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Dear Mr. Begley and Ms. Corkran:

FEASIBILITY STUDY FOR SOLID WASTE MANAGEMENT UNIT 4 OF THE BURIAL GROUNDS OPERABLE UNIT AT THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY, DOE/LX/07-2408&D1

Please find enclosed the certified *Feasibility Study for Solid Waste Management Unit 4 of the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-2408&D1, for review and comment.

In accordance with Section XX.G.2, Appendix F of the Federal Facility Agreement, there is a 90-day review/comment period for this document.

If you have any questions or require additional information, please contact Dave Dollins at (270) 441-6819.

Sincerely,

Tracey Duncan
Federal Facility Agreement Manager
Portsmouth/Paducah Project Office

Enclosures:

1. Certification Page
2. Feasibility Study for SWMU 4 of the BGOU, DOE/LX/07-2408&D1

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CERTIFICATION

Document Identification: ***Feasibility Study for Solid Waste Management Unit 4 of the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,*** **DOE/LX/07-2408&D1, dated April 2017**

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

Fluor Federal Services, Inc.

Myrna E. Redfield, Director
Environmental Management

4/21/17
Date Signed

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

U.S. Department of Energy

Jennifer Woodard, Paducah Site Lead
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4/21/2017
Date Signed

DOE/LX/07-2408&D1
Primary Document

Feasibility Study for Solid Waste Management Unit 4 of the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

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Primary Document

Feasibility Study for Solid Waste Management Unit 4 of the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—April 2017

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

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

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PREFACE

This *Feasibility Study for Solid Waste Management Unit 4 of the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-2408&D1, (FS) 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. 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, it was determined that additional data and information should be gathered for Solid Waste Management Unit (SWMU) 4. The additional information was evaluated and compiled into the *Addendum to the Remedial Investigation Report for the Burial Grounds Operable Unit Solid Waste Management Unit 4 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0030&D2/R1/A1/R2 (DOE 2017). This document uses information contained in the Addendum and develops and evaluates a range of remedial alternatives that could be selected for potential implementation at SWMU 4. 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 and FS analysis and process are referenced by CERCLA terminology within this document to reduce the potential for confusion.

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ACRONYMS

AL	action level
amsl	above mean sea level
ARAR	applicable or relevant and appropriate requirement
BGOU	Burial Grounds Operable Unit
bgs	below ground surface
BHHRA	baseline human health risk assessment
BRA	baseline risk assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
COC	contaminant of concern
COE	U.S. Army Corps of Engineers
COPC	chemical or radionuclide of potential concern
COPEC	chemical or radionuclide of potential ecological concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CSM	conceptual site model
DAF	dilution attenuation factor
DNAPL	dense nonaqueous-phase liquid
DOE	U.S. Department of Energy
DPE	dual-phase extraction
DQO	data quality objective
E/PP	excavation/penetration permit
ELCR	excess lifetime cancer risk
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
HU	hydrogeologic unit
IC	Institutional Control
ISCO	*in situ* chemical oxidation
KAR	*Kentucky Administrative Regulations*
KDEP	Kentucky Department for Environmental Protection
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
MIP	membrane interface probe
MLLW	mixed low-level waste
MNA	monitored natural attenuation
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
O&M	operation and maintenance
OMB	U.S. Office of Management and Budget
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PGDP	Paducah Gaseous Diffusion Plant
POE	point of exposure
PPE	personal protective equipment
PRB	permeable reactive barrier
PRG	preliminary remediation goal
PTW	principal threat waste
RAO	remedial action objective
RAWP	Remedial Action Work Plan
RCRA	Resource Conservation and Recovery Act
RD	remedial design
RG	remediation goal
RGA	Regional Gravel Aquifer
RI	remedial investigation
ROD	record of decision
RPO	representative process option
SERA	screening ecological risk assessment
SMP	Site Management Plan
SPH	six-phase heating
SSL	soil screening level
SVE	soil vapor extraction
SVOC	semivolatile organic compound
SWMU	solid waste management unit
T&E	threatened and endangered species
TBC	to be considered
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*
USEC	United States Enrichment Corporation
USFWS	U.S. Fish and Wildlife Service
UU/UE	unlimited use/unrestricted exposure
VOC	volatile organic compound
WAC	waste acceptance criteria
WAG	waste area grouping
WDA	waste disposal alternatives
WKWMA	West Kentucky Wildlife Management Area
ZVI	zero-valent iron

EXECUTIVE SUMMARY

This *Feasibility Study for Solid Waste Management Unit 4 of the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2408&D1, (FS) was prepared to develop and evaluate remedial alternatives to address risks associated with Solid Waste Management Unit (SWMU) 4 in support of remedy selection under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) at the Paducah Gaseous Diffusion Plant (PGDP). This document was prepared in accordance with the requirements of the *Federal Facility Agreement for the Paducah Gaseous Diffusion Plant* (FFA) (EPA 1998).

The Burial Grounds Operable Unit (BGOU) is one of several operable units (OUs) at PGDP being used to evaluate and implement remedial actions. Administratively, SWMU 4 is within the BGOU, which is a portion of PGDP that is subject to a remedial investigation (RI)/FS.

SWMU 4 encompasses the C-747 Burial Yard and the C-748-B Burial Area. The C-747 Burial Yard was in operation from 1951 to 1958 for disposal of radiologically contaminated and uncontaminated debris originating from the C-410 uranium hexafluoride feed plant. The area originally consisted of two pits covering an area of approximately 8,300 ft^2 (50 ft by 15 ft and 50 ft by 150 ft) (Union Carbide 1978). According to employee interviews, a majority of the contaminated metal was buried in the northern part of the C-747 Burial Yard. Some of the trash was burned before burial. Scrapped equipment with surface contamination from the enrichment process also was buried. When the yard was closed, a smaller cell was reported to have been dug for disposal of radiologically contaminated scrap metal (Union Carbide 1978).

The C-748-B Burial Area, located on the west side of C-747, is identified as a "Proposed Chemical Landfill Site" in the 1973 Union Carbide document on waste disposal (Union Carbide 1973). The C-748-B Burial Area was incorporated into SWMU 4 starting in the mid-1990s as a result of the review of a geophysical survey. With this incorporation, the area of the SWMU was changed from 8,300 ft^2 to 286,700 ft^2 (6.58 acres), and this change was documented in a revised SWMU Assessment Report (DOE 2007a). In fall of 1999, employee interviews led to designation of the SWMU as a classified area, and appropriate access restrictions were implemented.

Five primary burial cells have been identified in SWMU 4 based on geophysical interpretations. Historical and process information indicates that the burial cells have a maximum depth of 15 ft to 18 ft below ground surface (bgs). The direct measurement of the depth of the water table beneath SWMU 4 reported in the Waste Area Grouping (WAG) 3 Report has the shallowest groundwater elevation at approximately 18 ft bgs; thus, SWMU 4 waste was not found to be in groundwater during the WAG 3 investigation (DOE 1998). Based on other nearby burial grounds, however, the potential for waste in the burial cells to be located beneath the water table at SWMU 4 existed. The BGOU SWMU 4 RI Addendum fieldwork confirmed that some waste was buried below the water table. Excavation in the SWMU 4 landfill cells identified that the level to groundwater was variable. The depths identified varied from 1.1 ft to 11 ft bgs. The variation depended upon the location within the SWMU and the season in which the measurements were recorded.

An active subsurface raw water pipeline is present across the southeastern portion of the SWMU, traversing the SWMU diagonally. The pipeline gets as close as ~ 30 ft from the nearest geophysically delineated burial cell. The lowest point of the pipeline is at an elevation of approximately 367 ft above mean sea level (amsl), which is approximately 8 to 10 ft below the current grade in the area (DOE 2010b).

Based upon disposal records, SWMU 4 contains industrial wastes, some of which are low-level waste (LLW). Industrial wastes in burial grounds at PGDP are known to contain waste that could be contaminated with polychlorinated biphenyls (PCBs) or to be Resource Conservation and Recovery Act hazardous wastes. Based upon the waste inventory and other data collected during the RI and RI Addendum fieldwork, other buried wastes at SWMU 4 (including LLW) are considered low-level threat waste. Pursuant to a Resolution Agreement among the FFA parties, dated February 10, 2012, trichloroethene (TCE) dense nonaqueous-phase liquid (DNAPL) and high concentrations of TCE in soils are considered principal threat waste (PTW) (DOE 2012). The results of the RI Addendum fieldwork confirmed the presence of TCE PTW below SWMU 4.

Remedial Investigation Summary

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 an 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 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) evaluated impacts to the environment.

In January 2011, EPA, KY, and DOE convened to discuss SWMU 4 data gaps and uncertainties that remained after completion of the BGOU RI Report. They developed data quality objectives and incorporated them into a sampling plan to address those gaps. The SWMU 4 investigation followed the field sampling plan outlined in the BGOU RI/FS Work Plan Addendum (DOE 2014a). The primary goal of this supplemental remedial investigation was to address the identified remaining uncertainties and data gaps by further characterizing the nature, extent, and magnitude of source zones and secondary sources (such as contaminated soil) at SWMU 4.

The additional field investigation data generated were combined with previously collected information and resulted in the *Addendum to the Remedial Investigation Report for the Burial Grounds Operable Unit Solid Waste Management Unit 4 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0030&D2/R1/A1/R2 (DOE 2017). The major findings of the BGOU SWMU 4 RI Addendum Report concerning SWMU 4 are summarized as follows.

- The investigation has provided data, particularly related to the nature and extent of contamination at SWMU 4, that are sufficient and adequate for proceeding with the FS and subsequent CERCLA documents.

- Environmental media, specifically subsurface soil and groundwater, have been impacted by releases of contaminants from buried waste. Contamination resulting from the buried waste is found concentrated in the Upper Continental Recharge System (UCRS) soils and groundwater immediately within and under the burial cells, with a lesser amount of contamination dispersed laterally from the cells. In addition, activities at SWMU 4 have resulted in contamination of surface soil.

- TCE trends in the UCRS and Regional Gravel Aquifer (RGA) groundwater indicate that TCE DNAPL is present at SWMU 4 in the subsurface soils of the UCRS. While TCE contamination is found in Burial Cells 1, 4, and 5, the contaminant levels within the upper 20 ft in the burial cells at SWMU 4 do not indicate the presence of a DNAPL source within the burial cells. This indicates the TCE DNAPL source no longer is present within the burial cells or emanating from an isolated point source at the base of the burial cell (greatest soil concentration of 750 mg/kg TCE was from a sample collected in boring 004-019P3 at a depth interval of 25 ft to 30 ft bgs and located beneath Burial Cell 4). Also, elevated TCE concentrations in the RGA beneath SWMU 4 likely are the result of a TCE DNAPL source in the UCRS, rather than a DNAPL source within the RGA.

- The risk screening update indicates that excess lifetime cancer risks (ELCRs) > 1E-06 and hazard indices (HIs) greater than 1 exist for the industrial worker and excavation worker scenarios for surface and subsurface soils, respectively. Arsenic, Total polycyclic aromatic hydrocarbons (PAHs), Total PCBs, cesium-137, neptunium-237, thorium-230, uranium-234, uranium-235, and uranium-238 present the dominant risks from exposure to surface and subsurface soil. The major contaminants presenting groundwater risks [ELCRs > 1E-04 or hazard index (HI) greater than 3] in the RGA include arsenic, cobalt, iron, manganese, vanadium, 1,1,2-trichloroethane, chloroform, *cis*-1,2-dichloroethene (DCE), TCE, and vinyl chloride.

- Ecological risk screening includes several chemicals or radionuclides of potential ecological concern (COPECs). COPECs whose maximum concentration was greater than 10 times their ecological screening value include PCBs, PAHs, and metals (aluminum, cadmium, chromium, iron, manganese, mercury, and uranium).

- Analytical results from both surface and subsurface soil were screened against screening values for the protection of both UCRS and RGA groundwater. Contaminants that most commonly exceeded both background values and the screening level for the protection of RGA groundwater include the following: iron, silver, uranium and its isotopes, Total PCBs, TCE, *cis*-1,2-DCE, vinyl chloride, and technetium-99 (Tc-99). TCE and its degradation products exceeded the RGA groundwater protection screening values from approximately 15 ft to 60 ft bgs.

Remedial Action Objectives

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. This SWMU 4 FS evaluates taking actions as necessary to protect human health and the environment from SWMU 4 contaminants and addresses releases or potential releases from these source areas that may impact RGA groundwater, soils, subsurface soils, 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;

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

(3) Treat or remove PTW wherever practicable, consistent with 40 *CFR* § 300.430(a)(iii)(A).

SWMU 4 is located within the industrial area of the PGDP facility, and a reasonable future use of this area is expected to remain industrial (DOE 2012).

For each of these general RAOs, a SWMU-specific RAO is defined. The following are the SWMU-specific RAOs.

SWMU 4-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 RGA groundwater of the maximum contaminant level (MCL) (or risk-based concentration for residential use of groundwater in the absence of an MCL).

SWMU 4-specific RAO 2. Prevent exposure to waste that exceeds target cumulative ELCRs and cumulative non-cancer HIs for the future excavation worker receptor. The acceptable cumulative risk levels for this RAO are defined as follows:

- Waste: Cumulative ELCR < 1E-05 and cumulative HI ≤ 1 for a future excavation worker.

SWMU-4 specific RAO 3. Prevent exposure to contaminated soils that exceed target cumulative ELCRs and cumulative non-cancer HIs for the current and future industrial worker and future excavation 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 current and future industrial worker (considering default exposures in the Risk Methods Document).

- Surface and Subsurface Soil: Cumulative ELCR < 1E-05 and cumulative HI ≤ 1 for a future excavation worker.

SWMU 4-specific RAO 4. Treat or remove PTW wherever practicable, consistent with 40 *CFR* § 300.430(a)(iii)(A).

<u>Preliminary Remediation Goals</u>

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 PGDP that includes SWMU 4 is industrial. This future use is consistent with SWMU 4 remaining as a burial ground. The BHHRA, which is summarized in the BGOU SWMU 4 RI Addendum Report, identified pathways that potentially could require a response, including Future Industrial Worker, Future Excavation Worker, and Future Off-Site Residents (Groundwater).

Table ES.1 shows the preliminary remediation goals (PRGs) for the target contaminants of concern (COCs) for the associated media for the pathways.

<u>Remedial Alternatives</u>

The primary object of this FS is to identify remedial technologies and process options that, when applied to SWMU 4, potentially would allow the RAOs to be attained, then to combine the process options into a range of remedial alternatives. CERCLA requires that an FS include a range of alternatives that include a No Action alternative so that an appropriate alternative is selected for implementation. The screening process consists of the following series of steps:

- Identifying general response actions (GRAs) that may meet the RAOs individually or in combination with other GRAs;

- Identifying, screening, and evaluating remedial technology types for the GRAs; and

- Following screening of the technologies, one or more representative process options are assembled into remedial alternatives.

Table ES.1. SWMU 4 FS Preliminary Remediation Goals for RGA Groundwater Protection, Surface Soils, and Subsurface Soils

Chemical or Radionuclide of Potential Concern	Units	PRG for Surface Soils[a]	PRG for Subsurface Soil[b]
Aluminum	mg/kg	N/A	1.20E+04
Arsenic	mg/kg	1.69E+01	1.69E+01
Barium	mg/kg	N/A	4.78E+03
Beryllium	mg/kg	N/A	1.83E+02
Cobalt	mg/kg	N/A	1.30E+01
Fluoride	mg/kg	N/A	6.96E+02
Iron	mg/kg	N/A	2.80E+04
Manganese	mg/kg	N/A	8.20E+02
Nickel	mg/kg	N/A	1.48E+02
Uranium	mg/kg	N/A	4.92E+02
Vanadium	mg/kg	N/A	5.01E+02
1,1,2-Trichloroethane	mg/kg	N/A	9.41E-02
1,1-Dichloroethene	mg/kg	N/A	1.46E-01
1,2-Dichloroethane	mg/kg	N/A	8.22E-02
Benzene	mg/kg	N/A	1.48E-01
Carbon Tetrachloride	mg/kg	N/A	1.13E-01
Chloroform	mg/kg	N/A	1.29E+00
cis-1,2-Dichloroethene	mg/kg	N/A	1.19E+00
Ethylbenzene	mg/kg	N/A	4.55E+01
Total PAHs	mg/kg	4.41E-01	1.62E+00
Total PCBs	mg/kg	1.00E+01	1.00E+01
Total Xylene	mg/kg	N/A	5.71E+02
Trichloroethene	mg/kg	N/A	1.04E-01
Vinyl Chloride	mg/kg	N/A	4.00E-02
Cs-137	pCi/g	5.10E-01	3.42E+00
Np-237	pCi/g	1.15E+00	3.11E+00
Tc-99	pCi/g	N/A	2.80E+00
Th-230	pCi/g	N/A	1.06E+02
U-234	pCi/g	N/A	2.87E+00
U-235	pCi/g	1.70E+00	2.83E+00
U-238	pCi/g	2.34E+00	2.34E+00

[a] PRG for surface soil is the lower of the direct contact PRG and groundwater protective PRG for soil. If the risk-based value is less than background, then background becomes the revised PRG for surface soil.
[b] PRG for subsurface soil is the lower of the direct contact PRG and groundwater protective PRG for soil. If the risk-based value is less than background, then background becomes the PRG for surface soil.

Six remedial alternatives were assembled, and, after screening, five alternatives were advanced to be evaluated further, consistent with the CERCLA detailed analysis (Table ES.2).

During detailed analysis, the five alternatives are compared against the CERCLA evaluation criteria. Overall protection of human health and environment and compliance with applicable or relevant and appropriate requirements (ARARs) are categorized as threshold criteria that any viable alternative must meet or receive a waiver for that ARAR. Long-term effectiveness and permanence; reduction of toxicity, mobility, and volume through treatment; short-term effectiveness; implementability; and cost are considered balancing criteria upon which the detailed analysis is primarily based. CERCLA has two modifying criteria, state acceptance and community acceptance, which are evaluated following the FS and the public review of the proposed plan and are addressed as the final decision is made and the record of decision is prepared.

Table ES.2. SWMU 4 Alternatives

Alternative	Name	Alternative Major Components
1	No Action	No activities.
2	Limited Action	No detailed analysis; screened from further evaluation.
3	Recharge Control and Hydraulic Control	• Engineered cover over all waste area for recharge control, • Slurry wall, • Groundwater extraction and treatment, • Groundwater monitoring, and • Land Use Controls (LUCs).
4	Targeted Excavation, Electrical Resistance Heating (ERH), and Bioremediation	• Excavation of wastes over volatile organic compound (VOC) source areas, • Engineered cover over remaining waste, • Slurry wall, • ERH treatment of VOC source areas, • Bioremediation of the targeted VOC source area and residual contamination, • Groundwater monitoring, and • LUCs.
5	Full Excavation, ERH, and Bioremediation	• Excavation of all waste areas, • ERH treatment of VOC source areas, • Bioremediation of the targeted VOC source area and residual contamination, • Groundwater monitoring, and • LUCs.
6	Recharge Control and Bioremediation	• Engineered cover for recharge containment, • Slurry wall, • Bioremediation of targeted VOC source area, • Groundwater monitoring, and • LUCs.

The comparative analysis identifies the relative advantages and disadvantages of each alternative so that the key tradeoffs that risk managers must make are identified. Alternatives are ranked with respect to the evaluation criteria, and the overall detailed and comparative evaluations are summarized. The results of the Comparative Analysis are shown in Table ES.3 where a ranking of low means the alternative least meets the criteria, and a term of very high means the alternative best meets the criteria being considered.

Table ES.3. Summary of Comparative Analysis of Alternatives

Evaluation Criteria	Alternative 1	Alternative 3	Alternative 4	Alternative 5	Alternative 6
	No Action	**Recharge Control and Hydraulic Control**	**Targeted Excavation, ERH, and Bioremediation**	**Full Excavation, ERH, and Bioremediation**	**Recharge Control and Bioremediation**
Overall Protection of Human Health and the Environment	No	Yes	Yes	Yes	Yes

Table ES.3. Summary of Comparative Analysis of Alternatives (Continued)

Evaluation Criteria	Alternative 1 No Action	Alternative 3 Recharge Control and Hydraulic Control	Alternative 4 Targeted Excavation, ERH, and Bioremediation	Alternative 5 Full Excavation, ERH, and Bioremediation	Alternative 6 Recharge Control and Bioremediation
Compliance with ARARs	No ARARs Identified	Yes	Yes	Yes	Yes
Long-term Effectiveness	Low	High	Medium	Very High	Medium
Reduction in Toxicity, Mobility, or Volume through Treatment	Low	Low	Medium	Very High	Medium Low
Short-term Effectiveness	Low	High	Medium	Medium	Medium High
Implementability	Very High	High	Medium	Medium Low	High
Overall Cost Rating (1 = Best and 5 = Worst)	1 of 5	5 of 5	3 of 5	4 of 5	2 of 5
Average Balancing Criteria Rating	N/A—Does Not Pass Threshold Criteria	Medium High	Medium	Medium	Medium
Total Project Cost (M$)	$0	$931	$345/$280*	$540/$359*	$164
Total Project Cost (M$) (Present Worth)	$0	$93	$236/$171*	$530/$349*	$48

*Estimated Total Project Cost, with a waste disposal alternatives facility.

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1. INTRODUCTION

This *Feasibility Study for Solid Waste Management Unit 4 of the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-2408&D1 (FS), was prepared to evaluate remedial alternatives for Solid Waste Management Unit (SWMU) 4 at 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 SWMU 4 is addressed in this D1 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 is a conceptual site model (CSM) that summarizes 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 SWMU 4 and a range of remedial alternatives that, upon implementation, would be 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 efforts to evaluate and implement remedial actions. A final Comprehensive Site OU evaluation will be conducted following the completion of remedial 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 2015a), 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). This waste may include low-level threat waste and principal threat waste (PTW) and affected media (see Section 1.3.3). PTW is defined by EPA as "source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur" (EPA 1991). The National Contingency Plan (NCP) [as promulgated at 40 *CFR* § 300.430(a)(iii)(A)] states that EPA expects to use treatment to address principal threats posed by a site, where practicable. Principal threats for which treatment is most likely to be appropriate include liquids, areas contaminated with high concentrations of toxic compounds, and highly mobile materials.

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	C-747-A Burial Grounds
30	C-747-A Burn Area
145 (9 and 10)	Area P and C-746-S and C-746-T Landfills

***Bold** indicates the SWMU addressed in this FS.

1.2 PURPOSE AND ORGANIZATION OF REPORT

Under a work plan approved by EPA and KY (DOE 2006), 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 BGOU RI 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.

In January 2011, EPA, KY, and DOE convened to discuss SWMU 4 data gaps and uncertainties that remained after completion of the BGOU RI Report (DOE 2010b). They developed data quality objectives (DQOs) and incorporated them into a sampling plan to address those gaps. The SWMU 4 investigation followed the field sampling plan outlined in the BGOU RI/FS Work Plan Addendum (DOE 2014a). The primary goal of that supplemental RI was to address the identified data gaps by further characterization of nature, extent, and magnitude of source zones and secondary sources (such as contaminated soil) at SWMU 4. This FS uses findings from the 2010 BGOU RI Report and the 2016 BGOU SWMU 4 RI Addendum Report. Some sections of the approved BGOU RI Report (DOE 2010b) and BGOU SWMU 4 RI Addendum Report (DOE 2017) for SWMU 4 are incorporated by reference into this FS.

This FS was prepared in accordance with NCP requirements and is consistent with EPA RI/FS guidance to support CERCLA remedy selection. 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 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 and Restoration Program, the SWMU 4 FS will be provided to trustee agencies for their review. It is DOE's policy to integrate natural resource concerns early into the investigation and remedy selection and implementation processes 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 minor format changes. 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 following are the sections of this FS:

Chapter 1—Introduction

Chapter 2—Identification and Screening of Technologies

Chapter 3—Development and Screening of Alternatives

Chapter 4—Detailed and Comparative Analyses of Alternatives

Chapter 5—References

Appendix A—Applicable or Relevant and Appropriate Requirements and To Be Considered Guidance for SWMU 4

Appendix B—Cost Estimates

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 and highlights 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 SWMU 4.

1.3.1 PGDP Site Description

PGDP is located approximately 10 miles west of Paducah, Kentucky, and 3.5 miles south of the Ohio River in the western part of McCracken County (Figure 1.1). The PGDP industrial area occupies 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 the Commonwealth of Kentucky 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 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 after World War II. Construction of PGDP was initiated in 1951 and the plant began operation in 1952. 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, Martin Marietta Utility Services and later the United States Enrichment Corporation (USEC) assumed management and operation of PGDP enrichment facilities under a lease agreement with DOE. Uranium enrichment operations ceased in June 2013, and USEC returned the leased facilities to DOE in October 2014.

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

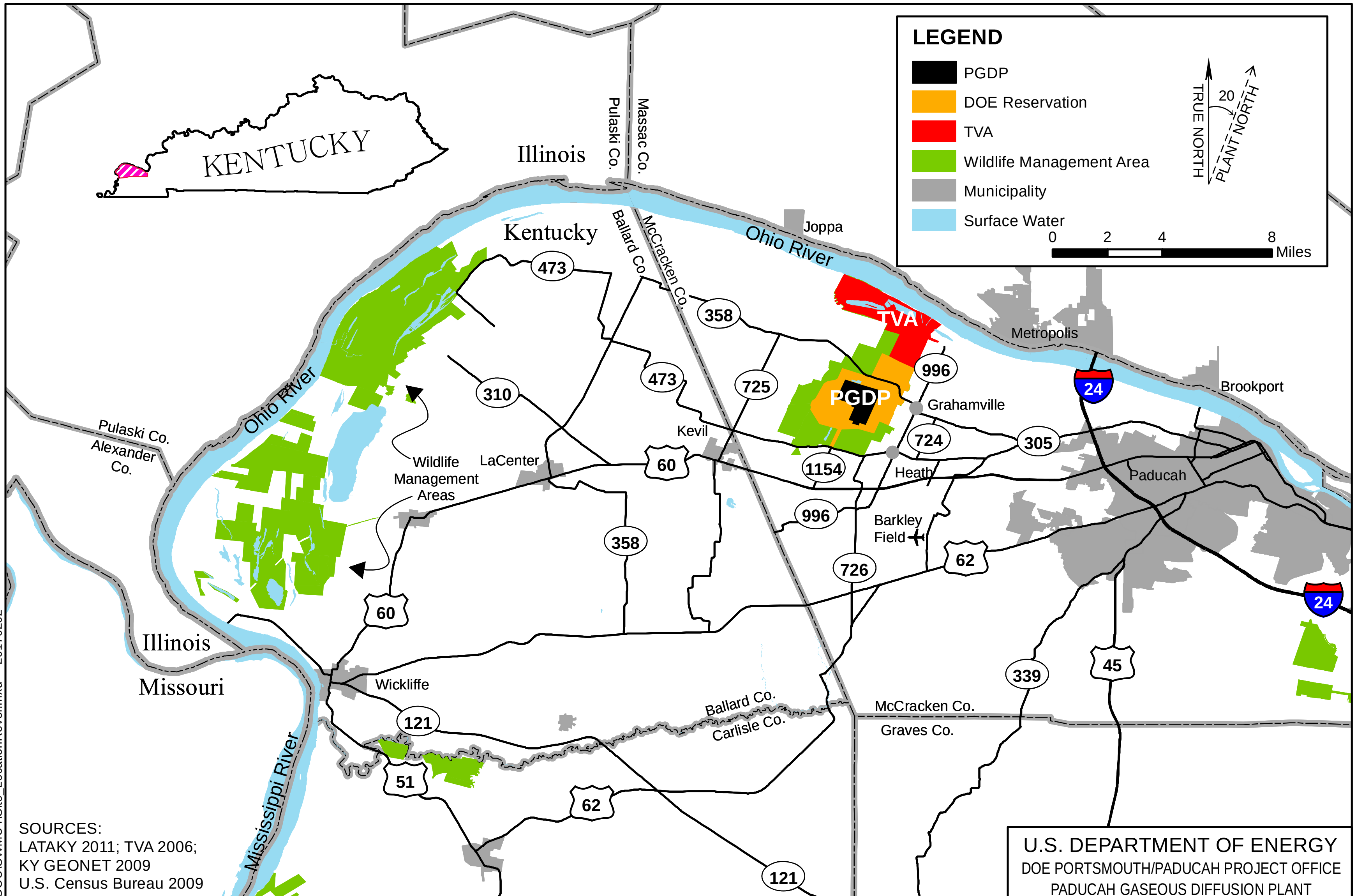

Figure 1.1 PGDP Location

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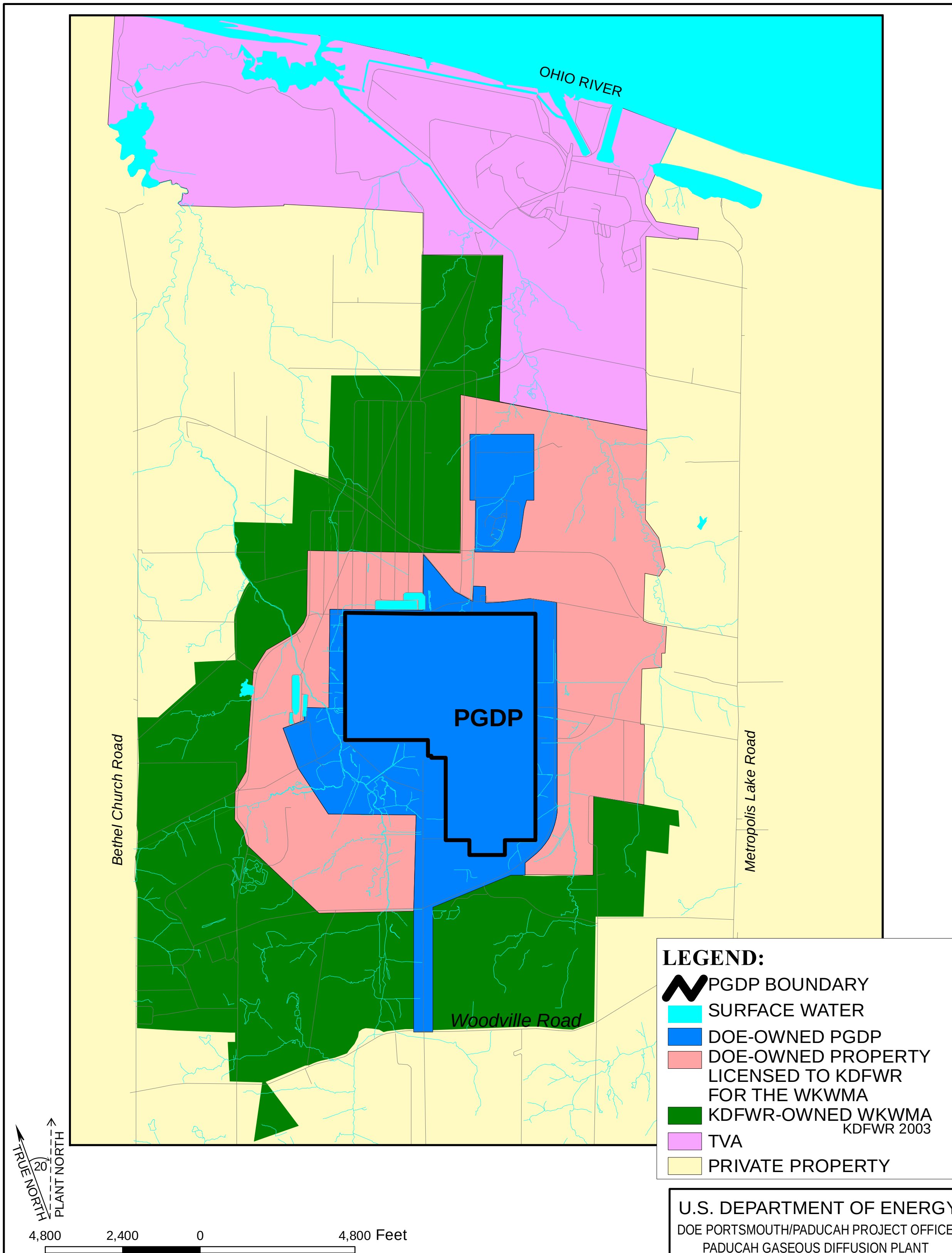

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Figure 1.2. PGDP Land Ownership Map

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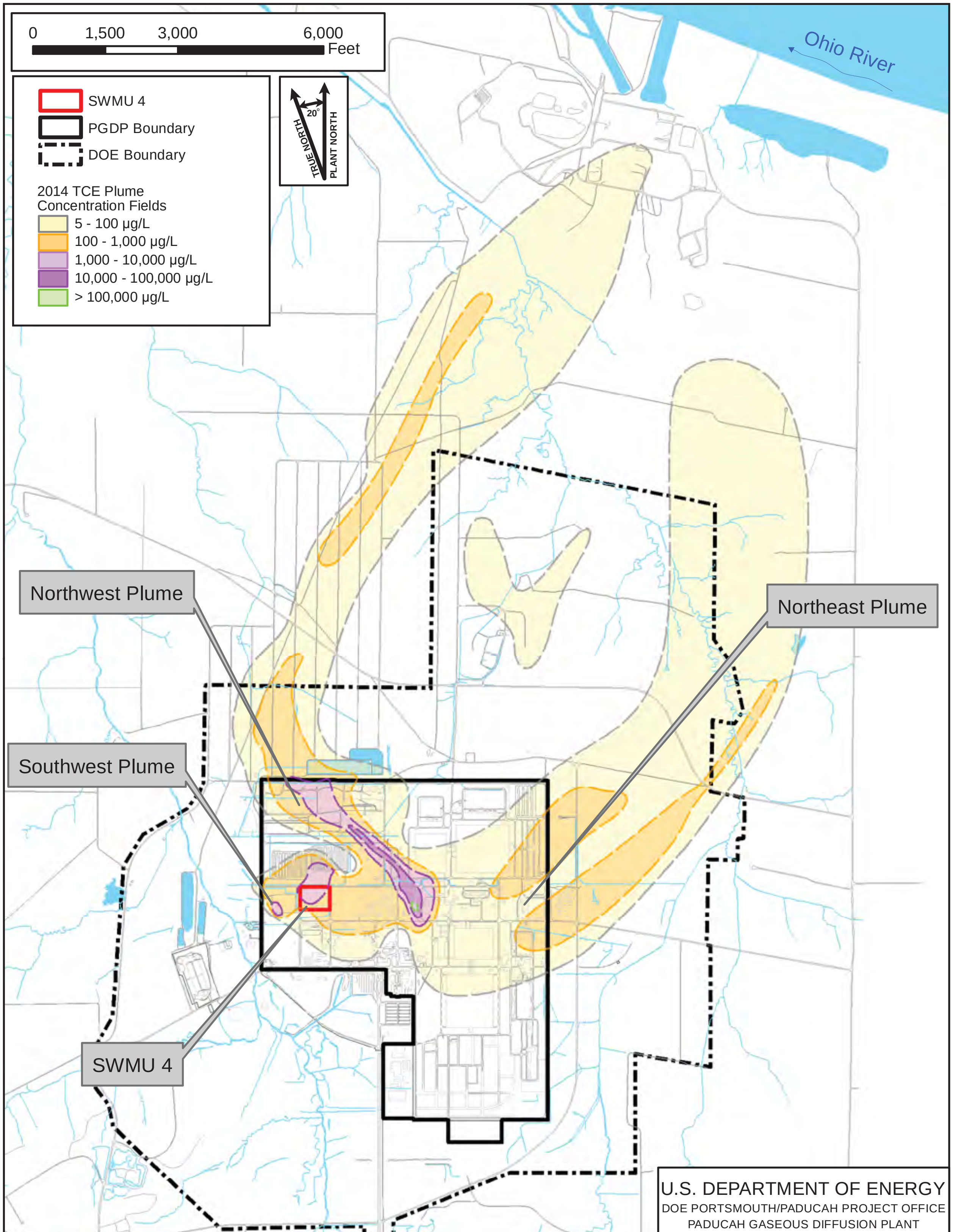

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Figure 1.3. SWMU 4 Location in Relation to PGDP Groundwater Plumes

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contained within the footprint of the TCE Northwest Groundwater Plume. The primary or significant source of the Northwest TCE Plume is at the C-400 Building, and the primary sources of the Southwest TCE Plume appear to be SWMUs 1 and 4.

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 2015a). The scope of this action is within the overall response strategy for PGDP.

1.3.1.1.1 Major statutes, regulations, and controlling documents

On June 30, 1994, EPA placed PGDP on the National Priorities List (NPL) [59 *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 NCP. As the lead agency under CERCLA, DOE is responsible for conducting cleanup activities at PGDP in compliance with the 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 summary.

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 (BRA) 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 1E-06;
- The BRA shows that the noncarcinogenic hazard quotient[1] 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 (MCLs), non-zero MCL 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.

The FFA requires that DOE develop and submit an annual SMP to EPA and Kentucky Department for Environmental Protection (KDEP). The SMP outlines the programmatic framework for implementing the FFA.

[1] The FFA uses the term hazard quotient; however, the intent of the text is the hazard index (HI).

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 under Section IX of the FFA. 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. RCRA corrective action requirements have been integrated through the FFA.

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

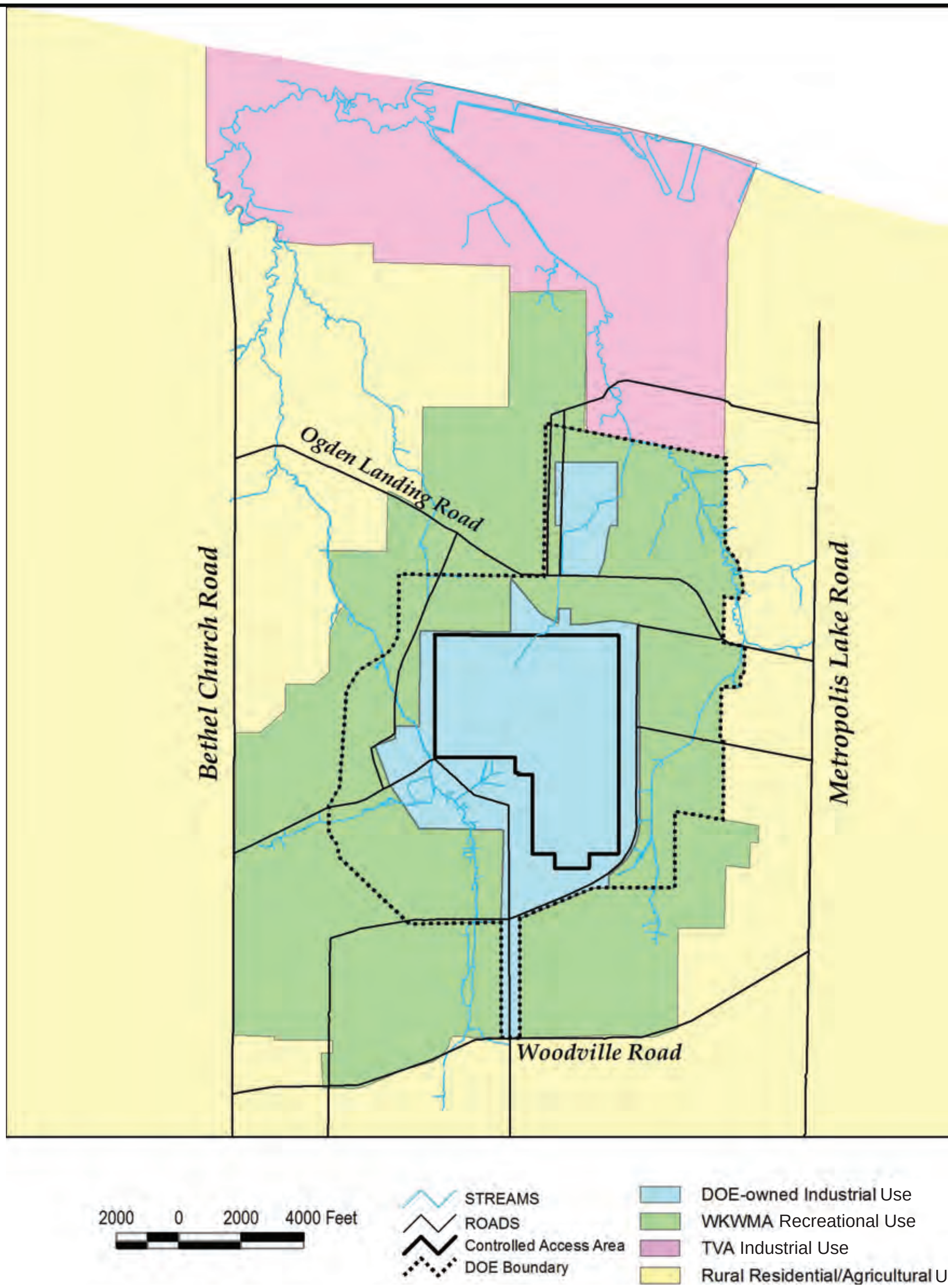
1.3.1.2.1 Land use

Current and anticipated future land uses for PGDP and surrounding areas are depicted in Figures 1.4 and 1.5 of the PGDP SMP (DOE 2015a). The area of PGDP that includes SWMU 4 is heavily industrialized. The area immediately beyond the secured industrial area is mostly agricultural and open land, with some forested areas (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. PGDP is a posted government property and trespassing is prohibited. The future use scenario considered reasonable for SWMU 4 is that of industrial (Figure 1.5). The PGDP site includes 1,986 acres licensed to the Kentucky Department of Fish and Wildlife Resources. This area is part of the WKWMA and borders PGDP to the north, west, east and south. 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 2015 was approximately 24,900. Metropolis, Illinois, had an estimated population in 2015 of approximately 6,300 (U.S. Census Bureau 2015). 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].

Major employers in the area of PGDP complex include Fluor Federal Services, Inc., Paducah Deactivation Project; Mid-America Conversion Services, LLC; Swift & Staley Inc.; and a number of DOE support contractors. Other employers near PGDP include the TVA Shawnee Fossil Plant and WKWMA.



Adapted from Site Management Plan, DOE 2015a.
NOTE: Boundaries are approximate.

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Figure 1.4. Current Land Use at PGDP

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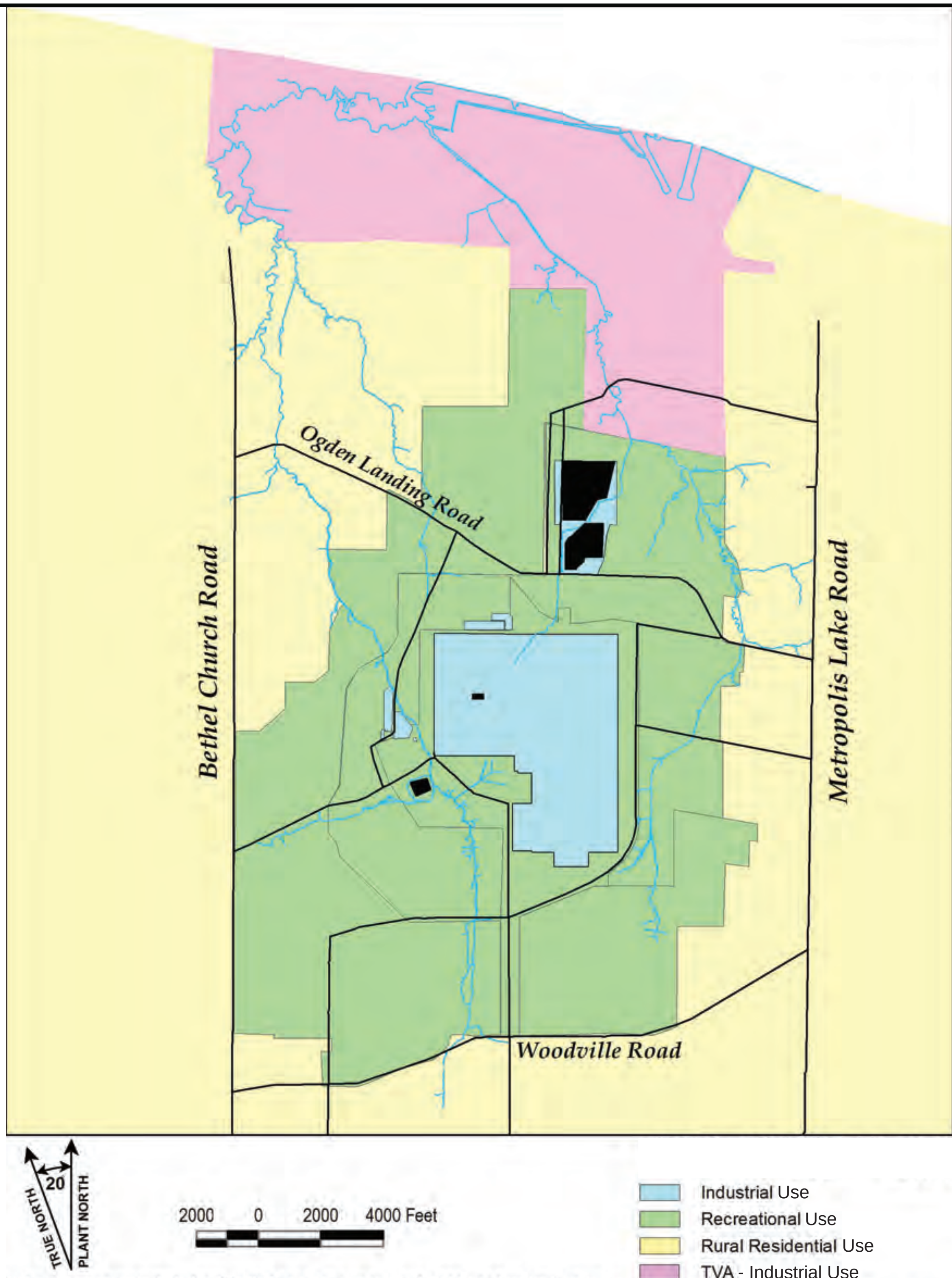

Note: These areas include landfills that are active or certified closed and under long-term custodial care (i.e., C-404, C-746 S&T, C-746-U), or that are under an Interim Corrective Measure (i.e., C-746-K). As such, these areas are not amenable to unrestricted future industrial use.

Adapted from the Site Management Plan, DOE 2015a.

NOTE: Boundaries are approximate.

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Figure 1.5. Reasonably Anticipated Future Land Use at PGDP

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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 SWMU 4 is located, ground surface elevations vary from 360 to 370 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.

The C-747 Contaminated Burial Yard and the C-748-B Burial Area (combined SWMU 4) are located in the western section of the PGDP secured area. SWMU 4 is bounded on the north, east, and west by plant roads Virginia Avenue, 6th Street, and 4th Street, respectively, and on the south by an active railroad spur (Figure 1.6). SWMU 4 is an open field covered with a variety of field grasses and clover. A short, narrow gravel road that enters from the west is nearly grass-covered. SWMU 4 is bounded on three sides (north, east, and west) by shallow drainage swales that direct surface runoff to the northwest corner of the SWMU. There is an elevation difference of approximately 10 ft between the highest point in the SWMU to the adjacent drainage swales. The entire SWMU 4 was covered with 2 ft to 3 ft of soil material, and a 6-inch clay cap was placed over the area in 1982 (DOE 1998). The SWMU is fenced to limit access to authorized personnel only. The SWMU is posted and controlled under DOE work rules that limit access; thus, this reduces the number of individuals who may be exposed and the potential to spread contamination.

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

[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).

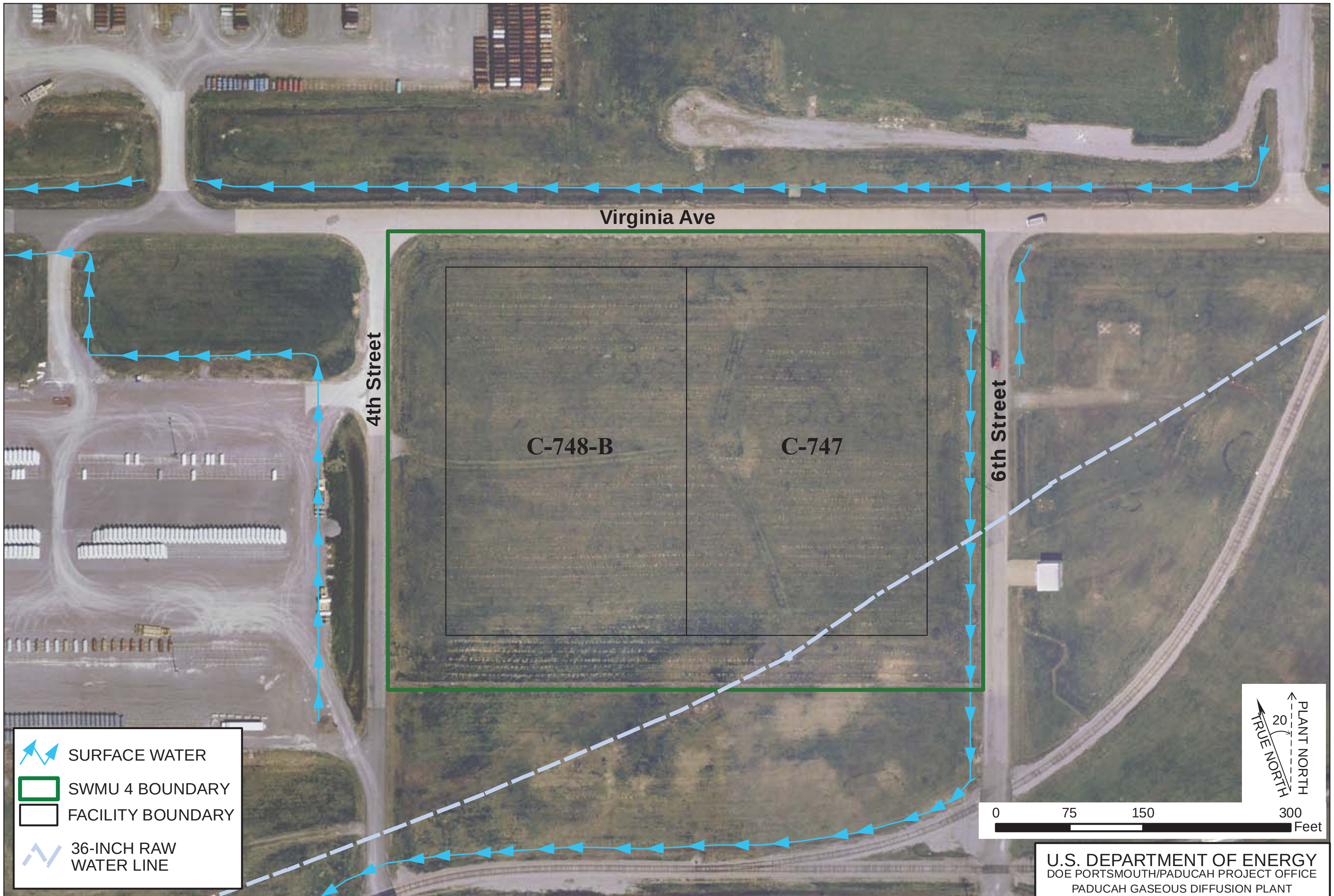

Figure 1.6. SWMU 4 Layout

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1.3.1.2.5 Air Quality

DOE operates and maintains a network of nine air monitoring stations for the site that include one background station. Samples from these air monitoring stations are analyzed for radionuclides. Air monitoring data are reviewed and included in the National Emission Standards for Hazardous Air Pollutants Annual Reports.

1.3.1.2.6 Noise

Noise associated with plant activities is associated with construction or maintenance activities on-site (e.g., mowing, decommissioning and decontamination activities, environmental restoration activities, road maintenance, etc.). 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 PGDP where past construction activities have disturbed the fragipan layer, the soils are best classified as "urban."

The area of SWMU 4 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 SWMU 4 would have destroyed the fragipan. The cover for SWMU 4 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 near the PGDP plant area. The prime farmland near 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 Department of Fish and Wildlife Resources manages a large percentage of the adjacent WKWMA to promote native prairie vegetation by burning, mowing, and various other techniques. 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 PGDP fence during the 1994 investigation of sensitive resources at 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 PGDP is within a maternity circle for Indiana bat (listed endangered). Subsequently, the USFWS published the Revised Conservation Strategy for Forest-Dwelling Bats (USFWS 2016). No bat habitat exists at SWMU 4.

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* (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 cultural, archaeological, or historic resources have been identified within the vicinity of SWMU 4.

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. 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 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. There are no wetlands in or adjacent to SWMU 4.

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 (NOAA 2004). In the updated report, the mean precipitation estimate for the 100-year, 24-hour event in Atlas 14 for the Paducah area is 10.1% to 15% greater than the mean estimate in previous publications. As stated in Atlas 14, in many cases, the mean precipitation estimate used previously still is within the confidence limits provided in Atlas 14; therefore, it is assumed the plant ditches still will contain the 100- and 500-year discharges. SWMU 4 is not located within the floodplain.

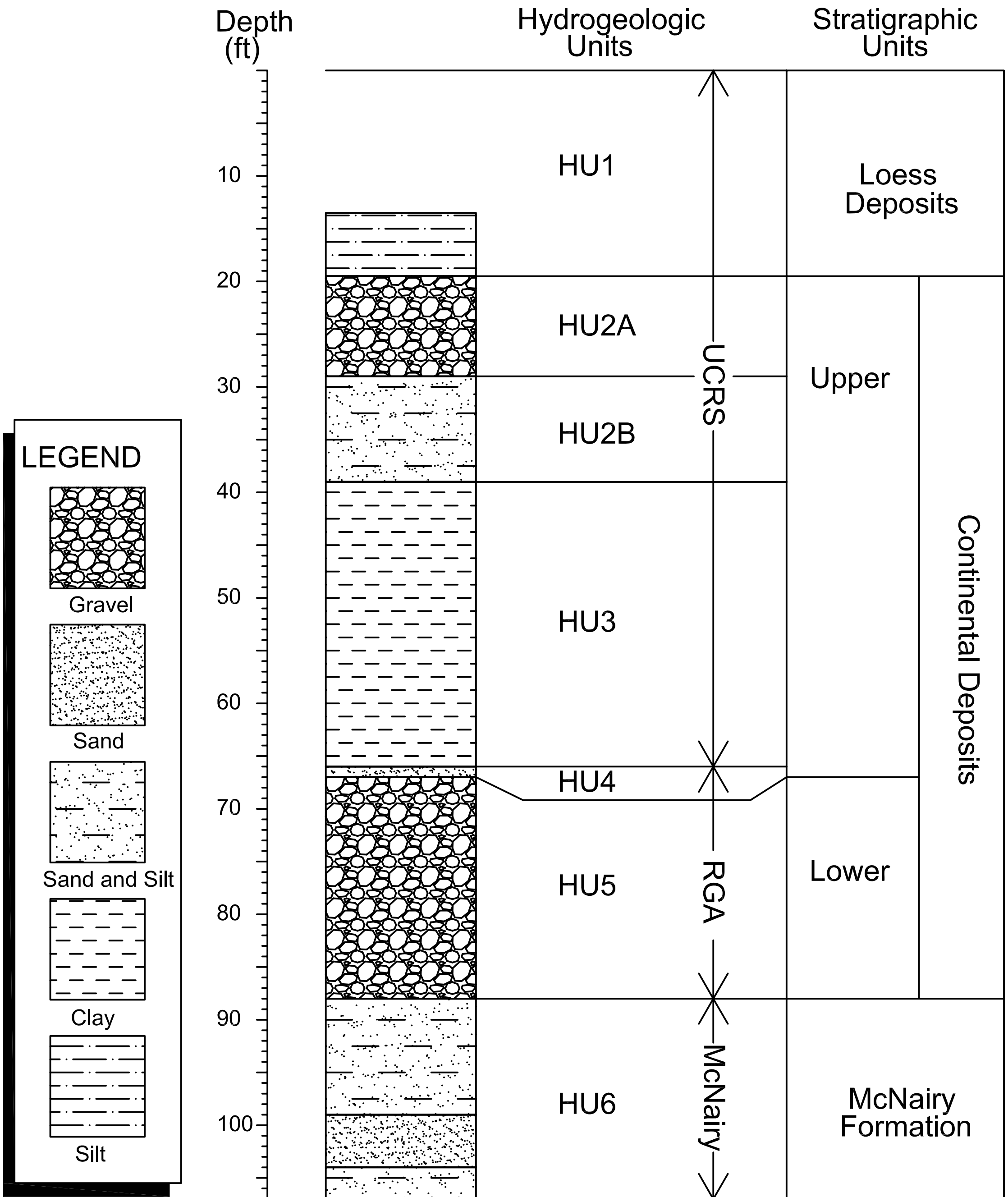
1.3.1.5 Regional and study area geology and hydrogeology

1.3.1.5.1 Regional geology

PGDP is located in the Jackson Purchase Region of western Kentucky, which is located at 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 1.7 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 PGDP in southern Illinois (MMES 1992). The Coastal Plain deposits unconformably overlie Mississippian carbonate bedrock and consist of the following: the Tuscaloosa Formation; the sand and 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.



Geology based on SI Phase 1 Boring H007.
Actual depths of hydrogeologic units and stratigraphic units vary across the site.

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DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure 1.7. Example Stratigraphic and Hydrogeologic Units

FLUOR.

The SWMU 4 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. Figure 1.8 provides a graphical representation of the geologic setting of PGDP. Pliocene through Paleocene formations in the SWMU 4 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.

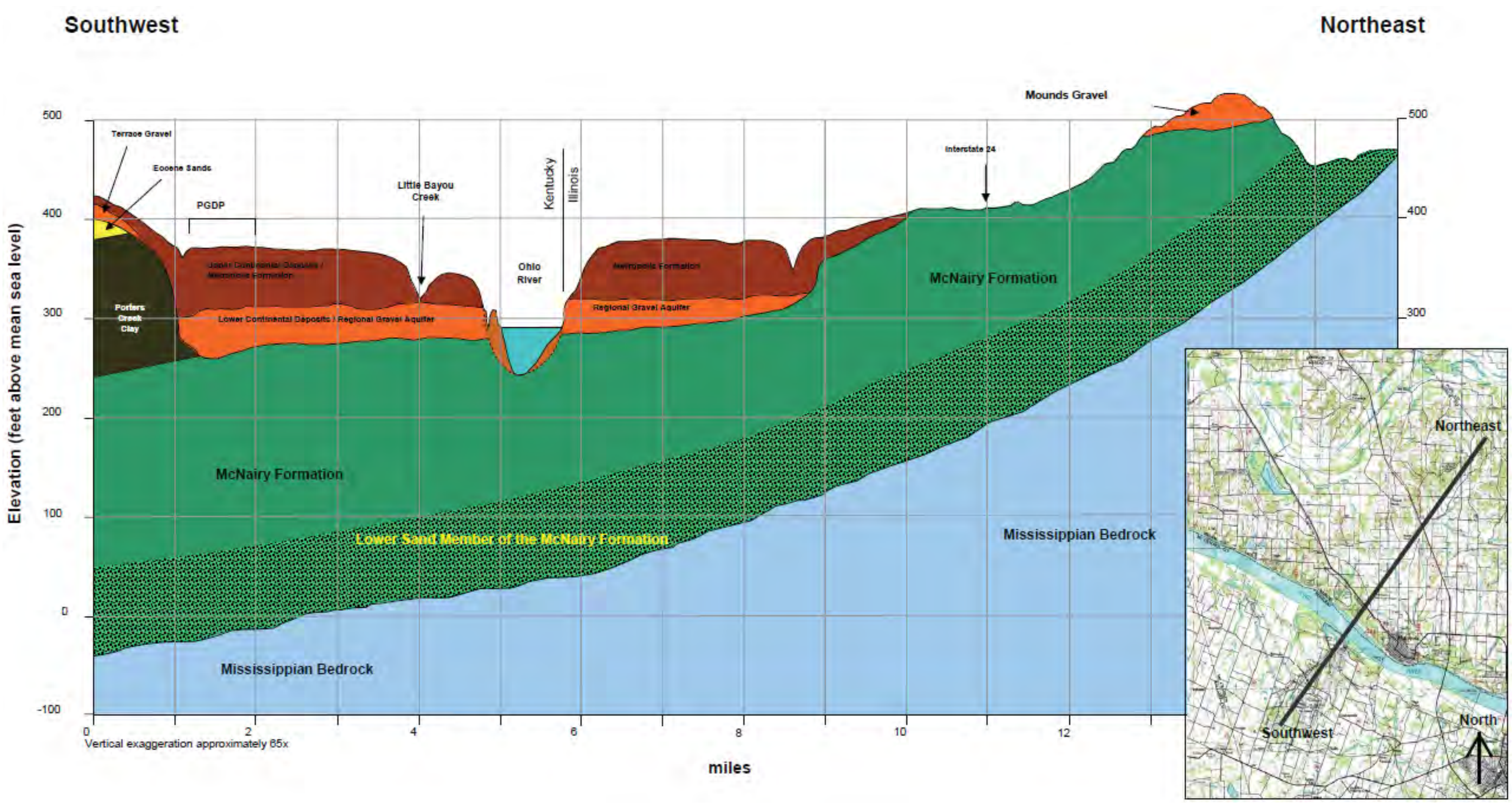
1.3.1.5.2 Regional hydrogeology

The significant geologic units relative to shallow groundwater flow at PGDP include the Terrace Gravel and Porters Creek Clay (south 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 northeast 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 losing reaches.

Upper Continental Recharge System. 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 Upper Continental Recharge System (UCRS). Groundwater flow is primarily downward in the UCD. 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. 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 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.



PGDP Regional Stratigraphy

Paducah Gaseous Diffusion Plant
McCracken County, Kentucky

Source: Adapted from Paducah Remediation Services, 2009; Figure 1

Figure 1.8. PGDP Regional Stratigraphy

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 Regional Gravel Aquifer (RGA). The RGA is the shallow aquifer beneath PGDP and contiguous lands to the north. The RGA is considered by EPA as Class IIA groundwater, current drinking water source, because it was an actual drinking water supply for nearby residents before it was contaminated by PGDP and continues to be a drinking water source outside the Water Policy protection area. It currently is not used on-site within DOE property or off-site within the Water Policy Box for drinking water. DOE provides municipal water to certain nearby residences and businesses and this serves to limit off-site human exposure to contaminated groundwater.

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 1E-04 ft/ft, but increases by an order of magnitude near the Ohio River. (Vertical gradients are not well documented, but small.) The hydraulic conductivity of the RGA varies spatially. Pumping tests have documented the hydraulic conductivity of the RGA ranges from 53 ft/day to 5,700 ft/day. East-to-west flow of the ancestral Tennessee River, which laid down the Pleistocene Continental Deposits gravel member, tended to orient permeable gravel and sand lenses east-west. Thus, with the hydraulic head in the RGA generally decreasing northward toward the Ohio River, groundwater flow trends to the northeast and northwest from PGDP in response to the anisotropy of the hydraulic conductivity as well as the anthropogenic recharge, which is greatest in the industrial portion of the plant. Anthropogenic recharge from waterline leaks, lagoons, cooling tower basins, and other sources provides the primary driving force in moving groundwater in northeastern and northwestern flow directions from the industrial plant area. Ambient groundwater flow rates in the more permeable pathways of the RGA commonly range from 1 to 3 ft/day.

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

1.3.1.5.3 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 1.7). In descending order, the HUs are described below.

- Upper Continental Deposits
  - HU1 (UCRS): Loess that covers the entire site.

— HU2 (UCRS): Discontinuous, sand and gravel lenses in a clayey silt matrix. In some areas of the plant, the HU2 interval consists of an upper sand and gravel member (HU2A) and a lower sand and gravel member (HU2B) separated by a thin silt unit.

— HU3 (UCRS): Relatively impermeable unit that acts as the upper semiconfining-to-confining layer for the RGA. The lithologic composition of HU3 varies from clay to fine sand, but is predominantly silt and clay.

— HU4 (RGA): Near-continuous sand unit with a clayey silt matrix that forms the top of the RGA.

- Lower Continental Deposits

  — HU5 (RGA): Gravel, sand, and silt.

1.3.1.6 DOE plant controls

Current DOE plant controls for PGDP are described below.

- The SWMU is 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 PGDP is prohibited by security fencing, and armed guards patrol DOE property 24 hours per day to restrict worker entry and prevent uncontrolled access by the public/site visitors.

- Vehicle and personnel access to SWMU 4 is restricted by passage through two security fences. Passage through the first fence is at a manned security check point; passage through the second fence is through a locked gate.

- SWMU 4 is in an area that is subject to routine patrol and visual inspection by plant protective forces, at a minimum of six times per day.

- 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 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 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 the site, DOE will comply with the applicable requirements of Section 120(h) in effecting that sale or transfer, including all notice requirements. In addition, Section XLII of the FFA requires DOE to notify EPA and KY of any such sale or transfer at least 90 days prior to such sale or transfer.

1.3.2 SWMU 4 History

SWMU 4 encompasses the C-747 Burial Yard and the C-748-B Burial Area. The C-747 Burial Yard was in operation from 1951 to 1958 for disposal of radiologically contaminated and uncontaminated debris originating from the C-410 uranium hexafluoride feed plant. The area originally consisted of two pits covering an area of approximately 8,300 ft^2 (50 ft by 15 ft and 50 ft by 150 ft) (Union Carbide 1978).

According to employee interviews, a majority of the contaminated metal was buried in the northern part of the C-747 Burial Yard. Some of the trash was burned before burial. Scrapped equipment with surface contamination from the enrichment process also was buried. When the yard was closed, a smaller cell was reported to have been dug for the disposal of radiologically contaminated scrap metal (Union Carbide 1978).

The C-748-B Burial Area, located on the west side of C-747, is identified as a "Proposed Chemical Landfill Site" in the 1973 Union Carbide document on waste disposal (Union Carbide 1973). The C-748-B Burial Area was incorporated into SWMU 4 starting in the mid-1990s as a result of the review of a geophysical survey. With this incorporation, the area of the SWMU was changed from 8,300 ft^2 to 286,700 ft^2 (6.58 acres), and this change was documented in a revised SWMU Assessment Report (DOE 2007a). In fall of 1999, employee interviews led to the designation of the SWMU as a classified area, and appropriate access restrictions were implemented.

SWMU 4 also may have received sludges designated for disposal at the C-404 Burial Ground. The source of these sludges is unknown, but the Waste Area Grouping (WAG) 3 RI Work Plan (DOE 1998) indicated that the sludges potentially included uranium-contaminated solid waste and technetium-99 (Tc-99)-contaminated magnesium fluoride. In the February 10, 2012, the Memorandum of Agreement resolving the Formal Dispute for the D2 Feasibility Study for the Burial Grounds Operable Unit (DOE 2012), the FFA parties recognized that high-concentration uranium waste intended for disposal at SWMU 3, based upon site history and process knowledge, may have been disposed of and, therefore, may be present at SWMU 4 (possibly in the form of sludge).

Five primary burial cells are based on geophysical interpretations. Historical and process information indicates that the burial cells have a maximum depth of 15 ft to 18 ft bgs. The direct measurement of the depth of the water table beneath SWMU 4 reported in the Waste Area Grouping (WAG) 3 Report has the shallowest groundwater elevation at approximately 18 ft bgs; thus, SWMU 4 waste was not found to be in groundwater during the WAG 3 investigation. The potential for waste in the burial cells to be located beneath the water table at SWMU 4 was confirmed in the SWMU 4 RI Addendum fieldwork. Excavation in the SWMU 4 landfill cells identified the level to groundwater was variable. The depths identified varied from 1.1 ft to 11 ft bgs. The variation depended upon the location within the SWMU and the season.

An active subsurface raw water pipeline is present across the southeastern portion of the SWMU, traversing the SWMU diagonally (see Figure 1.6). The pipeline gets as close as ~ 30 ft from the nearest delineated burial cell. The lowest point of the pipeline is at an elevation of approximately 367 ft amsl, which is approximately 8 ft to 10 ft below the current grade in the area (DOE 2010b).

Historical information that is known about SWMU 4 is compiled in Table 1.2. Based upon disposal records, SWMU 4 contains industrial wastes, some of which are LLW. Industrial wastes in burial grounds at PGDP are known to contain waste that could be contaminated with PCBs or be RCRA hazardous wastes. Based upon the waste inventory and other data collected during the RI and RI Addendum fieldwork, other buried wastes at SWMU 4 (including LLW) are considered low-level threat waste. Pursuant to the Resolution Agreement among the FFA parties, dated February 10, 2012, TCE dense nonaqueous-phase liquid (DNAPL) and high concentrations of TCE in soils are considered PTW

Table 1.2. Summary of Historical Information for BGOU SWMU 4

Dates of Operation	Area of Waste	Cover[a]	Volume of Contaminated Media Disposed of at SWMU 4	Known or Expected Contents (Special Hazards)
SWMU 4 C-747 Burial Yard				
1951–1958	8,300 ft^2 (16-ft deep)	2–3 ft soil 6-inch clay	Unknown	Debris (radiologically contaminated) from uranium hexafluoride feed plant
SWMU 4 C-748-B Burial Area				
1973–1978	278,400 ft^2 (16-ft deep)	2–3 ft soils 6-inch clay	Unknown	Proposed chemical landfill[b]

Table 1.2 is based on Table 1.3 of the BGOU RI Report (DOE 2010b).
[a] The source material used for the soil cover is unknown.
[b] The "Proposed Chemical Landfill" is the only name used to describe this burial area (Union Carbide 1973).

(DOE 2012). Based on the RI and the RI Addendum fieldwork data, the extent of the TCE PTW is thought to be limited to two areas of subsurface soil located beneath Cell 4 (see Figure 1.9). Further, the RI Addendum Report stated that no uranium source materials such as those described in historical records for SWMU 2 (i.e., uranium shavings and sawdust, and drums of uranyl fluoride solution) and SWMU 3 (i.e., bulk uranium and possible pyrophoric uranium) were observed during the supplemental investigation at SWMU 4. The collected data for SWMU 4 do not indicate the presence of high concentrations or significant quantities of uranium or potential uranium source material.

1.3.3 Nature and Extent of Contamination

The current understanding of the nature and extent of contamination at SWMU 4 in surface soils, subsurface soils, and groundwater was derived from historical investigations and data collected for the BGOU SWMU 4 RI Addendum fieldwork. The primary goal of the RI Addendum fieldwork was to address the identified data gaps and uncertainties that remained after completion of the BGOU RI Report (DOE 2010b) by further characterization of nature, extent, and magnitude of source zones and secondary sources at SWMU 4. The BGOU SWMU 4 RI Addendum fieldwork followed the field sampling plan outlined in the BGOU RI/FS Work Plan Addendum (DOE 2014a).

The primary objective of the data processing and screening for SWMU 4 was to identify potential site-related contaminants and delineate the extent of the potential contaminants. To achieve this goal, the analytical soil results of the RI Addendum fieldwork were compared to PGDP surface and subsurface soil background concentrations and applicable screening values. The historical data initially were screened during the BGOU RI (DOE 2010b).

Separate vertical boundaries and media designations were established for defining the nature and extent of contamination at SWMU 4 and for estimating potential risk at the SWMU. These boundaries are as follows:

- **Surface Soils.** The vertical extent of surface soils with respect to nature and extent was 0–1 ft bgs. These soils were screened against surface background values and groundwater protection screening values for the UCRS [i.e., a dilution attenuation factor (DAF) of 1] and for the RGA (i.e., a DAF of 58). Additionally, surface soils were screened against industrial worker no action levels (NALs)/action levels (ALs) and excavation worker NALs/ALs.

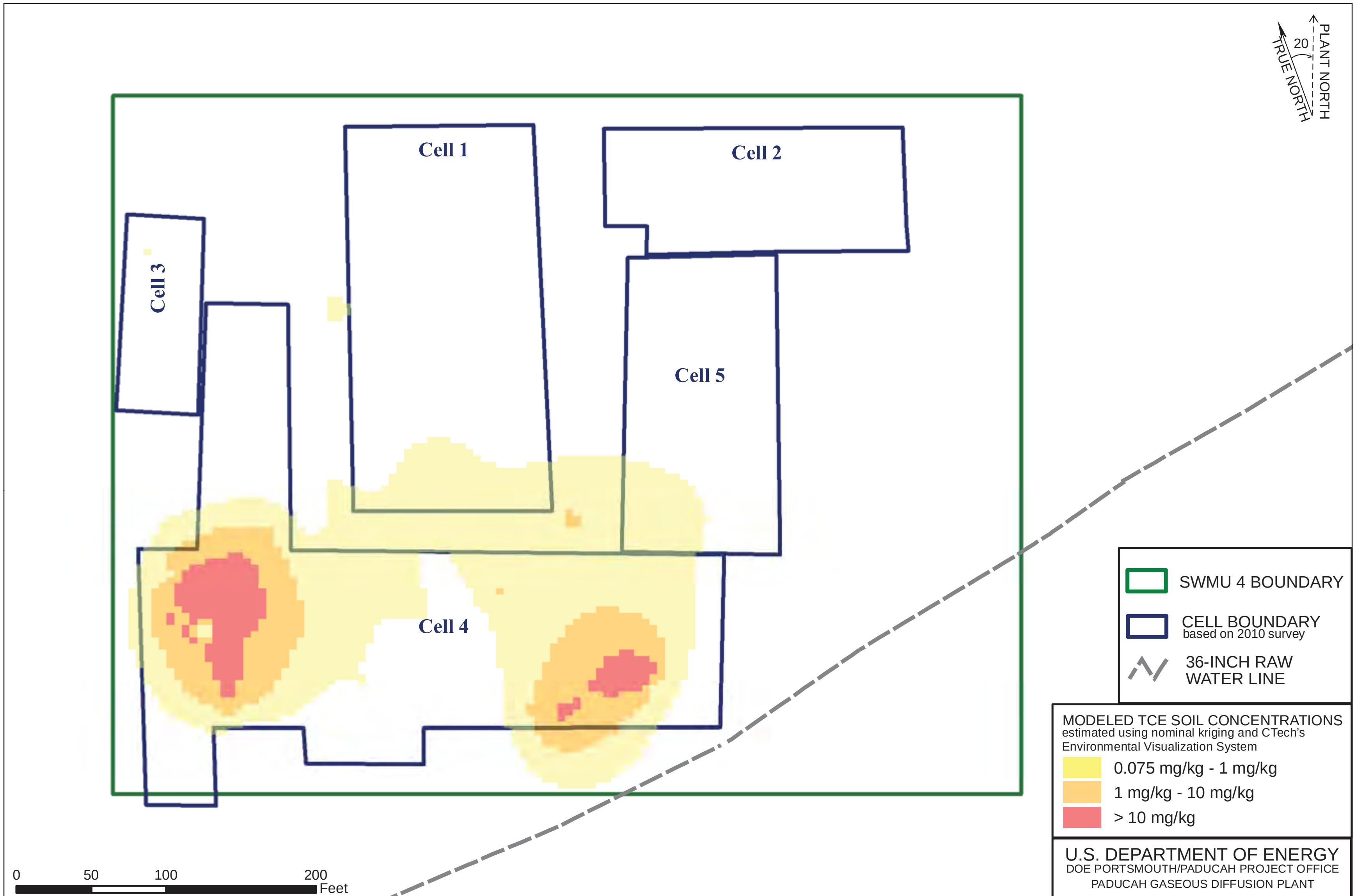


Figure 1.9. Approximate Areas of the Five Primary Burial Cells at SWMU 4 with BGOU RI Addendum Subsurface Soil Trichloroethene Results

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2/16/2017

- **Subsurface Soils.** The vertical extent of subsurface soil with respect to nature and extent was 1–60 ft bgs. These soils were screened against subsurface background values and groundwater protection screening values for the UCRS and for the RGA. Subsurface soils from 1–20 ft bgs also were screened against excavation worker NALs/ALs for nature and extent comparison. [The Risk Methods Document lists 0–16 ft bgs for comparison to the excavation worker (DOE 2015b); however, the maximum depth of 20 ft is used in order to fully encompass the maximum depth of burial.] Potential risk was estimated for the excavation worker using surface and subsurface soils (0–20 ft bgs). Soils deeper than 60 ft bgs are not screened against groundwater protection screening values or background because they are within the RGA.

- **Groundwater.** Results from groundwater samples are divided into UCRS, RGA, and McNairy data sets. Groundwater data were screened against residential NALs/ALs and MCLs for nature and extent comparison. Additionally, RGA and McNairy data were screened against background values. Potential risks were estimated for the child resident using RGA and McNairy results.

1.3.3.1 Key findings on nature and extent of contamination

Section 4 of the BGOU SWMU 4 RI Addendum Report (DOE 2017) provides an evaluation of historical and current data and presents summary tables containing analytical results from the screening process. The following are key findings from the BGOU SWMU 4 RI Addendum Report and outline the nature and extent of contamination at SWMU 4.

- Subsurface soil and groundwater have been impacted by releases of contaminants from waste. Contamination resulting from the buried waste is found concentrated in the UCRS soils and groundwater immediately within and under the burial cells, with a lesser amount of contamination dispersed laterally from the cells. In addition, activities at SWMU 4 have resulted in contamination of surface soil.

- TCE trends in the UCRS and RGA groundwater indicate that TCE DNAPL is present at SWMU 4 in the subsurface soils of the UCRS. While TCE contamination is found in Burial Cells 1, 4, and 5, the contaminant levels within the upper 20 ft in the burial cells at SWMU 4 do not indicate the presence of a DNAPL source within the burial cells.

- Excess lifetime cancer risks (ELCRs) greater than 1E-06 and HIs greater than 1 exist for the industrial worker and excavation worker scenarios for surface and subsurface soils, respectively. Arsenic, Total polycyclic aromatic hydrocarbons (PAHs), Total PCBs, cesium-137, neptunium-237, thorium-230, uranium-234, uranium-235, and uranium-238 present the dominant risks from exposure to surface and subsurface soil. The major contaminants presenting groundwater risks (ELCRs greater than 1E-04 or HIs greater than 3) in the RGA include arsenic, cobalt, iron, manganese, vanadium, 1,1,2-trichloroethane (TCA), chloroform, *cis*-1,2-dichloroethene (DCE), TCE, and vinyl chloride.

- Ecological risk screening identified several chemicals or radionuclides of potential ecological concern (COPECs) whose maximum concentration was greater than 10 times their ecological screening value. These included PCBs, PAHs, and metals (aluminum, cadmium, chromium, iron, manganese, mercury, and uranium).

- Analytical results from both surface and subsurface soil were compared to screening values [i.e., soil screening levels (SSLs)] for the protection of both UCRS and RGA groundwater. Contaminants that most commonly exceeded both background values and the screening level for the protection of RGA groundwater include the following: iron, silver, uranium and its isotopes, Total PCBs, TCE, *cis*-1,2-DCE, vinyl chloride, and Tc-99. TCE and its degradation products exceeded the RGA groundwater protection screening values from approximately 15 ft to 60 ft bgs.

1.3.4 Conceptual Site Model

The waste materials in SWMU 4 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 UCRS soils, ultimately reaching the RGA (Figure 1.10). Some lateral movement of contaminants could occur in the UCRS, but these pathways are considered to be limited. Based on this conceptual model, any contamination resulting from buried waste found at SWMU 4 is 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 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 SWMU 4 investigations and basis for evaluation of remedial alternatives.

Sources of contamination to the RGA considered in the BGOU SWMU 4 RI Addendum Report for SWMU 4 are waste materials in the burial cells and TCE contaminated soil. Releases from SWMU 4 have impacted soils below or adjacent to the burial cells. Through vertical infiltration in soil, these sources have contaminated the underlying groundwater. Subsequently, contaminated groundwater has migrated to various points of exposure (POEs). The potential POEs for SWMU 4 identified in the BGOU RI Report were the SWMU boundary, plant boundary, property boundary, and the Ohio River. Contaminant migration could have impacted three HUs underlying SWMU 4. These units, which control the flow of shallow groundwater and contaminant migration, are as follows, in descending depth order:

- UCRS—approximately 60 ft to 65 ft of silt and clay with horizons of sand and gravel;
- RGA—approximately 40 ft of gravel and sand deposits that overlie the McNairy Formation; and
- McNairy Formation—approximately 225 ft of silty and clayey sand that forms a lower confining unit to the RGA.

A previous uncertainty, identified as a data gap in the BGOU Work Plan Addendum, was the possible role of the bedding material surrounding the raw water pipe in the southeastern portion of SWMU 4 acting as a preferential pathway for migration outside of the SWMU. Based on the subsurface soil and passive soil gas data collected from Phases I and II of the SWMU 4 investigation, there is no evidence to suggest the bedding materials surrounding the raw water pipe have been impacted by site constituents or that the bedding materials act as a preferential pathway for migration of contaminants outside SWMU 4. While there may still be some uncertainty with this data gap, the uncertainty is small based on the data that have been collected and should not preclude the FS from evaluating alternatives for SWMU 4.

SWMU 4 is located inside the Limited Area. Although there is potential for contamination below the surface to migrate laterally toward surface water, the direction of shallow groundwater flow is primarily downward and represents limited risks to terrestrial receptors near these sites. Appendix D of the BGOU SWMU 4 RI Addendum Report presents a brief summary of the ecosystem relevant to defining the CSM and exposure pathways.

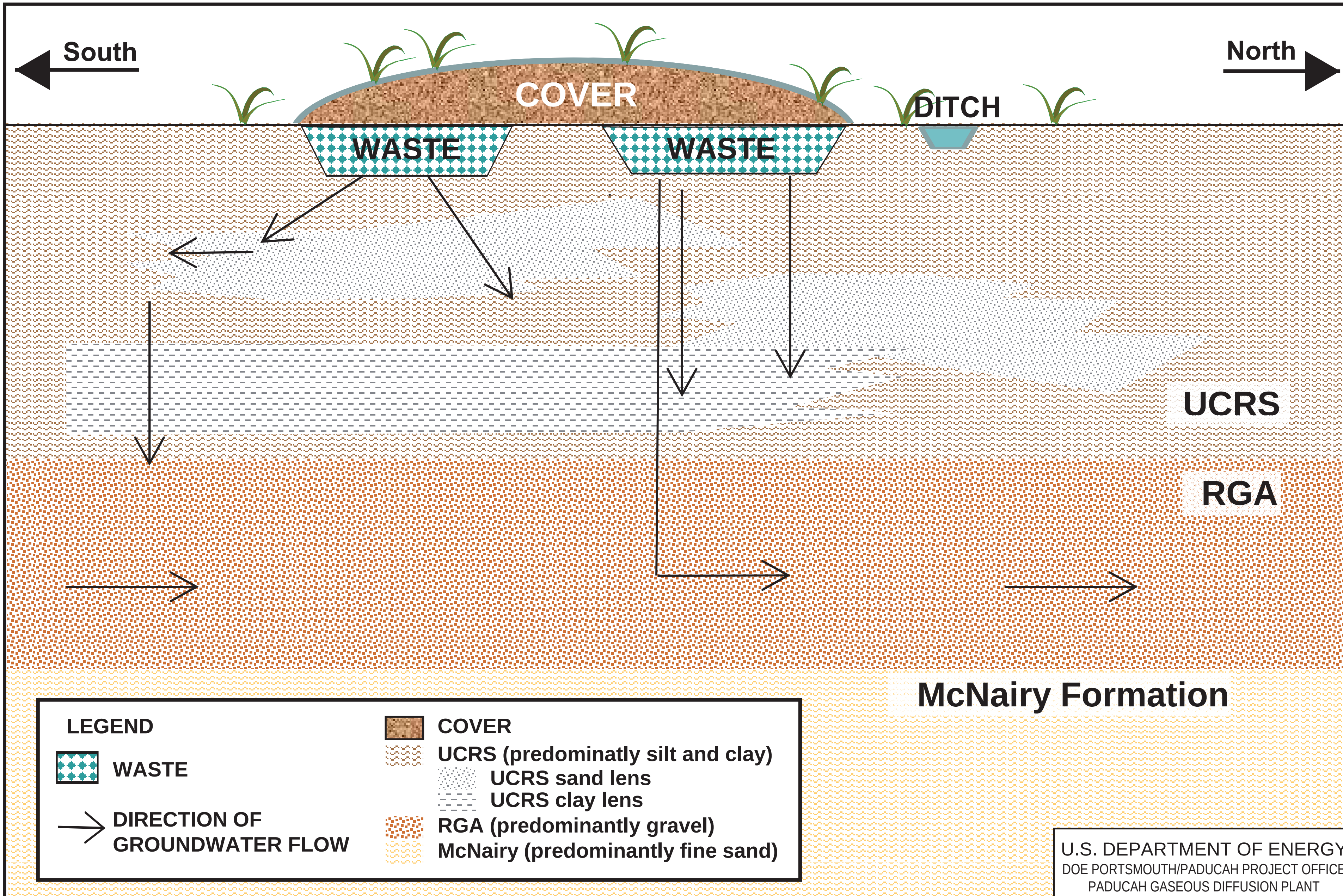

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Figure 1.10. Pictorial Conceptual Model of SWMU 4

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 also may 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.

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.

1.3.5.2 Contaminant transport

The transport of contaminants from SWMU 4 will occur primarily in the dissolved phase. This will occur due to partitioning from the solid or adsorbed phase to infiltrating rainfall or to groundwater where waste is saturated, which is an identified condition in SWMU 4. 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 of 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. 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.

1.3.5.3 Contaminant fate and transport modeling summary

For the BGOU RI Report, modeling assessed fate and transport of contaminants for two pathways: (1) dissolved-phase transport through the aquifer and (2) vapor transport to a residential basement. Section 5 and Appendix E of the BGOU RI document the fate and transport modeling performed for SWMU 4 (DOE 2010b). Modeling predicted the maximum concentration of analytes in groundwater at the SWMU boundary. Contaminants that were predicted to exceed the MCL at the SWMU 4 boundary included arsenic, *cis*-1,2-DCE, TCE, vinyl chloride, and Tc-99. The groundwater modeling results for SWMU 4 show that the predicted groundwater concentrations of *cis*-1,2-DCE, TCE, vinyl chloride, and Tc-99 will exceed their respective MCLs[3] at the plant boundary and DOE property boundary (DOE 2010b). TCE was the only contaminant predicted to exceed the MCL at the Ohio River POE.

[3] The MCL for Tc-99 is 4 mrem/yr. The value derived by EPA from the 4 mrem/yr MCL for Tc-99 is 900 pCi/L. An alternate value derived by EPA from the 4 mrem/yr MCL is 3,790 pCi/L and was proposed in the July 18, 1991, *Federal Register*. Results in the BGOU SWMU 4 RI Addendum Report are screened using 900 pCi/L, which is consistent with BGOU RI Report (DOE 2010b).

Vapor transport modeling assessed contaminant concentrations in a hypothetical residential basement at the SWMU and in hypothetical residential basements at POEs. (Appendix E, Section E.3.2 of the BGOU RI documents the vapor transport modeling performed for SWMU 4.) The resident scenario provides bounding risks and hazards for the vapor pathways when compared to the industrial worker exposure scenario. Hence, the industrial worker exposure scenario was not evaluated in the vapor modeling analysis. At SWMU 4, the vapor transport modeling for TCE at the on-site, plant boundary, and property boundary POEs exceeded the ELCR of 1E-06 or an HI of 0.1. Other contaminants exceeding the risk or hazard criteria at the on-site POE were *cis*-1,2-DCE and vinyl chloride.

1.3.5.4 Groundwater fate and transport modeling

Prior to the BGOU SWMU 4 RI Addendum fieldwork, the WAG 3 RI (DOE 2000a) provided the majority of data to characterize groundwater at SWMU 4. Temporary borings of the Southwest Plume Site Investigation (DOE 2007b) and a sitewide remedial evaluation for source areas (DOE 2000b) supplied additional RGA data for the SWMU 4 area. Data from historical investigations were combined with data from the current investigation to create a comprehensive data set for evaluation of groundwater at SWMU 4.

For the BGOU SWMU 4 RI Addendum Report, surface and subsurface soil analytical results were screened against screening values for the protection of both UCRS and RGA groundwater (DOE 2017). This screening is discussed in Section 4, with screening results provided in Tables 4.4 and 4.5 of the aforementioned report. The contaminants that most commonly exceeded the screening level for the protection of RGA groundwater are summarized below. In surface soil, the following contaminants most commonly exceeded the SSL for protection of RGA groundwater and background, where background values are available: silver, uranium and its isotopes, Total PCBs, and Tc-99. In SWMU 4 subsurface soil, the following contaminants most commonly exceeded the SSL for protection of RGA groundwater and the background screening levels, where background values are available: iron, uranium and its isotopes, Total PCBs, TCE, *cis*-1,2-DCE, vinyl chloride, and Tc-99. TCE was the most common volatile organic compound (VOC) to exceed the SSL for protection of RGA groundwater, with 63 of 400 analyses exceeding the value. TCE and its degradation products exceeded groundwater protection SSLs from approximately 15 ft to 60 ft bgs.

1.3.6 Risk Screening Evaluation Summary

Current land use of SWMU 4 is industrial. Under current use, because of access restrictions, only plant workers and authorized visitors are allowed access to the SWMU. As discussed in the PGDP SMP (DOE 2015a), foreseeable future land use of the area is expected to be industrial as well.

Consistent with the BGOU Work Plan Addendum, data collected from this sampling effort has been used to conduct a risk screening for the industrial worker. Risk screening used surface background values and NALs for the industrial worker from the Risk Methods Document (DOE 2015b) for surface soil (0−1 ft bgs), and subsurface background values and excavation worker NALs for the surface and subsurface soil (0–20 ft bgs).

For SWMU 4, there were 7 chemical or radionuclide of potential concerns (COPCs) that had an ELCR > 1E-06 or HI > 1 for the future industrial worker scenario exposed to surface soil and 9 COPCs that had an ELCR > 1E-06 and/or HI > 1 for the future excavation worker scenario exposed to surface and subsurface soil. COPCs that exceeded a cancer risk of 1E-06 or an HI above 1.0 included arsenic, Total PAH, Total PCBs, cesium-137, neptunium-237, thorium-230, uranium-234, uranium-235, and uranium-238.

For exposure to groundwater, the BGOU RI Work Plan Addendum called for comparison to NALs for the child resident exposure scenario because no NALs for an industrial worker being exposed to groundwater have been established (DOE 2014a). For groundwater, 17 COPCs in the RGA and 11 COPCs in the McNairy had an ELCR > 1E-06 and/or HI > 1 when compared to the child residential scenario. RGA COPCs with a cancer risk above 1E-06 or an HI above 1.0 include aluminum, arsenic, cobalt, iron, manganese, vanadium, 1,1,2-TCA, 1,1-DCE, benzene, carbon tetrachloride, chloroform, *cis*-1,2-DCE, ethylbenzene, TCE, vinyl chloride, Tc-99, and uranium-234. Of these, arsenic, cobalt, iron, manganese, vanadium, 1,1,2-TCA, chloroform, *cis*-1,2-DCE, TCE, and vinyl chloride exceed a cancer risk above 1E-04 or an HI above 3.0. McNairy COPCs include aluminum, arsenic, barium, beryllium, cadmium, chromium, iron, manganese, mercury, vanadium, and zinc.

The BGOU RI BHHRA used fate and transport modeling to determine the major contaminants driving the RGA groundwater risks and hazards for SWMU 4. The priority COCs, determined from modeling, were arsenic, manganese, *cis*-1,2-DCE, TCE, vinyl chloride, and Tc-99. While the TCE DNAPL zone at SWMU 4 was not specifically modeled for the BGOU RI BHHRA, it also would have exceeded 1E-04 risk at the property boundary and Ohio River POEs (DOE 2010b).

Table 1.3 shows a summary of estimated potential direct contact risks for SWMU 4 for the appropriate media/scenario, derived using comparisons to NALs.

Table 1.3. Summary of Estimated Maximum Direct Contact Total ELCR and Total HI for SWMU 4

		Direct Contact	
Media	**Scenario**	**Total ELCR**	**Total HI**
Surface Soil (0–1 ft bgs)	Industrial Worker	**8.3E-05**	< 1
Surface and Subsurface Soil (0–20 ft bgs)	Excavation Worker	**7.6E-05**	**1.1**
Groundwater (RGA)	Resident (child)	***5.3E-03***	***732.9***
Groundwater (McNairy)	Resident (child)	***7.6E-04***	***222.8***

Bold indicates total HI > 1 or total ELCR > 1E-06; ***bold italics*** indicates total HI > 3 or total ELCR > 1E-04.

Consistent with the BGOU Work Plan Addendum, a risk screening has been conducted for SWMU 4. Additional information associated with the SWMU 4 BHHRA, previously performed as part of the BGOU RI, has not been updated.

Consistent with the Paducah Ecological Risk Methods Document (DOE 2015c), which incorporates both EPA and KY risk assessment guidance, a SERA was performed for SWMU 4. The SERA was limited to a comparison of maximum concentrations in the upper 5 ft of soils at the SWMU against ecological screening levels in order to identify COPECs. The SERA does not consider the limited habitat, SWMU size, or other factors that also need to be considered to characterize ecological risk. The following observations were made for the SERA, as summarized on Table 1.4.

Table 1.4. Summary of Suite of COPECs Retained in Soil

Number of Metals	Number of Radionuclides	Number of PCBs	Number of SVOCs	Number of VOCs
19[a]	**2[b]**	**1[c]**	**2[d]**	**0[e]**

Table 1.4 is taken from Table 7.2 of the BGOU SWMU 4 RI Addendum Report (DOE 2017).
[a] Based on information in Appendix D of the BGOU SWMU 4 RI Addendum (DOE 2017), the 19 metals that are COPECs at SWMU 4 are aluminum, arsenic, barium, cadmium, calcium, chromium, copper, iron, lead, manganese, mercury, molybdenum, nickel, potassium, silver, sodium, uranium, vanadium, and zinc.
[b] Based on information in Appendix D of the BGOU SWMU 4 RI Addendum Report (DOE 2017), the 2 radionuclides that are COPECs at SWMU 4 are protactinium-234m and thorium-234 (both retained because no screening value was available).
[c] Based on information in Appendix D of the BGOU SWMU 4 RI Addendum Report (DOE 2017), the PCB that is a COPEC at SWMU 4 is Total PCB.
[d] Based on information in Appendix D of the BGOU SWMU 4 RI Addendum Report (DOE 2017), the 2 SVOCs that are COPECs at SWMU 4 are bis(2-ethylhexyl)phthalate and high molecular weight PAHs.
[e] Based on information in Appendix D of the BGOU SWMU 4 RI Addendum Report (DOE 2017), no VOCs are COPECs at SWMU 4.

1.4 SUMMARY, CONCLUSIONS, AND UNCERTAINTIES FROM THE BGOU SWMU 4 RI ADDENDUM REPORT

This section summarizes the major findings and uncertainties from the BGOU SWMU 4 RI Addendum Report.

1.4.1 Major Findings from the BGOU SWMU 4 RI Addendum Report

The following are the major findings from the SWMU 4 RI Addendum.

- The investigation has provided data, particularly related to the nature and extent of contamination at SWMU 4, that are sufficient and adequate for proceeding with the FS and subsequent CERCLA documents.

- Environmental media, specifically subsurface soil and groundwater, have been impacted by releases of contaminants from waste. Contamination resulting from the buried waste is found concentrated in the UCRS soils and groundwater immediately within and under the burial cells, with a lesser amount of contamination dispersed laterally from the cells. In addition, activities at SWMU 4 have resulted in contamination of surface soil.

- TCE trends in the UCRS and RGA groundwater indicate that TCE DNAPL is present at SWMU 4 in the subsurface soils of the UCRS below the bottom of the waste burial cells. While TCE contamination is found in Burial Cells 1, 4, and 5, the contaminant levels within the upper 20 ft in the burial cells at SWMU 4 do not indicate the presence of a DNAPL source within the burial cells. This indicates the TCE DNAPL source no longer is present within the burial cells or emanating from an isolated point source at the base of the burial cell (greatest soil concentration of TCE was from a sample collected at a depth interval of 25 to 30 ft below ground surface beneath Burial Cell 4). Also, the elevated TCE concentrations in the RGA beneath SWMU 4 likely are the result of a TCE DNAPL source in the UCRS rather than a DNAPL source within the RGA. (Note: The expected depth of the DNAPL is below the buried waste approximately 5–10 ft.)

- The risk screening update indicates that ELCRs greater than 1E-06 and HIs greater than 1 exist for the industrial worker and excavation worker scenarios for surface and subsurface soils, respectively. Arsenic, Total PAH, Total PCBs, cesium-137, neptunium-237, thorium-230, uranium-234, uranium-235, and uranium-238 present the dominant risks from exposure to surface and subsurface soil. The major contaminants presenting groundwater risks (ELCRs greater than 1E-04 or HI greater than 3) in the RGA include arsenic, cobalt, iron, manganese, vanadium, 1,1,2-TCA, chloroform, *cis*-1,2-DCE, TCE, and vinyl chloride.

- Ecological risk screening includes several COPECs. COPECs whose maximum concentration was greater than 10 times their ecological screening value include PCBs, PAHs, and metals (aluminum, cadmium, chromium, iron, manganese, mercury, and uranium).

- Analytical results from both surface and subsurface soil were screened against screening values for the protection of both UCRS and RGA groundwater. Contaminants that most commonly exceeded both background values and the screening level for the protection of RGA groundwater include the following: iron, silver, uranium and its isotopes, Total PCBs, TCE, *cis*-1,2-DCE, vinyl chloride, and Tc-99. TCE and its degradation products exceeded the RGA groundwater protection screening values from approximately 15 ft to 60 ft bgs.

1.4.2 Uncertainties Identified in the BGOU RI Report

In January 2011, EPA, KY, and DOE convened to discuss SWMU 4 data gaps and uncertainties that remained after completion of the BGOU RI Report. As part of the DQO meetings in January 2011, data at SWMU 4 were determined to be sufficient to develop an excavation alternative for buried materials and associated contaminated soils at SWMU 4, but were not sufficient to optimize remedy selection or support remedial design (RD). The BGOU RI Addendum fieldwork for SWMU 4 was conducted to address these data gaps. The data from the RI Addendum fieldwork were combined with the historical data to form a comprehensive data set that resolved the data gaps. Remaining uncertainty did not hinder the development of this FS. Section 7 of the BGOU SWMU 4 RI Addendum Report provides detailed summaries and conclusions reached in closing the data gaps (DOE 2017).

2. IDENTIFICATION AND SCREENING OF TECHNOLOGIES

A primary objective of this FS is to identify remedial technologies and process options that upon implementation may potentially meet the remedial action objectives (RAOs) for a remedial action and then combine them into a range of remedial alternatives. RAOs and preliminary remediation goals (PRGs) 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 SWMU 4 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 be protective of human health and the environment. The technology screening process consists of a series of steps that include the following:

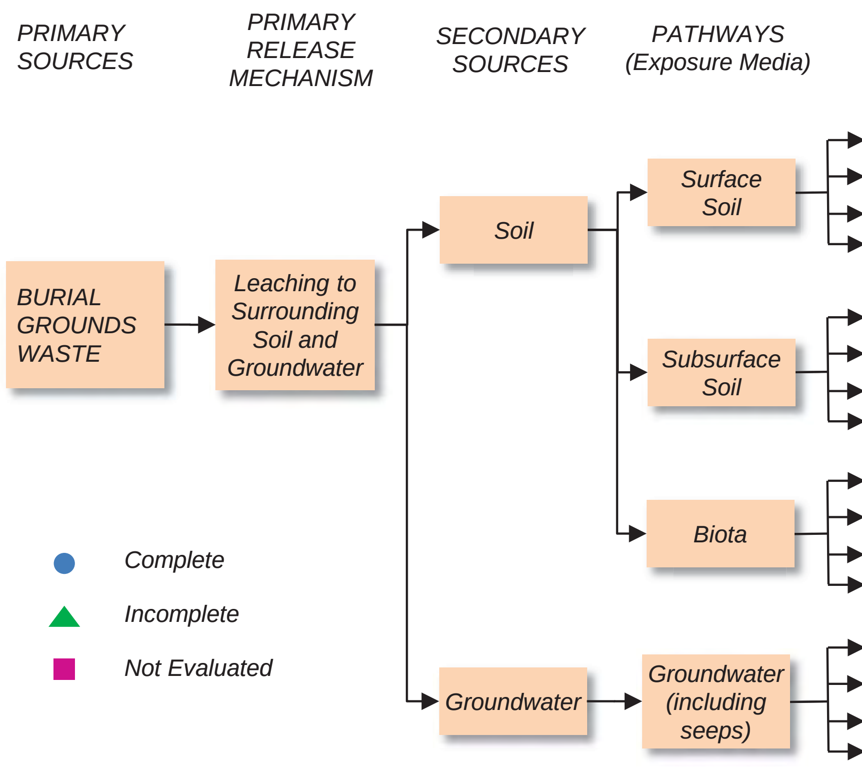
- Identifying general response actions (GRAs) that will meet RAOs, either individually or in combination with other GRAs;
- Identifying a volume or area of media to which the GRA will be applied;
- Identifying, screening, and evaluating remedial technology types for each GRA; and
- Selecting one or more 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 in Section 3, and then are evaluated in the detailed and comparative analyses of alternatives found in Section 4 of this FS.

2.1 INTRODUCTION

Previous PGDP investigations and reports used to develop the CSM and to identify and screen remedial technologies are summarized in Section 1.2. 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 5.

Technologies are identified and evaluated in this FS based on their effectiveness in eliminating direct contact risk with surface soil, subsurface soil, waste, and soils in close proximity to 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 SWMU 4 source area (Figure 2.1). Finally, RPOs are selected from the appropriate technology types necessary to address the physical and chemical nature of the contamination at SWMU 4. Alternatives will be developed by combining the appropriate RPOs in a manner sufficient to remediate the full scope of contamination at SWMU 4.



Pathway	EXPOSURE ROUTE	Current Industrial Worker	Future Industrial Worker	Future Excavation Worker	Future Recreational User	Future Rural Resident
Surface Soil	Ingestion	Complete	Complete	Complete	Complete	Complete
Surface Soil	Inhalation	Complete	Complete	Complete	Complete	Complete
Surface Soil	Dermal	Complete	Complete	Complete	Complete	Complete
Surface Soil	External (Radiation)	Complete	Complete	Complete	Complete	Complete
Subsurface Soil	Ingestion	Incomplete	Incomplete	Complete	Incomplete	Incomplete
Subsurface Soil	Inhalation	Incomplete	Incomplete	Complete	Incomplete	Incomplete
Subsurface Soil	Dermal	Incomplete	Incomplete	Complete	Incomplete	Incomplete
Subsurface Soil	External (Radiation)	Incomplete	Incomplete	Complete	Incomplete	Incomplete
Biota	Ingestion	Incomplete	Incomplete	Incomplete	Complete	Not Evaluated
Biota	Inhalation	Incomplete	Incomplete	Incomplete	Incomplete	Not Evaluated
Biota	Dermal	Incomplete	Incomplete	Incomplete	Incomplete	Not Evaluated
Biota	External (Radiation)	Incomplete	Incomplete	Incomplete	Incomplete	Not Evaluated
Groundwater (including seeps)	Ingestion	Incomplete	Incomplete	Incomplete	Incomplete	Complete
Groundwater (including seeps)	Inhalation	Incomplete	Incomplete	Incomplete	Incomplete	Complete
Groundwater (including seeps)	Dermal	Incomplete	Incomplete	Incomplete	Incomplete	Complete
Groundwater (including seeps)	External (Radiation)	Incomplete	Incomplete	Incomplete	Incomplete	Incomplete

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Figure 2.1. Conceptual Site Model for SWMU 4

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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 SWMU 4 FS were developed in accordance with NCP requirements, consist of site-specific goals for protecting human health and the environment (EPA 1988), and meet 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 and the contaminant migration pathways and exposure scenarios the action will address.

2.2.1 ARARs

ARARs include federal or more stringent state or local 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 A.

ARARs typically are divided into three categories: (1) chemical-specific, (2) location-specific, and (3) action-specific. "Chemical-specific ARARs usually are health-based 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 wastes or soils at the source areas with identified COCs.

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 SWMU 4 FS evaluates taking actions as necessary to protect human health and the environment from SWMU 4 contamination and addressing releases or potential releases from SWMU 4 source areas that may impact RGA groundwater. The following general RAOs were developed.

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

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

(3) Treat or remove PTW wherever practicable, consistent with 40 *CFR* § 300.430(a)(iii)(A).

SWMU 4 is located within the industrial area of the PGDP facility, and a reasonable future use of this area is expected to remain industrial (DOE 2014a). The RAOs presented in this section are relative to future industrial worker and future excavation worker receptors only. This FS evaluates alternatives designed to eliminate direct contact with wastes to ensure no risk to these future workers. Figure 2.1, "Conceptual Site Model for SWMU 4," identifies that the surface soil exposure pathway also is complete for the current industrial worker, future recreational user, and future rural resident.

For each of these general RAOs, a SWMU-specific RAO is defined. The following are the SWMU-specific RAOs.

SWMU 4-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 RGA groundwater of the MCL (or risk-based concentration for residential use of groundwater in the absence of an MCL).

SWMU 4-specific RAO 2. Prevent exposure to waste that exceeds target cumulative ELCRs and cumulative non-cancer HIs for the future excavation worker receptor. The acceptable cumulative risk levels for this RAO are defined as follows:

- Waste: Cumulative ELCR < 1E-05 and cumulative HI ≤ 1 for a future excavation.

SWMU 4-specific RAO 3. Prevent exposure to contaminated soils that exceed target cumulative ELCRs and cumulative non-cancer HIs for the current and future industrial worker and future excavation 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 current and future industrial worker (considering default exposures in the Risk Methods Document).

- Surface and Subsurface Soil: Cumulative ELCR < 1E-05 and cumulative HI ≤ 1 for a future excavation worker.

SWMU 4-specific RAO 4. Treat or remove PTW wherever practicable, consistent with 40 *CFR* § 300.430(a)(iii)(A).

The RAOs may not fully address those risks that are addressed more appropriately in other programs and are not within the scope of the BGOU SWMU 4 unit. Specifically, no remediation goals (RGs) will be identified in this FS to address potential ecological impacts or to address dissolved VOC concentrations in the RGA originating from SWMU 4 or other source areas.

The sitewide baseline ecological risk assessment is where cumulative effects to ecological receptors will be evaluated. COPCs identified in the SWMU 4 RI SERA will be incorporated into that evaluation. Most of the impacts identified in the SERAs for SWMU 4 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 that required short-term actions at SWMU 4. In addition, addressing human health risks within the SWMU boundary also would be expected to reduce exposures to these receptors.

2.2.3 Preliminary Remediation Goals

PRGs for the target COPCs are presented in this section (Tables 2.1 through 2.3). The PRG for surface soil (0 to 1 ft bgs) is the lesser of the direct contact PRG for the future industrial worker, future site-specific excavation worker, and the groundwater protective PRG, unless this risk-based value is less than background [see Table A.12 of the Risk Methods Document (DOE 2016a)]. If the risk-based value is less than background, then background becomes the PRG for surface soil. The PRG for subsurface soil (0 to 20 ft bgs) is the lesser of the direct contact PRG for the future site-specific excavation worker and the groundwater protective PRG, unless this risk-based value is less than background. If the risk-based value is less than background, then background becomes the PRG for subsurface soil. Finally, the PRG for subsurface soil below 20 ft bgs is the greater of the groundwater protective PRG and background. Direct contact does not apply for soil below 20 ft consistent with guidance in the Risk Methods Document (DOE 2016a). [The Risk Methods Document lists 0–16 ft bgs for comparison to the excavation worker (DOE 2016a); however, the maximum depth of 20 ft is used in order to encompass fully the maximum depth of burial (DOE 2017).]

To ensure that the residual cumulative ELCR will be equal to or below the ELCR target of 1E-05, and the residual cumulative HI will be equal to or below the HI target of 1, PRGs were calculated using chemical-specific targets of an ELCR = 5E-06 and HI = 0.5.

One exception to the PRG determination described in the preceding paragraph is for the direct contact PRG for Total PCBs. The direct contact PRG for Total PCBs of 10 mg/kg was agreed upon as part of risk management discussions during a June 2009 BGOU FS scoping meeting among DOE, EPA, and KY and is applied at other PGDP OUs as the PRG for soil at the BGOU. The 10 mg/kg PRG will be used as a starting point for PRG evaluation. The final RG for PCBs protective of the future industrial worker and future excavation worker will be presented in the record of decision (ROD). The 10 mg/kg value is not a Toxic Substances Control Act (TSCA) value, but is consistent with the risk-based cleanup value used for the Surface Water OU On-site Removal Action (i.e., 16 mg/kg), which was derived for industrial use and was determined to be protective for cumulative risk.

2.2.4 Basis for BGOU Technology Identification and Screening

Multiple field investigations have collected environmental data from within and around SWMU 4. As a result, specific waste characterization data are available information. The collective body of information that forms the basis for selecting remedial alternatives and preparing cost estimates for those alternatives are summarized in the BGOU SWMU 4 RI Addendum Report. The assumptions and rationale applied in developing estimates of the extent of contamination and the corresponding waste volumes are presented in the remaining sections of this FS.

2.3 GENERAL RESPONSE ACTIONS

GRAs describe those actions that potentially will satisfy the RAOs. This section develops GRAs that may be implemented individually or in combination to meet SWMU 4 RAOs.

GRAs for SWMU 4 FS include land use controls (LUCs), surface controls, monitoring, monitored natural attenuation (MNA), containment, removal, treatment, and disposal.

Table 2.1. SWMU 4 FS Preliminary Remediation Goals for Surface Soil

COPC	Units	Background[a]	Direct Contact PRG[b]	Groundwater-Protective PRG[c]	PRG for Surface Soil[d]
Arsenic	mg/kg	1.20E+01	8.00E+00	1.69E+01	1.69E+01
Total PAHs	mg/kg	N/A	4.41E-01	1.36E+01	4.41E-01
Total PCBs	mg/kg	N/A	1.48E+00	4.54E+00	1.00E+01[e]
Cs-137	pCi/g	4.90E-01	5.10E-01	2.78E+01	5.10E-01
Np-237	pCi/g	1.00E-01	1.15E+00	3.11E+00	1.15E+00
U-235	pCi/g	6.00E-02	1.70E+00	2.83E+00	1.70E+00
U-238	pCi/g	1.20E+00	8.00E+00	2.34E+00	2.34E+00

N/A = not available

[a] Background concentrations taken from Table A.12 of the Risk Methods Document (DOE 2016a) for surface soil.

[b] Direct contact PRGs are taken from 5 times the industrial worker NAL from Table A.4 of the Risk Methods Document (DOE 2016a). This value corresponds to the lesser of an ELCR of 5E-06 for carcinogenic COCs and an HI of 0.5 for noncarcinogenic COCs for chemical-specific targets to ensure that the residual cumulative ELCR will be equal to or below the ELCR target of 1E-05, and the residual cumulative HI will be equal to or below the HI target of 1.

[c] Groundwater protective PRGs are the soil screening level for the MCL or residential NAL if no MCL is available, using a DAF of 58, from Table A.7a for nonradionuclides (DOE 2016a). For radionuclides, groundwater protective PRGs are the soil screening level for the resident at 10^{-6}, using a DAF of 58, from Table A.7b of the 2016 Risk Methods Document (DOE 2016a).

[d] PRG for surface soil is the lower of the direct contact PRG and groundwater protective PRG for soil. If the risk-based value is less than background, then background becomes the PRG for surface soil. Shading indicates the revised PRG is set at background.

[e] Determined during June 2009 BGOU FS scoping meeting.

Table 2.2. SWMU 4 FS Preliminary Remediation Goals for Subsurface Soil

COPC	Units	Background[a]	Direct Contact PRG[b]	Groundwater-Protective PRG[c]	PRG for Subsurface Soil[d]
Arsenic	mg/kg	7.90E+00	1.87E+01	1.69E+01	1.69E+01
Manganese	mg/kg	8.20E+02	3.87E+03	1.64E+02	8.20E+02
Uranium[e]	mg/kg	4.60E+00	4.92E+02	7.83E+02	4.92E+02
Total PAHs	mg/kg	N/A	1.62E+00	1.36E+01	1.62E+00
Total PCBs	mg/kg	N/A	5.60E+00	4.54E+00	1.00E+01[f]
Cs-137	pCi/g	2.80E-01	3.42E+00	2.78E+01	3.42E+00
Np-237	pCi/g	N/A	7.50E+00	3.11E+00	3.11E+00
Th-230	pCi/g	1.40E+00	1.43E+02	1.06E+02	1.06E+02
U-234	pCi/g	1.20E+00	2.18E+02	2.87E+00	2.87E+00
U-235	pCi/g	6.00E-02	1.10E+01	2.83E+00	2.83E+00
U-238	pCi/g	1.20E+00	4.36E+01	2.34E+00	2.34E+00

N/A = not available

[a] Background concentrations taken from Table A.12 of the Risk Methods Document (DOE 2016a) for subsurface soil.

[b] Direct contact PRGs are site-specific excavation worker corresponding to an ELCR of 5E-06 for carcinogenic COCs and an HI of 0.5 for noncarcinogenic COCs for chemical-specific targets to ensure that the residual cumulative ELCR will be equal to or below the ELCR target of 1E-05, and the residual cumulative HI will be equal to or below the HI target of 1.

[c] Groundwater protective PRGs are the soil screening level for the MCL or residential NAL if no MCL is available, using a DAF of 58, from Table A.7a for nonradionuclides (DOE 2016a). For radionuclides, groundwater protective PRGs are the soil screening level for the resident at 10^{-6}, using a DAF of 58, from Table A.7b of the Risk Methods Document (DOE 2016a).

[d] PRG for subsurface soil is the lower of the direct contact PRG and groundwater protective PRG for soil. If the risk-based value is less than background, then background becomes the PRG for subsurface soil. Shading indicates the revised PRG is set at background.

[e] Direct contact PRGs are based on uranium, soluble salts.

[f] Determined during June 2009 BGOU FS scoping meeting.

Table 2.3. SWMU 4 FS Preliminary Remediation Goals for RGA Groundwater Protection

COPC	Units	Background[a]	Groundwater-Protective PRG[b]	PRG for Subsurface Soil[c]
Aluminum	mg/kg	1.20E+04	1.74E+05	1.74E+05
Arsenic	mg/kg	7.90E+00	1.69E+01	1.69E+01
Barium	mg/kg	1.70E+02	4.78E+03	4.78E+03
Beryllium	mg/kg	6.90E-01	1.83E+02	1.83E+02
Cobalt	mg/kg	1.30E+01	1.57E+00	1.30E+01
Fluoride	mg/kg	N/A	6.96E+02	6.96E+02
Iron	mg/kg	2.80E+04	2.04E+03	2.80E+04
Manganese	mg/kg	8.20E+02	1.64E+02	8.20E+02
Nickel	mg/kg	2.20E+01	1.48E+02	1.48E+02
Vanadium	mg/kg	3.70E+01	5.01E+02	5.01E+02
1,1,2-TCA	mg/kg	N/A	9.41E-02	9.41E-02
1,1-DCE	mg/kg	N/A	1.46E-01	1.46E-01
1,2-DCA	mg/kg	N/A	8.22E-02	8.22E-02
Benzene	mg/kg	N/A	1.48E-01	1.48E-01
Carbon tetrachloride	mg/kg	N/A	1.13E-01	1.13E-01
Chloroform	mg/kg	N/A	1.29E+00	1.29E+00
cis-1,2-DCE	mg/kg	N/A	1.19E+00	1.19E+00
Ethylbenzene	mg/kg	N/A	4.55E+01	4.55E+01
Total Xylene	mg/kg	N/A	5.71E+02	5.71E+02
TCE	mg/kg	N/A	1.04E-01	1.04E-01
Vinyl chloride	mg/kg	N/A	4.00E-02	4.00E-02
Tc-99	pCi/g	2.80E+00	4.41E-01	2.80E+00
U-234	pCi/g	1.20E+00	2.87E+00	2.87E+00

N/A = not available

[a] Background concentrations taken from Table A.12 of the Risk Methods Document (DOE 2016a) for subsurface soil.

[b] Groundwater protective PRGs are the soil screening level for the MCL or residential NAL if no MCL is available, using a DAF of 58, from Table A.7a for nonradionuclides (DOE 2016a). For radionuclides, groundwater protective PRGs are the soil screening level for the resident at 10^{-6}, using a DAF of 58, from Table A.7b of the Risk Methods Document (DOE 2016a).

[c] PRG for subsurface soil below 20 ft bgs is the groundwater protective PRG for soil because direct contact is unlikely. If the risk-based value is less than background, then background becomes the PRG for subsurface soil. Shading indicates the revised PRG is set at background.

Table 2.4 lists the GRAs and the technology types and process options contained within each GRA. 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 PGDP BGOU, as described in Section 2.4.1.1, are needed only for those alternatives that leave waste and/or contaminated soil in place at concentrations that would not allow for unlimited use/unrestricted exposure (UU/UE).

The LUCs GRA may include engineering and physical barriers, as well as Institutional Controls (ICs). EPA defines ICs as nonengineered instruments, such as administrative and legal controls, that help to minimize the potential for exposure to contamination and/or protect the integrity of a response action. ICs typically are designed to work by limiting land and/or resource use or by providing information that helps modify or guide human behavior at a site (EPA 2012).

Table 2.4. BGOU SWMU 4 GRA Technology and Process Option Screening

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments	Retain
No Action	None	Not Applicable	No action.	Available	Required for consideration by the NCP.	✓
Land Use Controls	Physical Controls	Warning Signs	Warning signs notify site workers of potential hazards and restrict access.	Available	Technically implementable.	✓
		Fences	Provides notification of potential hazards and prevents/restricts access.	Available	Technically implementable.	✓
	Institutional Controls	Property Record Notice, CERCLA Section 120(h)	Property notice that documents waste left in place and survey plat of its location filed at McCracken County Clerk's office. CERCLA Section 120 (h) is a notice required for transfer of federally owned property notifying anyone that hazardous substance was stored or released and remedial actions are complete.	Available	Technically implementable.	✓
		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.	✓
		Excavation/ Penetration Permit (E/PP) Program	For any proposed intrusive activities, the E/PP Program is implemented to protect workers and remedy integrity.	Available	Technically implementable.	✓
		Environmental Covenant	Environmental Covenant meeting the requirements of *KRS* 224.80-100 *et seq*. to be filed at the time of property transfer.	Available	Technically implementable.	✓
Surface Controls	Surface Barriers	Soil Cover	Monolayered cover that is used for surface soil contamination.	Commercially available	Technically implementable.	✓
		Riprap	Riprap is defined as a permanent, erosion-resistant ground cover of large, loose, angular stone. Its standard application is to protect slopes, stream banks, channels, or areas subject to erosion by wave action. However, it also can be used to prevent intrusion by serving as a physical impediment due to its size.	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 usually are 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 or in the performance support investigation and design work.	✓
		Soil Cores	Cores may be obtained using direct push technology, hollow-stem auger, or other drilling methods. Laboratory analysis may be used on core samples to detect VOCs or other constituents.	Commercially available	Technically implementable. This technology is screened from further evaluation as a primary technology, but its use may be incidental to other GRAs such as removal.	✓

Table 2.4. BGOU SWMU 4 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments	Retain
Monitoring (Continued)	Soil Monitoring (Continued)	Membrane Interface Probes (MIPs)	MIP sampling can be used to assess reductions in VOC concentrations in soils. The MIP uses a heating element and gas permeable membrane for volatilizing contaminants, which then are captured and analyzed with appropriate surface equipment.	Available	Technically implementable.	✓
		Soil Gas Monitoring (e.g., Gore-sorbers)	Multiple methods available either to collect soil gas directly or to indirectly measure soil gas concentrations such as use of Gore-sorbers.	Commercially available	Technically implementable. Retained for possible alternative development; also may be used as a secondary technology to other GRAs.	✓
	Groundwater Monitoring	Install/Sample Groundwater Monitoring Wells	Monitors contaminant migration in groundwater.	Available	Technically implementable.	✓
		Diffusion Bags	Diffusion bags are passive groundwater sampling devices that can be hung in the wells to collect VOCs or other soluble contaminants. Semipermeable diffusion bags containing deionized water are allowed to equilibrate with the surrounding groundwater and eventually reach the same concentrations of the soluble contaminants.	Available	Technically implementable.	✓
		Borehole Fluxmeter	The passive fluxmeter can be deployed in a well to directly measure subsurface water and contaminant flux. The interior is a matrix of hydrophobic and hydrophilic permeable sorbents that retain dissolved organic and/or inorganic contaminants present in fluid intercepted by the unit.	Available	Technically implementable retained for possible alternative development.	✓
		Ribbon Nonaqueous-Phase Liquid (NAPL) Sampler	Direct sampling device that provides a detailed depth discreet mapping of NAPLs in a borehole. The ribbon NAPL sampler has been deployed in the vadose and saturated zones.	Innovative/ Available	Technically implementable in the UCRS only.	✓
		DNAPL Interface Probe	Direct sampling devise that detects the DNAPL-water interface in groundwater monitoring wells.	Available	Technically implementable.	✓
	Surface Water Monitoring	Conventional Surface Water Sample Collection and Analysis	Grab samples of surface water would be collected. Analysis can be performed on-site using field instrumentation or at fixed-base laboratories.	Commercially available	Technically implementable. 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.	Available	Technically implementable.	✓

Table 2.4. BGOU SWMU 4 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments	Retain
Removal	Excavators	Backhoes, Trackhoes	Tracked excavators with 59-ft arms limited to approximately 42 ft bgs (Cat 330C Long). Buried waste may reduce effectiveness of the process due to interference.	Commercially available	Technically implementable.	✓
		Vacuum Excavation, Remote Excavator	Commercial vacuum excavators used for hydroexcavation/potholing, radioactive waste cleanup.	Commercially available	Technically implementable.	✓
		Crane and Clamshell	Excavation at depths greater than 100 ft bgs possible. Buried waste may reduce the effectiveness of the process due to interference.	Available	Technically implementable.	✓
		Large Diameter/Bucket Auger	Capable of drilling to depths of 100 ft bgs. Buried waste may reduce the effectiveness of the process due to interference.	Available	Technically implementable.	✓
Containment	Hydraulic Control	Recharge Controls/ Groundwater Extraction	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. Groundwater extraction is not applicable as direct treatment to COCs in the UCRS. Could be utilized as an indirect method by applying to the RGA to control migration.	✓
	Capping	Engineered Cover	Multilayered cover incorporating compacted clay impermeable geosynthetic, a drainage layer, and topsoil.	Commercially available	Technically implementable.	✓
		Flexible Membrane	Single layers of relatively impermeable polymeric plastic [high-density polyethylene (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.	✓
		Earthen Cover	Multilayered earthen cover.	Commercially available	Technically implementable.	✓

Table 2.4. BGOU SWMU 4 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments	Retain
Containment (Continued)	Capping (Continued)	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 due to local climate.	X
		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.	✓
		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.	✓
		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.	✓
	Subsurface Horizontal Barriers	Freeze Walls	Constructed by artificially freezing the soil pore water; results in decreased permeability and formation of a low-permeability barrier. The frozen soil remains relatively impermeable, and migration of contaminants thereby is 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 not practical as a permanent barrier.	X
		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.	X
		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.	X
	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.	✓

Table 2.4. BGOU SWMU 4 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments	Retain
Containment (Continued)	Subsurface Vertical Barriers (Continued)	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.	✓
		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.	✓
		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.	✓
Treatment	Bioremediation	*In Situ* Process Options—Enhanced Biodegradation and Phytoremediation	Bioremediation technologies 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	Technical implementability can be difficult due to reduced hydraulic conductivity of the UCRS that limits the ability to distribute effectively substrate using injection technologies. Establishing anaerobic conditions may inhibit ongoing natural aerobic degradation processes.	✓
		Ex Situ Process Options—Bioreactors and Constructed Wetlands	Bioremediation technologies are destruction techniques directed toward stimulating the microorganisms to grow and using the contaminants as a food and energy source by creating a favorable environment for the microorganisms.	Commercially available	Although theoretically implementable, eliminated from possible alternative development because of its reliance on extraction.	X

Table 2.4. BGOU SWMU 4 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments	Retain
Treatment (Continued)	Physical/ Chemical	Soil Vapor Extraction—*In Situ*	Removal of unsaturated zone air and vapor by applying vacuum.	Commercially available	Technical implementability is reduced in the UCRS due to low intrinsic permeability, stratified soil conditions, and high water table. Vapor extraction was successful at C-400 during electrical resistance heating (ERH) activities.	✓
		Dual-Phase Extraction—(DPE) *In Situ*	Enhancement of soil vapor extraction (SVE) that includes extraction of groundwater and soil vapor.	Commercially available	Effectiveness of this process option is reduced when soils have low conductivity.	✓
		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	Technical implementability is uncertain. UCRS has low intrinsic permeability and not uniformly saturated and stratified soil conditions, although pulsed air sparging has been used effectively under these site conditions.	X
		Soil Flushing—*In Situ*	Promotes dissolution or desorption of VOCs in soil; may mobilize DNAPLs by reducing interfacial tension. Can be applied *in situ* or *ex situ.*	Commercially available	Technical implementability uncertain. Surfactant/cosolvent flushing typically have reduced effectiveness in low-permeability settings such as the UCRS, but could be effective in passive treatment systems.	✓
		Electrokinetics—*In Situ*	Applied *in situ* as Lasagna™ process.	Commercially available	Technical implementability uncertain due to buried waste but retained for possible alternative development.	✓
		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 SVE. Potential adjunct technology for some *in situ* treatment, containment, or removal technologies.	Commercially available	This process option can increase secondary conductivity resulting in increased effectiveness for some marginal technologies.	✓

Table 2.4. BGOU SWMU 4 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments	Retain
Treatment (Continued)	Physical/ Chemical (Continued)	Permeable Reactive Barrier—(PRB) *In Situ*	PRBs are designed and constructed to permit the passage of water while immobilizing or destroying contaminants using various reactive agents. PRBs may be constructed to depths of 60 ft bgs, but complexity and cost increase with depth.	Commercially available	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.	X
		Air Stripping—*Ex Situ*	Applied *ex situ* for secondary waste treatment.	Commercially available	This process can be utilized with other processes to remove VOC contamination from media.	✓
		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 typically are resins made from synthetic organic materials, inorganic materials, or natural polymeric materials.	Commercially available	This process can be utilized with other processes to remove radionuclides and metals contamination from media.	✓
		Granular Activated Carbon (GAC) *Ex Situ*	GAC is used for VOC removal from aqueous streams. Dissolved contaminants are removed by adsorption onto activated carbon grains.	Commercially available	This process can be utilized with other processes to remove VOC contamination from media.	✓
		Vapor Condensation *Ex Situ*	Applied *ex situ* for secondary waste off-gas treatment.	Commercially available	This process can be utilized with other processes to remove VOC contamination from media.	✓
		Deep Soil Mixing—*In Situ*	Potential adjunct technology for some *in situ* treatment, containment, or removal technologies.	Commercially available	This process can be utilized with other processes to remove VOC contamination from media. Buried waste can prevent the soil mixing process.	✓
		Cement and Chemical Grouting—*In Situ*	Stabilization/solidification agents are injected at high pressure through conventional boreholes to form a grouted mass.	Commercially available	Technically implementable.	✓
		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.	✓

Table 2.4. BGOU SWMU 4 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments	Retain
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 DPE wells and treated. Can be implemented as three-phase or six-phase heating.	Commercially available	ERH was demonstrated at PGDP to be successfully implementable at PGDP in the C-400 project. The C-400 action treated the UCRS and Upper RGA from 20 to 60 ft subsurface. This process option is not technically implementable when the buried metal is present in the zone to be treated due to electrical interference.	✓
		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 DPE wells and treated.	Commercially available	Effectiveness is impacted by buried waste.	✓
		Steam Stripping	Steam or heated air is applied to the subsurface to vaporize VOC contaminants, which typically are vacuum extracted for further treatment.	Commercially available	Technology sensitive to soil conductivity and water saturation.	✓
		Catalytic Oxidation—*Ex Situ*	Applied *ex situ* for secondary vapor treatment.	Commercially available	Economic utilization sensitive to low contaminant concentrations.	✓
		Thermal Desorption—*Ex Situ*	Soils are heated *ex situ* to volatilize VOCs, which then are treated. Applied *ex situ* for excavated waste treatment.	Commercially available	The presence of solid materials such a metal beams, pipes, etc., may require removing in order to treat the soils.	✓
		Vitrification	Extremely high heat is used either *in situ* or *ex situ* to turn the contaminated media into glass.	Limited Commercial availability	Vitrification would reduce the uncertainties associated with SWMU 4 because it would reduce potential contaminant mobility and direct contact with waste. Waste may require sizing if performed *ex situ*.	✓
	Chemical	Permanganate *In Situ*	Injection of permanganate species compounds in subsurface to oxidize VOCs. Does not act directly on isolated pockets of DNAPLs.	Commercially available	Technical implementability uncertain in the UCRS due to low soil permeability, soil heterogeneity and stratification, and variable extent of saturation. Bench-scale test of permanganate on TCE-spiked RGA sediments determined it would not be effective on TCE DNAPL in RGA.	✓
		Fenton's Reagent *In Situ*	Injection of hydrogen peroxide and ferrous iron in subsurface to oxidize VOCs	Commercially available	Technical implementability uncertain in the UCRS due to low soil permeability, soil heterogeneity and stratification, and variable extent of saturation.	✓

Table 2.4. BGOU SWMU 4 GRA Technology and Process Option Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments	Retain
Treatment (Continued)	Chemical (Continued)	Zero-Valent Iron (ZVI) *In Situ*	Dechlorination of chloroethenes by elemental iron. Applied *in situ* as permeable reactive treatment zone or barrier. Can also treat uranium in groundwater by precipitation via soil mixing, thereby reducing mobility.	Commercially available	Placement proved feasible using soiling mixing technology. Presence of debris landfill waste will inhibit mechanical placement.	✓
		Ozonation *In Situ*	Injection of ozone gas in saturated zone to oxidize VOCs. Does not act directly on isolated pockets of DNAPLs.	Commercially available	Technical implementability uncertain in the UCRS due to low soil permeability, soil heterogeneity, stratification, and variable extent of saturation. Potentially more implementable in RGA.	✓
		Persulfate *In Situ*	Injection of sodium persulfate in soils to oxidize VOCs. Most effective when ferrous iron or other reagents are added as catalysts or when heated.	Commercially available	Technical implementability uncertain in the UCRS due to low soil permeability, soil heterogeneity and stratification, and variable extent of saturation. Potentially more implementable in RGA.	✓
		S-ISCO®	Coinjection of surfactant with one of the oxidants previously listed. The surfactant disperses DNAPL so that it can be readily destroyed by the oxidant.	Commercially available	Technical implementability uncertain in the UCRS due to low soil permeability, soil heterogeneity and stratification, and variable extent of saturation. Potentially more implementable in the RGA. S-ISCO® is an emerging technology with few full-scale field applications.	✓
Disposal	Land Disposal	Off-site Permitted Disposal Facility	Shallow land burial site for LLW, mixed low-level waste (MLLW), and hazardous waste disposal option.	Commercially available	Technically implementable.	✓
		Potential On-Site Disposal Unit	Planned radioactive and mixed waste on-site disposal unit.	Under consideration	Technically implementable.	✓
		PGDP C-746-U Landfill	Existing on-site nonhazardous nonradioactive waste landfill.	Available	Technically implementable.	✓
	Discharge of Wastewater	Wastewater Treatment Demonstrating Compliance with ARARs	Allowed under CERCLA after treatment, as necessary, to meet ARARs.	Available	Technically implementable.	✓

Note: X indicates technology or process option screened from alternative development, and ✓indicates technology retained for possible use in alternative development.

2.3.2 Surface Controls

The surface controls GRA provides a physical barrier that will prevent direct contact exposure to surface soil contamination. The technology type, surface barriers, and associated process options provide a physical means of preventing direct contact with contaminated soils without inclusion of a low-permeable barrier.

2.3.3 Monitoring

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

Any alternatives that leave waste in place will incorporate monitoring to confirm that there is no unacceptable groundwater migration from SWMU 4.

2.3.4 Monitored Natural Attenuation

The MNA GRA 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.

2.3.5 Removal

The removal GRA involves removal of all or some buried waste and soils. Removal would generate secondary wastes potentially requiring *ex situ* treatment and disposal or discharge. Removal can contribute to meeting RAOs.

2.3.6 Containment

The containment GRA isolates contaminated media from release mechanisms, transport pathways, and exposure routes using surface and/or subsurface barriers and hydraulic containment, thereby reducing contaminant flux and reducing or eliminating exposures to receptors. Containment can contribute to meeting RAOs 1 and 2.

2.3.7 Treatment

The treatment GRA 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 controlled. *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 the RAOs for this action.

2.3.8 Disposal

The disposal GRA 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 may contribute to meeting RAOs.

2.4 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

Table 2.4 lists the GRAs and the technology types and process options contained within each GRA. Identification was based on demonstrated process efficiencies, engineering judgment, and existing policies or procedures.

The technologies and associated process options are described in Section 2.4.1, as is the potential technical implementability for each. Evaluated technologies and process options that cannot be technically implemented or are impracticable are screened and eliminated from further consideration. In Section 2.4.2, the retained process options' effectiveness, implementability, and relative cost are rated. Finally, Section 2.4.3 identifies RPOs that will be used to develop the remedial alternatives.

2.4.1 Identification and Screening of Technologies and Process Options

The technology types and process options for each GRA are discussed in the following subsections, 2.4.1.1 through 2.4.1.8. Table 2.4 summarizes the narrative discussion that follows.

In this FS, technologies and process options are evaluated for effectiveness, implementability, and cost as to how they may address the identified risk/hazards and uncertainties at the SWMU.

Additionally, certain technologies or process options are retained as temporary or complementary actions subordinate to another retained action. For example, freeze wall is not implementable effectively as a long-term action, but is retained as a means to stabilize an excavation sidewall.

2.4.1.1 LUC technologies/process options

A land use control implementation plan (LUCIP) will be prepared after the ROD for EPA and KDEP approval. LUCs will be designed and implemented through a LUCIP to ensure protectiveness. LUCs for this remedial action consist of the following:

- E/PP Program
- Warning Signs
- Property Record Notices
- Contingent Deed/Lease Restrictions
- An Environmental Covenant meeting the requirements of *KRS* 224.80-100 *et seq.* to be filed at the time of property transfer

The E/PP Program includes a specific permitting procedure 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, or pavement. Warning signs are a physical control placed at the site to notify personnel of contamination.

A property record notice will be recorded by DOE in the McCracken County Clerk's office along with original property acquisition records after approval of the LUCIP for SWMU 4 that alerts anyone searching property records that an environmental covenant will be filed simultaneous with transfer of a fee simple interest in the property to a non-federal entity. The notice also will identify the restrictions to be included in the environmental covenant consistent with the ROD or any amendments made thereto, as well as important information about the contamination at the source areas site and protection of the landfill caps. Should DOE transfer or convey ownership of the property encompassing SWMU 4, any deed or lease would include, at a minimum, use restrictions prohibiting residential development or agricultural development. Should the federal government convey by deed a fee simple interest for contaminated real property at SWMU 4, an environmental covenant pursuant to Subchapter 80 of *KRS* Chapter 224 will be created, granted to the holder, and recorded that will contain the land use restrictions required in the ROD or any amendments made thereto. The environmental covenant will impose no obligation on DOE independent of CERCLA requirements, but will provide an additional means to assure that the use of the property by a subsequent owner is consistent with restrictions that are established under the CERCLA remedy. The terms of the environmental covenant will be enforced against a subsequent non-federal owner in accordance with applicable federal and state law in a court of competent jurisdiction. The holder(s) of the environmental covenant will be identified at the time the environmental covenant is created. Identification of a Kentucky environmental covenant as a LUC does not otherwise affect the DOE's ability as a federal agency to remove adjudication of a matter involving the environmental covenant to a U.S. district court, or otherwise affect any of DOE's rights as a federal agency with respect to any state proceeding or action.

LUCs are technically implementable.

2.4.1.2 Surface Barriers

Soil Cover. Soil covers are intended to prevent direct contact only and promote runoff, but not provide hydraulic containment. This type of cover is effective, technically implementable, commercially available, and is retained for further consideration.

Riprap. Riprap is defined as broken rock, cobbles, or boulders placed on earth surfaces, such as the face of a dam or the bank of a stream, for protection against runoff and wave action (http://www.mass.gov/eea/docs/dep/water/resources/a-thru-m/dirtroad.doc). Its standard application is to protect slopes, stream banks, channels, or areas subject to erosion by wave action; however, it also can be used to prevent intrusion by serving as a physical impediment due to its size and density.

2.4.1.3 Monitoring

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. Collection of samples for laboratory analysis for physical/chemical parameters yields data that may be used to support RD and verify effectiveness of remedial action.

This technology will not be evaluated as a primary technology; however, it is retained for evaluation as a subordinate technology in conjunction with a primary technology.

Multiple process options are available and can be implemented during investigation or remediation on a site-specific and COC-specific basis. Specifically, conventional surface soil sample collection and analysis, soil core collection and analysis, membrane interface probe, and soil gas monitoring will be considered during RAWP preparation.

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. The design of any such monitoring network would be addressed in the RD phase.

This technology is retained for further evaluation. In addition to conventional well monitoring, multiple techniques are available for consideration during the RAWP. These include the use of diffusion bags, borehole fluxmeters, ribbon NAPL samplers, and DNAPL interface probes.

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

2.4.1.4 Surface water monitoring

Monitoring may be used after remedial action implementation to determine the degree of COC contribution, if any, of waste and impacted soils to surface water. Conventional surface water monitoring consists of analyzing grab samples using field instrumentation or at fixed-base laboratories. Overall, surface water monitoring is used widely for compliance monitoring and is effective, technically implementable, and commercially available. The detailed design of any such monitoring program would occur during RD. This technology is retained for further evaluation.

2.4.1.5 Monitored Natural 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 characterized extensively and monitored over time to determine the effectiveness of the remedy. The sorption processes already have been estimated as part of the modeling of the impacts to groundwater; thus, the viability of this option in a source area is uncertain.

2.4.1.6 Removal technologies

Removal, in the context of this FS, means the excavation of source materials disposed of in SWMU 4, as well as UCRS soils containing COCs above PRGs. The technical complexity of conventional excavation increases greatly with depths greater than about 20 ft (Terzaghi et al. 1996); 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 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. Flow of groundwater and entry of heaving sands into the excavation can occur as excavation proceeds below the water table and also must be considered. Several types of excavation equipment that potentially could be used at SWMU 4 are discussed later in this section.

Excavation can have a large capital cost, but low operation and maintenance (O&M) cost, and may have the largest probability of achieving over 99% COC removal at smaller sites with contamination restricted to the upper 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 176,600 ft^3 (6,540 yd^3); and the contaminants do not require complex treatment or disposal (NRC 2004).

Removal technologies are combined 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, is commercially available, and is retained for further evaluation.

Backhoes and Trackhoes. 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, is commercially available, and is retained for further evaluation.

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 SWMU 4, 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 and is retained for further evaluation.

Cranes and Clamshells. Cranes and clamshells 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, is commercially available, and is retained for further evaluation.

Large Diameter Auger and Bucket Auger. Large diameter augers (LDAs) and bucket augers can be used to remove contaminated soil effectively 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 into the excavation. LDA borings can reach depths of 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 has limitations at SWMU 4. Large debris contained in SWMU 4 could cause the auger flights to bind, could cause auger refusal, and could cause equipment damage; however, this process option is retained for further evaluation in conjunction with implementation of excavation technology and/or should COCs not be collocated with large debris.

2.4.1.7 Containment Technologies

Containment technologies can hydraulically isolate source areas, reduce infiltration, and minimize contaminant migration. Containment technologies also can isolate 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.

Hydraulic Control (Containment). Hydraulic control involves implementing process options that control the results of water migrating through the waste or contaminated soil. This technology is implementable and is retained for further evaluation. Containment typically is accomplished by groundwater extraction.

Recharge Controls. Recharge controls can reduce water discharges to the UCRS, promote surface water runoff, and reduce recharge of the source areas, thereby limiting leaching of COCs from source areas and migration to the RGA. Recharge controls options are technically implementable using commercially available materials and equipment. Potential recharge control options include the following:

- Directing water away from source areas or to storm drains;
- Eliminating surface water drainage from adjacent areas onto source areas;
- Lining ditches and culverts in the vicinity of SWMU 4 source areas with concrete or membranes;
- Inspecting and repairing, as needed, asphalt areas to promote runoff and minimize infiltration;
- Inspecting, clearing and repairing, as needed, discharge pipes, culverts, and storm drains; and
- Inspecting, metering, and repairing water lines in the vicinity of SWMU 4 source areas as needed.

This technology is implementable and is retained for further evaluation.

Groundwater Extraction. Groundwater pumping may be used to contain contaminant plumes or may be used as a secondary technology to circulate or contain treatment amendments. This process option is retained for further evaluation.

2.4.1.7.1 Capping

The capping technology contains process options that are designed to both prevent direct contact and significantly reduce or eliminate infiltration into buried wastes either through a low permeability earthen cap, an engineered cap that includes an impermeable geosynthetic layer, concrete based covers, conventional asphalt covers, MatCon™ asphalt, and flexible membranes or through soil mass and vegetation (evapotranspiration cover).

All of the capping process options listed below are intended to reduce recharge of precipitation through the use of a low permeable layer, except the evapotranspiration cover. The evapotranspiration 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.

EPA (2008) identifies the following advantages and limitations of surface barriers for 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.

Engineered Cover. This type of cover would consist of the following (top to bottom):

- Upper vegetated soil layer,
- Sand drainage layer,
- Flexible membrane liner, and
- Compacted clay barrier.

A gas venting layer is not included because SWMU 4 contains mostly inorganic waste that will not generate methane. Nominal thickness of this type of cover is 4.9 ft, and the 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 also would deter human intrusion.

An engineered cover, which includes multilayers and synthetics that are distinctly different from the natural subsoils, provides greater depth to the buried waste. These aspects (thickness and distinct properties) of the cover are expected to provide protection of individuals from inadvertent intrusion by alerting them that this is a man-made cover over something that potentially is hazardous to human health and by making it more difficult to expose the buried waste.

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

Earthen Cover. This type of cover would consist of the following (top to bottom):

- 36-inch vegetative soil layer,

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

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

- Filter fabric or other approved material.

A gas venting layer is not included because SWMU 4 contains mostly inorganic waste that will not generate methane as it decomposes.

An earthen cover, which includes multilayers that are distinctly different from the natural subsoils, provides greater depth to the buried waste. These aspects (thickness and distinct properties) of the cover are expected to provide protection of individuals from inadvertent intrusion by alerting them that this is a man-made cover over something that potentially is hazardous to human health and by making it more difficult to expose the buried waste.

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

Evapotranspiration Cover. Evapotranspiration cover systems use one or more vegetated soil layers to retain water until it either is 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 best suited to arid climates; therefore, it is eliminated from 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 effective, technically implementable, commercially available, and is retained for further evaluation.

MatCon™. MatCon™ asphalt has been used for 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 (HDPE and others). Flexible membranes can be a component of an engineered 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.

2.4.1.7.2 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.

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; therefore, it 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 the Brookhaven and 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. Permeation grouting is screened from further evaluation because the UCRS clays at SWMU 4 have low permeability. Additionally, heterogeneity of the soils within the UCRS would make the efficacy of this technology difficult to verify.

2.4.1.7.3 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 in many instances may 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 at SWMU 4 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 and associated process options are 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, but 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 commonly is 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 commonly are used in excavations for shoring and to reduce groundwater flow into the excavation; therefore, they 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 barrier 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. 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.

2.4.1.7.4 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 SWMU 4: 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.

2.4.1.7.5 Bioremediation technologies

Bioremediation technologies 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 carcinogenic PAHs (cPAHs) behind. 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).

The behavior of Tc-99 species in soil is governed by the potential of oxidation reduction chemical (redox) reactions of the soil. If sufficient reduction conditions exist, the pertechnetate ion will be reduced to insoluble oxidation states of technetium such as $TcO_2 \cdot 2H_2O$, $^{99}Tc_2S_7$, and $^{99}TcS_2$. These reduced Tc-99 species are readily sorbed by soil constituents or form complexes with organic matter and become fixed in the soil. Reduced forms of technetium are not likely to reoxidize under normal conditions. If suitable oxidation conditions exist in the soil, the pertechnetate ion will not react with soil constituents or form complexes and will be available for transport.

Soils high in organic matter are particularly effective in reducing the pertechnetate ion to insoluble forms of technetium. Reducing conditions are created by the presence of large amounts of soil bacteria and positively charged organic compounds common to these types of soils. Some soil bacteria have the ability to reduce technetium by incorporating it in their metabolic processes. The reduced technetium reacts with carboxyl, amine, hydroxyl, and sulfide groups often found in soils high in organic matter, and insoluble technetium complexes are formed. These insoluble technetium complexes have substantially reduced migration potential.

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

2.4.1.7.6 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, DPE, 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. This technology is retained for further evaluation because it contains cement and chemical grouting and jet grouting that could be implemented at SWMU 4.

Soil Vapor Extraction—*In Situ*. 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 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 applicable for implementation at SWMU 4; it is effective, technically implementable, commercially available, and is retained for further evaluation.

Dual-phase Extraction—*In Situ*. DPE, also known as multiphase 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 effective, technically implementable, commercially available, and is retained for 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 SWMU 4 because it would not effectively mitigate the risk associated with the waste (see Section 1.3.6), and the UCRS is not a highly saturated zone. Therefore, it is 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 technology is implementable and, when combined with other technologies, can support attaining the RAOs. It is retained for 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 SWMU 4 as a primary technology because of the presence of metallic debris. Electrokinetics will be retained for technology and process options screening as a secondary means of treating VOCs after removal of buried waste.

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 SVE. The technology is a potential adjunct technology for some *in situ* treatment, containment, or removal technologies.

Permeable Reactive Barrier—*In Situ*. PRBs are designed and constructed to permit the passage of water while immobilizing or destroying contaminants using 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 SWMU 4 because it would not effectively mitigate the risk associated with the waste (see Section 1.3.6) and is not functional with the UCRS vertical gradients. Therefore, it is 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 applicable as a component of an *ex situ* water treatment system and is retained for 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 applicable as a component of an *ex situ* water treatment system and is retained for 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. 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 and 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.

This process option is applicable as a component of an *ex situ* water treatment system and is retained for further evaluation.

Vapor Condensation—*Ex Situ*. 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 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 applicable as a component of an *ex situ* water treatment system and is retained for further evaluation.

Deep Soil Mixing—*In Situ*. Deep soil mixing is a stabilization/solidification technique in which reagents, 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 4 without first removing large, rigid debris known to exist at this SWMU. This debris would interfere with the auger flights and could cause auger flights to bind, could cause auger refusal, or could cause equipment damage; however, this process option is retained for further evaluation for use in strata that is free of large debris.

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 through either 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 4 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 (Hayward Baker 2017).

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.

Jet grouting the wastes at SWMU 4 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.

2.4.1.7.7 Thermal technologies

Thermal processes burn, decompose, or detonate contaminants (destruction); melt the contaminants (vitrification); 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 lower 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 and associated process options are technically implementable and are retained for further evaluation.

ERH—*In Situ*. 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. for TCE DNAPL contamination in the saturated and unsaturated zones of the UCRS (Hightower 2001). 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 Interim Remedial Action 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 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 (SVE 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.

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

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 212°F 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 212°F, 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.

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

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 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, detailing varied results.

This process option is effective, technically implementable, and commercially available; a successful study was performed in the RGA at PGDP. Though the target zone for treatment at SWMU 4 is the UCRS soils, this process option is retained for further evaluation.

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 1,400°F to 1,600°F, and gas residence times typically are one second or less.

Catalytic oxidation is widely used for the destruction of VOCs and commercially available. It is retained for further evaluation.

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 carbon dioxide 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 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.

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

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 of 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-forming (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 (2,900°F to 3,650°F) and thereby immobilize most inorganics and destroy organic pollutants by pyrolysis. Inorganic pollutants are incorporated within the vitrified mass. Water vapor and organic pyrolysis combustion products are captured in a hood that 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 material similar to obsidian or basalt rock. The process destroys and/or removes organic materials. Radionuclides and heavy metals are retained within the vitrified soil (FRTR 2008).

In situ vitrification would mitigate the uncertainties associated with SWMU 4 wastes by reducing mobility. It is retained for further evaluation.

2.4.1.7.8 Chemical technologies

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

- Permanganate
- Fenton's reagent
- 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 DNAPL contaminants because they will not mix readily with DNAPL. 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.

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

Reductant (Zero-Valent Iron). ZVI conventionally is used in conjunction with a PRB to dechlorinate chlorinated hydrocarbons in the subsurface. The technology also may be applied as direct injection of particulate iron, mixing of iron with clay slurries, or incorporating micro or nanoscale ZVI into an oil emulsion prior to injection. A form of ZVI may be injected into the subsurface downgradient of the contaminant source to create a zone of treatment. This is an innovative/emerging technology that would require field demonstration prior to implementation. This technology potentially is implementable and commercially available and is retained for further evaluation.

2.4.1.8 Disposal technologies

Disposal process options for wastes and soil produced during excavation are discussed in the following subsections.

2.4.1.8.1 Land Disposal

Land disposal of buried waste and soils generated from excavation at SWMU 4 will require disposal facilities to accept the waste types generated during the action. It is acknowledged that once excavation begins, sampling of uncovered buried waste would be used to determine definitively the waste types and to confirm that the waste meets the 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 SWMU 4.

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 nonclassified, nonhazardous solid waste generated from SWMU 4.

On-site disposal of waste also may be possible for additional waste types depending upon the remedy selected from a waste disposal alternatives (WDA) 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 WDA facility. This potential facility would be designed and operated to accept LLW, RCRA, TSCA, and MLLW and also may be designed to accept classified wastes. The CERCLA WDA 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. Excavation and disposal alternatives evaluated in this FS will provide discussion of both off-site disposal and on-site disposal in a potential WDA facility for LLW, RCRA, TSCA, and MLLW. Cost for disposal of waste in a potential WDA also is included in Appendix B.

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. Wastes requiring off-site disposal include LLW, RCRA, TSCA, and MLLW. DOE has existing contracts with off-site commercial disposal facilities 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. Historically, the disposal facilities most frequently used have been Energy*Solutions* in Clive, UT, and NNSS (formerly known as the Nevada

Test Site); these facilities were used as the land disposal cost basis in the FS for the excavation and disposal estimates in Appendix B. Energy*Solutions* can be reached either by rail or truck; NNSS-bound waste can have final delivery only by truck. Containers typically used include gondola rail cars, intermodals, Sealand trailers, and B-25/ST-90s. Other off-site disposal facilities may be used in the future to maintain cost efficiency. One such facility is Waste Control Specialists in Andrews County, TX. Energy*Solutions* and Waste Control Specialists can receive nonclassified LLW/RCRA/TSCA/MLLW, but neither facility currently can accept depleted uranium.

Based on current restrictions for depleted uranium concentrations at both Energy*Solutions* and Waste Control Specialists facilities, it is anticipated that any uranium metal will be disposed of at NNSS; only uranium contaminated materials that meet the concentration restrictions will be disposed of at Energy*Solutions*, Waste Control Specialists, or other DOE-approved disposal facilities.

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, treatment (if required), and disposal fees. The costs also are dependent on the waste type (regulatory classification) and form (i.e., soil, debris) of the waste. Disposal fees are not always based on the volume of the waste in the container. Some facilities charge by the external size of the container and other facilities use an assumed volume on the contents of the container. Disposal of classified wastes results in an increase in transportation costs.

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 4, 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 Kentucky Pollutant Discharge Elimination System (KPDES)-permitted outfall or CERCLA outfall. Treated waste water would be required to meet ARARs under CERCLA for discharge of pollutants into waters of the Commonwealth. Pollutants may include VOCs, metals, and/or PCBs that could be present in extracted water from a burial ground during excavation.

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 2.5. 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

Table 2.5. Evaluation of SWMU 4 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
No Action	None	Not Applicable							
Land Use Controls	Institutional Controls	E/PP Program (Short-Term)	Moderate—Only effective for duration of plant presence	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 by future property owners	High—Effective for preventing groundwater and property use	High to moderate	High	High	Low	Low
		CERCLA § 120(H)	Moderate—Relies on continued future implementation	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 implementation	High—Effective for preventing groundwater and property use	High to moderate	High	High	Low	Low
		Environmental Covenant	Moderate—Relies on continued future implementation	High—Effective for preventing groundwater and property use	High to moderate	High	High	Low	Low
	Physical Controls	Warning Signs	Moderate—Prevents 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
		Fences	Moderate—Prevents and controls access; does not reduce contaminant levels	High—Effective at preventing worker exposure	High—Requires inspections and maintenance	High	High	High	High
Surface Controls	Surface Barriers	Soil Cover	Moderate	High	Moderate—Can be subject to erosion or rutting if not maintained	High	High	Moderate	Moderate
		Riprap	Low—Easily moved for limited access; permeable; does not remove contaminant	High	Moderate—Requires maintenance	High	High	Low	Moderate

Table 2.5. Evaluation of SWMU 4 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
Monitoring	Groundwater Monitoring	Monitoring Well Installation, Sample Collection and Analysis	High—Sampling can continue for many years	High—Can be installed quickly	High	High	High	Low to Moderate—Cost technique sensitive	Low
		Borehole Fluxmeter	Moderate—Formations typically are variable vertically and horizontally	Moderate	Moderate	Moderate	High	Moderate	None
		Diffusion Bags	High—Sampling can continue for many years	High—Can be installed quickly	High	High	High	Moderate	Low
		Ribbon NAPL Sampler	Low—Provides direct evidence of DNAPL in a single soil boring and is only applicable in the RGA	Low	Low—Provides specialized contaminant information but does not result in in reduction of contaminant levels or risk reduction	Moderate	High	Low	Low to None
		DNAPL Interface Sampler	Low—Provides direct evidence of DNAPL in a single soil boring and is only applicable in the RGA	Moderate	Low—Provides specialized contaminant information but does not result in in reduction of contaminant levels or risk reduction	Moderate	High	Low	Low to None
	Surface Water Monitoring	Conventional Surface Water Sample Collection and Analysis	Moderate	High	Moderate	High	High	Low	Low
	Soil Monitoring	Membrane Interface Probe	Moderate—Provides direct evidence of DNAPL or dissolved phase in a single soil boring	Moderate	Moderate—Provides VOC contaminant information but does not result in in reduction of contaminant levels or risk reduction	Moderate	High	Low	Low to None
		Soil Moisture Sampling	High—Provides direct evidence of soil properties in a single soil boring	Moderate	High—Does not provide a reduction in contaminant levels or risk reduction	High—Direct Push Technology very reliable above the RGA	High	Low	Low to None
		Gore-Sorbers	Moderate	Moderate	Moderate	High	High	Low	Low

Table 2.5. Evaluation of SWMU 4 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
Monitoring (Continued)	Soil Monitoring (Continued)	Soil Core	Moderate—Collection of core can affect the presence of contaminant	Moderate—Requires drilling	Moderate	Moderate—Requires drilling equipment and coring; can affect contaminant	Low	Moderate	Low
		Conventional Collection and Analysis	Moderate	High	Moderate	High	High	Low	Low
Monitored Natural Attenuation	Monitoring and Natural Processes	Soil and Groundwater Monitoring, Abiotic, and Biological Processes	Moderate—Functions better in reducing environment; not effective on DNAPL concentrations	High	High—UCRS is expected to be only slightly reducing to oxidizing; this will require continuous modification of the natural environment	Moderate—It is expected the subsurface environment is oxidative and will need to be changed	High	Moderate	Moderate
Removal	Excavators	Backhoes, Trackhoes	High—Remove source to 15–20 ft bgs with conventional equipment; deeper (42 ft) excavations possible, but with added complexity	Moderate—Risks to workers in excavation	High	High in dry soil conditions Moderate—Low effectiveness in saturated soil conditions	High	Moderate	Low
		Vacuum Excavation, Remote Excavator	High—Remove source/material to 0–40 ft bgs	Low—Work may be hampered by metal debris or other large pieces and risks to workers in excavation	Low—Because of the scrap and metal debris found at these SWMUs	Low to Moderate—Because of the scrap and metal debris found at these SWMUs and saturated soil conditions	High	Moderate	Moderate
		Crane and Clamshell	High—Remove source/material to > 100 ft bgs	Moderate—More technically complex; hoisting and rigging concerns	High	Moderate	Moderate	High	High
		Large Diameter/Bucket Auger	High—Remove source/material to > 100 ft bgs	Low—Generates significant quantities of cuttings and fluid in saturated zones	Highly effective in soils above the RGA; requires auger size reduction for work in the RGA	Low—Rigid materials buried in area can prevent excavation to desired depth; buried ridged waste complicates augering	High	High	High

Table 2.5. Evaluation of SWMU 4 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)	Groundwater Extraction	Pumping Wells	Low—Not effective for DNAPL	High—Groundwater control upon implementation	Low—Not effective for DNAPL	Low—Not effective in UCRS	Moderate—Discharge or reinjection required	High—Well installation costs	High—Continuous operating costs
Containment	Hydraulic Control	Hydraulic Controls/ Groundwater Extraction	Low—Not effective for DNAPL or in UCRS	High	High	High in RGA, Low in UCRS—Requires proper well placement	Moderate—Discharge or reinjection required	Moderate	Moderate
	Capping	Engineered Cover	Moderate	High	High	Moderate	High	High—Complex construction	Moderate—Ongoing maintenance and monitoring required
		Earthen Cover	Moderate	High	High	Moderate	High	High	Moderate
		Soil Cover	Moderate	High	Moderate	Moderate	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/Low Permeability Asphalt	High	High	Moderate	Moderate—Proprietary vendor technology	High	Moderate	Moderate
		Flexible Membrane	Moderate	High	Moderate—Must be protected from damage	Moderate	High	Moderate	Low—Ongoing maintenance and monitoring required
		Slurry Walls	Potentially high	Low—Intrusive and requires adequate space to implement	Moderate	Low	High	High	Low
	Subsurface Vertical Barriers	Sheet Pile	High—Steel sheets in the subsurface without protection have a finite lifespan	Moderate to High—Installation may contact waste depending upon placement	High	High	High	High	None

Table 2.5. Evaluation of SWMU 4 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)	Jet Grouting	Potentially high	Moderate—High pressures and installation may contact waste and generate some residuals for management	Moderate	Moderate	Low	High	Low
		Freeze Walls	Moderate—Requires continuous freezing and equipment presence to retain quality	Moderate	Moderate	Moderate—Requires specialized equipment for the entire time frame wall is needed	High	High	High
Treatment	Bioremediation	*In Situ* Process Options—Enhanced Biodegradation and Phytoremediation	Moderate—Effective in the correct environmental conditions and appropriate contaminant levels	Moderate	Moderate	Moderate—May require specific enhancements to certain contaminants and Phytoremediation may be depth limited	Low	Moderate	Moderate
	Physical/ Chemical	Cement and Chemical Grouting	High	High	Moderate	Moderate	High	Moderate	None
		Jet Grouting	High	High	Moderate	Moderate	High	Moderate	None
		Soil Vapor Extraction *In Situ*	Uncertain in UCRS due to low permeability, heterogeneity, and variable saturation of soils	Moderate—May require drilling into contaminated areas resulting in contact with buried waste	Moderate to High—Presumptive remedy for VOCs in soil	Moderate—Shallow water table at sites; recent activities using DPE/SVE have been successful when combined with thermal energy input	Moderate—May require drilling into contaminated areas resulting in contact with buried waste	Moderate	Moderate
		Dual-Phase Extraction	Uncertain in UCRS due to low permeability, heterogeneity, and variable saturation of soils	Moderate—May require drilling into contaminated areas resulting in contact with buried waste	Moderate to High—Effectiveness increases when combined with an *in situ* thermal process option	High—Recent activities using DPE/SVE have been successful when combined with thermal energy input	Moderate—May require drilling into contaminated areas resulting in contact with buried waste	Moderate	Moderate

Table 2.5. Evaluation of SWMU 4 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
Treatment (Continued)	Physical/ Chemical (Continued)	Soil Flushing	Unlikely to be effective in UCRS due to low permeability, heterogeneity, and variable saturation of soils; may be effective in RGA when combined with gradient controls	Moderate—May require drilling into contaminated areas resulting in contact with buried waste; uncontrolled mobilization of DNAPL may occur if not carefully implemented	Low	Moderate—Complex technology that requires significant lab and modeling work to select surfactant/cosolvent and design a surfactant flood; location of DNAPL must be defined; requires good knowledge of site hydrogeology and geochemistry	Moderate—Regulatory requirements may prevent chemical injection at some sites; may require drilling into contaminated areas resulting in contact with buried waste	High	High—Injected surfactant/ cosolvent and mobilized DNAPL must be recovered and treated *ex situ*; treatability study work performed on RGA water using surfactants and cosolvents identified recycling of additives difficult due to separation difficulties
		Deep Soil Mixing *In Situ*	Potentially high—Can treat all VOC phases and other contaminants	Moderate—Large equipment and handling of large quantities of excess soils required	Moderate	Moderate—Buried materials must be cleared from treatment area; increased technical difficulty if mixing of the RGA is needed	Moderate	High	Varies depending on application
		Air Stripping *Ex Situ*	High	High	High	High	Moderate—Air emissions	Moderate	Moderate—Ongoing energy costs
		Ion Exchange *Ex Situ*	High	High	High	High	High	Low	Moderate—Ongoing secondary waste treatment and disposal
		Granular Activated Carbon *Ex Situ*	High	High	High	High	High—May require shipment to off-site treatment facilities	Low	High—Ongoing carbon replacement costs
	Thermal	Vitrification *In Situ*	High	High	Moderate	Moderate	Low	High	None
		Catalytic Oxidation *Ex Situ*	High	High	High	Moderate	High	High	Moderate—Ongoing energy costs

Table 2.5. Evaluation of SWMU 4 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
Treatment (Continued)	Thermal (Continued)	Electrical Resistance Heating *In Situ*	High—Demonstrated at PGDP in UCRS-type sediments	High—*In situ* process	High	High—Presence of buried metallic waste may impact the system operations	Moderate—Air emissions	High	High energy costs during implementation; none after completion
		Thermal Conduction Heating *In Situ*	High	High—*In situ* process	High	High—Presence of buried metallic waste may impact the system operations	Moderate—Air emissions	Moderate	High energy costs during implementation; none after completion
		Thermal Desorption *Ex Situ*	High	Moderate—Soil must be excavated	High	High	Moderate—Air emissions	High	High energy costs during implementation; none after completion
		Steam Stripping *In Situ*	High	Moderate—Steam generation and treatment system required for operations	Moderate	Moderate—Implementability in the UCRS soils may be impacted by low permeability	Moderate—Air emissions	High	High energy costs during implementation; none after completion
		Ex Situ Vitrification	High—Immobilizes contaminants	Moderate with adequate process design and waste must be excavated	High—Requires extensive waste characterization to be effective	Moderate	Moderate—Rigorous engineering and administrative controls required	High	High
	Chemical	Permanganate	Uncertain in UCRS due to low permeability, heterogeneity, and variable saturation of soils; bench-scale treatability study determined that permanganate would be ineffective on DNAPL in RGA	Moderate—May require drilling into contaminated areas resulting in contact with buried waste	Uncertain for DNAPLs	High—For dissolved phase applicable contaminants; low in UCRS due to reduced permeability and sweep efficiency; uncertain in RGA	Moderate—May require drilling into contaminated areas resulting in contact with buried waste	Moderate	Low to Moderate—Primarily monitoring, but multiple injections may be required to treat DNAPL

Table 2.5. Evaluation of SWMU 4 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
Treatment (Continued)	Chemical (Continued)	Fenton's Reagent	Uncertain in UCRS due to low permeability, heterogeneity, and variable saturation of soils; bench-scale treatability study determined that Fenton's might be effective on DNAPLs in RGA but heating may be needed to increase reaction rate	Moderate—May require drilling into contaminated areas resulting in contact with buried waste; also operations with hazardous chemicals	Uncertain for DNAPLs	Low in UCRS—Uncertain in RGA because significant technical issues remain unresolved from bench-scale treatability study concerning full-scale implementation	Moderate—May require drilling into contaminated areas resulting in contact with buried waste	Moderate—Large amounts of oxidant would be required to oxidize VOC contaminants and soil background oxidation load	Low—Primarily monitoring
		ZVI	Uncertain in UCRS due to low permeability, heterogeneity, and variable saturation of soils; untested on DNAPLs in RGA; application through soil mixing determined to be highly effective	Moderate—May require drilling into contaminated areas resulting in contact with buried waste	Uncertain for DNAPLs	Low in UCRS—Uncertain in RGA	Moderate—May require drilling into contaminated areas resulting in contact with buried waste	Moderate to High—Depending on the grade of ZVI used	Low to Moderate—Primarily monitoring, but multiple injections may be required to treat DNAPL
		Ozonation	Uncertain in UCRS due to low permeability, heterogeneity, and variable saturation of soils; ozone gas permeability to UCRS sediments may increase coverage; untested on DNAPLs in RGA	Moderate—May require drilling into contaminated areas resulting in contact with buried waste	Uncertain for DNAPLs	Low in UCRS—Uncertain in RGA	Moderate—May require drilling into contaminated areas resulting in contact with buried waste	Moderate	Moderate—Continuing operation of ozone generator and sparging system
		Persulfate	Uncertain in UCRS due to low permeability, heterogeneity, and variable saturation of soils; untested on DNAPLs in RGA	Moderate—May require drilling into contaminated areas resulting in contact with buried waste	Uncertain for DNAPLs	Low in UCRS—Uncertain in RGA	Moderate—May require drilling into contaminated areas resulting in contact with buried waste	Moderate	Low to Moderate—Primarily monitoring, but multiple injections may be required to treat DNAPL

Table 2.5. Evaluation of SWMU 4 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
Treatment (Continued)	Chemical (Continued)	S-ISCO®	Uncertain in UCRS due to low permeability, heterogeneity, and variable saturation of soils; untested in the RGA	Moderate—May require drilling into contaminated areas resulting in contact with buried waste; uncontrolled mobilization of DNAPL could occur if adequate oxidant is not available to completely treat all mobilized DNAPL	Low—Emerging technology	Moderate—Complex technology that requires significant lab and modeling work to select surfactant/cosolvent and design a surfactant flood; location of DNAPL must be defined; requires good knowledge of site hydrogeology and geochemistry; previous testing of surfactants with RGA water identified issues with recovering and recycling surfactants/ cosolvents	Moderate—May require drilling into contaminated areas resulting in contact with buried waste	Moderate to High	High to Moderate—Primarily monitoring and additives, but multiple injections may be required to treat DNAPL
Disposal	Land Disposal	Off-Site Permitted Commercial Disposal Facility	High	Moderate—Long-distance transportation required	High	High	High	High	None
		Potential On-Site WDA Facility	High	High	High	Moderate	Moderate	Low—Assumes WDA construction costs not born by SWMU 4	None—Assumes WDA operational costs not born by SWMU 4
		On-Site C-746-U Landfill	High	High	High	High—Not all waste types generated can meet the waste acceptance criteria	High	Moderate	None—Long-term monitoring and maintenance not paid by program
	Discharge of Wastewater	Wastewater Treatment Demonstrating Compliance with ARARs	High	Moderate	High	High	Moderate	Moderate	Moderate—Monitoring required

- 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 2.5 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 1,000-year long-term monitoring program that is low to 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 2.6 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 SWMU 4, 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.

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Table 2.6. Selection of Representative Process Options

General Response Actions	Technology Type	Representative Process Options	Basis for Selection
LUCs	ICs	Engineering, legal, or administrative controls intended to prevent or limit exposure to hazardous substances	Effective and implementable with low costs.
	Physical Controls	Warning signs	Effective and implementable with low costs.
Surface Controls	Soil Barrier	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 capital and O&M cost.
Monitoring	Groundwater Monitoring	Conventional sampling and analysis from monitoring wells. Potential exists for installation of additional monitoring wells	Effective and implementable for monitoring; low to moderate capital and low O&M costs.
Removal	Excavators	Backhoes, trackhoes	Demonstrated effectiveness to depths of 20 ft bgs and to 42 ft with specialized equipment; technically implementable at SWMU 4 source areas. Moderate capital costs, but presence of water, large waste pieces (sizing and sorting) may complicate excavation. No O&M cost, unless waste left in place.
Containment	Capping	Engineered cover	Effective and implementable. Prevents direct contact and migration of residual contamination that cannot be effectively removed or destroyed by other means. Reduces infiltration using impermeable and drainage layers. Moderate capital and O&M cost due to complex construction and rigid monitoring and operation requirements.

Table 2.6. Selection of Representative Process Options (Continued)

General Response Actions	Technology Type	Representative Process Options	Basis for Selection
Containment (Continued)	Hydraulic Control	Groundwater extraction	Effective and implementable. Currently used on the Northwest and Northeast Plumes effectiveness is dependent upon continuous operation. Technology controls the migration of contaminants past the area of groundwater extraction. Moderate capital and O&M cost due to complex construction and rigid monitoring and operation requirements.
	Subsurface Vertical Barriers	Sheet pile	Sheet pile is selected as a complementary process option to excavation.
		Slurry wall	A vertical subsurface barrier is needed for the containment GRA to prevent horizontal migration into and out of the area of contaminated media. A slurry wall is selected as the RPO because it is less permeable than a sheet pile wall, and proper placement can be verified easier than jet grouting. High capital and low O&M costs.
Treatment	Biological	Anaerobic dechlorination	Moderate implementability due to DNAPL presence. Moderate capital and O&M costs.
	Thermal	ERH	Proven to be highly effective in UCRS target zone, high implementability if waste not buried in treatment area. High capital cost. Operational costs high due to power costs.

Table 2.6. 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 capital and no O&M costs.
		Potential on-site disposal unit	Effective as an adjunct technology for soil removal. Not currently implementable. Low cost assumes construction cost not born by the remedial action. Assumes no O&M cost born by users.
		C-746-U Landfill on-site	Effective and implementable for nonhazardous nonradioactive wastes, currently available. Wastes must meet WAC, including PCBs. Moderate capital and no O&M costs.
	Discharge of Wastewater	Wastewater treatment demonstrating compliance with ARARs	Effective and implementable for treated groundwater. Moderate capital and moderate O&M sampling costs.

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3. DEVELOPMENT AND SCREENING OF ALTERNATIVES

3.1 INTRODUCTION

Remedial alternatives for SWMU 4 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 SWMU 4, and address the DNAPL source areas that are present beneath the buried wastes at SWMU 4.

3.2 CRITERIA FOR THE DEVELOPMENT OF REMEDIAL ALTERNATIVES

The purpose of this 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 ICs, including, but not limited to, administrative and legal controls and physical controls are not included as a component of a No Action alternative.

3.3 DEVELOPMENT OF ALTERNATIVES

The GRAs and technologies retained for further evaluation in Section 2 have been combined to form six general remedial alternatives. Effectiveness, implementability, and cost are the balancing criteria that were used to guide the screening and development of these alternatives. The developed alternatives are summarized in Table 3.1. All alternatives that leave waste or contamination in place (above UU/UE levels) will include LUCs and monitoring to manage protection of human health and the environment. LUCs are expected to remain in place until contaminant contribution from UCRS soil no longer results in an exceedance of an RGA groundwater MCL (or risk-based concentration for residential use of groundwater in the absence of an MCL).

The final determination of successful remediation will be based on a demonstration that the target concentrations for COCs have been met or the risks associated with the contaminants have been mitigated successfully. Target concentrations are those concentrations that meet acceptable risk criteria for the specific COCs present incorporating all the risk/hazard control elements of the alternative. They differ from PRGs in that they consider the cumulative risk of actual COCs present in media at time of sampling and the realistic exposure scenarios to be allowed at the site.

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 are based on the available characterization data and site history.

Table 3.1. Development of Alternatives for BGOU SWMU 4

Alternative	Name	Description
1	No Action	• No activities.
2	Limited Action	• RD and RAWP, • Long-term groundwater monitoring, and • LUCs.
3	Recharge Control and Hydraulic Control	• RD and RAWP, • Engineered cover, • RGA hydraulic control system, • Slurry wall, • Long-term groundwater monitoring, and • LUCs.
4	Targeted Excavation, ERH, and Bioremediation	• RD and RAWP, • Targeted excavation of buried waste material, • Engineered cover over unexcavated portion of SWMU, • Sheet pile shoring, • Slurry wall, • Targeted implementation of ERH of high VOC concentration in targeted excavation area, • Bioremediation of targeted excavation area, including ERH residual VOC area, • Bioremediation and thermal performance monitoring well system, • Long-term groundwater monitoring, and • LUCs.
5	Full Excavation, ERH, and Bioremediation	• RD and RAWP, • Full excavation of SWMU buried waste material, • Sheet pile shoring, • Targeted implementation of ERH of high VOC concentration area, • Targeted bioremediation of high VOC concentration area, including ERH treated residual VOC area, • Bioremediation and thermal performance monitoring well system, • LUCs, and • Long-term groundwater monitoring.
6	Recharge Control and Bioremediation	• RD and RAWP, • Engineered cover over the SWMU, • Slurry wall, • Targeted bioremediation treatment of the area expected to contain TCE, • Bioremediation performance monitoring well system, • Long-term groundwater monitoring, and • LUCs.

3.4 REMEDIAL ALTERNATIVES FOR SWMU 4

3.4.1 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 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 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.

3.4.2 Alternative 2—Limited Action

This alternative eliminates direct contact risk via LUCs and recognizes the role played by the existing surface soil in preventing direct contact with the waste and contaminated materials. LUCs are expected to remain in place until contaminant contribution from UCRS soil no longer results in an exceedance of the RGA groundwater MCL (or risk-based concentration for residential use of groundwater in the absence of an MCL). Monitoring mitigates the uncertainties associated with managing risks associated with exposure to groundwater by monitoring any changes in SWMU status or condition that may warrant an additional response or action.

The specific details of the alternative will be developed once the alternative is selected in the ROD. This alternative will consist of the following, as necessary:

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

3.4.2.1 RD and RAWP

A detailed RD will be performed for this remedial alternative. The RD will be developed to allow the remedial action to be performed and to operate consistent with ARARs. Existing geophysical data and civil survey will be reviewed to confirm the defined limits of waste placement. It is necessary to determine these limits in order to develop the extent of LUCs accurately. To support estimating efforts, it was assumed that 12 monitoring wells will be included and sampled annually for a target compound list. Additionally, monitoring well placement will be considered in the context of satisfying the long-term needs of SWMU 4 and optimizing placement for other site needs, as applicable.

The RAWP will be developed and will identify the approach to be utilized in implementing the approved RD. The approach will include the identification of contractors, work control procedures, general health and safety protocols, waste management and disposal requirements, and schedule of implementation.

3.4.2.2 Groundwater monitoring

The groundwater monitoring program is expected to incorporate sampling of 12 total monitoring wells that will be located in upgradient and downgradient locations. These well will be screened in the RGA and sampled annually.

3.4.2.3 LUCs

All alternatives that leave waste or contamination in place above UU/UE levels will include LUCs. The following are specific LUCs included in Alternative 2.

General Response Action	Technologies	Process Options
LUCs	Physical Controls	• Warning signs
	Administrative Controls	• E/PP program • Property record notices • Contingent deed/lease restrictions • An environmental covenant meeting the requirements of *KRS* 224.80-100 *et seq*. to be filed at the time of property transfer

3.4.3 Alternative 3—Recharge Control and Hydraulic Control

An engineered cover will be placed over the entire SWMU 4 area. The cap will reduce infiltration of surface water and will provide a barrier to direct contact with the waste and soils in close proximity to the waste. The cap will be paired with a vertical slurry wall, which will reduce lateral migration of groundwater into the waste and soils in close proximity to the waste. The alternative also includes a hydraulic control system in the RGA to prevent migration of contaminants from the SWMU 4. 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 public health and environment. Remedial components of Alternative 3 are depicted in Figure 3.1.

The specific details of the alternative will be developed once the alternative is selected in the ROD. This alternative will consist of the following, as necessary:

- RD and RAWP,
- Engineered cover,
- Slurry wall,
- Hydraulic control system,
- Install monitoring wells and conduct long-term RGA groundwater monitoring, and
- Implement LUCs.

3.4.3.1 RD and RAWP

A detailed RD will be performed for this remedial alternative. The RD will be developed to allow the remedial action to be performed and to operate consistent with ARARs. Existing geophysical data will be reviewed to confirm the defined limits of waste placement. Geophysical and civil survey data will be collected as needed to allow the current surface to be defined; to plan for an efficient drainage pattern for the area; and to design the engineered cover, hydraulic control system, and groundwater monitoring system. Design analysis will be performed to determine optimal location of the extraction wells and their expected extraction rate for attaining the hydraulic control. Additionally, monitoring well placement will consider the long-term needs of SWMU 4.

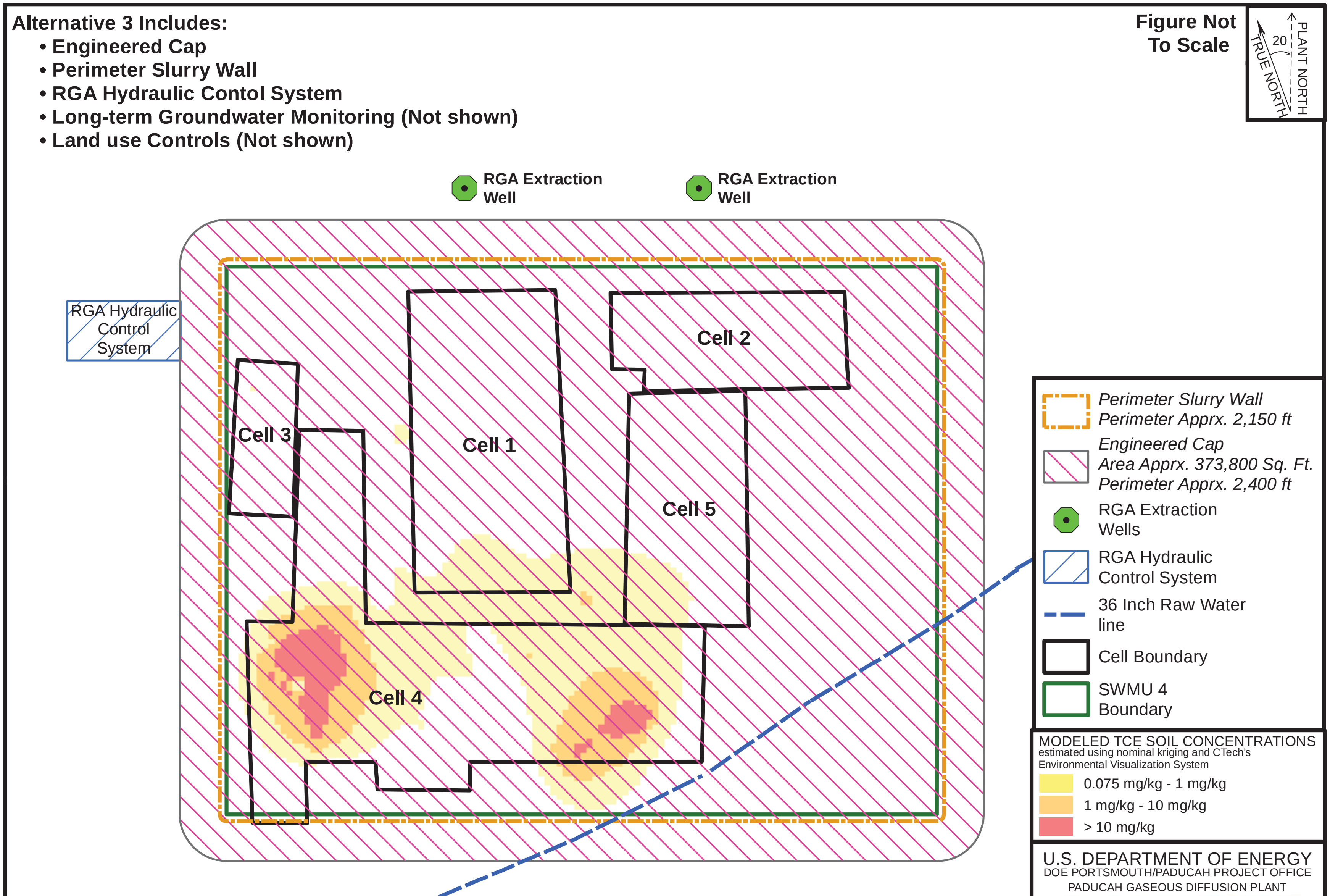

Figure 3.1. BGOU RI Addendum Subsurface Soil Trichloroethene Results Modified with Alternative 3 Remedial Components (Depicted)

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The RAWP will be developed and will identify the approach to be used in implementing the approved RD. The approach will include the identification of contractors, work control procedures, general health and safety protocols, waste management and disposal requirements, and schedule of implementation.

3.4.3.2 Engineered cover

An engineered cover will be constructed over the entire SWMU 4 area. Because the edges of the engineered cover must be tapered to allow for cover and the natural surfaces to meet, the cover is shown to be larger than the proper area of SWMU 4 (see Figure 3.1). The tapered edges allow for the barrier layer (impermeable) to cover the entire SWMU. For evaluation and cost estimating purposes, it is assumed the cover will include minimal regrading of the existing soil cover layer and addition of a 3-inch, compacted soil layer to provide an appropriate surface over which to contrast the engineered cover. Typical cover components include a base soil layer, a barrier layer that may be geomembrane or tightly compacted protective soil, drainage layer with appropriate filter layer, supporting geotextile layer, and topsoil. Because the waste material contained in SWMU 4 is aged and does not generate gas, a gas collection layer is not needed. The cover will be graded to drain, mulched, and seeded to prevent erosion. Energy dissipating ditch checks may be installed at sharp transition points or where erosion may occur. The tapering of the cover elements will extend beyond the edges of the burial ground. This will encroach upon a cylinder haul road located to the north of the burial ground. For costing purposes, it is assumed that portion of the road and adjacent road ditch will require relocation, but will not be active components of the remedy.

3.4.3.3 Slurry wall

A vertical slurry wall will be constructed to work with the engineered cover to prevent horizontal migration of UCRS groundwater into the landfill waste cells. The slurry wall will be located along the perimeter of the cover and encircle the burial ground. The slurry wall will be connected to the engineered cover to prevent water from entering the landfill between the cover and the slurry wall. The depth of the slurry wall is estimated to be approximately 40 ft and will not be keyed into any particular geologic horizon; it is not necessary because upward gradients are not present at depths shallower than 40 ft. The thickness and composition of the slurry wall are expected to be approximately 2–3 ft and composed of a soil-bentonite slurry, respectively.

UCRS geology in the PGDP area is made up of discontinuous interbeds of gravels. These shallow gravels were disturbed and truncated by the excavation and burial process at SWMU 4 and are in communication with the landfill. In some instances, these gravels are saturated. Under general conditions, the UCRS groundwater gradient is downward with minimal to no lateral migration. Once the engineered cover has been constructed over the SWMU, groundwater saturation will be reduced in soil below the cover. This reduced groundwater saturation will allow horizontal gradients to develop, causing groundwater in the area laterally adjacent to the cover to migrate laterally and enter into the landfill beneath the engineered cover. The presence of the slurry wall will prevent this lateral migration, further reducing water entering the landfill.

3.4.3.4 Hydraulic control system

Because the alternative components do not include a measure that either treats or removes existing contamination, a hydraulic control system will be installed to control, capture, and remove the resulting groundwater contaminants. The system will utilize a number of groundwater extraction wells along with a surface treatment system. For evaluating and estimating purposes, the system is assumed to include two groundwater extraction wells placed in the RGA downgradient of SWMU 4 that will intercept migrating contaminants. It is assumed that six performance monitoring wells will be used by the extraction system.

Extracted groundwater will be treated in an aboveground treatment system to meet ARARs before releasing the remediated water to an outfall. The treatment system is expected to have treatment units, such as greensand filtering, ion exchange, and air stripping with vapor phase carbon treatment. For estimating purposes, the system is expected to be sized to treat 200 gpm of contaminated water.

3.4.3.5 Long-term groundwater monitoring

The groundwater monitoring program is expected to incorporate sampling of 12 total monitoring wells that will be located in upgradient and downgradient locations. These wells will be screened in the RGA and sampled annually.

3.4.3.6 LUCs

All alternatives that leave waste or contamination in place above UU/UE levels will include LUCs. The following are the specific LUCs included in Alternative 3.

General Response Action	Technologies	Process Options
LUCs	Physical Controls	• Warning signs
	Administrative Controls	• E/PP program • Property record notices • Contingent deed/lease restrictions • An environmental covenant meeting the requirements of *KRS* 224.80-100 *et seq*. to be filed at the time of property transfer

3.4.4 Alternative 4—Targeted Excavation, ERH, and Bioremediation

This alternative will utilize excavation to remove buried waste and visually impacted soils to a depth of 20 ft bgs from the southern portion of SWMU 4. Contaminants below 20 ft will be treated with *in situ* technologies. The specific details of the alternative will be developed once the alternative is selected in the ROD. This alternative will consist of the following:

- RD and RAWP,
- Targeted excavation of SWMU,
- Targeted ERH,
- Targeted bioremediation,
- Engineered cover,
- Slurry wall,
- Install monitoring wells and conduct long-term RGA groundwater monitoring, and
- Implement LUCs.

The area targeted (107,000 ft^2) for excavation is the southern portion of SWMU 4 where higher concentrations of TCE are present. This is the same area that is expected to have the presence of a limited amount of DNAPL in the soil below the buried waste. Excavated material will be disposed of based on characterization data and availability of disposal facilities. The remaining excavation will be filled with clean fill. It is expected the excavation depth of up to 20 ft will require the placement of sheet piling around the location to be excavated to provide shoring for health and safety purposes.

ERH will be utilized to treat the soil located directly beneath the excavation down to the top of the RGA at approximately 60 ft. The ERH treatment system will include the necessary electrodes, temperature thermocouples, pressure monitors, and water circulation wells to support the planned soil treatment volume estimated at 6,750 yd^3. The ERH system also will include the necessary aboveground treatment system, such as air stripping, ion exchange, green sand filter, and vapor phase carbon.

The remediation goal for this component of the remedial action is to treat or remove PTW wherever practicable. The means of arriving at this point is to operate ERH system "until monitoring indicates that heating has stabilized in the subsurface and that recovery of TCE, as measured in the recovered vapor, diminishes to a point at which further recovery is at a constant rate (i.e., recovery is asymptotic)." At asymptosis, continued heating would not be expected to result in any further significant reduction of toxicity, mobility, or volume of the zone of contamination. In addition to the vapor concentration, extracted groundwater TCE concentrations will be evaluated as an indicator of when the point of diminishing returns is being approached in TCE mass recovery. Additional detail will be developed during the RD that will define asymptotic recovery in more detail and will provide additional detail regarding criteria for ceasing ERH operations, including temperature stabilization requirements.

Once the ERH activity is completed, the area, as soon as feasible, will undergo enhanced bioremediation treatment for remaining VOCs. Bioremediation treatment implementation will follow quickly the ERH treatment directly to allow the warm soils to enhance bacterial growth. The purpose of this follow-on action will be to reduce further the VOCs in the UCRS. The treatment of these areas will protect the RGA groundwater located below SWMU 4 from contaminants present in the UCRS.

Because this alternative will not result in the SWMU 4's having unlimited use and unrestricted exposure, LUCs and groundwater monitoring will be included in this alternative. Remedial components of Alternative 4 are depicted in Figure 3.2.

3.4.4.1 RD and RAWP

Detailed RD will be performed for this alternative. The excavation process is expected to require some support facilities for management of the excavated wastes and covering the excavation to control water infiltration. Dewatering also may be needed, because some waste materials may be sitting in water, which will need to be removed during the excavation process. The design will include fill calculations needed to replace the excavated waste and associated soil with clean fill. It is expected that the top 2 ft of soil that currently composes the existing SWMU 4 cap will be excavated, stockpiled, and reused as a portion of the clean fill soil. Replacement of the soil will require a placement approach that results in the area being stable, because the same area will be drilled extensively during implementation of the ERH in deeper soil.

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 RD. It is anticipated that soil will be imported from local sources.

The RAWP will be developed and will identify the approach to be used to implement the approved RD. The approach will include the identification of contractors, work control procedures, general health and safety protocols, waste management and disposal requirements, and schedule of implementation.

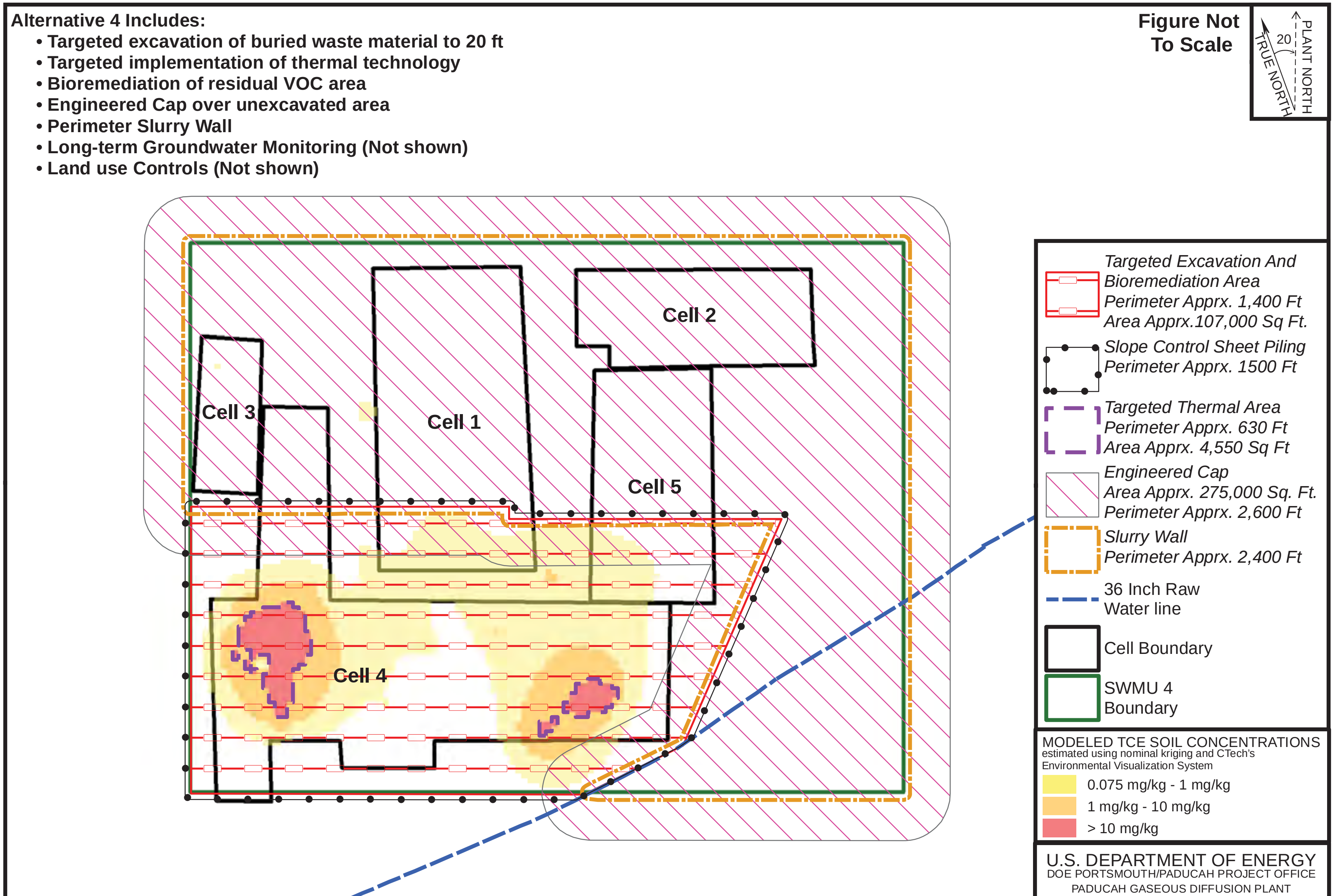

Figure 3.2. BGOU RI Addendum Subsurface Soil Trichloroethene Results Modified with Alternative 4 Remedial Components (Depicted)

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3.4.4.2 Targeted excavation (removal)

This alternative will target excavation technology over the southern portion of the SWMU 4 area. This area was identified in the BGOU SWMU 4 RI Addendum Report to contain the most volatile organic contamination. The presence of DNAPL within the vertical profile below the buried waste down to 60 ft also was indicated. The buried wastes in this area will be excavated, sorted, size-reduced, as needed, stabilized, packaged, and transported for disposal. The excavation depths of 20 ft will require use of steel sheet piling to control slopes during the excavation processes. It is expected that excavated material disposal and any required treatment will be performed at both off-site and at on-site facilities based on the characterized material and the availability of services at each facility type. Any classified waste will be sent to NNSS. Due to the presence of shallow groundwater in the SWMU 4 area, it is expected that dewatering likely will be required for the excavation and handling of the waste materials. It also is planned that roofed facilities will need to be constructed to assist in managing the excavated waste. The hole left from excavating the waste will be refilled with clean soil to provide a base for performing ERH and bioremediation on the subsurface soils beneath the excavation. For costing purposes, the estimated waste quantities to be excavated were evaluated, and determinations were made about the portions of the excavated materials that could be disposed of at on-site and off-site facilities. Those assumptions were utilized in developing estimated waste disposal costs.

3.4.4.3 ERH

The excavation of the buried waste at SWMU 4 will allow access to the VOC contamination in the subsurface soils that is located under the buried waste. ERH will be performed on the subsurface soils beneath the area that has been excavated. The treatment area will be where TCE soil sample results generally exceed 10 mg/kg. This is the highest concentration (isoconcentration contour) in SWMU 4. DNAPL likely would be present in or near the area with highest TCE concentration. ERH has been implemented at PGDP successfully on this same stratum and determined to be highly successful. The ERH system will include the necessary temperature monitoring probes, vacuum, water extraction and water injection wells, along with the geometrically spaced electrodes that will transmit current to the formation and heat it. The ERH system also will utilize a treatment system to treat the vapor and water streams extracted during the treatment. The treatment system is temporary because it will be utilized only during ERH operations. Typical components of the treatment system may include units, such as air stripping, ion exchange, water filtering, and vapor phase carbon, to treat both vapor and water streams.

The RAO for this component of the remedial action is to treat or remove PTW wherever practicable. The means of arriving at this point is to operate the ERH system "until monitoring indicates that heating has stabilized in the subsurface and that recovery of TCE, as measured in the recovered vapor, diminishes to a point at which further recovery is at a constant rate (i.e., recovery is asymptotic)." At asymptosis, continued heating would not be expected to result in any further significant reduction of toxicity, mobility, or volume of the zone of contamination. In addition to the vapor concentration, extracted groundwater TCE concentrations will be evaluated as an indicator of when the point of diminishing returns is being approached in TCE mass recovery. Additional detail will be developed during the RD that will define the asymptotic recovery criteria for ceasing ERH operations, including temperature stabilization requirements.

3.4.4.4 Bioremediation

After ERH treatment has been completed, residual VOC contamination in the UCRS soils beneath the clean fill will undergo enhanced bioremediation. The area to be treated is the southern portion of SWMU 4 and will include the area thermally treated for highly concentrated VOCs and adjacent areas that contain lower concentrations of VOCs. Bioremediation will follow the ERH treatment quickly to allow the warm soils to enhance bacterial growth.

There will be no need to enhance the biological activity in the clean soil used to backfill the excavation; therefore, horizontally drilled infiltration wells will be installed between the clean fill soil and the underlying zone of contamination. Infiltration will allow the bioamendments to migrate similar to the groundwater, which is vertical through the UCRS to the top of the RGA. A performance monitoring system will be put in place to allow evaluation of the bioremediation progress and when bioamendments need adjustment. The injection pressures are expected to be slightly higher than atmospheric pressure to allow the bioamendment to spread to areas between the injection wells. Lactate bioamendment use was assumed as the process option for evaluation and cost estimating. The estimated time frame for implementation of the bioremediation is approximately three years. The bioremedial effects of the operations will continue beyond the final injection and will be monitored by the long-term groundwater monitoring phase.

3.4.4.5 Engineered cover

An engineered cover will be constructed over the area of the SWMU 4 that is not excavated. Because the edges of the engineered cover must be tapered to allow for cover and the natural surfaces to meet, the cover is shown to be larger than the proper area of the SWMU 4, as shown in Figure 3.2. For evaluation and cost estimating purposes, it is assumed the cover will include minimal regrading of the existing soil cover layer and addition of a 3-inch, compacted soil layer to provide an appropriate surface over which to contrast the engineered cover. Typical cover components include a barrier layer that may be geomembrane or tightly compacted protective soil, drainage layer with appropriate filter layer, supporting geotextile layer, and topsoil. Because the waste material contained in SWMU 4 is not known to generate gas, a gas collection layer is not needed. The cover will be graded to drain, mulched, and seeded to prevent erosion. Energy dissipating ditch checks may be installed at sharp transition areas or where erosion may tend to occur. The tapering of the cover elements will extend beyond the edges of the burial ground to allow the impermeable cover layers to cover the buried waste. This will encroach upon a cylinder haul road located to the north of the burial ground. For costing purposes, it is assumed that portion of the road and adjacent road ditch will require relocation.

3.4.4.6 Slurry wall

A vertical slurry wall will be constructed to work with the engineered cover to prevent horizontal migration of groundwater from UCRS soils into the landfill waste cells. The slurry wall will be located along the perimeter the cover and encircle the unexcavated burial ground. The slurry wall will be connected to the engineered cover to prevent water from entering the landfill between the cover and the slurry wall. The depth of the slurry wall is estimated to be approximately 40 ft and will not be keyed into any particular geologic horizon because it is not necessary; upward gradients are not present at shallower depths than 40 ft. The thickness and composition of the slurry wall is expected to be approximately 2–3 ft and composed of a soil-bentonite slurry, respectively.

The UCRS in the PGDP area contains discontinuous interbeds of gravels. These shallow gravels were disturbed and truncated by the excavation and burial process at SWMU 4, but are in communication with the landfill. In some instances, these gravels are saturated. Under general conditions, the UCRS groundwater gradient is downward with minimal to no lateral migration. Once the engineered cover has been constructed over the SWMU, groundwater saturation in soil below the cover will be reduced. This reduced groundwater saturation will allow horizontal gradients to develop, causing groundwater in the area laterally adjacent to the cover to migrate laterally and enter into the landfill beneath the engineered cover. The presence of the slurry wall will prevent this lateral migration, further reducing water entering the landfill.

3.4.4.7 Long-term groundwater monitoring

The groundwater monitoring program is expected to incorporate sampling of 12 total monitoring wells that will be located in upgradient and downgradient locations. These wells will be screened in the RGA and sampled annually.

3.4.4.8 LUCs

All alternatives that leave waste or contamination in place above UU/UE levels will include LUCs. The following specific LUCs are included in Alternative 4.

General Response Action	Technologies	Process Options
LUCs	Physical Controls	• Warning signs
	Administrative Controls	• E/PP program • Property record notices • Contingent deed/lease restrictions • An environmental covenant meeting the requirements of *KRS* 224.80-100 *et seq*. to be filed at the time of property transfer

3.4.5 Alternative 5—Full Excavation, ERH, and Bioremediation

Alternative 5 will utilize excavation to remove all of the buried waste and visually impacted soils contained in SWMU 4 to a depth of 20 ft bgs. Contaminants below 20 ft will be treated with *in situ* technologies. The specific details of the alternative will be developed once the alternative is selected in the ROD. This alternative will consist of the following:

- RD and RAWP,
- Full excavation of SWMU,
- Targeted ERH,
- Targeted bioremediation,
- Install monitoring wells and conduct long-term RGA groundwater monitoring, and
- Implement LUCs, if necessary.

All SWMU 4 waste and visibly contaminated soil to a depth of 20 ft bgs will be excavated and dispositioned. The full excavation of SWMU 4 will allow complete access to the area that is expected to contain a limited amount of DNAPL in the soil below the buried waste. Once the waste has been excavated (283,000 ft^2), for evaluation and estimation purposes, it is expected that disposal will be performed at both off-site and at on-site facilities based on the characterized material and the availability of services at each facility type. The excavation will be backfilled with clean fill. It is expected the excavation depth of up to 20 ft will require placement of sheet piling around the location to be excavated to provide shoring. ERH will be utilized to treat the soil located in the southern portion of the SWMU. The area for this treatment is approximately 4,550 ft^2 and will be over the depth from 20 ft to 60 ft. The ERH treatment system will include the necessary electrodes, temperature thermocouples, pressure monitors, and water circulation wells to support the planned soil treatment volume. The ERH system also will include an aboveground treatment system with units, such as air stripping, ion exchange, green sand filter, and vapor phase carbon. Enhanced bioremediation will be implemented following ERH to reduce the residual VOCs in the subsurface soils further.

If the excavation and *in situ* remediation do not result in unlimited use and uncontrolled exposure conditions at SWMU 4, then LUCs and groundwater monitoring will be included in Alternative 5. Remedial components of Alternative 5 are depicted in Figure 3.3.

3.4.5.1 RD and RAWP

A detailed RD will be performed for this remedial alternative. The RD will be developed to allow the remedial action to be performed and to operate consistent with ARARs. Existing geophysical data will be reviewed to confirm the defined limits of waste placement. The excavation process is expected to require some support facilities for management of the excavated wastes and to cover the excavation to control water infiltration. Although the complete removal of the buried waste and the treatment of the subsurface soils that contain VOC contamination will be performed, the expectation is that SWMU 4 still will need to have groundwater monitoring and LUCs until UU/UE to groundwater is declared. LUCs are expected to remain in place until contaminant contribution from UCRS soil no longer results in an exceedance of an RGA groundwater MCL (or risk-based concentration for residential use of groundwater in the absence of an MCL).

Additionally, monitoring well placement will be considered in the context of satisfying the long-term needs of SWMU 4 as well as optimizing placement for other site needs, as applicable.

The RAWP will identify the approach to be utilized in implementing the approved RD. The approach will include the identification of contractors, work control procedures, general health and safety protocols, waste management and disposal requirements, and schedule of implementation. The approach to implementation will require a process for the handling, sizing, management, containerization, transportation, and disposal of the excavated waste. The RAWP also will include the process for long-term monitoring of the remediated SWMU until RAOs are attainted.

3.4.5.2 Full excavation

This alternative will excavate all buried waste and visibly contaminated/stained soils to a depth of 20 ft bgs. In addition to the actual excavation of waste, a number of other activities will be implemented to support excavation. Support facilities will be needed for waste sorting and size-reduction. The excavation will require the use of steel sheet piling to control slopes during the excavation processes. Due to the shallow groundwater located in the SWMU 4 area, the waste removal activities will require support of dewatering equipment. For evaluation and estimating purposes, it is expected that vacuum trucks and a mobile water treatment unit will be used to handle a heavy amount of suspended solids. Following solids removal, treatment will be performed for the expected contaminants, including VOC and metals. Once the water is treated to meet ARARs, it will be released through an existing KPDES or new CERCLA outfall. Excavated waste will be sorted, size-reduced, as needed, stabilized, and packaged for disposal. Waste disposal and any required treatments will be performed, as needed, based on the characterization and the availability of facilities. The hole left from excavating the waste will be filled with clean soil to provide a base for performing ERH and bioremediation on the subsurface soils from approximately 20 to 60 ft bgs. Full excavation of the SWMU will encroach upon a cylinder haul road located to the north of the burial ground. For costing purposes, it is assumed that portion of the road and adjacent road ditch will require relocation.

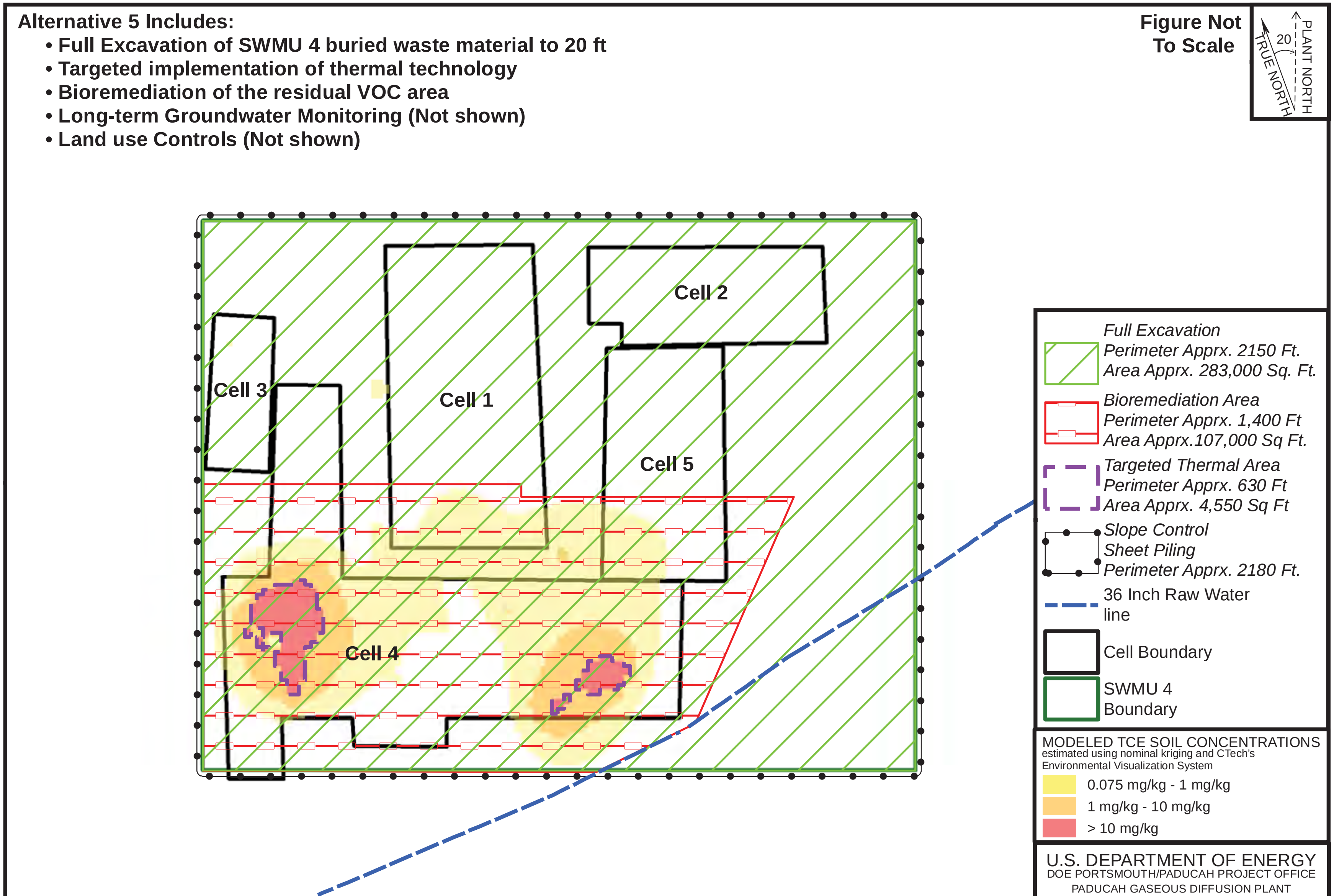

Figure 3.3. BGOU RI Addendum Subsurface Soil Trichloroethene Results Modified with Alternative 5 Remedial Components (Depicted)

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3.4.5.3 ERH

Excavation of the buried waste at SWMU 4 will allow access to the VOC contamination in the subsurface soils that are located under the buried waste. ERH will be performed on the subsurface soils beneath the area that has been excavated. The treatment area will be where historical TCE soil sample results generally exceed 10 mg/kg. This is the highest concentration (isoconcentration contour). Residual DNAPL could be present in or near the area with highest TCE concentration in soil. ERH has been implemented at PGDP on this same stratum and has been determined to be highly successful. The ERH system will include the necessary temperature monitoring probes, vacuum, water extraction, and water injection wells, along with the geometrically spaced electrodes that will transmit current to the formation and heat it. The ERH system also will treat the vapor and water streams extracted from the subsurface; this portion of the treatment likely will include units, such as air stripping, ion exchange, water filtering, and vapor phase carbon, to treat both vapor and water streams. The treatment system is temporary because it will be utilized only during ERH operations.

The RG for this component of the remedial action is to treat or remove PTW wherever practicable. The means of arriving at this point is to operate the ERH system "until monitoring indicates that heating has stabilized in the subsurface and that recovery of TCE, as measured in the recovered vapor, diminishes to a point at which further recovery is at a constant rate (i.e., recovery is asymptotic)." At asymptosis, continued heating would not be expected to result in any further significant reduction of toxicity, mobility, or volume of the zone of contamination. In addition to the vapor concentration, extracted groundwater TCE concentrations will be evaluated as an indicator of when the point of diminishing returns is being approached in TCE mass recovery. Additional detail will be developed during the RD that will define asymptotic recovery in more detail and will provide additional detail regarding criteria for ceasing ERH operations, including temperature stabilization requirements.

3.4.5.4 Bioremediation

After ERH treatment has been completed, residual VOC contamination in UCRS soils beneath the clean fill will undergo enhanced bioremediation. The area to be treated is the southern portion of SWMU 4 and will include thermally treating the area for highly concentrated VOCs and adjacent areas containing lower concentrations of VOCs. Bioremediation will follow the ERH treatment quickly to allow the warm soils to enhance bacterial growth.

There will be no need to enhance the biological activity in the clean soil used to backfill the excavation; therefore, horizontally drilled infiltration wells will be installed between the clean fill soil and the underlying zone of contamination. Infiltration will allow the bioamendments to migrate similar to the groundwater, which is primarily vertical through the UCRS to the top of the RGA. A performance monitoring system will be put in place to allow evaluation of the bioremediation progress and when bioamendments need adjustment. The injection pressures are expected to be slightly higher than atmospheric pressure to allow the bioamendment to spread to areas between the injection wells. Lactate bioamendment use was assumed as the process option for evaluation and cost estimating. The estimated time frame for implementation of the bioremediation is approximately three years. The bioremedial effects of the operations will continue beyond the final injection and will be monitored by the long-term groundwater monitoring phase.

3.4.5.5 Long-term groundwater monitoring

The groundwater monitoring program is expected to incorporate sampling of 12 total monitoring wells that will be located in upgradient and downgradient locations. These wells will be screened in the RGA and sampled annually.

3.4.5.6 LUCs

All alternatives that leave waste or contamination in place above UU/UE levels will include LUCs. The following are specific LUCs included in Alternative 5. LUCs are expected to remain in place until contaminant contribution from UCRS soil no longer results in an exceedance of an RGA groundwater MCL (or risk-based concentration for residential use of groundwater in the absence of an MCL).

General Response Action	Technologies	Process Options
LUCs	Physical Controls	• Warning signs
	Administrative Controls	• E/PP program • Property record notices • Contingent deed/lease restrictions • An environmental covenant meeting the requirements of *KRS* 224.80-100 *et seq*. to be filed at the time of property transfer

3.4.6 Alternative 6—Recharge Control and Bioremediation

Alternative 6 will include the placement of an engineered cover over the entire SWMU. The cover will be paired with a vertical slurry wall to reduce recharge further. *In situ* bioremediation will be used to reduce contaminant levels below 20 ft bgs. The specific details of the alternative will be developed once the alternative is selected in the ROD. This alternative will consist of the following:

- RD and RAWP,
- Engineered cover,
- Slurry wall,
- Targeted bioremediation,
- Install monitoring wells and conduct long-term RGA groundwater monitoring, and
- Implement LUCs.

The cover will reduce the infiltration of surface water and will provide a barrier to direct contact with the waste and soils in close proximity to the waste. The engineered cover also will provide a groundwater recharge control to reduce water from coming into contact with the waste and the contaminants that have migrated from the waste into the UCRS subsurface soils. The alternative also includes a targeted bioremediation to treat the contamination beneath the buried waste. Because the buried waste will remain in place for this alternative and vertical drilling will be problematic, an innovative means will need to be used to allow the bioamendments to be introduced. A system of horizontal injection wells could be drilled beneath the waste for injection of the bioamendments. As with the other alternatives, LUCs and groundwater monitoring will be included in this alternative. Remedial components of Alternative 6 are depicted in Figure 3.4.

3.4.6.1 RD and RAWP

A detailed RD will be performed for this remedial alternative. The RD will be developed to allow the remedial action to be performed and to operate consistent with ARARs. Existing geophysical data will be reviewed to confirm the defined limits of waste placement. Data will be collected as needed to allow the current surface to be defined and plan for an efficient drainage pattern for the area and to design the

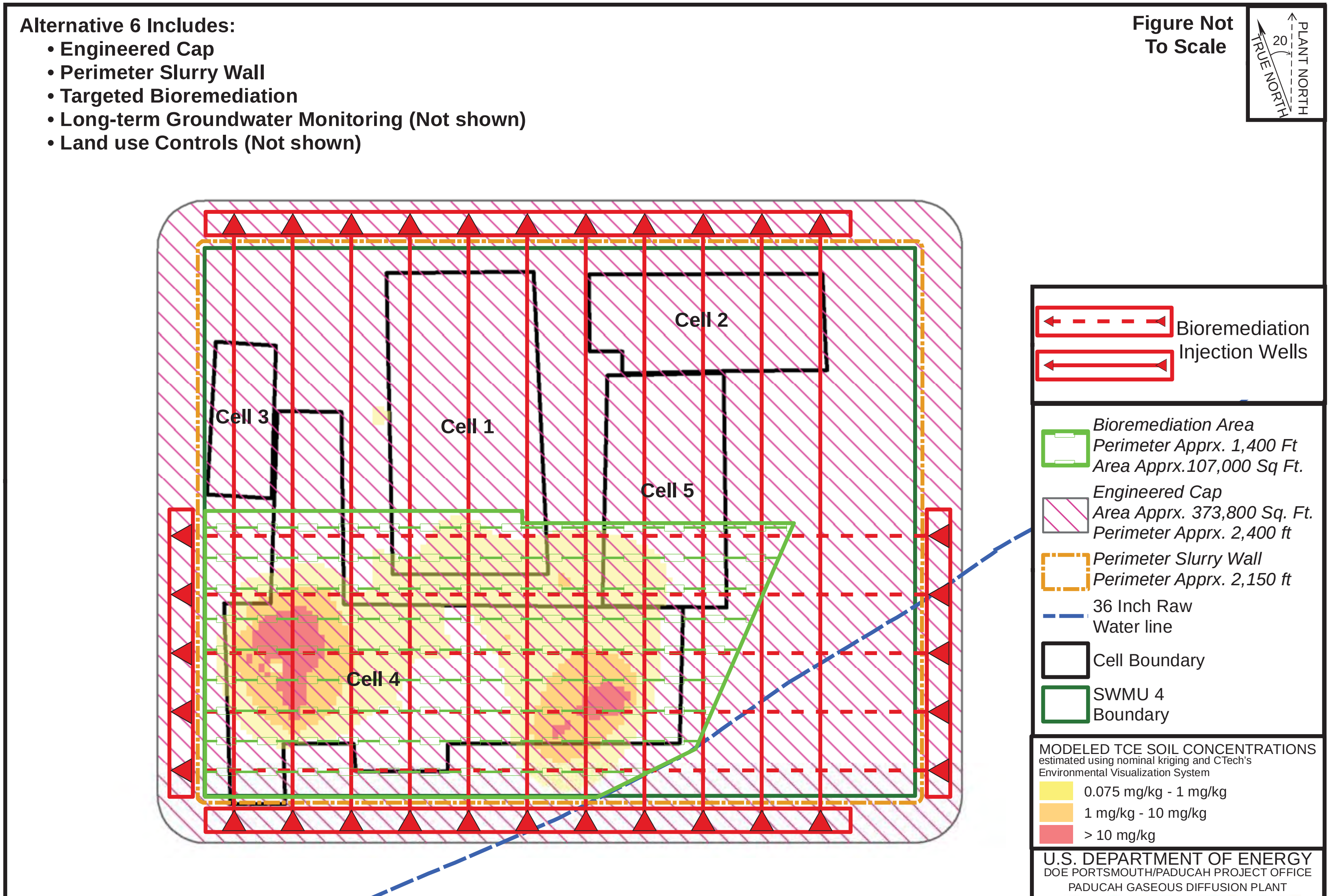

Figure 3.4. BGOU RI Addendum Subsurface Soil Trichloroethene Results Modified with Alternative 6 Remedial Components (Depicted)

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2/20/2017

engineered cover. The subsurface bioremediation system will be designed to allow the bioamendments to be placed beneath the buried waste. A series of horizontal injection wells are expected to be utilized for injection of bioamendments. It is expected that bioamendment injections will be performed multiple times to allow for varied areal control and continued presence of subsurface conditions conducive to reductive anaerobic bioremediation. Additionally, monitoring well placement will be considered in the context of satisfying the long-term needs of SWMU 4, as well as optimizing placement for other site needs, as applicable.

The RAWP will be developed and will identify the approach to be utilized in implementing the approved RD. The approach will include identification of contractors, work control procedures, general health and safety protocols, waste management and disposal requirements, and schedule of implementation.

3.4.6.2 Engineered cover

A surface cover will be constructed over the entire SWMU. For evaluation and cost estimating purposes, it is assumed the cover will include a minimal regrading of the existing soil cover layer and the addition of a 3-inch, compacted soil layer to provide an appropriate surface over which to place the engineered cover. Because the waste material contained in SWMU 4 is not known to generate gas, gas vents will not be needed to vent the cover. Energy dissipating ditch checks may be installed at sharp transition points or where erosion may occur. Tapering of the cover elements will extend beyond the edges of the burial ground. This will encroach upon a cylinder haul road located to the north of the burial ground. For costing purposes, it is assumed that portion of the road and adjacent road ditch will require relocation.

3.4.6.3 Slurry wall

A vertical slurry wall will be constructed to prevent horizontal migration of groundwater from UCRS soils into the landfill waste cells. The slurry wall will be located along the perimeter the cap and encircle the burial ground. The slurry wall will connect to the engineered cap to prevent water from entering the landfill between the cap and the slurry wall. The depth of the slurry wall is estimated to be approximately 40 ft and will not be keyed into any particular geologic horizon because it is not necessary; upward gradients are not present at shallower depths than 40 ft. The thickness and composition of the slurry wall is expected to be approximately 2–3 ft and composed of a soil-bentonite slurry, respectively.

The UCRS in the PGDP area contains discontinuous interbeds of gravels. These shallow gravels were disturbed and truncated by the excavation and burial process at SWMU 4, but are in communication with the landfill. In some instances, these gravels are saturated. Under general conditions, the UCRS groundwater gradient is downward with minimal to no lateral migration. Once the engineered cover has been constructed over the SWMU, groundwater saturation in soil below the cover will be reduced. This reduced groundwater saturation will allow horizontal gradients to develop, causing groundwater in the area adjacent to the cover to migrate laterally and enter into the landfill beneath the engineered cover. The presence of the slurry wall will prevent this lateral migration, further reducing water entering the landfill.

3.4.6.4 Bioremediation

The target for bioremediation treatment is the TCE located beneath the buried waste in the southern portion of SWMU 4. Because the buried waste remains in place, access to the zone to be treated is hindered; therefore, horizontal drilling techniques will be used to install injection wells below the buried waste. Injection wells will allow the bioamendment, which is mixed with water, to be injected over the top of the UCRS contamination that is located beneath the buried waste. After injection, bioamendments will migrate downward through the contaminated UCRS just as water would naturally. During the migration, the bioamendment will provide nutrients (i.e., a carbon source) to support microbe/bacteria growth.

The increase in microbe/bacterial growth will result in consumption of all available oxygen present in the in the UCRS soils. The oxygen will become depleted, and reducing conditions will be temporarily established in the UCRS. Reducing conditions then allow anaerobic bacteria to flourish and reductively dechlorinate TCE and its degradation products. Additional bioamendments can be added to continue the temporary reducing conditions as needed. Because the reducing condition is temporary, natural conditions will return once there no longer are sufficient concentrations of bioamendments to sustain the microbe/bacterial growth. The injection pressures are expected to be slightly greater than atmospheric pressure to allow the bioamendment to spread to areas between the injection wells. Lactate bioamendment use was assumed for evaluation and cost estimating. The presence of TCE DNAPL has been indicated in the soils between 20 ft to 60 ft, and the estimated volume of TCE solvent is approximately 60 gal, as documented in the BGOU SWMU 4 RI Addendum Report (DOE 2017). Based on the widespread detection of TCE across Cell 4 (Figure 3.4), the TCE is dispersed. Dispersal of the estimated 60 gal of DNAPL in the TCE area, as mapped, will result in the DNAPL being at residual saturation and amenable to bioremediation. A performance monitoring system will be put in place to allow evaluation of the bioremediation progress and to monitor field conditions. The estimated time frame for field implementation of bioremediation is approximately three years. The bioremedial effects of the alternative will continue beyond the final injection and will be monitored by the long-term groundwater monitoring phase.

3.4.6.5 Long-term groundwater monitoring

The groundwater monitoring program is expected to incorporate sampling of 12 total monitoring wells that will be located in upgradient and downgradient locations. These wells will be screened in the RGA and sampled annually.

3.4.6.6 LUCs

All alternatives that leave waste or contamination in place above UU/UE levels will include LUCs. The following are the specific LUCs included in Alternative 6.

General Response Action	Technologies	Process Options
LUCs	Physical Controls	• Warning signs
	Administrative Controls	• E/PP program • Property record notices • Contingent deed/lease restrictions • An environmental covenant meeting the requirements of *KRS* 224.80-100 *et seq.* to be filed at the time of property transfer

3.5 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. However, the screening of alternatives is an optional phase, and if a manageable (i.e., not excessive) number of remedial alternatives has been developed, it is not necessary to screen these alternatives before conducting detailed analysis. It was determined in this section that Alternative 2, limited action, will not meet the RAOs. Alternative 2, therefore, was screened from detailed analysis. The remedial measures contained in Alternative 2, which are LUCs and groundwater monitoring, are included in each of the remaining alternatives. Section 4 contains the detailed analysis of the five alternatives evaluated in this FS. The five alternatives that will undergo detailed analysis are shown in Table 3.2.

Table 3.2. Alternatives for Detailed Analysis

Alternative	Name	Alternative Major Components
1	No Action	No activities.
2	Limited Action	No detailed analysis; screened from further evaluation.
3	Recharge Control and Hydraulic Control	• Engineered cover over all waste area for recharge control, • Slurry wall, • Groundwater extraction and treatment, • Groundwater monitoring, and • LUCs.
4	Targeted Excavation, ERH, and Bioremediation	• Excavation of wastes over VOC source areas, • Engineered cover over remaining waste, • Slurry wall, • ERH treatment of VOC source areas, • Bioremediation of the targeted VOC source area and residual contamination, • Groundwater monitoring, and • LUCs.
5	Full Excavation, ERH, and Bioremediation	• Excavation of all waste areas, • ERH treatment of VOC source areas, • Bioremediation of the targeted VOC source area and residual contamination, • Groundwater monitoring, and • LUCs.
6	Recharge Control and Bioremediation	• Engineered cover for recharge containment, • Slurry wall, • Bioremediation of targeted VOC source area, • Groundwater monitoring, and • LUCs.

4. DETAILED AND COMPARATIVE ANALYSES OF ALTERNATIVES

Remedial alternatives for this FS were developed in Section 3. The following are discussed in Section 4: the purpose and approach for performing the detailed analysis; results of the detailed analysis that form the basis for comparing alternatives; and the general approach for performing the comparative analysis. The specific comparative analyses of each alternative retained for consideration are presented in Section 4.4.2. The results of the detailed and comparative analyses ultimately will be used to recommend a preferred alternative in the proposed plan for SWMU 4.

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 that are 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 primarily is based include long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost. The final two criteria, 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 herein.

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

Alternatives in this FS will be assessed to determine whether they can protect adequately human health and the environment in both the short- and long-term perspective. Alternatives must protect human health and the environment from unacceptable risks posed by contaminants present at SWMU 4 by eliminating, reducing, or controlling exposures as established during development of RAOs consistent with 40 *CFR* § 300.430(e)(2)(i). Overall protection of human health and the environment draws on 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. These items include off-site soil treatment to remove a land disposal restriction, waste characteristic, etc. 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 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)].

Alternatives are assessed to determine whether they meet the 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 applicable or relevant and appropriate federal or state requirement.

(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 applied consistently, or demonstrated the intention to apply consistently, 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 are listed in Appendix A.

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. The focus of this criterion is the extent and the effectiveness of the controls required to manage the risk posed by untreated waste or treatment residuals, and the degree of reliability of those controls. 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 during the remedial action;
- 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:

- Technical feasibility, including the technical difficulties and the likelihood of the difficulty occurring 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 coordination with other agencies, ability of permitting, if available treatment, storage, and disposal activities are located off-site; 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 B. These are the types of costs assessed:

- RD and construction documentation costs, including remedial design work plan, RD, construction management and oversight, RD and RAWP document preparation; project/program management and implementation, including procurement support, work control, health and safety plans, operation and maintenance plans; and post-remedial reporting costs;

- Construction costs, including capital equipment, general and administrative costs, and construction subcontract fees;

- Operating and maintenance costs;

- Project lifecycle operations and 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 complexity and size of the project and inherent uncertainties related to the remedial technologies, scope contingency was applied to alternative cost estimates prepared for this FS, as appropriate.

Life-cycle costs include capital, O&M, and periodic costs for each alternative and are presented as both in non-discounted constant dollars and Net Present Worth. Discount rate guidelines for economic analysis were provided by U.S. Office of Management and Budget [(OMB) 2016].

Detailed total costs for implementing each alternative at SWMU 4 are presented in Appendix B. Summary level costs for implementing each alternative at SWMU 4 are presented in the sections for the individual alternative detailed analysis 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 KDEP may have regarding each of the alternatives. This criterion will be addressed in the proposed plan and ROD after KDEP comments are received on the FS.

4.1.2.9 Community acceptance (modifying criterion)

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

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 Other requirements 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 provides 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 Hazardous Waste Facility Operating permit, and the Solid Waste Landfill permit.

PGDP currently operates under KPDES Permits; Hazardous Waste Facility Operating Permit; and a Solid Waste Permit. The substantive requirements of the otherwise required permits are identified in the ARARs provided for each alternative. ARARs are provided in Appendix A.

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 have no identified short-term or long-term impacts on geological resources, migratory birds, cultural resources, or socioeconomics beyond that which is present due to the existing contamination. 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 will 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 will have impacts on geologic resources, and construction activities will have only short-term impacts on soils. Site clearing, excavation, grading, and contouring will alter the topography of the construction area, but the geologic formations underlying those sites should not be affected. Construction will disturb existing soils, and some soil and/or topsoil might be removed in the process of the evaluated remedial actions. Soil erosion impacts during construction will be mitigated through use of best management practices (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 alternatives. Any alternative that will create disturbances also will include restoration of these areas.

None of the activities associated with the remedial alternatives will 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). None of the identified wetlands are in SWMU 4.

Construction activities must avoid or minimize adverse impacts on wetlands and act to preserve and enhance their natural and beneficial values. As previously stated, there are no identified wetlands in SWMU 4.

No long- or short-term impacts have been identified to archeological or cultural resources. 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. The extent of direct impacts of contamination to surface water and groundwater reaches about 4.5 miles from the center of the site to the Ohio River. The minority population and the low-income population for the affected environment are lower than the state average (DOE 2016b). Because there are no potential impacts from any of these alternatives, there will be no disproportionate or adverse environmental justice impacts to these populations associated with these alternatives. Further sitewide analysis is contained in the recently approved Community Relations Plan (DOE 2016b).

No long- or short-term adverse transportation impacts are expected to result from implementation of these remedial alternatives. During construction and excavation activities, there will be an increase in the volume of truck traffic in the vicinity of SWMU 4, 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 applicable 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 will 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 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. Table 4.1 provides a summary of the potential impacts to the natural resources at SWMU 4 from implementation of the five alternatives that underwent detailed analysis. "Neutral," as

Table 4.1. Remedial Alternatives and the Relative Impacts on Natural Resources

	Alternative 1	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**Alternative 6**
Natural Resource	No Action	Limited Action (screened prior to analysis)	Recharge Control and Hydraulic Control	Targeted Excavation, ERH, and Bioremediation	Full Excavation, ERH, and Bioremediation	Recharge Control and Bioremediation
Groundwater	Neutral	N/A	Positive	Positive	Positive	Positive
Surface Water	Neutral	N/A	Positive	Positive	Positive	Positive
Air	Neutral	N/A	Neutral	Neutral	Neutral	Neutral
Biological	Neutral	N/A	Neutral	Positive	Positive	Neutral
Geological	Neutral	N/A	Neutral	Neutral	Neutral	Neutral

used in the table, is taken with respect of the current situation at SWMU 4. Alternative 1 was identified to be completely neutral if implemented. Alternatives 3 through 6 all were determined to have positive impacts on groundwater and surface water resources. Only Alternatives 4 and 5 were identified to have a positive impact on biological resources because all or a portion of SWMU 4 would be allowed to revert to native vegetation.

4.2 COMPARATIVE ANALYSIS

In this section, the SWMU 4 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, includes state and community acceptance. The modifying criteria will not be addressed until the proposed plan has been issued for public review. These modifying criteria will be addressed in the responsiveness summary of the ROD, which will be prepared following the public comment period held for the proposed plan.

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

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

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

- 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 detailed analyses and comparative analyses for remedial alternatives are presented in the sections that follow.

4.3 DETAILED ANALYSIS OF ALTERNATIVES

4.3.1 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 will be taken to implement remedial activities for SWMU 4 or to reduce or control the potential hazard to human or ecological receptors.

4.3.1.1 Overall protection of human health and the environment

Alternative 1 will not meet this threshold criterion. No additional controls will be implemented to protect site workers and the public. Alternative 1 is not protective of human health and the environment. It does not credit the existing site controls maintained outside of CERCLA that currently prevent contact with the buried waste and which will continue into the foreseeable future. If these current controls were not in place, there would be no means to prevent future exposure.

4.3.1.2 Compliance with ARARs

Alternative 1 will not meet this threshold criterion because no action will be implemented to reduce reliably the potential exposures and attain RGs. No administrative or engineering controls will be implemented as part of the alternative; thus, there will be the potential for unacceptable risks.

4.3.1.3 Long-term effectiveness and permanence

Alternative 1 does not provide any long-term effectiveness or permanence. Alternative 1 will leave contaminants detectable in the soil at current levels at SWMU 4. Additionally, Alternative 1 will leave PTW in the UCRS soils located beneath the SWMU.

4.3.1.4 Reduction of toxicity, mobility, or volume through treatment

The No Action alternative will not result in any reduction in toxicity, mobility, or volume through treatment. Reduction in contaminant mass and concentration will be achieved only through natural attenuation processes such as dilution, dispersion, and biodegradation.

4.3.1.5 Short-term effectiveness

No actions will be implemented under Alternative 1; therefore, no additional risks to workers, the public, or the environment will be incurred.

4.3.1.6 Implementability

The No Action alternative is considered implementable. If future remedial action is necessary, this alternative will not impede implementation of such action. The ongoing public awareness program will require regular coordination with DOE, KY, and possibly with other governmental agencies.

4.3.1.7 Cost

The net present worth cost, capital cost, and O&M costs of Alternative 1 are estimated to be $0.

4.3.2 Alternative 3—Recharge Control and Hydraulic Control

Alternative 3 is described in Section 3.4.3. The alternative prevents direct contact with the waste and contaminated soil through placement of an engineered cover and LUCs. The waste also is hydraulically isolated via the engineered cover, perimeter slurry wall, and RGA groundwater extraction containment system (Figure 3.1). Implementation of an associated groundwater extraction system located downgradient of SWMU 4 will contain contaminants that migrate from the buried waste into the RGA groundwater. The extracted groundwater will be treated as necessary to meet ARARs for discharge and released to a PGDP outfall. Finally, sampling will be conducted from each of the 12 monitoring wells installed to monitor the remedy.

4.3.2.1 Overall protection to human health and the environment

Alternative 3 will meet this threshold criterion of protection of human health and the environment. The engineered cover provides a physical barrier between receptors and contaminated surface soils, buried waste, and contaminated subsurface soil, including PTW located in the UCRS soils beneath the buried waste, thus preventing direct contact. The cover provides a reduction in migration of subsurface contamination by preventing infiltration of water that would carry contaminants to the surrounding soils and groundwater. Groundwater extraction will prevent further migration of contaminants in the RGA groundwater away from the SWMU.

4.3.2.2 Compliance with ARARs

Alternative 3 will meet this threshold criterion by complying with ARARs (see Appendix A). This alternative will not require a waiver of any ARARs.

4.3.2.3 Long-term effectiveness and permanence

Alternative 3 will be highly effective for achieving long-term effectiveness and permanence. It will limit exposure to surface and subsurface contamination and minimize the contribution of contaminants to the RGA; however, buried waste will remain at the unit. LUCs will be maintained to protect current and future receptors. The integrity of the engineered cover will be maintained.

The degree of long-term effectiveness and permanence for Alternative 3 is dependent upon construction materials; appropriate materials will be selected as part of RD activities. The presence of LUCs, an engineered cover, and containment components of Alternative 3 will prevent contact with site contaminants at the completion of construction. Long-term O&M of the groundwater extraction and treatment system and maintenance of the surface cover will be required.

Magnitude of Residual Risk. This alternative effectively manages direct contact risk by extending the depth from the ground surface to the buried waste. The hydraulic control system will capture SWMU 4 contaminants migrating in the RGA. Because the components of this alternative do not directly remove the waste materials from the landfill, reductions of risk are provided through direct contact mitigation and control of contaminant migration in groundwater. Administrative and physical LUCs provide controls against unwarranted contact with surface and subsurface contamination.

This remedy includes groundwater monitoring, which will monitor remedy effectiveness at preventing contaminant migration from SWMU 4 via RGA groundwater transport.

Need for Five-Year Review. Because this final remedial action will not result in UU/UE conditions, five-year reviews will be required to ensure that the remedy remains protective.

Adequacy and Reliability of Controls. The physical and administrative controls listed in the remedy are adequate to meet the criterion of long-term effectiveness and permanence. The physical controls that will protect from direct contact require a low degree of maintenance to maintain adequacy. The groundwater extraction system is reliable at preventing migration of groundwater contamination from the SWMU.

4.3.2.4 Reduction of toxicity, mobility, or volume through treatment

Alternative 3 includes technologies that will reduce mobility, toxicity, or volume through indirect treatment. The treatment system, which is part of the hydraulic control component, will reduce contaminant mass. Treatment is accomplished only for mobile COCs collected through the groundwater extraction system; therefore, reduction of toxicity, mobility, or volume through treatment is low.

Principal Threat Waste. Components of Alternative 3 will reduce the mobility and volume of the PTW (TCE DNAPL) located at SWMU 4 through hydraulic control. The hydraulic control system will capture groundwater and associated TCE emanating from TCE PTW.

Treatment Process Used and Materials Treated. The treatment component of Alternative 3 (i.e., groundwater extraction and treatment system) will be used to address the TCE identified in the UCRS soils below buried waste located at SWMU 4. This treatment will occur over time through dissolution of contaminants. Although the engineered cover provides no treatment of buried waste or of PTW located beneath the buried waste, it assists in mitigating the migration of contaminants to areas outside the SWMU 4 boundary. The groundwater treatment system consists of components commonly used in treatment of the contaminants identified at the SWMU; therefore, no special requirements are assumed for this process.

Amount of Hazardous Materials Destroyed or Treated. Groundwater extraction and treatment activities of Alternative 3 will serve indirectly to reduce the total volume of contaminants identified at SWMU 4. This alternative does not include waste excavation activities or direct treatment of the waste materials; therefore, the total volume of buried waste at the SWMU will not be reduced, except through the natural attenuation of waste that may be occurring.

Degree of Expected Reduction in Toxicity, Mobility, and Volume. Alternative 3 activities will reduce the toxicity and volume of contaminants identified below the buried waste at SWMU 4 indirectly via the groundwater treatment system. The recharge control and hydraulic control will reduce contaminant mobility.

Degree to which Treatment Is Irreversible. Contaminants that are extracted through the groundwater extraction system will be treated irreversibly.

Type and Quantity of Residuals Remaining after Treatment. Alternative 3 does not include *in situ* treatment or excavation of buried waste as part of the remedy components; therefore, contaminants that do not migrate to the groundwater extraction system will remain in place at SWMU 4.

4.3.2.5 Short-term effectiveness

The short-term effectiveness of Alternative 3 is relatively high. Components of Alternative 3 will reduce the mobility and volume of the PTW (TCE DNAPL) located at SWMU 4 through hydraulic control. The hydraulic control system will capture groundwater and associated TCE emanating from TCE PTW. In addition, Alternative 3 leaves waste undisturbed, creating little to no risk to the community, workers, or the environment during the remedial action.

Protection of Community during Remedial Actions. Implementation of Alternative 3 has a very low potential for impact to the community during remedial action. SWMU 4 is located within the PGDP's Limited Area. The wastes are not being hauled to off-site locations; therefore, potential exposure of the public to waste is very low. Vehicle traffic will increase slightly during construction of the cover because it is likely that raw materials will need to be brought from off-site. The road system near PGDP is good and historically has handled the level of increased traffic without issues.

Protection of Workers during Remedial Actions. Implementation of Alternative 3 will not expose workers to waste, thereby minimizing their exposure to contamination. Construction of the cover will not require intrusive activities, and construction of the groundwater extraction and treatment system will have minimal contact with the contaminants contained in the groundwater. This can be controlled through the use of appropriate training, engineering methods, and personal protective equipment (PPE).

Environmental Impacts. No ecological impacts at SWMU 4 are anticipated under this alternative. SWMU 4 is located at a previously operational facility, which already has been disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archaeological or historical sites or T&E species will be impacted by this alternative. No jurisdictional wetlands exist in the area of the remedial action at SWMU 4.

Time until Remedial Action Objectives Are Achieved. Alternative 3 components offer protection against direct contact with waste and associated soils, which will be achieved with installation of an engineered cover. The groundwater protection will become active upon achieving hydraulic control. Some of the protections are available now through existing plant activities. These include the Water Policy, excavation and penetration controls, and access restrictions.

When activities of Alternative 3 are complete, RAOs specific to protection of groundwater and prevention of exposure to waste and contaminated soils will have been met. Because the hydraulic control system captures groundwater and associated TCE emanating from TCE PTW, the time to completion is unknown because the rate of dissolution cannot be calculated realistically with the information available.

4.3.2.6 Implementability

Implementation of the remedial action components of Alternative 3 is technically feasible, and the alternative consists of demonstrated technologies, standard construction methods, materials, and equipment that are available from multiple vendors and contractors. Construction of an engineered cover has potential to disrupt site activities during hauling of engineered cover construction materials (i.e., dirt, gravel, etc.) from off-site locations. Implementability of Alternative 3 is considered high.

Ability to Construct and Operate Technology. All construction components of Alternative 3 are highly implementable and consist of demonstrated technologies and standard construction methods, materials, and equipment; therefore, this alternative is highly implementable.

Reliability of Technology. All the technologies employed in Alternative 3 are highly reliable for their intended purpose. This alternative, however, relies on continued operation of a groundwater extraction system into the foreseeable future to ensure that mobile COCs do not migrate from the unit.

Ease of Undertaking Additional Remediation. The presence of an engineered cover could impede, but not prevent, additional remediation, should it be undertaken (e.g., would increase the cost of a future excavation). The construction of the cover also will require some modification of streets surrounding the landfill. The landfill is mapped as being present directly adjacent to the streets on the north, east, and west sides of the landfill. The edge of the cover is required to be tapered at its edges to control erosional impacts and interfacing of the existing surrounding grade. Street modifications will be needed to accommodate the tapered edge of the cover.

Ability to Monitor Effectiveness of Remedy. Installation of 12 monitoring wells and periodic sampling will allow for monitoring the effectiveness of the remedy.

Ability to Obtain Approvals from Other Agencies. Alternative 3 will not require approvals from agencies other than the Paducah FFA parties.

Coordination with Other Agencies. The means and methods for coordinating with other agencies are established in the Paducah FFA. This remedy will not require involvement of new agencies.

Availability of Off-site Treatment, Storage, and Disposal Services and Capacity. Waste generated from Alternative 3 activities will be characterized and disposed of on-site. The quantity of waste generated by construction of the alternative is expected to be low and predominantly will consist of routine type construction wastes. Operational wastes from the alternative will include wastes such as spent activated carbon and spent ion exchange resin media. The alternative does not include intrusive activities in the landfill buried waste.

Availability of Necessary Equipment and Specialists. All equipment and specialists are readily available.

Availability of Prospective Technologies. Technologies incorporated as part of Alternative 3 are considered generally available from multiple vendors.

4.3.2.7 Cost

Consistent with EPA guidance (EPA 2000) and agreements reached during development of the Feasibility Study for Solid Waste Management Units 2, 3, 7, and 30 (DOE 2014b), the cost estimates in this FS consist of a 1,000-year period due to the nature of the contaminants, including long-lived radionuclides. Net present value/worth cost estimates are presented for the individual and comparative analysis of alternatives and for remedy selection (EPA 1988). The real discount rate has been obtained from OMB guidance (reference Appendix C in OMB circular A-94). In addition, nondiscounted cost estimates (i.e., capital and average annual O&M) are presented for comparison purposes only.

Net Present Worth Cost	$92,572,000
Nondiscounted Cost	
• Capital Cost	$35,953,000
• Average Annual O&M Cost	$895,337

4.3.3 Alternative 4—Targeted Excavation, ERH, and Bioremediation

Alternative 4 is described in Section 3.4.4. It includes targeted excavation of buried materials and associated visibly contaminated soils to a depth of 20 ft over an area of approximately 107,000 ft^2 (Figure 3.2); installation of an engineered cover and slurry wall; waste disposal characterization sampling; sorting, sizing, and lime stabilization of waste (as needed); excavation pit dewatering; treatment and disposal of waste in accordance with the WAC of the disposal facility; physical and administrative LUCs; and groundwater monitoring. If an appropriate on-site disposal facility is available at the time of implementation, the on-site facility will be used to the degree possible to conserve resources. Sheet piling will be used to control soil movement during excavation of the buried waste. Water extracted from excavation pits will be treated to meet ARARs for discharge. Typical components of the treatment system may include units, such as air stripping, ion exchange, vapor phase carbon, and liquid phase carbon or equivalent. The targeted excavation will support the alternative by removing waste that overlies soils containing TCE; this waste is expected to be the original source of this TCE. The excavation also removes interfering materials in the subsurface that will prevent implementation of more aggressive treatments for TCE in the UCRS soils such as thermal treatment.

Because targeted excavation will not result in RG attainment for contaminants that have migrated to subsurface soils below the targeted excavation depth, this alternative incorporates ERH and biological treatment of UCRS soils for volatiles from the bottom of excavation (20 ft) to the top of the RGA (60 ft). ERH treatment will be utilized over a targeted area where expected TCE soil concentrations are in excess of 10 mg/kg. Following the thermal treatment, the target excavation area also will be treated with enhanced anaerobic bioremediation to remove residual TCE concentration to protect RGA groundwater (Figure 3.2).

4.3.3.1 Overall protection of human health and the environment

Alternative 4 will meet this threshold criterion. Potential short-term risks to remediation workers due to direct contact with the waste material are greater for this alternative, compared to other retained alternatives that do not utilize excavation of waste, but these can be controlled with engineering, potential remote control equipment, and PPE. 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. Removal of waste and *in situ* remediation will provide long-term effectiveness and permanence against direct contact and migration to groundwater.

4.3.3.2 Compliance with ARARs

Alternative 4 will meet this threshold criterion by complying with ARARs. ARARs for this alternative are summarized in Appendix A. This alternative does not require an ARARs waiver.

4.3.3.3 Long-term effectiveness and permanence

Alternative 4 removes a portion of the buried waste and reduces contamination; therefore, it offers a medium degree of risk reduction, effectiveness, and permanence. Excavated materials will be treated as necessary to meet the WAC of a disposal facility.

Alternative 4 will reduce the potential for direct contact with wastes and subsurface soils. Waste will be excavated from the southern part of the SWMU. An engineered cover will be placed over the remaining portion of the landfill, thereby preventing direct contact risk of those wastes. The combination of the engineered cover and the slurry wall will minimize groundwater recharge through the waste, thereby reducing the migration of contaminants from the wastes to RGA groundwater.

The combination of an engineered cover and slurry wall has long-term effectiveness when the cover is maintained properly against erosion. The ERH treatment has been determined to be very effective at permanently removing VOC contamination, including PTW contained in UCRS soils. Bioremediation component also is effective at permanently reducing VOC residual contamination. The combination of ERH and bioremediation will promote groundwater protection through removal of mobile contaminants.

Magnitude of Residual Risk. This alternative effectively manages direct contact risk by removal of targeted waste and contaminated soils up to 20 ft bgs along with installation of an engineered cover over the unexcavated portion of the SWMU. Thermal treatment of targeted areas between 20 ft bgs and 60 ft bgs will reduce migration of TCE to RGA groundwater. The residual risk associated with the waste that will not be excavated will be mitigated by installation of an engineered cover. The LUCs also will mitigate that residual risk.

Need for Five-Year Review. Because this final remedial action will not result in UU/UE conditions, five-year reviews will be required to ensure that the remedy remains protective.

Adequacy and Reliability of Controls. The physical and administrative LUCs listed in this remedy are adequate to meet threshold criteria. LUCs will prevent unauthorized use and activity, as necessary.

4.3.3.4 Reduction of toxicity, mobility, or volume through treatment

Reduction of toxicity, mobility, and/or volume for Alternative 4 is considered medium and will be achieved through targeted excavation and post-excavation waste treatment/stabilization. Additionally, this alternative utilizes ERH and biological treatment of UCRS soils for contaminants that have migrated below the waste.

Principal Threat Waste. ERH and biological treatment of UCRS soils will treat the PTW.

Treatment Process Used and Materials Treated. The treatment component of Alternative 4 (i.e., ERH and biological treatment of UCRS soils) will be used to address the TCE PTW identified in the UCRS soils below the buried waste at SWMU 4. ERH treatment will be applied to UCRS soils with the highest localized concentrations of TCE; after that, bioamendments will be injected to treat TCE remaining in surrounding soils. Buried waste and associated soils removed as part of the targeted excavation component of Alternative 4 will be treated/stabilized to meet the WAC of the receiving disposal facility. Water removed from waste cells during excavation activities will be treated for contaminants. Typical components of the treatment system may include units, such as filtering, air stripping, ion exchange, vapor phase carbon, and liquid phase carbon, as part of an on-site mobile treatment system.

Amount of Hazardous Materials Destroyed or Treated. Treatment of UCRS soil below buried waste at SWMU 4 via ERH and bioremediation activities of Alternative 4 will serve to reduce the total volume of PTW. Because this alternative includes targeted excavation, total volume of buried waste and associated soils will be reduced.

Degree of Expected Reductions in Toxicity, Mobility, and Volume. ERH and biological treatment of contaminants identified in UCRS soils below SWMU 4, in combination with targeted excavation of buried waste and associated soils, will serve to reduce the total volume of contaminants including PTW, effectively reducing the toxicity and mobility. The portions of the landfill not excavated will be capped with an engineered cover and surrounded by a slurry wall. The cover and slurry wall will reduce contaminant mobility.

Degree to which Treatment Is Irreversible. ERH and biological treatment is irreversible.

Type and Quantity of Residuals Remaining after Treatment. Targeted excavation will remove all contaminants in the waste and associated soils in the southern portion of SWMU 4. The concentration of residual contaminants below the excavated area will be very low following ERH and biological treatment. Contaminants in the unexcavated waste and associated soils will remain in place at SWMU 4.

4.3.3.5 Short-term effectiveness

Alternative 4 meets this primary criterion, and Alternative 4 has a medium rating with respect to short-term effectiveness. Potential remedial worker exposure to surface and subsurface contaminants associated with targeted waste excavation will be mitigated through adherence to health and safety protocols, use of remote control equipment, as feasible, and shipping of wastes by rail, which will keep transported wastes off populated roadways. No negative impacts to the environment are anticipated, and the time required to meet the RAOs is relatively short.

Protection of Community during Remedial Actions. Short-term risks from excavation activities at the SWMU are expected only as they relate to transport of excavated materials to off-site disposal locations. To the degree possible, the off-site transport of waste will be by rail, as feasible, which will keep shipped wastes off populated roadways. It is expected that backfill soil will need to be trucked in for closing the excavation. This will increase the truck traffic slightly in the plant area, but with the close proximity of high-capacity, four-lane highways, this process should not impact local traffic patterns.

Protection of Workers during Remedial Actions. Short-term exposures of workers to COCs could occur during implementation of Alternative 4. Worker risks are not expected to exceed acceptable limits because these activities will be conducted under an approved health and safety plan; therefore, risks from handling waste/contaminated soils will be mitigated through adherence to health and safety protocols.

Implementation of remedies for Alternative 4 will be conducted by trained personnel in accordance with work planning documents to maintain a work environment that minimizes injury or exposure to risks to human health or the environment.

Environmental Impacts. No ecological impacts at SWMU 4 are anticipated under Alternative 4. SWMU 4 is located at a previously operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archeological or historical sites or T&E species will be impacted by this alternative. No jurisdictional wetlands exist in the area of the remedial action at SWMU 4.

Time until Remedial Action Objectives Are Achieved. Protection against direct contact to waste and associated soils will be effective upon completion of targeted excavation and placement of the engineered cover. Additionally, the completion of engineered cover construction will result in attaining direct contact protection from the waste not excavated. Protection of groundwater and treatment of PTW will be active upon completion of ERH and bioremediation.

When activities of Alternative 4 are complete, RAOs specific to the protection of groundwater, prevention of exposure to waste and contaminated soils, and treatment of PTW at SWMU 4 will have been met.

4.3.3.6 Implementability

Alternative 4 is technically and administratively feasible and implementable. The equipment and technologies associated with implementation of this alternative have been proven to be feasible technically and are available from contractors or vendors. The implementability of construction-related activities is similar to that at other sites. Likewise, waste sampling, analysis, transportation, and disposal are performed routinely and are proven to be safe. Some excavated waste materials and affected soils may be contaminated with radiological constituents, heavy metals, PCBs, VOCs, or mixed radioactive waste. Treatment of wastes with multiple regulatory classifications is more complex and may require more than one treatment process to make the waste suitable for transportation and/or land disposal. Alternative 4 has a medium rating with respect to the implementability criterion.

Ability to Construct and Operate Technology. Alternative 4 is technically and administratively feasible and implementable. The equipment and technologies associated with implementation of this alternative have been proven to be feasible technically and are available from contractors or vendors. The implementability of construction-related activities during excavation and backfilling at SWMU 4 subject to Alternative 4 are very similar to that carried out at other sites.

Reliability of Technology. All of the technologies employed in Alternative 4 are highly reliable for their intended purpose.

Ease for Undertaking Additional Remediation. Targeted excavation, ERH and bioremediation activities will not impede undertaking of additional remediation; however, the combination of those actions will result in the removal of wastes in that portion of the landfill. The presence of horizontal injection well casing could impede additional remediation should it be undertaken (e.g., may require removal), but will not prevent additional remediation. Alternative 4 will not prevent undertaking of remedial actions at the portion of the landfill that is not excavated, but the cover may need to be removed to provide access.

Ability to Monitor Effectiveness of Remedy. Sampling of 12 monitoring wells installed as part of this alternative will be conducted to monitor effectiveness of Alternative 4 at protecting groundwater over time.

Ability to Obtain Approvals from Other Agencies. Alternative 4 will not require approval from agencies other than the Paducah FFA parties.

Coordination with Other Agencies. The means and methods for coordinating with other agencies are established in the Paducah FFA. This remedy will not require involvement of new agencies.

Availability of Off-site Treatment, Storage, and Disposal Services and Capacity. Adequate treatment, storage capacity, and disposal services are available for the waste generated as part of Alternative 4. Although SWMU 4 is designated as a classified burial area, the plan is to declassify all but a small portion of the excavated waste. This approach will allow use of off-site and on-site nonclassified disposal facilities. If the planned WDA is not available, then any portion of waste that may be deemed classified will be shipped to NNSS.

Availability of Equipment and Specialists. All equipment and specialists are readily available.

Availability of Prospective Technologies. Technologies used as part of Alternative 4 are considered generally available and have been demonstrated sufficiently as part of other remedial projects at PGDP.

4.3.3.7 Cost

Consistent with EPA guidance (EPA 2000) and agreements reached during development of the Feasibility Study for Solid Waste Management Units 2, 3, 7, and 30 (DOE 2014b), the cost estimates in this FS consist of a 1,000-year period due to the nature of the contaminants, including long-lived radionuclides. Net present value/worth cost estimates are presented for the individual and comparative analysis of alternatives and for remedy selection (EPA 1988). The real discount rate has been obtained from OMB guidance (reference Appendix C in OMB circular A-94). In addition, nondiscounted cost estimates (i.e., capital and average annual O&M) are presented for comparison purposes only. For Alternative 4, cost estimates with waste disposal both off-site and on-site at a potential WDA facility have been included.

Cost with off-site and on-site waste disposal:

Net Present Worth Cost	$236,467,000
Nondiscounted Cost	
• Capital Cost	$227,453,000
• Average Annual O&M Cost	$118,002

Cost with on-site WDA facility waste disposal:

Net Present Worth Cost	$171,460,000
Nondiscounted Cost	
• Capital Cost	$162,446,000
• Average Annual O&M Cost	$118,002

4.3.4 Alternative 5—Full Excavation, ERH, and Bioremediation

Alternative 5 is described in Section 3.4.5. This alternative will involve excavation of wastes and associated visibly contaminated soils to a depth of 20 ft bgs over an area of approximately 283,000 ft^2 (Figure 3.3); waste disposal characterization sampling; sorting, sizing, and treatment/stabilization of waste (as needed); excavation pit dewatering; and treatment and disposal of waste in accordance with the WAC of the off-site disposal facility. If an appropriate on-site disposal facility is available at the time of implementation, the on-site facility will be utilized to the degree possible to conserve resources. Sheet piling will be used to control soil movement during excavation. Water extracted from excavation pits will be batch treated in a temporary mobile treatment system.

Excavation will not result in RG attainment for COCs that have migrated below the targeted excavation depth; therefore, this alternative incorporates ERH and biological treatment of UCRS soils from the bottom of excavation (20 ft) to the top of the RGA (60 ft). ERH will be utilized over the southern portion of the SWMU that contains TCE contaminant concentrations indicative of the presence of DNAPL (Figure 3.3). Bioremediation will occur in the southern portion of the excavated area to protect the underlying groundwater.

The area of excavation for Alternative 5 encompasses all of SWMU 4. The southeast corner of the SWMU contains a 36-inch raw water line that historically and currently provides water to the plant site. Alternative 5 also includes the LUCs associated with the other alternatives under consideration. The LUCs are expected to remain in place until contaminant contribution from UCRS soil no longer results in an exceedance of an RGA groundwater MCL (or risk-based concentration for residential use of groundwater in the absence of an MCL).

4.3.4.1 Overall protection of human health and the environment

Alternative 5 will meet this threshold criterion. Potential short-term risks to remediation workers as a result of direct contact with the waste material and inhalation hazards are greater for this alternative compared to other retained alternatives. The excavated wastes will be disposed of in an on-site or off-site facility; potential risks to the public and the environment, as a result of potential shipping and handling concerns, should be considered for off-site shipments. Removal of waste and *in situ* remediation will provide long-term effectiveness and permanence against direct contact and migration to groundwater.

4.3.4.2 Compliance with ARARs

Alternative 5 will meet this threshold criterion by complying with ARARs, which are summarized for this alternative in Appendix A. This alternative does not require an ARAR waiver.

4.3.4.3 Long-term effectiveness and permanence

This alternative effectively manages direct contact risk by removal of buried waste. This activity, combined with ERH and biological treatment of UCRS soils, provides very high long-term effectiveness and permanence. Post excavation treatment processes manage the treatment of soils to attain ARARs prior to disposal at an approved off-site or on-site facility.

Risks associated with direct contact with wastes, surface soils, and subsurface soils will be eliminated because the primary source and associated soils will be removed. Alternative 5 reduces uncertainties associated with these soils in terms of continued contributions to the hydrogeological system by removal of solid waste and associated mobile contaminants. This alternative includes excavation of all of the buried waste at SWMU 4. This includes the general area that would be expected to have released the DNAPL to the UCRS soils below the waste in the southern portion of the landfill. After excavation of the waste, the areas will be refilled to grade. ERH then will be utilized to remove the contaminants from the area expected to have concentrations greater than 10 mg/kg of TCE. Bioremediation then will be applied to approximately the southern portion of the SWMU to treat further the residual VOC contamination.

Magnitude of Residual Risk. This alternative effectively manages direct contact risk by removal of buried waste. Treatment of the deeper UCRS soils (that may contain DNAPL and result in groundwater contamination in the RGA) will reduce further the magnitude of the residual risk of the SWMU.

Finally, this remedy includes groundwater monitoring, which will monitor remedy effectiveness at preventing COC migration to the RGA.

Need for Five-Year Review. Because this final remedial action may not result in UU/UE conditions, five-year reviews may be required to ensure that the remedy remains protective.

Adequacy and Reliability of Controls. This alternative results in removal of all buried waste, and treats contaminants at depth; however, LUCs have been included in the alternative in case UU/UE levels remain in place after remedial operations. These LUCs will provide adequate and reliable controls.

4.3.4.4 Reduction of toxicity, mobility, or volume through treatment

This alternative removes buried waste and associated soils contributing to mobile contaminants, thus reducing or eliminating the toxicity, mobility, and volume of contaminants from the unit. The extracted contaminants are treated prior to disposal in a manner that meets the WAC of the disposal facility. ERH and bioremediation will be utilized to treat COCs below the level of excavation at targeted locations within the SWMU, effectively preventing or reducing the quantity of contaminant volume mobilized to the RGA groundwater. For Alternative 5, reduction of toxicity, mobility, or volume through treatment is considered very high.

Principal Threat Waste. ERH treatment and bioremediation treatment of UCRS soils will treat the PTW identified below the buried waste located at SWMU 4.

Treatment Process Used and Materials Treated. The treatment component of Alternative 5 (i.e., ERH bioremediation treatment of UCRS soils) will be used to address contaminants identified in the UCRS soils below the buried waste at SWMU 4. Buried waste and associated soils removed as part of the full excavation component of Alternative 5 will be treated/stabilized to meet the WAC of the receiving facility. Water removed from waste cells during excavation activities will be treated in an on-site mobile treatment system.

Amount of Hazardous Materials Destroyed or Treated. Treatment of UCRS soil below buried waste at SWMU 4 via the ERH treatment and bioremediation activities of Alternative 5 will serve to reduce the total volume of PTW. Because this alternative includes full excavation of all buried waste, the total volume of buried waste and associated soils will be reduced.

Degree of Expected Reductions in Toxicity, Mobility, and Volume. ERH and biological treatment of PTW identified in UCRS soils below SWMU 4, in combination with full excavation of buried waste and associated soils, will reduce the total volume of contaminants, including PTW, effectively reducing the toxicity and mobility to the degree of meeting RGs.

Degree to which Treatment Is Irreversible. ERH treatment and bioremediation will treat the PTW identified at SWMU 4 to such an extent that treatment is irreversible.

Type and Quantity of Residuals Remaining after Treatment. Alternative 5 actions will reduce the volume of residuals through full excavation, ERH treatment, and bioremediation.

4.3.4.5 Short-term effectiveness

Alternative 5 meets the primary criterion of short-term effectiveness. Potential remedial worker exposure to surface and subsurface contaminants associated with full excavation of buried waste will be mitigated through adherence to health and safety protocols; use of remote control equipment as feasible; and shipping of wastes by rail, which will reduce the presence of the shipped wastes in close proximity to the public.

Protection of Community during Remedial Actions. Short-term risks to the community resulting from excavation activities at SWMU 4 have not been identified; however, potential risks to the community as a result of potential shipping and handling concerns should be considered for off-site shipments. To the degree possible, the off-site transport of waste will be by rail, which will reduce the presence of the shipped wastes in close proximity to the public. It is expected that backfill soil will need to be trucked in to close the excavation. This will increase slightly the truck traffic in the plant area, but with the close proximity of high-capacity four-lane highways, this process will not impact local traffic patterns.

Protection of Workers during Remedial Actions. Short-term exposures of workers to COCs could occur during implementation of Alternative 5. Risks from handling waste and associated soils will be mitigated through adherence to health and safety protocols. To protect workers, PPE, ambient conditions monitoring, and decontamination protocols will be used in accordance with an approved, site-specific health and safety plan.

Excavation and disposal will be conducted by trained personnel in accordance with standard radiological, engineering, and operational procedures, documented safety analyses, health and safety plans, and safe work practices to maintain a work environment that minimize injury or exposure to risks to human health or the environment.

Environmental Impacts. No ecological impacts at SWMU 4 are anticipated under this alternative. SWMU 4 is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archeological or historical site or T&E species will be impacted by this alternative. No jurisdictional wetlands exist in the area of the remedial action at SWMU 4.

Time until Remedial Action Objectives Are Achieved. Protection against direct contact to waste and associated soils by the activities of Alternative 5 will be active upon completion of full excavation and regrading of the SWMU with clean backfill. Protection of groundwater will be active upon completion of ERH and biological treatment of TCE identified in the UCRS below buried waste at SWMU 4.

At the time activities of Alternative 5 are complete, RAOs specific to the protection of groundwater, prevention of exposure to waste and contaminated soils, and treatment of PTW at SWMU 4 will have been met.

4.3.4.6 Implementability

Alternative 5 is technically and administratively feasible and implementable. The equipment and technologies associated with implementation of this alternative have been proven to be feasible technically and are available from contractors or vendors. The excavation-related activities in this alternative are similar to that carried out at other sites, but are logistically more complex due to the volume and variety of waste at SWMU 4. Storage or staging and treatment of waste with multiple regulatory classifications is complex and may require more than one treatment process to make the waste suitable for transportation and/or land disposal. This alternative is rated medium-low with respect to overall implementability.

Ability to Construct and Operate Technology. The equipment and technologies associated with implementation of this alternative have been proven to be feasible technically and are available from contractors and vendors.

Reliability of Technology. All of the technologies employed in Alternative 5 are reliable for their intended purpose.

Ease of Undertaking Additional Remediation. None of the treatment technologies employed in Alternative 5 will impede additional remediation. However, this alternative results in the complete removal of the wastes buried in SWMU 4, so further remediation of these wastes in this location will not be necessary. The presence of horizontal injection well casing could impede, but not prevent, additional remediation should it be undertaken (e.g., may require removal, etc.).

Ability to Monitor Effectiveness of Remedy. Sampling of 12 monitoring wells installed as part of this alternative will be conducted to monitor effectiveness of Alternative 5 at protecting groundwater over time.

Ability to Obtain Approvals from Other Agencies. Alternative 5 will not require approvals from agencies other than the Paducah FFA parties.

Coordination with Other Agencies. The means and methods for coordinating on-site activities are established in the Paducah FFA; however, possible off-site transportation, treatment, and disposal, of waste may require coordination with other agencies.

Availability of Off-site Treatment, Storage, and Disposal Services and Capacity. Adequate treatment, storage capacity, and disposal services are available for the waste generated as part of Alternative 5. Although SWMU 4 is designated as a classified burial area, plans are to declassify all but a small portion of the excavated waste. This approach will allow use of nonclassified disposal facilities. Any portion of the excavated waste that is deemed classified will be shipped to NNSS if the WDA is not available.

Availability of Equipment and Specialists. All equipment and specialists are readily available.

Availability of Prospective Technologies. Technologies incorporated as part of Alternative 5 are available from multiple vendors and have been sufficiently demonstrated as applicable.

4.3.4.7 Cost

Consistent with EPA guidance (EPA 2000) and agreements reached during development of the Feasibility Study for Solid Waste Management Units 2, 3, 7, and 30 (DOE 2014b), the cost estimates in this FS consist of a 25-year period, because all waste will have been removed. In the case of Alternative 5 where all wastes either have been removed from the site or treated, minimal, ongoing periodic activities are required. For Alternative 5, the only ongoing periodic activity will be the development of five-year reviews if UU/UE is not achieved. Net present value/worth cost estimates are presented for the individual and comparative analysis of alternatives and for remedy selection (EPA 1988). The real discount rate has been obtained from OMB guidance (reference Appendix C in OMB circular A-94). In addition, nondiscounted cost estimates (i.e., capital and average annual O&M) are presented for comparison purposes only. For Alternative 5, cost estimates with waste disposal both off-site and on-site at a potential WDA facility have been included.

Cost with off-site and on-site waste disposal:

Net Present Worth Cost	$530,491,000
Nondiscounted Cost	
• Capital Cost	$525,094,000
• Average Annual O&M Cost	$15,254

Cost with on-site WDA facility waste disposal:

Net Present Worth Cost	$349,165,000
Nondiscounted Cost	
• Capital Cost	$343,768,000
• Average Annual O&M Cost	$15,254

4.3.5 Alternative 6—Recharge Control and Bioremediation

Alternative 6 is described in Section 3.4.6. This alternative consists of installation of an engineered cover over the entire SWMU and an associated slurry wall for recharge control; *in situ* bioremediation for treatment of PTW identified in UCRS soils below a limited number of burial cells; physical and administrative LUCS; and performance and groundwater monitoring wells. *In situ* bioremediation will treat COCs and PTW found in the UCRS soil under partial areas of the southern half of SWMU 4 to include the southwest quarter, western half of the southeast quarter, and southern 25 ft of the northwest quarter (see Figure 3.4). The bioremediation system will use a series of horizontal wells to place/circulate bioamendments into the soils beneath the buried waste.

Consistent with other alternatives brought forward in this FS, Alternative 6 implements groundwater monitoring wells to monitor long-term remedy effectiveness.

4.3.5.1 Overall protection of human health and the environment

Alternative 6 will meet this threshold criterion. The engineered cover provides a physical barrier between receptors and contaminated waste soil, thus preventing direct contact. The cover and slurry wall will reduce mobility of subsurface contamination by preventing infiltration of water that would carry contaminants to the surrounding soils and groundwater. Additionally, the alternative includes bioremediation treatment of contaminants, including PTW, located in the UCRS soils beneath the buried waste to assist in protecting RGA groundwater.

4.3.5.2 Compliance with ARARs

Alternative 6 will meet this threshold criterion by complying with ARARs, which are summarized in Appendix A. This alternative will not require a waiver of any ARARs.

4.3.5.3 Long-term effectiveness and permanence

This alternative is designed to provide protection against exposure to waste, surface soils, and subsurface soil, primarily through installation and maintenance of an engineered cover. This alternative also provides treatment of contaminants found in the UCRS soil using enhanced bioremediation.

The engineered cover reduces recharge of groundwater from infiltration. This reduction in recharge, along with bioremediation of COCs currently found in the UCRS, provides long-term effectiveness in preventing RGA groundwater contamination. Alternative 6 offers a medium level of long-term effectiveness and permanence.

Magnitude of Residual Risk. This alternative effectively manages direct contact risk by extending the depth from the surface to the buried waste. Physical and administrative LUCs inform the intruder of the potential dangers associated with direct contact to the waste and contaminated soil. Because the cover component of this alternative does not remove waste materials from the landfill, the risk reductions afforded the capping portion is provided through mitigation and control of migration. The alternative using bioremediation will reduce the risks present from the PTW located beneath the buried wastes in the southern portion of SWMU 4. This remedy like the other alternatives includes groundwater monitoring, which will monitor remedy effectiveness at preventing COC migration to the RGA, and LUCs.

Need for Five-Year Review. Because this final remedial action will not result in UU/UE conditions, five-year reviews will be required to ensure that the remedy remains protective.

Adequacy and Reliability of Controls. The physical and administrative controls listed in this remedy are adequate to meet criteria. The physical controls to protect from direct contact require a low degree of maintenance to maintain adequacy.

4.3.5.4 Reduction of toxicity, mobility, or volume through treatment

Mobility and toxicity of COCs at SWMU 4 will be reduced with implementation of Alternative 6. Installation of soil cover and slurry wall will reduce infiltration and provide recharge control. VOC contaminants currently found in UCRS soils beneath the SWMU, including PTW, will be treated with *in situ* bioremediation, further reducing the mobility of COCs to RGA groundwater.

Because this alternative does not include excavation, the volume of buried waste will not be reduced through implementation of Alternative 6.

Principal Threat Waste. *In situ* bioremediation will treat the PTW identified below the buried waste, reducing the toxicity, mobility, and volume. Bioremediation is expected to be effective because the SWMU 4 PTW is expected to be in a dispersed state, as indicated in Figure 3.4.

Treatment Process Used and Materials Treated. The treatment component of Alternative 6 (i.e., *in situ* bioremediation of UCRS soil) will address TCE PTW identified in the UCRS soils below the buried waste at SWMU 4.

Amount of Hazardous Materials Destroyed or Treated. Treatment of UCRS soil below buried waste via *in situ* bioremediation activities of Alternative 6 will reduce the total volume of PTW. Because this alternative does not include excavation, the total volume of buried waste and associated soils will not be reduced.

Degree of Expected Reductions in Toxicity, Mobility, and Volume. Alternative 6 activities will reduce the volume of contaminants identified in soils below SWMU 4 via *in situ* bioremediation to assist in meeting RAOs. The engineered cover and slurry wall provide mitigation to mobility through the reduction of recharge water allowed to contact the buried waste.

Degree to which Treatment Is Irreversible. *In situ* bioremediation is irreversible.

Type and Quantity of Residuals Remaining after Treatment. Alternative 6 does not include excavation of buried waste as part of the remedy components; therefore, these materials and associated contaminants will remain in place at SWMU 4. It is expected that over time, the quantity of organic contaminants will be reduced through bioremediation activities.

4.3.5.5 Short-term effectiveness

The short-term effectiveness is medium high. Although the time required for Alternative 6 to meet the RAO for treatment or removal of PTW would be lengthy, it does quickly meet the remaining RAOs. Because it leaves waste undisturbed, Alternative 6 creates little to no risk to the community, workers, or the environment during the remedial action.

Protection of Community during Remedial Actions. Alternative 6 achieves the criterion of protection of community during remedial action because it leaves buried waste undisturbed and treatment occurs *in situ*.

Protection of Workers during Remedial Actions. Implementation of Alternative 6 has low impact to the worker during remedial action. Installation of an engineered cover requires minimal excavation of existing surface cover. Although construction of the slurry wall requires excavation, the work will be performed outside the area of buried waste, reducing the potential for exposure. Potential exposure to contaminated soils can be mitigated through implementation of safe work practices. Implementation of bioremediation does not require handling of hazardous chemicals that could be a danger to worker health.

Environmental Impacts. No ecological impacts at SWMU 4 are anticipated under Alternative 6 because it is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archeological or historical site or T&E species will be impacted by this alternative. No jurisdictional wetlands exist in the area of the remedial action at SWMU 4.

Time until Remedial Action Objectives Are Achieved. Protection against direct contact with waste and associated soils by the activities of Alternative 6 will be active upon completion of an engineered cover. Protection of groundwater will be active upon installation of the engineered cover and associated slurry wall. Groundwater protection will be supplemented with implementation of *in situ* bioremediation of contaminants identified in the UCRS.

When activities of Alternative 6 are complete, RAOs specific to protection of groundwater, prevention of exposure to waste and contaminated soils, and treatment of PTW at SWMU 4 will have been met.

4.3.5.6 Implementability

Implementability of the remedial action components of Alternative 6 is high. The alternative consists of demonstrated technologies and standard construction methods. Materials and equipment are available from multiple vendors and contractors.

Ability to Construct and Operate the Technology. The equipment and technologies to implement this alternative have been proven to be feasible technically and are available from multiple contractors and vendors.

Reliability of Technology. Technologies employed in Alternative 6 are reliable for their intended purpose. Periodic maintenance of the engineered cover and bioremediation injection system will be required to ensure long-term reliability.

Ease of Undertaking Additional Remediation. None of the treatment technologies employed in Alternative 6 will prevent additional remediation. The presence of an engineered cover could impede, but not prevent, additional remediation. The presence of horizontal injection well casing also could impede, but not prevent, additional remediation. The subsurface conditions developed to support bioremediation will be temporary in nature, and normal subsurface conditions will return after treatment is discontinued.

Ability to Monitor Effectiveness of Remedy. Sampling of 12 monitoring wells installed as part of this alternative will monitor effectiveness of Alternative 6.

Ability to Obtain Approvals from Other Agencies. Alternative 6 will not require approvals from agencies other than the Paducah FFA parties.

Coordination with Other Agencies. The means and methods for coordinating with other agencies are established in the Paducah FFA. This remedy will not require involvement of new agencies.

Availability of Off-site Treatment, Storage, and Disposal Services and Capacity. Adequate treatment, storage capacity, and disposal services are available for the waste generated as part of Alternative 6.

Availability of Equipment and Specialists. All equipment and specialists are readily available.

Availability of Prospective Technologies. Technologies incorporated as part of Alternative 6 are considered generally available from multiple vendors.

4.3.5.7 Cost

Consistent with EPA guidance (EPA 2000) and agreements reached during development of the Feasibility Study for Solid Waste Management Units 2, 3, 7, and 30 (DOE 2014b), the cost estimates in this FS consist of a 1,000-year period due to the nature of the contaminants, including long-lived radionuclides. Net present value/worth cost estimates are presented for the individual and comparative analysis of alternatives and for remedy selection (EPA 1988). The real discount rate has been obtained from OMB guidance (reference Appendix C in OMB circular A-94). In addition, nondiscounted cost estimates (i.e., capital and average annual O&M) are presented for comparison purposes only.

Net Present Worth Cost	$47,884,000
Nondiscounted Cost	
• Capital Cost	$39,901,000
• Average Annual O&M Cost	$123,915

4.4 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section provides a comparative analysis of source area alternatives for SWMU 4.

4.4.1 Threshold Criteria

The remedial alternatives for SWMU 4 are compared with respect to the CERCLA threshold criteria in the following sections.

4.4.1.1 Overall protection of human health and the environment

Alternative 1—No Action. Alternative 1 does not meet the threshold criterion of overall protection of human health and the environment, and it will not treat or remove waste. There will be no protection for future industrial workers through engineering or administrative controls. Risk to future off-site groundwater users from the migration of COCs to RGA groundwater could reach unacceptable levels at the SWMU 4 boundary.

Alternative 3—Recharge Control and Hydraulic Control. Alternative 3 will meet this criterion through an engineered cover, slurry wall, hydraulic control, and LUCs. No direct waste removal is performed as part of this alternative. The engineered cover will isolate the in-place waste from contact, while the contaminated groundwater that is released from the unit to the RGA is captured by hydraulic containment. An additional attribute of the engineered cover is that it will prevent infiltration into and through the buried waste, preventing migration of contaminants from the buried waste. The use of physical and administrative LUCs will mitigate unwarranted contact of surface and subsurface contamination. Groundwater monitoring will determine the effectiveness of the alternative.

Alternative 4—Targeted Excavation, ERH, and Bioremediation. Alternative 4 provides protection through a combination of waste removal, isolation, ERH and biological treatments, and LUCs. Approximately one-third of the buried waste, including the apparent source of PTW, will be excavated in this alternative. The remaining two-thirds of the buried waste will remain in place and will be isolated by installation of an engineered cover and slurry wall. Additionally, the PTW in the UCRS soils beneath the buried waste materials will be treated by ERH and then with bioremediation. The use of physical and administrative LUCs will mitigate unwarranted contact with subsurface contamination. Groundwater monitoring will determine the effectiveness of the alternative.

Alternative 5—Full Excavation, ERH, and Bioremediation. Alternative 5 provides the greatest amount of permanent protection of the alternatives because it includes full excavation of all buried waste material and subsequent backfilling of the area. Additionally, organic contaminants in the UCRS beneath the buried waste materials will be treated by ERH; any residual organic contamination then will be treated by bioremediation. The use of physical and administrative LUCs will mitigate unwarranted contact with subsurface contamination. Groundwater monitoring will determine the effectiveness of the alternative.

Alternative 6—Recharge Control and Bioremediation. Alternative 6 will meet this protection criterion through the use of isolation and treatment. No direct waste removal is performed as part of this alternative. The engineered cover will isolate the in-place waste from contact. An engineered cover and associated slurry wall will prevent infiltration into and through the buried waste preventing migration of contaminants from the buried waste. Bioremediation will be utilized to treat organic contaminants that have migrated from the buried waste to the UCRS. The use of physical and administrative LUCs will mitigate unwarranted contact with surface and subsurface contamination. Groundwater monitoring will determine the effectiveness of the alternative.

Note: None of the alternatives, except Alternative 5, are expected to result in UU/UE conditions at SWMU 4 in the near-term. Depending on the effectiveness of thermal treatment and bioremediation in the area containing PTW, Alternative 5 has the highest possibility of returning SWMU 4 to unencumbered use because of the total waste excavation.

4.4.1.2 Compliance with ARARs

No ARARs have been identified for Alternative 1, the No Action alternative. Alternatives 3–6 will meet these threshold criteria by complying with ARARs. None of the alternatives will require an ARAR waiver.

4.4.1.3 Balancing criteria

The remedial alternatives for SWMU 4 are compared to the five CERCLA threshold criteria in the following sections.

4.4.1.4 Long-term effectiveness and permanence

Alternative 1—No Action. The No Action alternative will not be effective. The risk posed by waste material and COCs in soil will remain unabated. No additional administrative or engineering controls will be established to protect future on-site workers or off-site groundwater users.

Alternative 3—Recharge Control and Hydraulic Control. Alternative 3's effectiveness and permanence is high as long as the action is maintained and is active. Its effectiveness is temporary because it provides isolation only. The action does not include treatment of the buried waste and, as such, the current risks will continue to be present, but isolated. The use of a cover, hydraulic containment, and LUCs mitigates risks associated with contact with wastes and associated contaminants that may have migrated to groundwater.

Alternative 4—Targeted Excavation, ERH, and Bioremediation. Alternative 4's effectiveness and permanence is medium. The alternative will remove approximately one-third of the buried waste, which will reduce the amount of waste contributing to the migration of contaminants. The portion of the waste excavated is likely the source material of the PTW that has migrated to the UCRS soils below the southern portion of the burial ground. The remaining portion of the buried waste material will remain in place, but will be isolated by an engineered cover and slurry wall to prevent contact and groundwater recharge. The PTW and residual VOCs will be removed from the UCRS soils using a combination ERH and biological treatment. Under this alternative, the entire SWMU will be protected by LUCs and long-term monitoring.

Alternative 5—Full Excavation, ERH, and Bioremediation. Alternative 5 provides a very high level of effectiveness and permanence provided by the excavation and removal of buried waste associated with the SWMU. The PTW and residual VOCs will be removed from the UCRS using a combination of ERH and biological treatments. The use of physical and administrative LUCs will mitigate unwarranted contact with subsurface contamination. This remedy includes groundwater monitoring that will monitor remedy effectiveness at preventing COC migration to the RGA.

Alternative 6—Recharge Control and Bioremediation. Alternative 6 provides a medium level of effectiveness and permanence. It is provided through isolation and treatment. The biological treatment in the alternative is intended to treat organic contaminants present in the UCRS beneath the buried waste and provides this alternative's highest level of effectiveness and permanence. The buried waste will be covered with an engineered cover and surrounded by a slurry wall to prevent contact and groundwater recharge control. Under this alternative, the entire SWMU will be protected by LUCs and long-term monitoring.

4.4.1.5 Reduction of toxicity, mobility, and volume through treatment

Alternative 1—No Action. The No Action alternative provides no reduction of toxicity and volume through treatment; therefore, it ranks low in this CERCLA criterion.

Alternative 3—Recharge Control and Hydraulic Control. Alternative 3's impact on reduction of toxicity, mobility, and volume through treatment is low because the alternative provides only isolation. The only treatment will occur in the groundwater extraction and treatment system.

Alternative 4—Targeted Excavation, ERH, and Bioremediation. Alternative 4's impact in the reduction of toxicity, mobility, and volume through treatment is medium. The alternative will remove approximately one-third of the buried waste; a portion of this waste will be treated to reduce toxicity or mobility to meet the receiving facilities' WACs. Reduction of contaminants in the UCRS will be achieved using a combination ERH and biological treatment.

Alternative 5—Full Excavation, ERH, and Bioremediation. Alternative 5's impact on reduction of toxicity, mobility, and volume through treatment is very high. The reduction of toxicity, mobility, and volume is provided by the excavation and removal of buried waste associated with the SWMU. The PTW and residual VOCs will be removed from the UCRS soils using a combination ERH and biological treatment.

Alternative 6—Recharge Control and Bioremediation. Alternative 6's impact in the reduction of toxicity, mobility, and volume through treatment is medium. It is provided through isolation as well as through treatment. The treatment contained within the alternative is intended to treat the PTW present in the UCRS soils beneath the buried waste and provides this alternative's reduction in toxicity, mobility, and volume of contaminants. This treatment will include bioremediation. The buried waste will be covered with an engineered cover to prevent contact and infiltration and provide isolation. Under this alternative, the entire SWMU will be protected by LUCs and long-term monitoring.

4.4.1.6 Short-term effectiveness

Alternative 1—No Action. The No Action alternative has low short-term effectiveness. Because there is no remedial action, the remedial objectives will not be met.

Alternative 3—Recharge Control and Hydraulic Control. Alternative 3's short-term effectiveness is high. The alternative does not include intrusive work in the buried waste. The other components, including treatment system and engineered cover, are developed through standard civil and mechanical construction activities with low potential for injury or contamination to workers or the public and low potential for negatively impacting the environment. Components of Alternative 3 will reduce the mobility and volume of the PTW (TCE DNAPL) located at SWMU 4 through hydraulic control. The hydraulic control system will capture groundwater and associated TCE emanating from TCE PTW.

Alternative 4—Targeted Excavation, ERH, and Bioremediation. Alternative 4's short-term effectiveness is medium. Because the alternative includes excavation of a portion of the buried waste, the potential worker injury and contamination is increased. Because waste also may be shipped off-site, there is a slight increased risk to the public and environment. The time to achieving RAOs is 5–10 years.

Alternative 5—Full Excavation, ERH, and Bioremediation. Alternative 5 provides medium short-term effectiveness similar to Alternative 4. Because this alternative includes excavation of all waste, the time to achieving objectives is 10–20 years.

Alternative 6—Recharge Control and Bioremediation. Alternative 6's short-term effectiveness is medium-high. As with Alternative 3, there is no intrusive work. The bioremediation activities are lower risk construction activities, with RAOs expected to be met in about five years.

4.4.1.7 Implementability

Alternative 1—No Action. The No Action alternative provides the highest implementability factor.

Alternative 3—Recharge Control and Hydraulic Control. Alternative 3 has high implementability. All of the activities are routine construction activities for which there are readily available contractors and vendors. There is no need for off-site treatment and shipment. A standard monitoring well network is used to determine effectiveness.

Alternative 4—Targeted Excavation, ERH, and Bioremediation. Alternative 4's implementability is medium. The action involves the excavation, sorting, treating, packaging, and disposal off-site and on-site of large quantities of waste. The activities are complex and numerous, but have been successfully performed at other sites in the United States. Because wastes also may be going off-site and out of state, there is increased complexity associated with multiple state and agency interaction.

Alternative 5—Full Excavation, ERH, and Bioremediation. Alternative 5's implementability is medium to low. Alternative 5 contains the same complexities to achieve successful performance as Alternative 4; however, the project volumes are approximately three times larger.

Alternative 6—Recharge Control and Bioremediation. Alternative 6 has high implementability. There are sufficient technologies and providers for its performance. The bioremediation action complexity is increased slightly due to the use of horizontal wells and treatment of vadose zone. Both technologies have been implemented successfully at other sites.

4.4.1.8 Cost

Capital, O&M, and net present value costs for alternatives at SWMU 4 are presented in Table 4.2.

Table 4.2. Estimated Cost of Alternatives

Alternative	Capital, $	Total Annual/ Operation and Maintenance, $	Total, $	Net Present Total, $
1—No Action	0	0	0	0
3—Recharge Control and Hydraulic Control	35,953,000	895,337,000	931,290,000	92,572,000
4—Targeted Excavation, ERH, and Bioremediation	227,453,000	118,002,000	345,455,000	236,467,000
4a—with WDA Facility Waste Disposal	162,446,000	118,002,000	280,448,000	171,460,000
5—Full Excavation, ERH, and Bioremediation	525,094,000	15,254,000	540,348,000	530,491,000
5a—with WDA Facility Waste Disposal	343,768,000	15,254,000	359,022,000	349,165,000
6—Recharge Control and Bioremediation	39,901,000	123,915,000	163,816,000	47,884,000

4.4.2 Summary of Comparative Analysis of Alternatives

This section provides a succinct summary of the attributes associated with each alternative evaluated, and Table 4.3 provides a comparative analysis of all alternatives. All alternatives, except Alternative 1, pass the Threshold Criteria.

Alternative 1 provides no action beyond existing PGDP site controls and monitoring. Current site controls will continue to control access to the site and prevent direct contact with the contents of the buried waste without authorization and appropriate protection. The No Action alternative may not provide an adequate level of overall protection to human health and the environment. Alternative 1 ranks 1 of 5 in Cost (1 being least costly) at $0.

Alternative 3 includes the construction of an engineered cover over the buried waste and a perimeter slurry wall to control water infiltration into the waste. The other major action contained in the alternative is hydraulic control of migrating contaminants from the SWMU in the RGA. Alternative 3 has high long-term effectiveness, implementability, and short-term effectiveness, but ranks low in reduction of toxicity, mobility, or volume through treatment. The hydraulic control system will capture groundwater and associated TCE emanating from TCE PTW; as such, Alternative 3 provides indirect treatment of PTW.

Table 4.3. Summary of Comparative Analysis of Alternatives

Evaluation Criteria	Alternative 1 No Action	Alternative 3 Recharge Control and Hydraulic Control	Alternative 4 Targeted Excavation, ERH, and Bioremediation	Alternative 5 Full Excavation, ERH, and Bioremediation	Alternative 6 Recharge Control and Bioremediation
Overall Protection of Human Health and the Environment	No	Yes	Yes	Yes	Yes
Compliance with ARARs	No ARARs Identified	Yes	Yes	Yes	Yes
Long-term Effectiveness	Low	High	Medium	Very High	Medium
Reduction in Toxicity, Mobility, or Volume through Treatment	Low	Low	Medium	Very High	Medium Low
Short-term Effectiveness	Low	High	Medium	Medium	Medium High
Implementability	Very High	High	Medium	Medium Low	High
Overall Cost Rating	1 of 5	5 of 5	3 of 5	4 of 5	2 of 5
<u>Average Balancing Criteria Rating</u>	N/A—Does Not Pass Threshold Criteria	Medium High	Medium	Medium	Medium
Total Project Cost (M$),	$0	$931	$345/$280*	$540/$359*	$164
Total Project Cost (M$), (Present Worth)	$0	$93	$236/$171*	$530/$349*	$48
PTW Treatment (TCE)	No	Indirect—Capture through Dissolution in Groundwater	Direct	Direct	Direct
Treatment of COCs	No	Partial Treatment—*Ex Situ* Groundwater Treatment	Partial Treatment—Excavation, ERH, and Bioremediation	Yes—Full Excavation, ERH, and Bioremediation	Partial Treatment—Bioremediation

*Estimated Total Project Cost with WDA facility.

Alternative 3 ranks 5 of 5 in Cost (1 being least costly) at $931M. LUCs mitigate contact with the buried waste and contaminants. This alternative also includes monitoring to evaluate changed site conditions or impacts.

Alternative 4 includes the excavation, treatment, and disposal of approximately one-third of the buried waste. The remaining two-thirds of the buried waste will remain in place and be covered by an engineered cover. ERH and bioremediation will be used to treat UCRS soils in the area beneath the excavated waste with ERH treatment focusing on the areas of higher TCE soil concentrations.

Bioremediation will be implemented on all UCRS soils beneath the area excavated. LUCs mitigate contact with the buried waste and contaminants. This alternative also includes monitoring to evaluate changed site conditions or impacts. Alternative 4 ranks medium in the balancing criteria because its activities focus mainly on the PTW and the buried waste that is assumed to be the source of PTW now located in the UCRS. Alternative 4 ranks 3 of 5 in Cost (1 being least costly) at $345M.

Alternative 5 includes the excavation, treatment, and disposal of all buried waste at SWMU 4. ERH and bioremediation will be used to treat UCRS soils with PTW in the area beneath the excavated waste. ERH will be focused on the areas of higher TCE soil concentrations. Bioremediation will be implemented on roughly the southern one-third of the SWMU where the higher concentrations of TCE are located in UCRS soils beneath the area excavated. The use of physical and administrative LUCs will mitigate unwarranted contact with subsurface contamination. This alternative also includes monitoring to evaluate changed site conditions or impacts. Alternative 5 ranks very high in long-term effectiveness and reduction of toxicity, mobility, and volume because no buried waste will remain in the SWMU. Alternative 5 ranks medium and medium-low for short-term effectiveness and implementability, respectively, due to the complexity of and large quantities of waste requiring excavation, treatment, and disposal. Alternative 5 ranks 4 of 5 in Cost (1 being least costly) at $540M.

Alternative 6 includes the construction of an engineered cover over the buried waste and a perimeter slurry wall to control groundwater recharge. The cover also prevents contact with waste and contaminated soil. ERH and bioremediation will be used to treat UCRS soils with PTW in the southern one-third of the landfill area beneath the waste. Thermal treatment will be focused on the areas of higher TCE soil concentrations. Bioremediation will be implemented on roughly the southern one-third of the SWMU where the higher concentrations of TCE are located in UCRS soils. LUCs will mitigate contact with the buried waste and contaminants. This alternative also includes monitoring to evaluate changed site conditions or impacts. Alternative 6 ranks medium-low in reduction of toxicity, mobility, or volume through treatment and medium in long-term effectiveness because a large part of the buried waste remains in place, untreated. The alternative ranks high in implementability and medium-high in short-term effectiveness because the techniques utilized are standard and readily available. Alternative 6 ranks 2 of 5 in Cost (1 being least costly) at $164M. This alternative also includes monitoring to evaluate changed site conditions or impacts.

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APPENDIX A

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND TO BE CONSIDERED GUIDANCE FOR SWMU 4

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ACRONYMS

ANOVA	analysis of variance
ARAR	applicable or relevant and appropriate requirement
BGOU	Burial Grounds Operable Unit
BMP	Best Management Practice
CAMU	corrective action management unit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
CI	compression ignition
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
E.O.	Executive Order
EPA	U.S. Environmental Protection Agency
ERH	electrical resistance heating
ESD	explanation of significant differences
FFA	Federal Facility Agreement
HAP	hazardous air pollutant
HMR	Hazardous Material Regulations
KAR	*Kentucky Administrative Regulations*
KPDES	Kentucky Pollutant Discharge Elimination System
LLW	low-level waste
NGS	National Geodetic Survey
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
OSWER	EPA's Office of Solid Waste and Emergency Response
PGDP	Paducah Gaseous Diffusion Plant
PHC	principal hazardous constituent
PM	particulate matter
PPE	personal protection equipment
PQL	practical quantitation limit
RAWP	remedial action work plan
RCRA	Resource Conservation and Recovery Act
ROD	record of decision
SWMU	solid waste management unit
TBC	to be considered
TCLP	Toxicity Characteristic Leaching Procedure
TOC	total organic compound
TSCA	Toxic Substances Control Act
USDW	underground source of drinking water
USGS	United States Geological Survey
UTS	Universal Treatment Standard
VOC	volatile organic compound
VOHAP	volatile organic hazardous air pollutant

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A.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)]. ARARs and TBC guidance for the Burial Grounds Operable Unit (BGOU) Feasibility Study for Solid Waste Management Units (SWMU) 4 are identified in Tables A.1 and A.2.

A.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 SWMU 4 source areas.

A.3. LOCATION-SPECIFIC ARARs/TBC GUIDANCE

Location-specific requirements establish restrictions on activities conducted within protected or environmentally sensitive areas.

A.3.1 WETLANDS

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 and complied with, as appropriate.

A.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.

A.4.1 GENERAL CONSTRUCTION ACTIVITIES

Requirements for storm-water runoff and fugitive dust emission control measures potentially provide ARARs for construction and site preparation activities. ARARs for these common activities are discussed here.

A.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.

A.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. Reasonable precautions must be taken to prevent particulate matter from becoming airborne.

Radionuclide emissions, excluding radon-220 and radon-222, from the 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 limit ambient air radionuclide emissions from DOE facilities to levels that would prevent any individual from receiving an effective dose equivalent (EDE) of 10 millirem per year (mrem/year) or more (40 *CFR* § 61.92). Nonpoint-source fugitive radionuclide emissions are estimated by plant monitoring stations.

A.4.4 COLLECTION/TREATMENT OF VOLATILE ORGANIC CONSTITUENTS

SWMU 4 alternatives that include electrical resistance heating (ERH) involve *in situ* heating of soils using an ERH process. This will result in the collection and recovery of contaminants from the Upper Continental Recharge System soils and vadose zone. Prior to emission of collected vapor/gases, contaminants must be removed to comply with 401 *KAR* 63:020. An off-gas treatment system shall be employed to ensure contaminant emissions do not exceed allowable levels. This system may include such equipment as condensers, accumulators, and/or filters to accomplish the required contaminant removal.

A.4.5 WASTE-WATER TREATMENT

Contaminated water, including decontamination fluid, collected storm water, and groundwater, will be treated before discharge, as needed, to meet discharge limits. Wastewater will be discharged through either an existing KPDES-permitted outfall or a new CERCLA outfall established as part of this CERCLA action. ARARs for both discharge options are included in Table A.2. Under alternatives that include ERH, hydraulic containment, or excavation, a wastewater treatment facility may be constructed and designed to meet the ARARs.

A.4.6 WASTE MANAGEMENT

All primary waste (i.e., groundwater and contaminated soils) and secondary waste (i.e., contaminated personal protective equipment, treatment residuals, and decontamination wastewaters) generated during remedial activities will be characterized as 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 (O)/Manual (M) requirements. Waste managed on-site must comply with the substantive requirements of the aforementioned ARARs. A combination of regulatory methods will be used to provide for efficient and cost-effective management of generated waste, such as application of the area of contamination policy, corrective action management units (CAMUs), and temporary units.

A.4.7 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 complied with fully for shipment. Before shipment of CERCLA waste 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 A.1. Location-Specific ARARs and TBC Guidance for FS—SWMU 4

Location	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
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)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Site Preparation, Construction, and Excavation							
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)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Activities causing fugitive dust emissions (Continued)	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)	✓	✓	✓	✓
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 [Paducah Gaseous Diffusion Plant (PGDP)] with an existing BMP Plan—**TBC**.	Appendix C of the PGDP Best Management Practices Plan (2007)—Examples of Storm water Controls	✓	✓	✓	✓
Air Emissions							
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	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
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	✓	✓	✓	✓
Emission standards for stationary emergency engines (e.g., generators)	Must comply with the emission standards in Table 1 Subpart IIII of Part 60.	Operation of pre-2007 model year emergency stationary compression ignition internal combustion engines as defined in 40 *CFR* § 60.4219 with a displacement of less than 10 liters per cylinder that are not fire pump engines—**applicable**.	40 *CFR* § 60.4205(a)		✓	✓	
	Must comply with the emission standards for new nonroad compression ignition engines in 40 *CFR* § 60.4202, for all pollutants, for the same model year and maximum engine power for their 2007 model year and later emergency stationary compression ignition internal combustion engines.	Operation of 2007 model year and later emergency stationary compression ignition internal combustion engines with a displacement of less than 30 liters per cylinder that are not fire pump engines—**applicable**.	40 *CFR* § 60.4205(b)		✓	✓	

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Emission standards for stationary emergency engines (e.g., generators) (Continued)	Must meet the following (1) Reduce nitrogen oxide (NO_X) emissions by 90 percent or more, or limit the emissions of NO_X in the stationary compression ignition (CI) internal combustion engine exhaust to 1.6 grams per KW-hour (1.2 grams per HP-hour). (2) Reduce particulate matter (PM) emissions by 60 percent or more, or limit the emissions of PM in the stationary CI internal combustion engine exhaust to 0.15 g/KW-hr (0.11 g/HP-hr).	Operation of emergency stationary compression ignition internal combustion engines with a displacement of greater than or equal to 30 liters per cylinder—**applicable**.	40 *CFR* § 60.4205(d)		✓	✓	
General standards for process vents used in treatment of volatile organic compounds (VOCs)	Select and meet the requirements under one of the options specified below: (3) Control hazardous air pollutants (HAPs) emissions from the affected process vents according to the applicable standards specified in §§ 63.7890 through 63.7893. (4) Determine for the remediation material treated or managed by the process vented through the affected process vents that the average total volatile organic hazardous air pollutant (VOHAP) concentration, as defined in § 63.7957, of this material is less than 10 ppm. Determination of VOHAP concentration will be made using procedures specified in § 63.7943. (5) Control HAP emissions from affected process vents subject to another subpart under 40 *CFR* Part 61 or 40 *CFR* Part 63 in compliance with the standards specified in the applicable subpart.	Process vents as defined in 40 *CFR* § 63.7957 used in site remediation of media (e.g., soil and groundwater) that could emit HAP listed in Table 1 of Subpart GGGGG of Part 63 and vent stream flow exceeds the rate in 40 *CFR* § 63.7885(c)(1)—**relevant and appropriate**.	40 *CFR* § 63.7885(b) 401 *KAR* 63:002, §§ 1 and 2, except for 40 *CFR* § 63.72 as incorporated in § 2(3)	✓	✓	✓	

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Emission limitations for process vents used in treatment of VOCs	Meet the requirements under one of the options specified below: (6) Reduce from all affected process vents the total emissions of the HAP to a level less than 1.4 kilograms per hour (kg/hr) and 2.8 Mg/yr [3.0 pounds per hour (lb/hr) and 3.1 tpy]; or (7) Reduce from all affected process vents the emissions of total organic compounds (TOC) (minus methane and ethane) to a level below 1.4 kg/hr and 2.8 Mg/yr (3.0 lb/hr and 3.1 tpy); or (8) Reduce from all affected process vents the total emissions of the HAP by 95 percent by weight or more; or (9) Reduce from all affected process vents the emissions of TOC (minus methane and ethane) by 95 percent by weight or more.	Process vents as defined in 40 *CFR* § 63.7957 used in site remediation of media (e.g., soil and groundwater) that could emit HAPs listed in Table 1 of Subpart GGGGG of Part 63 and vent stream flow exceeds the rate in 40 *CFR* § 63.7885(c)(1)—**relevant and appropriate**.	40 *CFR* § 63.7890(b)(1)-(4) 401 *KAR* 63:002, §§ 1 and 2, except for 40 *CFR* § 63.72 as incorporated in § 2(3)	✓	✓	✓	
Standards for closed vent systems and control devices used in treatment of VOCs	For each closed vent system and control device you use to comply with the requirements above, you must meet the operating limit requirements and work practice standards in Sec. 63.7925(d) through (j) that apply to the closed vent system and control device. *Note: U.S. Environmental Protection Agency (EPA) approval to use alternate work practices under paragraph (j) in 40 CFR § 63.7925 will be obtained in Federal Facility Agreement (FFA) CERCLA document (e.g., remedial design).*	Closed vent system and control devices as defined in 40 *CFR* § 63.7957 that are used to comply with § 63.7890(b)—**relevant and appropriate**.	40 *CFR* § 63.7890(c)	✓	✓	✓	

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Monitoring of closed vent systems and control devices used in treatment of VOCs	Must monitor and inspect the closed vent system and control device according to the requirements in 40 *CFR* § 63.7927 that apply to the affected source. *Note: Monitoring program will be developed as part of the CERCLA process and included in a remedial design or other appropriate FFA CERCLA document.*	Closed vent system and control devices, as defined in 40 *CFR* § 63.7957, that are used to comply with § 63.7890(b)—**relevant and appropriate**.	40 *CFR* § 63.7892		✓	✓	
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)	✓	✓	✓	✓
	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: (10) Section 2. Design Factors; (11) Section 3. Monitoring Well Construction; (12) Section 7. Materials for Monitoring Wells; and (13) Section 8. Surface Completion.		401 *KAR* 6:350 § 2, 3, 7, and 8	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Monitoring well installation (Continued)	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:* (14) *A justification for the variance; and* (15) *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 A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Direct push monitoring well installation (Continued)	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)	✓	✓	✓	✓
	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)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Extraction well installation	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 extraction well for remedial action—**relevant and appropriate**.	401 *KAR* 6:350 § 1 (2)	✓	✓	✓	✓
Reinjection of treated contaminated groundwater	No owner or operator shall construct, operate, maintain, convert, plug, abandon, or conduct any other injection activity in a manner that allows the movement of fluid containing any contaminant into underground sources of drinking water, if the presence of that contaminant may cause a violation of any primary drinking water regulation under 40 *CFR* Part 142 or may otherwise adversely affect the health of persons.	Underground injection into an underground source of drinking water—**relevant and appropriate**.	40 *CFR* § 144.12(a)		✓	✓	
	Wells are not prohibited if injection is approved by EPA or a State pursuant to provisions for cleanup of releases under CERCLA or RCRA *as provided in the FFA CERCLA document*.	Class IV wells [as defined in 40 *CFR* § 144.6(d)] used to reinject treated contaminated groundwater into the same formation from which it was drawn—**relevant and appropriate**.	40 *CFR* § 144.13(c) RCRA § 3020(b)		✓	✓	
Plugging and abandonment of Class IV injection wells	Prior to abandonment any Class IV well, the owner or operator shall plug or otherwise close the well in a manner *as provided in the FFA CERCLA document*.	Class IV wells [as defined in 40 *CFR* § 144.6(d)] used to reinject of treated contaminated groundwater into the same formation from which it was drawn—**relevant and appropriate**.	40 *CFR* § 144.23(b)(1)		✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Injection of fluids for Class V injection wells	Injection activity cannot allow movement of fluid containing any contaminant into an underground source of drinking water (USDW), if the presence of that contaminant may cause a violation of the primary drinking water standards under 40 *CFR* Part 141, or other health-based standards, or may otherwise adversely affect the health of persons. This prohibition applies to well construction, operation, maintenance, conversion, plugging, closure, or any other injection activity.	Operation of a Class V injection well—**relevant and appropriate to bioremediation**.	40 *CFR* § 144.82(a)		✓	✓	✓
Closure of Class V injection wells	Close the well in a manner that complies with the above prohibition of fluid movement [40 *CFR* § 144.82(a)]. Also must dispose of or otherwise manage any soil, gravel, sludge, liquids, or other material removed from or adjacent to well in accordance with all applicable federal, state, and local regulations and requirements.	Closure of a Class V injection well—**relevant and appropriate to bioremediation**.	40 *CFR* § 144.82(b)		✓	✓	✓
Plugging and abandonment of Class V injection wells	Prior to abandoning a Class V well, the owner or operator shall close the well in a manner that prevents the movement of fluid containing any contaminant into an USDW, if the presence of that contaminant may cause a violation of any primary drinking water regulation under 40 *CFR* Part 141, or may otherwise adversely affect the health of persons.	Closure of a Class V injection well—**relevant and appropriate for bioremediation**.	40 *CFR* § 146.10(c)		✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Closure of units with hazardous waste remaining in place	The owner or operator must close the facility in a manner that: (a) minimizes the need for further maintenance; (b) 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 (c) complies with the closure requirements in this table.	Closure of units with hazardous waste remaining in place—**relevant and appropriate**.	40 *CFR* § 264.111 401 *KAR* 34:070 § 2	✓	✓		✓
Installation of low-permeability cover for landfills with hazardous waste remaining in place	Must install cover designed and constructed to: (1) provide long-term minimization of migration of liquids through the closed landfill; (2) function with minimum maintenance; (3) promote drainage and minimize erosion or abrasion of the cover; (4) accommodate settling and subsidence so that the cover's integrity is maintained; and (5) have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.	Design and construction of cover for disposal units with hazardous waste or polychlorinated biphenyls (PCBs) remaining in place—**relevant and appropriate**.	40 *CFR* § 264.310(a) 401 *KAR* 34:230 § 7	✓	✓		✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Installation of low-permeability cover for landfills with hazardous waste remaining in place (Continued)	EPA guidance provides technical recommendations on the design parameters for a multilayer low permeability cover including a two component low permeability layer, a soil drainage layer, and a two component top layer. The guidance acknowledges that other final cover designs may be acceptable.	Design and construction of cover for landfills with hazardous waste remaining in place—**TBC**.	Sections 1.4.1, 2, 3, and 4 of the EPA Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface Impoundments, EPA OSWER 530- SW-89-047, (July 1989)	✓	✓		✓
Maintenance of low-permeability cover for landfills with hazardous waste remaining in place	Must maintain the integrity and effectiveness of the cover, including making repairs to the cap as necessary to correct the effects of settling, subsidence, erosion, or other events; and	Installation of cover for landfills with hazardous waste remaining in place—**relevant and appropriate**.	40 *CFR* § 264.310(b)(1) 401 *KAR* 34:230 § 7	✓	✓		✓
	Prevent run on and runoff from eroding or otherwise damaging the final cover.		40 *CFR* § 264.310(b)(5) 401 *KAR* 34:230 § 7	✓	✓		✓
	Post-closure care for each hazardous waste management unit subject to the requirements of §§ 264.117 through 264.120 must begin after completion of closure of the unit and continue for 30 years after that date.		40 *CFR* § 264.117(a)(1) 401 *KAR* 34:070 § 8	✓	✓		✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Disturbance of integrity of low-permeability cover	Post-closure use of property on or in which hazardous wastes remain after partial or final closure must never be allowed to disturb the integrity of the final cover, or any other components of the containment system, or the function of the facility's monitoring systems, unless the Regional Administrator finds that the disturbance: (1) Is necessary to the proposed use of the property, and will not increase the potential hazard to human health or the environment; or (2) Is necessary to reduce a threat to human health or the environment.		40 *CFR* § 264.117(c) 401 *KAR* 34:070 § 8	✓	✓		✓
General post-closure care	Owner or operator must:	Post-closure of a RCRA landfill—**relevant and appropriate**.	40 *CFR* § 264.310(b) 401 *KAR* 34:230 § 7	✓	✓		✓
	• Maintain the integrity and effectiveness of the final cover including making repairs to the cap as necessary to correct effects of settling, erosion, or other events;		40 *CFR* § 264.310(b)(1) 401 *KAR* 34:230 § 7	✓	✓		✓
	• Prevent run on and runoff from eroding or otherwise damaging final cover; and		40 *CFR* § 264.310(b)(5) 401 *KAR* 34:230 § 7	✓	✓		✓
	• Protect and maintain surveyed benchmarks used in complying with § 264.309.		40 *CFR* § 264.310(b)(6) 401 *KAR* 34:230 § 7	✓	✓		✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Installation of a low-level waste (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 disposal facility—**relevant and appropriate**.	902 *KAR* § 100:022 § 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 § 23(5) 10 *CFR* § 61.51(a)(5)	✓	✓		✓
	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 the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring, or minor custodial care are required.*		902 *KAR* 100:022 § 21	✓	✓		✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
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)	✓	✓		✓
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)		✓	✓	

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Management of PCB/radioactive waste (Continued)	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 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.		40 *CFR* § 761.50(b)(7)(ii)		✓	✓	
Waste Characterization							
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	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Characterization of hazardous waste	Must obtain a detailed chemical and physical analysis on a representative sample of the waste(s), which at a minimum 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.	Generation of RCRA-hazardous waste for storage, treatment or disposal—**applicable**.	40 *CFR* § 264.13(a)(1) 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 (CWA), 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 A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Determinations for management of hazardous waste (Continued)	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 PCB waste	Any person land disposing of non-liquid PCBs may avoid otherwise-applicable sampling requirements by presuming that the PCBs disposed of are ≥ 500 ppm (or ≥ 100 µg/100 cm^2 if no free-flowing liquids are present).	Generation of PCB waste—**applicable**.	40 *CFR* § 761.50(a)(5)		✓	✓	
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 waste acceptance criteria of the receiving facility.	Generation of LLW for storage and disposal at a DOE facility—**TBC**.	DOE M 435.1-1(IV)(I)	✓	✓	✓	✓
	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;		DOE M 435.1-1(IV)(I)(2)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Characterization of LLW (Continued)	• 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.						
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	✓	✓	✓	✓
	• 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	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
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	✓	✓	✓	✓
	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	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Designation and management of CAMUs	To implement remedies under § 264.101 or RCRA Section 3008(h), or to implement remedies at a permitted facility that is not subject to § 264.101, the Regional Administrator may designate an area at the facility as a corrective action management unit under the requirements in this section. CAMUs means an area within a facility that is used only for managing CAMU-eligible wastes for implementing corrective action or cleanup at the facility. A CAMU must be located within the contiguous property under the control of the owner or operator where the wastes to be managed in the CAMU originated. One or more CAMUs may be designated at a facility. *Note: Designation of a CAMU will be documented in a CERCLA decision document [i.e., record of decision (ROD), ROD amendment, or explanation of significant differences (ESD)] subject to review and approval under the FFA process.*	Management of CAMU-eligible wastes within a CAMU—**applicable**.	40 *CFR* § 264.552(a)	✓	✓	✓	✓
	CAMU-eligible waste means: All solid and hazardous wastes, and all media (including ground water, surface water, soils, and sediments) and debris that are managed for implementing cleanup. As-generated wastes (either hazardous or non-hazardous) from ongoing industrial operations at a site are not CAMU-eligible wastes.		40 *CFR* § 264.552(a)(1)(i)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Designation and management of CAMUs (Continued)	Wastes that would otherwise meet the description in paragraph (a)(1)(i) of this section are not "CAMU-Eligible Wastes" where: (A) The wastes are hazardous wastes found during cleanup in intact or substantially intact containers, tanks, or other non-land-based units found above ground, unless the wastes are first placed in the tanks, containers or non-land-based units as part of cleanup, or the containers or tanks are excavated during the course of cleanup.		40 *CFR* § 264.552(a)(1)(ii)(A)	✓	✓	✓	✓
	Notwithstanding paragraph (a)(1)(i) of this section, where appropriate, as-generated non-hazardous waste may be placed in a CAMU where such waste is being used to facilitate treatment or the performance of the CAMU.		40 *CFR* § 264.552(a)(1)(iii)	✓	✓	✓	✓
	Placement of CAMU-eligible wastes into or within a CAMU does not constitute land disposal of hazardous wastes.		40 *CFR* § 264.552(a)(4)	✓	✓	✓	✓
Minimum treatment requirements	Minimum treatment requirements: Unless the wastes will be placed in a CAMU for storage and/or treatment only in accordance with paragraph (f) of this section, CAMU eligible wastes that, absent this section, would be subject to the treatment requirements of part 268 of this chapter, and that the Regional Administrator determines contain principal hazardous constituents must be treated to the standards specified in paragraph (e)(4)(iii) of this section.	Treatment of CAMU-eligible wastes within a new, replacement, or laterally expanded CAMUs located within the contiguous property under the control of the owner or operator—**applicable**.	40 *CFR* § 264.552(e)(4)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Minimum treatment requirements	(i) Principal hazardous constituents are those constituents that the Regional Administrator determines pose a risk to human health and the environment substantially higher than the cleanup levels or goals at the site. (A) In general, the Regional Administrator will designate as principal hazardous constituents: (1) Carcinogens that pose a potential direct risk from ingestion or inhalation at the site at or above 10^{-3}; and (2) Noncarcinogens that pose a potential direct risk from ingestion or inhalation at the site an order of magnitude or greater over their reference dose.		40 *CFR* § 264.552(e)(4)(i)	✓	✓	✓	✓
	(B) The Regional Administrator will also designate constituents as principal hazardous constituents, where appropriate, when risks to human health and the environment posed by the potential migration of constituents in wastes to ground water are substantially higher than cleanup levels or goals at the site; when making such a designation, the Regional Administrator may consider such factors as constituent concentrations, and fate and transport characteristics under site conditions. *Note: Designation of principal hazardous constituents will be documented in a CERCLA decision document (i.e., ROD, ROD Amendment, or ESD) subject to review and approval under the FFA process.*						

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Minimum treatment requirements (Continued)	(ii) In determining which constituents are "principal hazardous constituents," the Regional Administrator must consider all constituents which, absent this section, would be subject to the treatment requirements in 40 *CFR* Part 268.		40 *CFR* § 264.552(e)(4) (ii)	✓	✓	✓	✓
	(C) The Regional Administrator may also designate other constituents as principal hazardous constituents that the Regional Administrator determines pose a risk to human health and the environment substantially higher than the cleanup levels or goals at the site. *Note: Designation of principal hazardous constituents will be documented in a CERCLA decision document (i.e., ROD, ROD amendment, or ESD) subject to review and approval under the FFA process.* (iii) Waste that the Regional Administrator determines contains principal hazardous constituents must meet treatment standards determined in accordance with paragraph (e)(4)(iv) or (e)(4)(v) of this section.		40 *CFR* § 264.552(e)(4) (iii)	✓	✓	✓	✓
	(iv) Treatment standards for wastes placed in CAMUs. (A) For non-metals, treatment must achieve 90 percent reduction in total principal hazardous constituent concentrations, except as provided by paragraph (e)(4)(iv)(C) of this section.		40 *CFR* § 64.552(e)(4) (iv)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Minimum treatment requirements (Continued)	(B) For metals, treatment must achieve 90 percent reduction in principal hazardous constituent concentrations as measured in leachate from the treated waste or media [tested according to the Toxicity Characteristic Leaching Procedure (TCLP)] or 90 percent reduction in total constituent concentrations (when a metal removal treatment technology is used), except as provided by paragraph (e)(4)(iv)(C) of this section.						
	(C) When treatment of any principal hazardous constituent to a 90 percent reduction standard would result in a concentration less than 10 times the Universal Treatment Standard (UTS) for that constituent, treatment to achieve constituent concentrations less than 10 times the UTS is not required. Universal Treatment Standards are identified in § 268.48 Table UTS of this chapter. (D) For waste exhibiting the hazardous characteristic of ignitability, corrosivity or reactivity, the waste must also be treated to eliminate these characteristics. (E) For debris, the debris must be treated in accordance with § 268.45 of this chapter, or by methods or to levels established under paragraphs (e)(4)(iv)(A) through (D) or paragraph (e)(4)(v) of this section, whichever the Regional Administrator determines is appropriate.						

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Minimum treatment requirements (Continued)	(F) Alternatives to TCLP. For metal bearing wastes for which metals removal treatment is not used, the Regional Administrator may specify a leaching test other than the TCLP [SW846 Method 1311, 40 *CFR* § 260.11(c)(3)(v)] to measure treatment effectiveness, provided the Regional Administrator determines that an alternative leach testing protocol is appropriate for use, and that the alternative more accurately reflects conditions at the site that affect leaching. *Note: Specification of a leaching test as an alternative to TCLP for metal bearing wastes will be documented in the appropriate FFA CERCLA primary document and subject to review and approval under the FFA process.*						
	(v) Adjusted standards. The Regional Administrator may adjust the treatment level or method in paragraph (e)(4)(iv) of this section to a higher or lower level, based on one or more of the following factors, as appropriate. The adjusted level or method must be protective of human health and the environment: (A) The technical impracticability of treatment to the levels or by the methods in paragraph (e)(4)(iv) of this section;		40 *CFR* § 264.552(e)(4) (v)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Minimum treatment requirements (Continued)	(B) The levels or methods in paragraph (e)(4)(iv) of this section would result in concentrations of principal hazardous constituents (PHCs) that are significantly above or below cleanup standards applicable to the site (established either site-specifically, or promulgated under state or federal law); (C) The views of the affected local community on the treatment levels or methods in paragraph (e)(4)(iv) of this section as applied at the site, and, for treatment levels, the treatment methods necessary to achieve these levels; (D) The short-term risks presented by the on-site treatment method necessary to achieve the levels or treatment methods in paragraph (e)(4)(iv) of this section; (E) The long-term protection offered by the engineering design of the CAMU and related engineering controls: (1) Where the treatment standards in paragraph (e)(4)(iv) of this section are substantially met and the principal hazardous constituents in the waste or residuals are of very low mobility; or						
	(2) Where cost-effective treatment has been used and the CAMU meets the Subtitle C liner and leachate collection requirements for new land disposal units at § 264.301(c) and (d); or	Treatment of CAMU-eligible wastes within a new, replacement, or laterally expanded CAMUs located within the contiguous property under the control of the owner or operator—**applicable**.	40 *CFR* § 264.552(e)(4)(v)				

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Minimum treatment requirements (Continued)	(3) Where, after review of appropriate treatment technologies, the Regional Administrator determines that cost-effective treatment is not reasonably available, and the CAMU meets the Subtitle C liner and leachate collection requirements for new land disposal units at § 264.301(c) and (d); or (4) Where cost-effective treatment has been used and the principal hazardous constituents in the treated wastes are of very low mobility; or (5) Where, after review of appropriate treatment technologies, the Regional Administrator determines that cost-effective treatment is not reasonably available, the principal hazardous constituents in the wastes are of very low mobility, and either the CAMU meets or exceeds the liner standards for new, replacement, or laterally expanded CAMUs in paragraphs (e)(3)(i) and (ii) of this section, or the CAMU provides substantially equivalent or greater protection. *Note: Any adjusted treatment level or method, along with appropriate factor(s), will be documented in a FFA CERCLA decision document. Should it be necessary to subsequently adjust any treatment level or method after the initial signed ROD, then any such changes, along with the appropriate factor(s), will be documented in an ESD subject to review and approval under the FFA process.*						
	(vi) The treatment required by the treatment standards must be completed prior to, or within a reasonable time after, placement in the CAMU.		40 *CFR* § 264.552(e)(4)(vi)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Minimum treatment requirements (Continued)	(vii) For the purpose of determining whether wastes placed in CAMUs have met site-specific treatment standards, the Regional Administrator may, as appropriate, specify a subset of the principal hazardous constituents in the waste as analytical surrogates for determining whether treatment standards have been met for other principal hazardous constituents. This specification will be based on the degree of difficulty of treatment and analysis of constituents with similar treatment properties. *Note: Specification of a subset of the principal hazardous constituents in the waste as analytical surrogates will be included in the appropriate FFA CERCLA primary document and subject to review and approval under the FFA process.*		40 *CFR* § 264.552(e)(4)(vii)	✓	✓	✓	✓
Designation, design, operation, and closure of a CAMU used for storage and/or treatment only	CAMUs used for storage and/or treatment only are CAMUs in which wastes will not remain after closure. Such CAMUs must be designated in accordance with all of the requirements of this section, except as follows.	Management of CAMU-eligible wastes within a CAMU used for storage and/or treatment only—**applicable**.	40 *CFR* § 264.552(f)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Designation, design, operation, and closure of a CAMU used for storage and/or treatment only (Continued)	CAMUs that are used for storage and/or treatment only and that operate in accordance with the time limits established in the staging pile regulations at §264.554(d)(1)(iii), (h), and (i) are subject to the requirements for staging piles at §264.554(d)(1)(i) and (ii), §264.554(d)(2), §264.554(e) and (f), and §264.554(j) and (k) in lieu of performance standards and requirements for CAMUs in this section at paragraphs (c) and (e)(3) through (6). *Note: It is recognized that a CAMU for storage and/or treatment may need to be operated past the two-year time limit. Any time period for storage and/or treatment of waste greater than two years will be documented and justified in the appropriate FFA CERCLA primary document subject to review and approval under the FFA process.*	CAMU used for storage and/or treatment only and that operate in accordance with the time limits established in the staging pile regulations at 40 *CFR* § 264.554(d)(1)(iii), (h), and (i)—**applicable**.	40 *CFR* § 264.552(f)(1)	✓	✓	✓	✓
Designation, design, operation, and closure of a CAMU	(g) CAMUs into which wastes are placed where all wastes have constituent levels at or below remedial levels or goals applicable to the site do not have to comply with the requirements for liners at paragraph (e)(3)(i) of this section, caps at paragraph (e)(6)(iv) of this section, ground water monitoring requirements at paragraph (e)(5) of this section or, for treatment and/or storage-only CAMUs, the design standards at paragraph (f) of this section.		40 *CFR* § 264.552(g)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Temporary tanks and container storage areas used to treat or store hazardous remediation wastes	(a) For temporary tanks and container storage areas used to treat or store hazardous remediation wastes during remedial activities required under § 264.101 or RCRA 3008(h), or at a permitted facility that is not subject to § 264.101, the Regional Administrator may designate a unit at the facility, as a temporary unit. A temporary unit must be located within the contiguous property under the control of the owner/operator where the wastes to be managed in the temporary unit originated. For temporary units, the Regional Administrator may replace the design, operating, or closure standards applicable to these units under this part 264 or part 265 of this chapter with alternative requirements which protect human health and the environment. (b) 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. *Note: The designation of temporary units will be documented in a CERCLA decision document (e.g. ROD, ROD amendment, or ESD) subject to review and approval under the FFA process. Alternate design, operating, and/or closure requirements for a temporary unit will be documented in the appropriate FFA CERCLA primary document subject to review and approval under the FFA process.*	Use of temporary tanks and container storage areas to treat or store hazardous remediation wastes during remedial activities—**applicable**.	40 *CFR* § 264.553(a) and (b) 401 *KAR* 34:287	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Temporary tanks and container storage areas used to treat or store hazardous remediation wastes (Continued)	In establishing standards to be applied to a temporary unit, the Regional Administrator shall consider the following factors: (1) Length of time such unit will be in operation; (2) Type of unit; (3) Volumes of wastes to be managed; (4) Physical and chemical characteristics of the wastes to be managed in the unit; (5) Potential for releases from the unit; (6) Hydrogeological and other relevant environmental conditions at the facility which may influence the migration of any potential releases; and (7) Potential for exposure of humans and environmental receptors if releases were to occur from the unit.	Use of temporary tanks and container storage areas to treat or store hazardous remediation wastes during remedial activities—**applicable**.	40 *CFR* § 264.553(c) 401 *KAR* 34:287	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Temporary tanks and container storage areas used to treat or store hazardous remediation wastes (Continued)	(d) The Regional Administrator shall specify in the permit or order the length of time a temporary unit will be allowed to operate, to be no longer than a period of one year. The Regional Administrator shall also specify the design, operating, and closure requirements for the unit. (e) The Regional Administrator may extend the operational period of a temporary unit once for no longer than a period of one year beyond that originally specified in the permit or order, if the Regional Administrator determines that: (1) Continued operation of the unit will not pose a threat to human health and the environment; and (2) Continued operation of the unit is necessary to ensure timely and efficient implementation of remedial actions at the facility. *Note: It is recognized that a treatment unit may need to be operated past the one-year limit. Any time period for operating greater than one year will be documented and justified in the appropriate CERCLA primary document subject to review and approval under the FFA process*.	Use of temporary tanks and container storage areas to treat or store hazardous remediation wastes during remedial activities—**applicable**.	40 *CFR* § 264.553(d) and (e) 401 *KAR* 34:287		✓	✓	

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Temporary tanks and container storage areas used to treat or store hazardous remediation wastes (Continued)	(g) The Regional Administrator shall document the rationale for designating a temporary unit and for granting time extensions for temporary units and shall make such documentation available to the public. *NOTE: The rationale for designating temporary units will be documented in a CERCLA decision document (e.g., ROD, ROD Amendment, or ESD) subject to review and approval under the FFA process. Any time extensions for a temporary unit along with the rationale will be documented in the appropriate FFA CERCLA primary document subject to review and approval under the FFA process.*	Use of temporary tanks and container storage areas to treat or store hazardous remediation wastes during remedial activities—**applicable**.	40 *CFR* § 264.553(g) 401 *KAR* 34:287	✓	✓	✓	✓
	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	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	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Temporary on-site storage of remediation waste in staging piles (e.g., excavated soils/sediments, sludge)	• located within the contiguous property under the control of the owner/operator where the wastes to be managed in the staging pile originated;		40 *CFR* § 264.554(a) 401 *KAR* 34:287 § 5	✓	✓	✓	✓
	• designed to facilitate a reliable, effective, and protective remedy;		40 *CFR* § 264.554(d)(1)(i) 401 *KAR* 34:287 § 5	✓	✓	✓	✓
	• designed to 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, run-off/run-on controls, as appropriate).		40 *CFR* § 264.554(d)(1)(ii) 401 *KAR* 34:287 § 5	✓	✓	✓	✓
	In determining the design, the following factors must be considered: (i) Length of time the pile will be in operation; (ii) Volumes of wastes intended to be stored in the pile; (iii) Physical and chemical characteristics of the wastes to be stored in the unit; (iv) Potential for releases from the unit; (v) Hydrogeological and other relevant environmental conditions at the facility that may influence the migration of any potential releases; and (vi) Potential for human and environmental exposure to potential releases from the unit.		40 *CFR* § 264.554(d)(2) 401 *KAR* 34:287 § 5	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Temporary on-site storage of remediation waste in staging piles (e.g., excavated soils/sediments, sludge) (Continued)	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	✓	✓	✓	✓
	• The remediation waste no longer meets the definition of ignitable or reactive under 40 *CFR* § 261.21 and §261.23; and		40 *CFR* § 264.554(e)(1)(i) 401 *KAR* 34:287 § 5	✓	✓	✓	✓
	• You have complied with 40 *CFR* § 264.17(b), 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 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	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Temporary on-site storage of remediation waste in staging piles (e.g., excavated soils/sediments, sludge) (Continued)	Must separate the incompatible materials or protect them from one another by using a dike, berm, wall, or other device.	Storage of remediation waste in a staging pile that is incompatible with any waste or material stored nearby in containers, other piles, open tanks or land disposal units (for example, surface impoundments)—**applicable**.	40 *CFR* § 264.554(f)(2) 401 *KAR* 34:287 § 5	✓	✓	✓	✓
Disposal of CAMU-eligible wastes in permitted hazardous waste landfills	The Regional Administrator with regulatory oversight at the location where the cleanup is taking place may approve placement of CAMU-eligible wastes in hazardous waste landfills not located at the site from which the waste originated, without the wastes meeting the requirements of RCRA 40 *CFR* Part 268, if the conditions in paragraphs (a)(1) through (3) of this section are met: (1) The waste meets the definition of CAMU-eligible waste in § 264.552(a)(1) and (2). (2) The principal hazardous constitutes in such waste are identified, in accordance with § 264.552(e)(4)(i) and (ii), and such principal hazardous constituents are treated to any of the following standards specified for CAMU-eligible wastes: (i) The treatment standards under § 264.552(e)(4)(iv); or (ii) Treatment standards adjusted in accordance with § 264.552(e)(4)(v)(A), (C), (D) or (E)(1); or (iii) Treatment standards adjusted in accordance with § 264.552(e)(4)(v)(E)(2), where treatment has been used and that	Placement of CAMU-eligible wastes in hazardous waste landfills not located at the site from which the waste originated—**applicable**.	40 *CFR* § 264.555(a)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Disposal of CAMU-eligible wastes in permitted hazardous waste landfills (Continued)	treatment significantly reduces the toxicity or mobility of the principal hazardous constituents in the waste, minimizing the short-term and long-term threat posed by the waste, including the threat at the remediation site. (3) The landfill receiving the CAMU-eligible waste must have a RCRA hazardous waste permit, meet the requirements for new landfills in Subpart N of this part, and be authorized to accept CAMU-eligible wastes; for the purposes of this requirement, "permit" does not include interim status.						
Storage of PCB waste and/or PCB/radioactive waste in a RCRA-regulated container storage area	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 disposal—**applicable**.	40 *CFR* § 761.65(b)(2)		✓	✓	✓
	• 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)		✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Storage of PCB waste and/or PCB/radioactive waste in non-RCRA regulated unit	*Note: For purpose of this exclusion, CERCLA remediation waste, which also is 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.*				✓	✓	✓
	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)		✓	✓	✓
	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% 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)		✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Storage of PCB waste and/or PCB/radioactive waste in non-RCRA regulated unit (Continued)	• 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)		✓	✓	✓
Risk-based management of PCB remediation waste	May sample, cleanup, or dispose of PCB remediation waste in a manner other than prescribed in paragraphs (a) or (b) of this section, or 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.*	Management 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., personal protective equipment (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 Department of Transportation (DOT) Hazardous Material Regulations (HMR) at 49 *CFR* §§ 171–180.		40 *CFR* § 761.65(c)(6)		✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 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)		✓	✓	✓
	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 A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Temporary storage of bulk PCB remediation waste or PCB bulk product waste in a waste pile (Continued)	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*)		✓	✓	✓
	Waste pile must have 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)		✓	✓	✓
	Waste pile must have 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*)		✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Temporary storage of bulk PCB remediation waste or PCB bulk product waste in a waste pile (Continued)	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)	✓	✓	✓	✓
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)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
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 Nuclear Regulatory Commission (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)	✓	✓	✓	✓
	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)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Packaging of LLW for off-site disposal (Continued)	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 offsite 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 offsite disposal of the waste container at a commercial NRC or Agreement State licensed disposal facility—relevant and appropriate.	10 *CFR* § 61.56(b)(3)	✓	✓	✓	✓
Transport or conveyance of collected RCRA wastewater to a wastewater treatment unit located on the facility	Any dedicated tank systems, conveyance systems, and ancillary equipment used to treat, store or convey wastewater to an on-site Kentucky Pollutant Discharge Elimination System (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 A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Release of property with residual radioactive material	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 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.	Generation of DOE materials and equipment with residual radioactive contamination—**TBC**.	DOE O 458.1 § 4.k(3)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
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)	✓	✓	✓	✓
Disposal of a restricted RCRA hazardous waste soil in a land-based unit	Prior to land disposal, all "constituents subject to treatment" as defined in 40 *CFR* § 268.49(d) must be treated as follows.	Land disposal, as defined in 40 *CFR* § 268.2 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) or 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	✓	✓	✓	✓
	When treatment of any constituent subject to treatment to a 90 percent reduction standard would result in a concentration less than 10 times the UTS for that constituent, treatment to achieve constituent concentrations less than 10 times the universal treatment standard is not required. (UTSs are identified in 40 *CFR* § 268.48 Table UTS.)		40 *CFR* § 268.49(c)(1)(C) 401 *KAR* 37:040 § 10	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Disposal of a restricted RCRA hazardous waste soil in a land-based unit (Continued)	In addition to the treatment requirement required by paragraph (c)(1) of 40 *CFR* § 268.49, soils must be treated to eliminate these characteristics.	Land disposal, as defined in 40 *CFR* § 268.2 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 RCRA hazardous waste soil in a land-based unit	Must be treated according to the alternative treatment standards of 40 *CFR* § 268.49(c) or 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 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 Universal Treatment Standards, 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 A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Disposal of RCRA characteristic wastewaters in an National Pollutant Discharge Elimination System (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—a**pplicable**.	40 *CFR* § 268.1(c)(4)(i) 401 *KAR* 37:010 § 2	✓	✓	✓	✓
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 or 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	✓	✓	✓	✓
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	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Disposal of hazardous debris treatment residues	Except as provided in 268.45(d)(2) and (d)(4), must be separated from debris by simple physical or mechanical means, and such residues are subject to the waste-specific treatment standards for the waste contaminating the debris.	Residue from treatment of hazardous debris —**applicable**.	40 *CFR* § 268.45(d)(1) 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)*	✓	✓	✓	✓
	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)*	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
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 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 for off-site disposal—**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 for off-site disposal—**applicable**.	40 *CFR* § 761.61 (a)(5)(ii)(B) (2)		✓	✓	✓
Disposal of PCB-contaminated porous surfaces	Shall be disposed 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)		✓	✓	✓
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)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
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 non-hazardous 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)	✓	✓	✓	✓
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)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Performance-based disposal of PCB remediation waste (Continued)	• 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)	✓	✓	✓	✓
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)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
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 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 publicly owned treatment works—**applicable**.	40 *CFR* § 125.3(c)(2)	✓	✓	✓	✓
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)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Water quality-based effluent limits for wastewater discharge (Continued)	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)	✓	✓	✓	✓
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)	✓	✓	✓	✓
Effluent limits for radionuclides in wastewater	The FFA parties have not reached an agreement on any requirement for effluent limits for radionuclides in wastewater in CERCLA projects at PGDP. Any requirement will be documented here upon agreement by the FFA parties.	Discharge of wastewater with radionuclides.	To Be Determined	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
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)	✓	✓	✓	✓
Discharge of Wastewater from Treatment System through a CERCLA Outfall							
Minimum criteria applicable to all surface waters	Surface waters shall not be aesthetically or otherwise degraded by substances that: • Settle to form objectionable deposits; • Float as debris, scum, oil, or other matter to form a nuisance; • Produce objectionable color, odor, taste, or turbidity; • Injure, are chronically or acutely toxic to or produce adverse physiological or behavioral responses in humans, animals, fish, and other aquatic life; • Produce undesirable aquatic life or result in the dominance of nuisance species; 1. Cause fish flesh tainting. 2. The concentration of phenol shall not exceed 300 mg/L as an instream value.	Discharge of pollutants to surface waters—**applicable**.	401 *KAR* 10:031 § 2(1)(a-f)	✓	✓	✓	✓
	The water quality criteria for the protection of human health related to fish consumption in Table 1 of 401 *KAR* 10:031 § 6 are applicable to all surface water at the edge of assigned mixing zone except for those points where water is withdrawn for domestic water supply use.		401 *KAR* 10:031 § 2(3)(a) and (b)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Minimum criteria applicable to all surface waters (Continued)	(a) The criteria are established to protect human health from the consumption of fish tissue and shall not be exceeded. (b) For those substances associated with a cancer risk, an acceptable risk level of not more than one (1) additional cancer case in a population of 1,000,000 people, (or 1 x 10^{-6}) shall be utilized to establish the allowable concentration.						
Criteria for surface water designated as warm water aquatic life habitat	The following parameters and associated criteria shall apply for the protection of productive warm water aquatic communities, fowl, animal wildlife, arborous growth, agricultural, and industrial uses: • Natural alkalinity as $CaCO_3$ shall not be reduced by more than 25 percent; • pH shall not be less than 6.0 nor more than 9.0 and shall not fluctuate more than 1.0 pH units over a period of 24 hours; • Flow shall not be altered to a degree that will adversely affect the aquatic community; • Temperature shall not exceed 31.7°C (89°F);	Discharge of pollutants to surface waters designated as warm water aquatic life habitat—**applicable**.	401 *KAR* 10:031 § 4(1)(a)-(i) and (k)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Criteria for surface water designated as warm water aquatic life habitat (Continued)	• Dissolved oxygen shall be maintained at a minimum concentration of 5.0 mg/L as a 24 hour average; instantaneous minimum shall not be less than 4.0 mg/L; • Total dissolved solids or specific conductance shall not be changed to the extent that the indigenous aquatic community is adversely affected; • Total suspended solids shall not be changed to the extent that the indigenous aquatic community is adversely affected; • Addition of settleable solids that may alter the stream bottom so as to adversely affect productive aquatic communities shall be prohibited; • Concentration of the un-ionized ammonia shall not be greater than 0.05 mg/L at any time instream after mixing; Instream concentrations for total residual chlorine shall not exceed an acute criteria value of 19 µg/L or a chronic criteria value of 11 µg/L.						
	The allowable instream concentration of toxic substances, or whole effluents containing toxic substances, which are noncumulative or nonpersistent with a half-life of less than 96 hours, shall not exceed: (a) 0.1 of the 96 hour median LC_{50} of representative indigenous or indicator aquatic organisms; or (b) A chronic toxicity unit of 1.00 utilizing the 25 percent inhibition concentration, or LC_{25}.	Discharge of toxic pollutants to surface waters designated as warm water aquatic life habitat—**applicable**.	401 *KAR* 10:031 § 4(1)(j)(1)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Criteria for surface water designated as warm water aquatic life habitat (Continued)	The allowable instream concentration of toxic substances, or whole effluents containing toxic substances, which are bioaccumulative or persistent, including pesticides, if not otherwise regulated, shall not exceed: (a) 0.01 of the 96 hour median LC_{50} of representative indigenous or indicator aquatic organisms; or (b) A chronic toxicity unit of 1.00 utilizing the LC_{25}.		401 *KAR* 10:031 § 4(1)(j)(2)	✓	✓	✓	✓
	In the absence of acute criteria for pollutants listed in Table 1 of 401 *KAR* 10:031 § 6, for other substances known to be toxic but not listed in this regulation, or for whole effluents that are acutely toxic, the allowable instream concentration shall not exceed the LC_1 or 1/3 LC_{50} concentration derived from toxicity tests on representative indigenous or indicator aquatic organisms or exceed 0.3 acute toxicity units.		401 *KAR* 10:031 § 4(1)(j)(3)	✓	✓	✓	✓
	If specific factors have been determined for a toxic substance or whole effluent such as an acute to chronic ratio or water effect ratio, they may be used instead of the 0.1 and 0.01 factors upon demonstration that such factors are scientifically defensible. *NOTE: Demonstration that such factors are scientifically defensible will be reflected in the appropriate CERCLA document.*		401 *KAR* 10:031 § 4(1)(j)(4)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Criteria for surface water designated as warm water aquatic life habitat (Continued)	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), develop effluent limits for whole effluent toxicity.	Discharge of wastewater 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)	✓	✓	✓	✓
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	✓	✓	✓	✓
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% of the PCB container capacity.	Decontaminating a PCB Container as defined in 40 *CFR* § 761.3—**applicable**.	40 *CFR* § 761.79(c)(1)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	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)	✓	✓	✓	✓
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 run-off, 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.	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 A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
Closure of RCRA container storage unit (Continued)	[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.]						
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—**applicable**.	40 *CFR* § 761.65(e)(3)		✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
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 or 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 DOT, United States Postal Service, or any other applicable shipping requirements. • 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.		40 *CFR* § 261.4(d)(2)(i) 401 *KAR* 31:010 § 4 40 *CFR* § 261.4(d)(2)(i)(A) 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	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
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)	✓	✓	✓	✓
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 460.1D and DOE Order 460.2A.	Preparation of shipments of radioactive waste—**TBC**.	DOE M 435.1-(I)(1)(E)(11)	✓	✓	✓	✓

Table A.2. Action-Specific ARARs and TBC Guidance for FS—SWMU 4 (Continued)

Action	Requirement	Prerequisite	Citation	Alt 3	Alt 4	Alt 5	Alt 6
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)	✓	✓	✓	✓
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., Fluor Federal Services, Inc., Paducah Deactivation Project *Transportation Safety Document for On-Site Transport within the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, CP2-WM-0661, March 2015).	Any person who, under contract with the DOE, transports a hazardous material on the DOE facility—**TBC**.	DOE O 460.1D	✓	✓	✓	✓
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 460.1D	✓	✓	✓	✓

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APPENDIX B

COST ESTIMATES

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ALTERNATIVE 3—RECHARGE CONTROL AND HYDRAULIC CONTROL

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COST ESTIMATE
BGOU SWMU 4
Alternative 3—Recharge Control and Hydraulic Control

Cost Estimate Summary					
Capital Cost	**Quantity**	**Units**	**Unit Price**	**Total**	
1.0 CERCLA Documents	1	ls	$689,000	$689,000	
2.0 Other Plans/Support	1	ls	$2,243,000	$2,243,000	
3.0 Monitoring Wells	1	ls	$701,000	$701,000	
4.0 Recharge Control (Cover & Slurry Wall)	1	ls	$13,760,000	$13,760,000	
5.0 Hydraulic Control	1	ls	$4,923,000	$4,923,000	
6.0 Land Use Controls	1	ls	$28,000	$28,000	
Subproject Management	1	ls	$2,234,400	$2,234,000	Subproject Management = 10%
Management Reserve	1	ls	$3,686,700	$3,687,000	Contractor MR=15%
Fee	1	ls	$1,695,900	$1,696,000	Fee = 6%
Contingency	1	ls	$5,992,200	$5,992,000	Contingency = 20%
			SUBTOTAL CAPITAL COST	**$35,953,000**	
Annual Cost					
Inspections	1000	EA	$23,000	$23,000,000	Quarterly for 1,000 years
Mowing	1000	EA	$9,000	$9,000,000	7 Times per year for 1,000 years
Fence Replacement	10	EA	$381,000	$3,810,000	Every 100 years for 1,000 years
Sign Replacement	33	EA	$3,000	$100,000	Every 30 years for 1,000 years
Well Sampling	1000	EA	$28,000	$28,000,000	Annually for 1,000 years
Monitoring Well Rehab	40	EA	$135,000	$5,400,000	Every 25 years for 1,000 years
Monitoring Well Replacement	20	EA	$701,000	$14,020,000	Every 50 years for 1,000 years
Extraction Well Rehab	40	EA	$389,000	$15,560,000	Every 25 years for 1,000 years
Extraction Well Replacement	20	EA	$830,000	$16,600,000	Every 50 years for 1,000 years
Treatment System Replacement	10	EA	$4,109,000	$41,090,000	Every 100 years for 1,000 years
Engineered Cover Replacement	5	EA	$5,703,000	$28,515,000	Every 200 years for 1,000 years
Treatment System O&M	1000	EA	$699,000	$699,000,000	Annually for 1,000 years
Five Year Review	200	EA	$50,000	$10,000,000	Every 5 years for 1,000 years
Capital Projects Reporting/Reviews	3	EA	$414,000	$1,242,000	Annually for 3 years
			SUBTOTAL ANNUAL COST	**$895,337,000**	
			TOTAL	**$931,290,000**	

COST ESTIMATE
BGOU SWMU 4
Alternative 3—Recharge Control and Hydraulic Control

Present Worth Value									
	Quantity	Unit	Unit Cost	Total				Present Worth	
Total Capital Cost	1	ls	$35,953,000	$35,953,000				**$35,953,000**	
Inspections	1000	EA	$23,000	$23,000,000				**$1,533,333**	1.5% discount rate
Mowing	1000	EA	$9,000	$9,000,000				**$600,000**	1.5% discount rate
Fence Replacement	10	EA	$381,000	$3,810,000				**$111,012**	1.5% discount rate
Sign Replacement	33	EA	$3,000	$100,000				**$5,328**	1.5% discount rate
Well Sampling	1000	EA	$28,000	$28,000,000				**$1,866,666**	1.5% discount rate
Monitoring Well Rehab	40	EA	$135,000	$5,400,000				**$299,371**	1.5% discount rate
Monitoring Well Replacement	20	EA	$701,000	$14,020,000				**$634,250**	1.5% discount rate
Extraction Well Rehab	40	EA	$389,000	$15,560,000				**$862,632**	1.5% discount rate
Extraction Well Replacement	20	EA	$830,000	$16,600,000				**$750,966**	1.5% discount rate
Treatment System Replacement	10	EA	$4,109,000	$41,090,000				**$1,197,245**	1.5% discount rate
Engineered Cover Replacement	5	EA	$5,703,000	$28,515,000				**$305,905**	1.5% discount rate
Treatment System O&M	1000	EA	$699,000	$699,000,000				**$46,599,984**	1.5% discount rate
Five Year Review	200	EA	$50,000	$10,000,000				**$646,964**	1.5% discount rate
Capital Projects Reporting/Reviews	3	EA	$414,000	$1,242,000				**$1,205,651**	1.5% discount rate
							Capital Costs	**$35,953,000**	
						Present Worth Values	**Annual**	**$56,619,000**	
							Avg. Annual	**$56,619**	
							Total	**$92,572,000**	
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.									

CAPITAL COSTS									
	Material/Equipment/Subcontractors/ODCs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
1.0 CERCLA Documents									
Refer to the Success reports for detailed cost and resources.									
RDWP					1784		$133,448		
Remedial Design Report					3524		$266,528		
RAWP					2964		$224,648		
RACR					874		$64,008		
TASK TOTAL				**$0**	**9146**		**$688,632**	**$689,000**	
2.0 Other Plans/Support									
Refer to the Success reports for detailed cost and resources.									
Health/Safety Plan					628		$42,000		
SAP/QAPP					478		$34,700		
Security Plan					288		$27,320		
O&M Plan					390		$27,240		
Civil Surveying					260		$20,520		
Work Packages/Readiness					616		$46,788		
Procurement					380		$23,140		
Training	1	LS	$60,000	$60,000	760		$60,120		
Critical Decision Documents	1	LS	$1,388,250	$1,388,250	5180		$513,380		Capital Projects SMEs
TASK TOTAL				**$1,448,250**	**8980**		**$795,208**	**$2,243,000**	

COST ESTIMATE
BGOU SWMU 4
Alternative 3—Recharge Control and Hydraulic Control

3.0 Monitoring Wells									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Installation									
Contractor Labor					2720		$183,560		
Subcontractors	1	LS	$466,180	$466,180					Local quote from existing drilling sub
Materials	1	LS	$40,842	$40,842					
Vehicles and Equipment	1	LS	$3,731	$3,731					
Sampling/Analytical									
Contractor Labor					48		$2,376		
Subcontractors	1	LS	$4,360	$4,360					Local subcontractor sampling
TASK TOTAL				**$ 515,113**	**2768**		**$ 185,936**	**$701,000**	
4.0 Recharge Control (Cover & Slurry Wall)									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Surveying, Marking, Testing									
Contractor Labor					160		$11,760		
Subcontractors	1	LS	$183,600	$183,600					Local Engineering Firm
Materials	1	LS	$2,528	$2,528					
Vehicles and Equipment	1	LS	$5,728	$5,728					
Fence Removal									
Contractor Labor					1020		$71,020		
Subcontractors	1	LS	$22,617	$22,617					
Materials	1	LS	$1,192	$1,192					
Sampling/Analytical	1	LS	$6,540	$6,540					Local subcontractor sampling
Vehicles and Equipment	1	LS	$4,286	$4,286					
Cover Construction									
Contractor Labor					12640		$854,640		
Subcontractors	1	LS	$4,626,194	$4,626,194					
Materials	1	LS	$5,632	$5,632					
Vehicles and Equipment	1	LS	$12,592	$12,592					
Slurry Wall									
Contractor Labor					6078		$436,107		
Subcontractors	1	LS	$5,212,712	$5,212,712					
Materials	1	LS	$3,758	$3,758					
Sampling/Analytical	1	LS	$156,000	$156,000					Local subcontractor sampling
Vehicles and Equipment	1	LS	$64,296	$64,296					
Road Relocation									
Contractor Labor					2170		$151,690		
Subcontractors	1	LS	$1,642,465	$1,642,465					
Materials	1	LS	$832	$832					
Vehicles and Equipment	1	LS	$8,073	$8,073					
Install Fence Replacement									
Contractor Labor					1265		$79,712		
Subcontractors	1	LS	$193,630	$193,630					
Materials	1	LS	$1,183	$1,183					
Vehicles and Equipment	1	LS	$859	$859					
TASK TOTALS				**$12,154,717**	**23,333**		**$1,604,929**	**$13,760,000**	

COST ESTIMATE
BGOU SWMU 4
Alternative 3—Recharge Control and Hydraulic Control

5.0 Hydraulic Control									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Extraction Wells									
Contractor Labor					3469		$242,960		
Subcontractors	1	LS	$536,181	$536,181					Local quote from existing drilling sub
Materials	1	LS	$170,020	$170,020					
Sampling/Analytical	1	LS	$17,023	$17,023					Local subcontractor sampling
Vehicles and Equipment	1	LS	$12,294	$12,294					
Performance Monitoring Wells									
Contractor Labor					1260		$86,920		
Subcontractors	1	LS	$291,070	$291,070					Local quote from existing drilling sub
Materials	1	LS	$23,493	$23,493					
Sampling/Analytical	1	LS	$10,460	$10,460					Local subcontractor sampling
Vehicles and Equipment	1	LS	$1,866	$1,866					
Treatment System									
Contractor Labor					3109		$270,880		
Subcontractors	1	LS	$1,899,271	$1,899,271					RSMeans and local subcontractor
Materials	1	LS	$1,353,709	$1,353,709					
Vehicles and Equipment	1	LS	$7,155	$7,155					
TASK TOTALS				**$4,322,542**	**7,838**		**$600,760**	**$4,923,000**	
6.0 Land Use Controls									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Revise Procedures/Deed Restriction									
Contractor Labor					368		$25,248		
Install Signs									
Contractor Labor					40		$2,820		
TASK TOTAL				**$ -**	**408**		**$28,068**	**$28,000**	
							SUBTOTAL CAPITAL COST	**$22,344,000**	
ANNUAL COSTS									
Inspections									
Duration: Occurs quarterly for 1,000 years.									
Contractor Labor					240		$23,280		
Vehicles and Equipment	1	LS	$143	$143					
TASK TOTAL				**$143**	**240**		**$23,280**	**$23,000**	ANNUAL COST
Mowing									
Duration: 7 times per year per 1,000 years.									
Contractor Labor					70		$2,800		
Subcontractors	1	LS	$6,300	$6,300					
TASK TOTAL				**$6,300**	70		**$2,800**	**$9,000**	ANNUAL COST
Fence Replacement									
Duration: Every 100 years for 1,000 years.									
Contractor Labor					2285		$150,732		
Subcontractors	1	LS	$216,246	$216,246					
Materials	1	LS	$2,375	$2,375					
Sampling/Analytical	1	LS	$6,540	$6,540					Local subcontractor sampling
Vehicles and Equipment	1	LS	$5,146	$5,146					
TASK TOTAL				**$230,307**	2285		**$150,732**	**$381,000**	EVERY 100 YEARS
Sign Replacement									
Duration: Every 30 years for 1,000 years.									
Contractor Labor					30		$2,320		
Materials	1	LS	$500	$500					
TASK TOTAL				**$500**	30		**$2,320**	**$3,000**	EVERY 30 YEARS

COST ESTIMATE
BGOU SWMU 4
Alternative 3—Recharge Control and Hydraulic Control

Well Sampling									
Duration: Annually for 1,000 years									
Contractor Labor					318		$21,096		
Sampling/Analytical	1	LS	$6,240	$6,240					Local subcontractor sampling
Vehicles and Equipment	1	LS	$215	$215					
TASK TOTAL				**$6,455**	318		**$21,096**	**$28,000**	ANNUAL COST
Monitoring Well Rehab									
Duration: Every 25 years for 1,000 years.									
Contractor Labor					790		$52,370		
Subcontractors	1	LS	$75,840	$75,840					Local quote from existing drilling sub
Materials	1	LS	$3,164	$3,164					
Sampling/Analytical	1	LS	$2,080	$2,080					Local subcontractor sampling
Vehicles and Equipment	1	LS	$1,866	$1,866					
TASK TOTAL				**$82,950**	790		**$52,370**	**$135,000**	EVERY 25 YEARS
Monitoring Well Replacement									
Duration: Every 50 years for 1,000 years.									
Installation									
Contractor Labor					2720		$183,560		
Subcontractors	1	LS	$466,180	$466,180					Local quote from existing drilling sub
Materials	1	LS	$40,842	$40,842					
Vehicles and Equipment	1	LS	$3,731	$3,731					
Sampling/Analytical									
Contractor Labor					48		$2,376		
Subcontractors	1	LS	$4,360	$4,360					Local subcontractor sampling
TASK TOTAL				**$515,113**	2768		**$185,936**	**$701,000**	EVERY 50 YEARS
Extraction Well Rehab									
Duration: Every 25 years for 1,000 years.									
Contractor Labor					1100		$76,480		
Subcontractors	1	LS	$266,146	$266,146					Local quote from existing drilling sub
Materials	1	LS	$26,417	$26,417					
Sampling/Analytical	1	LS	$17,023	$17,023					Local subcontractor sampling
Vehicles and Equipment	1	LS	$3,432	$3,432					
TASK TOTAL				**$313,018**	1100		**$76,480**	**$389,000**	EVERY 25 YEARS
Extraction Well Replacement									
Duration: Every 50 years for 1,000 years.									
Contractor Labor					3060		$213,220		
Subcontractors	1	LS	$414,998	$414,998					Local quote from existing drilling sub
Materials	1	LS	$173,389	$173,389					
Sampling/Analytical	1	LS	$17,023	$17,023					Local subcontractor sampling
Vehicles and Equipment	1	LS	$11,864	$11,864					
TASK TOTAL				**$617,274**	3060		**$213,220**	**$830,000**	EVERY 50 YEARS
Treatment System Replacement									
Duration: Every 100 years.									
Contractor Labor					3961		$334,520		
Subcontractors	1	LS	$2,399,271	$2,399,271					RSMeans and local subcontractor
Materials	1	LS	$1,353,709	$1,353,709					
Vehicles and Equipment	1	LS	$21,155	$21,155					
TASK TOTALS				**$3,774,135**	**3,961**		**$334,520**	**$4,109,000**	EVERY 100 YEARS

COST ESTIMATE
BGOU SWMU 4
Alternative 3—Recharge Control and Hydraulic Control

Engineered Cover Replacement									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Duration: Every 200 years.									
Surveying, Marking, Testing									
Contractor Labor					160		$11,760		
Subcontractors	1	LS	$183,600	$183,600					Local Engineering Firm
Materials	1	LS	$2,528	$2,528					
Vehicles and Equipment	1	LS	$5,728	$5,728					
Cover Construction									
Contractor Labor					12640		$854,640		
Subcontractors	1	LS	$4,626,194	$4,626,194					
Materials	1	LS	$5,632	$5,632					
Vehicles and Equipment	1	LS	$12,592	$12,592					
TASK TOTALS				**$4,836,274**	**12,800**		**$866,400**	**$5,703,000**	EVERY 200 YEARS
Five Year Review									
Duration: Every 5 years.									
Contractor Labor					720		$49,720		
TASK TOTAL					**720**		**49720**	**$50,000**	EVERY 5 YEARS
Treatment System O&M									
Duration: Occurs annually for 1,000 years.									
Contractor Labor					8644		$685,672		
Sampling/Analytical	1	LS	$6,267	$6,267					Local subcontractor sampling
Vehicles and Equipment	1	LS	$6,874	$6,874					
TASK TOTAL				**$13,141**	**8644**		**$685,672**	**$699,000**	ANNUAL COST
Capital Projects Reporting/Reviews									
Duration: Every year for 3 years.									
Contractor Labor					2000		$193,600		
Subcontractors	1	LS	$220,500	$220,500					Capital Projects SMEs
TASK TOTAL				**$220,500**	2000		**$193,600**	**$414,000**	ANNUAL COST

ALTERNATIVE 4—TARGETED EXCAVATION, ERH, AND BIOREMEDIATION

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COST ESTIMATE
BGOU SWMU 4
Alternative 4—Targeted Excavation, ERH, and Bioremediation

Cost Estimate Summary

Capital Cost	Quantity	Units	Unit Price	Total	
1.0 CERCLA Documents	1	ls	$1,084,000	$1,084,000	
2.0 Other Project Plans	1	ls	$2,441,000	$2,441,000	
3.0 Monitoring Wells	1	ls	$701,000	$701,000	
4.0 Shoring	1	ls	$2,022,000	$2,022,000	
5.0 Excavation	1	ls	$6,067,000	$6,067,000	
6.0 Water Treatment	1	ls	$4,353,000	$4,353,000	
7.0 Waste Handling, Disposal, and Transportation	1	ls	$90,246,000	$90,246,000	
8.0 Excavation Backfill	1	ls	$5,154,000	$5,154,000	
9.0 ERH	1	ls	$8,612,000	$8,612,000	
10.0 Bioremediation	1	ls	$7,613,000	$7,613,000	
11.0 Recharge Control (Cover & Slurry Wall)	1	ls	$13,034,000	$13,034,000	
12.0 Land Use Controls	1	ls	$28,000	$28,000	
Subproject Management	1	ls	$14,135,500	$14,136,000	Subproject Management = 10%
Management Reserve	1	ls	$23,323,650	$23,324,000	Contractor MR=15%
Fee	1	ls	$10,728,900	$10,729,000	Fee = 6%.
Contingency	1	ls	$37,908,800	$37,909,000	Contingency = 20%
		SUBTOTAL CAPITAL		**$227,453,000**	
Annual Cost					
Inspections	1000	EA	$23,000	$23,000,000	Quarterly for 1,000 years
Mowing	1000	EA	$9,000	$9,000,000	7 Times per year for 1,000 years
Fence Replacement	10	EA	$381,000	$3,810,000	Every 100 years for 1,000 years
Sign Replacement	33	EA	$3,000	$100,000	Every 30 years for 1,000 years
Well Sampling	1000	EA	$28,000	$28,000,000	Annually for 1,000 years
Monitoring Well Rehab	40	EA	$135,000	$5,400,000	Every 25 years for 1,000 years
Replacement	20	EA	$701,000	$14,020,000	Every 50 years for 1,000 years
Engineered Cover Replacement	5	EA	$4,272,000	$21,360,000	Every 200 years for 1,000 years
Five Year Review	200	EA	$50,000	$10,000,000	Every 5 years for 1,000 years
Capital Projects Reporting/Reviews	8	EA	$414,000	$3,312,000	Annually for 8 years
		SUBTOTAL ANNUAL		**$118,002,000**	
			TOTAL	**$345,455,000**	

COST ESTIMATE
BGOU SWMU 4
Alternative 4—Targeted Excavation, ERH, and Bioremediation

Present Worth Value									
	Quantity	**Unit**	**Unit Cost**	**Total**				**Present Worth**	
Total Capital Cost	1	ls	$227,453,000	$227,453,000				**$227,453,000**	
Inspections	1000	EA	$23,000	$23,000,000				**$1,533,333**	1.5% discount rate
Mowing	1000	ls	$9,000	$9,000,000				**$600,000**	1.5% discount rate
Fence Replacement	10	ls	$381,000	$3,810,000				**$111,012**	1.5% discount rate
Sign Replacement	33	ls	$3,000	$100,000				**$5,328**	1.5% discount rate
Well Sampling	1000	ls	$28,000	$28,000,000				**$1,866,666**	1.5% discount rate
Monitoring Well Rehab	40	ls	$135,000	$5,400,000				**$299,371**	1.5% discount rate
Monitoring Well Replacement	20	ls	$701,000	$14,020,000				**$634,250**	1.5% discount rate
Engineered Cover Replacement	5	ls	$4,272,000	$21,360,000				**$218,084**	1.5% discount rate
Five Year Review	200	ls	$50,000	$10,000,000				**$646,964**	1.5% discount rate
Capital Projects Reporting/Reviews	8	ls	$414,000	$3,312,000				**$3,099,173**	1.5% discount rate
							Capital Costs	**$227,453,000**	
						Present	**Annual**	**$9,014,000**	
						Worth	**Avg. Annual**	**$9,014**	
						Values	**Total**	**$236,467,000**	
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.									
CAPITAL COSTS									
	Material/Equipment/Subcontractors/ODCs				**Labor**				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
1.0 CERCLA Documents									
Refer to the Success reports for detailed cost and resources.									
RDWP					2644		$203,608		
Remedial Design Report					5424		$422,328		
RAWP					4564		$342,048		
RACR					1584		$116,348		
TASK TOTAL				**$0**	**14216**		**$1,084,332**	**$1,084,000**	

COST ESTIMATE
BGOU SWMU 4
Alternative 4—Targeted Excavation, ERH, and Bioremediation

2.0 Other Project Plans									
Refer to the Success reports for detailed cost and resources.									
Health/Safety Plan					628		$42,240		
SAP/QAPP					628		$45,840		
Security Plan					348		$33,400		
O&M Plan					624		$42,788		
Civil Surveying					260		$20,520		
Work Packages/Readiness					1144		$85,748		
Procurement					640		$39,440		
Training	1	LS	$120,000	$120,000	1360		$109,520		
Critical Decision Documents	1	LS	$1,388,250	$1,388,250	5180		$513,380		Capital Projects SMEs
TASK TOTAL				**$1,508,250**	**10812**		**$932,876**	**$2,441,000**	
3.0 Monitoring Wells									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Installation									
Contractor Labor					2720		$183,560		
Subcontractors	1	LS	$466,180	$466,180					Local quote from existing drilling sub
Materials	1	LS	$40,842	$40,842					
Vehicles and Equipment	1	LS	$3,731	$3,731					
Sampling/Analytical									
Contractor Labor					48		$2,376		
Subcontractors	1	LS	$4,360	$4,360					Local subcontractor sampling
TASK TOTAL				**$ 515,113**	**2768**		**$ 185,936**	**$701,000**	
4.0 Shoring									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Sheet Piling									
Contractor Labor					2250		$161,500		
Subcontractors	1	LS	$1,854,589	$1,854,589					
Materials	1	LS	$3,102	$3,102					
Vehicles and Equipment	1	LS	$2,685	$2,685					
TASK TOTAL				**$ 1,860,376**	**2250**		**$ 161,500**	**$2,022,000**	
5.0 Excavation									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Excavation									
Contractor Labor					40750		$3,104,000		
Subcontractors	1	LS	$2,832,337	$2,832,337					
Materials	1	LS	$91,300	$91,300					
Vehicles and Equipment	1	LS	$39,380	$39,380					
TASK TOTALS				**$2,963,017**	**40,750**		**$3,104,000**	**$6,067,000**	

COST ESTIMATE
BGOU SWMU 4
Alternative 4—Targeted Excavation, ERH, and Bioremediation

6.0 Water Treatment									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Treatment Facility Construction									
Contractor Labor					1894		$147,870		
Subcontractors	1	LS	$477,465	$477,465					
Materials	1	LS	$1,495,061	$1,495,061					
Vehicles and Equipment	1	LS	$2,359	$2,359					
Treatment Operations									
Contractor Labor					27500		$2,189,000		
Materials	1	LS	$22,000	$22,000					
Vehicles and Equipment	1	LS	$19,690	$19,690					
TASK TOTALS				**$2,016,575**	**29,394**		**$2,336,870**	**$4,353,000**	
7.0 Waste Handling, Disposal, and Transportation									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Contractor Labor					260999		$19,669,100		
Subcontractors	1	LS	$420,679	$420,679					
Containers	1	LS	$5,434,925	$5,434,925					
Materials	1	LS	$2,840,278	$2,840,278					
Characterization Sampling	1	LS	$3,584,446	$3,584,446					
Disposal	1	LS	$44,492,883	$44,492,883					
Transportation	1	LS	$12,776,669	$12,776,669					
Vehicles and Equipment	1	LS	$1,027,152	$1,027,152					
TASK TOTALS				**$70,577,032**	**260,999**		**$19,669,100**	**$90,246,000**	
8.0 Excavation Backfill									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Contractor Labor					6985		$515,620		
Subcontractors	1	LS	$988,465	$988,465					RSMeans and local Engineering firm
Materials	1	LS	$3,643,080	$3,643,080					
Vehicles and Equipment	1	LS	$6,874	$6,874					
TASK TOTAL				**$ 4,638,419**	**6985**		**$515,620**	**$5,154,000**	
9.0 ERH									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Electrical Resistance Heating									
Labor/Materials/Equipment							$8,611,672		Source: C-400 ERH
TASK TOTALS				**$0**	**0**		**$8,611,672**	**$8,612,000**	

COST ESTIMATE
BGOU SWMU 4
Alternative 4—Targeted Excavation, ERH, and Bioremediation

10.0 Bioremediation									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Horizontal Wells									
Contractor Labor					7456		$523,112		
Subcontractors	1	LS	$2,028,065	$2,028,065					Local quote from existing drilling sub
Materials	1	LS	$75,318	$75,318					
Sampling/Analytical	1	LS	$20,800	$20,800					Local subcontractor sampling
Vehicles and Equipment	1	LS	$23,357	$23,357					
Tanks and Piping									
Contractor Labor					1632		$115,980		
Subcontractors	1	LS	$869,076	$869,076					
Materials	1	LS	$194,167	$194,167					
Vehicles and Equipment	1	LS	$1,859	$1,859					
Treatment									
Contractor Labor					5640		$448,440		
Materials	1	LS	$2,304,750	$2,304,750					
Vehicles and Equipment	1	LS	$10,310	$10,310					
Performance Monitoring Wells				$0					
Contractor Labor					2552		$159,344		
Subcontractors	1	LS	$344,861	$344,861					Local quote from existing drilling sub
Materials	1	LS	$40,842	$40,842					
Sampling/Analytical	1	LS	$449,280	$449,280					Local subcontractor sampling
Vehicles and Equipment	1	LS	$3,731	$3,731					
TASK TOTAL				**$6,366,416**	**17280**		**$1,246,876**	**$7,613,000**	

COST ESTIMATE
BGOU SWMU 4
Alternative 4—Targeted Excavation, ERH, and Bioremediation

11.0 Recharge Control (Cover & Slurry Wall)									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Surveying, Marking, Testing									
Contractor Labor					160		$11,760		
Subcontractors	1	LS	$171,400	$171,400					Local Engineering Firm
Materials	1	LS	$2,528	$2,528					
Vehicles and Equipment	1	LS	$5,728	$5,728					
Fence Removal									
Contractor Labor					1020		$71,020		
Subcontractors	1	LS	$22,617	$22,617					
Materials	1	LS	$1,192	$1,192					
Sampling/Analytical	1	LS	$6,540	$6,540					Local subcontractor sampling
Vehicles and Equipment	1	LS	$4,286	$4,286					
Cover Construction									
Contractor Labor					10070		$682,097		
Subcontractors	1	LS	$3,379,837	$3,379,837					
Materials	1	LS	$7,417	$7,417					
Vehicles and Equipment	1	LS	$10,874	$10,874					
Slurry Wall									
Contractor Labor					7190		$515,810		
Subcontractors	1	LS	$5,818,842	$5,818,842					
Materials	1	LS	$4,512	$4,512					
Sampling/Analytical	1	LS	$166,400	$166,400					Local subcontractor sampling
Vehicles and Equipment	1	LS	$72,655	$72,655					
Road Relocation									
Contractor Labor					2170		$151,690		
Subcontractors	1	LS	$1,642,465	$1,642,465					
Materials	1	LS	$832	$832					
Vehicles and Equipment	1	LS	$8,073	$8,073					
Install Fence Replacement									
Contractor Labor					1265		$79,712		
Subcontractors	1	LS	$193,630	$193,630					
Materials	1	LS	$1,183	$1,183					
Vehicles and Equipment	1	LS	$859	$859					
TASK TOTALS				**$11,521,870**	**21,875**		**$1,512,089**	**$13,034,000**	

COST ESTIMATE
BGOU SWMU 4
Alternative 4—Targeted Excavation, ERH, and Bioremediation

12.0 Land Use Controls									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Revise Procedures/Deed Restriction									
Contractor Labor					368		$25,248		
Install Signs									
Contractor Labor					40		$2,820		
TASK TOTAL				**$0**	**408**		**$28,068**	**$28,000**	
							SUBTOTAL CAPITAL	**$141,355,000**	
ANNUAL COSTS									
Inspections									
Duration: Occurs quarterly for 1,000 years.									
Contractor Labor					240		$23,280		
Vehicles and Equipment	1	LS	$143	$143					
TASK TOTAL				**$143**	**240**		**$23,280**	**$23,000**	ANNUAL COST
Mowing									
Duration: 7 times per year per 1,000 years.									
Contractor Labor					70		$2,800		
Subcontractors	1	LS	$6,300	$6,300					
TASK TOTAL				**$6,300**	70		**$2,800**	**$9,000**	ANNUAL COST
Fence Replacement									
Duration: Every 100 years for 1,000 years.									
Contractor Labor					2285		$150,732		
Subcontractors	1	LS	$216,246	$216,246					
Materials	1	LS	$2,375	$2,375					
Sampling/Analytical	1	LS	$6,540	$6,540					Local subcontractor sampling
Vehicles and Equipment	1	LS	$5,146	$5,146					
TASK TOTAL				**$230,307**	2285		**$150,732**	**$381,000**	EVERY 100 YEARS
Sign Replacement									
Duration: Every 30 years for 1,000 years.									
Contractor Labor					30		$2,320		
Materials	1	LS	$500	$500					
TASK TOTAL				**$500**	30		**$2,320**	**$3,000**	EVERY 30 YEARS
Well Sampling									
Duration: Annually for 1,000 years									
Contractor Labor					318		$21,096		
Sampling/Analytical	1	LS	$6,240	$6,240					Local subcontractor sampling
Vehicles and Equipment	1	LS	$215	$215					
TASK TOTAL				**$6,455**	318		**$21,096**	**$28,000**	ANNUAL COST

COST ESTIMATE
BGOU SWMU 4
Alternative 4—Targeted Excavation, ERH, and Bioremediation

Monitoring Well Rehab									
Duration: Every 25 years for 1,000 years.									
Contractor Labor					790		$52,370		
Subcontractors	1	LS	$75,840	$75,840					Local quote from existing drilling sub
Materials	1	LS	$3,164	$3,164					
Sampling/Analytical	1	LS	$2,080	$2,080					Local subcontractor sampling
Vehicles and Equipment	1	LS	$1,866	$1,866					
TASK TOTAL				**$82,950**	790		**$52,370**	**$135,000**	EVERY 25 YEARS
Monitoring Well Replacement									
Duration: Every 50 years for 1,000 years.									
Installation									
Contractor Labor					2720		$183,560		
Subcontractors	1	LS	$466,180	$466,180					Local quote from existing drilling sub
Materials	1	LS	$40,842	$40,842					
Vehicles and Equipment	1	LS	$3,731	$3,731					
Sampling/Analytical									
Contractor Labor					48		$2,376		
Subcontractors	1	LS	$4,360	$4,360					Local subcontractor sampling
TASK TOTAL				**$515,113**	2768		**$185,936**	**$701,000**	EVERY 50 YEARS
Engineered Cover Replacement									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated and therefore includes labor, material, and equipment where applicable.									
Surveying, Marking, Testing									
Contractor Labor					160		$11,760		
Subcontractors	1	LS	$171,400	$171,400					Local Engineering Firm
Materials	1	LS	$2,528	$2,528					
Vehicles and Equipment	1	LS	$5,728	$5,728					
Cover Construction									
Contractor Labor					10070		$682,097		
Subcontractors	1	LS	$3,379,837	$3,379,837					
Materials	1	LS	$7,417	$7,417					
Vehicles and Equipment	1	LS	$10,874	$10,874					
TASK TOTAL				**$3,577,784**	10230		**$693,857**	**$4,272,000**	EVERY 200 YEARS
Five Year Review									
Duration: Every 5 years.									
Contractor Labor					720		$49,720		
TASK TOTAL					720		$49,720	**$50,000**	EVERY 5 YEARS
Capital Projects Reporting/Reviews									
Duration: Every year for 8 years.									
Contractor Labor					2000		$193,600		
Subcontractors	1	LS	$220,500	$220,500					Capital Projects SMEs
TASK TOTAL				**$220,500**	2000		**$193,600**	**$414,000**	ANNUAL COST

ALTERNATIVE 4A—TARGETED EXCAVATION, ERH, AND BIOREMEDIATION WITH WDA

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COST ESTIMATE
BGOU SWMU 4
Alternative 4a—Targeted Excavation, ERH, and Bioremediation w/WDA

Cost Estimate Summary					
Capital Cost	**Quantity**	**Units**	**Unit Price**	**Total**	
1.0 CERCLA Documents	1	ls	$1,084,000	$1,084,000	
2.0 Other Project Plans	1	ls	$2,441,000	$2,441,000	
3.0 Monitoring Wells	1	ls	$701,000	$701,000	
4.0 Shoring	1	ls	$2,022,000	$2,022,000	
5.0 Excavation	1	ls	$6,067,000	$6,067,000	
6.0 Water Treatment	1	ls	$4,353,000	$4,353,000	
7.0 Waste Handling, Disposal, and Transportation	1	ls	$49,846,000	$49,846,000	
8.0 Excavation Backfill	1	ls	$5,154,000	$5,154,000	
9.0 ERH	1	ls	$8,612,000	$8,612,000	
10.0 Bioremediation	1	ls	$7,613,000	$7,613,000	
11.0 Recharge Control (Cover & Slurry Wall)	1	ls	$13,034,000	$13,034,000	
12.0 Land Use Controls	1	ls	$28,000	$28,000	
Subproject Management	1	ls	$10,095,500	$10,096,000	Subproject Management = 10%
Management Reserve	1	ls	$16,657,650	$16,658,000	Contractor MR=15%
Fee	1	ls	$7,662,540	$7,663,000	Fee = 6%.
Contingency	1	ls	$27,074,400	$27,074,000	Contingency = 20%
	SUBTOTAL CAPITAL COST			**$162,446,000**	
Annual Cost					
Inspections	1000	EA	$23,000	$23,000,000	Quarterly for 1,000 years
Mowing	1000	EA	$9,000	$9,000,000	7 Times per year for 1,000 years.
Fence Replacement	10	EA	$381,000	$3,810,000	Every 100 years for 1,000 years
Sign Replacement	33	EA	$3,000	$100,000	Every 30 years for 1,000 years
Well Sampling	1000	EA	$28,000	$28,000,000	Annually for 1,000 years
Monitoring Well Rehab	40	EA	$135,000	$5,400,000	Every 25 years for 1,000 years
Monitoring Well Replacement	20	EA	$701,000	$14,020,000	Every 50 years for 1,000 years
Replacement	5	EA	$4,272,000	$21,360,000	Every 200 years for 1,000 years
Five Year Review	200	EA	$50,000	$10,000,000	Every 5 years for 1,000 years
Capital Projects Reporting/Reviews	8	EA	$414,000	$3,312,000	Annually for 8 years
	SUBTOTAL ANNUAL COST			**$118,002,000**	
			TOTAL	**$280,448,000**	
Present Worth Value					

COST ESTIMATE
BGOU SWMU 4
Alternative 4a—Targeted Excavation, ERH, and Bioremediation w/WDA

	Quantity	Unit	Unit Cost	Total				Present Worth	
Total Capital Cost	1	ls	$162,446,000	$162,446,000				**$162,446,000**	
Inspections	1000	EA	$23,000	$23,000,000				**$1,533,333**	1.5% discount rate
Mowing	1000	ls	$9,000	$9,000,000				**$600,000**	1.5% discount rate
Fence Replacement	10	ls	$381,000	$3,810,000				**$111,012**	1.5% discount rate
Sign Replacement	33	ls	$3,000	$100,000				**$5,328**	1.5% discount rate
Well Sampling	1000	ls	$28,000	$28,000,000				**$1,866,666**	1.5% discount rate
Monitoring Well Rehab	40	ls	$135,000	$5,400,000				**$299,371**	1.5% discount rate
Monitoring Well Replacement	20	ls	$701,000	$14,020,000				**$634,250**	1.5% discount rate
Engineered Cover Replacement	5	ls	$4,272,000	$21,360,000				**$218,084**	1.5% discount rate
Five Year Review	200	ls	$50,000	$10,000,000				**$646,964**	1.5% discount rate
Capital Projects Reporting/Reviews	8	ls	$414,000	$3,312,000				**$3,099,173**	1.5% discount rate
							Capital Costs	**$162,446,000**	
						Present	**Annual**	**$9,014,000**	
						Worth	**Avg. Annual**	**$9,014**	
						Values	**Total**	**$171,460,000**	
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.									

COST ESTIMATE
BGOU SWMU 4
Alternative 4a—Targeted Excavation, ERH, and Bioremediation w/WDA

CAPITAL COSTS									
	Material/Equipment/Subcontractors/ODCs				**Labor**				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
1.0 CERCLA Documents									
Refer to the Success reports for detailed cost and resources.									
RDWP					2644		$203,608		
Remedial Design Report					5424		$422,328		
RAWP					4564		$342,048		
RACR					1584		$116,348		
TASK TOTAL				**$0**	**14216**		**$1,084,332**	**$1,084,000**	
2.0 Other Project Plans									
Refer to the Success reports for detailed cost and resources.									
Health/Safety Plan					628		$42,240		
SAP/QAPP					628		$45,840		
Security Plan					348		$33,400		
O&M Plan					624		$42,788		
Civil Surveying					260		$20,520		
Work Packages/Readiness					1144		$85,748		
Procurement					640		$39,440		
Training	1	LS	$120,000	$120,000	1360		$109,520		
Critical Decision Documents	1	LS	$1,388,250	$1,388,250	5180		$513,380		Capital Projects SMEs
TASK TOTAL				**$1,508,250**	**10812**		**$932,876**	**$2,441,000**	
3.0 Monitoring Wells									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated and therefore includes labor, material, and equipment where applicable.									
Installation									
Contractor Labor					2720		$183,560		
Subcontractors	1	LS	$466,180	$466,180					Local quote from existing drilling sub
Materials	1	LS	$40,842	$40,842					
Vehicles and Equipment	1	LS	$3,731	$3,731					
Sampling/Analytical									
Contractor Labor					48		$2,376		
Subcontractors	1	LS	$4,360	$4,360					Local subcontractor sampling
TASK TOTAL				**$ 515,113**	**2768**		**$ 185,936**	**$701,000**	

COST ESTIMATE
BGOU SWMU 4
Alternative 4a—Targeted Excavation, ERH, and Bioremediation w/WDA

4.0 Shoring									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Sheet Piling									
Contractor Labor					2250		$161,500		
Subcontractors	1	LS	$1,854,589	$1,854,589					
Materials	1	LS	$3,102	$3,102					
Vehicles and Equipment	1	LS	$2,685	$2,685					
TASK TOTAL				**$ 1,860,376**	**2250**		**$ 161,500**	**$2,022,000**	
5.0 Excavation									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Excavation									
Contractor Labor					40750		$3,104,000		
Subcontractors	1	LS	$2,832,337	$2,832,337					
Materials	1	LS	$91,300	$91,300					
Vehicles and Equipment	1	LS	$39,380	$39,380					
TASK TOTALS				**$2,963,017**	**40,750**		**$3,104,000**	**$6,067,000**	
6.0 Water Treatment									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Treatment Facility Construction									
Contractor Labor					1894		$147,870		
Subcontractors	1	LS	$477,465	$477,465					
Materials	1	LS	$1,495,061	$1,495,061					
Vehicles and Equipment	1	LS	$2,359	$2,359					
Treatment Operations									
Contractor Labor					27500		$2,189,000		
Materials	1	LS	$22,000	$22,000					
Vehicles and Equipment	1	LS	$19,690	$19,690					
TASK TOTALS				**$2,016,575**	**29,394**		**$2,336,870**	**$4,353,000**	
7.0 Waste Handling, Disposal, and Transportation									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Contractor Labor					243199		$18,330,400		
Subcontractors	1	LS	$420,679	$420,679					
Containers	1	LS	$1,716,600	$1,716,600					
Materials	1	LS	$2,493,505	$2,493,505					
Characterization Sampling	1	LS	$6,428,664	$6,428,664					
Disposal	1	LS	$17,234,789	$17,234,789					
Transportation	1	LS	$1,929,893	$1,929,893					
Vehicles and Equipment	1	LS	$1,291,602	$1,291,602					
TASK TOTALS				**$31,515,732**	**243,199**		**$18,330,400**	**$49,846,000**	

COST ESTIMATE
BGOU SWMU 4
Alternative 4a—Targeted Excavation, ERH, and Bioremediation w/WDA

8.0 Excavation Backfill									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Contractor Labor					6985		$515,620		
Subcontractors	1	LS	$988,465	$988,465					RSMeans and local Engineering firm
Materials	1	LS	$3,643,080	$3,643,080					
Vehicles and Equipment	1	LS	$6,874	$6,874					
TASK TOTAL				**$ 4,638,419**	**6985**		**$515,620**	**$5,154,000**	
9.0 ERH									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Electrical Resistance Heating									
Labor/Materials/Equipment							$8,611,672		Source: C-400 ERH
TASK TOTALS				**$0**	**0**		**$8,611,672**	**$8,612,000**	
10.0 Bioremediation									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Horizontal Wells									
Contractor Labor					7456		$523,112		
Subcontractors	1	LS	$2,028,065	$2,028,065					Local quote from existing drilling sub
Materials	1	LS	$75,318	$75,318					
Sampling/Analytical	1	LS	$20,800	$20,800					Local subcontractor sampling
Vehicles and Equipment	1	LS	$23,357	$23,357					
Tanks and Piping									
Contractor Labor					1632		$115,980		
Subcontractors	1	LS	$869,076	$869,076					
Materials	1	LS	$194,167	$194,167					
Vehicles and Equipment	1	LS	$1,859	$1,859					
Treatment									
Contractor Labor					5640		$448,440		
Materials	1	LS	$2,304,750	$2,304,750					
Vehicles and Equipment	1	LS	$10,310	$10,310					
Performance Monitoring Wells				$0					
Contractor Labor					2552		$159,344		
Subcontractors	1	LS	$344,861	$344,861					Local quote from existing drilling sub
Materials	1	LS	$40,842	$40,842					
Sampling/Analytical	1	LS	$449,280	$449,280					Local subcontractor sampling
Vehicles and Equipment	1	LS	$3,731	$3,731					
TASK TOTAL				**$6,366,416**	**17280**		**$1,246,876**	**$7,613,000**	

COST ESTIMATE
BGOU SWMU 4
Alternative 4a—Targeted Excavation, ERH, and Bioremediation w/WDA

11.0 Recharge Control (Cover & Slurry Wall)									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Surveying, Marking, Testing									
Contractor Labor					160		$11,760		
Subcontractors	1	LS	$171,400	$171,400					Local Engineering Firm
Materials	1	LS	$2,528	$2,528					
Vehicles and Equipment	1	LS	$5,728	$5,728					
Fence Removal									
Contractor Labor					1020		$71,020		
Subcontractors	1	LS	$22,617	$22,617					
Materials	1	LS	$1,192	$1,192					
Sampling/Analytical	1	LS	$6,540	$6,540					Local subcontractor sampling
Vehicles and Equipment	1	LS	$4,286	$4,286					
Cover Construction									
Contractor Labor					10070		$682,097		
Subcontractors	1	LS	$3,379,837	$3,379,837					
Materials	1	LS	$7,417	$7,417					
Vehicles and Equipment	1	LS	$10,874	$10,874					
Slurry Wall									
Contractor Labor					7190		$515,810		
Subcontractors	1	LS	$5,818,842	$5,818,842					
Materials	1	LS	$4,512	$4,512					
Sampling/Analytical	1	LS	$166,400	$166,400					Local subcontractor sampling
Vehicles and Equipment	1	LS	$72,655	$72,655					
Road Relocation									
Contractor Labor					2170		$151,690		
Subcontractors	1	LS	$1,642,465	$1,642,465					
Materials	1	LS	$832	$832					
Vehicles and Equipment	1	LS	$8,073	$8,073					
Install Fence Replacement									
Contractor Labor					1265		$79,712		
Subcontractors	1	LS	$193,630	$193,630					
Materials	1	LS	$1,183	$1,183					
Vehicles and Equipment	1	LS	$859	$859					
TASK TOTALS				**$11,521,870**	**21,875**		**$1,512,089**	**$13,034,000**	
12.0 Land Use Controls									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Revise Procedures/Deed Restriction									
Contractor Labor					368		$25,248		
Install Signs									
Contractor Labor					40		$2,820		
TASK TOTAL				**$0**	**408**		**$28,068**	**$28,000**	
							SUBTOTAL CAPITAL	**$100,955,000**	

COST ESTIMATE
BGOU SWMU 4
Alternative 4a—Targeted Excavation, ERH, and Bioremediation w/WDA

ANNUAL COSTS									
Inspections									
Duration: Occurs quarterly for 1,000 years.									
Contractor Labor					240		$23,280		
Vehicles and Equipment	1	LS	$143	$143					
TASK TOTAL				**$143**	**240**		**$23,280**	**$23,000**	ANNUAL COST
Mowing									
Duration: 7 times per year per 1,000 years.									
Contractor Labor					70		$2,800		
Subcontractors	1	LS	$6,300	$6,300					
TASK TOTAL				**$6,300**	70		**$2,800**	**$9,000**	ANNUAL COST
Fence Replacement									
Duration: Every 100 years for 1,000 years.									
Contractor Labor					2285		$150,732		
Subcontractors	1	LS	$216,246	$216,246					
Materials	1	LS	$2,375	$2,375					
Sampling/Analytical	1	LS	$6,540	$6,540					Local subcontractor sampling
Vehicles and Equipment	1	LS	$5,146	$5,146					
TASK TOTAL				**$230,307**	2285		**$150,732**	**$381,000**	EVERY 100 YEARS
Sign Replacement									
Duration: Every 30 years for 1,000 years.									
Contractor Labor					30		$2,320		
Materials	1	LS	$500	$500					
TASK TOTAL				**$500**	30		**$2,320**	**$3,000**	EVERY 30 YEARS
Well Sampling									
Duration: Annually for 1,000 years									
Contractor Labor					318		$21,096		
Sampling/Analytical	1	LS	$6,240	$6,240					Local subcontractor sampling
Vehicles and Equipment	1	LS	$215	$215					
TASK TOTAL				**$6,455**	318		**$21,096**	**$28,000**	ANNUAL COST
Monitoring Well Rehab									
Duration: Every 25 years for 1,000 years.									
Contractor Labor					790		$52,370		
Subcontractors	1	LS	$75,840	$75,840					Local quote from existing drilling sub
Materials	1	LS	$3,164	$3,164					
Sampling/Analytical	1	LS	$2,080	$2,080					Local subcontractor sampling
Vehicles and Equipment	1	LS	$1,866	$1,866					
TASK TOTAL				**$82,950**	790		**$52,370**	**$135,000**	EVERY 25 YEARS

COST ESTIMATE
BGOU SWMU 4
Alternative 4a—Targeted Excavation, ERH, and Bioremediation w/WDA

Monitoring Well Replacement									
Duration: Every 50 years for 1,000 years.									
Installation									
Contractor Labor					2720		$183,560		
Subcontractors	1	LS	$466,180	$466,180					Local quote from existing drilling sub
Materials	1	LS	$40,842	$40,842					
Vehicles and Equipment	1	LS	$3,731	$3,731					
Sampling/Analytical									
Contractor Labor					48		$2,376		
Subcontractors	1	LS	$4,360	$4,360					Local subcontractor sampling
TASK TOTAL				**$515,113**	2768		**$185,936**	**$701,000**	EVERY 50 YEARS
Engineered Cover Replacement									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated and therefore includes labor, material, and equipment where applicable.									
Surveying, Marking, Testing									
Contractor Labor					160		$11,760		
Subcontractors	1	LS	$171,400	$171,400					Local Engineering Firm
Materials	1	LS	$2,528	$2,528					
Vehicles and Equipment	1	LS	$5,728	$5,728					
Cover Construction									
Contractor Labor					10070		$682,097		
Subcontractors	1	LS	$3,379,837	$3,379,837					
Materials	1	LS	$7,417	$7,417					
Vehicles and Equipment	1	LS	$10,874	$10,874					
TASK TOTAL				**$3,577,784**	10230		**$693,857**	**$4,272,000**	EVERY 200 YEARS
Five Year Review									
Duration: Every 5 years.									
Contractor Labor					720		$49,720		
TASK TOTAL					720		$49,720	**$50,000**	EVERY 5 YEARS
Capital Projects Reporting/Reviews									
Duration: Every year for 8 years.									
Contractor Labor					2000		$193,600		
Subcontractors	1	LS	$220,500	$220,500					Capital Projects SMEs
TASK TOTAL				**$220,500**	2000		**$193,600**	**$414,000**	ANNUAL COST

ALTERNATIVE 5—FULL EXCAVATION, ERH, AND BIOREMEDIATION

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COST ESTIMATE
BGOU SWMU 4
Alternative 5—Full Excavation, ERH, and Bioremediation

Cost Estimate Summary

Capital Cost	Quantity	Units	Unit Price	Total	
1.0 CERCLA Documents	1	ls	$1,220,000	$1,220,000	
2.0 Other Project Plans	1	ls	$2,471,000	$2,471,000	
3.0 Monitoring Wells	1	ls	$701,000	$701,000	
4.0 Shoring	1	ls	$2,891,000	$2,891,000	
5.0 Excavation	1	ls	$15,767,000	$15,767,000	
6.0 Water Treatment	1	ls	$7,891,000	$7,891,000	
7.0 Waste Handling, Disposal, and Transportation	1	ls	$265,811,000	$265,811,000	
8.0 Excavation Backfill	1	ls	$13,326,000	$13,326,000	
9.0 ERH	1	ls	$8,612,000	$8,612,000	
10.0 Bioremediation	1	ls	$7,613,000	$7,613,000	
11.0 Land Use Controls	1	ls	$28,000	$28,000	
Subproject Management	1	ls	$32,633,100	$32,633,000	Subproject Management = 10%
Management Reserve	1	ls	$53,844,600	$53,845,000	Contractor MR=15%
Fee	1	ls	$24,768,540	$24,769,000	Fee = 6%.
Contingency	1	ls	$87,515,600	$87,516,000	Contingency = 20%
		SUBTOTAL CAPITAL		**$525,094,000**	
Annual Cost					
Five Year Review	200	EA	$50,000	$10,000,000	Every 5 years for 1,000 years
Well Sampling	25	EA	$28,000	$700,000	Annually for 25 years
Capital Projects Reporting/Reviews	11	EA	$414,000	$4,554,000	Annually for 11 years
		SUBTOTAL ANNUAL		**$15,254,000**	
			TOTAL	**$540,348,000**	

Present Worth Value

	Quantity	Unit	Unit Cost	Total			Present Worth	
Total Capital Cost	1	ls	$525,094,000	$525,094,000			**$525,094,000**	
Five Year Review	200	ls	$50,000	$10,000,000			**$646,964**	1.5% discount rate
Well Sampling	25	ls	$28,000	$700,000			**$580,149**	1.5% discount rate
Capital Projects Reporting/Reviews	11	ls	$414,000	$4,554,000			**$4,169,443**	1.5% discount rate
						Capital Costs	**$525,094,000**	
					Present	**Annual**	**$5,397,000**	
					Worth	**Avg. Annual**	**$5,397**	
					Values	**Total**	**$530,491,000**	

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.

COST ESTIMATE
BGOU SWMU 4
Alternative 5—Full Excavation, ERH, and Bioremediation

CAPITAL COSTS									
	Material/Equipment/Subcontractors/ODCs				**Labor**				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
1.0 CERCLA Documents									
Refer to the Success reports for detailed cost and resources.									
RDWP					2644		$203,608		
Remedial Design Report					6364		$494,968		
RAWP					5404		$405,368		
RACR					1584		$116,348		
TASK TOTAL				**$0**	**15996**		**$1,220,292**	**$1,220,000**	
2.0 Other Project Plans									
Refer to the Success reports for detailed cost and resources.									
Health/Safety Plan					658		$44,620		
SAP/QAPP					688		$50,360		
Security Plan					348		$33,400		
O&M Plan					624		$42,788		
Civil Surveying					360		$27,400		
Work Packages/Readiness					1336		$101,640		
Procurement					640		$39,440		
Training	1	LS	$120,000	$120,000	1360		$109,520		
Critical Decision Documents	1	LS	$1,388,250	$1,388,250	5180		$513,380		Capital Projects SMEs
TASK TOTAL				**$1,508,250**	**11194**		**$962,548**	**$2,471,000**	
3.0 Monitoring Wells									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated and therefore includes labor, material, and equipment where applicable.									
Installation									
Contractor Labor					2720		$183,560		
Subcontractors	1	LS	$466,180	$466,180					Local quote from existing drilling sub
Materials	1	LS	$40,842	$40,842					
Vehicles and Equipment	1	LS	$3,731	$3,731					
Sampling/Analytical									
Contractor Labor					48		$2,376		
Subcontractors	1	LS	$4,360	$4,360					Local subcontractor sampling
TASK TOTAL				**$ 515,113**	**2768**		**$ 185,936**	**$701,000**	
4.0 Shoring									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated and therefore includes labor, material, and equipment where applicable.									
Sheet Piling									
Contractor Labor					3375		$242,249		
Subcontractors	1	LS	$2,639,801	$2,639,801					
Materials	1	LS	$4,653	$4,653					
Vehicles and Equipment	1	LS	$4,028	$4,028					
TASK TOTAL				**$ 2,648,482**	**3375**		**$ 242,249**	**$2,891,000**	

COST ESTIMATE
BGOU SWMU 4
Alternative 5—Full Excavation, ERH, and Bioremediation

5.0 Excavation									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Excavation									
Contractor Labor					106875		$8,151,000		
Subcontractors	1	LS	$7,258,782	$7,258,782					
Materials	1	LS	$255,600	$255,600					
Vehicles and Equipment	1	LS	$102,030	$102,030					
TASK TOTALS				**$7,616,412**	**106,875**		**$8,151,000**	**$15,767,000**	
6.0 Water Treatment									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Treatment Facility Construction									
Contractor Labor					1894		$147,870		
Subcontractors	1	LS	$477,465	$477,465					
Materials	1	LS	$1,495,061	$1,495,061					
Vehicles and Equipment	1	LS	$2,359	$2,359					
Treatment Operations									
Contractor Labor					71250		$5,671,500		
Materials	1	LS	$45,600	$45,600					
Vehicles and Equipment	1	LS	$51,015	$51,015					
TASK TOTALS				**$2,071,500**	**73,144**		**$5,819,370**	**$7,891,000**	
7.0 Waste Handling, Disposal, and Transportation									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Contractor Labor					632599		$47,615,700		
Subcontractors	1	LS	$420,679	$420,679					
Containers	1	LS	$9,837,000	$9,837,000					
Materials	1	LS	$8,468,637	$8,468,637					
Characterization Sampling	1	LS	$9,897,730	$9,897,730					
Disposal	1	LS	$148,564,315	$148,564,315					
Transportation	1	LS	$36,476,349	$36,476,349					
Vehicles and Equipment	1	LS	$4,530,288	$4,530,288					
TASK TOTALS				**$218,194,998**	**632,599**		**$47,615,700**	**$265,811,000**	
8.0 Excavation Backfill									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Contractor Labor					16610		$1,226,120		
Subcontractors	1	LS	$2,449,691	$2,449,691					RSMeans and local Engineering firm
Materials	1	LS	$9,634,080	$9,634,080					
Vehicles and Equipment	1	LS	$16,217	$16,217					
TASK TOTAL				**$ 12,099,988**	**16610**		**$1,226,120**	**$13,326,000**	

COST ESTIMATE
BGOU SWMU 4
Alternative 5—Full Excavation, ERH, and Bioremediation

9.0 ERH									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Electrical Resistance Heating									
Labor/Materials/Equipment							$8,611,672		Source: C-400 ERH
TASK TOTALS				**$0**	**0**		**$8,611,672**	**$8,612,000**	
10.0 Bioremediation									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Horizontal Wells									
Contractor Labor					7456		$523,112		
Subcontractors	1	LS	$2,028,065	$2,028,065					Local quote from existing drilling sub
Materials	1	LS	$75,318	$75,318					
Sampling/Analytical	1	LS	$20,800	$20,800					Local subcontractor sampling
Vehicles and Equipment	1	LS	$23,357	$23,357					
Tanks and Piping									
Contractor Labor					1632		$115,980		
Subcontractors	1	LS	$869,076	$869,076					
Materials	1	LS	$194,167	$194,167					
Vehicles and Equipment	1	LS	$1,859	$1,859					
Treatment									
Contractor Labor					5640		$448,440		
Materials	1	LS	$2,304,750	$2,304,750					
Vehicles and Equipment	1	LS	$10,310	$10,310					
Performance Monitoring Wells				$0					
Contractor Labor					2552		$159,344		
Subcontractors	1	LS	$344,861	$344,861					Local quote from existing drilling sub
Materials	1	LS	$40,842	$40,842					
Sampling/Analytical	1	LS	$449,280	$449,280					Local subcontractor sampling
Vehicles and Equipment	1	LS	$3,731	$3,731					
TASK TOTAL				**$6,366,416**	**17280**		**$1,246,876**	**$7,613,000**	
11.0 Land Use Controls									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Revise Procedures/Deed Restriction									
Contractor Labor					368		$25,248		
Install Signs									
Contractor Labor					40		$2,820		
TASK TOTAL				**$0**	**408**		**$28,068**	**$28,000**	
							SUBTOTAL CAPITAL	**$326,331,000**	

COST ESTIMATE
BGOU SWMU 4
Alternative 5—Full Excavation, ERH, and Bioremediation

ANNUAL COSTS									
Five Year Review									
Duration: Every 5 years.									
Contractor Labor					720		$49,720		
TASK TOTAL					720		$49,720	**$50,000**	EVERY 5 YEARS
Capital Projects Reporting/Reviews									
Duration: Every year for 11 years.									
Contractor Labor					2000		$193,600		
Subcontractors	1	LS	$220,500	$220,500					Capital Projects SMEs
TASK TOTAL				**$220,500**	2000		**$193,600**	**$414,000**	ANNUAL COST
Well Sampling									
Duration: Annually for 25 years									
Contractor Labor					318		$21,096		
Sampling/Analytical	1	LS	$6,240	$6,240					Local subcontractor sampling
Vehicles and Equipment	1	LS	$215	$215					
TASK TOTAL				**$6,455**	318		**$21,096**	**$28,000**	ANNUAL COST

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ALTERNATIVE 5A—FULL EXCAVATION, ERH, AND BIOREMEDIATION WITH WDA

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COST ESTIMATE
BGOU SWMU 4
Alternative 5a—Full Excavation, ERH, and Bioremediation w/WDA

Cost Estimate Summary									
Capital Cost	**Quantity**	**Units**	**Unit Price**	**Total**					
1.0 CERCLA Documents	1	ls	$1,220,000	$1,220,000					
2.0 Other Project Plans	1	ls	$2,471,000	$2,471,000					
3.0 Monitoring Wells	1	ls	$701,000	$701,000					
4.0 Shoring	1	ls	$2,891,000	$2,891,000					
5.0 Excavation	1	ls	$15,767,000	$15,767,000					
6.0 Water Treatment	1	ls	$7,891,000	$7,891,000					
7.0 Waste Handling, Disposal, and Transportation	1	ls	$153,123,000	$153,123,000					
8.0 Excavation Backfill	1	ls	$13,326,000	$13,326,000					
9.0 ERH	1	ls	$8,612,000	$8,612,000					
10.0 Bioremediation	1	ls	$7,613,000	$7,613,000					
11.0 Land Use Controls	1	ls	$28,000	$28,000					
Subproject Management	1	ls	$21,364,300	$21,364,000					Subproject Management = 10%
Management Reserve	1	ls	$35,251,050	$35,251,000					Contractor MR=15%
Fee	1	ls	$16,215,480	$16,215,000					Fee = 6%.
Contingency	1	ls	$57,294,600	$57,295,000					Contingency = 20%
			SUBTOTAL CAPITAL COST	**$343,768,000**					
Annual Cost									
Five Year Review	200	EA	$50,000	$10,000,000					Every 5 years for 1,000 years
Well Sampling	25	EA	$28,000	$700,000					Annually for 25 years
Capital Projects Reporting/Reviews	11	EA	$414,000	$4,554,000					Annually for 11 years
			SUBTOTAL ANNUAL COST	**$15,254,000**					
			TOTAL	**$359,022,000**					
Present Worth Value									
	Quantity	**Unit**	**Unit Cost**	**Total**				**Present Worth**	
Total Capital Cost	1	ls	$343,768,000	$343,768,000				**$343,768,000**	
Five Year Review	200	ls	$50,000	$10,000,000				**$646,964**	1.5% discount rate
Well Sampling	25	ls	$28,000	$700,000				**$580,149**	1.5% discount rate
Capital Projects Reporting/Reviews	11	ls	$414,000	$4,554,000				**$4,169,443**	1.5% discount rate
							Capital Costs	**$343,768,000**	
						Present	**Annual**	**$5,397,000**	
						Worth	**Avg. Annual**	**$5,397**	
						Values	**Total**	**$349,165,000**	
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.									

COST ESTIMATE
BGOU SWMU 4
Alternative 5a—Full Excavation, ERH, and Bioremediation w/WDA

CAPITAL COSTS									
	Material/Equipment/Subcontractors/ODCs				**Labor**				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
1.0 CERCLA Documents									
Refer to the Success reports for detailed cost and resources.									
RDWP					2644		$203,608		
Remedial Design Report					6364		$494,968		
RAWP					5404		$405,368		
RACR					1584		$116,348		
TASK TOTAL				**$0**	**15996**		**$1,220,292**	**$1,220,000**	
2.0 Other Project Plans									
Refer to the Success reports for detailed cost and resources.									
Health/Safety Plan					658		$44,620		
SAP/QAPP					688		$50,360		
Security Plan					348		$33,400		
O&M Plan					624		$42,788		
Civil Surveying					360		$27,400		
Work Packages/Readiness					1336		$101,640		
Procurement					640		$39,440		
Training	1	LS	$120,000	$120,000	1360		$109,520		
Critical Decision Documents	1	LS	$1,388,250	$1,388,250	5180		$513,380		Capital Projects SMEs
TASK TOTAL				**$1,508,250**	**11194**		**$962,548**	**$2,471,000**	
3.0 Monitoring Wells									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Installation									
Contractor Labor					2720		$183,560		
Subcontractors	1	LS	$466,180	$466,180					Local quote from existing drilling sub
Materials	1	LS	$40,842	$40,842					
Vehicles and Equipment	1	LS	$3,731	$3,731					
Sampling/Analytical									
Contractor Labor					48		$2,376		
Subcontractors	1	LS	$4,360	$4,360					Local subcontractor sampling
TASK TOTAL				**$ 515,113**	**2768**		**$ 185,936**	**$701,000**	
4.0 Shoring									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Sheet Piling									
Contractor Labor					3375		$242,249		
Subcontractors	1	LS	$2,639,801	$2,639,801					
Materials	1	LS	$4,653	$4,653					
Vehicles and Equipment	1	LS	$4,028	$4,028					
TASK TOTAL				**$ 2,648,482**	**3375**		**$ 242,249**	**$2,891,000**	
5.0 Excavation									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Excavation									
Contractor Labor					106875		$8,151,000		
Subcontractors	1	LS	$7,258,782	$7,258,782					
Materials	1	LS	$255,600	$255,600					
Vehicles and Equipment	1	LS	$102,030	$102,030					
TASK TOTALS				**$7,616,412**	**106,875**		**$8,151,000**	**$15,767,000**	

COST ESTIMATE
BGOU SWMU 4
Alternative 5a—Full Excavation, ERH, and Bioremediation w/WDA

6.0 Water Treatment									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Treatment Facility Construction									
Contractor Labor					1894		$147,870		
Subcontractors	1	LS	$477,465	$477,465					
Materials	1	LS	$1,495,061	$1,495,061					
Vehicles and Equipment	1	LS	$2,359	$2,359					
Treatment Operations									
Contractor Labor					71250		$5,671,500		
Materials	1	LS	$45,600	$45,600					
Vehicles and Equipment	1	LS	$51,015	$51,015					
TASK TOTALS				**$2,071,500**	**73,144**		**$5,819,370**	**$7,891,000**	
7.0 Waste Handling, Disposal, and Transportation									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Contractor Labor					632599		$47,615,700		
Subcontractors	1	LS	$420,679	$420,679					
Containers	1	LS	$2,111,700	$2,111,700					
Materials	1	LS	$8,366,402	$8,366,402					
Characterization Sampling	1	LS	$17,677,884	$17,677,884					
Disposal	1	LS	$66,198,699	$66,198,699					
Transportation	1	LS	$6,201,388	$6,201,388					
Vehicles and Equipment	1	LS	$4,530,288	$4,530,288					
TASK TOTALS				**$105,507,040**	**632,599**		**$47,615,700**	**$153,123,000**	
8.0 Excavation Backfill									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Contractor Labor					16610		$1,226,120		
Subcontractors	1	LS	$2,449,691	$2,449,691					RSMeans and local Engineering firm
Materials	1	LS	$9,634,080	$9,634,080					
Vehicles and Equipment	1	LS	$16,217	$16,217					
TASK TOTAL				**$ 12,099,988**	**16610**		**$1,226,120**	**$13,326,000**	
9.0 ERH									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Electrical Resistance Heating									
Labor/Materials/Equipment							$8,611,672		Source: C-400 ERH
TASK TOTALS				**$0**	**0**		**$8,611,672**	**$8,612,000**	

COST ESTIMATE
BGOU SWMU 4
Alternative 5a—Full Excavation, ERH, and Bioremediation w/WDA

10.0 Bioremediation									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Horizontal Wells									
Contractor Labor					7456		$523,112		
Subcontractors	1	LS	$2,028,065	$2,028,065					Local quote from existing drilling sub
Materials	1	LS	$75,318	$75,318					
Sampling/Analytical	1	LS	$20,800	$20,800					Local subcontractor sampling
Vehicles and Equipment	1	LS	$23,357	$23,357					
Tanks and Piping									
Contractor Labor					1632		$115,980		
Subcontractors	1	LS	$869,076	$869,076					
Materials	1	LS	$194,167	$194,167					
Vehicles and Equipment	1	LS	$1,859	$1,859					
Treatment									
Contractor Labor					5640		$448,440		
Materials	1	LS	$2,304,750	$2,304,750					
Vehicles and Equipment	1	LS	$10,310	$10,310					
Performance Monitoring Wells				$0					
Contractor Labor					2552		$159,344		
Subcontractors	1	LS	$344,861	$344,861					Local quote from existing drilling sub
Materials	1	LS	$40,842	$40,842					
Sampling/Analytical	1	LS	$449,280	$449,280					Local subcontractor sampling
Vehicles and Equipment	1	LS	$3,731	$3,731					
TASK TOTAL				**$6,366,416**	**17280**		**$1,246,876**	**$7,613,000**	
11.0 Land Use Controls									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Revise Procedures/Deed Restriction									
Contractor Labor					368		$25,248		
Install Signs									
Contractor Labor					40		$2,820		
TASK TOTAL				**$0**	**408**		**$28,068**	**$28,000**	
							SUBTOTAL CAPITAL	**$213,643,000**	
ANNUAL COSTS									
Five Year Review									
Duration: Every 5 years.									
Contractor Labor					720		$49,720		
TASK TOTAL					720		$49,720	**$50,000**	EVERY 5 YEARS
Capital Projects Reporting/Reviews									
Duration: Every year for 11 years.									
Contractor Labor					2000		$193,600		
Subcontractors	1	LS	$220,500	$220,500					Capital Projects SMEs
TASK TOTAL				**$220,500**	2000		**$193,600**	**$414,000**	ANNUAL COST
Well Sampling									
Duration: Annually for 25 years									
Contractor Labor					318		$21,096		
Sampling/Analytical	1	LS	$6,240	$6,240					Local subcontractor sampling
Vehicles and Equipment	1	LS	$215	$215					
TASK TOTAL				**$6,455**	318		**$21,096**	**$28,000**	ANNUAL COST

ALTERNATIVE 6—RECHARGE CONTROL AND BIOREMEDIATION

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COST ESTIMATE
BGOU SWMU 4
Alternative 6—Recharge Control and Bioremediation

Cost Estimate Summary										
	Capital Cost	**Quantity**	**Units**	**Unit Price**	**Total**					
	1.0 CERCLA Documents	1	ls	$543,000	$543,000					
	2.0 Other Plans/Support	1	ls	$2,152,000	$2,152,000					
	3.0 Monitoring Wells	1	ls	$701,000	$701,000					
	4.0 Recharge Control (Cover & Slurry Wall)	1	ls	$13,760,000	$13,760,000					
	5.0 Bioremediation	1	ls	$7,613,000	$7,613,000					
	6.0 Land Use Controls	1	ls	$28,000	$28,000					
	Subproject Management	1	ls	$2,479,700	$2,480,000					Subproject Management = 10%
	Management Reserve	1	ls	$4,091,550	$4,092,000					Contractor MR=15%
	Fee	1	ls	$1,882,140	$1,882,000					Fee = 6%
	Contingency	1	ls	$6,650,200	$6,650,000					Contingency = 20%
			SUBTOTAL CAPITAL		**$39,901,000**					
	Annual Cost									
	Inspections	1000	EA	$23,000	$23,000,000					Quarterly for 1,000 years
	Mowing	1000	EA	$9,000	$9,000,000					7 Times per year for 1,000 years
	Fence Replacement	10	EA	$381,000	$3,810,000					Every 100 years for 1,000 years
	Sign Replacement	33	EA	$3,000	$100,000					Every 30 years for 1,000 years
	Well Sampling	1000	EA	$28,000	$28,000,000					Annually for 1,000 years
	Monitoring Well Rehab	40	EA	$135,000	$5,400,000					Every 25 years for 1,000 years
	Monitoring Well Replacement	20	EA	$701,000	$14,020,000					Every 50 years for 1,000 years
	Engineered Cover Replacement	5	EA	$5,703,000	$28,515,000					Every 200 years for 1,000 years
	Five Year Review	200	EA	$50,000	$10,000,000					Every 5 years for 1,000 years
	Capital Projects Reporting/Reviews	5	EA	$414,000	$2,070,000					Annually for 5 years
			SUBTOTAL ANNUAL		**$123,915,000**					
				TOTAL	**$163,816,000**					

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Present Worth Value									
	Quantity	**Unit**	**Unit Cost**	**Total**				**Present Worth**	
Total Capital Cost	1	ls	$39,901,000	$39,901,000				**$39,901,000**	
Inspections	1000	EA	$23,000	$23,000,000				**$1,533,333**	1.5% discount rate
Mowing	1000	EA	$9,000	$9,000,000				**$600,000**	1.5% discount rate
Fence Replacement	10	EA	$381,000	$3,810,000				**$111,012**	1.5% discount rate
Sign Replacement	33	EA	$3,000	$100,000				**$5,328**	1.5% discount rate
Well Sampling	1000	EA	$28,000	$28,000,000				**$1,866,666**	1.5% discount rate
Monitoring Well Rehab	40	EA	$135,000	$5,400,000				**$299,371**	1.5% discount rate
Monitoring Well Replacement	20	EA	$701,000	$14,020,000				**$634,250**	1.5% discount rate
Replacement	5	EA	$5,703,000	$28,515,000				**$305,905**	1.5% discount rate
Five Year Review	200	EA	$50,000	$10,000,000				**$646,964**	1.5% discount rate
Capital Projects Reporting/Reviews	5	EA	$414,000	$2,070,000				**$1,980,015**	1.5% discount rate
							Capital Costs	**$39,901,000**	
						Present Worth Values	**Annual**	**$7,983,000**	
							Avg. Annual	**$7,983**	
							Total	**$47,884,000**	
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.									

CAPITAL COSTS									
	Material/Equipment/Subcontractors/ODCs				**Labor**				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
1.0 CERCLA Documents									
Refer to the Success reports for detailed cost and resources.									
RDWP					1434		$98,668		
Remedial Design Report					3104		$210,528		
RAWP					2604		$179,168		
RACR					804		$54,708		
TASK TOTAL				**$0**	**7946**		**$543,072**	**$543,000**	
2.0 Other Plans/Support									
Refer to the Success reports for detailed cost and resources.									
Health/Safety Plan					444		$29,552		
SAP/QAPP					448		$32,320		
Security Plan					268		$25,120		
Civil Surveying					240		$18,580		
Work Packages/Readiness					560		$40,008		
Procurement					280		$16,880		
Training	1	LS	$48,000	$48,000	520		$40,200		
Critical Decision Documents	1	LS	$1,388,250	$1,388,250	5180		$513,380		Capital Projects SMEs
TASK TOTAL				**$1,436,250**	**7940**		**$716,040**	**$2,152,000**	

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3.0 Monitoring Wells									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Installation									
Contractor Labor					2720		$183,560		
Subcontractors	1	LS	$466,180	$466,180					Local quote from existing drilling sub
Materials	1	LS	$40,842	$40,842					
Vehicles and Equipment	1	LS	$3,731	$3,731					
Sampling/Analytical									
Contractor Labor					48		$2,376		
Subcontractors	1	LS	$4,360	$4,360					Local subcontractor sampling
TASK TOTAL				**$ 515,113**	**2768**		**$ 185,936**	**$701,000**	
4.0 Recharge Control (Cover & Slurry Wall)									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Surveying, Marking, Testing									
Contractor Labor					160		$11,760		
Subcontractors	1	LS	$183,600	$183,600					Local Engineering Firm
Materials	1	LS	$2,528	$2,528					
Vehicles and Equipment	1	LS	$5,728	$5,728					
Fence Removal									
Contractor Labor					1020		$71,020		
Subcontractors	1	LS	$22,617	$22,617					
Materials	1	LS	$1,192	$1,192					
Sampling/Analytical	1	LS	$6,540	$6,540					Local subcontractor sampling
Vehicles and Equipment	1	LS	$4,286	$4,286					
Cover Construction									
Contractor Labor					12640		$854,640		
Subcontractors	1	LS	$4,626,194	$4,626,194					
Materials	1	LS	$5,632	$5,632					
Vehicles and Equipment	1	LS	$12,592	$12,592					
Slurry Wall									
Contractor Labor					6078		$436,107		
Subcontractors	1	LS	$5,212,712	$5,212,712					
Materials	1	LS	$3,758	$3,758					
Sampling/Analytical	1	LS	$156,000	$156,000					Local subcontractor sampling
Vehicles and Equipment	1	LS	$64,296	$64,296					
Road Relocation									
Contractor Labor					2170		$151,690		
Subcontractors	1	LS	$1,642,465	$1,642,465					
Materials	1	LS	$832	$832					
Vehicles and Equipment	1	LS	$8,073	$8,073					
Install Fence Replacement									
Contractor Labor					1265		$79,712		
Subcontractors	1	LS	$193,630	$193,630					
Materials	1	LS	$1,183	$1,183					
Vehicles and Equipment	1	LS	$859	$859					
TASK TOTALS				**$12,154,717**	**23,333**		**$1,604,929**	**$13,760,000**	

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5.0 Bioremediation									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Horizontal Wells									
Contractor Labor					7456		$523,112		
Subcontractors	1	LS	$2,028,065	$2,028,065					Local quote from existing drilling sub
Materials	1	LS	$75,318	$75,318					
Sampling/Analytical	1	LS	$20,800	$20,800					Local subcontractor sampling
Vehicles and Equipment	1	LS	$23,357	$23,357					
Tanks and Piping									
Contractor Labor					1632		$115,980		
Subcontractors	1	LS	$869,076	$869,076					
Materials	1	LS	$194,167	$194,167					
Vehicles and Equipment	1	LS	$1,859	$1,859					
Treatment									
Contractor Labor					5640		$448,440		
Materials	1	LS	$2,304,750	$2,304,750					
Vehicles and Equipment	1	LS	$10,310	$10,310					
Performance Monitoring Wells				$0					
Contractor Labor					2552		$159,344		
Subcontractors	1	LS	$344,861	$344,861					Local quote from existing drilling sub
Materials	1	LS	$40,842	$40,842					
Sampling/Analytical	1	LS	$449,280	$449,280					Local subcontractor sampling
Vehicles and Equipment	1	LS	$3,731	$3,731					
TASK TOTALS				**$6,366,416**	**17,280**		**$1,246,876**	**$7,613,000**	
6.0 Land Use Controls									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated									
and therefore includes labor, material, and equipment where applicable.									
Revise Procedures/Deed Restriction									
Contractor Labor					368		$25,248		
Install Signs									
Contractor Labor					40		$2,820		
TASK TOTALS				**$0**	**408**		**$28,068**	**$28,000**	
							SUBTOTAL CAPITAL	**$24,797,000**	

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ANNUAL COSTS									
Inspections									
Duration: Occurs quarterly for 1,000 years.									
Contractor Labor					240		$23,280		
Vehicles and Equipment	1	LS	$143	$143					
TASK TOTAL				**$143**	**240**		**$23,280**	**$23,000**	ANNUAL COST
Mowing									
Duration: 7 times per year per 1,000 years.									
Contractor Labor					70		$2,800		
Subcontractors	1	LS	$6,300	$6,300					
TASK TOTAL				**$6,300**	70		**$2,800**	**$9,000**	ANNUAL COST
Fence Replacement									
Duration: Every 100 years for 1,000 years.									
Contractor Labor					2285		$150,732		
Subcontractors	1	LS	$216,246	$216,246					
Materials	1	LS	$2,375	$2,375					
Sampling/Analytical	1	LS	$6,540	$6,540					Local subcontractor sampling
Vehicles and Equipment	1	LS	$5,146	$5,146					
TASK TOTAL				**$230,307**	2285		**$150,732**	**$381,000**	EVERY 100 YEARS
Sign Replacement									
Duration: Every 30 years for 1,000 years.									
Contractor Labor					30		$2,320		
Materials	1	LS	$500	$500					
TASK TOTAL				**$500**	30		**$2,320**	**$3,000**	EVERY 30 YEARS
Well Sampling									
Duration: Annually for 1,000 years									
Contractor Labor					318		$21,096		
Sampling/Analytical	1	LS	$6,240	$6,240					Local subcontractor sampling
Vehicles and Equipment	1	LS	$215	$215					
TASK TOTAL				**$6,455**	318		**$21,096**	**$28,000**	ANNUAL COST
Monitoring Well Rehab									
Duration: Every 25 years for 1,000 years.									
Contractor Labor					790		$52,370		
Subcontractors	1	LS	$75,840	$75,840					Local quote from existing drilling sub
Materials	1	LS	$3,164	$3,164					
Sampling/Analytical	1	LS	$2,080	$2,080					Local subcontractor sampling
Vehicles and Equipment	1	LS	$1,866	$1,866					
TASK TOTAL				**$82,950**	790		**$52,370**	**$135,000**	EVERY 25 YEARS
Monitoring Well Replacement									
Duration: Every 50 years for 1,000 years.									
Installation									
Contractor Labor					2720		$183,560		
Subcontractors	1	LS	$466,180	$466,180					Local quote from existing drilling sub
Materials	1	LS	$40,842	$40,842					
Vehicles and Equipment	1	LS	$3,731	$3,731					
Sampling/Analytical									
Contractor Labor					48		$2,376		
Subcontractors	1	LS	$4,360	$4,360					Local subcontractor sampling
TASK TOTAL				**$515,113**	2768		**$185,936**	**$701,000**	EVERY 50 YEARS

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Engineered Cover Replacement									
Refer to the Success reports for detailed cost and resources. 'Subcontractors' line item determined from RSMeans unless otherwise stated and therefore includes labor, material, and equipment where applicable.									
Duration: Every 200 years.									
Surveying, Marking, Testing									
Contractor Labor					160		$11,760		
Subcontractors	1	LS	$183,600	$183,600					Local Engineering Firm
Materials	1	LS	$2,528	$2,528					
Vehicles and Equipment	1	LS	$5,728	$5,728					
Cover Construction									
Contractor Labor					12640		$854,640		
Subcontractors	1	LS	$4,626,194	$4,626,194					
Materials	1	LS	$5,632	$5,632					
Vehicles and Equipment	1	LS	$12,592	$12,592					
TASK TOTALS				**$4,836,274**	**12,800**		**$866,400**	**$5,703,000**	EVERY 200 YEARS
Five Year Review									
Duration: Every 5 years.									
Contractor Labor					720		$49,720		
TASK TOTAL				**$0**	**720**		**$49,720**	**$50,000**	
Capital Projects Reporting/Reviews									
Duration: Every year for 8 years.									
Contractor Labor					2000		$193,600		
Subcontractors	1	LS	$220,500	$220,500					Capital Projects SMEs
TASK TOTAL				**$220,500**	2000		**$193,600**	**$414,000**	ANNUAL COST