazardous waste residues must be removed from the containment system. Remaining containers, liners, bases, and soils containing or contaminated with hazardous waste and hazardous waste residues must be decontaminated or removed. [Comment: At closure, as throughout the operating period, unless the owner or operator can demonstrate in accordance with 40 *CFR* § 261.3(d) of this chapter that the solid waste removed from the containment system is not a hazardous waste, the owner or operator becomes a generator of hazardous waste and must manage it in accordance with all applicable requirements of parts 262 through 266 of this chapter.]	Storage of RCRA hazardous waste in containers in a unit with a containment system—**applicable**.	40 *CFR* § 264.178 401 *KAR* 34:180 § 9	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Closure of staging piles of remediation waste	Must be closed by removing or decontaminating all remediation waste, contaminated containment system components, and structures and equipment contaminated with waste and leachate.	Storage of remediation waste in staging pile located in previously contaminated area—**relevant and appropriate**.	40 *CFR* § 264.554(j)(1) 401 *KAR* 34:287 § 5		✓
	Must decontaminate contaminated sub-soils in a manner that will protect human and the environment.		40 *CFR* § 264.554(j)(2) 401 *KAR* 34:287 § 5		✓
	Must be closed according to substantive requirements in 40 *CFR* § 264.258(a) and 264.111.	Storage of remediation waste in staging pile located in uncontaminated area—**relevant and appropriate**.	40 *CFR* § 264.554(k) 401 *KAR* 34:287 § 5		✓
Clean closure of TSCA storage facility	A TSCA/RCRA storage facility closed under RCRA is exempt from the TSCA closure requirements of 40 *CFR* § 761.65(e).	Closure of TSCA/RCRA storage facility—**relevant and appropriate**.	40 *CFR* § 761.65(e)(3)	✓	✓
Transportation of samples (i.e., contaminated soils and wastewaters)	Are not subject to any requirements of 40 *CFR* Parts 261 through 268 or 270 when: • The sample is being transported to a laboratory for the purpose of testing; or • The sample is being transported back to the sample collector after testing.	Samples of solid waste <u>or</u> a sample of water, soil for purpose of conducting testing to determine its characteristics or composition—**applicable**.	40 *CFR* § 261.4(d)(1)(i) and (ii) 401 *KAR* 31:010 § 4	✓	✓
	In order to qualify for the exemption in paragraphs (d)(1)(i) and (ii), a sample collector shipping samples to a laboratory must: • Comply with U.S. DOT, U.S. Postal Service, or any other applicable shipping requirements.		40 *CFR* § 261.4(d)(2)(i) 401 *KAR* 31:010 § 4 40 *CFR* § 261.4(d)(2)(i)(A)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
	• Assure that the information provided in (1) thru (5) of this section accompanies the sample. • Package the sample so that it does not leak, spill, or vaporize from its packaging.		401 *KAR* 31:010 § 4 40 *CFR* § 261.4(d)(2)(i)(B) 401 *KAR* 31:010 § 4		
Transportation of RCRA hazardous waste on-site	The generator manifesting requirements of 40 *CFR* § 262.20–262.32(b) do not apply. Generator or transporter must comply with the requirements set forth in 40 *CFR* § 263.30 and 263.31 in the event of a discharge of hazardous waste on a private or public right-of-way.	Transportation of hazardous wastes on a public or private right-of-way within or along the border of contiguous property under the control of the same person, even if such contiguous property is divided by a public or private right-of-way—**applicable**.	40 *CFR* § 262.20(f) 401 *KAR* 32:020 § 1	✓	✓
Transportation of RCRA hazardous waste off-site	Must comply with the generator requirements of 40 *CFR* § 262.20–23 for manifesting, Sect. 262.30 for packaging, Sect. 262.31 for labeling, Sect. 262.32 for marking, Sect. 262.33 for placarding, Sect. 262.40, 262.41(a) for record keeping requirements, and Sect. 262.12 to obtain EPA ID number.	Preparation and initiation of shipment of hazardous waste off-site—**applicable**.	40 *CFR* § 262.10(h) 401 *KAR* 32:010 § 1	✓	✓
Transportation of PCB wastes off-site	Must comply with the manifesting provisions at 40 *CFR* § 761.207 through 218.	Relinquishment of control over PCB wastes by transporting, or offering for transport—**applicable**.	40 *CFR* § 761.207(a)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Determination of radionuclide concentration	The concentration of a radionuclide may be determined by an indirect method, such as use of a scaling factor which relates the inferred concentration of one (1) radionuclide to another that is measured or radionuclide material accountability if there is reasonable assurance that an indirect method may be correlated with an actual measurement. The concentration of a radionuclide may be averaged over the volume or weight of the waste if the units are expressed as nanocuries per gram.	Preparation for off-site shipment of LLW to a commercial NRC or Agreement State licensed disposal facility—**relevant and appropriate**.	10 *CFR* § 61.55 (a)(8) 902 *KAR* 100:021 § 6(8)(a) and (b)	✓	✓
Labeling of LLW packages	Each package of waste shall be clearly labeled to identify if it is Class A, Class B, or Class C waste, in accordance with 10 *CFR* § 61.55 or Agreement State waste classification requirements.	Preparation for off-site shipment of LLW to a commercial NRC or Agreement State licensed disposal facility—**relevant and appropriate**.	10 *CFR* § 61.57 902 *KAR* 100:021 § 8	✓	✓
Transportation of radioactive waste	Shall be packaged and transported in accordance with DOE Order 460.1B and DOE Order 460.2.	Preparation of shipments of radioactive waste—**TBC**.	DOE M 435.1-(I)(1)(E)(11)	✓	✓
Transportation of LLW	To the extent practicable, the volume of the waste and the number of the shipments shall be minimized.	Preparation of shipments of LLW—**TBC**.	DOE M 435.1-1(IV)(L)(2)	✓	✓
Transportation of hazardous materials	Shall be subject to and must comply with all applicable provisions of the HMR at 49 *CFR* §§ 171–180 related to marking, labeling, placarding, packaging, emergency response, etc.	Any person who, under contract with a department or agency of the federal government, transports "in commerce," or causes to be transported or shipped, a hazardous material—**applicable**.	49 *CFR* § 171.1(c)	✓	✓

Table D.2. Action-Specific ARARs and TBC Guidance for BGOU SWMUs 5 and 6 FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 5	Alt 6
Transportation of hazardous materials on-site	Shall comply with 49 *CFR* Parts 171-174, 177, and 178 or the site- or facility-specific Operations of Field Office approved Transportation Safety Document that describes the methodology and compliance process to meet equivalent safety for any deviation from the HMR [i.e., *Transportation Safety Document for On-Site Transport within the Paducah Gaseous Diffusion Plant*, PRS-WSD-0661, (PRS 2007b)].	Any person who, under contract with the DOE, transports a hazardous material on the DOE facility—**TBC**.	DOE O 460.1B(4)(b)	✓	✓
Transportation of hazardous materials off-site	Off-site hazardous materials packaging and transfers shall comply with 49 *CFR* Parts 171-174, 177, and 178 and applicable tribal, State, and local regulations not otherwise preempted by DOT and special requirements for Radioactive Material Packaging.	Preparation of off-site transfers of LLW—**TBC**.	DOE O 460.1B(4)(a)	✓	✓

ARAR = applicable or relevant and appropriate requirement
BMP = Best Management Practices
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR = Code of Federal Regulations
CWA = Clean Water Act
DOE = U.S. Department of Energy
DOE M = DOE Manual
DOE O = DOE Order
DOT = U.S. Department of Transportation
EDE = effective dose equivalent
EPA = U.S. Environmental Protection Agency
FFA = Federal Facility Agreement
HMR = Hazardous Material Regulations
KAR = Kentucky Administrative Regulations
KPDES = Kentucky Pollutant Discharge Elimination System
LLW = low-level (radioactive) waste
mrem = millirem
NRC = Nuclear Regulatory Commission
NWP = Nationwide Permit
PCB = polychlorinated biphenyl
PGDP = Paducah Gaseous Diffusion Plant
PPE = personal protective equipment
RCRA = Resource Conservation and Recovery Act
SWMU = solid waste management unit
TBC = to be considered
TCLP = Toxicity Characteristic Leaching Procedure
TSCA = Toxic Substances Control Act
UTS = Universal Treatment Standards
WAC = waste acceptance criteria
WWTU = wastewater treatment unit

THIS PAGE INTENTIONALLY LEFT BLANK