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FEASIBILITY STUDY REPORT FOR OPERABLE UNIT 1

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

REMEDIAL INVESTIGATION AND FEASIBILITY STUDY

VOLUME 1 OF 3

MARCH 1994

U.S. DEPARTMENT OF ENERGY
FERNALD FIELD OFFICE

DRAFT

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LIST OF ACRONYMS AND ABBREVIATIONS

ACA	Amended Consent Agreement
AEA	Atomic Energy Act
AEC	Atomic Energy Commission
AIRFA	American Indian Religions Freedom Act
ALARA	as low as reasonably achievable
ARAR	applicable relevant or appropriate requirement
ARPA	Archaeological Resource Protection Act
ASTM	American Society for Testing and Materials
AWWT	Advanced Waste Water Treatment (Facility)
bcy	bulk cubic yards
BDAT	best demonstrated available technology
BF	bulking factor
CAA	Clean Air Act
CDD	chlorinated dibenzo-p-dioxins
CDF	chlorinated dibenzofurans
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CI	confidence interval
cm	centimeter
CMSA	consolidated metropolitan statistical area
COC	constituents of concern
COE	U.S. Army Corp of Engineers
CPC	constituents of potential concern
CRARE	comprehensive response action risk evaluation
CRQL	contract required quantitation limit
CRP	chlorosulfanated reinforced polyethylene
CT	central tendency
D&D	decontamination and decommissioning
DAC	derived air concentration
DCG	Derived Concentration Guideline

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

DDT	dichlorodiphenyl-trichloroethane
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOE-NV	Department of Energy Nevada Field Office
DOT	U.S. Department of Transportation
EA	environmental assessment
EDE	effective dose equivalent
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
EPDM	ethylene propylene diene monomer
ERDA	Energy Research and Development Administration
ERMC	Environmental Restoration Management Contractor
ESA	Endangered Species Act
EWMF	engineered waste management facility
FAR	Federal Acquisition Regulations
FEMP	Fernald Environmental Management Project
FERMCO	Fernald Environmental Restoration Management Corporation
FFCA	Federal Facility Compliance Agreement
FMPC	Feed Materials Production Center
FONSI	finding of no significant impact
FR	Federal Register
FS	feasibility study
FS/PP-EA	feasibility study/proposed plan-environmental assessment
FS/PP-EIS	feasibility study/proposed plan-environmental impact statement
ft	feet
ft^3	cubic feet
FW	field work
FY	fiscal year
g	gram
GCC	geosynthetic clay cap

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

GCL	geosynthetic clay liner
GMA	Great Miami Aquifer
gpm	gallons per minute
GRA	general response actions
H	horizontal
ha	hectare
HDPE	high density polyethylene
HEAST	Health Effects Assessment Summary Tables
HEPA	High Efficiency Particulate Air
HI	hazard index
HQ	hazard quotient
HSL	Hazardous Substances List
HWMU	hazardous waste management unit
ILCR	incremental lifetime cancer risk
IRIS	Integrated Risk Information System
ISA	Initial Screening of Alternatives (Report)
ISCLT	industrial source complex long term model
IT	International Technologies (Corporation)
kg	kilogram
km	kilometer
Kow	octanol/water coefficient
L	liter
LC/DS	leachate collection/disposal system
lbs	pounds
LDR	land disposal restrictions
LLRW	low-level radioactive waste
LLW	low-level waste
LRA	leading remedial alternative
LSA	low specific activity

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

μg	microgram
m	meter
m^3	cubic meters
MAWS	minimum additive waste stabilization
MCLG	maximum contaminant level goals
MCLs	maximum contaminant levels
mg	milligram
mi	mile
mrad	millirad
mrem	millirem
MTF	memorandum to file
MUSLE	modified universal soil loss equation
NA	not applicable
NAAQS	National Ambient Air Quality Standards
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NCRP	National Council on Radiation Protection and Measurements
NAGPRA	Native Americans Grave Protection and Repatriation Act
ND	not detected
NEPA	National Environmental Policy Act
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NLCO	National Lead Company of Ohio
NLO	National Lead of Ohio
NOAA	National Oceanic and Atmospheric Administration
NOEL	no observed effect level
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRHP	National Register of Historic Places
NTS	Nevada Test Site

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

OAC	Ohio Administrative Code
ODUC	Ohio Data Users Center
OEPA	Ohio Environmental Protection Agency
OHPO	Ohio Historic Preservation Office
O&M	operation and maintenance
ORC	Ohio Regulatory Code
OSHA	Occupational Safety and Health Act
PAH	polycyclic aromatic hydrocarbon
PBRA	preliminary baseline risk assessment
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
pCi	picoCuries
PCT	product consistency test
PMF	probable maximum flood
PP	proposed plan
ppb	parts per billion
ppm	parts per million
PRG	preliminary remediation goal
PRL	proposed remedial level
Pu	plutonium
QA	quality assurance
Ra	radium
RA	risk assessment
RAO	remedial action objectives
RAD	radiation absorbed dose
RAWPA	Risk Assessment Work Plan Addendum
RCRA	Resource Conservation and Recovery Act
RfC	reference dose concentration
RfD	reference dose
RI	remedial investigation

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

RI/FS	remedial investigation/feasibility study
RME	reasonable maximum exposure
Rn	radon
ROD	Record of Decision
RPD	relative percent difference
RSC	relative source contribution
s	second
SHPO	State Historic Preservation Officer
SOWC	Southwestern Ohio Water Company
SQL	sample quantitation limit
SRHLWC	Savannah River High Level Waste Criteria
SWCR	Site-Wide Characterization Report
SWIFT	Sandia Waste Isolation Flow and Transport (computer model)
SWMU	solid waste management unit
SWOAPCA	Southwestern Ohio Air Pollution Control Agency
TBC	to-be-considered (requirements)
Tc	technetium
TCDD	tetrachlorodibenzo-p-dioxin
TCE	tetrachloroethylene
TCLP	toxicity characteristic leaching procedure
Th	thorium
TPD	tons per day
TSCA	Toxic Substances Control Act
TSDF	treatment storage and disposal facility
U	uranium
UAP	uranium ammonium phosphate
UCL	upper confidence level
UCS	unconfined compressive strength
UF_4	uranium tetrafluoride (green salt)
UMTRA	Uranium Mill Tailings Remediation Act

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

UO_3	uranium oxide (orange oxide)
USC	U.S. Code
USDA	U.S. Department of Agriculture
USLE	universal soil loss equation
V	vertical
VOC	volatile organic compound
WEMCO	Westinghouse Environmental Management Company of Ohio
WMCO	Westinghouse Materials Company of Ohio
yd^3	cubic yards
yr	year

EXECUTIVE SUMMARY

INTRODUCTION

This feasibility study (FS) has been prepared to support the decision-making process for remediation of the Fernald Environmental Management Project (FEMP) Operable Unit 1, known as the Waste Pit Area. The Fernald site consists of a 425-hectare (1,050-acre) area about 29 kilometers (18 miles) northwest of Cincinnati in southwestern Ohio. The FEMP is listed on the National Priorities List of the U.S. Environmental Protection Agency (EPA), meaning it has high priority for cleanup attention. The U.S. Department of Energy (DOE) is responsible for cleanup activities at the site under its Environmental Restoration and Waste Management Program.

Formerly known as the Feed Materials Production Center, the Fernald facility operated from 1952 to 1989. The facility's primary function was to provide high-purity uranium metal products to support U.S. defense programs. Production operations were suspended in 1989 and focus shifted to environmental restoration and waste management activities at the site. As a result of past processing and disposal activities, the site became radioactively and chemically contaminated.

The Remedial Investigation/Feasibility Study (RI/FS) at the Fernald site is conducted in accordance with the terms of the 1991 Amended Consent Agreement between DOE and EPA entered into under Sections 120 and 106(a) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended. The objective of the RI/FS process is to gather and evaluate information to support a decision about which cleanup remedy is the most appropriate action for addressing the environmental concerns identified at the FEMP. The Ohio Environmental Protection Agency (OEPA) is also participating in the RI/FS process at the Fernald site.

The FEMP must also comply with the requirements of the Resource Conservation and Recovery Act (RCRA). Any RCRA closure requirements that must be met will be incorporated into the CERCLA process.

For remedial action sites, it is DOE policy to integrate National Environmental Policy Act (NEPA) values into the procedural requirements of CERCLA, wherever practicable. To support cleanup decisions for contaminated material at the Fernald site, RI/FS documents under CERCLA have been written to incorporate NEPA values. The content of the documents prepared for this project is not intended to represent a statement on the legal applicability of NEPA to remedial actions conducted under CERCLA.

This Feasibility Study has integrated NEPA requirements at the level of an Environmental Assessment. The Operable Unit 1 Feasibility Study, with the Proposed Plan, constitutes the Environmental Assessment. Thus, this report is identified as the Operable Unit 1 Feasibility Study/Proposed Plan-Environmental Assessment (FS/PP-EA). The Feasibility Study and Proposed Plan contain the NEPA impact analysis for each remedial alternative for Operable Unit 1; the discussion of any potential impacts is provided in Section 4.0 of the Feasibility Study and Section 6.0 of the Proposed Plan. In addition, this Feasibility Study provides the NEPA cumulative impact analyses associated with implementing cleanup actions for each of the five operable units. The resources analyzed to determine potential impacts include socioeconomic, environmental, and cultural. For NEPA purposes, Operable Unit 1 will undergo the EA process. At the completion of this process, a determination will be made as to whether an EIS is necessary or whether the proposed action would have no significant impacts resulting in the issuance of a Finding of No Significant Impact (FONSI).

Under the terms of the Amended Consent Agreement, cleanup activities have been categorized by environmental issues into five study areas, called operable units. Remediation of each operable unit is an incremental step toward comprehensively addressing Fernald site problems. Distinct RI/FS documents are being developed for each of the five operable units. Those documents include:

- The Remedial Investigation, which presents information on the nature and extent of contamination
- The Baseline Risk Assessment, which evaluates health and environmental effects that might occur if no cleanup action were taken
- The Feasibility Study, which evaluates alternatives for cleanup

- The Proposed Plan, which summarizes key information from the Remedial Investigation, Baseline Risk Assessment, and Feasibility Study, and identifies the preferred alternative for remedial action
- The Responsiveness Summary, which provides responses to public comments to the Proposed Plan
- The Environmental Assessment, which addresses NEPA values
- The Record of Decision, which documents the cleanup decisions made for each operable unit

The Remedial Investigation and Baseline Risk Assessment for Operable Unit 1 were published in draft in October 1993 and have been revised to reflect comments from EPA and OEPA. The revised drafts were submitted to EPA and OEPA on February 8, 1994 (DOE 1994a). These documents, as well as the Site-Wide Characterization Report (DOE 1993b), are incorporated into the Operable Unit 1 Feasibility Study/Environmental Assessment by reference. The results of the feasibility study, when combined with input from support agencies and from the general public on the preferred remedial alternative and the other remedial alternatives identified in the Proposed Plan, will form the basis for selecting the remedial action. Input from the public and other interested parties will be obtained during the time frame that the Proposed Plan will be available for public review and comment—during the summer of 1994 and documented in the Responsiveness Summary. The alternative(s) selected for implementation will be documented in the Record of Decision for Operable Unit 1, a draft of which is scheduled to be submitted to EPA and OEPA on November 6, 1994. Operable Unit 1 reports are available in the Administrative Record, located near the FEMP in the JAMTEK Building, 10845 Hamilton-Cleves Highway, Harrison, Ohio, 45030.

OPERABLE UNIT 1 DESCRIPTION

Operable Unit 1 known as the Waste Pit Area—a well-defined 37.7-acre area located in the northwest portion of the FEMP property.

Operable Unit 1 is located within the Waste Storage Area, west of the former Production Area. Operable Unit 1 consists of the following site facilities and their associated environmental media:

- Waste Pits 1 through 6 and their contents

- Burn Pit and its contents
- Clearwell and its contents
- Miscellaneous structures and facilities such as berms, liners, concrete pads, underground piping, utilities, and fencing

This feasibility study presents information to support selection of the most appropriate cleanup remedy for Operable Unit 1. The analyses in this report address: (1) remedial technologies that could be applied to the various contaminated media, including the practicability of various treatment options; (2) the specific areas and media to be remediated; (3) the goals for cleanup levels; (4) potential health and environmental impacts associated with cleanup; and (5) the disposal location for contaminated material generated by site cleanup activities.

To facilitate the analyses in this FS, the components of Operable Unit 1 were grouped into three categories:

- Waste pit contents and associated material, which includes the contents of Waste Pits 1 through 6, the contents of the Clearwell and the Burn Pit, pit liners, berms and grossly contaminated portions of the pit covers. The feasibility study identifies a full range of potential process options and technologies and screens them to develop preliminary remedial alternatives. These identified preliminary remedial alternatives are further screened with a detailed analysis completed in the FS for those alternatives surviving the screening process.
- Residual water, which includes surface water, perched groundwater incidental to waste pit remediation, and residual process water. Treatment of residual water would be performed at the FEMP Advanced Wastewater Treatment (AWWT) facility. Operable Unit 1 would be responsible for extraction and conveyance of residual water to the AWWT facility. The AWWT has been designed to handle these types of flows and has sufficient excess capacity. This is discussed in Section 3.0 of the FS. This strategy for addressing residual water is common to all alternatives undergoing detailed analysis in the FS.
- Contaminated surface soil and soils beneath the waste pits. Proposed remediation levels will be established for these soils and those with contamination above these levels will be excavated. Operable Unit 5 has taken the lead in evaluating remedial alternatives most appropriate to this type of waste stream. This includes completion of ongoing treatability studies.

These soils will be managed following excavation by the methodologies specified in the Operable Unit 5 Record of Decision for the process area soils. Depending on the final remedy selected by Operable Unit 5 for the soils, some of the less contaminated waste pit cover soils may also be managed in this fashion. This strategy is common to all alternatives undergoing detailed analysis in the feasibility study.

Groundwater in the Great Miami Aquifer is not addressed as a source medium within this Operable Unit 1 Feasibility Study. Potential remediation of groundwater contamination for the entire FEMP site is being addressed as part of Operable Unit 5. Thus, within this report, groundwater is considered as an environmental receptor medium.

OPERABLE UNIT 1 REMEDIAL INVESTIGATION AND BASELINE RISK ASSESSMENT CONCLUSIONS RELEVANT TO THE FEASIBILITY STUDY

As stated earlier, the Operable Unit 1 Draft Final Remedial Investigation Report, inclusive of the Operable Unit 1 Baseline Risk Assessment, has been forwarded to the U.S. and Ohio EPA. The baseline risk assessment concluded that the wastes of Operable Unit 1 present a potentially unacceptable risk to human health and the environment. As discussed earlier, the FS identifies and evaluates a range of alternatives to implement required remedial action to address this potential risk. While all the findings of the RI are relevant to the FS, the following general findings are particularly important in developing and evaluating remedial alternatives:

- First, there is a very large volume (over 600,000 cubic yards) of contaminated material associated with the waste pits.
- Second, the waste pit contents are heterogeneous both in terms of contaminant type and concentration and also in the physical makeup of the wastes.
- Third, that while there is a potential increased risk associated with direct contact exposures, a principal potential threat is associated with exposure to groundwater contaminated by the waste pits. Two important findings are associated with this. Large volumes of contaminated pit materials are in very close proximity to the geologic formation of the sole-source Great Miami Aquifer. In addition, significant portions of the waste pit contents exhibit an elevated moisture content (some are saturated) meaning that there is a large pool of contaminated leachate available for migration into the aquifer formation.

- Finally, while radiological contaminants are the principal sources of risk, there are also potentially unacceptable risks associated with volatile and semi-volatile organic chemicals and heavy metals. Elevated concentrations of these contaminants are found in each of the waste pits. The potential implementability and effectiveness of the identified remedial alternatives must be evaluated in specific consideration of the above findings.

FEASIBILITY STUDY PROCESS AND CONCLUSIONS

Remedial action objectives (RAOs) have been developed for each of the contaminated media within Operable Unit 1. At the most general level, these RAOs (provided in Section 2.0 of this FS), can be summarized as eliminating or reducing to acceptable levels human and ecological exposure to contaminated media. Proposed remediation levels for surface soils and soils beneath the pits are established in Section 2.0 of the FS. These levels will be finalized in the Operable Unit 5 Record of Decision (see Section 2.2).

In light of the Operable Unit 1-specific characteristics and factors described above, a wide range of potential remedial technologies and process options are identified. In Section 2.0 of the FS, these individual technologies and process options are screened against the criteria of effectiveness, implementability and cost. As an example of this process, bioremediation was identified as a potential remedial technology. But because biological treatment is not effective in addressing the principal threats associated with radioactivity, this option is one of many that were not retained for detailed analysis in the FS. Other options, however, such as a variety of mechanical waste removal technologies, were considered potentially viable for Operable Unit 1. Section 2.0 documents how technologies and process options were evaluated and identifies those that survived the screening. Table 2-2 in the FS provides a concise list of the initial screening of technologies and process options for Operable Unit 1.

Once the technologies and process options are screened, those surviving the screening process are combined to form preliminary remedial alternatives. Eight cleanup remedies initially were developed in this FS. Section 3.0 discusses how the preliminary remedial alternatives identified in this report were developed and screened. It also identifies and explains the differences in the FS analyses and those performed in the Operable Unit 1 Initial Screening of Alternatives (ISA) Report, completed in

1991. As explained in Section 3.0, the FS is based on a base of information that is more developed than what was available at the time the ISA Report was prepared. Table 3.1 identifies the technologies and options assembled to form cleanup alternatives.

Preliminary Remedial Alternatives

The eight preliminary remedial alternatives that were identified are:

- Alternative 1 -- No Action
  - Under this alternative, no further action would be taken at Operable Unit 1. The No-Action Alternative was retained to provide a baseline for comparison in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).
- Alternative 2 - In Situ Containment
  - Under this alternative, the waste would be isolated by slurry walls and subsurface drains at the perimeter of the pits and by an infiltration-limiting multimedia cap over the pit area.
- Alternative 3 - In Situ Treatment and Containment
  - This alternative is identical to Alternative 2 with the addition of a waste solidification step. Waste solidification would involve mixing grout with the upper portions of selected pits.
- Alternative 4 -- Removal, Treatment, and On-Property Disposal

  Alternative 4A -- Treatment Consists of Vitrification
  - Under this alternative, wastes would be turned into a glass-like matrix and placed in an engineered disposal cell at the Fernald site.

  Alternative 4B -- Treatment Consists of Cement Solidification
  - Under this alternative, the waste would be cement solidified and placed in an engineered disposal cell at the Fernald site.

  Alternative 4C -- Treatment Consists of Thermal Drying
  - Under this alternative the wastes would be dried with no additional treatment and placed in an engineered disposal vault at the Fernald Site.
- Alternative 5 -- Removal, Treatment Consisting of Thermal Drying, and Disposal Off Site

  Alternative 5A -- Disposal at the Nevada Test Site
  - Under this alternative, the waste would be excavated, treated by drying to meet waste acceptance criteria, and shipped by rail to a point near Las Vegas and then trucked to the Nevada Test Site for disposal.

Alternative 5B -- Disposal at a Representative Permitted Commercial Disposal Facility

- Under this alternative, the waste also would be excavated and treated by drying to meet waste acceptance criteria, then shipped by rail to a representative permitted commercial disposal facility.

Institutional controls are an element in each of these alternatives.

Results of Detailed and Comparative Analyses

These preliminary remedial alternatives were screened, again using the criteria of effectiveness, implementability, and cost. On the basis of this screening, Alternatives 1, 4A, 4B, 5A, and 5B were judged to be appropriate for consideration in the detailed analysis portion of this feasibility study. Alternatives 2, 3, and 4C were screened out for further consideration. The basis for screening out these alternatives is discussed in detail in Section 3.0 of the FS. In summary, Alternatives 2 and 3 were judged to be ineffective in mitigating potentially unacceptable impacts to the Great Miami Aquifer. Alternative 4 C was screened out because it added no value over that presented by Alternative 4B but it had a slightly higher cost and short-term risk potential.

The objectives of the detailed/comparative analysis are: (1) to further define the reasonable alternatives that have been carried forward from the alternative screening phase of the CERCLA process; (2) to individually assess each alternative against the evaluation criteria as specified in the NCP (40 CFR 300.430); and (3) to compare alternatives with each other to assess the relative performance of each alternative with respect to each evaluation criterion.

Nine evaluation criteria have been developed to address the CERCLA requirements as stated in the NCP (40 CFR 300.430). They are:

Threshold Criteria

- Overall protection of human health and the environment
- Compliance with applicable or relevant and appropriate requirements (ARARs)

Assessments against these two criteria relate directly to evaluation against regulatory requirements. An alternative must satisfy these threshold criteria to be selected as a remedial action.

Balancing Criteria

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

Modifying Criteria

- State acceptance
- Community acceptance

The final two modifying criteria will be evaluated following public and agency comments on the Proposed Plan and will be addressed in the Record of Decision once a final remedial action decision is made.

Except for the No-Action Alternative, the remedial alternatives for Operable Unit 1 would provide a permanent solution to the environmental problems in Operable Unit 1. Each action alternative would reduce exposures and risks to humans and the environment by removing sources of contamination, treating the waste, and isolating the treated materials from the environment in a disposal facility. For each of the remedial alternatives, an equal degree of protectiveness of human health and the environment is provided by removal of contaminated pit wastes and soils to attain health-based action levels. That protectiveness is maintained in Alternatives 4A and 4B by treating the waste to limit contaminant mobility. The wastes are then disposed in a facility designed to preclude human and ecological intrusion and to reduce impacts to groundwater to acceptable levels. Protectiveness is maintained in Alternatives 5A and 5B by drying the wastes and disposing of them at engineered disposal facilities in the arid west where, due to harsh climatic conditions, there are no resident human populations in the immediate vicinity or usable surface water or groundwater resources.

With one exception, all of the action alternatives can be designed to meet identified ARARs. The exception involves Alternatives 4A and 4B. Specifically, the State of Ohio, at OAC 3745-27-07(B)(5), prohibits sanitary waste landfills from being constructed over sole source aquifers. The Great Miami Aquifer beneath the site has been designated a sole source aquifer. This citation has been determined to be relevant and appropriate to Operable Unit 1 remedial actions. Accordingly, a waiver or exemption from this regulation would be required to implement either Alternative 4A or 4B.

Two options were considered for the primary treatment technology for Alternatives 4A and 4B. The first is chemical stabilization/solidification, which would involve mixing the waste with cement to generate a cement-like product. The second is treatment by vitrification, which would involve melting the waste in a ceramic melter to generate a fritted glass-like product. Prior to both vitrification and cement solidification, the wastes would be dried. The primary treatment for Alternatives 5A and 5B is physical treatment in the form of drying. Alternatives 4A and 4B offer significant advantages in reduction in contaminant mobility over Alternatives 5A and 5B. Alternative 4A is the most advantageous relative to reduction in toxicity because, due to the high temperatures involved, any residual volatile organics and some semi-volatile organics can be destroyed. There is no significant difference among the other alternatives in reduction in toxicity through treatment. Cement solidification would result in a significant volume increase while each of the other alternatives would realize a slight decrease in volume.

As designed, all action alternatives provide an adequate measure of long-term effectiveness and permanence. This is accomplished by the removal of contaminated materials, and by treatment and disposal in an engineered facility. Alternatives 5A and 5B would be equally effective at reducing residual risks permanently. They are also more effective than Alternatives 4A and 4B, since the pit waste material would be removed from the site. Of particular note is the fact that in the event of releases from the disposed wastes in Alternatives 5A and 5B, the likelihood of impacting receptors is very low due to harsh socioeconomic and climatic factors at the disposal facility. Releases from disposed waste in failure scenarios for Alternatives 4A and 4B represent a more significant threat

primarily due to the presence of the sole source Great Miami Aquifer and a large nearby residential population.

The technical implementability of Alternatives 5A and 5B is judged to be equal and relatively straightforward as the principal remedial elements (excavation, drying, transportation) are robust technologies that are routinely implemented in industry. Waste heterogeneity should not significantly impact the ability to implement these alternatives. There are greater uncertainties associated with the technical implementability of Alternatives 4A and 4B. Appendix C of this document summarizes treatability work specific to these alternatives. Cement solidification has been previously applied to low-level radioactive wastes at other sites with varying degrees of success. The cement solidification facility would be difficult to operate due to the heterogeneous nature of the wastes in the pits. Heterogeneity also impacts the implementability of vitrification. There are additional uncertainties associated with vitrification because a full-scale facility for vitrification of wastes similar to those in Operable Unit 1 has not been constructed elsewhere. The start-up of a first-of-a-kind facility is expected to be difficult. There are no known administrative barriers against implementation of Alternatives 4A and 4B, except for the ARAR issue of the state prohibition against on-property disposal over a sole-source aquifer. Obtaining a waiver or exemption from this regulation would be moderately difficult. While Alternatives 5A and 5B must comply with a variety of transportation regulations, there are no known regulations which would prohibit shipment of Operable Unit 1 wastes.

The short-term risks (excluding transportation) to off-site individuals and non-remediation workers would be approximately the same for all four action alternatives. During transportation of waste materials, Alternative 5A would result in slightly higher risks to communities along the transportation route than Alternative 5B. No transportation risks are associated with Alternatives 4A and 4B. The short-term risks (excluding transportation) to remediation workers would be approximately the same for Alternatives 4A and 4B, with 4B having a slightly higher potential for accidents than 4A. The short-term risks for on-site workers of Alternatives 5A and 5B (excluding transportation and package handling) would be equal, and somewhat lower than Alternatives 4A and 4B, due to the higher potential for accidents associated with on-property disposal. However, there would be the potential

for exposures and accidents associated with transportation and package handling. Taking these risks into account, Alternative 5A would have higher dose equivalents and potential accidents for remediation workers than any of the other action alternatives. Alternative 5B, with less waste handling, would have the potential for substantially fewer accidents than the other alternatives, even after the addition of risks associated with transportation.

Cost estimates are used in the feasibility study process under CERCLA to eliminate those remediation alternatives which are significantly more expensive than competing alternatives but do not offer commensurate performance or overall protection of human health and the environment. The cost estimates developed are order-of-magnitude estimates with an intended accuracy range of -30 to +50 percent. Estimates are considered to be order-of-magnitude because of the uncertainties in the information used to develop the estimates.

The estimated present value costs are:

- Alternative 1: $0
- Alternative 4A: $446,690,000
- Alternative 4B: $388,609,000
- Alternative 5A: $645,870,000
- Alternative 5B: $348,202,000

Section 4.0 of the feasibility study describes in detail and compares each alternative to the above evaluation criteria.

ORGANIZATION OF THE FEASIBILITY STUDY

The Operable Unit 1 Feasibility Study includes five sections and 10 appendices, as follows:

- Section 1.0, Introduction
  - Contains information about the purpose and organization of the report; site background; and a summary of Operable Unit 1 nature and extent of contamination, contaminant fate and transport, and baseline risk assessment
- Section 2.0, Identification and Screening of Technologies and Processes
  - Identifies the range of cleanup technologies and process options that were developed into preliminary remedial alternatives and documents how the technologies were evaluated

- Section 3.0, Development and Screening of Alternatives
  - Presents the development and screening of remedial alternatives assembled from combinations of the technologies and process options evaluated in Section 2.0
- Section 4.0, Detailed Analysis of Alternatives
  - Discusses the detailed analysis of the alternatives that passed the screening process, evaluating each alternative against the nine EPA criteria; NEPA impact analysis for each alternative has been integrated into this section.
- Section 5.0, Comparative Analysis
  - Compares the final remedial action alternatives; distinguishes the relative advantages and disadvantages of each alternative so that the preferred remedial action can be identified in the Proposed Plan
- Appendix A, Operable Unit 1 Remedial Investigation Data Summary
  - Summarizes information contained in the Remedial Investigation about the nature and extent of contamination in Operable Unit 1
- Appendix B, Description of Technologies and Process Options
  - Describes the representative technologies and process options evaluated for Operable Unit 1 wastes
- Appendix C, Treatability Studies for Operable Unit 1
  - Summarizes studies of treatment options for Operable Unit 1 wastes
- Appendix D, Public Health and Occupational Risk Consideration
  - Evaluates residual risks associated with the action alternatives
- Appendix E, Cost Estimates
  - Discusses the costs, and the assumptions made in estimating those costs, for the various remedial alternatives
- Appendix F, Analysis of Potential ARARs for Operable Unit 1
  - Identifies and evaluates the Applicable, Relevant, and Appropriate Requirements that apply to Operable Unit 1 and analyzes compliance with these requirements
- Appendix G, NEPA Cumulative Impact Analysis
  - Discusses the impacts, including socioeconomic, etc., of Operable Unit 1 remediation
- Appendix H, Wetland/Floodplain Assessment
  - Discusses the assessment of impacts to wetlands, as required by federal regulations
- Appendix I, Comprehensive Response Action Risk Evaluation
  - Evaluates the total cumulative residual risk to human health estimated to remain after the proposed cleanup of the Fernald site is complete

- Appendix J, Waste Acceptance Criteria
  - Discusses the acceptance criteria for waste at the Nevada Test Site and the representative permitted commercial disposal facility

Generally, it is expected that the preferred remedial action alternative identified in the Proposed Plan for Operable Unit 1 will consist of the alternative that performs best when evaluated against the nine criteria. The Proposed Plan will be issued for public review and comment with Operable Unit 1's integrated Feasibility Study/Proposed Plan-Environmental Assessment (this document). The final remedy for Operable Unit 1 will be determined after public consideration of the Proposed Plan and review of any significant new information that may become available subsequent to submittal of the Feasibility Study/Proposed Plan-Environmental Assessment. The alternatives selected for implementation will be documented in the Operable Unit 1 Record of Decision.

1.0 INTRODUCTION

1.1 PURPOSE AND ORGANIZATION OF REPORT

This report documents the feasibility study (FS) phase of the Remedial Investigation/Feasibility Study (RI/FS) for Operable Unit 1, Waste Pit Area, at the U.S. Department of Energy (DOE) Fernald Environmental Management Project (FEMP). This phase of the RI/FS process includes development, screening, and detailed analysis of alternatives considered for remediation of Operable Unit 1. The FS report provides the necessary information to support the decision regarding the appropriate remedy for Operable Unit 1.

The purpose of this FS report is to evaluate a range of available Remedial Action Alternatives for the permanent disposition of the Operable Unit 1 waste pit material and associated contaminated environmental media, and to provide a basis for selection of a remedy. The DOE has determined that the National Environmental Policy Act (NEPA) must be complied with, therefore NEPA has been addressed in this report. This report is referred to as the Operable Unit 1 Feasibility Study-Environmental Assessment (FS-EA).

1.1.1 Purpose

1.1.1.1 Compliance with CERCLA

The FEMP, formerly known as the Feed Materials Production Center (FMPC), is owned by the DOE and was operated from 1952 until 1989, as a uranium processing facility providing high-purity uranium metal products in support of United States defense programs. The FEMP is located in southwestern Ohio about 29 kilometers (18 miles) northwest of the city of Cincinnati, Ohio (Figure 1-1). Production operations were halted in 1989 to focus available resources on environmental restoration initiatives at the facility, including the RI/FS. It is being conducted pursuant to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) as amended by the Superfund Amendments Reauthorization Act (SARA), jointly referred to as CERCLA and in accordance with the Consent Agreement (as amended) between the U.S. Environmental Protection Agency (EPA) and the DOE. The Amended Consent Agreement calls for cleanup actions to address identified environmental concerns at the FEMP. These concerns have been identified by the DOE, EPA, the Ohio Environmental Protection Agency (OEPA), and community members. These concerns

have included potential impacts on human health and the environment from past releases of hazardous materials from the FEMP to air, water, and the surrounding soils; continuing releases of hazardous materials from the facility; and the on-site accumulation of a large inventory of uranium process materials and low-level radioactive and hazardous wastes at the site. On the basis of these concerns and an evaluation of existing environmental data, the FEMP was placed by EPA on the National Priorities List (NPL) in November 1989. Inclusion in the NPL reflects the relative importance placed by the federal government on ensuring the expedient completion of the RI/FS and resulting remedial actions at the FEMP.

To promote a more structured and expeditious cleanup of the FEMP site, in accordance with a 1990 Consent Agreement between EPA and DOE, the facility and environmental issues associated with the site are being managed as five operable units. The term "operable unit" identifies a logical grouping of environmental issues at a cleanup site. Discrete RI/FS studies and reports are being completed for each of the operable units. Operable Unit 1 is a well-defined, 37.7-acre area located in the northwest quadrant of the FEMP site (depicted in Figure 1-2) and consists of the following FEMP facilities and associated environmental media:

- Waste Pits 1 through 6, the Burn Pit, Clearwell, and associated materials
- Associated Environmental Media. These media include surface water, soils, air, flora and fauna of the immediate area.

The RI/FS process at the FEMP includes the following primary components:

- Remedial Investigation (RI)/Baseline Risk Assessment presents information on existing conditions at the site, defines the nature and extent of contamination, and assesses risks to human health and the environment due to existing environmental conditions.
- Feasibility Study (FS) develops, screens, and evaluates remedial technologies and alternatives for potential implementation to address identified environmental concerns.
- Proposed Plan (PP) summarizes the proposed remedial alternative for implementation at a specific operable unit based on information assessed in the FS. It facilitates input from the public and other interested parties in the decision-making process. Each operable unit's PP will summarize key information from the RI, Baseline Risk Assessment, and Comprehensive Response Action Risk Evaluation (CRARE), and will identify the preferred comprehensive alternative for remedial action. In addition, the PP will provide a summary of the environmental impacts from implementation of the preferred alternative. Note that there is not

a specific CRARE for Operable Unit 1 is not included in this draft FS report. The reasons for this are discussed in Section 1.1.3.

- Record of Decision (ROD) which is issued by EPA and is responsive to public comments on the PP, documents the selection of the remedial alternative, and defines proposed remediation levels and long-term monitoring requirements.

These integrated components are shown in Figure 1-3.

The other four operable units of the FEMP for which RI/FS documents are being compiled are defined as:

- Operable Unit 2 - Flyash piles, other South Field disposal areas, lime sludge ponds, solid waste landfill, berms, liners, and soil within the operable unit boundary as approved in the RI/FS Work Plan Addendum.

- Operable Unit 3 - The Former Production Area and production-associated facilities and equipment (includes all above- and below-grade improvements) including, but not limited to, all structures, equipment, utilities, drums, tanks, solid waste, waste, product, thorium, effluent lines, a portion of the K-65 transfer line, wastewater treatment facilities, fire training facilities, scrap metal piles, feedstocks, and coal pile.

- Operable Unit 4 - Silos 1, 2, 3, and 4, berms, decant sump tank system, and soil within the operable unit boundary as approved in the RI/FS Work Plan Addendum.

- Operable Unit 5 - Environmental media including groundwater, surface water, and soil not remediated in Operable Unit 1 through Operable Unit 4.

Following the issuance of the ROD for the last of the five operable units, the Amended Consent Agreement provides for a Comprehensive Site-Wide Operable Unit (Operable Unit 6). The Comprehensive Site-Wide Operable Unit will include completion of a risk assessment to evaluate the residual risk projected to remain after the remedies selected for the five operable units have been implemented. The intent of the risk assessment is to provide a final examination of site-wide residual risks to ensure protection of human health and the environment from a site-wide perspective. If the risk assessment deems that the residual risk has been sufficiently reduced to reach levels that are protective of human health and the environment after implementation of the five remedies, a no-action ROD will be issued for the Comprehensive Site-Wide Operable Unit. If the risk evaluation deems the projected residual risk for the five selected remedies to not be protective, a Comprehensive Site-Wide Operable Unit FS will be conducted. The focus of this FS would be to determine what, if any,

supplemental actions must be undertaken by one or more of the five operable units to reduce overall site risks to acceptable levels.

The objectives of the Operable Unit 1 RI report were to develop a detailed characterization of the waste pit materials, their impacts on the surrounding environment, and the threat that Operable Unit 1 facilities may pose to human health and the environment. Section 1.2 goes into some detail in summarizing the findings of the RI Report, inclusive of the baseline risk assessment. The baseline risk assessment concluded that the wastes of Operable Unit 1 present a potentially unacceptable risk to human health and the environment and must be remediated.

As discussed earlier, the FS identifies and evaluates a range of alternatives to implement remedial action. While all the findings of the RI are relevant to the FS, a number of general conclusions are particularly important in developing and evaluating remedial alternatives.

- First, there is a very large volume (over 600,000 cubic yards) of contaminated material associated with the waste pits.

- Second, the waste pit contents are very heterogeneous both in terms of contaminant type and concentration and also in the physical makeup of the wastes. There is significant variability in the degree of waste stratification and the amount and location of debris in the pits.

- Third, while there is a potential increased risk associated with direct contact type exposures, a principal potential threat is associated with exposure to groundwater contaminated by the waste pits. There are two especially important findings associated with this conclusion:

  (1) large volumes of contaminated pit materials are in very close proximity to the geologic formation of the sole source Great Miami Aquifer.

  (2) In addition, the waste pit contents generally exhibit elevated moisture content, including significant zones of saturation, meaning that there is a large pool of contaminated leachate already available for migration into the aquifer formation.

- Finally, while radiological contaminants are the principal sources of risk, there are also potentially unacceptable risks associated with volatile and semi-volatile organic chemicals and heavy metals. The potential implementability and effectiveness of the identified remedial alternatives must be evaluated in specific consideration of the above findings.

1.1.1.2 CERCLA and NEPA Integration

Consistent with DOE Order 5400.4, the FEMP is integrating the values of NEPA into RI/FS documentation. RI/FS documents prepared under CERCLA to support cleanup decisions for each operable unit are being written to reflect these values. On May 15, 1990, a Notice of Intent (NOI) was published in the Federal Register (FR), which outlined the NEPA/CERCLA integration approach to evaluate the environmental impacts associated with planned cleanup activities at the site. As identified in the NOI, the FS for the lead FEMP operable unit (Operable Unit 4), was issued as a Feasibility Study-Environmental Impact Statement (FS-EIS); it has been written to incorporate NEPA values at the level of an EIS. Furthermore, the RI/FS documents for the remaining operable units were also written to include NEPA values and to tier from the Operable Unit 4 FS-EIS (Figure 1-4).

This strategy is also outlined in the Implementation Plan for the NEPA/CERCLA integration activities at the FEMP. This plan was conditionally approved by DOE-Headquarters EH-1 on January 19, 1993. The purpose of the Implementation Plan is to record the results of the scoping process and to provide guidance to DOE for the preparation of the Lead FS-EIS for Operable Unit 4 and integrated NEPA/CERCLA documents for the remaining operable units.

The RI reports for Operable Unit 1 and the other operable units contain or will contain characterization data for the specific operable unit and nearby environment media, and will support the description of the affected environment for NEPA purposes. In addition, the RI report will contain a baseline risk assessment addressing the impact on human health that would be associated with the no-action alternative for the specific operable unit. Since the Site-Wide Characterization Report (SWCR) was published, additional human health risk information has been obtained and is provided in the baseline risk assessment included in the RI report. The ecological risk assessment in the SWCR addresses the entire FEMP and is based on data collected in each operable unit before December 1991. Since then, no new ecological data have been collected for Operable Unit 1. Environmental media not directly related to Operable Units 1, 2, 3, or 4 will be addressed in a "second iteration" of the site-wide ecological risk assessment and will be included by definition in the Operable Unit 5 RI.

FS documents prepared for Operable Unit 1 and the other operable units will incorporate NEPA values. The NEPA evaluation for the specific operable units will contain the impact analysis of each remedial alternative for that particular operable unit.

The evaluation of environmental impacts in this report (the Operable Unit 1 FS-EA) include: a discussion of the impacts to biotic resources, cultural resources, etc.; a floodplain/wetlands assessment pursuant to the requirements of Title 10 Part 1022 of the Code of Federal Regulations (10 CFR 1022) as appropriate; and a qualitative evaluation of ecological risks associated with Operable Unit 1 residual contaminants. The NEPA impact analysis of each alternative is integrated into Section 4.0, Detailed Analysis of Alternatives, of this report and will likewise occur in the FS documents for the remaining operable units. In addition, the Operable Unit 1 FS-EA has been supplemented to incorporate evaluation of the environmental consequences, consistent with NEPA, of implementing the Operable Unit 1 preferred remedial alternative with the leading remedial candidates for each of the other FEMP operable units (Appendix G). This discussion of the NEPA impact analysis related to potential remedial actions for the five operable units will be updated in each operable unit-specific FS-EA document, as appropriate, in sequence as each operable unit progresses through the RI/FS process.

Appendix G also contains a list of contributors and a list of agencies contacted pursuant to NEPA requirements. Appendix H contains a floodplain/wetland assessment pursuant to the requirements of 10 CFR 1022.

In accordance with both CERCLA and NEPA, these documents are made available to the public for comment. Public involvement is an important factor in the decision-making process for site remediation. Public comments will be considered in remedy selection for each operable unit. Applying the integrated approach for CERCLA and NEPA, the U.S. Department of Energy plans to prepare and issue a ROD to be signed by both DOE and EPA for Operable Unit 1, as well as individual Records of Decision for the other remaining operable units, for CERCLA purposes. For NEPA purposes, Operable Unit 1 will undergo the EA process. At the completion of this process, a determination will be made as to whether an EIS is necessary or that the proposed action would have no significant impacts, resulting in the issuance of a Finding of No Significant Impact as defined in

the Code of Federal Regulations. DOE's CERCLA/NEPA integration policy is not intended to represent a statement on the legal applicability of NEPA to remedial actions under CERCLA.

The DOE is currently preparing a programmatic EIS for environmental restoration and waste management nationwide. The document is expected to be issued as a draft for public comment. All proposed remedial actions at the FEMP are considered to qualify as interim action for the programmatic EIS under the conditions established in 40 CFR 1506.1(c). Presently, the Operable Unit 1 action proposed is considered an interim action because it is: (1) justified independently of the program, (2) accompanied by an adequate EA, (3) and will not prejudice the ultimate decision on the program by determining subsequent development or limiting alternatives. However, before issuing the ROD pursuant to the FS-EA for Operable Unit 1 at the FEMP, DOE will further review these conditions to ensure that they are met at that time.

1.1.1.3 CERCLA and RCRA Integration

Section VIII of the Amended Consent Agreement requires the DOE to integrate CERCLA response and corrective action obligations under the Resource Conservation and Recovery Act (RCRA). In addition, the Part B Permit Application requires the DOE to investigate releases from Solid Waste Management Units (SWMUs) as part of the RI/FS required for each operable unit identified under the CERCLA program. The document further states that if corrective action is required for SWMUs and Hazardous Waste Management Units (HWMUs), the corrective action will be part of the CERCLA program.

1.1.1.4 Report Organization

The FS report is organized as follows:

- The remainder of Section 1.0 presents a summary of the history, environmental setting, and the nature and extent of contamination associated with the FEMP site and Operable Unit 1. This summary is based on information from the RI Report for Operable Unit 1 (DOE 1993a). The section also presents a brief discussion of the human health impacts that might occur at the site and within Operable Unit 1 if no remedial actions are taken.

- Section 2.0 identifies the scope of proposed remedial actions for Operable Unit 1. It states the volume of waste and contaminated media being addressed, and the goals and objectives of proposed remedial actions. The section identifies potential technologies and available process options for managing the waste materials and contaminated media.

- Section 3.0 develops and screens preliminary remedial action alternatives (RAAs).

- Section 4.0 describes in more detail the remedial action alternatives surviving the screening in Section 3.0 and includes a detailed analysis of the alternatives employing criteria established by federal regulation. Each detailed analysis also includes an impact analysis of the affected environment pursuant to the requirements of NEPA.

- Section 5.0 presents a comparative analysis of the Remedial Action Alternatives evaluated in Section 4.0.

Figure 1-5 presents, by section, the topics of the FS. All figures and tables are found at the conclusion of the chapter in which they are first referenced.

In addition, the following appendices provide detailed information that support the discussions in Sections 1.0 through 5.0:

- Appendix A provides data summary tables from the Operable Unit 1 RI report.

- Appendix B describes the technologies and process options evaluated in Section 2.0.

- Appendix C summarizes relevant results of the Operable Unit 1 Treatability Study Report.

- Appendix D provides the technical approach to and results of the Operable Unit 1 FS risk evaluation.

- Appendix E provides remediation cost estimates and schedules that are incorporated into the analyses in Section 3.0 and 4.0.

- Appendix F identifies and evaluates applicable or relevant and appropriate requirements, referred to as ARARs, that must be met during the remediation of Operable Unit 1.

- Appendix G provides the NEPA-required analysis of the cumulative impacts associated with remediating Operable Unit 1 and the other operable units at the FEMP.

- Appendix H provides the NEPA-required assessment of floodplains and wetlands that may be impacted by remediating Operable Unit 1.

- Appendix I further explains the rationale for performing the Operable Unit 1 CRARE as part of the Operable Unit 2 CRARE; it also provides a summary of the risks associated with Operable Unit 1, as published in the Operable Unit 4 FS-EIS.

- Appendix J identifies and analyzes the potential for Operable Unit 1 waste to meet the waste acceptance criteria for the two off-site disposal facilities identified in Alternatives 5A and 5B.

The risk summary tables of the Operable Unit 4 Comprehensive Response Action Risk Evaluation (CRARE) are included in Appendix I to this FS report. This level of CRARE documentation is the result of an agreement between DOE and EPA reached in October 1993. This agreement is based on the following factors:

Operable Unit 1's contribution to overall site risks is, essentially, as documented in the Operable Unit 4 CRARE; i.e., the results are generally the same although there are some differences in the risk scenarios developed for Operable Unit 4 and Operable Unit 1. In its CRARE, Operable Unit 4 assumed an Operable Unit 1 Leading Remedial Alternative (LRA) to include excavating the pits, backfilling with clean soil, placing a low-permeability cover over the pit area, treating the waste and placing it in an on-site disposal facility. It is noted that the concept of a LRA was developed only to facilitate completion of the CRARE. Further, it is only applicable to operable units that have not selected (or established a preference for) a remedial alternative through the CERCLA process. While this FS does not establish a preferred alternative for Operable Unit 1, it does specify four alternatives for detailed analysis. Two of these alternatives are essentially identical to that assumed as the Operable Unit 1 LRA by Operable Unit 4. The other two involve off-site disposal of Operable Unit 1 wastes which would result in a lower residual risk because of the reduced volume of source material.

1.2 BACKGROUND INFORMATION

This section provides a brief summary, description and history of Operable Unit 1. The Operable Unit 1 RI Report and the SWCR are incorporated herein by reference. These are part of the FEMP Administrative Record which is located at the FEMP Public Information Office, 10845 Hamilton-Cleves Road, Harrison, Ohio, 45030.

1.2.1 Site Description

The FEMP is a 425-hectare (1,050-acre), government-owned, contractor-operated facility located in southwestern Ohio, approximately 29 kilometers (18 miles) northwest of downtown Cincinnati, Ohio. The facility is located just north of Fernald, Ohio, a small farming community, and lies on the boundary between Hamilton and Butler counties (Figure 1-1).

Production operations at the FEMP site were limited to a fenced in, 55 hectare (136 acre) tract of land known as the former Production Area, located near the center of the site. Large quantities of

liquid and solid wastes were generated by various operations at the FEMP site. Prior to 1984, solid and slurried wastes from FEMP processes were stored or disposed in the on-site Waste Storage Area. This area, located west of the production facilities, includes six low-level radioactive and chemical waste pits; two earthen-bermed concrete silos containing K-65 residues; one concrete silo containing metal oxides; one unused concrete silo; two lime sludge ponds; a Burn Pit; a Clearwell; and a solid waste landfill. The six waste storage pits, Burn Pit and Clearwell comprise Operable Unit 1. The remaining FEMP site areas consist of forest and pasturelands, of which a portion is being leased to a dairy farmer for livestock grazing.

The following is a brief presentation of the characteristics of the FEMP site and its surrounding environment. Included is a description of the physical, environmental, and demographic settings of the FEMP area. Topics discussed include air quality, climate, topography, seismology, surface water hydrology, geology, groundwater hydrology, soils, land use, population, vegetation, and wildlife. Additional detailed discussion on each of these subjects are available in the RI Report for Operable Unit 1.

Air Quality

National Ambient Air Quality Standards (NAAQS) are health-protective standards that apply to the six pollutants regulated under the Clean Air Act (CAA) of 1990: inhalable (PM 10) particulate, carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, and lead. Extensive monitoring has been performed by the Southwestern Ohio Air Pollution Control Agency (SWOAPCA) in urban locations where the highest concentrations within its four-county jurisdiction (Hamilton, Butler, Warren, and Clermont counties) are found. With the exception of ozone, pollutant concentrations at the FEMP site meet the NAAQS. Ozone is a widespread problem requiring regional control and abatement measures mandated by the CAA of 1990. Air quality standards for toxic compounds not regulated under the CAA are defined by individual states. The State of Ohio, acting through the SWOAPCA, evaluates emissions of chemically toxic compounds including ammonia, hydrogen fluoride, and nitric acid, all of which have been released from the FEMP site in small amounts. Estimates of the impacts to air quality resulting from releases from the FEMP site have been developed using air dispersion modeling. The results of this modeling, which are supported by site monitoring results, indicate that concentrations of air contaminants attributable to FEMP site operations have been within limits set by the State of Ohio in recent years, particularly since production ceased.

Meteorology

The FEMP has installed and maintains a site meteorological monitoring system. This system provides site-specific data for wind speed and direction, ambient air temperature, lapse rate, dew point, temperature, relative humidity, barometric pressure, and precipitation. The system was used by the National Oceanic and Atmospheric Administration (NOAA) to examine the complexity of the local wind field at the FEMP site.

Prevailing winds are generally from the southwest and west-southwest. Compiled wind rose information from the FEMP meteorological tower for the years 1987 through 1992 are available in Appendix D of the RI Report for Operable Unit 1.

As part of the probabilistic risk assessment performed for the FEMP (DOE 1989), an annual probability was assessed for a tornado occurring per square mile within Ohio. Based on data accumulated from Ohio during the years 1978 through 1990, the probability of a tornado occurring at the FEMP was calculated to be 1.248×10^{-4}.

The average annual precipitation for the Cincinnati area for the period of 1960 through 1989 was 103 centimeters (40.56 inches) and ranged from 71.1 centimeters (27.99 inches.) in 1963 to 134 centimeters (54.76 inches) 1979. The highest precipitation occurs during the spring and early summer. The maximum 24-hour rainfall event on record occurred in March 1964 when 13.2 centimeters (5.21 inches) fell. Precipitation is typically lowest in late summer and fall.

The average annual snowfall for the 1960 to 1989 period was 59.7 centimeters (23.5 inches), with the heaviest snowfall usually occurring in January. The maximum monthly snowfall of 80 centimeters (31.5 inches) occurred in January 1978.

The regional climate is defined as continental, with temperatures ranging from a monthly average of -1.57°C (29.2°F) in January to 24.5°C (75.7°F) in July. The highest temperature recorded from 1960 through 1989 was 39.8°C (103°F) in July 1988, and the lowest was -32°C (-25°F) in January 1977. Average ambient air temperatures measured at the FEMP meteorological station for the years 1987 through 1992 ranged from 10.5°C (50.7°F) to 13.1°C (55,4.°F), with the highest annual average daily maximum temperature of 18.5°C (65.1°F) and the lowest annual average daily

minimum temperature of 5°C (41°F). The average number of days per year with a maximum temperature of 0°C (32°F) is 109 days, and average number of days per year with a maximum temperature of 32°C (90°F) or greater is 20 days. Frost depth ranges from 76.2 to 91.4 centimeters (30 to 36 inches).

Topography and Surface Water

Maximum elevation along the northern boundary of the FEMP property is slightly over 213 meters (700 feet) above mean sea level (MSL). The former Production Area and Waste Storage Area rest on a relatively level plain approximately 177 meters (580 feet) above MSL. The plain slopes from 183 meters (600 feet) above MSL along the eastern boundary of the FEMP site to 178 meters (585 feet) above MSL at the center of the waste pit area. It then drops off toward Paddys Run at an elevation of 168 meters (550 feet) above MSL. All surface water drainage on the FEMP site is generally from west to east toward the Great Miami River.

Surface waters on and adjacent to the FEMP site are the Storm Sewer Outfall Ditch, Paddys Run, and the Great Miami River (Figure 1-6). The Storm Sewer Outfall Ditch originates within the FEMP site and flows in an unnamed tributary toward the southwest where it enters Paddys Run, which flows southward along the western boundary of the facility. Paddys Run, in turn, is a tributary of the Great Miami River. The Great Miami River flows generally toward the southwest. It is located to the east and south of the FEMP site.

The Storm Sewer Outfall Ditch historically has conveyed surface water runoff from the former production area directly into Paddys Run during periods of heavy precipitation when the pumping capacity of the FEMP storm sewer lift station has been exceeded. One such overflow location is a ditch found south of the K-65 silos.

Paddys Run originates north of the FEMP site, flows southward along the western boundary of the facility, and enters the Great Miami River approximately 2.4 kilometers (1.5 miles) south of the southwest corner of the FEMP property. The stream is approximately 14 kilometers (8.8 miles) long and drains an area of approximately 40.9 square kilometers (15.8 square miles). Due to the highly permeable channel bottom, the stream loses water to the underlying Great Miami Aquifer. The stream is intermittent and is generally dry during the summer months.

Paddys Run is a steep-sided stream, and its banks erode severely during high flow periods. In 1961 and 1962, the course of the stream was altered to prevent erosion into the Operable Unit 1 Study Area [Westinghouse Materials Company of Ohio (WMCO) 1987]. In 1970, a reach of the stream south of the K-65 Silos was straightened to prevent erosion of Paddys Run Road. The stream is ungauged, but typically flows from January through May and flow ranges from 5.7 to 113 liters per second (0.2 to 4.0 cubic feet per second). Channel overflow resulting from 25-year, 24-hour and 100-year, 24-hour storm events is possible, but peak flows occurring during storm events have not been measured.

The Great Miami River is the main surface water feature in the vicinity of the FEMP site and is the receiving water body from a National Pollutant Discharge Elimination System (NPDES)-permitted discharge from the FEMP site. The river flows generally to the southwest and has a drainage area of approximately 8702 square kilometers (3,360 square miles) at the Hamilton gauge, which is located about 16.1 kilometers (10 miles) upstream from the FEMP site discharge outfall.

The river exhibits meandering patterns that result in sharp directional changes over distances of less than 900 meters (2,952 feet). Directly east of the FEMP site and within the site-wide RI/FS Study Area, the river passes through a 180-degree curve known as the Big Bend. A 90-degree bend in the river also occurs near New Baltimore, approximately 3.2 kilometers (2 miles) downstream from the FEMP site discharge outfall.

Soil and Seismology

The Butler County and Hamilton County Soil Surveys [U.S. Department of Agriculture (USDA) 1980, 1982] have 15 specific soil series or types mapped within the FEMP site boundaries. The major series are Fincastle and Xenia silt loams, which cover large areas west of the FEMP. These soils are moderately high in productivity when properly managed. Moisture-supplying capacity is moderate, as is fertility and organic content.

The Fincastle series consists of deep, nearly level, and somewhat poorly drained soils on broad flats. Permeability is low and the available water capacity is high. These soils are associated with the former Production Area and with the pastures to the east and west of the facility. The Xenia soil

series is a deep, nearly level, moderately well drained soil located on till plains. Permeability is moderately low, available water capacity is high, and the runoff potential is low.

A seismic risk zone of one (a measurement of earthquake intensity on a scale of less-than-one to four) has been assigned to the FEMP region. An earthquake in the FEMP region could damage facilities and cause release of contaminants into the environment. Local geologic structures and historic seismicity are used to analyze the potential for seismic events and structural damage.

The presence of minor faults is not evident, but it cannot be dismissed because bedrock in the region is largely covered by Pleistocene sediment. Pre-Pleistocene fault traces could be obscured; however, the historic record of seismicity and the absence of post-Wisconsin faults indicate that significant local earthquakes are unlikely.

Geology and Groundwater

The following discussion provides a summary of the physiography, geologic history, and hydrogeological setting of the area of and surrounding the FEMP site.

Physiography

The FEMP site lies in the Till Plains section of the Central Lowland physiographic province. This province is characterized by structural and sedimentary basins and domes. The main physiographic features in the area are greatly rolling uplands, steep hillsides along the major streams, and the Great Miami River Valley. This valley is a relatively broad, flat-bottomed valley flanked on both sides by bluffs that rise to a maximum of 90 meters (300 feet) above the general level of the valley floor. The Great Miami Aquifer beneath the FEMP has been designated a sole source aquifer by the EPA.

Geologic History

In summary, the FEMP overlies a 3.2- to 4.8-kilometer (2- to 3-mile) wide buried Pleistocene valley known as the New Haven Trough. This valley was formed (eroded) by the ancestral Ohio River during the Pleistocene period and was subsequently filled with glacial outwash materials. These materials were in turn covered by glacial overburden as glaciers advanced across the area. The outwash deposits under the FEMP are a part of the Great Miami Aquifer, which is a widely

distributed buried valley aquifer. In addition to surface water, the valley fill aquifer system is the major source of drinking water in the southwestern Ohio area.

Since the last retreat of continental glaciers, the streams in the area have removed much of the glacial overburden and is now in direct contact with the glaciofluvial outwash deposits that comprise the Great Miami Aquifer. Paddys Run is also in contact with these deposits in its lower reaches. The FEMP site is located on a dissected glacial overburden plain left by the Wisconsin Glaciation.

Site-Wide Hydrogeology

The Great Miami Aquifer is the principal aquifer within the FEMP Study Area. The Great Miami Aquifer has been designated a sole source aquifer under the provisions of the Safe Drinking Water Act (SDWA). The buried valley is about 0.8 to 3.2 kilometers (0.5 to 2 miles) wide and is U-shaped, having a broad, relatively flat bottom and steep valley walls (Figure 1-7). Interbedded fine-grained fluvial and lacustrine deposits occur within the outwash deposits but, in most cases, are of limited lateral extent.

Contained within the sand and gravel that underlies much of the FEMP property is a relatively continuous, low-permeability clay interbed. This interbed ranges in thickness from about 1.5 to 4.5 meters (5 to 15 feet). The clay interbed occurs at an approximate elevation of 140 meters (460 feet). Where present, the interbed divides the aquifer into upper and lower sand and gravel units, referred to as the Upper Great Miami Aquifer and the Lower Great Miami Aquifer.

Large groundwater supplies occur in the sand and gravel deposits, allowing the aquifer to yield a considerable amount of water. In areas where the aquifer is 45 to 60 meters(150 to 200 feet) thick or more and induced stream infiltration is available, water supply wells in the Great Miami Aquifer are the most productive. Individual wells can yield 11,355 liters per minute (3,000 gallons per minute) or more in these areas (Spieker 1968). In areas where the aquifer is capped by glacial till, subdivided by the clay interlayer, and induced stream recharge in not available, wells generally yield 379 to 1893 liter per minute (100 to 500 gallons per minute). However, yields of 3785 liter per minute (1000 gallons per minute) are not uncommon in these areas. The bedrock outside the buried valleys has a lower hydraulic conductivity. Bedrock well yields are generally less than 38 liter per minute (10 gallons per minute) (Spieker 1968).

Hydrogeology of the Glacial Overburden

Overlying the Great Miami Aquifer, throughout most of the FEMP property, are a series of glacial overburden deposits. The glacial overburden is composed primarily of till; a dense, silty clay that contains discontinuous and isolated lenses of poorly sorted fine- to medium-grained sand and gravel, silty sand, and silt. Lacustrine deposits lie upon till in place and have at least one, and possibly more, laterally extensive permeable sand/silt strata. The glacial overburden exposed at the surface has relatively low permeability. Therefore most of the precipitation that falls on it is lost to evaporation and surface water runoff. Limited infiltration occurs along the upper weathered portion of the overburden and in isolated areas where more permeable deposits of silt, sand, and gravel are the primary overburden constituents. The thickness of the glacial overburden ranges from 1.5 to 15 meters (5 to 50 feet) within the FEMP Study Area, but most commonly averages between 6 to 9 meters (20 and 30 feet). With the exception of some scattered deposits, this overburden does not exist along the floodplain of the Great Miami River to the east and south of the FEMP site. The only on-property areas that lack overburden are certain reaches of Paddys Run and the Storm Sewer Outfall Ditch where this material has been eroded away. These streams are in direct contact with the upper portion of the Great Miami Aquifer along reaches, allowing surface water leakage directly to the aquifer.

Heterogeneous and non-symmetric pockets of silty sand and gravel within the glacial overburden contain zones of perched groundwater. Perched groundwater is separated from the underlying aquifer by the surrounding relatively impermeable clay silt components of the overburden. These low-permeable units behave as an aquitard that can store groundwater but transmit it slowly downward from one more porous saturated zone to another. Depth to perched groundwater at the FEMP site ranges from 0.3 to 4.5 meters (1 to 15 feet) below the land surface. This measurement can fluctuate seasonally by up to 3 meters (10 feet) at a single location. The highest water levels occur during the early spring and the lowest during the late fall.

In areas adjacent to the Operable Unit 1 waste pits, sand and gravel outwash deposits of the buried valley are overlain by 1.5 to 3 meters (5 to 10 feet) of till that is in turn overlain by 4.5 to 6 meters (15 to 20 feet) of lacustrine sediments. The till is an unsorted mixture of clay, silt, sand, and pebble to cobble size material with 70 to 80 percent of the material falling in the clay and silt size range. The till contains sparse, thin, and discontinuous lenses of sand and gravel.

The lacustrine strata consists of a 1.5- to 3.0-meter (5- to 10-foot) thick coarse-grain stratum that is overlain by clay and silt. The coarse grain stratum is part of a widespread glacial outwash unit located at the base of lacustrine strata throughout the northern half of the filled lacustrine basin. The coarse grain unit was deposited by streams and debris flows entering the basin from the north. The unit comprises clayey silt, silt, sands with appreciable fine fractures, and clean sands with silty/clayey sand being the dominant lithology. Strata that overlie the outwash unit were deposited by lower energy depositional lacustrine processes. The low-energy lacustrine sediment consists of clay, silty clay, clayey silt, silt and fine sand with silty clay comprising the dominant lithology. The loess cap probably overlies the lacustrine strata; however, it cannot be readily distinguished from the low-energy lacustrine deposits using the USC soil description/classification methods employed during the RI/FS process. Elsewhere on the site, where the loess cap can be distinguished, loess is a clayey silt approximately 0.9-meter (3-feet) thick.

The conceptual model for groundwater flow in the glacial overburden is described as follows. The lacustrine strata has good, but slow, hydraulic communication and that the till that underlies the lacustrine strata acts as a localized aquitard. Groundwater within the approximately 6 meters (20 feet) of lacustrine strata is predicted to flow at a lateral rate that is significantly greater than its downward rate. Therefore, groundwater is likely discharging westward to the bank of Paddys Run and southward in the east-west drainageway.

Hydrogeology of the Great Miami Aquifer

The principle sources of aquifer recharge in the FEMP Study Area are direct precipitation and stream infiltration. Infiltration of rainfall and snowmelt is the dominant regional source of groundwater recharge, providing approximately 2,157 liters per day per square kilometer (570,000 gallons per day per square mile), or roughly 31 centimeters (12 inches) per year to the water table of the aquifer (Dove 1961). Much of the precipitation that runs off the glacial overburden on the FEMP property enters Paddys Run and the Storm Sewer Outfall Ditch, both of which are subject to leakage directly to the aquifer over portions of their length. These streams are intermittent and provide recharge on a seasonal basis. Southwestern Ohio Water Company (SOWC) supply wells are located at the Big Bend meander of the Great Miami River which is east of the FEMP site. In areas of the river not influenced by the pumping wells, groundwater flows from the aquifer to the river, except during dry periods when the elevation of the water table is below the bed of the river. Recharge from

groundwater, occurring in bedrock, is limited due to its low permeability. However, erratically distributed joints and cracks allow small amounts of water to seep into the aquifer. Groundwater enters the FEMP Study Area from three separate flow systems. These systems are the Dry Fork Section of the New Haven Trough to the west, the Shandon Tributary to the north, and the Ross Section of the New Haven Trough to the northeast (Figure 1-8). Natural gradients cause the groundwater to exit the FEMP Study Area either by flowing east to the Great Miami River, upstream from New Baltimore, or south through the branch of the bedrock channel west of New Baltimore.

Population and Land Use

The land adjacent to the FEMP is primarily devoted to open land use such as agriculture and recreation (Figure 1-9). Commercial activity is generally restricted to the village of Ross, approximately 4.8 kilometers (3 miles) northeast of the facility, and along State Route 128 just south of the village. There are no areas within the FEMP boundaries considered to be prime farmland under the Farmland Policy Protection Act of 1981 (7 CFR 658). More than 162 hectare (400 acres) of the open land on the FEMP site are leased to a nearby dairy farmer whose livestock graze on the property. Pine plantations are located to the northeast and southeast of the former Production Area. Because the area had been intensively used for agricultural purposes prior to the establishment of the FEMP site, there is no land on or in the vicinity of the FEMP site where a predevelopment natural environment remains intact. The land closest to that description is the recreated prairie lands on the Miami Whitewater Forest property, located several miles south of the FEMP site.

The area surrounding the FEMP site has a large and diverse archaeological and historical resource base. According to records kept by the Miami Purchase Association for Historic Preservation, an unusually high percentage of the existing 19th century buildings in the area are historically important. Within the vicinity of the FEMP site [a 3.2-kilometer (2-mile) radius from the boundary], there are three properties listed in the National Register of Historic Places (NRHP). A number of additional structures exist that have been judged eligible for inclusion in this listing. Six major archaeological sites lie within 8 kilometers (5 miles) of the FEMP; five of these are included in the NRHP.

Ecology

This section describes the regional ecology, ecological communities on the FEMP, the floodplains and wetlands, and threatened and endangered species at the FEMP.

Regional Ecology

The FEMP site and surrounding areas lie in a transitional zone between two distinct sections of the Eastern Deciduous Forest Province as described by Bailey (1978). These sections are the Oak-Hickory and the Beech-Maple. The region is characterized by the presence of a mosaic of these forest types. The Oak-Hickory and Beech-Maple forest sections share many characteristics, including similar fauna and the presence of white oak as a common species. The Beech-Maple section covers northern Ohio, Indiana, and lower Michigan. It is bordered by Oak-Hickory to the southwest, Mixed Mesophytic to the southeast, and Appalachian Oak to the east. Beech-Maple forests are typically dominated by beech trees in the canopy. The Oak-Hickory section covers southwest Ohio, western Kentucky and Tennessee, and parts of Indiana, Illinois, Missouri, and Arkansas.

The dominant species are oaks, with an abundance of hickories. The fauna vary little between the two forest sections. Typical fauna include white-tailed deer, gray fox, gray squirrel, white-footed mouse, and short-tailed shrew; the cardinal, woodthrush, summer tanger, red-eyed vireo, and the hooded warbler; the box turtle, common garter snake, and timber rattlesnake (Bailey 1978; Shelford 1963).

Ecological Communities on the FEMP Site

Ecological communities on the FEMP site consist of grazed and ungrazed pastures, two pine plantations, deciduous woodlands, riparian woodlands, and the "reclaimed flyash pile area." The reclaimed flyash area coincides approximately with the South Field and the inactive Flyash Pile. It was considered a distinct habitat by Facemire et al. (1990). This is due to the unique plant and animal species composition. A total of 47 species of trees and shrubs, 190 species of herbaceous plants, 20 mammal species, 98 bird species, 10 species of amphibians and reptiles, 21 species of fish, 47 families of benthic macroinvertebrates, and 132 families of terrestrial invertebrates inhabit the FEMP site. Threatened and endangered species are discussed later in this section.

Typical grasses found on the FEMP site are red fescue, Kentucky bluegrass, timothy, and red top. Herbs include teasel, red and white clovers, and goldenrod. The dominant tree species in the pine plantations are the white and Austrian pine, with Norway spruce occurring occasionally. Common trees in the deciduous woodlands are white ash, American elm, shagback hickory, and slippery elm. Dominant tree species in the riparian woodlands are eastern cottonwood, hackberry, American elm,

and box elder. The reclaimed flyash pile area is dominated by American elm, eastern cottonwood, and black locust.

Mammal species observed on the FEMP site include white-tailed deer, coyote, red fox, opossum, raccoon, groundhog, eastern cottontail, fox squirrel and several species of bats. Common small mammals are the white-footed mouse, short-tailed shrew, meadow vole, meadow jumping mouse, and eastern chipmunk.

The most common birds breeding on the site include the mourning dove, American robin, blue jay, American crow, American goldfinch, northern bobwhite, and common grackle. Species occurring in the greatest density are the goldfinch, song sparrow, and robin. Raptor species observed on site are the northern harrier, red-shouldered hawk, Cooper's hawk, red-tailed hawk, and American kestrel. In addition, the eastern screech owl and great horned owl have been observed in the vicinity of the FEMP site.

Amphibians and reptiles that occur on the FEMP site include the American toad, spring peeper, eastern box turtle, and snapping turtle. Several species of snakes also occur on site, including the eastern garter snake, butler's garter snake, black garter snake, black rat snake, northern water snake, and the queen snake.

Approximately 130 insect families from 15 orders are represented in FEMP site habitats. Leaf hoppers are abundant in all FEMP site habitats. Less abundant groups include short-horned grasshoppers, leaf beetles, springtails, fruit flies, dark-winged fungus gnats, ants, bees, and wasps.

Floodplains and Wetlands

Floodplains within the FEMP property are confined to the north-south corridor containing Paddys Run. Outside the boundaries of the FEMP site, the 100- and 500-year floodplain of the Great Miami River extends west of the Big Bend area nearly to the eastern boundary of the facility (Figure 1-10). A 100- and 500-year floodplain of the river also extends northward along Paddys Run from the confluence of these two streams to a point about 182 meters (600 feet) from the southern boundary of the FEMP site. This area overlaps, a body of uranium-contaminated groundwater (referred to as the "South Plume") that is a component of Operable Unit 5.

A site-wide wetland delineation, conducted in February 1993 in accordance with guidelines the 1987 U.S. Army Corps of Engineers (COE) Wetlands Delineation Manual, was approved by the COE on August 12, 1993. The purpose of the delineation was to determine the extent of jurisdictional wetlands and waters of the United States so as to avoid or minimize impacts to these resources during future activities at the FEMP. Results from the site-wide delineation, (shown in Figure 1-11) indicate a total of 14.4 hectares (35.9 acres) of wetlands. Included in these areas are 10.63 hectares (26.58 acres) of palustrine forested wetlands, 2.78 hectares (6.95 acres) of drainage ditches/swales, and 0.95 hectares (2.37 acres) of isolated emergent and emergent-scrub/shrub wetlands. On-property waters of the United States are confined to Paddys Run and its unnamed tributaries. When combined they total approximately 3.6 hectares (8.9 acres).

The largest of the four palustrine forested wetland areas is located north of the former Production Area. The remaining three areas are located: (1) along the east bank of Paddys Run near the northern site border; (2) on the northeast corner of the site; and (3) southwest of the K-65 Silos. Drainage ditches and swales are located in four sections throughout the site: (1) north of the former Production Area traversing west into Paddys Run; (2) drainage of the Waste Pit Area; (3) drainage of the area south of the K-65 Silos; and (4) adjacent to the east boundary of the Former Production Area, draining higher elevations of the site to the east.

Two of the four scrub/shrub and/or emergent wetlands are located in the northern part of the site: one near the eastern corner and the other just east of Paddys Run, near the western corner of the site. The remaining two are located in the vicinity of the Waste Pit Area, one to the east and one to the west.

Threatened and Endangered Species

Potential remedial actions at the FEMP must comply with the substantive requirements of the Endangered Species Act (ESA) of 1973 16 U.S.C § § d1531, et. seq. To comply with Section 7 (a)(2) of the ESA of 1973, as amended, requiring federal agencies "...in consultation with and with the assistance of..." the Secretaries of the Interior and Commerce, to ensure that their actions are "...not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of the critical habitat of such species...", Miami University performed an Ecological Characterization Study of the FEMP in 1989. The following

discussion concerns threatened and endangered species with potential habitats in the vicinity of the FEMP. This information was drawn from the 1989 study and from supplemental investigations conducted as part of the Operable Unit 1 RI.

Indiana Bat (*Myotis sodalis*)

The Indiana bat is listed as both a federal and state endangered species. It is found to exist in Butler and Hamilton Counties. Surveys were conducted at the FEMP to determine its distribution and presence and to identify potential habitat on the FEMP and in the immediate vicinity. The Indiana bat has not been identified at the FEMP, but during the summer of 1988, a population was identified approximately 4.8 kilometers (3.0 miles) northeast of the FEMP on Banklick Creek, a tributary of the Great Miami River (Facemire et al. 1990). Potential habitat for the Indiana bat occurs in portions of the riparian woodland associated with Paddys Run. Potentially good to excellent habitat occur within the western boundaries of Operable Unit 1.

Cave Salamander (*Eurycea lucifuga*)

The cave salamander, a state listed endangered species, has not been identified at the FEMP site. During the summer of 1988, a population was identified 1.6 kilometers (1.0 mile) northeast of the FEMP at the Ross Trails Girl Scout Camp. Preliminary data from a 1993 Cave Salamander survey has identified excellent habitat in an on property water well, but no salamanders were discovered.

Sloan's Crayfish (orconectes sloanii)

Sloan's crayfish is a state threatened species reported to be present in Paddys Run (Facemire et al. 1990). Current preliminary data from a September 1993 Sloan's crayfish survey indicates populations residing in northern sections of Paddys Run on FEMP property and southern sections of Paddys Run off FEMP property near New Haven Road.

Other

The northern waterthrush (*Seiurus noveboracenusis*) is a state listed endangered species. It was reported as a spring migrant along Paddys Run during the Spring of 1987 (Facemire et al. 1990). The northern harrier (*Circus cyaneus*), also a state listed endangered species, and the red-shouldered hawk (*Buteo lineatus*), a state listed threatened species, were observed flying over the FEMP site.

The cobblestone tiger beetle (*Cicendela marginpennis*), listed as a Federal 2 (F2) species and state-listed special-interest species, was found in 1988 on a gravel bar in the Great Miami River two miles west/southwest of the bridge at New Baltimore, Ohio. As an F2 species, this beetle has been considered by the U.S. Fish and Wildlife Service for possible inclusion on the federal threatened or endangered species list. Special-interest species are listed by the Ohio Department of Natural Resources and are often eligible, with more information, to be listed as state threatened or endangered. This beetle remains on both lists because of uncertain information sufficient to delete it from either list.

Slender finger-grass (*Digitaria filiformis*) and mountain bindweed (*Polygonum cilinode*) are state listed endangered species recorded in low densities along Paddys Run and in the northern pine plantation by Facemire et al. The dark-eyed junco (*Junco hyemalis*), a state listed endangered species, was observed throughout the FEMP during the winter of 1986 and 1987 by Facemire et al.. Running Buffalo Clover (*Trifolium stoloniferum*), a state and federally listed endangered species, has not been identified at the FEMP. A population was identified less than 8.0 kilometers (5.0 miles) southwest of the FEMP at Miami Whitewater Forest. Potential habitat exists in introduced grassland areas, and riparian and deciduous woodlands on the FEMP site.

1.2.1.1 Description of Operable Unit 1

Since the beginning of FMPC uranium production operations in 1951, on-site facilities have been used for the storage of low-level radioactive wastes generated by the plants chemical and metallurgical processes. Specifically, much of these wastes have been deposited in one of six waste pits, or a clearwell, or burned in a burn pit. The six pits, the Clearwell, and the Burn Pit make up approximately 5.3 hectares (37.7 acres). A detailed discussion of each pit's construction, contents and volume are provided in the Operable Unit 1 RI. Table 1-1 provides a summary of the physical features and operating history of Waste Pits 1 through 6, the Burn Pit, and the Clearwell, along with the predominant radiological and inorganic constituents presented within the waste units. Relevant information is summarized here:

Waste Pit 1

Waste Pit 1 was constructed in 1952 by excavating into existing clay lens, and then lining the waste pit with clay excavated from an area to the northeast of the waste pit, which later became the Burn Pit. The waste pit surface area is oval-shaped; the dimensions at the bottom are approximately 50 meters (165 feet) wide by 106 meters (347 feet) long. The waste pit is an average 9 meters (29.5 feet) deep, including approximately 5.5 meters (18 feet) of wastes, 3.34 meters (11 feet) of lining comprised of a low permeability material (clay) and a 15-centimeter (6-inch) cover. The bottom of Waste Pit 1 slopes approximately 30 centimeters (1 foot) from east to west. About 1.2 meters (4 feet) of excavated clay was placed in the southeast corner of Waste Pit 1 and a berm was constructed on the west side of the waste pit. This berm is elevated approximately 6 meters (20 feet) above ground surface. The sides of Waste Pit 1 were constructed with 3:1 slopes and then seeded.

Waste Pit 1 is considered a dry pit, since the waste slurries other than effluent from the general sump were filtered or calcined to remove water before they were placed in the pit. This waste pit received primarily depleted magnesium fluoride slag, and depleted residues with smaller amounts of trailer cake, UAP filtrate, graphite/ceramics, and general sump sludge. It was, however, used as a clear well for liquids removed from Waste Pit 2 in 1958 and 1959. Waste Pit 1 was closed and covered with clean fill in 1959. This waste pit is currently classified as a RCRA Solid Waste Management Unit. The results of material volume calculations are presented in Table 1-2.

Waste Pit 2

In 1957, Waste Pit 2 was constructed northeast of Waste Pit 1. An existing spring-fed pond (water level elevation 175$\pm$ 0.43 meters (574$\pm$1 feet) existed on what became the southern portion of the waste pit. The waste pit was constructed by draining the pond and excavating into the existing native clay. Trees, stumps, and roots had to be removed from the north end. The bottom and side slopes were then lined with 1.34 meters (4.5 feet) of additional clay from an area immediately northeast of the waste pit, which later became the Burn Pit. The surface area boundary of the waste pit resembles a six-sided polygon with dimensions at the top of approximately 58 meters (190 feet) wide by 82 meters (270 feet) long. The waste pit is approximately 7.2 meters (23.5 feet) deep, including 4.6 meters (15 feet) of wastes, 1.34 meters (4.5 feet) of lining, and 0.3 to 1.2 meters (1 to 4 feet) of cover. Logs from Borings Nos. 1768 and 1769 conducted during the RI/FS activities indicate that the top of the low permeability material for Waste Pit 2 is encountered at an elevation of 171 meters (561

feet). There are two 20-centimeter (8-inch) cast iron decant pipes installed through the northwest berm of the waste pit. The decant lines were rarely used.Waste Pit 2 is also considered a dry pit and received trailer cake and general sump sludge with smaller amounts of UAP filtrate, raffinate, depleted residues and graphite/ceramics. Waste Pit 2 was also used as a settling basin for neutralized, raffinate during 1958 and 1959, prior to completion of Waste Pit 3, because the drying equipment available at that time could not process all of the raffinate being produced by plant operations. Waste Pit 2 was closed and covered with clean fill in 1964. This waste pit is currently classified as a RCRA Solid Waste Management Unit. The results of material volume calculations are presented in Table 1-3.

Waste Pit 3

Waste Pit 3 was placed in service in December 1958 and was constructed by excavating into the underlying naturally occurring clay lens. To construct Waste Pit 3 and the Clearwell, a small creek that ran along the west embankment of Waste Pit 2 was relocated north of the Burn Pit and parallel to the railroad tracks. The surface area boundary of the waste pit is oval-shaped and has dimensions of approximately 193.5 meters (450 feet) wide by 309.6 meters (720 feet) long. The waste pit is approximately 18.1 meters (42 feet) deep, including 11.6 meters (27 feet) of wastes, 43 centimeters (1 foot) of liner, and 6 meters (14 feet) of cover. The sides of Waste Pit 3 were constructed with a 1.5:1 slope and lined with 43 centimeters (12 inches) of clay. The west berm of Waste Pit 3 was constructed approximately 8.6 meters (20 feet) above the 1958 ground level. Some of the soil excavated from the waste pit itself was used to form the west wall. No berm was constructed on the north side of Waste Pit 3. A natural layer of low permeability clay forms the bottom of the waste pit, so the placement of additional clay material was not necessary. The bottom of Waste Pit 3 has an elevation of approximately 167 meters (548 feet).

Waste Pit 3 was the first waste pit built specifically for settling solids from liquid waste streams. Primarily, lime-neutralized raffinate slurries, as well as contaminated storm water from the Burn Pit, were pumped to Waste Pit 3. After Waste Pit 2 was filled, Waste Pit 3 received general sump sludge, raffinate, trailer cake and slag leach with lesser amounts of water treatment sludge and thorium wastes. Starting in December 1958, lime sludge from the Water Treatment Plant was added to supplement the lime used for raffinate neutralization. Also, large quantities of neutralized residues from acid leaching of uranium-bearing magnesium fluoride slag were pumped to Waste Pit 3 during

the late 1960s, prior to completion of Waste Pit 5. In 1973, fill material including filter cake, slag leach residue, lime sludge, and flyash was placed in Waste Pit 3 and construction activities were initiated to cover this waste pit with soil. Waste Pit 3 covering activities were complete in 1977. This waste pit is currently classified as a RCRA Solid Waste Management Unit. The results of material volume calculations are presented in Table 1-4.

Waste Pit 4

Waste Pit 4 was constructed in 1960. The waste pit sides and bottom are lined with 0.3 to 0.6 meters (1 to 2 feet) of low permeability clay. The surface area boundary of the waste pit is trapezoidal in shape and has maximum dimensions of approximately 116 meters (380 feet) wide by 94 meters (310 feet) long. The waste pit is approximately 10 meters (32 feet) deep, including 7.6 meters (25 feet) of waste, 0.3 to 0.6 meters (1 to 2 feet) of liner, and 1.8 meters (6 feet) of cover. The waste pit was constructed with side slopes of 2:1. The top of the waste pit has an elevation of 178 meters (584 feet) above MSL with the existing ground elevation at 178 to 179 meters (584 feet to 588 feet) above MSL.

Waste Pit 4 received solid wastes that included trailer cake, depleted slag and depleted residues with lesser amounts of thorium wastes and graphite/ceramics as well as unknown quantities of noncombustible wastes. The process residues included filter sludges, raffinates, graphite, magnesium fluoride slag, and pyrophoric uranium-bearing materials. Thorium metal and residues were hauled to the waste pits in drums and were placed in Waste Pit 4 when additional metal recovery was not economically feasible. At least 100 drums were deposited on the west side of this waste pit. Waste Pit 4 also received noncombustible trash including cans, concrete, asbestos, and construction rubble. Lime was occasionally added to standing water within Waste Pit 4 for uranium precipitation prior to the transfer of liquids to Waste Pit 5 for settling and discharge. Barium chloride was also disposed of in Waste Pit 4 from 1980 to 1983. Disposal activities in Waste Pit 4 were terminated in 1985. The waste pit was closed in 1986 and cover activities started. Waste Pit 4 is currently classified as a RCRA Hazardous Waste Management Unit and has undergone interim closure. Final closure of Waste Pit 4 will be completed in conjunction with remedial actions under CERCLA. The results of material volume calculations are presented Table 1-5.

Waste Pit 5

Waste Pit 5 was constructed and placed into service in 1968. The Waste Pit 5 surface area boundary is rectangular in shape and is approximately 250 meters (820 feet) long by 73 meters (240 feet) wide. The waste pit is approximately 8.8 meters (29 feet) deep, including 8.5 to 8.8 meters (28 to 29 feet) of wastes, and a membrane liner. Waste Pit 5 was constructed with side slopes of 2.5:1. The waste pit berm extends about 10 feet above grade on the south side and 4.3 to 6.1 meters (14 to 20 feet) above grade on the north side. Excavated material was used to build the waste pit dike. The waste pit was lined with a 60-mil thick Royal-Seal ethylene propylene diene monomer (EPDM) elastomeric membrane.

Waste Pit 5 served as a settling basin for slurries in the form of general sump sludge, raffinate, slag leach, water treatment sludge, and thorium waste. Lime sludge was added to this waste pit to supplement the lime used to neutralize the raffinate and heat treatment quench water was discharged directly to Waste Pit 5. The supernatant and sludges produced by the co-precipitation of thorium wastes with barium carbonate and aluminum sulfate, and the precipitation of uranium with calcium oxide were deposited in Waste Pit 5. The discharge of slurried waste materials into Waste Pit 5 was stopped in 1983 and use of this waste pit as a settling basin was discontinued in 1987. Waste Pit 5 is currently classified as a RCRA Hazardous Waste Management Unit. The results of material volume calculations are presented in Table 1-6.

Waste Pit 6

Waste Pit 6 was constructed from September 1978 to June 1979. It is square shaped, measuring approximately 64.0 meters (210 feet) on both sides. The waste pit is approximately 7.3 meters (24 feet) deep, measured from the top of the berm to the liner, but the depth of the wastes in the waste pit is only 6.1 meters (20 feet). Waste Pit 6 was constructed in the same manner as Waste Pit 5 and lined with a 60-mil EPDM elastomeric liner. There is a berm around all sides except for the west side, which is adjacent to Waste Pit 4. The berm varies in height from approximately 1.2 to 2.4 meters (4 to 8 feet) above grade.

Waste Pit 6 received depleted slag and depleted residues. Extrusion residue and heat treatment quench water were also deposited in Waste Pit 6. Use of Waste Pit 6 ceased in 1985. Waste Pit 6 is

currently covered by water and is classified as a RCRA Solid Waste Management Unit. The results of material volume calculations are presented in Table 1-7.

Clearwell

The Clearwell was constructed in 1959 during Waste Pit 3 construction activities. To allow for construction of Waste Pit 3 and the Clearwell, a small creek that ran along the west embankment of Waste Pit 2 was relocated north of the existing Burn Pit and parallel to the railroad tracks. The Clearwell was excavated into existing low permeability material to an elevation of 167±0.3 meters (548±1 feet) above MSL. The Clearwell is approximately 61 meters (200 feet) long by 54.9 meters (180 feet) wide, with a maximum depth of 8.2 meters (27 feet). The east, west, and south sides of the Clearwell were constructed with a 1.5:1 slope and lined with 30.5 centimeters (12 inches) of clay. The north side was constructed with a 2:1 slope and also lined with 30.5 centimeters (12 inches) of clay. The west berm of the Clearwell was constructed approximately 6.1 meters (20 feet) above grade in 1958. The north side is adjacent to the south side of Waste Pit 3. The east side was formed from the west side of Waste Pit 1. A natural layer of low permeability material forms the bottom of the Clearwell, and additional clay material was not placed in the bottom. The bottom of the Clearwell is at elevation of 167±0.3 meters (548±1 feet) above MSL.

A series of three 20-centimeters (8-inch) pipes are located in the berm between Waste Pit 1 and the Clearwell, but these decant lines were rarely used. Also, a weir was constructed on the north side of the Clearwell to drain Waste Pit 3. Finally, the 30-centimeter (12-inch) line from the overflow of Waste Pit 5 extends through the east berm of the Clearwell.

The Clearwell received surface water runoff from the waste pits and surface liquid (supernatant) from Waste Pits 3 and 5. It acted as a final settling basin prior to periodic discharge to the Great Miami River. The Clearwell is currently classified as a RCRA Solid Waste Management Unit. The results of material volume calculations are presented in Table 1-8.

Burn Pit

Clay to line Waste Pits 1 and 2 during their construction was obtained from an area immediately northeast of Waste Pit 2, which at that time was called the clay pit. A gravel dumping pad was eventually built up on the north end of the resulting excavation so that trucks could back into the

deepest part of the waste pit to dump combustible wastes. Thus, the waste pit became known as the Burn Pit. Although records were not kept on all of the materials or amounts deposited, it is known that the Burn Pit was used primarily to burn combustible materials such as laboratory chemicals; pyrophoric and reactive chemicals; oils; low-level contaminated combustible material, such as pallets and skids; and cafeteria debris. In addition, several materials were deposited directly into the Burn Pit, including cans, bottles, general refuse, and laboratory glassware. The Burn Pit was filled in 1968 during the construction of Waste Pit 5. The results of material volume calculations are presented in Table 1-9.

1.2.2 Site History

The primary mission of the FEMP site during its 37 years of operation was the processing of "feed" materials to produce high-purity uranium metal. These high-purity uranium metal products were then shipped to other DOE facilities for use in the nation's ongoing weapons program.

The Atomic Energy Commission (AEC), predecessor to the U.S. Energy Research and Development Administration (ERDA) and DOE, established the FMPC in conformance with AEC orders in the early 1950s. In 1951, National Lead Company of Ohio, (NLO) Inc., entered into a contract with the AEC to be the Operations and Management Contractor for the facility. This contractual relationship lasted, first with the AEC and finally with DOE, until January 1, 1986. Westinghouse Materials Company of Ohio (WMCO), a wholly-owned subsidiary of Westinghouse Electric Corporation, then assumed management responsibilities for the site operations and facilities. In 1991, Westinghouse renamed this subsidiary the Westinghouse Environmental Management Company of Ohio (WEMCO). On December 1, 1992, the Fernald Environmental Restoration Management Corporation (FERMCO), a wholly-owned subsidiary of Fluor-Daniel., Inc, assumed management responsibility for the site as the first Environmental Restoration Management Contractor (ERMC) for DOE.

The FEMP began operations in 1951 upon completion of the Pilot Plant, which was the site's first operational facility. Production peaked in 1960 at approximately 12,000 metric tons (13,228 tons) of uranium per year. A product decline began in 1964 and reached a low in 1975 of about 1,230 metric tons of uranium (1,355 tons). During the 1970s, DOE considered closing the FEMP. Therefore, capital improvements and staffing were minimized. The staffing level peaked at 2,891 personnel in 1956, slowly declined to 662 personnel in 1972 and then to 538 personnel in 1979. In 1981, the

FEMP began planning to accommodate increased production requirements. Production levels significantly increased and there was a rapid staff buildup for several years. The renewed need for uranium metal resulted in the implementation of a major facilities restoration program. All production ceased in the summer of 1989 and plant resources were focused on environmental remediation activities. In June 1991, the site was officially closed as a federal uranium production facility. To identify this new mission, the site was renamed the Fernald Environmental Management Project.

On July 18, 1986, a Federal Facilities Compliance Agreement (FFCA) was jointly signed by DOE and EPA detailing actions to be taken by DOE to assess environmental impacts associated with the FEMP site. The FFCA was entered into pursuant to Executive Order 12088 [43 Federal Register (FR) 47707] to ensure compliance with existing environmental statutes and implementing regulations such as the CAA, RCRA, and CERCLA. In particular, the FFCA was intended to ensure that environmental impacts associated with past and present activities at the FEMP site would be thoroughly and adequately investigated so that appropriate remedial response actions could be formulated, evaluated, and implemented. As required by the FFCA, a RI/FS was initiated at the FEMP site in July 1986, pursuant to CERCLA.

In November 1989, the FEMP site was placed on the NPL for investigation and remediation under CERCLA. This placement, in addition to progressive findings in the RI/FS program, resulted in the amendment of the existing agreement between DOE and EPA. The 1986 FFCA was amended by a Consent Agreement under Section 120 and 106(a) of CERCLA providing for the implementation of the operable unit concept for the FEMP RI/FS and revising the milestone commitments for the RI/FS program without modifying the underlying objectives in the FFCA. The Consent Agreement was signed on April 9, 1990, and became effective on June 29, 1990, following a period of public comment. In September 1991, parts of the 1990 Consent Agreement, including the provisions relating to schedules for completion of the RI/FS for each operable unit, were amended. This agreement is known as the Amended Consent Agreement.

1.2.3 Nature And Extent of Contamination

This section summarizes the nature and extent of contamination both on a site-wide basis and for Operable Unit 1. The site-wide summary is presented in this section to frame Operable Unit 1 within

the entire FEMP. This summary is based on the SWCR (DOE 1993b) and the RI Report for Operable Unit 1 (DOE 1993a).

1.2.3.1 Site-Wide Summary

DOE submitted the final FEMP SWCR to EPA in March 1993. It is incorporated herein by reference and is part of the Administrative Record located in the FEMP Public Environmental Information Center. The SWCR compiles all FEMP site data available as of December 1, 1991. The major purpose of the SWCR is to support preparation of individual operable unit RI and FS reports. This is accomplished by describing the regional environment of the FEMP and providing site-wide information needed for FS cumulative response action risk evaluations. Also provided in the SWCR are detailed technical appendices on ecological studies, population estimates, and modeling efforts supporting the RI/FS.

The site characterization work performed to determine the nature and extent of contamination at the FEMP has generated thousands of data points. Additional data continue to be collected through an ongoing environmental monitoring program and remaining RI/FS characterization activities. The results of six primary data collection programs compiled by the SWCR are listed below:

- DOE Litigation Study
- Characterization Investigation Study (CIS)
- RCRA Groundwater Compliance Monitoring
- DOE Sampling and Analysis
- Annual Environmental Monitoring Program
- RI/FS Characterization Studies

These data collection programs encompass solid and liquid waste, structures and equipment, and environmental media. These media include air, surface water and groundwater, soils, and flora and fauna.

1.2.3.2 Summary of RI Report for Operable Unit 1

The following information is summarized from Section 7.0 of the RI Report for Operable Unit 1 (DOE 1994a). This section goes into some detail in summarizing the findings of the RI Report, inclusive of the baseline risk assessment. The baseline risk assessment concluded that the wastes of Operable Unit 1 present a potentially unacceptable risk to human health and the environment and must be remediated. This conclusion precipitated the need for a Feasibility Study. As discussed earlier,

the FS identifies and evaluates a range of alternatives to implement remedial action. While all the findings of the RI are relevant to the FS, a number of general findings are particularly important in developing and evaluating remedial alternatives. First, there is a very large volume (over 600,000 cubic yards) of contaminated material associated with the waste pits. Second, the waste pit contents are very heterogeneous both in terms of contaminant type and concentration and also in the physical makeup of the wastes. There is significant variability in the degree of waste stratification and the amount and location of debris in the waste pits. Third, that while there is a potential increased risk associated with direct contact type exposures, a principal potential threat is associated with exposure to groundwater contaminated by the waste pits. There are two important findings associated with this. Large volumes of contaminated pit materials are in very close proximity to the geologic formation of the sole source Great Miami Aquifer. In addition, the waste pit contents are generally saturated, meaning that there is a large pool of contaminated leachate available for migration into the aquifer. Finally, while radiological contaminants are the principal sources of risk, there are also potentially unacceptable risks associated with volatile and semi-volatile organics and heavy metals. The potential implementability and effectiveness of the identified remedial alternatives must be evaluated in specific consideration of the above findings.

1.2.3.3 Contaminant Source Characterization

This section presents characterization data regarding the nature of contaminants, or sources, within the waste units of Operable Unit 1. Contaminant sources considered in this section include Waste Pits 1 through 6, the Burn Pit and the Clearwell. The nature and extent of contamination within environmental media are detailed in Section 4.0 of the RI Report for Operable Unit (DOE 1994a).

Radiological Characteristics

Waste materials in Waste Pits 1 through 4 and the Burn Pit were sampled for radiological characterization under the CIS and the 1991 RI/FS waste pit sampling program. Waste materials in Waste Pits 5 and 6 and the Clearwell were sampled under the CIS and the 1992 RI/FS Waste Pit Sampling Program (conducted as part of the Operable Unit 1 treatability program). (CIS and RI/FS radiological analytical results are presented Appendices A, B, C, and summarized in Section 4.0. of the RI Report for Operable Unit 1. Summary data are presented in Appendix A to this FS report. The CIS and RI/FS radiological analytical results are comparable; however, some differences exist due to hydrologic seasonal variations in groundwater levels at the site. The process knowledge

estimate does not account for all potential sources of metals in the waste pits but focuses on the contribution from raffinates and UAP residues. Other sources which may account for differences in the two estimates include varying impurities in the processed ore, the magnesium fluoride and dolomite residues, and erosion and corrosion products from reaction vessels and piping.

The predominant radiological constituents in all waste pits, in terms of activity concentration, include uranium-238, uranium-234, thorium-230, and radium-226, all of which are part of the uranium-238 decay series. This is consistent with process knowledge, since only limited quantities of enriched uranium were processed at the FEMP. The highest uranium concentrations were found in Waste Pit 6 (greater than 15,000 picoCuries per gram). The lowest average concentrations (less than 1,000 picoCuries per gram uranium-238) were found in Waste Pits 3 and 5, the Burn Pit, and the Clearwell.

Waste Pits 3 and 5 showed elevated thorium-230 activity concentrations, confirming that these waste pits received raffinate from the FEMP refinery (Plant 2/3). The 1991 RI/FS sampling program revealed the highest reported thorium-230 activity concentrations in a portion of Waste Pit 2. Operational records indicate that approximately 2,300 55-gallon drum equivalents of cold raffinates from other AEC sites were placed in Waste Pit 2. This would account for elevated thorium-230 activity concentration observed in the portion of the pit where the drum contents were placed.

Fission products (technecium-99, strontium-90, cesium-137) were noted in lower concentrations, but were primarily found in Waste Pit 5 and the Clearwell. Technetium-99 was the most prevalent transuranic fission product. It was found at an average activity concentration of 1,270 picoCuries per gram in Waste Pit 5 and 300 picoCuries per gram in the Clearwell. The presence of fission products and by-products in the waste pits stems from the processing of recycled tails from several DOE facilities, including the Hanford Purex Fuel Reprocessing Facility.

Chemical Characteristics

Waste material and pit leachate in Waste Pits 1 through 4 and the Burn Pit were sampled for inorganic and organic parameters under the CIS and the 1991 RI/FS waste pit sampling program. Waste material and surface water in Waste Pits 5 and 6 and the Clearwell were sampled under the CIS and the 1992 RI/FS waste pit sampling program.

The distribution of metallic parameters in the waste pits is consistent between the CIS and RI/FS data sets. For both data sets, arsenic, barium, chromium, cobalt, copper, lead, magnesium, nickel, silver, and vanadium are the predominant species. Waste Pits 1 and 6 and the Burn Pit contain the lowest levels of inorganic constituents. Waste Pits 3, 4, 5, and the Clearwell contain the highest concentration of inorganic constituents. All of the waste pits contain high levels of magnesium, consistent with the disposal of large quantities of magnesium fluoride slag. Waste Pit 1 is characterized by significant (but lower than other waste pits) levels of barium, cadmium, chromium, and magnesium. Waste Pit 2 is characterized by moderate levels of arsenic, barium, cobalt, copper, lead, manganese, and nickel. Waste Pit 3 has the highest levels of arsenic and manganese, but the CIS values are much lower than the RI/FS 1991 values. Waste Pit 4 is characterized by significant levels of antimony, barium, chromium, manganese, and silver. Waste Pit 5 is characterized by significant levels of arsenic, barium, copper, manganese, molybdenum, nickel, and vanadium. Waste Pit 6 is characterized by significant levels of manganese and vanadium. The Burn Pit has lower levels of metal contamination than the other waste pits, but has significant levels of barium, copper, lead, manganese, and zinc. The Clearwell contains significant amounts of barium, copper, lead, manganese, and vanadium. This mirrors the concentrations in Waste Pit 5 leachate in accordance with the Clearwell's use as a collection pit for supernatant liquid from Waste Pit 5.

Polynuclear aromatic hydrocarbons (PAHs), from coal tars, flyash, or fuel oils are concentrated in Waste Pit 2. Aroclors (PCBs) are generally distributed at concentrations less than 50 ppm throughout the waste pits, but are present only in small amounts in Waste Pit 6 and the Clearwell.

Polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs) have been reported in very low concentrations in Waste Pits 2, 3, and 4. Waste Pits 5 and 6 and the Clearwell were not analyzed for PCDDs and PCDF. Chlorinated solvents and volatile aromatic compounds were widespread at relatively low concentration in the waste pits.

1.2.3.4 Characterization Data Summary

This section summarizes characterization data regarding the nature and extent of contamination in environmental media within Operable Unit 1. Environmental media addressed include the surface and vadose zone soil, groundwater, surface water and sediment, air, and direct radiation. Also included is a summary of ecological characterization results.

Surface and Vadose Zone Soil

Surface soil radiological analyses performed under the CIS and the RI/FS show that uranium is the predominant radionuclide contaminant in Operable Unit 1 surface soils. Uranium-238 was present at above- background concentrations in all sample locations. The highest noted uranium-238 activity concentration was 1,500 picoCuries per gram found at sample point SS-46-504 located south of Waste Pit 6 and east of Waste Pit 4. An area east of Waste Pit 2 yielded uranium-238 activity concentrations in the range of 25 to 750 picoCuries per gram.

Uranium-238 contamination in surface soil may be the result of sporadic spills of waste material prior to disposal, overland storm water drainage flow, and airborne deposition. Based upon the areal distribution of soil contamination at locations east of Waste Pit 2 and south of Waste Pit 6, it is likely that this soil contamination resulted from airborne spreading of dried uranium-bearing wastes placed in the adjacent waste pits (i.e., Waste Pits 6 and 2).

Chemical analyses of surface soil indicate that cadmium, chromium, manganese, molybdenum, and silver are the principal inorganic contaminants. These constituents are consistent with the contents of waste material in the waste pits. Organics sampling revealed elevated concentrations of pesticides and PCBs in those samples within the boundaries of Operable Unit 1. These contaminants correspond to the characteristics of waste material contained in the adjacent waste pits. Pesticides and herbicides were used throughout the lifetime of the waste pits for insect control (principally those waste pits with surface water present) and weed/grass control. Their presence in the waste pits of Operable Unit 1 was anticipated. One sample exhibited significantly elevated levels of various PAHs.

Subsurface soil was analyzed from four geologic zones: (1) glacial overburden; (2) upper saturated sand and gravel layer; (3) lower saturated sand and gravel layer; and (4) the deep saturated sand and gravel layer. Principal radiological constituents in the glacial overburden include uranium-238 and its progeny products (uranium-234, thorium-230, and radium-226). Uranium-238 activity concentrations range from 1.32 to 4682 picoCuries per gram. The highest activity, 4,682 picoCuries per gram of uranium-238, was found at a depth of 1.5 to 3 feet in Boring 1644 immediately southeast of the Burn Pit. Based on the boring logs and the elevated uranium-238 activity concentration, it is likely that this boring penetrated the southern edge of the Burn Pit.

The upper saturated sand and gravel layer radionuclide activity concentrations were significantly lower than those found in the glacial overburden. One sample obtained at a depth of 66.5 feet showed slightly elevated levels of uranium-234 and strontium-90. No radiological constituents exceeded background in samples from either the lower saturated sand and gravel layer or the deep saturated sand gravel layer.

Only one subsurface soil sample, taken at a depth of 4.5 feet near the Burn Pit, revealed elevated levels of organic compounds. One constituent, 2-butanone, may be attributed to migration of waste pit leachate. The other two, acetone and carbon disulfide, are common laboratory chemicals and the measured values are likely due to laboratory cross-contamination.

Groundwater

Groundwater at the FEMP is monitored via wells that were installed for the RI/FS and RCRA programs. Many of the wells, in fact, were used to provide data for both programs. Table 1-10 identifies the numbers of monitoring wells used in each sampling program. Twenty-two of the 1000-series wells are monitored under both programs. Fourteen different 2000-series wells monitor the upper water table of the aquifer, while only eleven wells monitor the middle region of the aquifer. Six wells monitoring the bottom region of the aquifer. The location of the 1000-, 2000-, 3000-, and 4000-series wells within or near the Operable Unit 1 study area are presented in Section 2.0 of the Operable Unit 1 RI report on Figures 2-14, 2-15, 2-16, and 2-17, respectively.

All of the 1000-series wells in Operable Unit 1 reported positive concentrations of total uranium in micrograms per liter. The pattern of the elevated uranium concentrations under the RI/FS program within Operable Unit 1 appears to be centered in the vicinities of the southern-most edge of Waste Pit 4 (Well 1021 with an average concentration of 11,482 picoCuries per liter uranium-238) and the northern-most edge of Waste Pit 4 (Well 1021 with an average concentration of 3,625 micrograms per liter). The average total uranium concentration ranged form 0.75 to 11,482 picoCuries per liter. The RCRA pattern of elevated total uranium concentrations and isotopic activity concentrations center around Well 1022 which is located in the berm area between the western boundary of Waste Pit 4 and the eastern boundary of the Burn Pit. Although the RCRA uranium results for Well 1022 are the highest, they are only approximately one-half of the concentrations reported for Well 1021 under the RI/FS program.

Although the thorium results for the 1000-series wells are not identical, the results indicate the elevated thorium results center around the same "hotspots" as the uranium, i.e. Wells 1021 and 1022, located on the southern and western boundaries, respectively of Waste Pit 4. Well 1073 (on the northern boundary of Waste Pit 1) reported the highest average thorium-230 concentration (8.1 picoCuries per liter). Reported maximum radium concentrations locations varied considerably for the two monitoring programs. Radium-226 (7.3 picoCuries per liter) and radium-228 (2.7 picoCuries per liter) maximum under the RI/FS program were reported form Wells 1644 and 1643, respectively. These wells are located west and northwest of Waste Pit 4 and on the fringes of the Burn Pit boundaries. The radium-226 (1.99 picoCuries per liter) and radium-228 (3.7 picoCuries per liter) RCRA maximum were reported from Wells 1021 and 1083, respectively which are located in the southern section of Waste Pit 4 and east of Waste Pit 4 (south of Waste Pit 6), respectively.

No reportable concentrations of cesium-137, ruthenium-106, or neptunium-237 were reported for either program. The plutonium isotopes were only identified at low concentrations during the RCRA program with Well 1081 reporting 0.42 picoCuries per liter (plutonium-238) and 0.13 picoCuries per liter (plutonium-239/240) as the highest observed average activity concentrations. Well 1081 is located approximately midway between Waste Pit 5 and Waste Pit 6. Other fission products and by-products were detected in various 1000-series wells. During the RI/FS program the highest mean strontium-90 activity concentrations were reported from Well 1643 (15.9 picoCuries per liter) which is located north of the Burn Pit and south of Waste Pit 5. The strontium-90 maximum average was reported form Well 1083 (2.35 picoCuries per liter) which is slightly southeast of Waste Pit 6. Technetium-99 was observed in eight of the twenty-five wells with the highest average concentration reported being 1,379 picoCuries per liter, found in Well 1073 (the same well reporting the second highest concentration of total uranium). Well 1073 was not sampled for technecium-99 during the RCRA. The highest reported mean RCRA concentration for technecium-99 (270 picoCuries per liter) was reported from Well 1083 which was the same well reporting the highest mean strontium-90 concentration.

Generally the level of radionuclide contamination was reduced significantly in the RI/FS 2000-series wells. Uranium-238 was reported for each of the thirteen RI/FS monitoring wells. Additionally, uranium-234 was observed in all thirteen wells and uranium-235/-236 was reported for only two of these wells. The highest average uranium-238 concentration was reported for Well 2822 (11.3

picoCuries per liter) which also was the location for the highest reported average uranium-234 and uranium-235/-236 activity (7.97 picoCuries per liter and 0.41 picoCuries per liter, respectively). This well is located south of Waste Pit 2 and east of Waste Pit 1. The appearance of thorium isotopes was very limited with respect to the 2000-series wells. Only five wells exhibited results for thorium-230 and four wells for thorium-228, with the highest average maximum reported at 1.8 picoCuries per liter (thorium-228), 0.85 picoCuries per liter (thorium-230) and 0.015 picoCuries per liter (thorium-232). Increased maximum concentrations in the 2000-series wells with respect to the 1000-series wells were observed for both strontium-90 and technetium-99. RI/FS Well 2021, which is located along the southern boundary of Waste Pit 4 (near the location of Well 1021) reported average activity concentrations for strontium-90 and technecium-99 of 27.35 picoCuries per liter and 3207 picoCuries per liter, respectively. This is approximately a two-fold increase in the average concentration and most probably is due to the solubility and mobility of these species. The results of the twelve RCRA monitoring wells generally reflect the data generated from the RI/FS well with the respect to the total uranium concentrations. Well 2084 was determined to be the total-uranium "hotspot" with 19.9 picoCuries per liter, but this may be because the RI/FS "hotspot" (Well 2822) was not sampled during the RCRA program. Thorium-228 was also reported in all twelve wells ranging in concentration from 0.42 to 6.92 picoCuries per liter. Thorium-230 was reported in only nine wells and thorium-232 in only three. Low levels of radium isotopes were detected in all twelve wells. One well (Well 2008) reported neptunium-237 at near detection limit levels (0.02 picoCuries per liter). Strontium-90 was reported for only two wells but technecium-99 was detected in six of the wells and reported at some of the highest quantities determined from either program. The average activity concentrations for Wells 2019 and 2021 were 2,913 and 1,999 picoCuries per liter, respectively. These two wells are located on the eastern and southern perimeter of Waste Pit 4, which indicates of the mobility of certain soluble species out of Waste Pit 4.

The eight RI/FS 3000-series monitoring wells generally reported radionuclide concentrations less than those found in either the 1000 or 2000-series wells. Plutonium-238 and plutonium-239/-240 were only detected in one well at 0.325 and 0.065 picoCuries per liter, respectively and radium-226 and radium-228 were detected in two of the wells (monitoring Well 3821 which is located southwest of Waste Pit 2 reported discernable concentrations for all analytes tested). Neither strontium-290 nor technecium-99 were reported for any of these RI/FS wells. Thorium was reported for only two of the monitoring wells, whereas seven of the eight wells reported uranium isotopes (only Well 3011 did not

report any uranium). The maximum levels of uranium-234, uranium-235/-236, and uranium-238 were all reported form the same monitoring well, Well 3084, which is located in the area north of Waste Pit 4 and between Waste Pit 5 and 6. The ten RCRA 3000-series wells reported similar results, however more analytes were reported as hits. Neptunium-237 was detected in three of the wells varying in concentration from 0.04 to 0.13 picoCuries per liter. Additionally, plutonium isotopes were present in five of the wells and radium isotopes were present in nine of the wells. Strontium-90 was detected in four of the wells ranging form 0.19 to 0.5 picoCuries per liter and technecium-99 was detected in one well at an average concentration of 11.5 picoCuries per liter. Thorium-228 was present in all ten wells as were uranium-234 and uranium-238. The highest average activity concentration were reported in Well 3019 at values of 72.5 and 313 picoCuries per liter, respectively. Well 3019 is located east of Waste Pit 4 and south of Waste Pit 6.

The results of the two RI/FS 4000-series monitoring wells reported only three detected elements. Thorium-230 was detected in one of the wells and the other well reported uranium-234 and uranium-238 in secular equilibrium. (2.44 and 2.23 picoCuries per liter, respectively). The five RCRA monitoring wells (one well was monitored only for total uranium) portrayed a slightly more varied picture. Radium-226 was detected in three of the wells ranging in concentration from 0.11 to 1.02 picoCuries per liter. Plutonium-238 and 239/-240 were detected in two and three wells respectively at low concentrations and radium-228 was reported in one of the 4000-series RCRA wells at 1 picoCuries per liter. Cesium-137, neptunium-237 and technecium-99 were not detected in any of the wells, but strontium-90 was reported for one of the wells at an average activity concentration of 0.26 picoCuries per liter. Thorium and uranium were detected in all the wells reported, but the concentrations were the lowest quantities reported for all series of groundwater (< 1.6 picoCuries per liter). Additional information regarding the groundwater results can be found in Section 4.4 of the Remedial Investigation report.

Surface Water and Sediment

A review of data from the different studies shows a high degree of variability in the surface water contamination concentration pattern. The reasons for the variations in the data could be attributed to the amount of rainfall runoff during the time of sampling, topography which would affect flow from the area, the settling of contaminated suspend solids, and the existence of a contaminant source upgradient of the sampling location.

The highest concentration of contaminants in surface water were detected at drainageways which received surface runoff from Waste Pits 3, 4, 5, and 6. The predominant contaminant is uranium. The two drainageways running east-west between Waste Pits 3, 4, and 5 were found to be contaminated along their total lengths. uranium contamination in the surface water is as high as 8,148 picoCuries per liter. Another drainageway running southeast and turning southwest between Waste Pits 4 and 6 contained water with elevated uranium concentrations. The drainageways in the north part of Operable Unit 1 were found to be the least contaminated. It should be noted that these drainageways were significantly modified as part of the Storm Water Control Removal Action, which included removal of some contaminated soils in these areas and other actions taken under Removal Action No. 22.

Most of the sampling activities took place before the surface runoff was controlled. At that time, surface runoff from the waste pit area discharged into Paddy's Run. With the implementation of the Waste Pit Area Runoff Control Removal Action, potentially contaminated surface water runoff now flows into a catchment basin for treatment before being discharged into the Great Miami River.

Sediments were sampled along drainageways which were considered downstream of potential release locations within Operable Unit 1. The highest levels of contaminants were detected at locations downgradient from Waste Pit 4. The predominant contaminant was depleted uranium. Uranium-238 activity was detected at concentrations as high as 761 picoCuries per gram. The drainageway located south of Waste Pits 4 and 6 revealed elevated levels of uranium along its entire length. Another drainageway between Waste Pits 4 and 5 showed elevated uranium concentrations.

Air and Direct Radiation

Airborne radon measurements are routinely collected both on and off the FEMP property as part of the ongoing environmental monitoring program. As part of this program, the FEMP monitors radon concentrations at 21 locations along the FEMP perimeter fence. The average annual radon concentration along the FEMP fenceline for 1989 through 1992 was 0.74 picoCuries per liter in 1989, 0.74 picoCuries per liter in 1990, 0.90 picoCuries per liter in 1991 and 0.57 picoCuries per liter in 1992. The maximum annual radon concentration recorded during this period was 1.5 picoCuries per liter observed at the radon monitoring station located at the northeast corner of the site. None of the observed radon concentrations exceeded either the DOE guideline of 3.0 picoCuries per liter above

background or the U.S. EPA limit of 4.0 picoCuries per liter for indoor radon concentrations. The state of Ohio has no radon emission standard.

In addition to perimeter monitoring, the FEMP performed radon flux measurements in the vicinity of Waste Pits 1 through 4. Elevated radon flux levels were observed at concentrations up to 81 picoCuries per square minute per second within localized areas over Waste Pits 1, 2, and 3. Average radon flux densities for Waste Pits 1 through 4 were 9.1, 6.4, 2.6, and 0.1 picoCuries per square minute per second, respectively; these levels were well below the NESHAP emission limit of 20 picoCuries per square minute per second.

The FEMP operates nine on-site air monitoring stations to measure the concentration of airborne radioactive particulates along the site perimeter. The average annual concentration of airborne uranium at each fenceline monitoring station was well below the DOE guideline of 0.1 picoCurie per cubic meter during the period 1989 through 1992. Data show a general decrease in airborne uranium concentrations along the FEMP fenceline since production operations ceased in 1989.

Direct radiation measurements were taken throughout Operable Unit 1 to help assess worker health and safety and to identify appropriate soil sampling locations. Localized areas yielded elevated exposure rates greater than 3 millirad per hour. The highest dose rate, 35 millirad per hour, was located near the southwest perimeter of Waste Pit 6. Radiological analyses of soil samples revealed that uranium-238 and short-lived progeny are the principal constituents causing elevated dose rates.

Ecological Characterization

Radiological constituents were detected at low levels near the analytical detection limit in soil, agricultural crops, and garden produce samples from both off-site control areas and other areas in the vicinity of the FEMP. Ecological concentration ratios indicate limited bioaccumulation at control areas and other areas in the vicinity of the FEMP.

Samples collected near Operable Unit 1 suggest limited evidence of uptake, assimilation, and transfer of radiological constituents through ecological food chains. Although concentrations of uranium in soil and vegetation within Operable Unit 1 were the highest from the site, ratios of radionuclide

concentrations in the vegetable and soil were generally similar to concentration ratios in garden produce and agricultural crops from control sites in the FEMP vicinity.

Detectable levels of radionuclides in fish collected from Paddys Run suggest that organisms may have been exposed to FEMP constituents (both hazardous and nonhazardous). Benthic macroinvertebrates collected (such as crayfish, snails, clams, and annelid worms) also exhibited detectable levels of uranium isotopes. This finding is consistent with uranium's known potential to bioconcentrate in aquatic organisms.

Results of the ecological chemical characterization demonstrate that the only organic Constituent of Potential Concern (CPC) in Operable Unit 1 vegetation is butyl benzyl phthalate. In addition, elevated levels of arsenic, barium, mercury, and zinc were noted. Elevated levels of these constituents may have resulted from FEMP releases.

Operable Unit 1 mammals were free of detectable concentrations of organic constituents. However, elevated levels of arsenic, fluoride, sulfate, and zinc were recorded. Fish collected from Paddys Run yielded no detections of organics or pesticides. However, elevated concentrations of aluminum, arsenic, barium, cadmium, fluoride, mercury, sulfide, and zinc were found. The presence of these constituents suggests that fish and wildlife may have been exposed to inorganic constituents from the FEMP.

1.2.4 Summary of Contaminant Fate and Transport

The potential fate and transport of the constituents contained in the Operable Unit 1 waste pits were evaluated to provide a basis for estimating current and future risks posed by Operable Unit 1 and identifying the location of the potential receptors. Contaminant concentrations were estimated for both on-site and off-site areas to provide a range of potential exposure scenarios. The fate and transport evaluation included modeling of surface water, groundwater, and air releases. Conservative assumptions were built into the modeling process in order to provide a reasonable worst-case scenario regarding the migration of constituents from the waste pits and to account for uncertainties associated with the database and models. Screening of CPCs was performed at various stages during the fate and transport assessment process in order to effectively focus the evaluation on those compounds that could potentially pose some measure of risk through the various media.

The fate and transport analysis assumed that the waste pits would remain essentially in their current conditions, without any remedial actions taken. The following discussions summarize the evaluation of constituent migration from Operable Unit 1 through surface water, groundwater, and air.

1.2.4.1 Surface Water

The fate and transport evaluation for surface water assessed the potential impacts on Paddys Run from contaminants transported to the stream via surface water runoff from the Operable Unit 1 area. Concentrations of various constituents were estimated in Paddys Run for both surface water and sediments. In addition, the impacts of discharges of water from Paddys Run to both the Great Miami River and Great Miami Aquifer were evaluated.

Based on the modeling results, uranium is the primary CPC migrating to Paddys Run from the Operable Unit 1 area. Uranium concentrations are at least three orders of magnitude higher than any other constituent, and no other constituent is modeled to reach Paddys Run at a concentration of 1 microgram per liter or higher. Paddys Run surface water concentrations ranged from a minimum of 2.68×10^{-11} micrograms per liter for cesium-137 to a maximum of 255 micrograms per liter (85 picoCuries per liter) for uranium-238. Paddys Run sediment is predicted to have a concentration of 742 milligrams per kilogram (250 picoCuries per gram) for uranium-238 (the maximum constituent).

In general, the modeling results compare favorably with actual surface water sampling data for Paddys Run.

Great Miami River concentrations for the various constituents are approximately three orders of magnitude lower than the Paddys Run concentrations due to dilution effects. As a result, no constituent from Operable Unit 1 is projected to increase the respective river concentrations by as much as 1 micrograms per liter.

Because of the infiltration that occurs from Paddys Run to the Great Miami Aquifer, dissolved contaminants in Paddys Run can infiltrate into the Great Miami Aquifer in locations where the stream bed lies in direct contact with the aquifer. Modeling of Paddys Run infiltration to the Great Miami Aquifer indicates that uranium is the dominant constituent that reaches the aquifer, at a projected maximum concentration of 86 micrograms per liter. This value is in general agreement with

groundwater sampling data. The only other constituent projected to reach the Great Miami Aquifer as a result of Paddys Run infiltration at a concentration of 1 micrograms per liter or higher is manganese, at approximately 5 micrograms per liter. The results of the simulations of Paddys Run infiltration to the Great Miami Aquifer were used as inputs to the groundwater fate and transport modeling.

1.2.4.2 Groundwater

Groundwater transport of contaminants from Operable Unit 1 is considered to be the most significant pathway for the migration of the wastes from Operable Unit 1, due to the physical setting of the waste pits. The Great Miami Aquifer, which is designated as a sole source aquifer and is extensively used for water supply in the region, underlies the waste pits with little or no glacial till separating portions of the waste pits from the aquifer. The fate and transport evaluation for groundwater consisted of geochemical modeling to estimate leachate concentrations migrating from the waste pit, modeling of vadose zone transport vertically downward to the Great Miami Aquifer, and modeling of the transport of contaminants through groundwater. In addition, the infiltration of contaminated surface water from Paddys Run to the aquifer was included as another source of contamination to groundwater.

Each constituent that was included in the groundwater transport portion of the modeling was modeled for a period of 1,000 years or until the concentration in the aquifer decreased below 1 microgram per liter. Two receptor points were evaluated with respect to the modeling: one point on site in the waste pit area and one point at the downgradient property boundary. Modeling results indicate the on-property and off-property maximally exposed receptors to be located to the east of the Operable Unit 1 area.

As with the surface water modeling, uranium was modeled to be present in the aquifer at the greatest concentrations. The maximum concentration of 12.5 micrograms per liter is the modeled peak value at 630 years. Almost all of the modeled impacts were due to releases from the waste pit leachate as opposed to the waste to surface water to aquifer pathway. The maximum concentrations of other radiological, organic, and inorganic constituents were generally in the low micrograms per liter range or lower.

1.2.4.3 Air

Air modeling was performed to determine the maximum concentration of contaminants both on-property and off-property. Simulations were completed for the current waste pit conditions (current source-term scenario) and for postulated pit conditions if no active maintenance was performed on the waste pits (future source-term scenario).

Current Source Scenario Results

Based on the calculated on-site concentrations for all potential contaminants in the current emissions scenario, radon was modeled to be present at the highest activity concentration of 28 picoCuries per cubic meter (0.028 picoCuries per liter). Uranium-238, technecium-99, and thorium-230 were the radionuclides with the next highest activity concentrations at the location of maximum predicted concentrations, with concentrations in the 10^{-2} to 10^{-3} picoCuries per cubic meter (10^{-5} to 10^{-6} picoCuries per liter) range.

In addition to the identified radionuclides, trace levels of a variety of inorganic constituents were modeled to be present. No inorganic concentration was predicted to significantly exceed a level of 10^{-1} microgram per cubic meter, with manganese the compound with the highest detection at 1.6×10^{-1} microgram per cubic meter. The only organic constituent modeled to be present was aroclor-1254, at a concentration of 4×10^{-4} microgram per cubic liter.

The maximum off-site annual average concentrations for the current scenario were predicted to occur at the western FEMP boundary. Radon-222, uranium-238, and thorium-230 were the radiological constituents predicted at the highest activity concentrations, ranging from 2.30 (radon) to less than 10^{-3} picoCuries per cubic meter (10^{-6} picoCuries per liter).

In addition to the radiological compounds, trace levels of a variety of inorganics were modeled to be present. No predicted inorganic concentration significantly exceeded a level of 10^{-2} micrograms per cubic meter, with manganese the compound with the highest predicted concentration at 1.5×10^{-2} micrograms per cubic meter. The only organic constituent modeled to move off-site was aroclor-1254, at a concentration of 3.5×10^{-5} micrograms per cubic meter.

Future Source Scenario Results

Based on the calculated on-site concentrations for all potential contaminants in the future emissions scenario, radon-222 was modeled to be present at the highest activity concentration at 480 picoCurie per cubic meter (0.48 picoCuries per liter). Uranium-238, technecium-99, and thorium-230 were the radionuclides with the next highest predicted activity concentrations at the location of maximum concentrations, with activities in the 10^{-1} picoCurie per cubic meter (10^{-4} picoCuries per liter) range. On a comparative basis, the future scenario concentrations were generally about two orders of magnitude higher than in the current scenario. Trace levels of a variety of inorganics were also modeled to be present. No predicted inorganic concentration exceeded a level of 10 microgram per cubic meter, with arsenic and barium the metals with the highest predicted concentrations at 4.2 micrograms per cubic meter and 2.8 microgram per cubic meter, respectively. A variety of organics were also modeled to be present at trace levels, with tetrachloroethene at the highest predicted concentration of 1.1×10^{-3} microgram per cubic meter.

The maximum off-site annual average concentrations for the future scenario were predicted to occur at the western FEMP boundary. As with the other simulations, radon, uranium-238, thorium-230, and technecium-99 were the radiological constituents projected at the highest activity concentrations, ranging from 40 (radon) to less than 10^{-2} picoCurie per cubic meter (10^{-5} picoCuries per liter).

Low levels of a variety of inorganics were also predicted at this location. No predicted inorganic concentration exceeded a level of 1 microgram per cubic meter, with arsenic, manganese, and barium the metals with the highest predicted concentrations at 3.4×10^{-1} microgram per cubic meter, 2.8×10^{-1} microgram per cubic meter, and 2.0×10^{-1} microgram per cubic meter, respectively. A variety of organics were also modeled to be present at trace levels, with no predicted value exceeding a concentration of 10^{-5} microgram per cubic meter.

1.2.5 Baseline Risk Assessment

As delineated above, the chemical and radiological constituents present within the stored waste inventories and environmental media on the FEMP site, and specifically within the Operable Unit 1 Study Area, present certain risks to human and environmental receptors. The type and degree of this risk has been estimated for existing, or baseline, conditions using EPA risk assessment methodology and is documented in a baseline risk assessment. A baseline risk assessment estimates the risks that

could occur in and around the FEMP site in the event no further cleanup actions would be taken. These risks are evaluated for the situation as it presently exists and as it could exist as far as 1,000 years in the future.

Baseline risks at the FEMP have been evaluated for both the site as a whole and on an operable unit basis. A preliminary site-wide baseline risk assessment was prepared for the FEMP and is included as part of the SWCR. In addition, a Baseline Risk Assessment for Operable Unit 1 was prepared to evaluate potential risk due to sources specifically located in Operable Unit 1.

The objective of the preliminary site-wide baseline risk assessment was to present the site-wide risks for the current and potential future land use scenarios under existing waste pit conditions. The risk assessment characterizes the current and potential future threat to human health and the environment that may be posed by all hazardous constituents and all viable exposure pathways from the FEMP site. The preliminary site-wide baseline risk assessment was based on all data pertaining to the FEMP site. The preliminary site-wide risk assessment includes an assessment of the ecological impacts of the FEMP and is supplemented by a NEPA analysis of the environmental consequences of the no-action alternative and is detailed further below in Section 1.2.5.1.

The Operable Unit 1 baseline risk assessment addresses exposure scenarios, contaminates and pathways of potential exposure, and risk characterization results. Four exposure scenarios including current industrial land use with and without access controls and future agricultural land use were evaluated. These scenarios were then combined with two source terms, current and future. Results of the Operable Unit 1 baseline risk assessment are provided below in Section 1.2.5.2.

1.2.5.1 Site-Wide Baseline Ecological Risk Assessment

The purpose of the ecological risk assessment, which was completed as a companion to the preliminary site-wide baseline risk assessment in the SWCR, was to estimate the potential and future baseline risks of FEMP contaminants to ecological receptors.

The EPA and DOE have agreed in the Amended Consent Agreement (September 1991) that the Site-Wide Ecological Risk Assessment will be performed as part of the RI for Operable Unit 5. The Site-Wide Ecological Risk Assessment in the RI for Operable Unit 5 will quantify and assess the possible

risks from current concentrations of site contaminants to ecological receptors inhabiting on-site and off-site areas not presently targeted for remediation based on human-health concerns.

The ecological receptors potentially exposed to FEMP contaminants include all organisms, exclusive of humans and domestic animals. The ecological risk assessment focused on a group of indicator species selected to represent a variety of exposure pathways and trophic positions. Terrestrial vegetation was represented by a generic plant species. Terrestrial wildlife species to be evaluated were selected based on species abundance on the FEMP site, trophic level position, and habitat requirements. The species evaluated were the white-tailed deer (*Odocoileus vriginianus*), white-footed mouse (*Peromyscus leucopus*), raccoon (*Procyon lotor*), red fox (*Vulpes*), muskrat (*Ondatra zibethica*), American robin (*Turdus migratorius*), and red-tailed hawk (*Bueto jamaicensis*).

The assessment examined risks to terrestrial organisms associated with contaminants in two environmental media -- surface soils, summarized for the entire site, and surface water in Paddys Run from the northern boundary of the FEMP site to the confluence with the storm sewer outfall ditch. Risks to aquatic organisms were evaluated for exposure to contaminants in Paddys Run, the Great Miami River, and in runoff in the storm sewer outfall ditch. Estimated ecological risks associated with exposure to FEMP site constituents of concern are primarily due to nonradioactive inorganic chemicals in soils, rather than to organic chemicals or radionuclides. This is true for both terrestrial and aquatic organisms and for plants as well as wildlife. In particular, estimated intakes of arsenic, cobalt, lead, and silver from FEMP soils were all higher than estimated no observed effect levels (NOELs) for at least six of the seven indicator species selected for this assessment. The relative hazards to individual species varied, but the white-footed mouse consistently had the highest indices of these chemicals. This can be attributed to the assumed intake by the mouse of insects (using earthworms as surrogates), which in turn were assumed to assimilate chemicals from soil with a transfer coefficient of 1.0.

Estimated hazards to terrestrial organisms of exposure to constituents of concern in FEMP surface waters were relatively low, with HIs greater than one only for arsenic, lead, molybdenum, and silver. These chemicals presented hazards of two, five, four and three to indicator species, respectively, and the highest HI estimated was for lead intake by the mouse. Surface water exposure is therefore unlikely to be a significant source of risk to terrestrial ecological receptors at the FEMP site.

Estimated doses to terrestrial organisms at the FEMP site, originating from soil uptake by plants and earthworms, were below levels expected to cause detectable effects. However, as with inorganic chemicals, this conclusion is sensitive to assumptions about muscle-to-muscle transfer of radionuclides. Highly efficient transfer or biomagnification of uranium, in particular, could expose terrestrial wildlife at the FEMP to potentially harmful radiation levels. Radiation doses due to water intake were insignificant.

Exposure to radiological contaminants does not appear to pose a risk to aquatic organisms at the measured concentrations in the surface waters and sediments impacted by the FEMP site. However, modelled concentrations of radionuclides in runoff from the FEMP site into surface water would cause estimated exposures to exceed the upper limit of 1 rad/day. The most affected organisms would be aquatic plants, receiving a total dose from internal and external exposure of about 140 rad/day. The total dose to fish is minimally over the limit, at 1.6 rad/day, and the total dose to benthic macroinvertebrates is about 14 rad/day. Although the maximum concentrations at low flow were used in source runoff calculations, the minimum values in the storm sewer outfall ditch and Paddys Run are within the same magnitude of values. Doses to aquatic organisms in the Great Miami River would be well below 1 rad/day. The measured concentrations of cadmium, copper, mercury, and silver in surface water exceeded chronic toxicity criteria for the protection of freshwater organisms.

Field studies on the impact of the FEMP site on terrestrial and aquatic communities do not indicate any effects consistent with contaminant impacts expected for above-background levels of arsenic and mercury recorded in RI/FS plant samples. In addition, although potential impacts at the individual level were predicted for wildlife species, detrimental or adverse impacts have not been observed in the field. This suggests that the potential effects may not occur. A comparison of the concentrations of inorganic chemical concentrations in FEMP soils to regional background values indicate the mean FEMP concentrations may be similar to the upper 95 percent confidence levels of background values. This indication suggests that ecological risks estimated using background values of inorganics would be comparable to those estimated for the FEMP site, and emphasizes the conservative nature of the method used.

In summary, although radionuclides are the most ubiquitous contaminants at the FEMP, estimated ecological risks to both terrestrial and aquatic organisms are primarily associated with nonradioactive

inorganic chemicals. Although estimated risks are substantial in some instances, they are based on soil inorganic chemical concentrations comparable to background levels, and deleterious effects have not been observed in the field. This suggests that current FEMP site-specific ecological risks are low.

1.2.5.2 Operable Unit 1 Baseline Risk Assessment

This section summarizes the Operable Unit 1 baseline risk assessment, as published in Section 7.0 of the RI Report for Operable Unit 1 (DOE 1994a). Included are discussions of exposure scenarios, CPCs, and risk characterization results. Since the estimate of potential risks from Operable Unit 1 require many assumptions and the modeling of future concentrations of contaminants in the environment, a degree of uncertainty is associated with these estimates. This uncertainty is discussed extensively in Appendix E to the RI which contains the entire risk assessment.

The baseline risk assessment evaluates the potential risk to hypothetical receptors, due to sources in Operable Unit 1, which may exist if no remedial actions were taken to correct known environmental deficiencies. The results of the baseline risk assessment are employed to identify the key contaminants and pathways of potential exposure which must be addressed by a remedial action. The baseline risk assessment is often employed as a point of comparison to evaluate the potential reduction in risk from each of the proposed remedial alternatives considered.

Exposure Scenarios

Four land use/source term scenario combinations are evaluated in the Operable Unit 1 baseline risk assessment, including:

Land Use Scenario	Source Term
Current Land Use (Industrial)	
- With Access Controls	Current Source Term
- Without Access Controls	Current Source Term
- Without Access Controls	Future Source Term
Future Land Use (Agricultural)	Future Source Term

Under the first land-use scenario, the site access restrictions historically provided by DOE are assumed to be maintained, and no further remedial actions are assumed to have been taken (other than those completed to date). The scenario further assumes that no members of the public have established residence in the Operable Unit 1 study area, and that DOE maintains a site-specific health

and safety program to ensure that nonremediation workers are properly protected. Potential receptors under this scenario include an off-property farmer and a site visitor.

Under the second land-use scenario, current land use without access controls, the FEMP is assumed to be managed by an industrial concern other than DOE. Access restrictions currently provided by DOE are assumed to be discontinued. In addition, no remedial actions are assumed to have been taken, and no members of the public establish residence within the boundaries of Operable Unit 1. Thus, potential receptors include an off-property farmer, a trespassing child, an off-property user of meat and dairy products from cattle grazed on site, and an off-site user of surface water from the Great Miami River.

The third land use scenario, future land use without access controls, includes exposure routes associated with development of residences, such as a home and farm, within the boundaries of Operable Unit 1. Access controls are assumed to be absent and no additional remedial actions are assumed to have been taken. Hypothetical receptors under this scenario are a reasonable maximum exposure (RME) resident farmer, a central tendency (CT) resident farmer, a resident child, and an on-property home builder.

In addition to the three land use scenarios, there are two source term scenarios: the current source term and the future source term. The current source term scenario considers the waste pit area as it exists today. The future source term scenario assumes that all maintenance activities within Operable Unit 1 have been discontinued. The cap on Waste Pit 3 is assumed to erode over time, exposing pit contents. Caps on Waste Pits 1, 2, and 4 are assumed to remain intact. Water in Waste Pits 5 and 6 is assumed to evaporate, exposing pit contents in more than half of the surface area of each pit. The Clearwell is assumed to remain water-filled. The surface water runoff control system constructed under Removal Action No. 22 (as defined in Appendix G Attachment II) is assumed to be non-functional under the future source term scenario.

Under the current land use without access control scenario, risks are calculated using both current and future source terms. The current land use with access control scenario assumes that the site remains under the institutional control of DOE and the waste pit area is maintained. The current land use with access control scenario estimates risk using only the current source term. The future land use

scenario is addressed using only the future source term. In summary, four land use/source-term scenario combinations are evaluated in the Operable Unit 1 Baseline Risk Assessment.

The CT receptor was added in response to new guidance from EPA, which suggests that all risk assessments provide an evaluation of the CT of the risk range, using the best information available to describe the average situation. This scenario is used to provide an estimate of risk closer to average for the resident adult scenario. The CT receptor for this scenario is located at the same location as the RME resident farmer receptor.

Constituents of Potential Concern

In the risk assessment process, CPCs are selected to focus the quantitative risk assessment on those chemical and radiological constituents which are of most significance, based on prevalence, concentration, and toxicity. The selection of CPCs for Operable Unit 1 considers site data characterizing the following environmental media: pit wastes; surface water in Waste Pits 5, 6, and the Clearwell; soils within the Operable Unit 1 study area; berm fill material; and pit leachate. The raw data sets on which analyses are performed are presented in Section 4.0 of the RI Report and are tabulated in Appendices A, B, and C of the RI report.

The selection of chemical and radionuclide CPCs for Operable Unit 1 is based on environmental characterization data generated in a number of site investigations. The CPC selection is based primarily on data collected in the Operable Unit 1 RI and the CIS. As described in Section 2.0 of the RI report, these investigations characterized radiological and chemical composition of solid and liquid media and wastes in the Waste Pit Area. Supplemental data characterizing the subsurface pit materials in the water-filled waste pits in Operable Unit 1 (i.e., Waste Pits 5, 6, and the Clearwell) were obtained during an investigation by the 1992 RI/FS. A full radiological and chemical analysis was performed on the sludge samples collected from these waste pits during the 1992 RI/FS investigation. These data were used, along with the RI and CIS data, in selection of CPCs for Operable Unit 1.

Because of heterogeneity in wastes contained in the Operable Unit 1, CPCs for waste pit material and pit surface water were selected on a pit-by-pit basis. Surface soils within the Operable Unit 1 boundary were treated as a discrete entity for selection of CPCs.

The CPCs were selected for inclusion in the quantitative risk assessment, based on a three-step process. In the initial step, each constituent detected in a given medium was reviewed for exclusion of those that would not significantly impact the results of the risk assessment. Known laboratory contaminants, essential nutrients, and ubiquitous minerals were excluded as CPCs in a preliminary screening step. In the second step, statistical analyses were used to compare measured on-property concentrations of each remaining CPC to background concentrations of that constituent in the same media.

Risk Characterization Results

Risks resulting from carcinogenic contaminants are assessed in terms of the lifetime cancer risk they present to human populations over and above that to which humans are already exposed. This incremental lifetime cancer risk is referred to as the ILCR. Statistics show a greater than 33 percent (1 in 3) probability that the average human will acquire cancer from all causes. As established by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 CFR 300), risks from waste sites should generally not add greater than 1 in 10,000 (1×10^{-4}) to 1 in 1,000,000 (1×10^{-6}) probability of acquiring cancer over the average lifetime of a potentially exposed human.

As a basis for comparison, calculations of the risk associated with the natural background concentration of radionuclides and inorganic metals in soil were performed using the same assumptions as used in the resident farmer scenario. The radiocarcinogenic risk associated with background concentrations of radionuclides under these conditions was calculated as 7×10^{-4} for the soil pathways. Of the scenarios presented, the current land use with access controls most closely approximates current conditions at the FEMP. However, conservative assumptions were made, consistent with those made for other scenarios, to ensure that the calculated baseline risk represents an upper bound.

Risk estimates are derived by combining the results of the exposure assessment and the toxicity information to quantitatively estimate the degree of hazard associated with exposure to CPCs. The ranges of generally acceptable risk under CERCLA are an ILCR less than 10^{-4} (1 in 10,000) and a hazard quotient of less than 1.

Current Land Use With Access Controls - Current Source Term. The maximally exposed individual in this scenario is the site visitor. This person, through routine exposure over a period of 25 years, could incur a risk of 3×10^{-4} (3 in 10,000) from radiocarcinogens. Inhalation of dust and radon would contribute about 40 percent of the total risk, with the remainder deriving from approximately equal contributions from exposure to penetrating radiation from buried waste pit materials (under extremely conservative assumptions) and external exposure from surface soil.

The total chemical carcinogenic risk for this receptor was estimated at 3×10^{-6} and is due solely to the inhalation of fugitive dust emissions. This receptor is not defined as experiencing chemical exposure from any other medium. Chromium and arsenic are the major contributors to the total chemical risk.

The total hazard index for this receptor was estimated at 0.5, which is within the range generally considered acceptable.

Current Land Use Without Access Controls - Current Source Term. Under this scenario, the maximally exposed individual is assumed to be the off-property resident farmer. This receptor is exposed only to those contaminants subject to transport through air. Because the current source term is considered, only those contaminants identified in the surface soil were evaluated in the air modeling.

The results of the air modeling indicated that the point of maximum off-property risk was located 450 meters west and 150 meters south of the center of the Burn Pit, which is just off the western fenceline of the site. At this point, risks were evaluated for the off-property resident farmer.

The total radiocarcinogenic risk for this receptor was 5×10^{-5}, with 98 percent due to the inhalation of dust and gaseous emissions. Uranium-238, uranium-234, thorium-230, and radon-222 were the major contributors to this risk. The food pathways were not significant for the radionuclides.

The total chemical carcinogenic risk for the off-property resident farmer was 3×10^{-6}. This risk was fairly evenly divided between all the food pathways and inhalation of dust. Aroclor-1254, chromium, and arsenic were the primary chemical carcinogens in this assessment.

The hazard index for this receptor was estimated at 0.07, which was within the range generally considered acceptable.

The trespassing child could also experience risks of a similar magnitude. The total radiocarcinogenic risk was estimated at 5 x 10^{-5} (5 in 100,000), which is comprised of several components roughly similar in magnitude of risk. Penetrating radiation exposures from buried waste pit materials, external exposure from surface soil, and inhalation of dust and radon make up 100 percent of the total risk. The most significant contributors to the risk, in descending order, are uranium-238, thorium-230, uranium-234, and radon-222 for air exposures, and radium-226 and thorium-228 for the external exposures. The hazard index for this receptor was 0.3.

Current Land Use - Future Source Term. The receptor subject to the greatest ILCR for the current land use/future source term configuration is the off-property resident farmer. This receptor is only exposed to those media and contaminants subject to transport from the site. Since the source term is varied to account for erosion of caps, etc., this receptor would experience additional risks over those of the current source term scenario. For example, exposure to contaminants migrating in the Great Miami Aquifer are considered for the future source term.

While the risks are presented as a total for both air and groundwater exposures, it should be noted that the points of maximum risk for these two media do not coincide temporarily. Risk sums did assume these two occur during the same time frame.

The total carcinogenic risk from exposure to radionuclides is projected at 2 x 10^{-3}, and the total chemical carcinogenic risk is 4 x 10^{-3}. Uranium and thorium isotopes and radon are the primary CPCs in the radiologic risk via inhalation, and uranium-238 and other radionuclides control the groundwater risks from all pathways. Arsenic and nickel are the primary chemical carcinogens, and affect the receptor only via inhalation of fugitive dust emissions from the site.

The total hazard index for this receptor is 60, with ingestion of fruits and vegetables affected by areal deposition of metals presenting the majority of the risk.

Future Land Use - Future Source Term. The RME receptor for this configuration is obviously the on-property RME resident. This receptor, as discussed in the exposure assessment, is assumed to live in a home in the vicinity of Waste Pit 4, use water from the Great Miami Aquifer for all potable and agricultural purposes, and grow food in the area of Waste Pits 1 and 2. The soil caps over Waste Pit 3 is assumed to have eroded, and waste material in Waste Pits 5 and 6 is exposed after the waste pits partially dry up.

Risks associated with ingestion of groundwater from the perched aquifer was not included in the total risk estimates. The aquifer is discontinuous, and is unlikely to yield enough water for anything other than ingestion alone. Therefore, while risks were calculated, they are not summed with the other pathway risks.

The total radiocarcinogenic risk for this receptor is estimated at 4×10^{-2}; these are primarily risks associated with the inhalation of dust and radon and external exposure to soil and exposed waste pit material. As with the other scenarios discussed above, uranium and thorium isotopes and radon drive the inhalation risks, and uranium, thorium, and radium isotopes drive the external exposure risks.

The chemical carcinogenic risks for this hypothetical receptor are 6×10^{-2}, and are due primarily to ingestion of drinking water from the Great Miami Aquifer and ingestion of fruits and vegetables irrigated with groundwater or affected by particulate emissions from the waste pits. Arsenic is the primary contributor to the chemical carcinogenic risk, although other carcinogenic compounds such as PAHs and dioxins are present in the exposed waste pit material. However, these other compounds present a risk at least an order of magnitude lower than that for arsenic.

The food ingestion pathways clearly drive the hazard quotient, with ingestion of fruits and vegetables affected by particulates having the highest hazard index (400), followed by ingestion of fruits and vegetables irrigated with contaminated groundwater (containing arsenic and uranium, primarily). The total hazard quotient for this receptor was estimated at 700. Section 2.0 discusses how this information was used to develop proposed remediation levels.

TABLE 1-1

WASTE UNIT CHARACTERISTICS

Waste Unit	Operation Period	Cover Type	RCRA Status	Liner Type	Est. Waste Volume (CY)	Est. Total Volume (CY)	Approx Depth (feet)	Surface Area (acre)
Pit 1	1952-1959	Soil	SWMU[a]	Clay[b]	48,500	68,400	29.5	2.11
Pit 2	1957-1964	Soil	SWMU	Clay	24,200	37,400	23.5	0.90
Pit 3	1958-1977	Soil	SWMU	Clay	204,100	307,500	42	5.00
Pit 4	1960-1986	RCRA Cap	HWMU[c]	Clay	55,100	72,800	32	1.50
Pit 5	1968-1983	Water	HWMU	EPDM[d]	97,900	97,900	29	3.74
Pit 6	1979-1985	Water	SWMU	EPDM	9,600	9,600	20	0.74
Burn Pit	1957-1968	Soil	SWMU	None	30,300	30,300	26	0.50
Clearwell	1959-1987	Water	SWMU	Clay	3,700	4,300	12	0.65

[a] RCRA Solid Waste Management Unit
[b] Native clay liner
[c] RCRA Hazardous Waste Management Unit
[d] 60-mil thick Royal Seal ethylene popylene diene monomer elastomeric membrane

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TABLE 1-2
MATERIAL VOLUME CALCULATION RESULTS FOR WASTE PIT 1

Material	Depth (ft)	Volume (yd^3)	Volume (m^3)
Cover	0.5	1700	
Waste	18 (maximum)	48,500	37,083
Low Permeability Material	11 (maximum)	18,200	
TOTAL	29.5 (maximum)	68,400	

TABLE 1-3
MATERIAL VOLUME CALCULATION RESULTS FOR WASTE PIT 2

Material	Depth (ft)	Volume (yd^3)	Volume (m^3)
Cover	1 to 4	4200	
Waste	15 ± 1	24,200	18,503
Low Permeability Material	4.5 (approximate)	9000	
TOTAL	23.5 (maximum)	37,400	

TABLE 1-4
MATERIAL VOLUME CALCULATION RESULTS FOR WASTE PIT 3

Material	Depth (ft)	Volume (yd^3)	Volume (m^3)
Cover	14 (maximum)	93,700	
Waste	27 (maximum)	204,100	156,055
Low Permeability Material	1 (approximate)	9700	
TOTAL	42 (maximum)	307,500	

TABLE 1-5
MATERIAL VOLUME CALCULATION RESULTS FOR WASTE PIT 4

Material	Depth (ft)	Volume (yd^3)	Volume (m^3)
Cover	6	14,600	
Waste	25	55,100	42,130
Low Permeability Material	1	3100	
TOTAL	32 (maximum)	72,800	

TABLE 1-6
MATERIAL VOLUME CALCULATION RESULTS FOR WASTE PIT 5

Material	Depth (ft)	Volume (yd^3)	Volume (m^3)
Cover	N/A[a]	N/A[a]	
Waste	28 ± 1	97,900	74,854
Low Permeability	N/A[a]	N/A[a]	
TOTAL	29 (maximum)	97,900	

[a] Not applicable.

TABLE 1-7
MATERIAL VOLUME CALCULATION RESULTS FOR WASTE PIT 6

Material	Depth (ft)	Volume (yd^3)	Volume (m^3)
Cover	N/A[a]	N/A[a]	
Waste	20	9600	7340
Low Permeability Material	N/A[a]	N/A[a]	
TOTAL	24 (maximum)[b]	9600	

[a] Not applicable.
[b] Distance from top of berm to liner.

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TABLE 1-8
MATERIAL VOLUME CALCULATION RESULTS FOR THE CLEARWELL

Material	Depth (ft)	Volume (yd^3)	Volume (m^3)
Cover	N/A[a]	N/A[a]	
Waste	11	3700	2829
Low Permeability Material	1	600	
TOTAL	27 (maximum)[b]	4300	

[a] Not applicable.
[b] Distance from top of berm to bottom of Clearwell.

TABLE 1-9
MATERIAL VOLUME CALCULATION RESULTS FOR THE BURN PIT

Material	Depth (ft)	Volume (yd^3)	Volume (m^3)
Cover	N/A[a]	N/A[a]	
Waste	26	30,300	23,167
Low Permeability Material	N/A[a]	N/A[a]	
TOTAL	26 (maximum)	30,300	

[a] Not available.

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TABLE 1-10

RCRA AND RI/FS GROUNDWATER MONITORING WELLS OPERABLE UNIT 1

	Total Monitoring Wells	1000-Series Wells	2000-Series Wells	3000-Series Wells	4000-Series Wells
RCRA	52	24	12	10	6
RI/FS	48	25	13	8	2

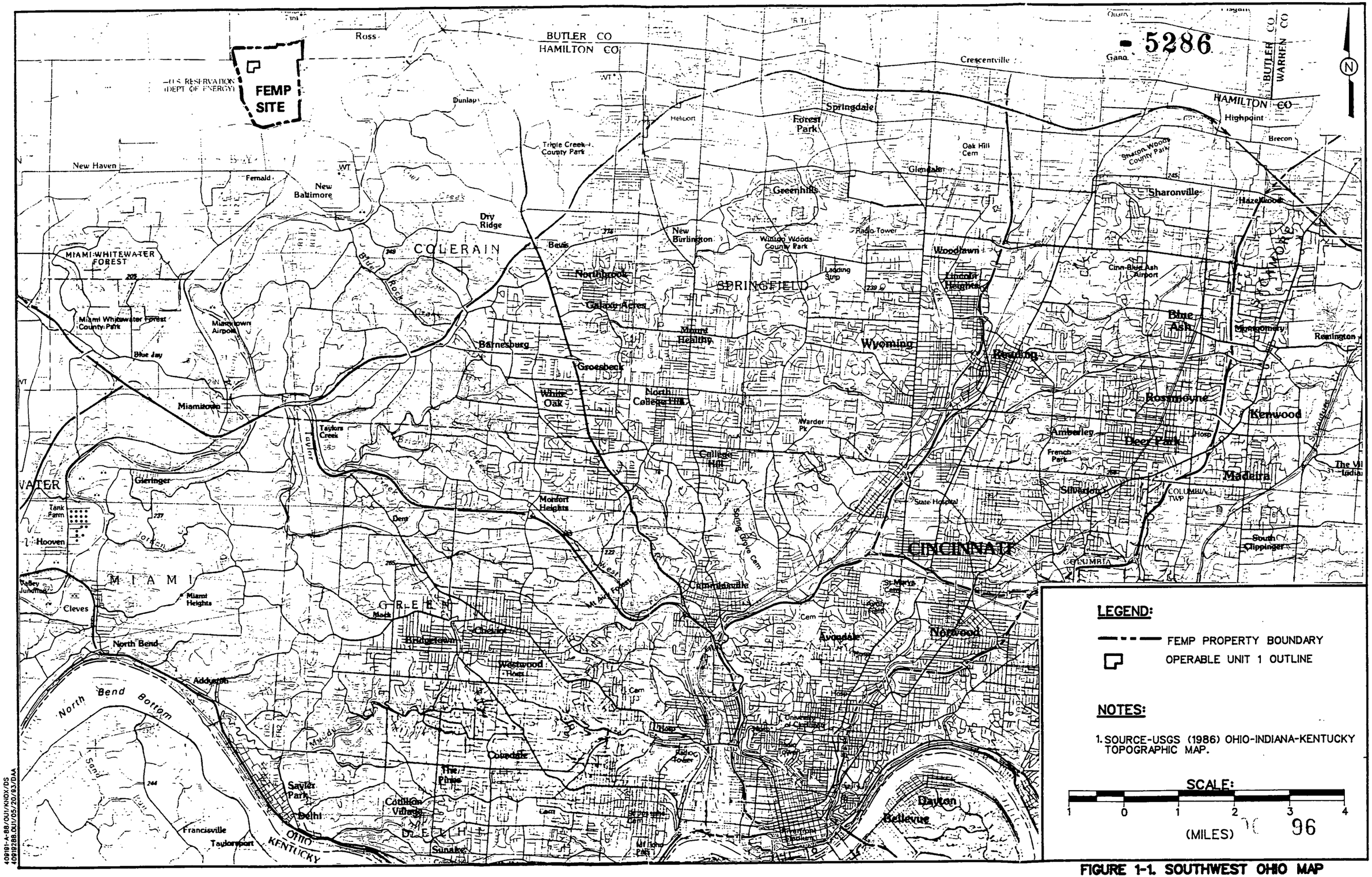
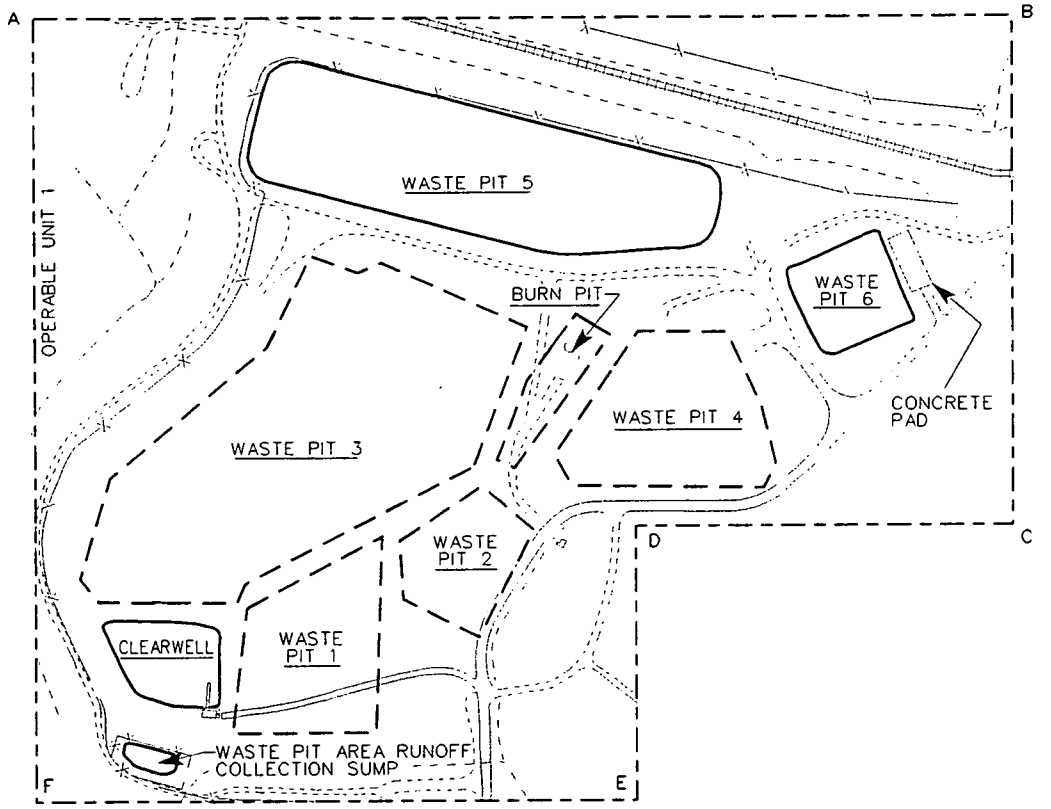


FIGURE 1-1. SOUTHWEST OHIO MAP

409191-A-88/OU1/KNOX/DS
40919288.OU1/05/20/93/DAA

FER/OU1FS/BJH/SEC-1/02/28/94 5:35pm



NOTES:

1. PITS 1, 2, 3 AND THE BURN PIT ARE COVERED WITH SOIL CAPS AND VEGETATED.
2. PIT 4 HAS AN INTERIM CAP.
3. PITS 5, 6 AND CLEARWELL ARE WATER COVERED
4. COORDINATES SHOWN ARE OHIO STATE PLANAR COORDINATES, ADJUSTED PER THE NORTH AMERICAN DATUM (NAD) OF 1983.

OU1 STATE PLANAR COORDINATES		
POINT	NORTHING	EASTING
A	482364	1377824
B	482364	1379432
C	481499	1379432
D	481499	1378812
E	481033	1378812
F	481033	1377824

LEGEND:

- FENCE LINE
- DRAINAGE WAY
- CSX RAIL LINE
- PAVED ROADWAY
- GRAVEL ROADWAY
- OPERABLE UNIT 1 OUTLINE
- COVERED PIT OUTLINE
- OPEN PIT OUTLINE

SCALE: 0 — 300 FEET

409191-A-410 / OU1/ KNOX/ DS
40919410.OU1 02-10-94 DON GOSS

FIGURE 1-2. OPERABLE UNIT 1 SITE MAP

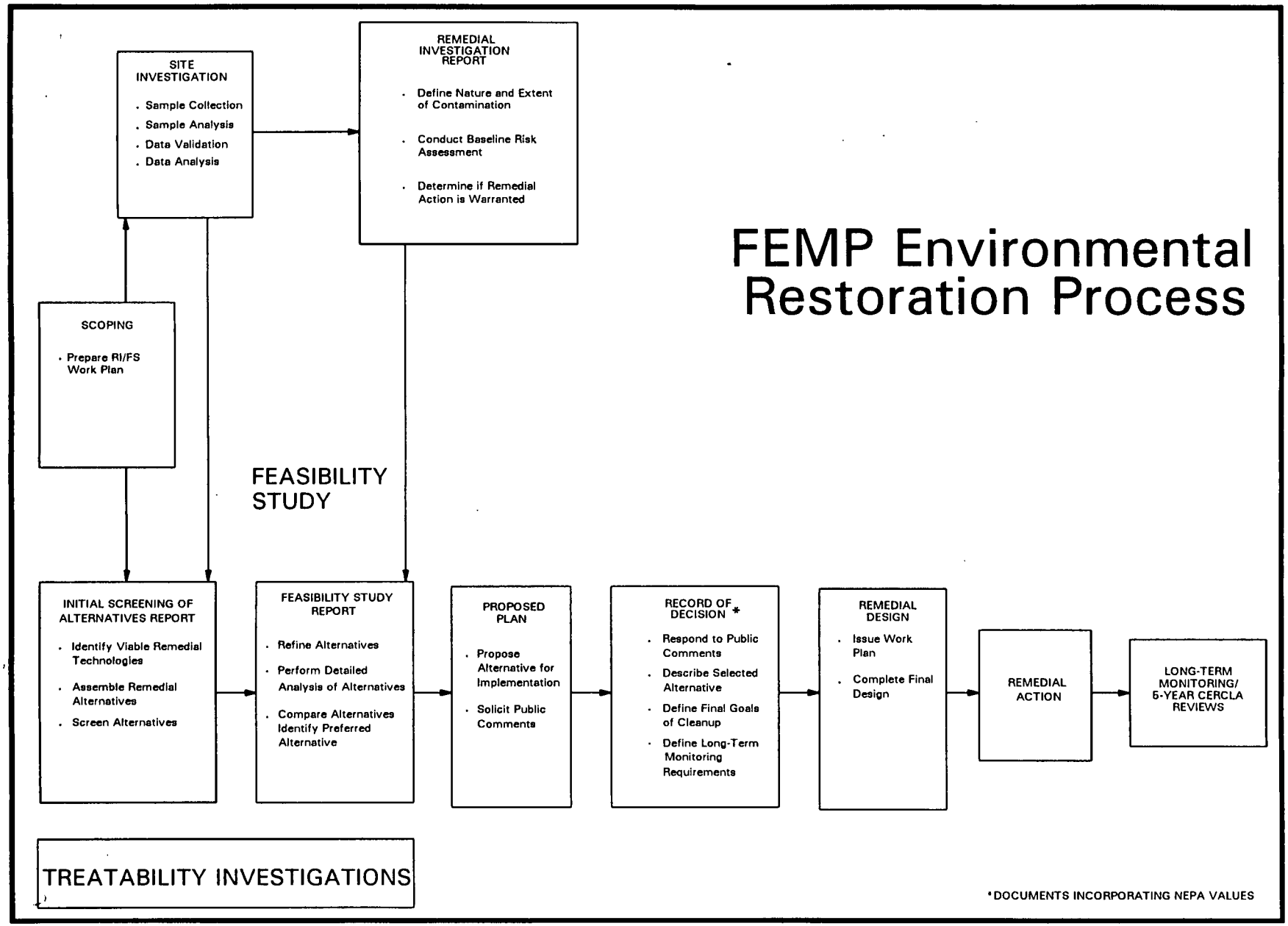


FIGURE 1-3 FEMP ENVIRONMENTAL RESTORATION PROCESS

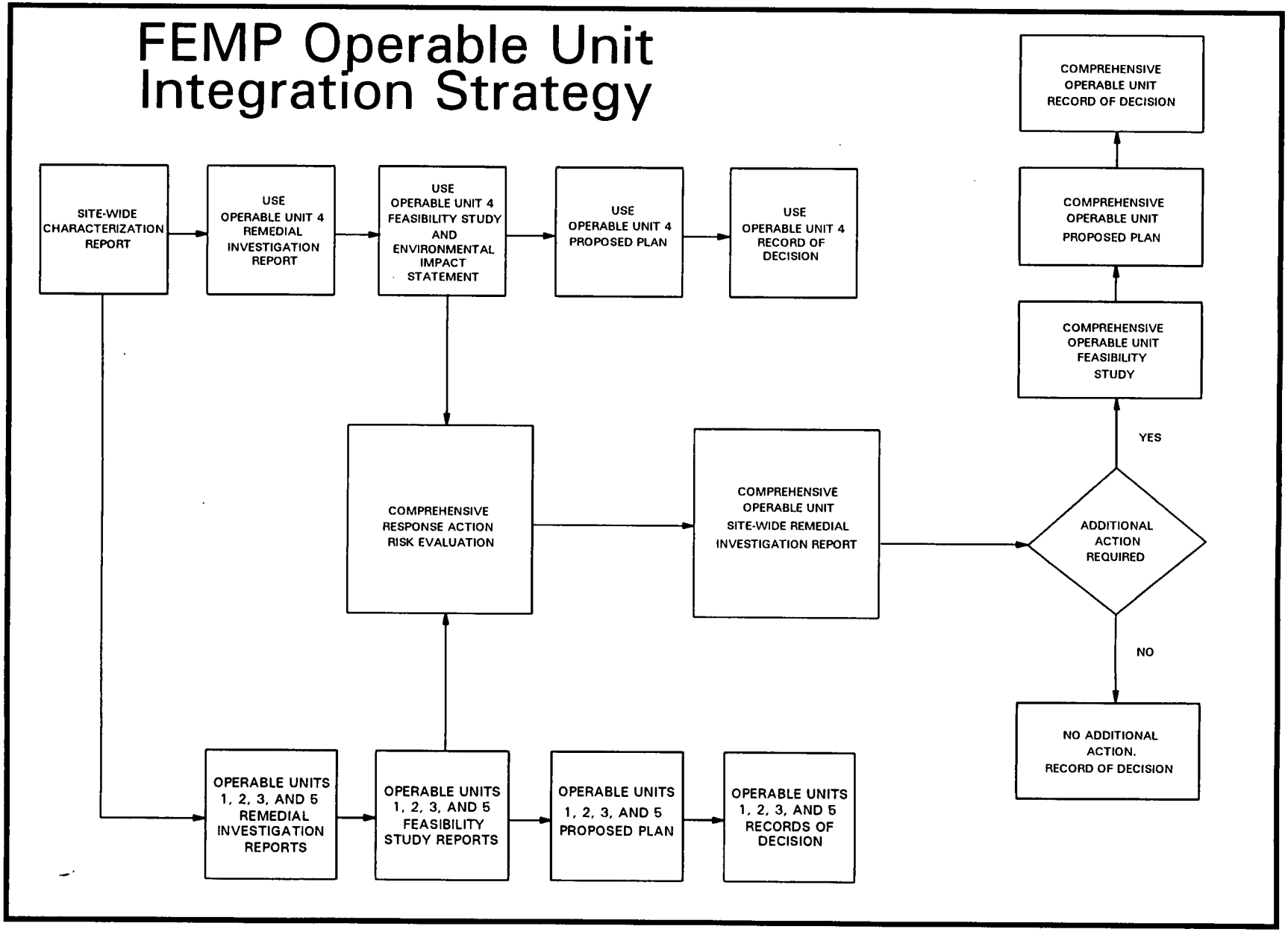


FIGURE 1-4 OPERABLE UNIT INTEGRATION STRATEGY

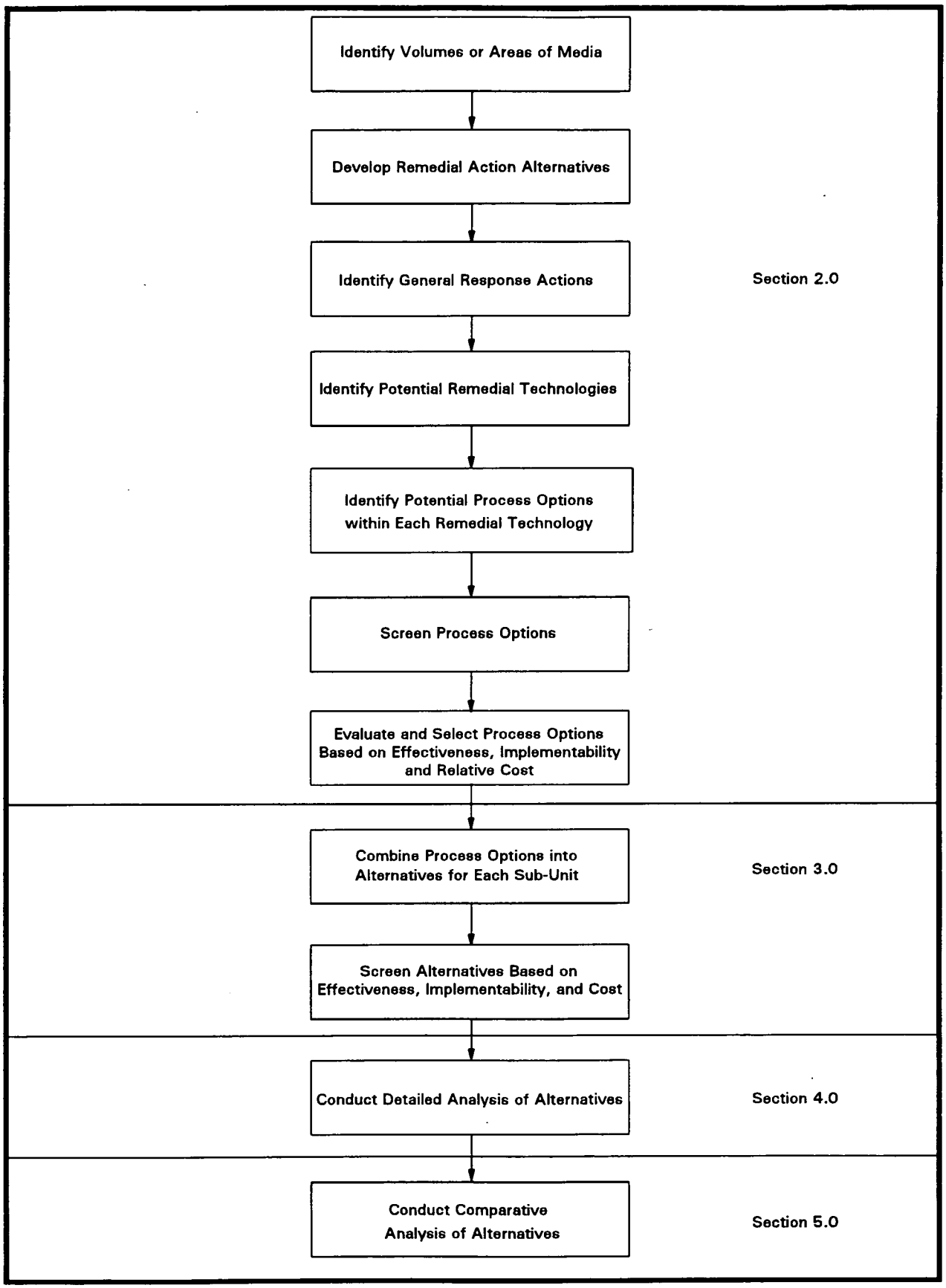
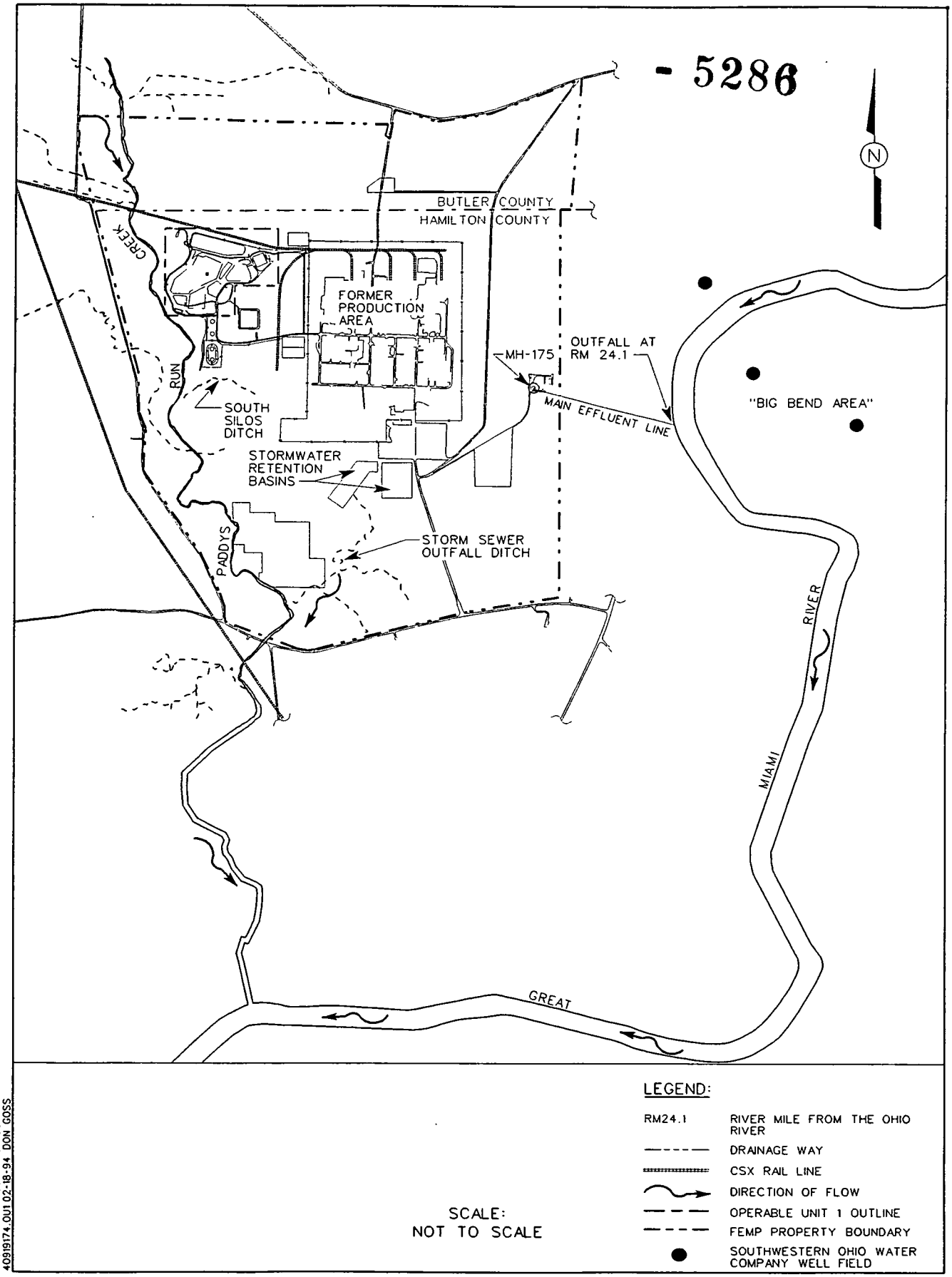


FIGURE 1-5 ELEMENTS OF THE FS PROCESS



409191-A-174 /OU1 /KNOX/DS
4091917A.OU1 02-18-94 DON GOSS

FIGURE 1-6. SURFACE WATER BODIES ON AND ADJACENT TO THE FEMP

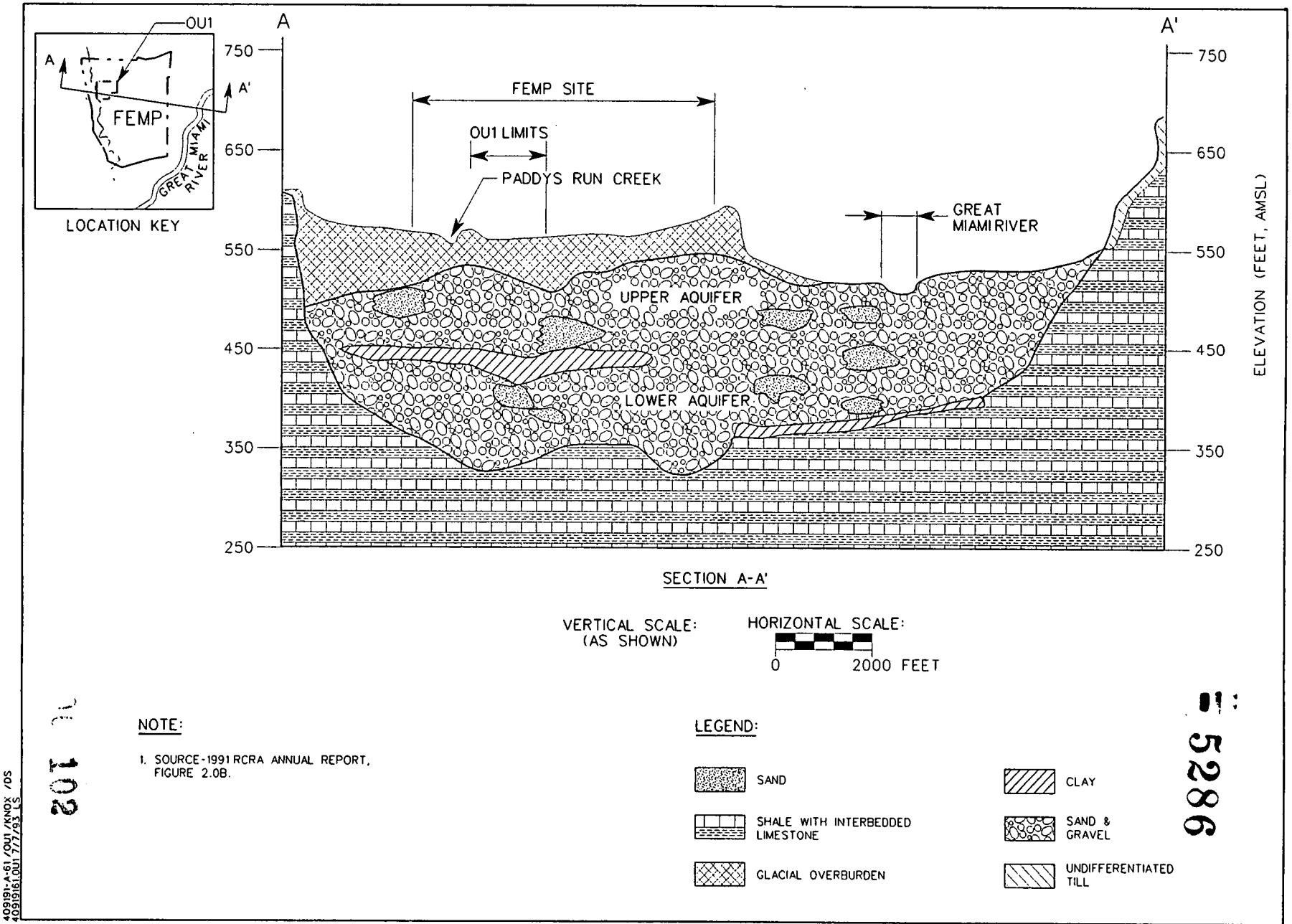
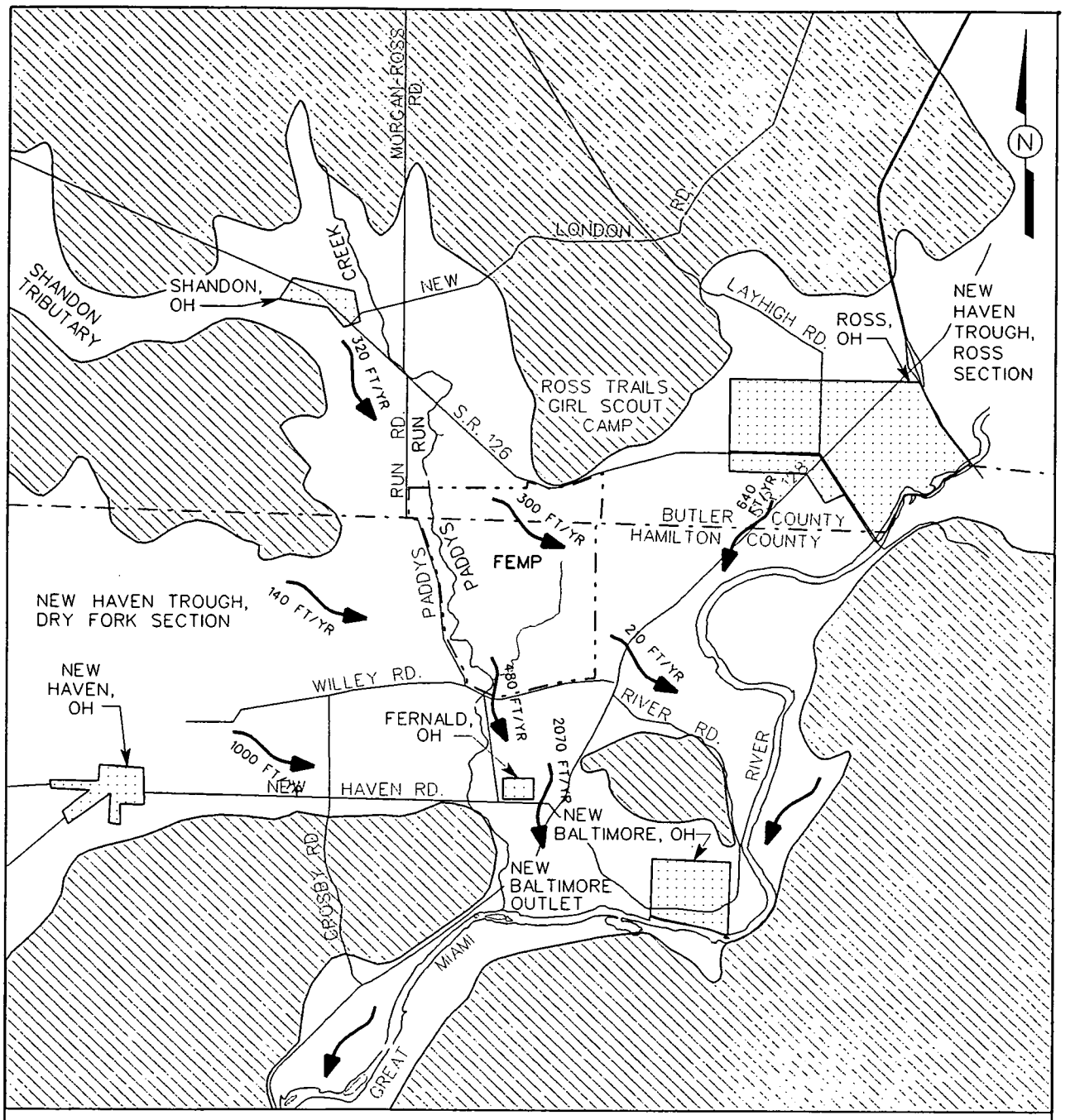


FIGURE 1-7. SCHEMATIC CROSS SECTION OF THE FEMP AREA

409191-A-61 /OU1 /KNOX /OS
409191OU1 7/7/93 LS



NOTES:

1. DIRECTION OF GROUNDWATER FLOW BASED ON APRIL 1986 WATER LEVEL CONTOURS AND GROUNDWATER MODELING OUTPUT (3DPART07.OUT).
2. VELOCITIES CALCULATED FROM GRADIENTS ON SEVERAL POTENTIOMETRIC MAPS, USING HYDRAULIC CONDUCTIVITY EQUAL TO 450 FT/DAY AND EFFECTIVE POROSITY EQUAL TO 0.23.

LEGEND:

- COUNTY LINE
- FEMP PROPERTY BOUNDARY
- 340 FT/YR — GENERALIZED GROUNDWATER FLOW DIRECTION, & HORIZONTAL FLOW VELOCITY AT THE 2000-SERIES LEVEL.
- BEDROCK OUTSIDE GREAT MIAMI AQUIFER
- TOWNS AND VILLAGES

SCALE: 0 — 5000 FEET

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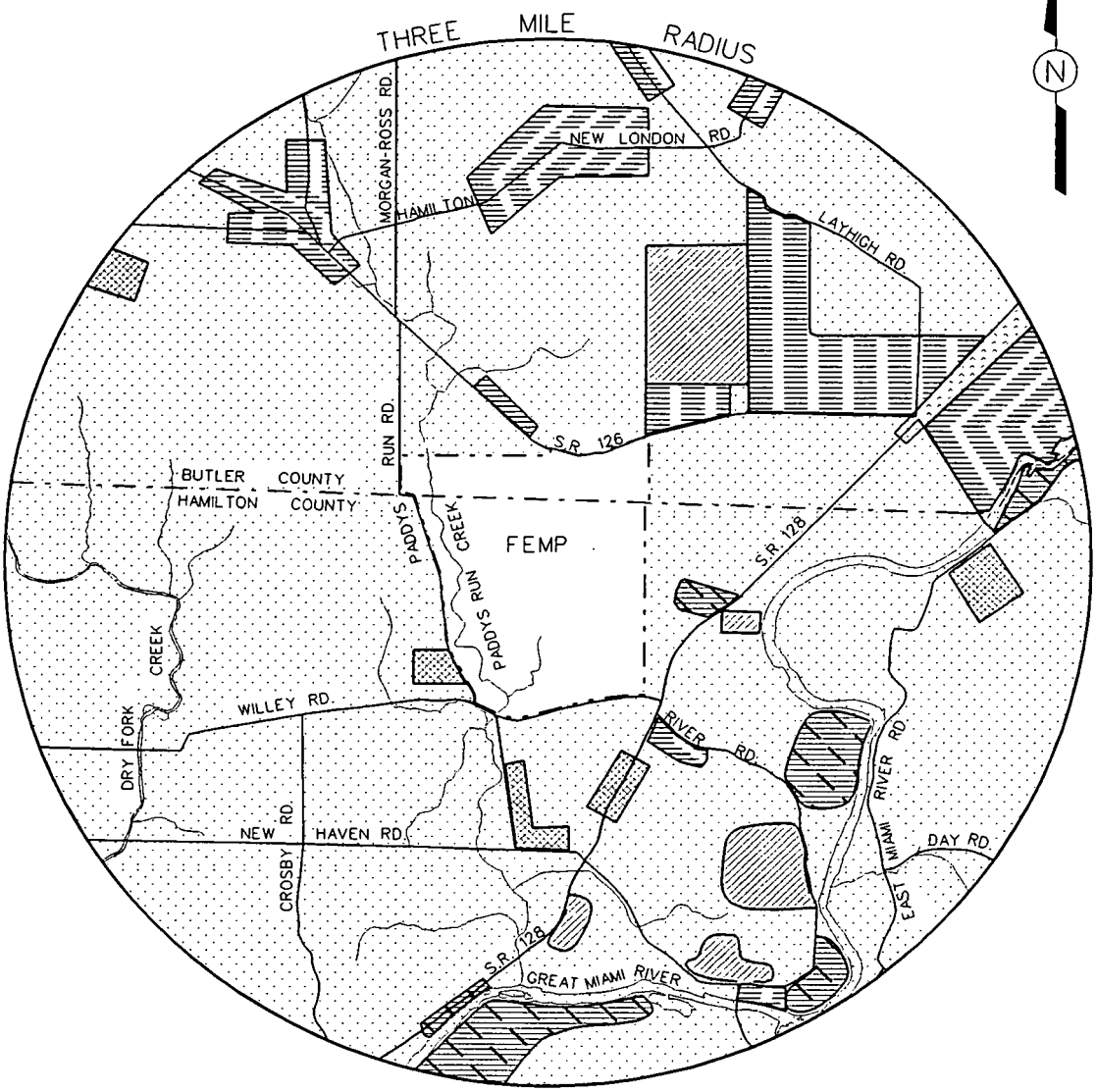
40919164.OU1 01-05-94 DON GOSS

FIGURE 1-8. GREAT MIAMI AQUIFER UNDERLYING THE FEMP AND VICINITY

- 5286



LEGEND:

COUNTY LINE

FEMP PROPERTY BOUNDARY

RESIDENTIAL

MINING

INDUSTRIAL

MIXED USE

RECREATION

AGRICULTURE/OPEN LAND

SCALE

0 1 MILE

4091191-A-151 /OU1 /KNOX /DS
4091191.OU1 02-11-94 DON GOSS

FIGURE 1-9. LAND USE ADJACENT TO THE FEMP

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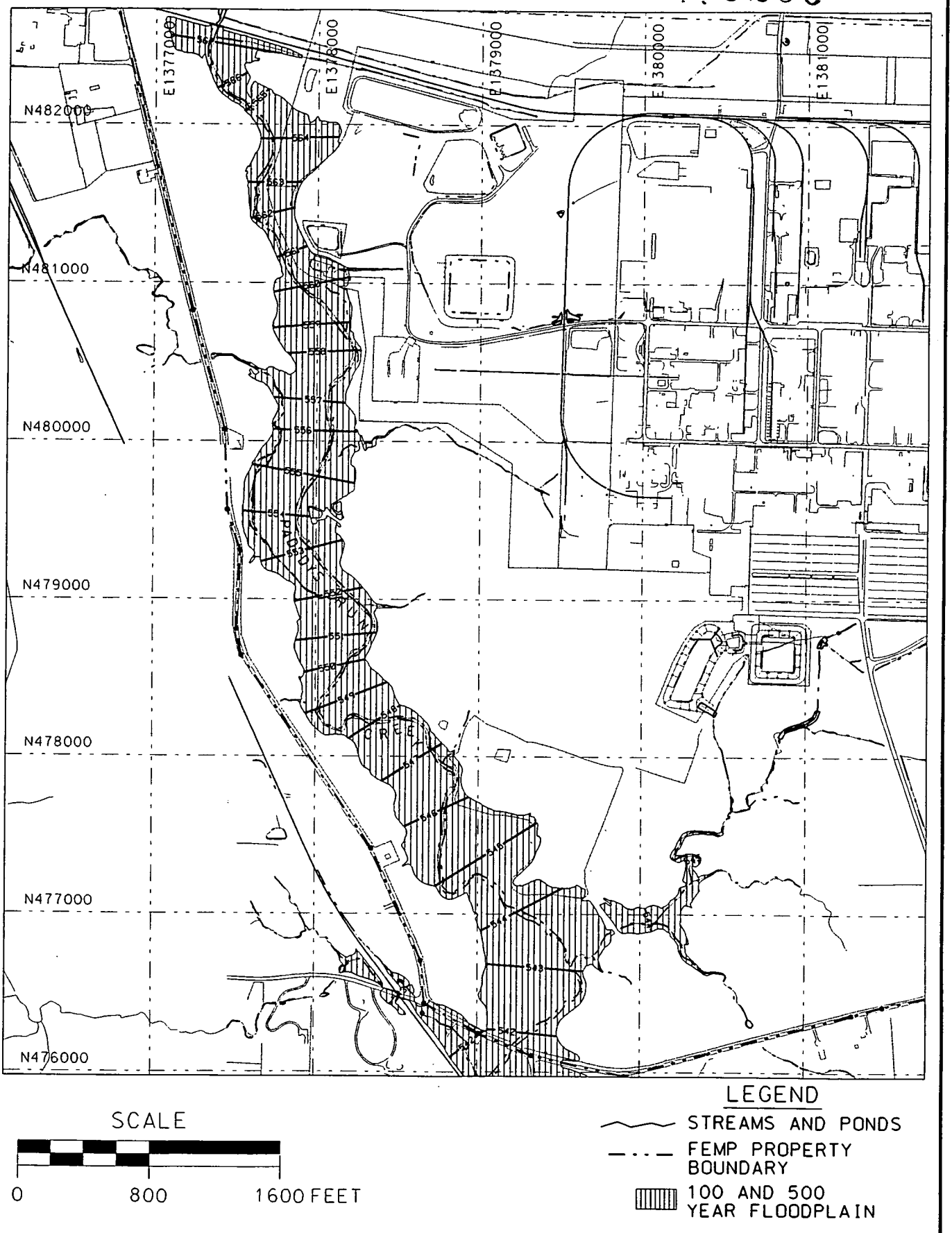
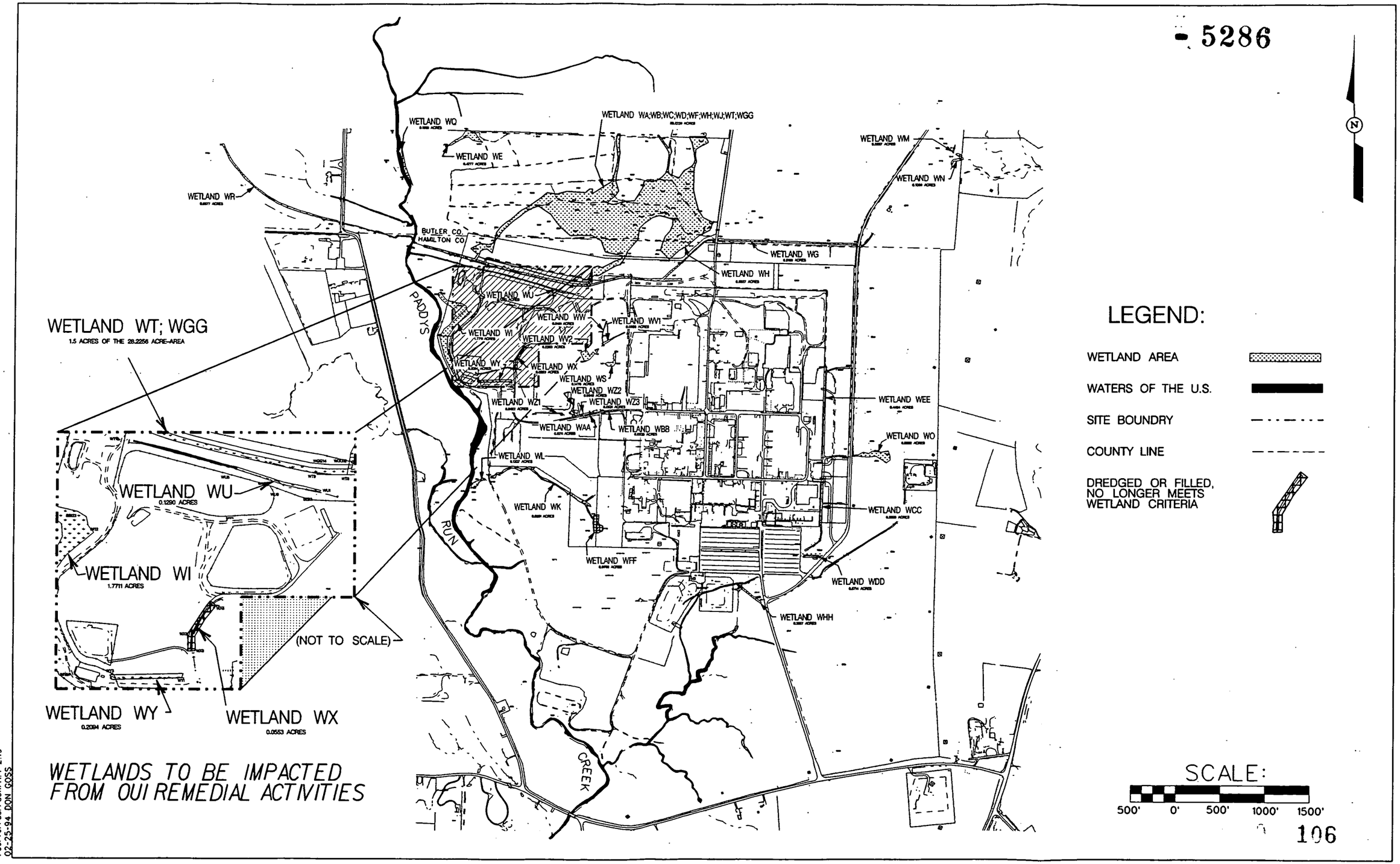


RES2236 A FIG1-12.DGN R.O CRU-2 FERMCO/ENG 2-11-94 DON GOSS

FIGURE 1-10. PADDYS RUN CREEK 100 AND 500 YEAR FLOODPLAIN



/server/usr/don/H.4-2.fs
02-25-94 DON GOSS

FER/OU1FS/BJH/SEC-1/02/28/94 5:35pm

FIGURE 1-11. 1993 JURISDICTIONAL WETLANDS & WATERS OF THE U.S.
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

2.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

2.1 INTRODUCTION

Identification, screening, and evaluation of potentially applicable technology types and process options are key steps in the Feasibility Study (FS) process. The primary objective of this phase of the Operable Unit 1 FS is to identify an appropriate range of remedial technologies and process options to be developed into preliminary remedial alternatives. The criteria for identifying potentially applicable technologies are provided in the Environmental Protection Agency (EPA) Remedial Investigation/Feasibility Study (RI/FS) guidance (EPA 1988a) and in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (EPA 1990). The final remedy must protect human health and the environment and comply with applicable or relevant and appropriate requirements (ARARs).

Section 2.0 discusses the identification, development, and screening of applicable technologies and process options that will be used to assemble the remedial action alternatives for Operable Unit 1. The technology screening process consists of a series of analytical steps that include the following:

- Identify volumes or areas of media of concern
- Develop Remedial Action Objectives (RAOs)
- Identify General Response Actions
- Identify and screen remedial technologies and process options
- Evaluate and select representative process options

Figure 2-1 illustrates the general flow of the FS process and relates the process elements to relevant sections of the Operable Unit 1 FS Report.

The information in Section 2.0 is presented in a format consistent with EPA RI/FS guidance (EPA 1988a). Section 2.2 presents the development of Remedial Action Objectives (RAOs) for media of concern in Operable Unit 1, including an estimate of the nature and extent of the chemical and radiological contamination and proposed interim remediation levels. Section 2.3 identifies the General Response Actions that will potentially meet the Remedial Action Objectives identified in Section 2.2. Section 2.4 describes the full range of potentially applicable technologies and associated process options. In Section 2.5, technologies and process options are evaluated against the criteria of

effectiveness, implementability, and cost to select representative options for incorporation into preliminary remedial alternatives.

2.2 REMEDIAL ACTION OBJECTIVES

RAOs are site-specific, qualitative goals that define the objectives of remedial actions. According to the NCP, remedial action objectives specify contaminants and media of concern, potential exposure pathways, and remediation goals.

Because RAOs for protecting environmental receptors typically seek to preserve or restore a resource (e.g., groundwater and surface soil), they are expressed in terms of the medium of interest and target cleanup levels whenever possible (EPA 1988a).

Potential risks associated with exposures related to Operable Unit 1 contamination were assessed in detail in Section 6.0 and Appendix E of the RI Report for Operable Unit 1 (DOE 1994a). The results of this baseline risk assessment identify those media that should be addressed to achieve RAOs. From this assessment, contaminated media contained in Operable Unit 1 were identified as follows:

- Waste pit contents and associated material, which include the contents of Waste Pits 1 through 6, the contents of the Clearwell and the Burn Pit, pit liners, and grossly contaminated covers.
- Residual water, which includes surface water, perched groundwater encountered during remediation of the pits, and residual process water. Treatment of residual water would be performed at the FEMP site Advanced Wastewater Treatment (AWWT) facility. Operable Unit 1 would be responsible for extraction and conveyance of residual water to the AWWT facility. A description of the AWWT facility is provided in Section 3.2.3.2 and Appendix B.
- Surface and subsurface soils, which includes contaminated soil beneath each pit and contaminated surface soil from the entire affected Operable Unit 1 area.
- Miscellaneous facilities and structures (piping, catwalks, etc.).

Groundwater in the Great Miami Aquifer and the full extent of perched groundwater is not addressed as a source medium within this Operable Unit 1 FS, because potential remediation of groundwater contamination for the entire FEMP site is being addressed as part of Operable Unit 5. Thus, within this FS Report, groundwater is considered as an environmental receptor medium.

A preliminary volume estimate of materials considered for remediation under Operable Unit 1 is presented in Table 2-1. The volume of soil is based on the assumption that three feet of soil beneath the pits will require remediation. This number is used for cost estimating purposes. Actual volumes will be determined relative to final action (i.e., cleanup) levels.

The development of Operable Unit 1 RAOs is presented in three steps. First, the constituents of concern (CPCs), by media, are identified. Second, allowable exposures in terms of the medium of interest, exposure routes, and receptors are identified, and PRGs are established for environmental media. Third, these data are used to develop RAOs.

2.2.1 Constituents of Concern

Not all CPCs identified in the Operable Unit 1 RI Baseline Risk Assessment pose significant health risks; thus, not all CPCs need to be considered in future remedial activities. The Baseline Risk Assessment (RA) evaluated CPCs and exposure pathways to ascertain their present and potential future impacts on human health. Two lists of contaminants can be generated from the Baseline RA: the contaminants of concern (COCs), which actually present potential risk, and those that are not COCs. Only those contaminants that are COCs need to be considered in the FS. The purpose of restricting the number of COCs in the FS remedial alternative evaluations is to focus on the contaminants which require remediation for the protection of human health and the environment.

The NCP defines the point of departure for unacceptable risk as one in a million (10^{-6}) for carcinogenic compounds, which includes radiological effects. The acceptable limit for noncarcinogenic effects is a hazard index (HI) of 1.0. A HI of greater than 1.0 is considered indicative of a potential toxic effect. However, since multiple contaminants are being considered, the screening point of departure for this FS is at a 10^{-7} risk and an individual Hazard Quotient (HQ) of 0.2 to ensure no significant COCs are eliminated. Therefore, any contaminant with a risk level or HQ less than this FS point of departure for all media pathway receptor combinations is not considered further.

Radiological and chemical constituents of concern, by media, are shown in Table 2-2.

2.2.2 Preliminary Remediation Goals

In the early stages of the RI/FS, as stated in the Site Wide Characterization Report (SWCR) (DOE 1993b), PRGs are used as action levels to determine if constituents in the environment need to be further addressed. PRGs are not action levels for remedial actions. PRGs are chemical-specific, medium-specific concentration limits necessary to address all contaminants and all pathways found to be of concern during the Baseline Risk Assessment process. PRGs are based on the following:

- For chemical toxicants, an HI = 1.0
- For chemical and radiation carcinogens, an (ILCR) = 10^{-6}
- Dose limit applicable or relevant and appropriate requirements (ARARs) and to be considered (TBCs) requirements

PRGs must comply with ARARs and protect human health and the environment. However, ARARs do not exist for all COCs. Therefore, both ARAR-based and risk-based PRGs are considered for Operable Unit 1 in the development of proposed remedial levels.

Certain media associated with Operable Unit 1, such as groundwater, are outside the scope of remedial actions being considered under this FS and will be addressed in Operable Unit 5. PRGs are presented for groundwater; however, because groundwater serves as an environmental receptor and a pathway for uptake of CPCs by man for residual waste components from Operable Unit 1. PRGs are presented for waste material contained in the pits because remnants of waste materials at the bottoms of the pits and/or contaminated till may be left behind and could migrate into the groundwater. Table 2-3 summarizes the media addressed within this section and provides the rationale for development of PRGs, for those media.

The rationale for using risk information and other technical evaluations in the decision making process for Operable Unit 1 is described below:

- Step I identifies existing and previously approved documents (SWCR and Risk Assessment Work Plan Addendum [RAWPA]) that provide an information base to support the path forward for decision making.
- Step II reviews the data developed in the Operable Unit 1 Baseline Risk Assessment and identifies important information carried forward, such as sensitive receptors, exposure pathways, COCs, and summary risks.

- Step III integrates the information developed from the Operable Unit 1 FS and Operable Unit 4 CRARE with the conclusions associated with the site-wide risks and the fact that contaminant sources have been removed under the proposed FS remedial action alternatives. The Operable Unit 1 FS was developed to determine the alternatives that would satisfy remedial goals and to reduce site-wide risk contributions.

- Step IV describes the process used for developing remedial goals and includes the process used in developing Operable Unit 1 PRGs and Proposed Remediation Levels (PRLs).

The following discussion presents how ARARs, TBCs, risk ranges, and hazard quotients indices of radiological and chemical constituents in surface soil and groundwater are used in developing the PRGs and ultimately, PRLs.

Calculating Preliminary Remedial Goals (PRGs)

Step 1	For a single chemical toxicant, calculate a PRG based on an HQ of 0.2 for all pathways for each receptor.
Step 2	For each chemical and radiological carcinogen, calculate PRGs at the 10^{-6} risk level for each receptor.
Step 3	Review all pertinent ARARs for all CPCs.
Step 4	For radionuclides, consider dose limit ARARs and to be considered (TBC) requirements.
Step 5	Compare risk based PRGs with ARARs and determine which value is more protective of human health and the environment.
Step 6	From data developed in the Baseline Risk Assessment, select the CPCs that contributed greater than 10^{-6} cancer risk or an HI greater than 1.0 to a receptor's total risk estimates. These are now identified as COCs.

The PRGs are to be presented simultaneously with the risk calculations in the Baseline Risk Assessment.

Calculations of Proposed Remedial Levels (PRLs).

Step 7	Identify all receptors considered for determination of risk-based criteria and calculate PRGs for each carcinogen at the 10^{-6}, 10^{-5}, 10^{-4} risk levels.
Step 8	For all receptors, revise the PRGs based on HIs to include all COCs. This requires determination of the relative source contribution from each COC to the total HI of 1.0 for chemical toxicants. The target HQ may be less than or greater than 0.2, depending upon the number of COCs.

Step 9 Pertinent ARARs are identified for the individual COCs for that medium. Present both values, the ARARs level and the calculated risk value. Compare risk-based and ARAR PRGs. If the ARAR concentration level for that COC is less than the risk-based level, the ARAR level should be adopted as the remedial goal.

Step 10 Subtract this calculated or ARAR level from the background level previously determined for each COC. The difference between them will be the level required by remedial action.

Step 11 In the event the proposed remediation level from the first two steps is less than the 95th percentile of the background data for that medium, the proposed action level will be considered indistinguishable from background level. That is, concentrations that are at or below background concentrations would be considered acceptable as a conclusion for any remedial action.

Step 12 The proposed remediation level is compared to the 95th percentile of the observed concentrations for that particular medium, which includes the maximum detected values as reported in the data summary of the RI. The frequency of detection of the COCs will also be considered in this evaluation. If the proposed remediation level is greater than the maximum observed concentrations or it is infrequently detected, consideration may be given to eliminating the need to propose remediation levels for those COCs.

2.2.2.1 Risk-Based PRG Development

Potential health effects resulting from exposures to radioactive and chemical contaminants are divided into two categories: carcinogenic and noncarcinogenic. For carcinogens, EPA has identified, in the NCP, a target range for incremental risks of 10^{-6} to 10^{-4}, or 1 in 1,000,000 to 1 in 10,000, to limit the possibility that an individual will develop cancer due to exposures to residual contaminants at an NPL site (40 Code of Federal Regulations [CFR] 300). As part of cleanup at sites named to the National Priorities List (NPL), EPA strives to manage possible incremental cancer risks within the target range, which is generally 10^{-6} to 10^{-4}.

For noncarcinogens, EPA guidance provides protection to individuals from health effects other than cancer by proposing that potential intakes or dermal exposures to a toxic chemical are maintained below the reference dose. The ratio of actual or potential dose to the reference dose, referred to as the HQ, is maintained at less than one to provide protection. Exposures to more than one contaminant can result in multiple HQs. The sum of these HQs equals the HI, which must also be maintained at less than one to provide protection.

For sites where the total estimated Incremental Lifetime Cancer Risk (ILCR) for each receptor is less than 10^{-4}, and the HI is less than 1.0, action may not be warranted. However, the total incremental

risk should be less than 10^{-4} after remediation and/or have a total HI of less than 1.0 for the non-carcinogenic toxic effects.

Although the upper end of the target range may be used to make risk management decisions to determine whether or not remedial actions are necessary or warranted, EPA does not consider 10^{-4} a discrete limit. That is, risks above that level may be considered acceptable based on site-specific conditions, or risks below 10^{-4} may not be acceptable (EPA 1991). In addition, factors other than the results of the site-specific risk assessment are used to make the final risk management decision, including conservative assumptions applied to estimate risks from possible exposures at the site and other health-based guidance available for certain constituents. As part of cleanup at NPL sites, EPA strives to manage possible incremental cancer risks within the target range, which is generally 10^{-6} to 10^{-4}.

These considerations were incorporated into the development of PRGs for Operable Unit 1. The following general principles for carcinogenic and noncarcinogenic constituents were applied to identify general risk-based objectives for remedial actions:

- Exposures to radionuclides should be reduced to levels as low as reasonably achievable (ALARA) and/or result in a ILCR of less than 10^{-6} to 10^{-4}.
- Exposures to carcinogenic chemicals present above background levels should not result in an ILCR of more than 10^{-6} to 10^{-4}.
- Exposures to noncarcinogenic constituents should not result in significant adverse health effects, indicated by a HI greater than 1.0.

The methods and assumptions used to estimate carcinogenic and noncarcinogenic effects from exposures to site constituents are described in the RI Report for Operable Unit 1 (DOE 1994a) and are also described in Appendix D of this FS. The discussions presented in the remainder of this section are based on those detailed analyses.

In developing risk-based PRGs, target risk levels are established for carcinogens, and target HQs and target HIs (the sum of the target HQs) are established for noncarcinogens. Once established, these target risk levels are used in calculating the PRGs. Toxicity data used to develop PRGs are cancer slope factors and reference doses from the Integrated Risk Information System (IRIS) database (EPA 1992b) and Health Effects Assessment Summary Tables (HEAST) (EPA 1992a).

One goal of the NCP is to manage total, site-wide risks such that the sum of all risks does not exceed 10^{-4}. The default target risk of 10^{-6} is suggested by EPA (1991) as the point of departure. In keeping with the NCP, PRGs were calculated for 10^{-4}, 10^{-5}, and 10^{-6} risk levels, using 10^{-6} as the target risk to ensure that cumulative site-wide risk does not exceed 10^{-4}.

EPA indicates that the cumulative site HI should be less that 1.0. However, no EPA guidance is available on apportioning the allowable level among the range of constituents in various environmental media. The most relevant guidance is provided by the Office of Drinking Water which, in calculating maximum contaminant level goals (MCLGs), uses a relative source contribution (RSC) factor to account for other sources of exposure (EPA 1989a) which results in a target HI of 0.2. Since these PRGs will be used to develop PRLs (at which time the multiple chemical effects will be considered), the default HI target value of 1.0 was used to calculate PRGs for the non-carcinogenic effects.

Following completion of the Baseline Risk Assessment, the land use scenarios, receptor scenarios, exposure parameters, and COCs employed to derive PRGs were reviewed to determine whether refinements were required.

Land Use Scenarios

Each Superfund site has a spectrum of current and future potential land uses. The land use scenario describes the potential use of the land, exposure pathways, and receptors. The most common land use scenarios are industrial, commercial, residential, and farming. Typical receptors are the industrial worker, commercial worker, residents, and farmers, respectively. Due to its unique past, land use, (uranium metal processing, government owned) and location (rural surrounded by farm land), the current and future land uses for the FEMP site are somewhat different from other Superfund sites.

It should be noted that the current land use scenarios from the Baseline Risk Assessment are no longer appropriate for evaluating land uses for the FS. After remedial actions are complete, DOE will have removed all structures from the FEMP site, with no plans for any operational missions. All structures will have been removed and major sources of contaminants will have been either removed or placed in disposal cells. Any residual waste materials for Operable Unit 1 will be under multiple feet of fill, which will be covered with a cap. The disposal cells are designed to last for at least 1,000 years and are covered with intrusion barriers and other barriers to limit water infiltration.

While the RI Report/Baseline Risk Assessment presented risk information for a range of receptors under current and future land use scenarios, these land use assumptions and receptors were refined to provide managers with the range of necessary information to support informed decisions in establishing proposed interim remediation levels. In accordance with the Risk Assessment Work Plan Addendum (DOE 1992), and to ensure consistency with EPA's guidance "Part B, Development of Risk-Based PRGs," the Baseline Risk Assessment for Operable Unit 1 evaluated a future land use scenario, which included the loss of federal ownership of the FEMP and the establishment of a family farm on the property. This land use scenario was evaluated to understand the potential worst-case exposures to site contaminants. This future land use scenario is completely described in the RI Report for Operable Unit 1 (DOE 1994a).

In addition to the future land use scenario examined in the RI Report, it is conceivable, as part of any future land use of the FEMP, that the federal government could retain ownership of the property to preclude further development of the property, including the establishment of residential or farming units. This future land use scenario, termed Future Land Use With Continued Federal Ownership where the land use is a government reserve, does not assume any form of perpetual maintenance or active access restrictions to the property following the completion of remedial actions and attainment of site-wide remedial goals. It is assumed that the site will be fenced, and No Trespassing and No Hunting signs will be posted. This retention of ownership would support the application of some form of institutional control. A potential expanded trespasser receptor is proposed merely as an example and to develop an upper bound residual risk, as compared to the off-site farmer or the trespassing child. This scenario, then, typifies a reasonable maximum exposure possible given institutional controls. It is noted that the Future Land Use Scenarios discussed here are considered by DOE to be conservative. Input from the Fernald Citizens Task Force (defined in Appendix G Attachment II) will be integrated into final recommendations for the future land use. The receptors for the two land uses are as follows:

<u>Future Land Use Without Continued Federal Ownership</u>

The FEMP site is owned by private individuals with unrestricted use. The principal land use is for farming. The receptors are:

- On-Property Farmer — A farm family who is living on the FEMP property, growing crops, and raising dairy cows.

- Off-Site Farmer — A family living and actively farming adjacent to the FEMP site boundary. Exposure to contaminants transported by air and groundwater.

Future Land Use With Continued Federal Ownership

The FEMP property is owned by the federal government which controls land use but does not completely restrict access. The land is not used for any purpose. The receptors are:

- Trespassing Child — Infrequent visits to the FEMP remediated property.
- Expanded Trespasser — Occasional visits to the property for hiking, roaming, and hunting by a youth and/or adults.
- Off-Site Farmer — A family living and actively farming adjacent to the FEMP site boundary. Exposure to contaminants transported by air and groundwater.

As a result of this review, the PRGs originally appearing in the SWCR have been revised to more appropriately reflect Operable Unit 1 conditions. The risk-based PRGs presented in Part III of the SWCR were typically based upon the consideration of a single exposure pathway for each media for the identified receptors. For example, for the groundwater media, an ingestion pathway was examined assuming consumption of 2 liters of water per day for 52 years. An exception to this single pathway framework was the development of PRGs for the recreational user (now designated as the expanded trespasser) as defined in the SWCR. For this expanded trespasser, the SWCR report considered ingestion and external exposure for the development of PRGs for the soil media. Subsequent to the SWCR, the Baseline Risk Assessment for Operable Unit 1 provided a more comprehensive quantitative examination of the viable pathways of exposure to each of the receptors considered in which multiple pathways of exposure are considered. Table 2-4 presents the spectrum of land uses and the potential receptors considered at possible risk when comparing the baseline conditions to the amended conditions as described under the FS alternatives.

For purposes of providing additional information for use in decision making, PRGs were developed for both the future land use with and without the assumption of continued federal ownership. To establish the PRGs for the future land use without continued ownership scenario, an on-property resident farmer was adopted as the receptor. For PRG development, the on-property resident farmer was assumed to be exposed to COCs in the soil via the inhalation of dusts, consumption of farm products contaminated by dust deposition, oral ingestion of soil, dermal contact, and external radiation pathways associated with the soils. Additionally, the on-property resident farmer was

assumed to be exposed to COCs in groundwater through ingestion. The equations and parameters used to calculate these PRGs are presented in the revised Risk Assessment Work Plan Addendum and in the Operable Unit 1 Baseline Risk Assessment.

For the purposes of establishing a PRG for a future land use under the continued federal ownership scenario, an on-property receptor was considered assuming a trespassing-type exposure scenario: it includes both adult and child/youth age groups. The frequency of exposure was expanded to account for the lack of active access controls. The expanded trespassing-type scenario was employed because it represents a reasonable maximum estimate of the exposures a receptor could reasonably be expected to receive under the assumption that the federal government continues to exercise its rights of ownership to preclude site development for residential, farming, industrial/commercial, and recreational uses (i.e. ball fields, jogging trails, biking trails, etc.).

The expanded trespassing receptor considered for PRG development for the future land use with continued federal ownership is an individual who visits the property during childhood then visits during adulthood, perhaps for roaming, hiking, bird watching, or similar type activities. Due to the size of the site, fencing, and signs indicating No Trespassing and No Hunting, it is assumed that hunting is not a likely activity. The expanded trespasser is assumed to be exposed to soil contaminants via the oral ingestion, dermal contact, inhalation of dusts, and external radiation pathways. Groundwater PRGs are not developed for the expanded trespasser since there are no viable pathways of exposure.

Finally, soil PRGs were developed for the off-property farmer. Exposure pathways from soil to this receptor were not considered identical for both the Future Land Use With and Without Continued Federal Ownership scenarios. The distinction is that two separate dust resuspension scenarios were considered. In the government reserve land use scenario, the soil was considered to be undisturbed. However, under the on-property farming land use scenario, the soil was considered to be disturbed through plowing and more dirt was resuspended. The off-site farmer is assumed to be exposed to soils within the Operable Unit 1 area through the inhalation of resuspended dust containing COCs and the consumption of farm products (e.g., milk, meat, and vegetables) contaminated by dust deposition. Since the on-property farmer is a controlling receptor under the farming land use scenario, separate PRGs were not calculated for the off-site farmer. Qualitative information regarding the time periods of exposure can be found in Appendix D, Feasibility Study Risk Evaluation.

2.2.2.2 ARAR/TBC PRG Development

Chemical-specific ARARs also were examined to identify PRGs for Operable Unit 1 COCs. These ARARs included non-zero Maximum Contaminant Level Goals (MCLGs) and Maximum Contaminant Levels (MCLs) for drinking water. Other selected considerations, including available guidance and health advisories, were examined to identify PRGs, termed TBC-based PRGs. TBC guidance examined includes DOE orders, ecological benchmark criteria, and drinking water health advisories.

2.2.2.3 As Low As Reasonably Achievable (ALARA)

In addition to establishing PRGs that comply with ARARs and protect human health and the environment, DOE plans to apply the principles of ALARA during remedial actions at the FEMP. The goal of DOE's ALARA process is to reduce exposures and the risk associated with residual contamination to levels that are "as low as reasonably achievable," considering technical, economic, and social constraints as appropriate. In applying the ALARA process at the FEMP site, the two factors used in developing PRGs (ARAR-based environmental standards and protectiveness of human health and the environment) are combined with technical and economic considerations in order to identify the levels of risk reduction that might reasonably be achieved.

The ALARA process includes both planning and field components. The discussions presented in this section are consistent with the planning component of ALARA, in which PRGs are estimated for residual contamination based on hypothetical exposures. This initial analysis will be used to support implementation of ALARA in the field, where additional contamination might be removed below those levels determined in the planning phase when reasonably achievable, based on specific field conditions.

As specified previously, ALARA is site specific. The application of ALARA at another site with different contaminants and exposure scenarios would invariably produce different results.

2.2.2.4 Preliminary Remediation Goals for Soils

The PRGs for soils were calculated using the equations and parameters for all exposure pathways as detailed in the revised Risk Assessment Work Plan Addendum and the Operable Unit 1 Baseline Risk Assessment for all receptors. For PRG development, a target risk for both chemical and radiological carcinogenic effects of 10^{-4}, 10^{-5}, and 10^{-6} were employed to derive PRGs for each of the receptors. A target value (HI) of 1.0 was employed for non-carcinogenic effects.

To support the derivation of PRGs, it is assumed that dust from soils are inhaled by the receptor and deposited on the crops and forage. The on-property and off-site resident farmers are assumed then to consume the crops and consume meat and milk from cows grazing on the forage. Dust resuspension and transport modeling was performed for the RI Report for Operable Unit 1 (Appendix D) to examine exposure point concentrations, both on-property and off-site, as a result of baseline conditions within Operable Unit 1. These modeling results were used to calculate resuspension factors and, ultimately, soil concentration-based PRGs.

The off-site farmer is assumed to inhale the dust particulate and consume the farm produce contaminated by particulate deposition from Operable Unit 1 for a lifetime of 70 years.

The on-property resident farmer is assumed to build a home and farm the residual soils within Operable Unit 1. The resident farmer is exposed to COCs in soils by incidental ingestion, dermal contact, consumption of meat, milk, produce, and direct radiation. The meat, milk, and produce are contaminated with COCs via the direct uptake by roots from the soils and by deposition of particulates on the plant surfaces.

The expanded trespasser is assumed to be exposed to Operable Unit 1 soil via incidental ingestion, dermal exposure, inhalation of particulates, and external radiation. The expanded trespasser is assumed to be present within Operable Unit 1 as an adult and a child/youth for 40 days and 110 days, respectively, each year for a period of one and two hours per day, respectively. The breathing rate is assumed to be 20 cubic meters/day for all age groups, and the ingestion rate is assumed to be 100 milligrams of soil per day.

Tables 2-5, 2-6 and 2-7 present the PRGs for soil for the on-property resident farmer, expanded trespasser, and off-site farmer, respectively. It should be noted that PRGs for soils were derived only for those carcinogenic COCs exhibiting an ILCR greater than 10^{-6} to the on-property resident farmer under a current source term scenario, as defined in Table D.II-17 of the RI Report for Operable Unit 1. As previously discussed, risk-based PRGs have been derived for receptors under two land use scenarios, future land use with and without continued federal ownership. For the derivation of these risk-based PRGs, the progeny isotopes of radionuclides present at the FEMP site have been included within the results of the PRG calculation for the parent isotope. For example, uranium-238 is a radionuclide of concern at the FEMP site. If the presence of its two immediate short-lived progeny is neglected, the risk-based PRG for a residential farmer exposed to uranium-238 in soil is

approximately 25 picoCuries per gram. Including its two short-lived progeny, uranium-238 yields a PRG of 0.45 picoCurie per gram (Table 2-5). In another example, radium-228 without progeny would have a PRG of about 0.15 picoCurie per gram for the same scenario. Including its short-lived progeny, radium-228 reduces the PRG in soil to 0.0082 picoCurie per gram (Table 2-5). The PRGs presented in Tables 2-5, 2-6 and 2-7 consider contributions of radioactive progeny to be an integral part of the total risk from the parent nuclide.

Values representing 10^{-6} risk-based PRGs under the future land use without continued federal ownership residential farmer scenario differ from the ARARs-based PRG for radium-228 by several orders of magnitude. Moreover, the 10^{-6} risk-based PRGs for uranium-238 and radium-226 are 2.6 and 36 times less than background, respectively. Therefore, the PRGs for radium-226 and uranium-238 are indistinguishable from either the respective ARAR or background concentrations. If the ARAR or background concentrations were chosen as the remedial goal, there would not be an incremental risk due to the remediated soils.

EPA has promulgated standards for radium-226 and radium-228 in soil at uranium and thorium mill tailings sites (40 CFR § 192 Subpart B). In brief, these radionuclides are not to exceed background concentrations by more than 5 picoCuries per gram in the top 15 centimeters (6 inches) of soil or 15 picoCuries per gram in each 15-centimeter (6-inch) layer beneath the surface, averaged over an area of 100 square meters (1,100 square feet). Because the FEMP site is not a mill tailings site, these standards do not specifically apply. However, the requirements are considered relevant and appropriate because the waste material at the site is similar to mill tailings.

EPA has identified standards for airborne emissions of radionuclides other than radon-222, which limit exposures such that a member of the public will not exceed an effective dose equivalent of 10 millirem per year (40 CFR § 61 Subpart H). EPA has also identified annual dose limits of 25 millirem per year whole body, 75 millirem per year to the thyroid, and 25 millirem per year to any other organ for exposures associated with management of uranium and thorium by-product material.

As a general standard for radiological exposures, DOE requires compliance with all federal requirements for limiting doses from specific exposure modes. DOE Order 5400.5 also establishes requirements for nonspecific radiological exposures from DOE facilities. This order requires that the committed effective dose equivalent to a member of the public not exceed 100 millirem/year above background from all nonoccupational exposure routes and that these exposures be reduced to ALARA

levels. With DOE Order 5400.5, DOE defines the ALARA process for reducing residual exposures and risks to levels as low as reasonably achievable below applicable standards considering technical, economic, and social constraints as appropriate.

These radiological dose standards and requirements are considered as, depending on the citation, relevant and appropriate or TBCs to remediation efforts at the FEMP site. Current dose estimates for the site perimeter are within the specified limits. Applying ALARA to reduce residual concentrations of specific radionuclides would result in a similar reduction in the resulting radiological exposures and associated risk. The greatest reduction is associated with decreasing residual levels of radium-226 because this radionuclide and its progeny account for the greatest portion of the total risk estimate within Operable Unit 1, from both external gamma irradiation and inhalation of radon.

EPA has identified two different guidelines for establishing a residual level for lead in soil in a residential setting. These guidelines are considered TBCs. The first is an interim guidance that considers the natural presence of lead in soil and recommends a cleanup level of 500 to 1,000 milligrams per kilogram as determined by site-specific conditions (EPA 1992b). The second is draft guidance in the form of an uptake/biokinetic model that can be applied to site-specific data to estimate lead levels in blood for children, the most sensitive population. A blood lead level of 10 micrograms per deciliter or less is an acceptable level. This model yields a health-based level of 450 milligrams per kilogram for lead in surface soil.

A standard for cleanup of soil following a spill of material containing more than 50 milligrams per kilogram PCBs is identified in the Toxic Substances Control Act (See Appendix F). The standard indicates that soil in areas of unrestricted access at which a spill occurs can be decontaminated to 10 milligram per kilogram by weight by excavating at least 25 centimeters (10 inches) of soil and backfilling with material containing less than 1 milligram per kilogram of PCBs. Because PCB contamination in soil would have resulted from spills of material that occurred long before the effective date of these standards, they do not specifically apply; however, they are considered relevant and appropriate.

2.2.2.5 Preliminary Remediation Goals for Groundwater

Table 2-8 presents the PRGs for groundwater. For groundwater, the PRGs for the future land use with continued federal ownership (expanded trespasser) are the same as those for the future land use without continued federal ownership (reasonable maximum exposure [RME] on-property resident

farmer). The only difference is the source of groundwater. Under the RME resident farmer scenario, it is assumed that an individual takes up residence on the FEMP site and installs a domestic drinking water well at that location. Under the expanded trespasser scenario, there are no individuals establishing residences on the FEMP site. Consistent with this assumption, there will be no domestic drinking water wells on the FEMP site. Thus, the groundwater PRGs established under the expanded trespasser scenario must be met at the FEMP site boundary, while PRGs under the RME on-property resident farmer scenario would need to be met for groundwater directly beneath the FEMP site.

The risk-based PRGs for groundwater were calculated using the equations and parameters presented in the revised Risk Assessment Work Plan Addendum. The parameters are also presented in Appendix D.

For organics, most PRGs based on the 10^{-6} risk level are well below the Contract Required Quantitation Limits (CRQLs) established by EPA. To date, these CRQLs have been used for the site characterization study at the FEMP site. MCLs for many of the organic carcinogens appear to be equivalent to a 10^{-4} risk level (e.g., for PCBs, benzo(a)pyrene, chlordane, and vinyl chloride). For noncarcinogens, the MCLs appear to be close to risk-based values.

EPA has promulgated standards for radium-226 and radium-228 in groundwater through various regulations, all with the same basic requirements. The regulations include 40 CFR § 141.15, 40 CFR § 257.3-4, and 40 CFR § 264.94. Similar State of Ohio regulations include Ohio Administrative Code (OAC) 3745-81-15, OAC 3745-27-10(D), and OAC 3745-54-94. In brief, the regulations specify that the combined concentration of radium-226 and radium-228 in groundwater used as a drinking water source is not to exceed 5 picoCuries per liter. In addition, the gross alpha particle activity (including radium-226 but excluding radon and uranium) is not to exceed 15 picoCuries per liter.

EPA has proposed standards for uranium and radon-222 and revised standards for radium-226 and radium-228 in drinking water. Under these proposed regulations, the concentration of uranium in drinking water is not to exceed 0.02 milligrams per liter or 30 picoCuries per liter, radon-222 is not to exceed 300 picoCuries per liter, and the combined concentration of radium-226/228 are not to exceed 20 picoCuries per liter.

As a general standard for radiological exposures, the DOE requires compliance with all federal requirements for limiting doses from specific exposure modes. DOE Order 5400.5 also establishes standards for nonspecific radiological exposures. These standards require that the Effective Dose Equivalent (EDE) to a member of the public not exceed 100 mrem/year above background from all nonoccupational exposure routes and that these exposures be reduced to ALARA levels.

The Safe Drinking Water Act, 40 CFR § 141, establishes MCLs and MCLGs for specific inorganic and organic chemicals to protect drinking water quality. MCLs are the maximum permissible levels of a contaminant in water that is delivered to a free flowing outlet of the ultimate user of a public water system. The MCLs are not directly applicable because no public water system, as defined in 40 CFR § 141, is involved. The MCLs are relevant and appropriate, however, to protect the underlying aquifer, which may be used as a drinking water source, from contaminants that may leach or migrate from waste materials contained in Operable Unit 1.

The State of Ohio also provides MCLs in OAC 3745-81-11. The state MCLs are more stringent than the federal MCLs for barium, chromium, copper, silver, and selenium.

EPA provides additional MCLs in RCRA, Subtitles D and C, 40 CFR § 257 and 264, respectively. These MCLs are also contained in State of Ohio regulations, OAC-3745-27.

The Safe Drinking Water Act also establishes MCLGs for specific inorganic and organic chemicals. MCLGs are nonenforceable drinking water health goals intended to represent a contaminant concentration that presents "no known or anticipated adverse effects on the health of persons" while allowing for an adequate margin of safety. The non-zero MCLG is more stringent than the MCL for thallium. Similar to the MCLs, the MCLGs are considered to be relevant and appropriate. CERCLA Section 121(d)(2)(A) requires on-property remedies to attain MCLGs where relevant and appropriate under the circumstances of the release. If a MCLG is equal to zero, EPA believes it is not appropriate for setting cleanup levels, and the corresponding MCL will be the relevant and appropriate requirement.

Beyond the MCLGs, the Safe Drinking Water act establishes secondary MCLs in 40 CFR § 143. Secondary MCLs are also contained in Ohio regulations, OAC 3745-82-02. Secondary MCLs are nonenforceable goals for drinking water established for contaminants whose presence in excessive

quantities may discourage the use of a public water supply due to poor qualities such as taste, color, odor, and corrosivity. The secondary MCLs are a TBC in evaluating potential remedial actions.

A summary of the MCLs, MCLGs, and secondary MCLs previously discussed is presented in Table 2-9.

2.2.2.6 Preliminary Remediation Goals for Pit Waste Materials

Two sources of potential groundwater contamination will remain after all Operable Unit 1 remedial activities have been completed. The first is the migration of contaminants from residual soils remaining in the pit area after the pit wastes have been removed. These soils are contaminated by prior percolation of pit contaminants. The second is the migration of contaminants from the stabilized pit materials in an on-property disposal cell if a remedial alternative involving on-property disposal is chosen.

The PRGs for the residual soils are the concentration of COCs in the soils which will result in the groundwater concentrations of the COCs at the fenceline being equal to or less than the PRGs for the off-property farmer using groundwater. That is, the PRGs for groundwater listed in Table 2-9. Similarly the PRGs for the waste leachate from the on-site disposal cell are the concentrations of COCs in the waste leachate that would result in a groundwater concentration equal to or less than the PRGs for groundwater in Table 2-8 at the fenceline.

These two sets of PRGs were calculated using the ECTrans model developed at FEMP as a screening groundwater model. The PRGs were derived by iteratively running the model with different source terms (leachate concentrations) until the predicted fenceline COC concentrations were equal to the PRGs in Table 2-8. The input parameters (Kds, hydraulic conductivity, groundwater flow, etc.) for the model are the same as the SWIFT model used at the FEMP to predict groundwater contaminant flow. Table 2-10 presents the PRGs for the individual pits and Table 2-11 presents the PRGs (acceptable waste leachate concentrations) for the pit wastes in the disposal cell. These PRGs are used as source terms for the SWIFT model which predicts the incremental groundwater concentrations for Operable Unit 1 in Appendix D.

2.2.3 Proposed Remedial Levels (PRLs) for Surface Soils

Analysis of existing information indicates that it is not economically feasible to reduce levels of uranium-238 and its two progeny to essentially background concentrations. This situation also exists

for the other radionuclides. However, reduction to background concentrations is necessary to reduce the risk to the on-property farmer to an ICLR of 10^{-6} (a PRG of 0.45 picoCurie per liter). Volumes of soils to be managed would be expected to increase significantly over the volume that would need to be managed to protect the "expanded trespasser" and "off-site farmer." Therefore, the proposed remediation levels for Operable Unit 1 reflect a future land use consistent with the SWCR and the CRARE.

It is noted that the proposed remedial levels presented in this section (and in Section 2.2.4) should be considered as interim, as additional input from the Fernald Citizens Task Force (as defined in Appendix G Attachment II) and the public is essential before making final recommendations on land use from a site-wide perspective. To allow for Operable Unit 5, Task Force, and public input, the Operable Unit 5 FS and Record of Decision (ROD) will revisit the Operable Unit 1 proposed soil remediation levels and modify them appropriately if found to be necessary or feasible.

As previously defined, PRGs are developed from the risk-based PRGs for three receptors and the ARAR/TBC-based PRGs. PRLs are actual soil concentrations and could be considered as the PRG (incremental risk) concentrations plus background. In addition, cost benefit analysis and technology considerations can be used to modify a PRG to develop a PRL. Surface and subsurface soil PRLs will be the only PRLs developed for Operable Unit 1. Groundwater final remediation levels will be developed as part of Operable Unit 5 and will be presented in the Operable Unit 5 ROD.

The three receptors presented in Tables 2-5, 2-6, and 2-7 represent the two future land use scenarios. The expanded trespasser and the off-site resident farmer are the receptors for the government reserve land use (future land use, continued federal ownership). The off-site resident farmer and the on-property resident farmer are the receptors for the farming land use (future land use without continued federal ownership).

2.2.3.1 Basis of Proposed Remediation Levels for Surface Soils

The PRGs for soils presented in Tables 2-5, 2-6, and 2-7 indicate that the on-property resident farmer is the critical receptor for soil contamination. This is consistent with the Baseline Risk Assessment results, which indicate that the highest risks are associated with the on-property resident farmer, followed by the trespassing child and the off-site resident farmer, in descending order. Accordingly, the PRGs range in magnitude from the off-site resident farmer, to the expanded trespasser, to the on-property resident farmer. To compare these two groups of receptors, the risks associated with the

trespassing child exposures will be less than those of the expanded trespasser. Therefore, the expanded trespasser is a more conservative receptor than the trespassing child.

Table 2-12 presents a comparison of the PRGs for the key constituents which are uranium-238 plus two progeny, cesium-137 plus one progeny, and aroclor-1254 for the multiple receptor scenarios. These three constituents are shown because uranium is the key constituent driving site-wide clean-up and Operable Unit 1 cleanup with cesium-137 and aroclor as COCs for the soil clean-up of Operable Unit 1. The PRG values are shown in a tiered presentation, lower to higher. Receptors that are not applicable after remediation are listed as N/A.

For organics, most PRGs for soils based on the 10^{-6} risk level are well below the CRQLs established by EPA and these CRQLs have been used for the site characterization study at the FEMP site. MCLs for many of the organic carcinogens appear to be equivalent to a 10^{-4} risk level (e.g., for PCBs, benzo(a)pyrene, chlordane, and vinyl chloride). For noncarcinogens, the MCLs appear to be close to risk-based values.

Since PRGs are incremental above background concentrations, this implies that background concentrations would be a determining factor in the development of proposed PRLs. Since it is likely that PRGs for the on-property resident farmer are not achievable other than by removing all contaminated soils, the future land use scenario as a government reserve with the expanded trespasser was adopted as the most likely land use scenario to develop proposed PRLs.

An additional consideration which supports continued federal ownership is OAC 3734.02, which specifies that hazardous and solid waste disposal facilities must include a protective covenant to restrict mining, drilling, and residential uses. The site boundaries would likely be relocated to release as much uncontaminated land as possible while adequately enclosing the disposal cells and waste areas. As a government reserve (future land use with continued federal ownership), the reduced area would remain government owned with no land development, and no continued maintenance would be performed.

The following rationale was employed to identify the proposed soil action level. The results of applying this rationale to the Operable Unit 1 soil COCs are summarized in Table 2-13. Table 2-13 indicates which of the receptors are protected for an ILCR below 10^{-6}, if the PRL based on the expanded trespasser is achieved.

It is anticipated that to attain the referenced proposed remediation levels, a minimum of 15 centimeters (6 inches) of soils will be removed from contaminated portions of the Operable Unit 1 area. Deeper excavations may also be required to remove identified "hot spots." This is particularly true for the polycyclic aromatic compounds which were found in only one sample, for example aroclor-1254 was found in three of 16 samples at a sampling depth of 1.5 feet. Following excavation, the excavation areas will be backfilled with clean soils and seeded. The following steps were followed in developing PRLs for Operable Unit 1:

- Step 1. The soil concentration representing the PRG for the 10^{-6} risk level for the expanded trespasser from Table 2-6 was adopted as the proposed preliminary soil remediation level.

- Step 2. Pertinent ARARs were identified for the individual COC. If the ARAR concentration level for the COC was less than the value identified above, the ARAR level was adopted.

- Step 3. In the event the proposed soil remediation level from the first two steps was less than the 95th percentile of the background soil data set, the proposed soil action level was considered indistinguishable from background. That is, any soil concentrations at or below background concentrations would be considered acceptable as a conclusion for remedial actions.

- Step 4. The proposed soil remediation level was compared to the 95th percentile of the observed surface and subsurface soil concentrations, which includes the maximum detected values as reported in the RI Report for Operable Unit 1, including the data sets such as Characterization Investigation Study on-property gamma spectrometry analysis. The frequency of detection of the COCs in the soils was also considered in this evaluation. If the PRL was greater than the maximum observed concentrations or it was infrequently detected, consideration was given to eliminating the need to propose remediation levels for those COCs.

The risk or HI to the expanded trespasser and the on-property resident farmer was then calculated for the PRLs to demonstrate effectiveness for the expanded trespasser and to demonstrate the relationship to the on-property farmer. If the PRL was the SQL as in the case for aroclor-1254, the input concentration for the risk calculations was one half the SQL. In the case for the noncarcinogenic effects for uranium, the PRL was the PRG multiplied by 0.5 because other non-carcinogens were present.

2.2.3.2 Proposed Remediation Levels for Surface Soils

Table 2-13 presents the radionuclide and chemical PRLs for soil, formatted in bold print for ease of reference. Carcinogenic risks drive these proposed levels. The radionuclides neptunium-237, plutonium-238, strontium-90, and uranium-234 were present at concentrations below the PRGs soil background concentrations; hence, no remediation is required for these COCs. The surface soil

concentration for thorium-230 (972 picoCuries per gram) is just above the PRG (900 picoCuries per gram), so the PRL for thorium-230 is 902 picoCuries per gram [900 + 2 (for background)]. Cesium-137, uranium-235, uranium-238, beryllium, total uranium, and aroclor-1254 are present in surface soils or subsurface soils at concentrations above the PRGs or PRLs. Hence remediation is required for these COCs. The last two columns of Table 2-13 present the potential risk to the expanded trespasser for the government reserve land use. The risk calculations were performed using the equations presented in the Baseline Risk Assessment for the on-property RME resident farmer. The expanded trespasser risks were calculated by rationing the on-property RME resident farmer and expanded trespasser PRGs in Tables 2-5 and 2-6, respectively. These on-property risk calculations encompass all pathways of exposure as presented in the RI, that is, exposure through incidental ingestion, direct radiation, inhalation of dust, vegetable consumption, meat consumption, and dairy consumption. It should be noted that the trespassing child receptor would have a potential risk below that of the expanded trespasser, based on the decreased frequency of exposure. If unrestricted use of Operable Unit 1 occurs allowing agricultural use, then the on-property RME resident farmer would have a potential combined risk greater than $2x10^{-3}$, with thorium-230 being the major contributor.

The PRGs for the expanded trespasser were all above the existing surface and subsurface soil concentrations for chemical COCs with the exception of beryllium, uranium, and aroclor-1254. However, the beryllium PRL of 0.63 milligram per kilogram is within the limits of analytical precision for soil sampling (+/-40 percent) for the existing soil concentrations (0.77 milligram per kilogram) and may be indistinguishable from these surface soil concentrations. Uranium is expected to be of concern because of the elevated uranium-238 concentrations. Aroclor-1254 was found infrequently (found in 3 out of 16 samples) and may be removed by "hot spot" soil excavation.

2.2.4 Proposed Remediation Levels for Subsurface Soils

Among the alternatives being considered for Operable Unit 1 is removal of the contents of the pits, the existing liners, and a portion of the contaminated till or the sand and gravel material as appropriate. However, there is inadequate data at the current time (due to potential for direct contamination conduit from the pits to the Greater Miami Aquifer) to determine how much (i.e. how deep) of the till or sand and gravel must be removed to prevent further contamination of the Great Miami Aquifer.

Section 2.2.2.6 presented the development of subsurface soil PRGs. These PRGs were based on being protective for the groundwater user at the FEMP fence line (off-site farmer). This assumption

is consistent with the development of the surface soil PRLs presented in Section 2.2.3, where it is assumed that no land development will occur. These PRGs were compared against the existing waste concentrations to determine if the PRGs were less than the existing waste concentration. The remedial levels must be developed to determine how much or how deep the material needs to be removed to protect the future users of the Great Miami Aquifer. The assumption here is that if the subsurface soil concentration at the bottom of the pits is at or below these interim proposed remediation levels, then COC concentrations in the groundwater at the fenceline will be at risk levels of less than 10^{-6} or have an HI of less than 1.0 (which are levels that protect human health).

Values representing existing waste concentrations were the upper confidence level (UCL) concentrations presented in Appendix E of the Operable Unit 1 RI in Tables E.2-3 through E.2-13. These waste concentrations were used because, as previously pointed out, there are no data concerning the contaminant concentrations in the soil layers beneath the pit waste materials. This means the only assumption that can be made is that the subsurface soil layers will have the same or lower concentration than the pit wastes.

Table 2-14 presents the comparison of the off-site user subsurface soil pit PRGs, the on-property user subsurface soil pit PRGs, and the pit waste contaminant concentrations for the groundwater COCs. The column labeled "Proposed Remedial Levels" (formatted in bold print for ease of reference) was determined by comparing the waste concentration with the off-property PRG, if the waste concentration is greater than the PRG, then the PRG is presented. If the concentration was less than the PRG, then an NR appears. This means no remediation is required for this COC for the respective pit. An example of this is seen in Waste Pit 1 for uranium-234 and uranium-238. The PRG for uranium-234 was 2.2×10^4 picoCuries per gram with a pit waste concentration of 2×10^3 picoCuries per gram. The modeling predicted that a residual waste concentration of 2.2×10^4 picoCuries per gram for uranium-234 would not migrate in sufficient quantities to produce an excess ILCR at the fenceline for the off-property user. Since this is less than the pit waste concentration, then no remediation is necessary for uranium-234. However, the uranium-238 waste concentration is 1.6×10^4 which is greater than the PRG of 1.3×10^4 picoCuries per gram. Therefore to be protective of the off-property use the uranium-238 is to be remediated to a level below 1.3×10^4 picoCuries per gram. These calculations don not take into account the isotopic ratio between uranium-238 and uranium-234. In actual practice, the final concentration of uranium-234 will take into account this ratio. An NC in the PRG columns means that the PRG was not calculated using the screening model for this COC or the contaminant was not a COC for the respective pit. Thorium-230 in Waste Pit 1

is an example of this. The preliminary modeling screening indicated that thorium-230 would not migrate through the till or sand and gravel layer in sufficient quantities to present an excess risk for the off-property user. However, it must be remembered that these calculations assume that all pit waste material down to and including the liner, is removed and the groundwater source term is based on remaining till or sand and gravel material. It cannot be inferred that "NR" means no removal of waste material.

Technetium-99 is the component which will drive the remediation levels in Waste Pits 2, 3, 4, 5 and 6, the Burn Pit, and the Clearwell. Because of the extreme mobility of technetium-99 and the geochemical attention of the surrounding natural clays, the presence of technetium-99 is expected to be a leading contaminant indicator. Uranium-238 is a secondary driver in Waste Pits 4 and 5. aroclor-1221 is only a driver in Waste Pit 1.

These PRGs and proposed remedial levels were used as inputs to the ODAST and Swift groundwater models to predict groundwater concentrations for the on-property farm family and the off-site farm family. These results and the risks are presented in Appendix D. The estimated off-property radiological risk was 3×10^{-6}, the chemical carcinogenic risk was 5×10^{-7} and the Hazard Index was 0.05. The estimated on-property radiological risk was 1×10^{-4}, the chemical carcinogenic risk was 9×10^{-5}, and the Hazard Index was 1.0. Therefore, these PRLs are protective of the off-site farmer, but not the on-property user.

2.3 GENERAL RESPONSE ACTIONS

General Response Actions describe actions that could satisfy the Remedial Action Objectives. General Response Actions include no action, institutional control, containment, removal, treatment, and disposal. Individually, these General Response Actions do not have to meet the RAOs. Rather, the objectives will be met when the General Response Actions are combined to form alternatives. The following General Response Actions were considered for Operable Unit 1:

- No Action - The no-action alternative is retained throughout the FS process as required by the NCP (40 CFR 300.430(e)(6)). The no-action alternative provides a comparative baseline against which other alternatives can be evaluated. Under this alternative, no remedial action will be taken. In the no-action alternative, the site is considered to be left "as is," with no institutional action, containment, removal, treatment, or other mitigating actions. The no-action alternative does not provide for monitoring soil, groundwater, or radon emissions and does not provide for access controls (e.g., physical barriers, deed restrictions) to reduce the potential for exposure.

- Institutional Control - Institutional control includes various access controls or deed restrictions that would reduce or eliminate direct exposure pathways. The volume, mobility, and toxicity of the contaminants is not reduced through the application of institutional actions.

- Containment - Another method of reducing the risk to the public and the environment is through waste containment, which reduces the contaminants' mobility and availability. To reduce mobility and availability, the contaminated media must be isolated from the primary transport mechanisms such as wind, erosion, surface water, groundwater, biological means, and mechanical means. Contaminated media may be isolated by installing surface or subsurface barriers.

- Removal - Removal technologies move waste or contaminated media from its present location to another location for treatment and/or disposal elsewhere. Removal process options are typically combined with treatment or disposal process options to develop potential remedial alternatives.

- Treatment - Treatment response actions include treatment in place (in situ) or in another location (ex situ). These technologies are designed to reduce the toxicity, volume, or mobility of the contaminants present. Ex situ treatment technologies are normally used with removal and disposal process options to develop potential remedial alternatives.

- Disposal - Disposal technologies include waste transportation, on-property disposal, and off-site disposal for the final deposition of the material. Disposal process options are used in concert with removal options and possibly treatment options to develop potential remedial alternatives.

2.4 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

Viable remedial action alternatives for Operable Unit 1 are developed by identifying remedial technologies and feasible process options within these technologies, which may be applied to the various contaminated media at the site. These media include pit wastes and associated material, soil, and residual water.

Technologies considered in selecting remedial action alternatives include those identified in 40 CFR 300. Additional technologies were considered based on experience and information gained through remedial action planning and implementation at similar sites. In this section, a range of available technology types and process options is screened for applicability to Operable Unit 1 in accordance with EPA guidance (EPA 1988a). Following the technology screening process, the remaining process options will be evaluated to select representative process options that support the assembly of preliminary remedial action alternatives in Section 3.0.

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2.4.1 Criteria for Identifying and Screening Technologies

Based on available information, remedial technologies and process options are identified for each of the General Response Actions. Technologies and associated process options are compiled by using information available in EPA documents and other references. A review of process option effectiveness is performed, and those judged to be potentially effective are further screened for technical implementability and cost. Information including site description and contaminant characterization were used to eliminate technologies or process options that would not apply or could not be effectively implemented for Operable Unit 1. The screening process reduces the number of possible process options for a given technology family to a more manageable set of options that are considered potentially appropriate for Operable Unit 1 media.

Figure 2-2 summarizes the General Response Actions, remedial technologies, and associated process options considered for Operable Unit 1 wastes and media. It also presents the results of the initial screening process. Following is a brief summary of the identification and screening of technologies and process options. More detailed descriptions of process options are provided in Appendix B.

2.4.2 No-Action General Response Action

The no-action response provides no additional remediation, maintenance, or security activities at the site to minimize risk to public health and the environment. As previously stated, the No-Action General Response Action is retained as a baseline for comparison to other remediation alternatives as required by the NCP.

2.4.3 Institutional Controls General Response Action

Institutional controls include monitoring and access controls.

2.4.3.1 Monitoring

Monitoring would be conducted during any selected remedial action alternative to assess short-term impacts to workers and the public, after remedial action to demonstrate attainment of remedial action objectives, and, as applicable, to assess the continued performance of on-property waste disposal or containment systems. Groundwater (including leachate), air, surface water, and sediment monitoring are considered.

Groundwater Monitoring

Groundwater samples would be taken from existing or new monitoring wells to detect and monitor contaminant migration. Groundwater monitoring is retained for further evaluation because it is the most effective way of determining if groundwater remedial action objectives are being achieved.

Leachate Monitoring

Leachate would be monitored through a newly installed collection system. Such a system would be part of an engineered waste disposal facility. Leachate monitoring is retained for further evaluation because it is the most effective way of evaluating the performance of a remedial action in mitigating the migration of contaminated leachate from treated and/or contained waste.

Air Quality Monitoring

Air near wastes known to contain significant quantities of radioactive material and other contaminants of concern would be monitored to ensure compliance with the Clean Air Act and other appropriate standards. Consequently, air monitoring is retained for further evaluation because air emissions during remedial action are of potential concern.

Surface Water/Sediment Monitoring

Surface water and sediment monitoring is useful for determining the extent of surface contaminant migration due to runoff and emitted resuspended contaminants. Accordingly, surface water/sediment monitoring is retained for further evaluation.

2.4.3.2 Access Controls

Access controls would be implemented to regulate access to the site. The technologies for access control includes physical barriers and administrative controls.

Physical Barriers

Physical barriers can limit the potential for inadvertent public or worker exposure to on-property contamination by restricting entry. Public access to the FEMP site is already controlled by security forces and fencing. In addition, workers are restricted from contaminated areas within the Operable Unit 1 boundaries by access gates, internal fences, and signs. These barriers will be retained for further evaluation.

Administrative Controls

Administrative controls (e.g., deed restrictions) can limit the potential of public and worker exposure to contamination on property by restricting access and use. Administrative control is applicable and is retained for further evaluation.

2.4.4 Containment General Response Action

Long-term containment consists of technologies that limit the migration of contaminants and the associated potential for exposure, but do not reduce contaminant toxicity or volume. These containment technologies include subsurface flow control, capping, and run-on/runoff control.

2.4.4.1 Subsurface Flow Control Technologies

Subsurface contamination can be isolated by lateral barriers such as subsurface drains, slurry cut-off walls, pumping wells, sheet pilings, or grout curtains. There are two purposes for these technologies: (1) collect and control potentially contaminated leachate flow and (2) prevent groundwater from coming in contact with contaminated subsurface soils. The effectiveness of subsurface flow controls depends on the size of the affected area, the nature of the site-specific hydrogeological conditions, and the life expectancy of the technology.

Subsurface Drains

Subsurface drains include any type of buried conduit used to collect and convey groundwater or leachate by gravity flow. A subsurface drainage system often uses a perforated drain pipe or a gravel bed for conveying flow to a storage tank or sump. This process option is retained for further evaluation because they could be effective in intercepting perched groundwater before it comes into contact with pit waste.

Slurry Cut-off Walls

Slurry cut-off walls are fixed, underground, physical barriers that are formed by pumping slurry, usually a soil or cement, bentonite, and water mixture, into a trench as excavation proceeds, allowing the slurry to set while backfilling. Slurry walls isolate the subsurface soil contamination by diverting the groundwater around the contamination. Slurry walls are retained for further evaluation for the same reason subsurface drains were retained.

Pumping Wells

Pumping wells either extract or inject water to contain or remove a "plume" of contamination or to adjust groundwater levels to prevent plume formation. They can also be used in conjunction with other groundwater controls to maximize efficiency. This process option is retained for further evaluation because they could be effective in preventing perched water from coming into contact with pit waste. They could also facilitate pit excavation by controlling inflows to the excavation.

Sheet Pilings

Sheet pilings are constructed by driving webbed sections of sheet piling into the ground. Sections are joined before being driven into the ground and initially are not watertight. However, the joints soon fill with fine- to medium-grained soil particles that generally minimize but do not completely stop groundwater flow. Because of costs and unpredictable wall integrity (i.e. long-term durability), sheet pilings are usually used only for temporary dewatering during construction or for erosion protection where another barrier intersects flowing water. Sheet pilings are eliminated as a process option due to installation difficulty at the depths needed to control groundwater flow in Operable Unit 1.

Grout Curtains

Grout curtains are underground barriers formed by injecting grout, either particulate (such as Portland cement) or chemical (such as sodium silicate), into the ground. Grout curtains have been retained for further evaluation because they make it possible to divert perched groundwater away from contaminated subsurface pit material and soil.

2.4.4.2 Capping Technologies

A contaminated area can be encapsulated by placing physical barriers on top of the waste. Capping of pit wastes and soil could effectively limit airborne emissions and reduce precipitation-enhanced percolation and leaching. A stabilized surface fill would be required before cap placement. Design life of any cap should be 1,000 years which is the general ARAR-based requirement for caps being considered for wastes of the type present in Operable Unit 1. The following sections discuss capping options considered.

Synthetic Cover

A synthetic membrane can be placed over contaminated materials to control erosion and prevent infiltration, thereby minimizing contaminant leaching. The design life of synthetic membranes is less than 1,000 years. Therefore, synthetic covers are eliminated as a process option.

Concrete-Based Cap

A cap composed of concrete can maintain integrity, effectively control erosion, and minimize generation of leachate from precipitation infiltration. Periodic application of special surface treatment may be required to maintain integrity. The design life of surface concrete-based caps is less than 1,000 years due to weathering. Therefore, single-layered concrete-based caps are eliminated from further evaluation as a process option.

Asphalt-Based Cap

This capping option functions similarly to the concrete-based cap but the material is a layer of asphalt. Again, periodic application of a special surface treatment may be required to maintain integrity. The design life of asphalt-based caps is less than 1,000 years due to weathering. Therefore, single-layered asphalt-based caps are eliminated from further evaluation as a process option.

Soil- or Clay-Based Cap

A soil- or clay-based cap is a single layer cap that uses soil or clay with a permeability lower than that of the waste being capped. This minimizes infiltration. The effectiveness of a single-layer soil or clay cap is not very high. Therefore, single-layer soil- or clay-based caps are eliminated from further evaluation as a process option.

Multimedia Cap

A multimedia cap incorporates the most effective attributes of other capping options by using more than one material to form multiple layers over the contaminated media. This layered design offers the highest effectiveness for capping by using the properties of cap components to minimize infiltration and control erosion while simultaneously providing protection (vegetation and drainage layers) that protects against freeze/thaw damage, cracking, or other damaging actions. This capping option is retained for further evaluation.

2.4.4.3 Run-On/Runoff Control Technologies

Run-on/runoff controls are used to divert surface runoff around contaminated areas, thus minimizing the potential for contaminant resuspension. Graded contours, swales, and berms can effectively control surface water run-on/runoff and can limit contaminant migration. These measures have been effectively used for Operable Unit 1 in the Waste Pit Area during Removal Action No. 22. Also, sediment traps such as siltation fences or hay bales may be used to intercept soil particles in runoff; however, their use requires continuous maintenance. Sedimentation basins or sediment traps could

also be used in conjunction with surface diversions/controls for surface water control, especially during remedial action. The following discussion presents run-on/runoff control process options.

Sedimentation Basin/Sediment Trap

Sedimentation basins and sediment traps can control suspended solids entrained in surface flows. A sedimentation basin is usually constructed by placing an earthen dam across a waterway or natural depression, by excavation, or by a combination of both. Sediment traps include silt fences or hay bales that intercept and collect soil particles in runoff. This process option is retained for further evaluation as a means to control surface water runoff during storm events.

Diversion/Collection

Essential to surface water management, surface diversion and collection includes the use of dams, dikes, berms, channels, waterways, terraces/benches, chutes, seepage ditches/basins, levees, and flood walls as temporary or permanent measures for effective surface water control. Diversion/collection may be used to prevent flooding, control erosion, or direct surface runoff and can effectively prevent the contact of surface runoff with contaminated water or waste material. Diversion/collection is retained for further evaluation as a means to control potential surface water runoff.

Grading

By reshaping the land surface through grading, both surface water infiltration and runoff are managed while controlling erosion. Soil spreading and compaction of soils are commonly used in conjunction with grading. This process option is retained for further evaluation as a common way to manage surface water infiltration and control runoff.

Revegetation

Revegetation is a cost-effective method to stabilize the surface, especially when preceded by capping and grading. Revegetation decreases erosion by wind and water and contributes to the development of a naturally fertile and stable surface environment. This process option is retained for further evaluation as a common way to stabilize the surface of regraded land.

2.4.5 Removal General Response Action

Removal of contaminated material is used before ex situ treatment or disposal. Removal measures can be applied to all affected Operable Unit 1 media. The appropriate technology and process option depends on the physical properties of the waste media. The waste removal technology encompasses

five mechanical removal process options, based on the physical properties of the soils and waste pit materials in Operable Unit 1, a single hydraulic removal process option, two pneumatic removal process options, and two water removal process options.

2.4.5.1 Mechanical Removal Technologies

Loader/Dozer

A tracked or wheeled front-end loader or dozer uses a front-mounted bucket to excavate and move material. This process option is retained as a potential method of removing the contaminated pit wastes and soils from Operable Unit 1.

Crane with Clamshell System

A clamshell suspended from a crane or other overhead structure could be used to remove pit wastes and soil. This process option is retained as a removal method for Operable Unit 1 wastes.

Conveyor System

A belt-type conveyor system with excavation buckets could be used to remove pit wastes and soil. This process option is retained for further evaluation.

Backhoe

A tracked or wheeled backhoe could be used to remove soil and other material. This process option is retained as a potentially applicable method for pit waste and soil removal.

Dragline System

A dragline system is a crane-suspended excavation tool that is pulled across the surface of the media. The process option is retained for removal of contaminated soil.

2.4.5.2 Hydraulic Removal Technology

Hydraulic Mining Pump

The hydraulic mining pump consists of a slurry pump and a water jetting ring to remove any solids in the waste pits as a slurry. This device could be supported from an overhead or floating structure. This process option is retained for further evaluation.

2.4.5.3 Pneumatic Removal Technologies

Pneuma/Oozer Dredging

A pneuma/oozer dredging system consists of a compressed air-driven pump that displaces and removes the wastes. This process option is retained for further consideration.

2.4.5.4 Water Removal Technologies

Pumping Wells

Pumping wells can be used to extract water from the waste pits to facilitate excavation and material handling. Pumping wells are retained as a process option for dewatering.

Subsurface Drains

Subsurface drains include any type of buried conduit used to collect and convey groundwater and leachate by gravity flow. This process option is retained for further evaluation.

2.4.6 Treatment General Response Action

This response action contains in situ technologies, waste stabilization, physical treatment, chemical treatment, thermal treatment, and biological treatment.

2.4.6.1 In Situ Treatment Technologies

In situ treatment technologies provide some level of treatment or containment in place, without prior removal of the contaminated materials. The following in situ treatment process options are considered for Operable Unit 1.

Shallow Soil Mixing

This process would add cement, flyash, and bentonite to pit waste and soil, and blend the mixture with augers lowered into the material. Stabilization would increase the volume of the material. This process option is retained for further evaluation because it has the potential to decrease the mobility of the principal Operable Unit 1 COCs.

In Situ Vitrification

This process option would heat the pit waste and soils by applying electrical energy until a molten mass is formed. Electrodes, through which a large current would pass, would be lowered into the waste in a closely spaced grid pattern. Upon cooling, a monolithic glass waste form is achieved. This process option is not retained for further evaluation due to: (1) its ineffectiveness for heterogeneous

wastes, (2) saturated wastes require special design considerations because of the large amount of water that will be vaporized during the process (Shelley, 1990), and (3) for wastes present at the depths in Operable Unit 1, specifically; this process option has not been shown to be implementable in full-scale tests at depths exceeding 17 to 20 feet (Bowlds, 1992 and Levi, 1992.)

Surcharging

This process option compacts waste by mounding or overburdening the material in place with a large quantity of soil for an extended time period. The overburden compacts the media and reduces the voids in the pits, while simultaneously forcing liquids from the media. This process option is retained for further evaluation because it could be used for in situ alternatives to stabilize the wastes to allow construction of a cap.

Dynamic Compaction

Dynamic compaction involves dropping 5- to 40-ton weights from a crane to compact surface and subsurface soils, thereby creating a surface capable of supporting a cap. This process option is effective when implemented in conjunction with groundwater flow control technologies, since the compacted materials still contain contaminants of concern. This process option is retained for further evaluation for the same reason as surcharging.

Vacuum Extraction

Vacuum extraction uses either a vacuum pump or a blower to force air through soils to remove volatile contaminants. Since volatile compounds are not the principal COCs and vacuum extraction provides no treatment of nonvolatiles, this process option is not retained for further evaluation.

2.4.6.2 Waste Solidification Technologies

Waste solidification techniques immobilize contaminants in a matrix to reduce or eliminate leachability and impart structural rigidity to the waste form. Ex situ waste solidification process options are asphalt-based solidification, cement-based solidification, thermoplastic encapsulation, vitrification, and lime/flyash solidification.

Cement-Based Solidification

The waste is mixed with water and cement-based reagents in a mixer or pug mill. The waste is incorporated into the rigid matrix of the hardened concrete. This method physically or chemically solidifies the waste, depending on waste characteristics and limits contaminant mobility. This process

option results in a volume increase. This process option is retained for evaluation since most treatability studies (see Appendix C) have shown that pit waste materials can be solidified by cement. Solidification has the potential ability to limit the mobility of the principal COCs (radionuclides and metals) in Operable Unit 1.

Thermoplastic Solidification

The waste is sealed in a matrix such as asphalt bitumen, paraffin, or polyethylene. The waste is then poured into a container, allowed to cure, and then placed into a disposal facility. Thermoplastic solidification with asphalt has been used to solidify heavy metal waste. This process option is retained for further evaluation for the same reason as for cement-based solidification.

Vitrification

Waste material is mixed with vitrification reagents (i.e., alumina, silica, sodium) in a surge hopper and fed into a glass melter for vitrification. The waste form is glass-like, and suitable for final disposal. Vitrified waste is leach resistant. Vitrification has been tested at lab and bench scale at numerous DOE facilities including Savannah River, Hanford, West Valley, and Oak Ridge. This process option is retained for further evaluation.

Lime/Flyash Solidification

Waste is mixed with lime and flyash in a cement mixer or pug mill. With proper additive ratios, this option has been used on a variety of waste. FEMP flyash piles could supply the flyash source. This process option is retained for evaluation for the same reason as cement-based solidification.

2.4.6.3 Physical Treatment Technologies

These physical treatment process options provide varying levels of treatment. Many of these process options are simply pretreatment steps for other technologies such as chemical treatment and waste solidification.

Solid/Liquid Separation

This process option is a primary pretreatment step for other treatment process options that require specific solid/liquid ratios. Solid/liquid separation schemes typically use filtration (solids removal) and/or dewatering systems. This process option is retained.

Soil Aeration

Soil aeration removes volatile contaminants from waste material by passing air through the materials and collecting the entrained volatiles. This process option is not retained because it is not applicable to inorganic or radionuclide contaminants (the principal COCs) present in the waste material.

2.4.6.4 Chemical Treatment Technologies

The only chemical treatment process option available for treating waste pit material and contaminated soil is chemical extraction. This process option is typically implemented above-ground following excavation or removal of the contaminated media.

Chemical Extraction

Chemical extraction is the process which makes use of the solubility of a waste contaminant in water or some other solute, such as acids or solvents, to transfer it from the solid waste matrix into solution. Once in solution, the waste contaminant can be more easily separated (isolated) and treated (destroyed or changed to a less hazardous form) or removed for off-site disposal. The remaining "cleaned" solid matrix may be redeposited at the site. Each of the treatment techniques for the chemical extraction technology involves separating the contaminant from the solid waste matrix using an extraction agent - a liquid, gas, chemical additive, or a combination of the above - to mobilize the contaminant which is chemically or physically attached to the solid waste material, i.e. producing a matrix. Most of the extraction techniques involve mixing the extractant with solid waste material, followed by solid/liquid separation where the "cleaned" solid material is separated from the extractant fluid. The extractant is then cleaned of the contaminant, normally through one or more chemical or physical processes, and is recycled back to the process as required.

The goal of the chemical extraction technology is to remove contaminants from solid waste material and allow the clean material to be returned to the environment. Consistent with this application of returning cleaned material to the site and reducing the volume of material requiring disposal, the FEMP site, as part of Operable Unit 5's RI/FS, is investigating chemical extraction application on site waste material (soil washing).

Chemical extraction techniques are defined as water or aqueous solution washing, including the use of acid or solvent extraction. Two very different types of solid waste material require remedial action in the Operable Unit 1 study area: soils contaminated with waste materials and the waste pit materials themselves. The application of chemical extraction technology to these materials is different. This

discussion is relative to the waste pit materials. The ability of this technology to achieve waste-specific removal objectives can only be evaluated through bench- and pilot-scale treatability testing. One or more of these chemical extraction techniques may be required to process a complex waste such as the material in the Operable Unit 1 waste pits.

The aqueous solutions used in washing can be comprised of basic solutions (caustic, lime, slaked lime, or industrial alkali-base); acidic solutions (sulfuric, hydrochloric, nitric, phosphoric, or carbonic); or solutions with surfactants or cheating agents. Waste materials most suited to the water washing technique are hydrophilic organics. Pretreatment, which chemically changes the contaminants of the solid waste material, with hydrogen peroxide, sodium hypochlorite, or other oxidizing agents may facilitate the washing process for some organic waste materials. Application of cheating agents for pretreatment can be used to increase the process effectiveness for metals in the waste matrix. The degree of pretreatment is directly related to the results of waste characterization and the targeted removal efficiency and treatment techniques to be employed.

The solid waste material is mixed with the water or the aqueous solution to remove the contaminant from the solid matrix. This is followed by solid/liquid separation where the coarse fraction of the waste material is separated from the aqueous solution now containing the contaminant and the smaller fraction (fine particles) of the solid material. Further separation steps to remove the fine particles from the aqueous solution/contaminant may be required. The contaminant is removed from the aqueous solution and the aqueous solution is cleaned (if required) and recycled back to the process. The separated solid material fraction may require removal of any residue (acid, excess cheating agent, etc.) from the process. Dewatering will be required for structural stability prior to its return to the ground.

The solvent extraction technique may be used on waste matrix containing high concentrations of nonvolatile hydrophobic organics. The choice of a suitable solvent includes having a sufficient boiling point difference between solvent and contaminant to facilitate post-extraction separation. Other properties contributing to choice of solvents are equilibrium characteristics, stability, density, viscosity, and interfacial tension (Raghavan, Coles, Dietz, 1991).

Extraction is comprised of two processes, leaching and immersion. Leaching is typically a batch operation in which screened solid waste material is placed on a porous surface and the solvent is sprayed over the solid material. The solvent leaches the contaminant from the solid matrix and is

collected below. Immersion is accomplished in an agitated tank filled with the solvent, thoroughly mixing the materials. When equilibrium has been reached, the agitation is stopped and the solids are allowed to settle.

In either process, the solid/solvent separation can be as simple as gravity settling or it may require filtration or even centrifugation. Residual solvent remaining in the solid matrix will require removal by either solvent displacement or gas, steam or vapor stripping. Contaminant removal from the solvent is generally by distillation, but may require some liquid/liquid extraction prior to distillation.

Chemical extraction is a separation technique that utilizes a liquid solvent to remove a contaminant from a solid material. This process option has been proven successful in individually removing metals, organics, inorganics, and radionuclides form a solid matrix; however, no complex matrix mixture such as that in the waste pits has ever been tested to prove effectiveness. The unknown interferences that one waste material in the matrix will have on another, coupled with the easily dissolved solids will most likely cause large amounts of reagents to be consumed during processing. Also, the heterogenous nature of the material in the waste pits causes, decreases in process efficiency and difficulty in material handling systems design. The majority of the uranium present in the waste pit material (particularly in Waste Pits 4 and 6) is in a depleted form which has been processed and repeatedly extracted under rigorous conditions to reach the economic discard limit of 0.2 to 0.42 percent. While it is possible to remove uranium from the waste pit material (NLCO, 1978 looked only at Waste Pit 5 material), it is extremely difficult and requires many processing steps under extreme conditions. If the processing operation could be accomplished, the removal (or in the reference case of recovery) is only estimated at 95 percent (NLCO, 1978). This removal efficiency will not satisfy the remedial objectives and would still require proper disposal of large amounts of solid waste materials.

This process option is moderately difficult to implement because of the large number of processing steps that would be required to remove the numerous types of wastes present in the pit material. Large quantities of intermediate liquid streams would require storage and processing capacity. Cost: The capital cost for the chemical extraction system would be high due to the costs of the material handling equipment, process equipment, chemical reagents, and labor. O&M costs would moderate. Overall, costs would be high.

Chemical extraction is not carried forward to alternative development for the waste pit material due to unknown effectiveness for removal of contaminants in the solid matrix. It may be carried forward to alternative development for contaminated soils, if Operable Unit 5 testing provides timely, efficient information.

2.4.6.5 Thermal Treatment Technologies

This technology proposes several treatment process options that will thermally treat the wastes through drying/calcination and incineration. These process options are summarized below:

Drying/Calcination

Drying or calcination is a weight and/or volume reduction technique that uses heat to remove water from sludges or solids. This process option is retained because it can be used to dry the wet pit wastes as principal treatment or as a pretreatment option for other technologies. This is likely to be necessary to facilitate waste handling and disposal.

Incineration

Waste material can be incinerated by rotary kiln, fluidized bed, slagging, and liquid injection incinerators. Incineration is typically used to destroy organic contaminants. Rotary kilns are refractory-lined rotating cylinders positioned at a slight incline. Waste is introduced at the high end, and ash is collected from the bottom end. Flue gasses pass through a secondary chamber and control equipment before exiting to the atmosphere. Fluidized bed incinerators contain a bed of sized granular refractory material in a refractory-lined vessel. Waste is injected onto the bed and incinerated as air is forced up through the bed at a velocity sufficient to fluidize the burning material. This process option is not retained because it is not effective for the removal of inorganic or radionuclide contaminants present in the waste material and it does not add any other benefit beyond drying.

2.4.6.6 Biological Treatment Technologies

Several biological treatment process options for treating contaminated soil, waste material and water are available for consideration. Biological treatment process options use living organisms such as bacteria or fungi to detoxify or immobilize contaminants in waste. These process options are applied primarily to convert organic contaminants into nontoxic products. Bioremediation has also been used to degrade inorganic contaminants such as nitrates and to detoxify or immobilize certain metals by changing their oxidation state.

Effective bioremediation technologies often require the use of amending agents and nutrients such as sewage sludge, hay, or manure for the remediation of solid material and a soluble organic compound such as glucose for the remediation of aqueous or slurry waste. The addition or control of oxygen, temperature, and pH are also commonly required. Use of microbes already present at the waste site is preferable to introducing other microbes that must be acclimated to site conditions. In bioremediation processes, limitations to microbial activity (e.g., nutrient deficiencies or improper oxygenation or temperature control) are identified and corrected to stimulate or accelerate naturally occurring processes.

Biological Treatment

This process utilizes biological processes to detoxify a waste stream by destroying the organic constituents using aerobic or anaerobic respiration. Biological treatment is not retained because it is not effective for the removal of some of the inorganic and the radionuclide contaminants (the principal COCs) present in the waste material.

2.4.7 Disposal Technologies

Several waste transportation and disposal technologies may be used following removal as part of the remedial action, and may include both on-property and off-site disposal. On-property disposal would require transportation by truck or conveyor, while off-site disposal would require transportation by rail, truck, or a combination of both.

2.4.7.1 Waste Transportation

Specific federal requirements for off-site transport of chemically hazardous and/or radioactive material have been identified to address factors such as packaging and labeling. Many states, including Ohio, also have transportation requirements and many require advance notice for shipments of radioactive material.

The waste material would be packaged and shipped in accordance with DOT requirements to assure proper handling of the radioactive materials. The containers may be either lined boxes with volumes of 2 cubic yards or gondola rail cars of 15 cubic yards for bulk shipments of low specific activity material. Containers will be designed and configured to limit the activity readings outside the transport vehicle to be within DOT limits.

The process options for waste transportation include both truck and rail transport. Both of these process options are retained for further evaluation since one or both would be necessary for transportation to an off-site disposal location.

Rail Transport

The FEMP site can readily support rail transportation by using existing on-property rail spurs. It is possible that some rail line upgrades would be required. Rail transport has a lower frequency of accidents per trip than trucks and the volume of material hauled per trip is many times higher.

Truck Transport

Truck transport can offer portal-to-portal service with the road system available at the FEMP site.

2.4.7.2 On-Property Disposal Technologies

On-property disposal technology consists of two engineered process options designed to restrict contaminant migration, thereby reducing the threat to potential receptors. There are essentially three possible geometries: above-grade placement, below-grade placement, and partial below-grade placement. Each of these geometries has its own advantages and disadvantages. The above-grade geometry is selected because of increased distance between the waste material and groundwater (statutory constraint), less complex design and detailing for liners and drains, and elimination of the need to pump potential leachate from the base of the cell or vault to the ground surface. The two options for on-property disposal facilities include:

Engineered Disposal Cell

An above-grade engineered disposal cell to dispose of the radioactive waste associated with Operable Unit 1 would be configured such that the waste would be placed on a low permeability liner that includes a leachate collection system to impede the percolation of free water from the cell into the ground. The waste would then be covered with a multilayered cap to limit radionuclide emissions from the cell, a drain layer, a frost protection layer, and an erosion protection barrier to limit erosion, water infiltration, frost penetration, and biotic intrusion. The design life for the disposal cell is 1,000 years. This process option of an engineered disposal cell is retained for further evaluation.

Above-Grade Concrete Vault

Concrete vaults would be constructed and divided into individual cells. The vault slab and walls would act as a base for supporting the double liner system. Upon completion of material

emplacement in the vault, a multimedia cap, and appropriate drainage controls would be placed over the vault. This on-property disposal facility would also be equipped with a leachate collection/disposal system (LC/DS). This process option of an above-grade concrete vault is retained for further evaluation.

2.4.7.3 Off-Site Disposal Technology

Nonradioactive and radioactive contaminated waste could be disposed off-site at a government or commercial facility, as long as concentrations of radionuclides and hazardous constituents are below the facility's waste acceptance criteria and the facility has the necessary regulatory permits to accept the wastes. Nonradioactive material determined to be hazardous under RCRA would be shipped to a RCRA-permitted treatment, storage, and disposal facility and would require meeting land disposal restrictions (LDRs) listed in 40 CFR part 268. Nonhazardous, nonradiologically contaminated waste may be disposed in sanitary, demolition, or solid waste landfills.

The potential for land disposal at an off-site facility is affected by the availability of disposal sites for the Operable Unit 1 waste. One commercial facility located near Clive, Utah, is authorized to accept low-level and mixed radioactive wastes. This commercial facility has been evaluated as a potential representative off-site disposal facility.

Other off-site disposal options are currently limited to facilities that are owned and operated by DOE. Disposal facilities for low-level radioactive waste are currently located at major DOE installations such as the Hanford site near Richland, Washington; the Idaho National Engineering Laboratory near Idaho Falls, Idaho; the Savannah River Site near Aiken, South Carolina; and the Nevada Test Site (NTS) near Las Vegas, Nevada. There are not any established DOE disposal facilities in the State of Ohio or in the surrounding states. The DOE has established an internal waste management program which indicates a preferred disposal site for each of its facilities. The DOE has assigned the FEMP site to NTS. The NTS facility is evaluated for potential off-site disposal as a reasonable, representative DOE facility.

Nevada Test Site

This process option calls for the disposal of the waste at an existing government facility located in an arid western environment. This facility is currently operating and accepting many types of DOE waste. Preliminary assessment of the Operable Unit 1 wastes indicated they either currently meet or with treatment would meet the NTS waste acceptance criteria. Detailed discussion of waste

acceptance criteria for the facility is presented in Appendix J. The wastes can be transported to the facility by truck or truck/rail. This process option of the NTS is retained for further evaluation.

Permitted Commercial Disposal Site

This process option calls for the disposal of the wastes at an existing commercial facility located in an arid western environment. There is such a facility currently operating near Clive, Utah, and accepting low-level radioactive and mixed waste that meets the LDR treatment standards for disposal at the facility. Wastes can be transported by truck or rail. Licensing restrictions embodied in the waste acceptance criteria for the permitted commercial disposal site limit the ability of the facility to receive wastes above certain radionuclide specific activity concentrations. Detailed discussion of waste acceptance criteria for the facility is presented in Appendix J. The process option of off-site disposal at the permitted commercial disposal site is retained for further evaluation.

2.5 EVALUATION OF TECHNOLOGIES AND PROCESS OPTIONS

In this section, specific application of retained technology types and process options to Operable Unit 1 material is evaluated to select representative options. The purpose of the evaluation is to obtain a reasonable number of options to combine into preliminary alternatives (Section 3.0). Process options were evaluated based on effectiveness, implementability, and cost. The evaluation is only relative to similar process options and does not compare process options between technologies.

2.5.1 Criteria for Evaluating Technologies and Process Options

The process options are evaluated against the criteria of effectiveness, implementability, and cost. The evaluation process primarily focuses on effectiveness factors, with less emphasis on the implementability and cost evaluations. A description of each evaluation criteria follows.

2.5.1.1 Effectiveness Evaluation

The evaluation for effectiveness is based on the following:

- The potential effectiveness of the process option for meeting the RAOs relative to other process options within the technology.
- The potential impacts to human health and the environment during the construction and implementation phase.
- The reliability of the process option as it relates to the constituents of concern and conditions within the Operable Unit 1 boundary.

2.5.1.2 Implementability Evaluation

The implementability evaluation includes both the technical and administrative feasibility of implementing a process option. Considerations of feasibility include the availability of skilled workers to implement the process option, the ability to obtain permits for off-site actions, and the availability and capacity of transport, storage and disposal facilities.

2.5.1.3 Cost Evaluation

Each process option is evaluated as to whether capital and operation and maintenance (O&M) costs are high, moderate or low relative to other process options of the same technology type.

2.5.2 No-Action General Response Action

Under the no-action General Response Action, no additional action would be taken at Operable Unit 1. DOE would release the site for other unrestricted uses. The evaluation of this General Response Action follows.

- Effectiveness: This General Response Action is not effective. It provides no protection of human health and the environment and does nothing to reduce the toxicity, mobility, or volume of contaminants present. The potential for exposures to wildlife, trespassers, on-property workers, and off-site residents would increase over time as contaminants continued to be released to groundwater, surface water, soil or air. Potential impacts to human health and the environment associated with no further action are discussed in Appendix D.

- Implementability: No technical issues exist that would affect implementation.

- Cost: There are no costs associated with this alternative.

The no-action General Response Action is retained for development into an alternative as required by the NCP.

2.5.3 Institutional Control General Response Action

The technologies considered for the institutional action General Response Action include monitoring and access control. Table 2-15 summarizes the results of the process options evaluation.

2.5.3.1 Monitoring Technology

Process options evaluated for the monitoring technology include:

- Groundwater monitoring
- Leachate collection/monitoring
- Air quality monitoring

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- Surface water/sediment monitoring

Groundwater Monitoring

- Effectiveness: Monitoring wells are effective in identifying contaminant migration and in evaluating the effectiveness of other remedial measures. This is of particular concern to Operable Unit 1 because groundwater is a principal medium of concern. The potential impact on human health and the environment during the construction and implementation phase of this option is negligible. The only additional exposure posed by instituting groundwater monitoring would be to sampling and analytical personnel.

- Implementability: A large number of monitoring wells currently exist at and near the FEMP site. Additional wells can be installed quickly, and required equipment and services are readily available.

- Cost: Capital costs are moderate and would only include the installation of additional monitoring wells. Major operation and maintenance (O&M) costs include well maintenance, sampling and analysis, data validation, database management, and payments to landowners. Overall, costs would be moderate.

The groundwater monitoring process option is carried forward into the development of alternatives.

Leachate Monitoring

- Effectiveness: Leachate monitoring is effective in detecting water that has infiltrated and passed through containment systems or waste sites (such as an on-site waste disposal facility). Leachate monitoring has negligible impact on human health and the environment. Leachate collected would be forwarded to the FEMP Advanced Waste Water Treatment System.

- Implementability: Leachate monitoring requires sampling of collected leachate and analyzing the samples. Equipment and services are readily available.

- Cost: The capital costs would be moderate for installation of the leachate collection system. O&M costs would be moderate and would include sampling and analyses. Overall, costs would be moderate.

Leachate monitoring is carried forward to the development of alternatives.

Air Quality Monitoring

- Effectiveness: Atmospheric monitoring is an effective means of measuring the impact of remedial actions on the air. This will be required. The impact on human health and the environment during the construction and implementation of this process option is negligible.

- Implementability: The required equipment is readily available, and depending on the type of monitoring systems (passive, continuous, or filter), most systems can be easily installed & operated.

- Cost: Capital costs for most monitoring systems are relatively low as are O&M costs, which include periodic monitoring and maintenance. Overall, costs would be low.

Air quality monitoring is carried forward to the development of alternatives.

Surface Water/Sediment Monitoring

- Effectiveness: Surface water/sediment monitoring is effective for identifying surface water contaminant migration and monitoring the performance of remedial actions. This will likely be required, especially during remedial construction.

- Implementability: Surface water/sediment monitoring is easily implemented and requires no unique training or equipment.

- Cost: Capital costs for this process option would be minimal. Laboratory analytical costs would constitute the largest part of the O&M cost. Overall, costs would be low to moderate.

The surface water/sediment monitoring process option is carried forward to the development of alternatives.

2.5.3.2 Access Control Technology

Process options evaluated for access control technology include:

- Physical barriers
- Administrative controls/deed restrictions

Physical Barriers

- Effectiveness: Physical barriers help mitigate potential exposure to contamination on property by restricting entry. Physical barriers are typically used in conjunction with other remedial actions.

- Implementability: Barriers can be constructed quickly and safely, without disturbing the operation of existing facilities and the environment. Some barriers (i.e. fences) already exist at the site.

- Cost: Capital costs would be low because barriers are relatively inexpensive to install, depending on the level of security required. Also, O&M costs would be low because once the barrier is installed, little maintenance is required. Overall costs would be low.

The option of physical barriers is carried forward to the development of alternatives.

Administrative Controls

- Effectiveness: Administrative controls can be highly effective in reducing contact between contaminants and receptors but often cannot be relied on as the sole method of remediation.

- Implementability: Administrative controls are easy to implement and typically are standard requirements at hazardous waste management facilities.

- Cost: Capital costs would be low for administrative controls. The O&M costs would be low. Overall costs would be low.

The option of administrative controls/deed restrictions is carried forward to the development of alternatives.

2.5.4 Containment General Response Action

The following technologies were considered for the containment General Response Action:

- Subsurface flow control
- Multilayer Capping
- Run-on/runoff control

Table 2-16 summarizes the results of the process options evaluation. A narrative discussion follows.

2.5.4.1 Subsurface Flow Control Technology

Subsurface flow control was determined to be a remedial technology potentially applicable for Operable Unit 1. Process options retained for evaluation for subsurface flow control include:

- Subsurface drains
- Slurry walls
- Pumping wells
- Grout curtains

Subsurface Drains

- Effectiveness: The effectiveness of subsurface drains to control leachate is dependent on their design and site geologic conditions. They are effective in minimizing off-site migration of contaminants. The potential impact to human health and the environment during implementation is considered minimal.

- Implementability: Installing drains near or under existing disposal/storage units can be moderately difficult, but achievable.

- Cost: Capital costs for installation and O&M of subsurface drains are moderate. Overall costs are moderate.

Subsurface drains for leachate collection are carried forward to the development of alternatives.

Slurry Walls

- Effectiveness: Slurry walls can form an effective barrier to confine contaminated groundwater that might otherwise flow from the site, or to divert the flow of groundwater away from the contaminated media. Slurry walls do not eliminate contamination but minimize the release of contaminants through lateral migration. This technology is subject to several limiting criteria, such as type of waste to be contained, site geology, and construction. The potential impact to human health and the environment during implementation is considered minimal.

- Implementability: Slurry walls are moderately difficult to install but can be constructed without disturbing the function or operation of existing facilities as long as they are not too deep. Deep slurry walls could be difficult to install and would require deep trenching.

- Cost: Construction equipment for trench construction, ingredients, removal of the soil during preparation, and slurry placement contribute to the moderate capital cost of this process. O&M costs for maintenance and repair would be low. Overall, costs would be moderate when compared to other control technologies.

Slurry walls are carried forward to the development of alternatives.

Pumping Wells

- Effectiveness: Pumping wells are moderately effective in controlling the lateral diffusion and flow of a contaminated plume, thereby restricting contaminant migration in the soil and groundwater. This process option is proven to be reliable with minimal impact on human health. Effectiveness is maintained only as long as pumping operations continue.

- Implementability: Equipment and services for this process option are readily available. The groundwater can be pumped to the FEMP Advanced Waste Water Treatment (AWWT) facility for treatment before discharge to the Great Miami River through the FEMP NPDES-permitted effluent line. It is relatively easy to keep the system operating as necessary to achieve the desired effects.

- Cost: Capital costs include equipment and installation and would be moderate. Pumps, screens, casings, and pipeline must be maintained to ensure proper water flow from the extraction well; also, maintenance is required to prevent loss of the well that would result in contaminant escape. Long-term costs for the pumping system would be moderately high. Additional costs for treating the pumped groundwater would be considered relatively low because the pumped groundwater would only be a small portion of the total volume of water treated by the FEMP AWWT facility. Overall, costs would be considered moderately high.

Pumping wells are carried forward to the development of alternatives.

Grout Curtains

- Effectiveness: This process option is less effective in retarding groundwater flow than a slurry wall. The incremental nature of the installation process for the grout curtains results in more gaps in the barrier than that for a slurry wall. This process option is only moderately effective.

- Implementability: This process requires extensive drilling and equipment for pressure injecting grout directly into the soil. Depending on the subsurface conditions, this process option could be difficult to implement.

- Cost: Capital cost of grout curtains can be three times as costly as a slurry wall. The O&M costs would include inspection, groundwater monitoring, and possibly repairs. Overall, costs would be moderately high.

Grout curtains are not carried forward to alternative development in favor of slurry walls due to their moderate effectiveness, implementation difficulty, and cost factors.

2.5.4.2 Capping Technology

Multimedia Cap

- Effectiveness: A multimedia cap is a highly effective method of preventing further contaminant migration; however, it does not address past contaminant migration. A well-constructed cap significantly reduces infiltration into waste, thereby minimizing further leachate generation. It promotes surface drainage and prevents erosion and sediment transport of waste. A multimedia cap also prevents exposure to surface contaminants.

- Implementability: Multimedia caps are readily constructed and require only standard construction equipment. Availability of construction materials, such as suitable clays, is the primary construction consideration.

- Cost: The capital cost for a multimedia cap is high. The O&M cost for a multimedia cap is relatively low. Overall, costs are rated high.

The multimedia cap is carried forward to the development of alternatives.

2.5.4.3 Run-On/Runoff Control Technology

Run-on/runoff control technology is an applicable remedial technology. Process options evaluated for run-on/runoff control include:

- Sedimentation basin/sediment trap
- Diversion/collection

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- Grading
- Revegetation

Sedimentation Basin/Sediment Trap

- Effectiveness: Sedimentation basins and sediment traps can effectively remove suspended solids. The effluent concentration of suspended solids is regulated by local and/or federal government authorities. This process option provides a reliable method for removing suspended solids from a runoff waste stream, provided the particles will settle.

- Implementability: To implement this process option, certain flow characteristics are required, fill material must be properly prepared, and emergency spillway of the sedimentation basin should be stabilized with temporary vegetation. Storage requirements of material must be considered when constructing the sedimentation basin. These requirements vary from state to state.

- Cost: Costs for sedimentation basins vary with size, location, and construction method. Capital costs for equipment, materials, and construction are low. O&M costs for maintenance and repair are low. Overall, costs are considered relatively low.

The sedimentation basin and sediment trap are retained for alternative development to be used for stormwater flow control, if needed.

Diversion/Collection

- Effectiveness: This surface water control method is used to prevent flooding, control erosion, and direct surface runoff. When used in conjunction with other remedial action technologies, this technology can be effective. Diversion of storm water runoff will reduce the amount of contaminated leachate produced.

- Implementability: This method can be easily and readily implemented using readily available equipment and materials and local contractors. Implementation of this method seldom poses significant risks to worker health and safety. Most excavation and grading equipment is available on property.

- Cost: Generally, capital cost of diversion and collection techniques is low, with the installation cost dependent on the site topography and geology. Low O&M costs are common to almost all diversion and collection methods. Overall, costs are considered low.

Diversion/collection is carried forward to the development of alternatives.

Grading

- Effectiveness: Grading is a highly effective method of promoting and controlling site drainage and thereby minimizing infiltration of water into contaminated areas. Grading can be used with in situ remediation alternatives as well as removal, treatment, and

disposal alternatives. Some form of site grading will be used with any remediation alternative. Short-term fugitive dust emissions are a potential concern to construction workers.

- Implementability: Grading can be easily implemented at the site and does not require specialized equipment. The techniques used in grading operations are well established and widely used. Personnel and equipment can usually be obtained locally.

- Cost: Capital costs would be moderate. Required equipment can be either purchased or leased. Periodic monitoring of the graded surface is necessary, and due to possible surface settling, smoothing operations may be required for several years. Also, O&M costs include annual inspections, mowing, erosion control, and drainage maintenance. Overall, costs are considered moderate.

Grading is carried forward to the development of alternatives.

Revegetation

- Effectiveness: Revegetation effectively establishes a vegetative cover that stabilizes the surface of waste disposal sites. This technique decreases erosion by wind and precipitation. No apparent impact to human health and the environment occurs from using this technique.

- Implementability: This process option is considered readily implementable due to the minimal equipment requirement. Planning involves the selection of suitable plant species, seed bed preparation, seeding/planting, mulching, fertilization, and maintenance.

- Cost: Relative to other technologies, revegetation is an inexpensive surface stabilization process. Periodic maintenance such as liming, fertilizing, mowing, replanting, and grading eroded slopes are O&M costs associated with this remedial technique. Overall, costs would be low.

Revegetation is carried forward for the development of alternatives.

2.5.5 Removal General Response Action

The following technologies were retained for the removal general response action:

- Mechanical removal
- Hydraulic removal
- Pneumatic removal
- Groundwater removal

Table 2-17 summarizes the results of the process options evaluation for the removal general response action.

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2.5.5.1 Mechanical Removal Technology

The process options evaluated for the mechanical removal technology include:

- Loader/dozer
- Crane with clamshell system
- Conveyor system
- Backhoe
- Dragline system

Loader/Dozer

- Effectiveness: This process option is very effective in removing soil and debris for treatment or for waste packaging. There is the potential for dust suspension that would require the use of dust controls. Workers would be protected in enclosed cabs and by use of personal protective equipment. The loader/dozer would be ineffective for removing water.

- Implementability: Front-end loaders and dozers are widely used for earth-moving activities and can be readily obtained. This process option is readily implementable.

- Cost: Capital costs for equipment would be low. O&M costs for equipment maintenance and repair would be low. Overall, costs would be low.

The loader/dozer is carried forward for alternative development because it effectively removes contaminated soil and debris and rates high in implementability.

Crane with Clamshell System

- Effectiveness: This system is effective for material excavation and in rehandling materials. Workers would be protected by enclosed cabs and personal protective equipment; however, dust generation is a concern. The crane and clamshell system would be ineffective for removing water.

- Implementability: The use of the clamshell is readily implemented because the equipment is easily obtained and the waste is accessible.

- Cost: Capital costs for equipment would be low. The O&M costs for equipment maintenance and repair would be low. Overall, costs are low.

The crane with clamshell is retained for alternative development due to its low costs and high implementability and effectiveness for soils and waste pit material removal.

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Conveyor System

- Effectiveness: This process option could be used for moving the soils and debris. Personnel may be exposed to fugitive dust emissions unless covered systems with emissions control equipment are used. Overall, effectiveness is rated moderate.

- Implementability: Conveyor equipment is readily available but would require an additional means, i.e. equipment, steps, manpower, of loading material onto the conveyor system. Implementability is considered moderate.

- Cost: Costs for equipment would be moderate. O&M costs for equipment maintenance and repair would be low. Overall, costs would be moderate.

Due to its moderate effectiveness and implementability, the belt-type conveyor system is not carried forward for alternative development.

Backhoe

- Effectiveness: This process option would be very effective in removing soils and debris for treatment or disposal. There is the potential for dust suspension that could spread contamination. Dust control measures may be needed. Workers would be protected by enclosed cabs and personal protective equipment.

- Implementability: The backhoe option is readily implemented and the equipment is easily obtained.

- Cost: Capital costs for equipment would be low. The O&M costs for equipment maintenance and repair would be low. Overall, costs would be low.

The backhoe is retained for alternative development because of its low cost, easy implementability and effectiveness in removing contaminated soil and debris.

Dragline System

- Effectiveness: A dragline system could be effective in removing soils and debris; however, it probably would require excavating a larger area than necessary due to the limited accuracy of its operation. Dust suspension is a potential concern. Workers would be protected by enclosed cabs.

- Implementability: A dragline system would be readily implemented.

- Cost: Capital costs for equipment would be moderate. The O&M costs for equipment maintenance and repair would be low. Overall, costs are considered moderate.

The dragline system is not carried forward for alternative development because its costs are higher than the other removal process options. Also, it would be less effective than a backhoe or loader/bulldozer because it requires a larger area with limited accuracy for operation.

2.5.5.2 Hydraulic Removal Technology

Hydraulic Mining Pump

- Effectiveness: This option is highly effective in pumping liquids with varying solids content ranging from slurries to sludges.

- Implementability: Equipment is readily available and does not require highly skilled personnel. The representative design prepared for cost estimating purposes incorporated the use of the Pit Hog Dredge existing on site for all wet pit waste (assumed to consist of 80 percent of Waste Pit 5 material).

- Cost: Capital costs for equipment are considered moderate. The O&M costs for equipment maintenance and repair would be moderate. Overall, costs are considered moderate.

The hydraulic mining pump is carried forward for alternative development because of its effectiveness and ease of implementation.

2.5.5.3 Pneumatic Removal Technology

Pneuma/Oozer Dredge

- Effectiveness: The pneuma/oozer dredge would be moderately effective for removal of sediments in the wet pits. Effectiveness is limited by the depth of the pit, with shallow pits reducing effectiveness.

- Implementability: The availability of pneuma/oozer dredges is limited and makes this process option difficult to implement.

- Cost: Capital costs for equipment are moderate. O&M costs for maintenance and repair are also considered moderate. Overall, costs are moderate.

The pneuma/oozer dredge is not retained for alternative development due to its moderate effectiveness and difficult implementability relative to other removal methods.

2.5.5.4 Groundwater Removal Technology

Process options retained for the evaluation of groundwater removal technology include:

- Pumping wells
- Subsurface drains

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Pumping Wells

- Effectiveness: Pumping wells are effective for extracting groundwater for subsequent treatment and disposal. Minimal impacts are encountered during the implementation of this process option.

- Implementability: Equipment and service for this process option are readily available. Extracted groundwater can be pumped to the FEMP AWWT for treatment and disposal.

- Cost: Capital costs include equipment and installation and are considered moderate. The pumping wells scheduled require maintenance and power; relative O&M costs are therefore considered high.

Pumping wells are carried forward to alternative development as a process option to be used for groundwater removal during remedial activities.

Subsurface Drains

- Effectiveness: Subsurface drains can be used for removal of groundwater during remedial activities. However, their effectiveness is limited in long-term applications due to their tendency to clog.

- Implementability: Subsurface drains would be moderately difficult to install since the excavation areas might intersect contaminated materials and because of the required depths (i.e., perhaps as much as 30 feet).

- Cost: Capital costs and O&M cost are moderate. Overall costs are considered moderate.

Subsurface drains are not carried forward as a process option because they are more difficult to implement than pumping wells and have no apparent increases in effectiveness.

2.5.6 Treatment General Response Action

The following treatment technologies have been evaluated:

- In Situ treatment
- Waste solidification
- Physical treatment
- Chemical treatment
- Thermal treatment

Table 2-18 summarizes the results of the process options evaluation for the treatment general response action. A narrative discussion follows. Refer to Appendix B for detailed description of process options.

2.5.6.1 In Situ Treatment Process Options

In situ treatment was determined to be a viable remedial technology. Process options retained for in situ treatment include:

- Shallow soil mixing
- Surcharging
- Dynamic Compaction

Shallow Soil Mixing

Shallow soil mixing is a method of in situ soil stabilization in which a stabilizing agent is blended with the soil or waste by mechanical means. Standard earth-moving equipment can be used, as well as special equipment such as crane-mounted augers or mixing blades which are manipulated to form stabilized overlapping columns of soils or waste to a depth of 30 feet or more.

- Effectiveness: This process is a potentially effective way to stabilize in situ soils. Transport of surficial site soil to downstream locations will be limited by this technology (i.e., this technology facilitates a chemical or physical reduction of the mobility of hazardous constituents). This process option is effective if the contaminated material is completely stabilized. Leachate generation and contaminant mobility would be greatly reduced.

- Implementability: Interference with below-grade debris makes implementation more difficult. Complete stabilization must be verified. Implementability is rated as difficult for pits with varying waste materials; however, for homogeneous pits, this is an easily implementable process option.

- Cost: Common construction machinery is required, such as backhoes, pumps, or front-end loaders. Minimal maintenance is required due to weathering influences. Overall, costs are considered moderate.

Shallow soil mixing is retained for alternative development as an in situ treatment process option.

Surcharging

Surcharging is the placement of an overburden in the form of a cap or berm on top of the waste. Over time, this loading drives out the water contained in the waste which consolidates as this occurs.

- Effectiveness: Surcharging is effective for compacting soils, particularly for large treatment areas such as those encountered in Operable Unit 1. Surcharging can provide consolidation of the waste pits, but the overall effectiveness is dependent on effective subsurface flow control.

- Implementability: Surcharging is very easily implemented, but treatment can take an excessive length of time (e.g., in excess of 1 year).

- Cost: Common construction equipment needed for surcharging make this process option very low cost. Minimal maintenance would be required. Overall costs are low.

Surcharging must be performed in conjunction with subsurface flow controls. Under such conditions, surcharging can effectively compact soils. This process option is carried forward to alternative development.

Dynamic Compaction

Dynamic compaction is a method of consolidating and compacting soils by lifting (e.g., with a crane) and releasing a weighted ram or other object allowing it to impact the soil. This is repeated as many times as necessary to achieve the desired compaction.

- Effectiveness: Dynamic compaction is an effective method of compaction. However, as with surcharging, the overall long-term effectiveness for protecting human health and the environment depends on effective subsurface flow control. The short-term impacts on human health and the environment are much greater for dynamic compaction then for surcharging, due to dust generation and resuspension of radioactive materials during implementation.

- Implementability: This process option is easily implemented using readily available construction equipment. The length of time for treatment is much shorter than that needed for surcharging.

- Cost: The cost for equipment needed to implement this process option is very low. O&M costs associated with dynamic compaction are for maintenance of equipment during implementation and considered low. Overall costs are low.

Dynamic compaction is not carried forward to alternative development because of uncertainties in the short-term effectiveness (i.e. dust generation) of this process option for protection of human health and the environment.

2.5.6.2 Waste Solidification Technology

Process options evaluated for ex situ waste stabilization technology include:

- Cement-based solidification
- Thermoplastic solidification
- Vitrification
- Lime/flyash solidification

Cement-Based Solidification

- Effectiveness: Treatability studies on Operable Unit 1 have demonstrated that cement-based solidification is moderately effective. The wastes are mechanically locked within a solidified matrix that significantly reduces the leachate generation. Safety concerns include organic vapors and dust generation. This process option is most suitable for immobilizing inorganic metals and is less effective for organics.

- Implementability: Cement-based solidification is easy to implement. Major advantages include the readily available equipment and materials. Disadvantages are the increased volume and weight for disposal once the waste is solidified.

- Cost: Capital cost for cement-based solidification is moderate. The O&M costs are low. Overall costs would be moderate.

Cement-based solidification is carried forward to alternative development.

Thermoplastic Solidification

- Effectiveness: This process option is useful in solidifying very soluble, toxic materials. In using this technology, compatibility of the waste and the matrix must be given major consideration. This process option is highly effective on a small scale but its effectiveness has not been tested on a large scale.

- Implementability: To implement this technology, treatability studies would be needed. Complex, specialized mixing equipment and a trained operations staff to ensure safe, consistent operations would be required for this process option. This process option is difficult to implement.

- Cost: The capital cost for this process option would be high for specialized equipment and materials. The O&M costs associated with this process would be low. Overall costs are considered high.

The difficult implementability, uncertain effectiveness, and high costs preclude this process option from being selected as a representative process option, in favor of cement solidification.

Vitrification

- Effectiveness: Vitrification is highly effective in stabilizing certain wastes. The vitrification process involves combining the waste with a molten glass at high temperatures. The resulting noncrystalline solid has an extremely low leach rate for most wastes. Considered an innovative technology, EPA determined that vitrification is the best demonstrated available technology (BDAT) for high-level radioactive waste. This process option is most suitable for immobilizing inorganic metals and radionuclides.

- Implementability: Vitrification is a relatively new technology without readily available equipment. The process also requires high energy demands and trained personnel who are not readily available. This process option is difficult to implement.

- Cost: Capital costs for vitrification would be high. The O&M costs would be high due to extremely large power requirements. Overall costs are considered high.

This process option is considered an innovative and effective method for immobilizing metals and radionuclides in a glass matrix. Vitrification is carried forward to alternative development.

Lime/Flyash Solidification

- Effectiveness: Although lime/flyash solidification is sometimes as effective as cement solidification, this technology is not effective on as wide a range of waste forms as cement solidification. Additionally, there is concern over the long-term stability of the final material and the potential for dust emissions.

- Implementability: Lime/flyash solidification is equivalent to cement-based solidification with respect to implementability. The equipment is conventional and readily available as with cement-based solidification. This process option is rated as easy to implement.

- Cost: Capital costs for lime/flyash solidification are essentially the same as those for cement-based solidification. The capital costs for this process option are moderate. O&M costs would be low for bulk quantities of lime and flyash and maintenance of the mechanical equipment. Overall costs are moderate.

This process option can be as effective as cement-based solidification; however, treatability studies conducted on samples of waste collected from within Operable Unit 1 demonstrated that cement-based solidification is only moderately effective in controlling leachability. This, coupled with the fact that cement-based solidification is considered more robust than lime/flyash-based solidification, precluded studies using flyash/lime-based formulations. For these reasons, lime/flyash solidification is not carried forward for alternative development.

2.5.6.3 Physical Treatment Technology

Solid/Liquid Separation

- Effectiveness: Solid/liquid separation options are effective, both for dewatering and for solids removal.

- Implementability: The equipment for solid/liquid separation is conventional and is manufactured and stocked by many companies. The personnel required to operate this equipment are readily available. This process option is considered readily implementable.

- Cost: Typical equipment used for solid/liquid separation include belt filter presses, centrifuges, filters, settling tanks or ponds, clarifiers, or hydrocyclones. This process option was rated moderate for capital costs. Operating costs for this process option include the energy for pumping slurries or liquids and replacement of any filtering media. Maintenance would include the typical requirements for a pump and piping system.

Overall, the O&M costs for the solid/liquid separation process option were rated as moderate. Overall costs are considered moderate.

Solid/liquid separation is carried forward for alternative development.

2.5.6.4 Thermal Treatment Technology

The only process option retained for evaluation as discussed in Section 2.4.6.5 for thermal treatment as defined in Appendix B is drying.

Drying

- Effectiveness: Rotary dryers can be used to effectively heat treat and dry material. Indirect rotary dryers are selected for use in the representative design used for costing purposes, as the most economical drying technology which will meet the requirements of the Clean Air Act. Combustion gases do not have to be mixed with the contaminated process off-gases and, therefore, will not have to be treated. This will minimize the size of the off-gas treatment system, minimize capital and operating costs, and minimize emissions to the atmosphere due to system inefficiency. Drying does not treat radionuclides and is therefore not an effective process option in the sense of reduction of toxicity, mobility or volume; however, it does provides suitable pretreatment for other treatment technologies where wet waste must be dried before treatment or disposal or to meet off-site disposal facility waste acceptance criteria.

- Implementability: Rotary dryers are readily available from a number of manufacturers so there would be no significant delay in constructing a system. Off-gas treatment would be required. Overall, this process option is rated as moderately implementable.

- Cost: The capital costs, including the cost of the rotary dryer, the required air quality equipment, and the material handling equipment are estimated to be moderate. The energy required to dry the Operable Unit 1 material would constitute the major operating cost. Maintenance costs would include maintenance on the dryer, the material handling equipment, and the emissions control system. Overall, costs are rated as moderate.

Drying is carried forward to alternative development as a treatment option for off-site disposal or as a pretreatment option for other technologies (e.g., vitrification).

2.5.7 Disposal General Response Action

The following disposal technologies have been evaluated:

- Waste transportation
- On-Property disposal
- Off-Site disposal

Table 2-19 summarizes the results of the disposal process options evaluation.

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2.5.7.1 Waste Transportation Technology

Waste transportation options retained for evaluation are rail transport and truck transport. The evaluation of these options is presented in the following sections.

Rail Transport

- Effectiveness: The rail transport process option is an effective option for off-site transportation. By transporting waste by rail, large tonnages of waste can be hauled at one time. On a per unit weight basis, there are less accidents by rail than by truck (see Appendix D). However, should a rail accident occur, there are much larger quantities of contaminants potentially exposed to the public.

- Implementability: Rail transport is readily implementable because rail transport at the FEMP site can be accommodated by the existing on-site rail spur. Some rail upgrades may be required. However, the rail transport process option is susceptible to route availability and coordination with state and local agencies along the route.

- Cost: The rail transport process option is of moderate capital cost because of the following requirements: upgrading of the on-site rail spur and the need to build or upgrade loading and unloading waste handling facilities. O&M costs are expected to be low because railway components have a relatively long life span and require little maintenance as compared to other transportation systems. Overall, costs are considered moderate.

Rail transportation is carried forward for the development of alternatives.

Truck Transport

- Effectiveness: Truck transport is effective for the off-site disposal option. Truck transportation would be required for on-property disposal.

- Implementability: Truck transport would be easily implemented at the site.

- Cost: The capital costs include the construction of access roads, trucking fees and waste handling. The overall capital costs would be high. Maintenance costs are considered low and include the maintenance of the access road and the loading terminal. Overall, costs are considered high.

Truck transportation is carried forward for the development of alternatives.

2.5.7.2 On-Property Disposal Technology

On-property disposal process options as defined in Appendix B that were retained for evaluation as discussed in Section 2.4.7.2 include:

- Engineered disposal cell
- Above-grade disposal vault

Engineered Disposal Cell

- Effectiveness: An engineered disposal cell with redundant engineering features would provide effective long-term containment of the wastes. State-of-the-art engineering practices would be incorporated to design for performance criteria in the 1,000-year time frame as required by 40 CFR 192.

- Implementability: This design employs standard construction materials and services that are readily available. This process option would be relatively easy to implement, requiring standard construction equipment.

- Cost: The detailed construction of the liner and cover would contribute to the high capital cost of the cap. The O&M costs are expected to be low, primarily associated with mowing, cap inspection, and groundwater monitoring. Overall costs are considered high.

The engineered disposal cell is carried forward for alternative development.

Above-Grade Concrete Vault

- Effectiveness: The disposal vault provides effective isolation of waste from potential receptors. State-of-the-art engineering practices would be incorporated to design for performance criteria for the 1,000-year time frame as required by 40 CFR 192.

- Implementability: The vault is constructed directly on grade with a liner system and leachate collection system and requires a cap that can be placed over the closed structure. This design employs standard construction materials and services that are readily available.

- Cost: Capital costs for construction of the disposal vault would be very high. O&M costs would be low. Overall, costs are considered very high.

The cost of the above-grade disposal vault would be significantly higher than the engineered disposal cell due to higher construction costs involving the extensive amount of concrete. However, this process option is acceptable for disposal of Operable Unit 1 material and is carried forward for alternative development.

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2.5.7.3 Off-Site Disposal Technology

Process options being evaluated for off-site disposal technology include:

- Nevada Test Site
- Permitted commercial disposal site

Nevada Test Site

- Effectiveness: A long operating disposal facility, NTS was rated as effective for disposal of solid Operable Unit 1 media. The site is located in an arid western location isolated from the aquifer and nearby population.

- Implementability: Appendix J discusses waste acceptance criteria and the ability to meet them. NTS is more than 3219 kilometers (2000 miles) from the FEMP site, making this option moderately difficult to implement from a logistical/material control and scheduling standpoint. Administratively this process option would be relatively easy to implement because the FEMP site has an approved NTS waste shipment and certification program already in place and has shipped similar waste to NTS.

- Cost: The high capital costs include the disposal fee and packaging costs. There would be no O&M costs after completion of remediation with this process option. Overall costs are considered very high.

The NTS process option is carried forward for alternative development.

Permitted Commercial Disposal Site

- Effectiveness: An operating permitted commercial disposal site would be effective for isolation of the waste materials from potential receptors. The representative site near Clive, Utah, is located in an arid western location isolated from the aquifer and nearby population.

- Implementability: Similar to the NTS process option, the representative permitted commercial disposal site is a relatively long distance from the FEMP site. Low specific activity waste designated for this site does not require containerization and can be shipped in bulk in railcars. To ship waste to this facility, a new waste certification program would need to be developed and implemented to assure compliance with the disposal facility's waste acceptance criteria. This is discussed in Appendix J. This would be moderately difficult to implement.

- Cost: The capital cost of implementation for transport and disposal would be high due to the large volume of waste involved, but possibly lower than for NTS because containerization of waste is not required. There would be no O&M costs after completion of remediation for this process option. Overall costs are rated high.

The permitted commercial disposal site option is carried forward to alternative development.

TABLE 2-1

OPERABLE UNIT 1
MATERIAL VOLUME ESTIMATES
FOR REMEDIATION

Waste Pit Contents and Associated Material[a]	Volume[b]
Waste Pit 1	68,400 yd^3
Waste Pit 2	37,400 yd^3
Waste Pit 3	307,500 yd^3
Waste Pit 4	72,800 yd^3
Waste Pit 5	97,900 yd^3
Waste Pit 6	9,600 yd^3
Burn Pit	30,300 yd^3
Clearwell	4,300 yd^3
Total	628,200 yd^3

Soils	Volume[c]
Waste Pit 1	10,400 yd^3
Waste Pit 2	5,200 yd^3
Waste Pit 3	27,400 yd^3
Waste Pit 4	9,500 yd^3
Waste Pit 5	18,100 yd^3
Waste Pit 6	3,600 yd^3
Burn Pit	4,400 yd^3
Clearwell	3,200 yd^3
Surface	16,200 yd^3
Total	98,000 yd^3

TABLE 2-1
(Continued)

Miscellaneous Structures	Volume[d]
Underground Pipes	19 yd^3
Telephone Poles (wood)	13 yd^3
Railroad Tracks	
Metal	5 yd^3
Wood	107 yd^3
Clearwell House	
Concrete	10 yd^3
Transite	15 yd^3
Waste Pit 6 Slab	90 yd^3
Waste Pit 5 Platform	< 1 yd^3
Walkway	< 1 yd^3
Step (Concrete, Metal)	4 yd^3
Clearwell Walkway	1 yd^3
Slab	1 yd^3
Fence	40 yd^3
	Total 307 yd^3

	Linear Feet
Clearwell Walkway Railings	369 ft
Waste Pit 5 Railings	441 ft
	Total 810 ft

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a Includes pit waste material, liner, and cap or cover material.
b Source: February 1994 Final RI Report for Operable Unit 1 (DOE 1994)
c Soil volumes represent 3 feet of soil beneath each pit. Surface soil volume represents 6 inches removed from the entire operable unit area, excluding the pit surface areas.
d Miscellaneous structures volumes were estimated in the Operational Scenarios

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TABLE 2-2

OPERABLE UNIT 1
CONSTITUENTS OF CONCERN

	Sediment	Air	Surface Soil	Groundwater	Perched Water	Surface Water
RADIOLOGICAL COCs						
Cesium-137	X	X	X			X
Lead-210 + 2 progeny		X				
Neptunium-237		X	X		X	
Plutonium-238		X	X	X	X	
Plutonium-239/240	X	X	X			
Radium-226 + 5 progeny		X				
Radium-228 + 1 progeny			X	X	X	
Radon-228 + 4 progeny		X				
Strontium-90 + 1 progeny		X	X		X	X
Technetium-99		X	X	X	X	X
Thorium-228	X	X	X	X	X	
Thorium-230		X	X	X	X	
Thorium-232	X	X	X		X	
Uranium-234		X	X	X	X	X
Uranium-235	X	X	X	X	X	X
Uranium-238	X	X	X	X	X	X
INORGANICS						
Antimony			X			
Arsenic	X	X	X			X
Barium		X				
Beryllium	X	X	X			
Boron				X	X	
Cadmium		X	X			
Chromium		X	X		X	
Cobalt		X				
Copper					X	
Cyanide				X	X	
Manganese		X	X	X	X	
Molybdenum		X	X		X	

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TABLE 2-2
(Continued)

	Sediment	Air	Surface Soil	Groundwater	Perched Water	Surface Water
Mercury		X	X			
Nickel		X	X		X	
Silver		X	X		X	X
Thallium	X	X	X			
Thorium		X	X	X	X	
Uranium		X	X	X	X	X
Vanadium		X	X			
Zinc		X	X		X	X
PCBs						
Aroclor 1248		X	X			
Aroclor 1254		X	X			
Aroclor 1260		X	X			
PAHs						
Benzo(a)anthracene		X	X			
Benzo(a)pyrene		X	X			
Benzo(b)fluoranthene		X	X			
Chrysene		X	X			
Indeno(1,2,3-cd)pyrene		X	X			
VOCs and SVOCs						
Tetrachloroethene						X
Pentachlorophenol			X			
Vinyl Chloride				X	X	
Polychlorinated Dibenzodioxins						
2378 Tetra CDD			X	X		
Hepta CDD			X	X		
Hexa CDD			X	X		
Octa CDD			X	X		
Polychlorinated Dibenzofurans						
Hepta CDF			X	X		
Hexa CDF			X	X		

OURCE: U.S. Department of Energy (DOE), 1994, "Draft Final Remedial Investigation Report for Operable Unit 1," DOE, Fernald Field Office, Fernald, OH.

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TABLE 2-3

OPERABLE UNIT 1
DEVELOPMENT OF PRELIMINARY REMEDIATION GOALS

Medium	Source of Preliminary Remediation Goals	Comments
Waste Pit Contents and Associated Materials	This material is heavily contaminated and is to be removed for treatment and disposal. Residual material remaining after removal (e.g., underlying soils) will be addressed under soil PRGs.	Exposure mitigation measures (e.g., containment, treatment, removal and disposal) will be considered as part of this FS.
Surface and Subsurface Soil	Regulatory-based chemical and radiological cleanup criteria are not available for most constituents of concern in soil. FEMP site soil cleanup criteria will be developed as part of Operable Unit 5, which includes remediation of site-wide soils. Soil PRGs developed as part of this FS will be subject to modification on the basis of additional information developed through Operable Unit 5.	Contaminated soils above action levels will be remediated.
Residual Water	Regulatory-based cleanup criteria are not available for all constituents of concern existing in residual liquids or that may be transported from Operable Unit 1 sources. Residual liquids will be directed through the FEMP Advanced Waste Water Treatment System. Discharges will be consistent with existing NPDES permit requirements and commitments defined under the South Groundwater Contamination Plume Removal Action. PRGs were therefore not derived for residual water within Operable Unit 1.	No comments.
Groundwater	Regulatory-based chemical and radiological cleanup criteria are not available for all contaminants of concern in groundwater. Final FEMP site groundwater cleanup criteria will be developed as part of Operable Unit 5, which includes remediation of site-wide groundwater. The chemical and radiological PRGs in this FS represent the concentration of a particular constituent of concern in groundwater presenting a specific ILCR or HI. These concentrations could occur in groundwater as a result of migration from residuals within Operable Unit 1 or stabilized source materials. These PRGs are established to provide a relative performance measure for groundwater protection that a given alternative must attain to be protective of human health and the environment.	Decisions regarding remediation of groundwater will be addressed by DOE as a part of FEMP site Operable Unit 5. Separation of final groundwater cleanup decisions from those considered under Operable Unit 1 allow further characterization of groundwater and consideration of remedial action for site groundwater as a whole.
Miscellaneous Structures[a]	The materials will be forwarded to Operable Unit 3 and managed according to the criteria established for process area demolition debris and rubble.	Contaminated miscellaneous structures above action levels will be remediated with Operable Unit 3 contaminated debris.

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[a] Miscellaneous Structures includes underground pipes, telephone poles, railroad tracks, Clearwell house, Waste Pit 6 slab, Waste Pit 5 platform, Clearwell walkway, and fence.

TABLE 2-4

OPERABLE UNIT 1
RISK ASSESSMENT LAND USE SCENARIOS

Report	Land Use Description	Ownership	Access	Use	RECEPTORS					
					Grounds-Keeper	Trespassing Child	Expanded Trespasser	Off-Property Farm	On-Property Farm	River User
RI	Current land use with access controls	Federal	Limited	Industrial		X		X		X
	Current land use without access controls	Private	Unlimited	Industrial	X	X	X	X		X
	Future land use	Private	Unlimited	Farm				X	X	X
FS	Future land use with federal ownership	Federal	Unlimited	Government reserve			X	X		
	Future land use without federal ownership	Private	Unlimited	Farm				X	X	

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TABLE 2-5

ON-PROPERTY RESIDENT ADULT FARMER PRELIMINARY REMEDIATION GOALS - SOILS FUTURE LAND USE

	Incremental Above Background Concentrations				ARAR/ TBC	Background 95th Percentile
	HI=1 RfD based PRG	10^{-4} risk based PRG	10^{-5} risk based PRG	10^{-6} risk based PRG		
Radionuclides (pCi/g)						
Cs-137 + 1 progeny	NA	1.0	0.10	0.010		0.711
Np-237 + 1 progeny	NA	4.5	0.45	0.045		ND
Pu-238	NA	80	8.0	0.80		ND
Pu-239/240	NA	78	7.8	0.78		ND
Ra-228 + 1 progeny	NA	0.82	0.082	0.0082		1.19
Sr-90 + 1 progeny	NA	1.6	0.16	0.016		ND
Tc-99	NA	1.7	0.17	0.017		ND
Th-228 + 7 progeny	NA	0.43	0.043	0.0043		1.43
Th-230	NA	410	41	4.1		1.97
Th-232	NA	430	43	4.3		1.36
U-234[a]	NA	260	26	2.6		1.24
U-235[a]	NA	10	1.0	0.10		0.148
U-238[a] + 2 progeny	NA	45	4.5	0.45		1.22
Inorganics (mg/kg)						
Antimony	9.0	N/A	N/A	N/A		7.70
Arsenic	24	4.5	0.45	0.045		8.45
Beryllium	60	0.28	0.028	0.0028		0.60
Cadmium	3.9	4,600	460	46		0.82
Chromium (VI)	280	690	69	6.9		15.5
Manganese	1,500	N/A	N/A	N/A		1,770
Mercury	0.025	N/A	N/A	N/A		0.30

TABLE 2-5
(Continued)

	Incremental Above Background Concentrations				ARAR/ TBC	Background 95th Percentile
	HI = 1 RfD based PRG	10^{-4} risk based PRG	10^{-5} risk based PRG	10^{-6} risk based PRG		
Molybdenum	24	N/A	N/A	N/A		2.6
Nickel	240	> 10,000	3,400	340		20.9
Silver	2.7	N/A	N/A	N/A		2.6
Thallium	1.8	N/A	N/A	N/A		0.58
Thorium[b]						ND
Uranium	130	N/A	N/A	N/A		ND
Vanadium	840	N/A	N/A	N/A		30.4
Zinc	26	N/A	N/A	N/A		62.2
Dioxins/Furans (mg/kg)						
2,3,7,8-TetraCDD	NA	1.8E-06	1.8E-07	1.8E-08		ND
HeptaCDD	NA	1.8E-04	1.8E-05	1.8E-06		ND
HeptaCDF	NA	0.0011	1.1E-04	1.1E-05		ND
HexaCDD	NA	1.8E-05	1.8E-06	1.8E-07		ND
HexaCDF	NA	1.1E-04	1.1E-05	1.1E-06		ND
OctaCDD	NA	0.0018	1.8E-04	1.8E-05		ND
PAHs (mg/kg)						
Benzo(a)anthracene	NA	1.7	0.17	0.017		ND
Benzo(a)pyrene	NA	0.18	0.018	0.0018		ND
Benzo(b)fluoranthene	NA	0.61	0.061	0.0061		ND
Benzo(k)fluoranthene	NA	0.89	0.089	0.0089		ND
Chrysene	NA	55	5.5	0.55		ND
Indeno(1,2,3-cd)pyrene	NA	0.032	0.0032	0.00032		ND
PCBs (mg/kg)						
Arochlor-1248	NA	0.14	0.014	0.0014		ND
Arochlor-1254	NA	0.11	0.011	0.0011		ND

TABLE 2-5
(Continued)

	Incremental Above Background Concentrations				ARAR/ TBC	Background 95th Percentile
	HI = 1 RfD based PRG	10^{-4} risk based PRG	10^{-5} risk based PRG	10^{-6} risk based PRG		
Arochlor-1260	NA	0.10	0.010	0.0010		ND
SVOCs (mg/kg)						
Pentachlorophenol	370	10	1.0	0.10		ND

[a] The methodology used to calculate PRGs results in different values for different isotopes of a given radionuclide. In most cases, this is due to differences in external dose rate factors among isotopes. The lowest value calculated for a given radionuclide will determine the choice of the PRG.

[b] No toxicity data available to develop a PRG.

NA - Not available - There is no reference dose data developed for these compounds.
N/A - Not applicable - These compounds are not carcinogens and therefore, a carcinogenic risk PRG was not developed for them.

TABLE 2-6

EXPANDED TRESPASSER
PRELIMINARY REMEDIATION GOALS - SOILS
FUTURE LAND USE

	Incremental Above Background Concentrations				ARAR/ TBC	Background 95th Percentile
	HI=1 RfD based PRG	10^{-4} risk based PRG	10^{-5} risk based PRG	10^{-6} risk based PRG		
Radionuclides (pCi/g)						
Cs-137 + 1 progeny	NA	110	11	1.1		0.711
Np-237 + 1 progeny	NA	500	50	5.0		ND
Pu-238	NA	>10,000	1,200	120		ND
Pu-239/240	NA	>10,000	1,200	120		ND
Ra-228 + 1 progeny	NA	77	7.7	0.77		1.19
Sr-90 + 1 progeny	NA	>10,000	8,500	850		ND
Tc-99	NA	>10,000	>10,000	>10,000		ND
Th-228 + 7 progeny	NA	40	4.0	0.40		1.43
Th-230	NA	>10,000	9,000	900		1.97
Th-232	NA	>10,000	9,600	960		1.36
U-234[a,c]	NA	>10,000	8,900	890		1.24
U-235[a]	NA	920	92	9.2		0.148
U-238[a,c] + 2 progeny	NA	5,500	550	55		1.22
Inorganics (mg/kg)						
Antimony	150	N/A	N/A	N/A		7.70
Arsenic	2,000	1,700	170	17		8.45
Beryllium	130	2.5	0.25	0.025		0.60
Cadmium	130	>10,000	>10,000	9,000		0.82
Chromium (VI)	5,200	>10,000	>10,000	1,300		15.5
Manganese	>10,000	N/A	N/A	N/A		1,770
Mercury	23	N/A	N/A	N/A		0.30

TABLE 2-6
(Continued)

	Incremental Above Background Concentrations				ARAR/ TBC	Background 95th Percentile
	HI=1 RfD based PRG	10^{-4} risk based PRG	10^{-5} risk based PRG	10^{-6} risk based PRG		
Molybdenum	4,500	N/A	N/A	N/A		2.6
Nickel	>10,000	>10,000	>10,000	>10,000		20.9
Silver	640	N/A	N/A	N/A		2.6
Thallium	140	N/A	N/A	N/A		0.58
Thorium[b]						ND
Uranium	380	N/A	N/A	N/A		ND
Vanadium	8,000	N/A	N/A	N/A		30.4
Zinc	>10,000	N/A	N/A	N/A		62.2
Dioxins/Furans (mg/kg)						
2,3,7,8-TetraCDD	NA	0.0012	0.00012	1.2E-05		ND
HeptaCDD	NA	0.12	0.012	0.0012		ND
HeptaCDF	NA	0.12	0.012	0.0012		ND
HexaCDD	NA	0.012	0.0012	0.00012		ND
HexaCDF	NA	0.012	0.0012	0.00012		ND
OctaCDD	NA	1.2	0.12	0.012		ND
PAHs (mg/kg)						
Benzo(a)anthracene	NA	3,900	390	39		ND
Benzo(a)pyrene	NA	570	57	5.7		ND
Benzo(b)fluoranthene	NA	4,700	470	47		ND
Benzo(k)fluoranthene	NA	>10,000	1,100	110		ND
Chrysene	NA	>10,000	>10,000	1,300		ND
Indeno(1,2,3-cd)pyrene	NA	2,100	210	21		ND
PCBs (mg/kg)						
Arochlor-1248	NA	3.5	0.35	0.035		ND
Arochlor-1254	NA	3.5	0.35	0.035		ND

TABLE 2-6
(Continued)

	Incremental Above Background Concentrations				ARAR/ TBC	Background 95th Percentile
	HI = 1 RfD based PRG	10^{-4} risk based PRG	10^{-5} risk based PRG	10^{-6} risk based PRG		
Arochlor-1260	NA	3.5	0.35	0.035		ND
SVOCs (mg/kg)						
Pentachlorophenol	2,300	270	27	2.7		ND

[a] The methodology used to calculate PRGs results in different values for different isotopes of a given radionuclide. In most cases, this is due to differences in external dose rate factors among isotopes. The lowest value calculated for a given radionuclide will determine the choice of the PRG.
[b] No toxicity data available to develop a PRG.
[c] The large difference between U-238 and U-234 PRGs is due to the direct radiation pathway impact which was controlling for these PRGs. These are risk based numbers which are not reflective of natural ratios.

NA - Not available - There is no reference dose data developed for these compounds.
N/A - Not applicable - These compounds are not carcinogens and therefore, a carcinagenic risk PRG was not developed for them.

TABLE 2-7

OFF-PROPERTY RESIDENT ADULT FARMER PRELIMINARY REMEDIATION GOALS - SOILS FUTURE LAND USE

	Incremental Above Background Concentrations				ARAR/ TBC	Background 95th Percentile
	HI=1 RfD based PRG	10^{-4} risk based PRG	10^{-5} risk based PRG	10^{-6} risk based PRG		
Radionuclides (pCi/g)						
Cs-137 + 1 progeny	NA	>10,000	>10,000	6,600		0.711
Np-237 + 1 progeny	NA	>10,000	4,900	490		ND
Pu-238	NA	>10,000	3,800	380		ND
Pu-239/240	NA	>10,000	3,800	380		ND
Ra-228 + 1 progeny	NA	>10,000	>10,000	7510		1.19
Sr-90 + 1 progeny	NA	>10,000	>10,000	>10,000		ND
Tc-99	NA	>10,000	>10,000	>10,000		ND
Th-228 + 7 progeny	NA	>10,000	1,900	190		1.43
Th-230	NA	>10,000	5,400	540		1.97
Th-232	NA	>10,000	5,600	560		1.36
U-234[a]	NA	>10,000	6,000	600		1.24
U-235[a]	NA	>10,000	6,200	600		0.148
U-238[a] + 2 progeny	NA	>10,000	3,000	300		1.22
Inorganics (mg/kg)						
Antimony	>10,000	N/A	N/A	N/A		7.70
Arsenic	>10,000	>10,000	5,800	580		8.45
Beryllium	>10,000	>10,000	3,300	330		0.60
Cadmium	>10,000	>10,000	>10,000	4600		0.82
Chromium (VI)	>10,000	>10,000	6,900	690		15.5
Manganese	>10,000	N/A	N/A	N/A		1,770
Mercury	>10,000	N/A	N/A	N/A		0.30

TABLE 2-7
(Continued)

	Incremental Above Background Concentrations				ARAR/ TBC	Background 95th Percentile
	HI = 1 RfD based PRG	10^{-4} risk based PRG	10^{-5} risk based PRG	10^{-6} risk based PRG		
Molybdenum	> 10,000	N/A	N/A	N/A		2.6
Nickel	> 10,000	> 10,000	> 10,000	> 10,000		20.9
Silver	> 10,000	N/A	N/A	N/A		2.6
Thallium	> 10,000	N/A	N/A	N/A		0.58
Thorium[b]						ND
Uranium	> 10,000	N/A	N/A	N/A		ND
Vanadium	> 10,000	N/A	N/A	N/A		30.4
Zinc	> 10,000	N/A	N/A	N/A		62.2
Dioxins/Furans (mg/kg)						
2,3,7,8-TetraCDD	NA	0.061	0.0061	0.00061		ND
HeptaCDD	NA	6.1	0.6	0.061		ND
HeptaCDF	NA	6.1	0.61	0.06		ND
HexaCDD	NA	0.61	0.061	0.0061		ND
HexaCDF	NA	0.61	0.061	0.0061		ND
OctaCDD	NA	6.1	6.1	0.6		ND
PAHs (mg/kg)						
Benzo(a)anthracene	NA	> 10,000	8,800	880		ND
Benzo(a)pyrene	NA	7,200	720	72		ND
Benzo(b)fluoranthene	NA	> 10,000	1,800	180		ND
Benzo(k)fluoranthene	NA	> 10,000	2,300	230		ND
Chrysene	NA	> 10,000	> 10,000	> 10,000		ND
Indeno(1,2,3-cd)pyrene	NA					ND
PCBs (mg/kg)						
Arochlor-1248	NA	1,500	150	15		ND
Arochlor-1254	NA	1,000	100	10		ND

TABLE 2-7
(Continued)

	Incremental Above Background Concentrations				ARAR/ TBC	Background 95th Percentile
	HI = 1 RfD based PRG	10^{-4} risk based PRG	10^{-5} risk based PRG	10^{-6} risk based PRG		
Arochlor-1260	NA	900	90	9		ND
SVOCs (mg/kg)						
Pentachlorophenol	> 10,000	> 10,000	> 10,000	> 10,000		ND

[a] The methodology used to calculate PRGs results in different values for different isotopes of a given radionuclide. In most cases, this is due to differences in external dose rate factors among isotopes. The lowest value calculated for a given radionuclide will determine the choice of the PRG.
[b] No toxicity data available to develop a PRG.

NA - Not available - There is no reference dose data developed for these compounds.
N/A - Not applicable - These compounds are not carcinogens and therefore, a carcinogenic risk PRG was not developed for them.

TABLE 2-8

PRELIMINARY REMEDIATION GOALS - GROUNDWATER

Chemical	Risk-Based PRGs, Above Background				ARAR/TBC-Based PRGs		
	HI=1.0 RfD-Based PRG[a]	10^{-4} Risk-Based PRG[b]	10^{-5} Risk-Based PRG[b]	10^{-6} Risk-Based PRG[b]	Federal Standards		State Standards
					Source[c]	Concentration[d]	Groundwater[e]
Radionuclides (pCi/L)							
Ra-226 + 5 progeny		2	2	2	PMCL[f]	20	5
Ra-228 + 1 progeny		5	5	5	PMCL[f]	20	5
Rn-222					PMCL[f]	300	
Sr-90		3	3	3	4 mrem dose	8	
Tc-99		770	77	7.7			
Th-228 + 7 progeny		2.9	29	29	4 mrem dose	14	
U-238 + 2 progeny		55	55	0.55			
Inorganics (mg/L)							
Antimony	0.008				MCLG[g]	0.006	
Arsenic	0.0077	$2x10^{-3}$	$2x10^{-4}$	$2x10^{-5}$	MCL	0.05	0.05
Barium	1.1				MCLG	2.0	1.0
Cadmium	0.0052				MCLG	0.005	0.001
Chromium VI	0.10				MCLG	0.1	0.05
Copper	0.33				MCL[j]	1.3	1.0
Molybdenum	0.084						
Nickel	0.19				MCLG	0.1	
Silver	0.014				MCL	0.05	0.05
Thallium	0.0012				MCLG	0.0005	

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TABLE 2-8
(Continued)

Chemical	Risk-Based PRGs, Above Background				ARAR/TBC-Based PRGs		
					Federal Standards		State Standards
	HI=1.0 RfD-Based PRG[a]	10^{-4} Risk-Based PRG[b]	10^{-5} Risk-Based PRG[b]	10^{-6} Risk-Based PRG[b]	Source[c]	Concentration[d]	Groundwater[e]
Uranium	0.079				PMCL	0.02	
Vanadium	0.17						
Zinc	0.0046						
Organics (mg/L)							
Benzo(a)anthracene		2.2×10^{-3}	2.2×10^{-4}	2.2×10^{-5}			
Benzo(a)pyrene		2.6×10^{-4}	2.6×10^{-5}	2.6×10^{-6}	MCL	0.0002	
Benzo(b)fluoranthene		1.1×10^{-3}	1.1×10^{-4}	1.1×10^{-5}			
Benzo(g,h,i)perylene							
Chrysene		7.1×10^{-2}	7.1×10^{-3}	7.1×10^{-4}			
Dibenzo(a,h)anthracene					PMCL		
Indeno(1,2,3-cd)pyrene		6.0×10^{-5}	6.0×10^{-6}	6.0×10^{-7}			
Vinyl chloride		4.2×10^{-3}	4.2×10^{-4}	4.2×10^{-5}	PMCL	0.005	

[a] PRG developed using equation and parameters for drinking water ingestion and chemical-specific RfDs from Health Effect Assessment Summary Tables (HEAST) (EPA 1992b) and the Integrated Risk Information System (IRIS) (EPA 1992a).
[b] PRG developed using equations and parameters for drinking water ingestion and chemical-specific SFs from HEAST and IRIS values represent cleanup goal above background since 10^{6} represents an incremental lifetime cancer risk goal.
[c] ARAR-based PRGs are developed from several sources. The primary source is promulgated or proposed Maximum Contaminant Levels (MCLs) developed under the Safe Drinking Water Act, 40 CFR 141, 142. If no MCL exists that strictly applies to the individual radionuclide, a PRG is developed using the 4 mrem dose limit that strictly applies to man-made beta and gamma emitters.
[d] Concentration in pCi/L for radionuclides and mg/L for chemicals corresponding to MCL or proposed MCL (PMCL) values.
[e] Based on OAC 3745-81-16; for many radionuclides, values are based on an average dose of beta particle and photon (e.g., gamma) of 4 mrem/yr.
[f] PRG based on interpretation to 4 mrem/yr dose limit for beta and gamma emitters may be applicable to alpha emitters. PRG developed using Committed Effective Dose Equivalents (CEDE) to 4 mrem/yr of intake at a rate of 730 L/yr, using Dose Conversion Factors (DCFs) from EPA (1988b).
[g] Proposed MCLs from "Federal Register," Vol. 55, No. 138, p. 33050.
[h] PRG developed using the strictly applicable MCL of 4 mrem/yr for man-made beta and gamma emitters (40 CFR 141, 142). Value developed using a CEDE or critical organ dose equivalent (if available or if more conservative) to 4 mrem/yr intake at a rate of 730 L/yr, using DCFs from EPA (1988b).
[i] No toxicity data available to develop a PRG.
[j] Tetrachloroethene also commonly referred to as Tetrachloroethylene.

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TABLE 2-9

SUMMARY OF MCLs, MCLGs, AND SECONDARY MCLs

Constituents	40 CFR 141.62 SDWA MCL (mg/L)	OAC 3745-81-11 MCL (mg/L)	40 CFR 257.3-4 and 264.94 Subparts C and D OAC-3745-27-10 MCL (mg/L)	40 CFR 141.50 and 141.51 SDWA-NPDWS MCLG (mg/L)	40 CFR 143 OAC 3745-82-02 SMCL(mg/L)
Antimony	0.006			0.006	
Arsenic	0.05[a]	0.05	0.05		
Barium	2.0	2.0	1.0	2.0	
Beryllium	0.004			0.004	
Cadmium	0.005	0.01	0.01	0.005	
Chloride					250
Chromium	0.1	0.1	0.05	0.1	
Copper				1.3[b]	1.0
Cyanide	0.2			0.2	
Fluoride	4.0	4.0	4.0	4.0	2.0
Iron					0.3
Lead	0.015[b]	0.05	0.05	0.0	
Manganese					0.05
Mercury	0.002	0.002	0.002	0.002	
Nickel	0.1			0.1	
Nitrate	10.0	10.0	10.0	10.0	
Radium-226/228	20 pCi/L[c]	5 pCi/L[d]			
Radon-222	300 pCi/L[c]				
Selenium	0.05	0.05	0.01	0.05	
Silver		0.05	0.05		0.1
Strantium-90	8pCi/L	8pCi/L			

TABLE 2-9
(Continued)

Constituents	40 CFR 141.62 SDWA MCL (mg/L)	OAC 3745-81-11 MCL (mg/L)	40 CFR 257.3-4 and 264.94 Subparts C and D OAC-3745-27-10 MCL (mg/L)	40 CFR 141.50 and 141.51 SDWA-NPDWS MCLG (mg/L)	40 CFR 143 OAC 3745-82-02 SMCL(mg/L)
Thallium	0.002			0.0005	
Uranium	0.02[c]				
Zinc					5.0
2,4-D	0.07	0.1	0.1	0.07	
2,4,5 - TP Silvex	0.05	0.01	0.01	0.05	
Benzo(a)pyrene	0.0002			0	
Bis(2-ethylhexyl)phthalate	0.0006			0	
Carbon tetrachloride	0.005	0.005	0.005	0	
Endrin	0.002	0.0002	0.0002	0.002	
Heptachlor epoxide	0.0002			0	
Lindane	0.0002	0.004	0.004	0.0002	
Methoxychlor	0.04	0.1	0.1	0.04	
Methylene Chloride	0.005			0	
Polychlorinated biphenyls	0.0005				
Tetrachloroethene	0.003			0	
Toluene	1.0			1.0	
Toxaphene	0.003	0.005	0.005	0	
Trihalomethanes	0.10[e]	0.10			
Xylenes	10.0			10.0	

[a] The MCL for arsenic, contained in 40 CFR 141.11, is the only inorganic MCL not superseded by 40 CFR 141.62.
[b] The MCL for lead and MCLG for copper are action levels found in 40 CFR 141.80(c).
[c] Proposed MCL.
[d] The state MCL for radium-226/228 is found in OAC 3745-81-15.
[e] The MCL for total trihalomethanes, contained in 40 CFR 141.12, is the only organic MCL not superseded by 40 CFR 141.61.

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TABLE 2-10
SUBSURFACE SOIL PIT PRGS
PROTECTIVE OF OFF-PROPERTY FARMER
MINIMUM EXCAVATION WITH CAP[a]

Radionuclides (pCi/g)	Waste Pit 1	Waste Pit 2	Waste Pit 3	Waste Pit 4	Waste Pit 5	Waste Pit 6	Clearwell	Burn
Np-237			1.11E+01		2.39E+01	2.03E+02		
Pu-238			1.40E+02		2.04E+02	3.56E+02		
Sr-90	>1.00E+04	>1.00E+04	>1.00E+04	>1.00E+04	>1.00E+04	>1.00E+04	>1.00E+04	>1.00E+04
Tc-99	2.55E+00	5.45E+00	7.45E-01	2.59E-01	1.43E+00	7.30E+00	9.93E+00	1.36E+01
U-234	>1.00E+04	>1.00E+04	4.06E+03	>1.00E+04	8.21E+03	>1.00E+04	>1.00E+04	>1.00E+04
U-235	>1.00E+04	>1.00E+04	3.76E+03	>1.00E+04	8.21E+03	>1.00E+04	>1.00E+04	>1.00E+04
U-238	>1.00E+04	>1.00E+04	2.15E+03	>1.00E+04	4.69E+03	>1.00E+04	>1.00E+04	>1.00E+04
Ra-226	>1.00E+04	>1.00E+04	1.00E+04	>1.00E+04	>1.00E+04	>1.00E+04	>1.00E+04	>1.00E+04
Chemicals (mg/kg)								
Antimony			>1.00E+04					
Boron	8.16E+03	1.92E+03	1.52E+03	7.05E+03				>1.00E+04
Cadmium			>1.00E+04					
Copper			>1.00E+04					
Cyanide			6.44E-01					
Lead			>1.00E+04					
Mercury					9.65E+00			
Arochlor	7.84E-01							
Vinyl Chloride		2.71E+01		9.80E-02				7.28E-01

[a] Based on groundwater modeling.

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TABLE 2-11

WASTE DISPOSAL CELL LEACHATE PRGS

COC	Waste Leachate PRG	Waste Leachate Concentration	
		Vitrification Stabilization	Cementation Stabilization
Radionuclides (pCi/L)			
Sr-90	>1.0E+04	8.3E+00	1.9E+01
Tc-99	1.9E+03	2.3E+01	6.2E+01
Ra-226	>1.0E+04	3.5E+01	4.2E+02
Th-230	>1.0E+04	8.1E+01	4.0E+01
U-234	>1.04+04	2.5E+02	5.9E+00
U-235	>1.0E+04	2.5E+01	4.0E+00
U-238	>1.0E+04	4.0E+02	1.5E+01
Np-237	>1.0E+04	6.8E+00	6.0E-01
Pu-238	>1.0E+04	9.1E-01	4.7E-01
Metals (mg/L)			
Arsenic	1.2E+03	9.2E-02	1.6E-02
Barium	>1.0E+04	1.7E+00	5.6E+00
Boron	8.1E+03	4.2E-01	5.6E-01
Cyanide			1.0E-02
Lead	>1.0E+04	1.9E-02	1.4E-02
Manganese	>1.0E+04	1.6E+00	1.5E-02
Molybdenum	>1.0E+04	4.5E-01	1.2E+00

TABLE 2-12

COMPARISON OF PRGS BASED ON A 10^{-6} RISK

	Evaluation of Receptor		Aroclor 1254 (mg/kg)	Cs-137 + 1 progeny (pCi/g)	U-238 + 2 progeny (pCi/g)
	Baseline Risk Assessment	FS Risk Assessment			
Miami River Water User	Yes	No	N/A	N/A	N/A
Off-property Farmer	Yes	Yes	10.2	6600	330
Trespassing Child	Yes	Yes			860
Groundskeeper	Yes	No	N/D	N/D	N/D
Expanded Trespasser	Yes	Yes	0.035	0.40	55
CT On-property Farmer	Yes	No	N/D	N/D	N/D
On-property Farmer	Yes	Yes	0.0011	0.010	0.45
Background*			ND	0.7	1.2
Surface Soil*			NA	6.0	1500
Subsurface Soil*			1.4	<0.2	104

N/A Not Applicable - Baseline risk less than 10^{-6}
NA Not Analyzed
N/D Not Determined - Vertical postion indicates relative risk levels
ND Not Detected
* UCL value from the OU1 RI

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TABLE 2-13

PROPOSED REMEDIATION LEVELS IN SOILS

Constituent of Concern	Expanded Trespasser HI = 1 PRG	Expanded Trespasser 10^{-6} ILCR PRG	Background (95th percentile)	ARAR Target	Max. Detected Soil Concentration		Proposed Remediation Levels[a]	HI to Receptors from Proposed Remediation Levels		Risk to Receptors from Proposed Remediation Level	
					Surface	Sub surface		Expanded Trespasser	On-Property Farmer	Expanded Trespasser[b]	On-Property Farmer[c]
Radionuclides (pCi/g)											
Cs-137 + 1 progeny	N/A	1.1	0.71	None	6	<0.2	**1.8**	N/A	N/A	1.6×10^{-6}	2.8×10^{-4}
Np-237 + 1 progeny	N/A	5.0	ND	None	0.5	<0.1	**NR**	N/A	N/A	$<1\times10^{-6}$	1.1×10^{-5}
Pu-238	N/A	120	ND	None	4.1	<0.1	**NR**	N/A	N/A	$<1\times10^{-6}$	5.5×10^{-6}
Pu-239/240	N/A	120	ND	None	0.8	<0.1	**NR**	N/A	N/A	$<1\times10^{-6}$	1.0×10^{-6}
Sr-90 + 1 progeny	N/A	850	ND	None	1.7	0.9	**NR**	N/A	N/A	$<1\times10^{-6}$	1.8×10^{-4}
Th-230	N/A	900	2.0	None	972	3.5	**902**	N/A	N/A	1×10^{-6}	4.4×10^{-4}
U-234	N/A	890	1.2	None	298	17.5	**NR**	N/A	N/A	$<1\times10^{-6}$	6.9×10^{-6}
U-235	N/A	9.2	0.15	None	51	3.9	**9.3**	N/A	N/A	$<1\times10^{-6}$	9.6×10^{-5}
U-238 + 2 progeny	N/A	55	1.2	None	1500	104	**56**	N/A	N/A	1.9×10^{-6}	2.3×10^{-4}
Chemical (mg/kg)											
Antimony	150	N/A	7.7	None	28	NA	**NR**	0.19	3.2	N/A	N/A
Beryllium	130	0.025	0.6	None	0.77	NA	**0.63**	<0.01	0.10	2.5×10^{-5}	1.8×10^{-3}
Cadmium	130	9000	0.82	None	7.7	NA	**NR**	0.06	2.0	$<1\times10^{-6}$	1.7×10^{-7}
Uranium	380	N/A	3.6	None	2100	309	**190[d]**	0.5	1.5	N/A	N/A

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TABLE 2-13
(Continued)

Constituent of Concern	Expanded Trespasser HI = 1 PRG	Expanded Trespasser 10^{-6} ILCR PRG	Background (95th percentile)	ARAR Target	Max. Detected Soil Concentration		**Proposed Remediation Levels**[a]	HI to Receptors from Proposed Remediation Levels		Risk to Receptors from Proposed Remediation Level	
					Surface	Sub surface		Expanded Trespasser	On-Property Farmer	Expanded Trespasser[b]	On-Property Farmer[c]
PAHs (mg/kg)											
Benzo(a)anthracene	NA	39	ND	None	NA	0.098	**NR**	N/A	N/A	$<1x10^{-6}$	$5.8x10^{-6}$
Benzo(a)pyrene	NA	5.7	ND	None	NA	0.042	**NR**	N/A	N/A	$<1x10^{-6}$	$2.3x10^{-5}$
Benzo(b)fluoranthene	NA	47	ND	None	NA	0.059	**NR**	N/A	N/A	$<1x10^{-6}$	$9.7x10^{-6}$
Benzo(k)fluoranthene	NA	110	ND	None	NA	0.046	**NR**	N/A	N/A	$<1x10^{-6}$	$6.6x10^{-6}$
Chrysene	NA	1,300	ND	None	NA	0.088	**NR**	N/A	N/A	$<1x10^{-6}$	$1.6x10^{-7}$
PCBs (mg/kg)											
Arochlor-1254	N/A	0.035	ND	None	NA	1.4	**ND**	N/A	N/A	$1x10^{-6}$	$1.4x10^{-3}$

[a] This PRL column is formatted in bold print for ease of reference only.
[b] Includes the direct radiation, soil ingestion, and inhalation pathways.
[c] Includes all pathways including the indirect pathways due to food crops.
[d] 0.5 times the PRG to protect for multiple chemicals.
NA = Not Available.
N/A = Not Applicable.
ND = Not Detected.
NR = No Remediation Required.

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TABLE 2-14

OPERABLE UNIT 1
PROPOSED PIT SUBSURFACE REMEDIAL LEVELS
BASED ON GROUNDWATER MODELING

	Waste Pit 1				Waste Pit 2				Waste Pit 3			
Constituent of Concern	Off-Property User PRG	On-Property User PRG	Pit Waste Conc. (95% UCL)[a]	**Proposed Remedial Level[b]**	Off-Property User PRG	On-Property User PRG	Pit Waste Conc. (95% UCL)	**Proposed Remedial Level[b]**	Off-Property User PRG	On-Property User PRG	Pit Waste Conc. (95% UCL)	**Proposed Remedial Level**
Radionuclides (pCi/g)												
Sr-90 +1d	>1.0E+04	NC[c]	7.7E+00	**NR[d]**	>1.0E+04	NC	4.0E+00	**NR**	>1.0E+04	1.4E-01	0.0E+00	**NR**
Tc-99	2.5E+00	2.2E-01	NA	**NR**	5.5E+00	3.3E-01	6.2E+02	**5.5E+00**	7.5E-01	7.7E-02	1.1E+03	**7.5E-01**
Ra-226	4.3E+15	NC	1.0E+02	**NR**	>1.0E+04	NC	9.5E+02	**NR**	>1.0E+04	NC	4.5E+02	**NR**
Th-230	NC	NC	5.5E+03	**NR**	NC	NC	>1.0E+04	**NR**	NC	NC	>1.0E+04	**NR**
U-234	>1.0E+04	3.4E+02	1.2E+03	**NR**	>1.0E+04	6.8E+02	>1.0E+04	**NR**	4.1E+03	8.0E+01	9.9E+02	**NR**
U-235 +1d	>1.0E+04	3.4E+02	2.6E+02	**NR**	>1.0E+04	6.8E+02	1.3E+02	**NR**	3.8E+03	8.0E+01	8.9E+01	**NR**
U-238 +2d	>1.0E+04	1.9E+02	>1.0E+04	**1.0E+04**	>1.0E+04	4.0E+02	>1.0E+04	**NR**	2.2E+03	4.6E+01	1.7E+03	**NR**
Np-237+1d	NA[e]	NA	NA	**NR**	NA	NA	NA	**NR**	1.1E+01	5.8E-01	2.1E+00	**NR**
Pu-238	NC	NC	1.0E+00	**NR**	NC	NC	0.1E+00	**NR**	1.4E+02	1.4E+02	1.0E+00	**NR**
Chemicals (mg/kg)												
Antimony	NC	NC	1.3E+02	**NR**	NC	NC	5.5E+01	**NR**	>1.0E+04	4.5E+02	6.4E+01	**NR**
Boron	8.2E+03	4.5E+02	1.7E+03	**NR**	1.9E+03	8.4E+02	NA	**NR**	1.5E+03	1.2E+02	NA	**NR**
Cadmium	NC	NC	1.9E+01	**NR**	NC	NC	1.3E+01	**NR**	>1.0E+04	1.8E+02	3.9E+01	**NR**

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TABLE 2-14
(Continued)

	Waste Pit 1				Waste Pit 2				Waste Pit 3			
Constituent of Concern	Off-Property User PRG	On-Property User PRG	Pit Waste Conc. (95% UCL)[a]	**Proposed Remedial Level[b]**	Off-Property User PRG	On-Property User PRG	Pit Waste Conc. (95% UCL)	**Proposed Remedial Level[b]**	Off-Property User PRG	On-Property User PRG	Pit Waste Conc. (95% UCL)	**Proposed Remedial Level**
Copper	NA	NA	NA	**NR**	NC	NC	1.3E+03	**NR**	>1.0E+04	7.5E+03	2.3E+03	**NR**
Chemical (mg/kg)												
Lead	NC	NC	5.3E+01	**NR**	NC	NC	7.6E+02	**NR**	1.0E+04	4.3E+04	8.4E+02	**NR**
Mercury	NA	NA	NA	**NR**	NC	NC	2.6E+00	**NR**	NC	NC	5.1E+00	**NR**
Aroclor 1221	7.8E-01	4.8E-03	4.6E+00	**7.8E-01**	NA	NA	NA	**NR**	NA	NA	NA	**NR**
Vinyl Chloride	NA	NA	NA	**NR**	2.7E+01	5.4E-03	1.9E+00	**NR**	NA	NA	NA	**NR**

	Waste Pit 4				Waste Pit 5				Waste Pit 6			
Constituent	Off-Property User PRG	On-Property User PRG	Pit Waste Conc. (95% UCL)	**Proposed Remedial Level[b]**	Off-property User PRG	On-Property User PRG	Pit Waste Conc. (95% UCL)	**Proposed Remedial Level[b]**	Off-property User PRG	On-Property User PRG	Pit Waste Conc. (95% UCL)	**Proposed Remedial Level[b]**
Radionuclides (pCi/g)												
Sr-90 +1d	>1.0E+04	NC	1.4E+02	**NR**	>1.0E+04	2.0E+01	3.1E+01	**NR**	>1.0E+04	1.6E+02	5.1E+00	**NR**
Tc-99	2.6E-01	2.0E-01	2.3E+02	**2.6E-01**	1.4E+00	9.5E-02	3.0E+03	**1.4E+00**	7.3E+00	4.2E-01	1.6E+02	**7.3E+00**
Ra-226	>1.0E+04	NC	5.0E+01	**NR**	>1.0E+04	NC	1.6E+02	**NR**	>1.0E+04	NC	4.3E+00	**NR**
Th-230	NC	NC	1.8E+03	**NR**	NC	NC	8.5E+03	**NR**	NC	NC	4.5E+01	**NR**

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TABLE 2-14
(Continued)

	Waste Pit 4				Waste Pit 5				Waste Pit 6			
Constituent	Off-Property User PRG	On-Property User PRG	Pit Waste Conc. (95% UCL)	**Proposed Remedial Level[b]**	Off-property User PRG	On-Property User PRG	Pit Waste Conc. (95% UCL)	**Proposed Remedial Level[b]**	Off-property User PRG	On-Property User PRG	Pit Waste Conc. (95% UCL)	**Proposed Remedial Level[b]**
Radionuclides (pCi/g)												
U-234	>1.0E+04	3.3E+02	4.1E+03	**NR**	8.2E+03	1.1E+02	1.3E+03	**NR**	>1.0E+04	8.4E+02	5.3E+03	**NR**
U-235 +1d	>1.0E+04	3.3E+02	9.3E+02	**NR**	8.2E+03	1.1E+02	5.8E+01	**NR**	>1.0E+04	8.4E+02	2.9E+02	**NR**
U-238 +2d	>1.0E+04	1.9E+02	>1.0E+04	**>1.0E+04**	4.7E+03	6.4E+01	1.5E+03	**NR**	>1.0E+04	4.8E+02	>1.0E+04	**NR**
Np-237+1d	NC	NC	4.0E-01	**NR**	2.4E+01	8.1E-01	8.3E+01	**2.4E+01**	2.0E+02	5.8E+00	3.6E+00	**NR**
Pu-238	NC	NC	5.0E-01	**NR**	2.0E+02	2.0E+02	4.4E+00	**NR**	3.6E+02	3.6E+02	1.4E+00	**NR**
Chemicals (mg/kg)												
Antimony	NC	NC	3.2E+02	**NR**	NC	NC	8.8E+01	**NR**	NA	NA	NA	**NR**
Boron	7.1E+03	4.3E+02	1.0E+03	**NR**	NA	NA	NA	**NR**	NA	NA	NA	**NR**
Cadmium	NC	NC	3.5E+01	**NR**	NC	NC	1.7E+01	**NR**	NC	NC	5.7E+00	**NR**
Copper	NC	NC	4.8E+02	**NR**	NC	NC	>1.0E+04	**NR**	NA	NA	NA	**NR**
Lead	NC	NC	6.3E+01	**NR**	NC	NC	2.4E+02	**NR**	NC	NC	9.0E+01	**NR**
Mercury	NA	NA	NA	**NR**	9.6E+00	1.1E-01	NA	**NR**	NA	NA	NA	**NR**
Arochlor 1221	NA	NA	NA	**NR**	NA	NA	NA	**NR**	NA	NA	NA	**NR**
Vinyl Chloride	9.8E-02	2.6E-03	1.4E-02	**NR**	NA	NA	NA	**NR**	NA	NA	NA	**NR**

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TABLE 2-14
(Continued)

Constituent	Burn Pit				Clearwell			
	Off-Property User PRG	On-Property User PRG	Pit Waste Conc. (95% UCL)	**Proposed Remedial Level[b]**	Off-Property User PRG	On-Property User PRG	Pit Waste Conc. (95% UCL)	**Proposed Remedial Level[b]**
Radionuclides (pCi/g)								
Sr-90 +1d	>1.0E+04	NC	NA	**NR**	>1.0E+04	NC	2.6E+01	**NR**
Tc-99	1.4E+01	2.9E-01	6.4E+01	**1.4E+01**	9.9E+00	5.9E-01	7.0E+02	**9.9E+00**
Ra-226	>1.0E+04	NC	3.9E+01	**NR**	>1.0E+04	NC	1.7E+02	**NR**
Th-230	NC	NC	4.5E+03	**NR**	NC	NC	5.6E+03	**NR**
U-234	>1.0E+04	6.3E+02	1.7E+03	**NR**	>1.0E+04	1.2E+03	1.1E+03	**NR**
U-235 +1d	>1.0E+04	6.3E+02	1.0E+02	**NR**	>1.0E+04	1.2E+03	3.7E+02	**NR**
U-238 +2d	>1.0E+04	3.6E+02	2.0E+03	**NR**	>1.0E+04	7.1E+02	1.6E+03	**NR**
Np-237+1d	NC	NC	6.0E-01	**NR**	NC	NC	2.2E+00	**NR**
Pu-238	NC	NC	5.0E-01	**NR**	NC	NC	4.9E-01	**NR**
Chemicals (mg/kg)								
Antimony	NC	NC	1.8E+01	**NR**	NA	NA	NA	**NR**
Boron	>1.0E+04	7.7E+02	NA	**NR**	NA	NA	NA	**NR**
Cadmium	NC	NC	3.5E+01	**NR**	NC	NC	7.2E+00	**NR**
Copper	NA	NA	NA	**NR**	NC	NC	3.3E+03	**NR**
Lead	NC	NC	2.8E+02	**NR**	NC	NC	4.3E+02	**NR**

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TABLE 2-14
(Continued)

	Burn Pit				Clearwell			
Constituent	Off-Property User PRG	On-Property User PRG	Pit Waste Conc. (95% UCL)	**Proposed Remedial Level[b]**	Off-Property User PRG	On-Property User PRG	Pit Waste Conc. (95% UCL)	**Proposed Remedial Level[b]**
Mercury	NA	NA	NA	**NR**	NC	NC	4.4E+00	**NR**
Chemicals (mg/kg)								
Arochlor 1254	NC	NC	7.7E+00	**NR**	NC	NC	7.4E-01	**NR**
Vinyl Chloride	7.3E+01	5.0E-03	3.0E-03	**NR**	NA	NA	NA	**NR**

[a] This concentration is the maximum of the upper confidence limit (UCL)/Maximum value from either the CIS or RIFS data. The UCL/Maximum value from each data set is the lower of the maximum detected value or the 95% UCL.
[b] These PRL columns are formatted in bold print for ease of reference only.
[c] NC - Not Calculated - Analyte was either not a CPC for this pit or groundwater model screening indicated that this analyte was not a factor in groundwater risk.
[d] NR - No Remediation Required - Even though an analyte, such as U-234, can leach in groundwater, the leachate concentration is such that the ILCR to the off-property user is less than $1x10^{-6}$.
[e] NA - Not Applicable - Analyte was not a CPC for this pit.

NC = Not calculated
NR = No Remediation Required

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TABLE 2-15

OPERABLE UNIT 1
SUMMARY OF EVALUATION ANALYSIS FOR INSTITUTIONAL CONTROL PROCESS OPTIONS

Remedial Technology	Process Option	Effectiveness	Implementability	Cost
Monitoring	Groundwater Monitoring*	Monitoring groundwater wells are effective in determining migration and evaluating effectiveness.	Readily implementable	Moderate
	Leachate Monitoring*	Effective in detecting water infiltration.	Readily implementable	Moderate
	Air Quality Monitoring*	A viable option for measuring the effectiveness of implementing other process options.	Readily implementable	Low
	Surface Water/Sediment Monitoring*	Can be effective for determining migration and evaluating effectiveness of other process options.	Readily implementable	Low
Access Control	Physical Barriers*	Can mitigate potential public exposure on site by restricting access.	Readily implementable	Low
	Administrative Controls*	Can be effective in reducing contact between contaminants and receptors.	Readily implementable	Low

* Indicates process option is retained for alternative development.

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TABLE 2-16

OPERABLE UNIT 1
SUMMARY OF EVALUATION ANALYSIS FOR CONTAINMENT PROCESS OPTIONS

Remedial Technology	Process Option	Effectiveness	Implementability	Cost
Subsurface Flow Control	Subsurface Drains*	Less effective if installed under existing waste. Would still mitigate leachate release to subsurface.	Moderately difficult to implement	Moderate
	Slurry Walls*	Most effective in controlling lateral migration and flow but does not eliminate the radioactive contaminants of the contained waste. Potential impact to human health and the environment is minimal.	Moderately difficult to implement	Moderate
	Pumping Wells	Moderately effective in controlling subsurface flow and diffusion. Effectiveness is maintained only as long as pumping continues.	Readily implementable	Moderately High
	Grout Curtains	Less effective in controlling lateral diffusion and flow than slurry walls.	Difficult to implement	Moderately High
Capping	Multimedia Cap*	Highly effective in preventing contaminant migration. It minimizes leachate generation, promotes surface drainage, prevents erosion and sediment transport of waste, and acts as an effective intrusion barrier.	Readily implementable	High

* Indicates process option is retained for alternative development.

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TABLE 2-16
(Continued)

Remedial Technology	Process Option	Effectiveness	Implementability	Cost
Run-On/Runoff Control	Sedimentation Basin/Sediment Trap*	Effective for the removal of suspended solids in runoff.	Readily implementable	Low
	Diversion/Collection*	Effective in preventing flooding, controlling erosion, and directing surface when used with other process technologies.	Readily implementable	Moderate
	Grading*	Highly effective in controlling site drainage and minimizing infiltration of water into contaminated areas. Some form of grading will be necessary for the development of all alternatives.	Readily implementable	Moderate
	Revegetation*	Effective in controlling erosion. No apparent impact to human health and the environment. It stabilizes the surface of waste disposal facilities.	Readily implementable	Low

* Indicates process option is retained for alternative development.

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TABLE 2-17

OPERABLE UNIT 1
SUMMARY OF EVALUATION ANALYSIS FOR REMOVAL PROCESS OPTIONS

Remedial Technology	Process Option	Effectiveness	Implementability	Cost
Mechanical Removal	Loader/Dozer*	Very effective in removing soil and debris.	Readily implementable	Low
	Crane w/Clamshell System*	Effective in removing sludges/soils.	Readily implementable	Low
	Conveyor System	Moderate effectiveness for removing solid materials but requires another method for loading material onto conveyor system.	Moderately implementable	Moderate
	Backhoe*	Very effective in removing soil and debris.	Readily implementable	Low
	Dragline System	Effective in removing soil and debris but less effective than a backhoe or loader/dozer due to the larger area required for operation.	Readily implementable	Moderate
Hydraulic Removal	Hydraulic Mining Pump	Effective in removing sludge-like material with accessibility problems.	Readily Implementable	Moderate
Pneumatic Removal	Pneuma/Oozer Dredge	Effective for removal of wet pit material.	Difficult to implement	Moderate
Groundwater Removal	Pumping Wells*	Effective for groundwater extraction during remedial activities.	Readily implementable	High
	Subsurface Drains	Effective for groundwater extraction during remedial activities.	Difficult to Implement	Moderate

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* Indicates process option is retained for alternative development.

TABLE 2-18

OPERABLE UNIT 1
SUMMARY OF EVALUATION ANALYSIS FOR TREATMENT PROCESS OPTIONS

Remedial Technology	Process Option	Effectiveness	Implementability	Cost
In Situ Treatment	Shallow Soil Mixing*	Effective in limiting the transport of surficial contaminants through controlling erosion and limiting migration.	Difficult to implement	Moderate
	Surcharging*	Effective for soil compaction; overall effectiveness depends on adequate subsurface flow control	Readily Implemented	Low
	Dynamic Compaction	Effective for soil compaction, overall effectiveness depends on adequate subsurface flow control; short-term impacts more adverse than surcharging.	Readily Implemented	Low
Waste Stabilization	Cement-Based Solidification*	Moderately effective in treating wastes. The solidified matrix reduces exposed surface area and leachate generation. Most suitable for immobilizing metals. Large volume increase.	Readily implemented	Moderate
	Thermoplastic Solidification	Effective in solidifying soluble, toxic materials, but not proven on large-scale projects. Waste and the matrix may not be compatible.	Difficult to implement	High
	Vitrification*	Very effective in stabilizing wastes. Considered innovative technology and BDAT for high-level radioactive waste. The noncrystalline solid is very effective for reducing the leachability.	Difficult to implement	Very High

* Indicates process option is retained for alternative development.

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TABLE 2-18
(Continued)

Remedial Technology	Process Option	Effectiveness	Implementability	Cost
	Lime/Flyash Solidification	As effective as cement solidification but concerns exist with stability of final matrix. Volume increase will occur.	Readily implemented	Moderate
Physical Treatment	Solid/Liquid Separation*	Effective for separation of liquids and solids.	Readily implemented	Moderate
Chemical Treatment	Chemical Extraction	Effective in removing heavy metals; not a stand-alone treatment, but requires proper treatment and disposal of chemical extraction agent. Large quantities of acids are required, introducing an additional waste stream. This process also requires post-treatment for stabilizing the primary waste streams before disposal.	Difficult to implement	High
Thermal Treatment	Drying*	Provides suitable pretreatment where liquid/solid ratio must be reduced before treatment or disposal.	Moderately implemented	Moderate

* Indicates process option is retained for alternative development.

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TABLE 2-19

OPERABLE UNIT 1
SUMMARY OF EVALUATION ANALYSIS FOR DISPOSAL PROCESS OPTIONS

Remedial Technology	Process Option	Effectiveness	Implementability	Cost
Waste Transportation	Rail Transport*	Effective form of transportation because of the reduced risk to human life. Rail spurs may need to be upgraded.	Readily implementable	Moderate
	Truck Transport*	Effective but less reliable than rail transportation. Truck transportation is required for on-property disposal.	Readily implementable	High
On-Property Disposal	Engineered Disposal Cell*	Effective by providing isolation from the groundwater and isolating waste from surface environment. Also provides intrusion barrier.	Difficult to implement	High
	Above-Grade Concrete	Effective by providing isolation from the groundwater and isolating waste from surface environment. Also provides intrusion barrier.	Difficult to implement	Very High
Off-Site Disposal	Nevada Test Site*	Very effective for disposal of waste from Operable Unit 1.	Difficult to implement	Very High
	Permitted Commerical Disposal Site*	Very effective disposal of stabilized or solid waste from Operable Unit 1.	Moderately difficult to implement	High

* Indicates process option is retained for alternative development.

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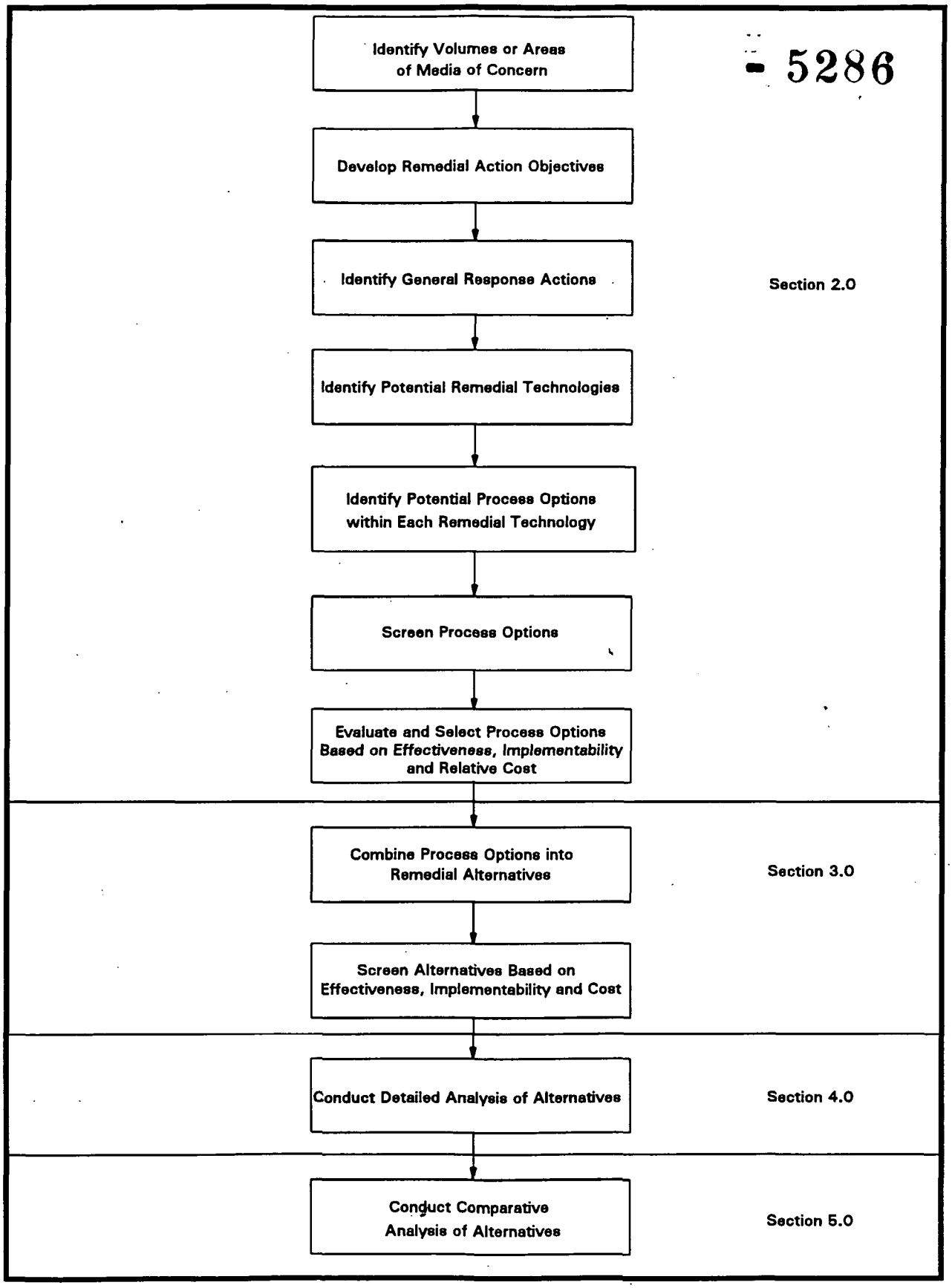

FIGURE 2-1 ELEMENTS OF THE FS PROCESS

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
No Action	None	Not Applicable	No Action	Required for consideration by NCP
Institutional Action	Monitoring	Groundwater Monitoring	Installation of wells for monitoring groundwater	Potentially applicable
		Leachate Monitoring	Monitoring of leachate collection /detection system	Potentially applicable
		Air Quality Monitoring	Installation of air monitoring device	Potentially applicable
		Surface Water/Sediment Monitoring	Collection /analysis of surface water/sediment samples	Potentially applicable
	Access Control	Physical Barriers	Fencing, security, limited road access, etc.	Potentially applicable
		Administrative Controls	Restricted access only, posted signs, etc.	Potentially applicable
Containment	Subsurface Flow Control	Subsurface Drains	Gravity driven collection system	Potentially applicable
		Slurry Walls	A soil/bentonite grout wall emplacement	Potentially applicable
		Pumping Wells	Extraction /injection of water into ground	Potentially applicable
		Sheet Pilings	Steel/concrete forms joined and driven into ground	Not applicable at required depths
		Grout Curtains	Close-spaced grout injections isolate area	Potentially applicable
	Capping	Synthetic Cover	Synthetic liner placed over areas of concern	Not applicable because of design life
		Concrete-Based Cap	Concrete slab poured over area of concern	Not applicable because of design life
		Asphalt-Based Cap	Asphalt poured over area of concern	Not applicable because of design life
		Soil/Clay-Based Cap	Compacted soil or clay cover over area of concern	Not applicable because of design life
		Multimedia Cap	Cap formed with various layers	Potentially applicable
	Run-On /Runoff Control	Sedimentation Basin /Sediment Trap	Temporary storage of runoff to allow settling /Traps to intercept soil particles in runoff	Potentially applicable
		Diversion /Collection	Surface water routing controls	Potentially applicable
		Grading	Topography modification for route control	Potentially applicable
		Revegetaion	Vegetative cover provides surface stability	Potentially applicable

Process option not retained

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FIGURE 2-2. OPERABLE UNIT 1 INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

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GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
Removal	Mechcanical Removal	Loader/Dozer	Tractor– or wheel–mounted excavation vehicles	Potentially applicable
		Crane w /Clamshell System	Tractor–, wheel– or skid–mounted system	Potentially applicable
		Conveyor System	Belt–type conveyor system excavates material	Potentially applicable
		Backhoe	Tractor– or wheel–mounted excavation vehicles	Potentially applicable
		Dragline System	Excavating tool pulled across material	Potentially applicable
	Hydraulic Removal	Hydraulic Mining Pump	Dislodges and hydraulically removes material	Potentially applicable
	Pneumatic Removal	Pneuma /Oozer Dredging	In situ sludge pumping system	Potentially applicable
		Airlift Dredging	Expanding air pulls material behind it	Not applicable, requires depths >20–30 feet
	Water Removal	Pumping Wells	Extraction / injection of water into ground	Potentially applicable
		Subsurface Drains	Gravity driven collection system	Potentially applicable
Treatment	In Situ Treatment	Shallow–soil Mixing	Chemical and /or flyash–based stabilization	Potentially applicable
		In Situ Vitrification	High–voltage crystallization / glassification of solids	Not applicable for heterogeneous wastes
		Surcharging	Compaction of material by addition of soil cover	Potentially applicable
		Dynamic Compaction	Mechanical compaction of materials	Potentially applicable
		Vacuum Extraction	Vacuum removal of VOCs from soil	Not applicable to inorganics
	Waste Stabilization	Cement–Based Solidification	Cement mixed with soil and solidified	Potentially applicable
		Thermoplastic Solidification	Polymers mixed with soil and solidified	Potentially applicable
		Vitrification	High–voltage crystallization / glassification of solids	Potentially applicable
		Lime / Flyash Solidification	Lime and flyash mixed with soil	Potentially applicable

Process option not retained

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FIGURE 2–2. (Continued)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
Treatment	Physical Treatment	Solid / liquid separation	Separation of solids and liquids	Potentially applicable
		Soil Aeration	Air injection removes volatile organics	Not applicable for inorganics
	Chemical Treatment	Chemical Extraction	Impurities removed through solubility / affinity	Potentially applicable
	Thermal Treatment	Drying	Removes water from waste materials	Potentially applicable
		Incineration	Destroys hazardous organics and reduces volume	Not applicable for inorganic materials and radionuclides
	Biological Treatment	Biological Treatment	Microbial action degrades organics	Not applicable for inorganic materials and radionuclides
Disposal	Waste Transportation	Rail Transportation	Railroad transportation along available routes	Potentially applicable
		Truck Transportation	Truck transportation along available routes	Potentially applicable
	On–Property Disposal	Engineered Disposal Cell	Engineered disposal facility, capped when filled	Potentially applicable
		Above–Grade Concrete Vault	Above–ground disposal vault	Potentially applicable
	Off–Site Disposal	Nevada Test Site	Licensed government facility	Potentially applicable
		Permitted Commercial Disposal Facility	Licensed commercial facility	Potentially applicable

Process option not retained

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FIGURE 2–2. (Continued)

3.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

3.1 INTRODUCTION

This section presents the development and screening of remedial alternatives assembled from combinations of technologies and associated process options evaluated in Section 2.0. Section 3.2 presents the development and description of a range of alternatives based on the general response actions discussed in Section 2.3 and a discussion of those factors common to all remedial alternatives. Section 3.3 presents the initial screening of alternatives evaluated against the three broad criteria of effectiveness, implementability, and cost. Section 3.4 summarizes the initial screening of alternatives.

The purpose of a feasibility study (FS) and the overall alternative selection process is to identify remedial actions that eliminate, reduce, or control risks to human health and the environment (40 CFR 300). The goal of the FS process, as defined in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (EPA 1990), is to select remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste. The criteria for identifying potentially applicable technologies to achieve these goals are provided in U.S. Environmental Protection Agency guidance (EPA 1988a) and the NCP. A statutory preference for remedies which will result in permanent and significant decreases in toxicity, mobility, or volume through treatment which provide long-term protection is stated in Section 121 of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The primary requirements for the final remedy are that it protects human health and the environment and comply with applicable or relevant and appropriate requirements (ARARs); thus, alternative screening focuses on these criteria.

In addition to the above objectives, the NCP defines the following preferences in developing and screening remedial action alternatives:

- Use of treatment to address the principal threats posed by a site, wherever practical
- Use of engineering controls, such as containment, for waste that poses a relatively low long-term threat and for which treatment is not practical

- Implementation of a combination of actions, as appropriate, to achieve protection of human health and the environment. For example, in appropriate site situations, treatment of principal threats would be combined with engineering controls, such as containment, and institutional controls for treatment residuals and untreated waste.

- Use of institutional controls, such as drinking water supply controls and deed restrictions, to supplement engineering controls for short- and long-term management to prevent or limit exposures to hazardous substances

- Selection of innovative technology when the technology offers the following: the potential for comparable or better treatment performance or implementability, fewer number of or lesser magnitude adverse impacts than other available approaches, or lower costs than demonstrated technologies for similar levels of performance

- Restoration of environmental media, such as groundwater, to their beneficial uses, whenever practicable, within a reasonable time frame. When restoration of groundwater to beneficial uses is not practical, EPA expects to prevent further migration of the contaminant plume, prevent human and environmental exposures to contaminated groundwater, and evaluate further risk reduction.

These preferences have been applied in the development and screening of alternatives which follow.

3.2 DEVELOPMENT OF REMEDIAL ALTERNATIVES

3.2.1 Criteria for Developing Remedial Alternatives

The EPA has established an approach for developing remedial action alternatives that are appropriate to the specific conditions at the Fernald Environmental Management Project (FEMP) site. In this approach, the scope, characteristics, and complexity of the site are considered in developing a range of alternatives that would be protective of human health and the environment. Protectiveness may be achieved by eliminating, reducing, or controlling risks posed by each pathway at a site.

The alternatives developed as part of the Operable Unit 1 Feasibility Study differ slightly from those presented in the Initial Screening of Alternatives Report (ISA) for Operable Unit 1 (DOE 1991b), primarily due to additional site information acquired after the ISA Report was prepared.

Various differences exist between the screened alternatives provided in the 1991 Initial Screening of Alternatives (ISA) for Operable Unit 1 and the alternatives presented in the this feasibility study. The ISA report presented seven alternatives and the feasibility study presented eight. The individual alternatives are as follows:

Initial Screening of Alternatives	Feasibility Study
-No Action	-No Action (Alternative 1)
-Nonremoval; Slurry Wall, & Cap	-In Situ Containment (Alternative 2)
-Nonremoval; Physical Stabilization Slurry Wall & Cap	-In Situ Treatment & Containment (Alternative 3)
-Removal, Waste Treatment, & On-property Disposal	-Removal, Vitrification, & On-property Disposal (Alternative 4A)
-Removal, Waste Treatment, & Off-property Disposal	-Removal, Cementation, & On-property Disposal (Alternative 4B)
-Removal, Waste Treatment, On-property Disposal	-Removal, Drying, & On-property Disposal (Alternative 4C)
-Removal, Waste Treatment, On-property Disposal, Soil Treatment, & Cap	-Removal, Thermal Drying, & Off-site Disposal at NTS (Alternative 5A)
	-Removal, Thermal Drying, & Off-site Disposal at a Representative Commercial Disposal Facility (Alternative 5B)

The No-Action Alternative for both programs are essentially identical.

The ISA's first nonremoval action and the FS's in situ containment (Alternative 2) are identical approaches. Both alternatives provide for subsurface flow control through the use of slurry walls, subsurface drains and temporary groundwater wells to lower the groundwater table. Additionally, both alternatives include a multiple layer cap over the waste pit area to provide protection from intrusion and to limit infiltration. Run-off/run-on control are also included as an integral part of the alternative.

The third alternative discussed for each program consisted of alternatives for stabilizing the waste and containing the resulting material, thus preventing mobilization into the Great Miami Aquifer. The proposed stabilization steps consist of shallow soil mixing for Waste Pits 5, 6 and the Clearwell and surcharging for Waste Pits 1 through 4 and the Burn Pit. Both alternatives include a multiple layer cap over the waste pit area.

For reasons documented later in this section, Alternatives 2 and 3 were screened out of further consideration. Additional documentation on the extreme waste heterogeneity that contributes to this screening was available for the feasibility study but was not available for the ISA Report.

In general, the ISA approach within Alternative 4 was to vitrify the waste within the waste area using applied electrical energy at predetermined grid points to achieve a temperature of 1,600°C, resulting in a conversion of the soil/waste into a molten mass. This step would be followed by the installation of a multimedia cap, flow realignment of Paddys Run, and run-off/run-on control of storm water. The FS alternative also includes the vitrification procedure; however, the treatment is performed following the removal of the waste material from the pits and subsequent drying. This alternative is similar to part of the fifth ISA alternative. In situ vitrification was screened out in Section 2 of the FS based on new information that the process option is ineffective at depths encountered in the waste pits and also that it is difficult to implement in the face of waste heterogeneity.

Alternative 5 from the ISA is generic with respect to the treatment process and includes both vitrification and cementation as the stabilization technology. The resulting stabilized waste would be contained in an above grade structure with a reinforced concrete roof. This alternative would encompass both Alternatives 4 and 5 presented in the FS report.

The ISA Alternative 6 is identical to ISA Alternative 5 with either vitrification or cementation as the stabilization technology but the difference is that the disposal is accomplished off site rather than on property in the above-grade structure. This is not an alternative action screened within the FS. The reason is that additional treatment is shown in this report to be unnecessary to safely transport the waste and meet waste acceptance criteria.

Alternative 7 presented in the ISA consisted of removal of the waste material as previously presented in Alternative 5, but the soil underlying and surrounding the waste pit would be left in place and covered with a closure cap. The removed waste would be stabilized via either vitrification or cementation. Following the removal, the waste pit area would be leveled and covered with a multilayer closure cap of an approximately fifteen foot thickness. This would be in conjunction with run-off/run-on control and flow realignment of Paddys Run. The only difference between this and Alternative 4A and 4B is the degree of subsurface soil removal.

The final alternative presented in the ISA is identical to the previous Alternative 7 with the exception of the underlying and surrounding soil of the waste pit area. These additional soils would also be treated by in situ vitrification, shallow soil mixing and capping following backfilling and horizontal grading of the waste pit area. Run-off/run-on control and realignment of Paddys Run are included in the alternative scenario. The reasons that the feasibility study screened out in situ vitrification are discussed above.

Drying was added as a principal element to all ex situ alternatives in the FS when it became clear that drying was required to meet waste acceptance criteria at the off-site disposal facility and to successfully implement vitrification and cement solidification.

The alternatives presented in this section were developed using technologies and process options surviving the screening process discussed in Section 2.0. The specific grouping of technologies and process options into alternatives was made in consideration of known waste characteristics and of the final disposition of the wastes. The waste disposition groupings are identified as in situ, off site, and on property. Further, the alternatives were grouped to include only those elements that are required to support remedy selection. For example, in light of waste characteristics relative to off-site transportation requirements and waste acceptance criteria at potential off-site disposal locations (refer to Appendix J), treatment beyond drying was shown to be unnecessary to successfully implement such an alternative. Additional treatment (such as cement solidification or vitrification) was deemed advantageous for on-site disposal in a cell. This approach mitigates short-term risks associated with waste placement and also provides containment redundancy for the disposed waste to address the

possibility of disposal cell failure over time. This was determined to be important because the Great Miami Aquifer is a regionally important aquifer as a sole-source aquifer. Off-site disposal was divided into two alternatives because of potentially significant cost differences between the Nevada Test Site (NTS) and a representative permitted commercial disposal facility. Other process elements were added to meet specific requirements of the waste treatment, such as waste component size reduction for drying, cement solidification, and vitrification.

3.2.2 Summary of Remedial Alternatives

Based on the results of the initial screening of technologies and process options discussed in Section 2.0, those process options that were retained were combined into specific remedial action alternatives as discussed above to satisfy the remedial action objectives (RAOs). These alternatives represent a full range of potentially viable remedial actions.

The following eight alternatives were developed for Operable Unit 1:

- Alternative 1 - No Action
- Alternative 2 - In Situ Containment
- Alternative 3 - In Situ Treatment and Containment
- Alternative 4 - Removal, Treatment, and On-Property Disposal
  - Alternative 4A - Removal, Treatment (Vitrification), and On-Property Disposal
  - Alternative 4B - Removal, Treatment (Cementation), and On-Property Disposal
  - Alternative 4C - Removal, Treatment (Thermal Drying), and On-Property Disposal
- Alternative 5 - Removal, Treatment, and Off-Site Disposal
  - Alternative 5A - Removal, Treatment (Thermal Drying), and Off-Site Disposal at NTS
  - Alternative 5B - Removal, Treatment (Thermal Drying), and Off-Site Disposal at a Representative Permitted Commercial Disposal Facility

Table 3-1 provides a list of the process options retained and illustrates the relation between these options and the assembled alternatives. These alternatives are further described in Section 3.3. The descriptions include a brief discussion of the remedial alternative, including the technologies, process options, and other features that constitute each alternative as well as preliminary estimates of the following information:

- Size and configuration
- Remediation time frame
- Spatial requirements
- Packaging/transportation requirements
- Residual waste generated

More detailed descriptions and estimates are provided in Section 4.0, Detailed Analysis of Alternatives, for those alternatives passing the initial screening process.

3.2.3 Factors Common to Remedial Alternatives

As noted in Table 3-1, various process options are common to all of the alternatives (collectively referred to as "action alternatives") except the No-Action Alternative. These process options address institutional controls, water extraction and treatment, surface and subsurface soil removal and management, and decontamination and decommissioning. These are further described below.

3.2.3.1 Institutional Controls

Institutional controls include access controls and monitoring. All action alternatives would likely include access control of Operable Unit 1 through the use of physical barriers and administrative controls, as follows:

- Physical Barriers - Access to the site would be confined to authorized personnel through the use of fences, gates, signs, or guards, until site-wide RAOs (including Operable Unit 5) are attained.

- Administrative Controls - This would control potential public exposure to on-property contamination by restricting access and use of the site through deed restrictions or continued government ownership.

All action alternatives that leave waste material on the property, such as the in situ alternatives (Alternatives 2 and 3) and on-property disposal alternatives (Alternatives 4A, 4B, and 4C) would include the following post-closure monitoring:

- Air Quality Monitoring - Air monitors would be installed around the cap to detect and warn of contaminants regulated by the Clean Air Act Amendments that may be emanating from the material underneath the cap. Monitoring would continue as required to demonstrate compliance with relevant ARARs/TBCs and in support of

CERCLA 5-year reviews. Air quality monitoring would also be an activity undertaken during the implementation of all alternatives.

- Groundwater Monitoring - A series of groundwater monitoring wells would be installed around the cap and sampled routinely to monitor containment system performance.

- Leachate Monitoring - The installed leachate collection/disposal system (LC/DS) would be routinely checked to monitor the cap performance.

- Surface Water/Sediment Monitoring - The surface water and sediment near the cap would be monitored to determine if contaminants from the material have been released to these media.

3.2.3.2 Water Extraction and Treatment

For all action alternatives, impounded surface water (Pits 5 and 6) would be extracted. For alternatives involving waste excavation, an intensive dewatering program would be undertaken, because of waste excavation, material handling, and drying efficiency considerations. Groundwater extraction wells constructed of PVC pipe would be installed in the waste and surrounding soil. The wells would be screened over their entire depth but would not penetrate the liner at the pit bottoms or the Great Miami Aquifer sumps could also be used. All extracted water would be forwarded to the FEMP Advanced Wastewater Treatment (AWWT) facility.

The FEMP AWWT facility is being built on the FEMP site and will be available for treating all wastewater generated during the restoration of Operable Unit 1, including perched groundwater, surface water from Pits 5 and 6, process wastewater, and decontamination wastewater. This system will utilize metals precipitation, activated carbon, and ion discharge requirements. These technologies have demonstrated effectiveness in removing contaminants that could be associated with the remedial effort. The AWWT facility is designed to reduce the concentration of uranium in FEMP's wastewater discharges to less than the proposed Safe Drinking Water Standard of 20 parts of uranium per billion parts of water, often referred to as "parts per billion."

The treatment system will consist of two parallel treatment systems. The first system will treat 265 liters per minute (70 gallons per minute) of contaminated storm water runoff from the FEMP storm

water retention basin. When capacity is available, this treatment system will also treat uranium-contaminated groundwater be to extracted from the South Groundwater Contamination Plume. The second system will treat 1,515 liters per minute (400 gallons per minute) of wastewater from cleanup and other activities at the site. This consists of approximately 760 liters per minute (200 gallons per minute) existing wastewater flows and 760 liter per minute (200 gallons per minute) future remediation flows. The AWWT facility is designed to have adequate excess capacity to permit treatment of wastewater generated during Operable Unit 1 restoration efforts. It is estimated that the combined average wastewater flow rate from all sources (including Operable Unit 1) during the term of the restoration effort will be approximately 454 liters per minute (120 gallons per minute).

Each of the two parallel systems will consist of the following major treatment steps:

- Flow equalization and pH adjustment to 11.5 to optimize precipitation
- Precipitation and clarification for bulk removal of radionuclides and heavy metals
- Filtration for removal of fines
- Activated carbon filtration for removal of any organic compounds
- pH adjustment to 8.0
- Ion exchange from removal of uranium and additional heavy metals
- Final pH adjustment to within NPDES limits (6.5 - 9.0)
- Final filtration

This design is adequate to handle the contaminants expected to be generated by Operable Unit 1 as documented by the Draft Final Remedial Investigation Report for Operable Unit 1 (DOE 1994a).

3.2.3.3 Surface and Subsurface Soil Removal or Treatment

For all action alternatives, remediation of surface and beneath the pits soils to health and ARARs-based levels is identified. All removal alternatives include on-property transportation of surface and subsurface soil to Operable Unit 5 for management. The specific strategy for these soils will be to establish final action levels and to excavate all soils exhibiting contamination above these levels. Proposed remediation levels are established in Section 2.2 of this FS. However, additional input from the Fernald Citizen's Advisory Task Force and the public is essential before making final recommendations on land use from a site-wide perspective. The Operable Unit 1 proposed remediation levels will thus be re-examined by the Operable Unit 5 Feasibility Study Report and

Record of Decision based upon available Operable Unit 5 Feasibility Study conclusions, recommendations from the Fernald Citizen's Advisory Task Force, and further public comment. The Operable Unit 5 Record of Decision may then modify the Operable Unit 1 interim remediation levels downward to ensure protectiveness of human health and the environment. This will provide for mitigation of risk posed by these unremediated soils. The excavated material will be addressed in a manner that will result in acceptable human health and environment risk levels. This will be accomplished by managing these soils along with the soils to be generated during remediation of the Operable Unit 3 process area. These two waste streams are anticipated to be sufficiently similar. Operable Unit 5 has taken the lead in evaluating alternatives, including completing ongoing treatability studies, most appropriate for soil. Again, excavated Operable Unit 1 soils will be managed by the methods for addressing process area soils specified in the Operable Unit 5 Record of Decision (ROD). To be selected in the Operable Unit 5 ROD, the selected remedial action must be shown to be protective of human health and the environment.

3.2.3.4 Decontamination and Decommissioning

For alternatives that include construction of treatment facilities (Alternatives 4A, 4B, 4C, 5A, and 5B), any on-property processing facilities constructed to support remediation of Operable Unit 1 would be decontaminated and demolished. Any concrete and construction debris generated during this activity which meets the free release criteria (see Operable Unit 4 FS (DOE 1994c) for these criteria) would be disposed in a solid waste/sanitary landfill. The remaining volume of contaminated debris will be managed by Operable Unit 3 as part of the contaminated construction debris to be generated during process area decontamination and decommissioning (D&D) activities. Included in this volume will be the miscellaneous facilities and structures of Operable Unit 1.

3.3 SCREENING OF ALTERNATIVES

The alternatives presented in the previous subsection were evaluated against three broad criteria: effectiveness (short and long term), implementability, and cost. The criteria for evaluating alternatives are provided in EPA guidance (EPA 1988a) and in the NCP (40 CFR 300) (EPA 1990). Of these criteria, effectiveness was given the highest consideration. Because this screening reduced the number of alternatives undergoing a more extensive analysis, alternatives are evaluated more

qualitatively in this phase than during the subsequent detailed analysis presented in Section 4.0. The no-action alternative is retained as a baseline against which other alternatives were compared. The detailed analysis will subject the remaining alternatives to nine specific criteria and their individual factors rather than the three general criteria used in the alternative screening process. The relationship between the three screening criteria and the nine specific evaluation criteria is illustrated in Figure 3-1.

Alternatives with innovative technologies were carried through the screening process if there were reason to believe that they offered significant advantages in performance or implementability. Technologies are classified as innovative if they are fully developed but lack sufficient cost or performance data for routine use at cleanup sites regulated by CERCLA. One remedial technology considered in this FS, vitrification, is considered "innovative" per EPA's Guide to Treatment Technologies for Hazardous Wastes at Superfund Sites (EPA 1989b).

Each alternative was subjected to a screening evaluation using effectiveness, implementability, and cost as the three general criteria. A description of each of these criteria and the results of that screening evaluation are presented in this section.

Effectiveness Evaluation

The key aspect of the effectiveness evaluation is the assessment of each alternative's ability to protect human health and the environment, and to meet ARARs. Additional factors considered in the effectiveness evaluation include: (1) long-term effectiveness and permanence; (2) reduction of contaminant toxicity, mobility, or volume through treatment; and (3) short-term effectiveness during remediation.

Implementability Evaluation

Implementability is the measure of: (1) technical feasibility; (2) administrative feasibility to construct, operate, and maintain a remedial action alternative; and (3) the availability of services and materials to implement the alternative.

This criterion provides a method to evaluate the potential of an alternative to be adapted to site-specific conditions. The technical feasibility evaluation considered the following factors:

- Constructability
- Maintenance

The administrative feasibility evaluation considered the ability to obtain permitting and licensing approval.

The availability of services and materials evaluation considered the following:

- Availability of on-site/off-site treatment, storage, and disposal facilities and capacity
- Availability of equipment
- Availability of design, operating, and support personnel

Cost Evaluation

Costs are discussed qualitatively for each alternative to compare similar alternatives. Cost discussions were based on a variety of cost-estimating data such as cost curves, generic unit costs, vendor information, conventional cost-estimating guides, commercial remedial costs, and previous similar estimates as modified by site-specific information.

3.3.1 Alternative 1 - No Action

3.3.1.1 Description

As required by the NCP, the No-Action Alternative provides a comparative baseline against which other alternatives can be evaluated. Under this alternative, no remedial action will be taken and the material in all the waste areas (e.g., Waste Pits 1 through 6, Burn Pit, and Clearwell) is considered to be left "as is", without the implementation of any containment, removal, treatment, or other mitigating actions. This alternative does not provide for the monitoring of soil, groundwater, or air emissions, and does not provide for any institutional controls to reduce the potential for exposure (e.g., physical barriers, deed restrictions).

3.3.1.2 Screening Evaluation

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment. Under this alternative, Operable Unit 1 would remain unchanged. Because the material would not be treated or further contained, the material's toxicity, mobility, and volume would not be altered.

Long-Term Protection of Human Health and the Environment. The material would not be contained, treated, or modified under the No-Action Alternative. RAOs for the waste pits, Burn Pit, and Clearwell wastes would not be attained under the no-action alternative. As described in the Baseline Risk Assessment (Baseline RA) for Operable Unit 1 (DOE 1994a), and summarized in Section 1.0 of this FS, the potential incremental lifetime cancer risk to a number of evaluated receptors exceeds the generally accepted risk range as defined in the NCP. Potential exposures would also lead to significant detrimental impacts to the regional environment. Therefore, no provision would be made for long-term protection of human health and the environment.

Short-Term Protection of Human Health and the Environment. Because no action would be taken, remedial activities would pose no short-term risks to human health and the environment.

Screening Criteria - Implementability

Technical Feasibility. Technical feasibility is not an issue because no construction or maintenance activities would be performed.

Administrative Feasibility. No permits or licenses would be required to implement this alternative, so administrative feasibility would not be an issue.

Availability of Services and Materials. No equipment or personnel would be required to implement this alternative.

Screening Criteria - Cost

No costs would be associated with this alternative.

Summary

This alternative does not meet RAOs and does not reduce the toxicity, mobility, or volume of wastes through treatment or other methods. No provision is made for long-term protection of human health and the environment. The No-Action Alternative is readily implementable and has the least cost. The No-Action Alternative was retained for detailed analysis as a baseline for comparison with other remediation alternatives.

3.3.2 Alternative 2 - In Situ Containment

The following is a conceptual description of this alternative developed for the Operable Unit 1 FS.

3.3.2.1 Description

This containment alternative for Operable Unit 1 is intended to isolate the contents of the waste pits, Burn Pit, and the Clearwell from human and environmental receptors and to minimize the generation and release of contaminated leachate to the underlying Great Miami Aquifer. The technologies implemented by this alternative are water extraction and transfer to the site's AWWT facility for treatment, subsurface flow control, excavation of surface soils, capping, run-on/runoff control, monitoring, and access controls. This alternative includes the installation of subsurface drains, construction of a slurry wall around the waste areas, and construction of a multimedia cap over the waste pits. Figure 3-2 illustrates a conceptual flow diagram for this alternative. The process options selected for this alternative are described as follows.

Water Extraction and Treatment

Waste Pits 5 and 6 and the Clearwell have standing water that must be removed. As described in Section 3.2.3.2, the water would be transferred to the AWWT facility for treatment.

Subsurface Flow Control

The subsurface flow control process options would minimize horizontal groundwater flow through the Operable Unit 1 area. These process options include the following:

- Slurry Walls - To divert groundwater flow around the waste pit area, a soil or cement/bentonite slurry wall would be constructed along three sides (north, east, and south) of the Operable Unit 1 study area. The slurry wall is not required in the down-gradient direction (west) relative to groundwater flow. The slurry wall would be installed through the surficial till layer into the clay layer or just below the waste elevation. The cement/bentonite would be obtained commercially and mixed on property with existing acceptable soils to produce a 0.9-meter (3-feet) wide slurry wall that would extend to the top of the Great Miami Aquifer formation [average depth 12 meters (38 feet)]. The purpose of the slurry wall would be to minimize contaminated leachate generation.

- Subsurface Drains - A subsurface drain system around the waste pits, Burn Pit, and Clearwell would consist of a series of perimeter drains that may be placed upgradient from the slurry wall. The drains would intercept and divert uncontaminated groundwater to prevent contact with waste and the contaminated soil.

Surface Soil Removal

As described in Section 3.2.3.3, surface soil from areas not covered by the multimedia cap would be excavated and forwarded to Operable Unit 5.

Multimedia Cap

A multimedia cap would be installed to minimize rainwater infiltration into the waste pits, Burn Pit, and Clearwell. The cap would consist of the following elements to control erosion and minimize generation of leachate as a result of rainwater infiltration: upper vegetative layer, gravel filter layer with geotextile underneath, cobble biotic barrier with geotextile beneath it, sand drainage layer with geotextile beneath it, a double layer of textured high-density polyethylene (HDPE) and a geosynthetic clay liner, a low-permeability clay layer with a maximum vertical permeability of 1×10^{-7} centimeters/second, and a contouring fill layer.

Run-On/Runoff Control

The run-on/runoff control for in situ containment includes a diversion channel or surface water collection system, grading and revegetation, as described below:

- Diversion/collection - The area surrounding the cap would contain small berms, channels, and waterways to redirect runoff as dictated by engineering design.
- Grading - The area surrounding the cap would be contoured or graded to redirect and control runoff.
- Revegetation - Vegetation would be used both on the multimedia cap and the area surrounding the cap to reduce erosion sediment runoff.

Monitoring

Air quality, groundwater, leachate, and surface water/sediment would be monitored, as described in Section 3.2.3.1.

Access Controls

Access controls would include physical barriers and administrative controls, as described in Section 3.2.3.1.

Size and Configuration

It is currently estimated that in situ containment would include 10 subsurface drains, a slurry wall, 16 groundwater extraction/monitoring wells, a 10-hectare (24-acre) cap, and removal of approximately 15,500 square meters (20,200 square yards) surface soil. Wells would be sized and placed to adequately control inflows. Exact size and configuration would be optimized during design.

Remediation Time Frame

Remediation is estimated to take approximately two years from the initial staging of construction equipment to the final capping of the waste areas.

Spatial Requirements

Overall area at the FEMP site required for implementation of this alternative is approximately 16 hectares (40 acres) of which approximately 10 hectares (24 acres) would be capped.

Packaging Transportation Requirements

The only transportation requirement identified is transporting the fill, aggregate, clay and other closure materials to the site.

Waste Generated

Waste generated by in situ containment would include personal protective equipment (protective clothing, gloves, HEPA filters, etc.), equipment not feasible to decontaminate, and nonhazardous solid waste from debris and equipment.

3.3.2.2 Screening Evaluation

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Although migration of contaminants would be reduced by engineering controls (multimedia cap, subsurface drains, slurry wall, and run-on/runoff controls), the waste material would not be treated; therefore, there would be no reduction of contaminant toxicity, mobility, or volume through treatment. However, contaminant migration will be decreased in the long term due to the engineering controls that would reduce infiltration through the wastes.

Long-Term Protection of Human Health and the Environment. While Alternative 2 would preclude direct contact and exposure to the wastes through containment within a capping system, the long-term protection of human health and the environment could not be assured because of several factors. Borings completed in the waste pits have shown that many of the waste materials have an elevated moisture content with significant amounts of the wastes being saturated. This indicates that a significant volume of contaminated leachate currently is present in the wastes. To meet remedial action objectives relative to groundwater, migration of this leachate would have to be effectively mitigated. Placement of an infiltration-limiting cover system could minimize significantly the

percolation of surface water into the wastes. This would not, however, affect the interstitial pore water (i.e. leachate) already in the wastes. Further, placement of the cover will add additional overburden on the waste which, in effect, produces a surcharging-like action. This will "squeeze out" the leachate and increase short-term transient drainage out of the wastes.

The waste pits cover a large contiguous area. The interior berms of the pits are difficult to distinguish. Therefore, placement of a horizontal-type drain system to intercept leachate would have to be from the perimeter of the pits. A related factor is that the distance from the bottom of the pits to the geologic formation of the Great Miami Aquifer is generally low. The Clearwell, Waste Pit 1, and Waste Pit 3 (representing almost half of the contaminated media volume) extend to within a few feet of the aquifer formation. In addition, based on geologic cross-sections presented in the Operable Unit 1 RI Report (DOE 1994a), higher permeability sand and gravel and silt may exist beneath Waste Pit 4 and the Burn Pit, introducing a preferential flow path into the aquifer formation. The combination of the size of the waste pit area with the proximity of the pits to the aquifer formation make installation of an effective sub-surface horizontal leachate interception system highly uncertain. In summary, effective mitigation of adverse groundwater impacts due to contaminated leachate within the waste pits can not be ensured by this alternative.

A second significant factor associated with this alternative is the fact that the wastes do not undergo any treatment to affect toxicity, mobility, or volume. Therefore, the protectiveness afforded by this alternative is due entirely to the engineered waste containment systems (slurry wall, waste cover, etc.). Most notable is the multimedia cap overlying the wastes. The cover essentially performs two functions. As referenced above, one is to preclude direct human and ecological contact and exposure to the wastes. The ability of the cap to perform this function over the long term (i.e. 1,000 years) is judged to be good, if human intrusion can be precluded (this could be an issue due to the agricultural attractiveness of the area) in the event that institution controls fail. The second primary function is to minimize infiltration of surface water through the wastes which would generate contaminated leachate that could potentially impact the Great Miami Aquifer. It is noted that, unlike engineered waste disposal facilities that are a part of other preliminary alternatives, for this alternative there is no containment redundancy offered by disposal facility liners or leachate collection systems. Therefore,

the ability of this alternative to provide long-term protectiveness is highly dependent on the ability of the single multimedia cap to effectively limit infiltration. This alone increases uncertainty relative to this alternative's ability to meet groundwater remedial action objectives and provide long-term protectiveness. Further increasing this uncertainty is the fact that there is significant potential for unacceptable cap deformation. This in turn could lead to breaches in the infiltration barriers within the multimedia cap. The potential for unacceptable cap deformation is due to the extreme heterogeneity of the wastes. This heterogeneity is in the form of varying degrees of waste moisture content and saturation, debris and actual waste form (filter cake, sump sludge, etc.). When these wastes are loaded by construction of a cap, the potential for significant differential settlement will exist. All of the above factors combine to form a conclusion that there is elevated uncertainty associated with this alternative relative to meeting groundwater remedial action objectives.

Short-Term Protection of Human Health and the Environment. Appropriate mitigative measures would be applied during remedial actions to ensure appropriate worker and public health exposure requirements are attained. This alternative is protective of both human health and the environment during remediation because the waste material remains in place, thereby minimizing the potential release of the waste material and direct contact with the waste material during remediation.

Potential short-term impacts associated with construction of the multimedia cap include the disturbance of soil, airborne emissions due to dust, and the displacement or loss of vegetation. Minimal impacts to wetlands and floodplain areas are anticipated. Overall, few additional risks to the public, workers, or the environment would result due to earth-moving activities.

Screening Criteria - Implementability

Technical Feasibility. Although the proposed containment technologies for in situ containment are widely used and well tested, a moderate level of difficulty would be experienced in construction of the multimedia cap, subsurface drains, and slurry wall. Construction of a multimedia cap over Waste Pits 3, 5, and 6 would be difficult without the use of physical stabilization techniques due to saturated waste conditions. There is potential for unacceptable cap deformation, as discussed previously.

Administrative Feasibility. This alternative is feasible based on administrative requirements. No permits or licenses are required to implement this alternative. Although minimal impacts are anticipated, there would be disturbances of wetlands. This would require coordination with the U.S. Army Corps of Engineers (COE) in addition to the State of Ohio and EPA Region V.

Availability of Services and Materials. No special equipment is required to implement this alternative. Installing an HDPE liner requires a specialty contractor. Resources required for construction, maintenance, and monitoring should be readily available.

Screening Criteria - Cost

The cost of this alternative, compared to other action alternatives, is low.

Capital Cost. The major components of capital cost include cap installation, slurry wall and groundwater well construction, and placement of monitoring systems.

O&M Cost. O&M costs include maintaining institutional actions and conducting a review every five years to ensure that the remedy continues to provide adequate protection. The cap is assumed to survive. Cap maintenance is assumed to be minimal (e.g., patching and mowing, for costing purposes).

Summary

There is significant uncertainty as to the ability of Alternative 2 to attain RAOs for the long term, particularly relative to groundwater. The alternative does not reduce the toxicity, mobility, or volume of wastes through treatment. Migration of and exposure to contaminants are reduced through engineering controls, but significant uncertainties relative to the long-term effectiveness exist due to the inability to intercept existing waste leachate and the long-term performance of the multimedia cap. The cost of this alternative is low compared to other preliminary alternatives. This alternative was screened out from further evaluation in the detailed analysis of alternatives because protectiveness cannot be adequately assured for all waste areas as discussed for the effectiveness criteria and because goals of waste treatment are not met.

3.3.3 Alternative 3 - In Situ Treatment and Containment

The following is a conceptual description of the in situ and containment alternative developed for the Operable Unit 1 Feasibility Study.

3.3.3.1 Description

This alternative is identical to Alternative 2, with the addition of a waste solidification step. The purpose of this additional process option is to promote the densification of the waste in a controlled manner which will minimize the potential for long-term waste settlement and the release of contaminated waste pit material to the underlying aquifer. The additional technologies that would be implemented by this alternative are shallow soil mixing and surcharging. Figure 3-3 illustrates a conceptual flow diagram for this alternative (relative to the waste pit contents). These additional technologies are further described as follows.

In Situ Physical Solidification

Material from the waste pits, Burn Pit, and Clearwell have a high moisture content ranging from 20 to 60 percent. Therefore, the potential for long-term waste settlement could be minimized if specific in situ physical solidification technologies were employed. Data from previous investigations indicate that Waste Pits 5 and 6 and the Clearwell only contain waste materials from plant production or surface soil sediments, whereas Waste Pits 1 through 4 and the Burn Pit contain drums, construction rubble, or miscellaneous site debris. Based on the composition of the various waste areas and access to the material (based on presence or lack of an existing soil cap), shallow soil mixing would be applied to the fairly homogeneous and accessible waste areas (Waste Pits 5 and 6 and the Clearwell) and surcharging, or overburdening, would be performed for the other waste areas that are more heterogeneous and/or less accessible. Each of these processes is further described below.

Shallow Soil Mixing

Shallow soil mixing of material in Waste Pits 5 and 6 and the Clearwell would involve mixing grout using a mixing head enclosed in a bottom-opened cylinder that allows a closed system for mixing the wastes and grout. As the mixing head blades pass in an up-and-down motion through the waste, a

negative pressure would be maintained on the cylinder headspace to pull up any vapors or dust to an air treatment system. This would solidify the waste and associated pore water into the grout matrix, thereby reducing the amount of standing water requiring removal and treatment at the AWWT facility. This would also reduce the mobility of contaminants in these treated wastes.

Surcharging

Waste Pits 1 through 4 and the Burn Pit would each receive a 5- to 6-meter (16- to 20-feet) thick soil overburden. Before the surcharge placement, a series of leachate (pore water) collection trenches and sumps would be installed in the surface of Waste Pits 1 through 4 and the Burn Pit. These would collect any liquids released during the surcharging process. A leachate collection system, in the form of wells, may also be used. All collected leachate would be treated by the AWWT facility.

Preliminary estimates of size and configuration, remediation time frame, spatial requirements, packaging/transportation requirements, and wastes generated for Alternative 3 are as follows.

Size and Configuration

Approximate sizes and numbers of components for this alternative, are preliminary and subject to change based upon additional information acquired for each alternative during detailed analysis. Except for the in situ treatment area, these are the same as for Alternative 2. The following components, which are identical to those for in situ contaminant, would be included: 10 subsurface drains, a slurry wall, 16 groundwater extraction/monitoring wells, a 10-hectare (24 acres) cap, and removal of approximately 15,500 square meters (20,200 square yards) surface soil. In addition, shallow soil mixing and surcharging would be included.

Remediation Time Frame

Remediation is estimated to take approximately 2 years from the initial staging of construction equipment to the final capping of the waste areas.

Spatial Requirements

Overall area at the FEMP site required for implementation of this alternative is approximately 16 hectares (40 acres), of which approximately 10 hectares (24 acres) would be capped.

Packaging/Transportation Requirements

The only transportation requirement identified is transporting the slurry mix, cement, and other materials to the site.

Waste Generated

Waste generated during remediation by in situ treatment and containment includes: personal protective equipment (protective clothing, gloves, HEPA filters, etc.), equipment not feasible to decontaminate, and nonhazardous solid waste from debris and equipment.

3.3.3.2 Screening Evaluation

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Although migration of contaminants would be reduced by the shallow soil mixing, surcharging, placement of a multimedia cap, leachate collection/disposal system (LC/DS), slurry wall, and run-on/runoff controls, the waste material, except for Waste Pits 5 and 6 and the Clearwell, would not be treated; therefore, there is limited reduction of contaminant toxicity, mobility, or volume through treatment. Shallow soil mixing of Waste Pit 5, Waste Pit 6, and the Clearwell could reduce the mobility of the wastes and the amount of water requiring treatment at the AWWT facility. The volume of contaminated material would increase due to the addition of grout although the mass of contaminants themselves would not increase.

Long-Term Protection of Human Health and the Environment. Alternative 3 would preclude direct contact and exposure to the waste material through limited treatment and containment within a capping system; however, uncertainties exist relative to the long-term protection of human health and the environment. In addition to the long-term effectiveness concerns associated with Alternative 2, which would apply directly to those waste pits not being treated (i.e. Pit 1 - 4, Clearwell, and Burn

Pit), there are uncertainties associated with the additional waste treatment. The shallow soil mixing would not directly affect the mobility of volatile organics in the pits. In fact, the presence of organics has been shown to interfere with the effectiveness for this and similar technologies in reducing the mobility of radiological and inorganic, contaminants. Organics can interfere with the pozolanic bonding which allows the treated waste to "set up" and gain a degree of structured stability. By applying 5 to 6 meters (16 to 20 feet) of overburden to the pits, the surcharging could actually increase short-term impacts to the Great Miami Aquifer. The success of surcharging depends on the ability of the trench drains to collect and direct transient moisture from the wastes away from the Great Miami Aquifer. The uncertainties associated with this are as discussed for Alternative 2.

Short-Term Protection of Human Health and the Environment. Potential short-term impacts associated with construction of the multimedia cap include the disturbance of soil, airborne emissions (due to fugitive dust), and the displacement or loss of vegetation. However, appropriate mitigative measures would be implemented to ensure compliance with DOE orders for exposure, as well as other worker and public health protection requirements. This alternative is protective of both human health and the environment during remediation.

Screening Criteria - Implementability

Technical Feasibility. Although the proposed solidification and containment technologies are widely used and well tested, a moderate level of difficulty would be experienced in performing shallow soil mixing, constructing the multimedia cap, subsurface drains, and slurry wall. The maintenance required for this alternative would be minimal.

Administrative Feasibility. This alternative is feasible based on administrative requirements. No permits or licenses are required to implement this alternative. Although minimal impacts are anticipated, impacts to wetlands would require coordination with the COE in addition to the State of Ohio and EPA Region V. The necessary deed restrictions and marking could be readily implemented.

Availability of Services and Materials. The required services and materials for Alternative 3 are readily available. This alternative can be implemented using readily available resources.

Screening Criteria - Cost

Compared to the other action alternatives, the costs associated with this alternative are moderately low.

Summary

There is significant uncertainty as to the ability of this alternative to attain groundwater RAOs for the long term, for the reasons associated with Alternative 2 and uncertainties associated with additional treatment of wastes. This alternative only treats some of the waste. This alternative does not reduce the toxicity of any wastes. Mobility of wastes is only reduced for the waste treated by shallow soil mixing, but in the process, it also increases the volume of contaminated material. The cost of this alternative is moderately low. Alternative 3 was screened out from further evaluation because long-term protectiveness of human health and the environment cannot be adequately assured as discussed for the effectiveness criteria.

3.3.4 Alternative 4A - Removal, Treatment (Vitrification), and On-Property Disposal

3.3.4.1 Description

This alternative would include water extraction and transfer to the AWWT facility for treatment, surface soil excavation, removal of the materials from the Waste Pits 1 through 6, Burn Pit, and Clearwell, treatment of the waste material, on-property disposal of the treated material, site restoration, and decontamination and decommissioning of the treatment facilities. The technologies included in this alternative are mechanical and slurry removal systems, drying, vitrification, on-property disposal, run-on/runoff controls, monitoring, and access controls. Figure 3-4 illustrates a conceptual flow diagram for this alternative, as well as for Alternatives 4B, 4C, 5A, and 5B. The process options selected for this alternative are described as follows.

Water Extraction and Treatment

Wastewater in the waste areas, perched groundwater, surface water, water entrained in the waste and water incidental to excavation and other water would be removed as required, and all wastewater would be transferred to the AWWT facility, as described in Section 3.2.3.2.

Waste Removal

Excavation of surface soils and Waste Pits 1 through 6, the Burn Pit, and the Clearwell would entail both dry and wet excavation methods. Select segregation of large structural shapes (e.g., steel beams) and appropriate disposal would be performed. The excavation and processing equipment would be selected to handle waste materials present in the pits, such as sludge, steel drums, timber, and other material.

The existing dredge would be used at Waste Pit 5 while a loader-excavator or a hydraulic front shovel would be used to excavate all remaining pits, including Waste Pit 6 and the Clearwell. The hydraulic front shovel would be the primary excavator while the tracked excavator would be used to excavate ramps into the pits, remove clay and plastic linings, to grade pit floors, and backup the front shovel. The overall removal rate would be controlled by the waste processing rate, which would be approximately 363 metric tons/day (400 tons/day).

Wastes would be covered during excavation except for the face being excavated to minimize rain infiltration and unnecessary exposure of waste to the environment. Waste pits would be backfilled and regraded concurrently with waste excavation. Dust and contaminant control measures would be employed.

Surge capacity in an enclosed building would be provided to accommodate excess waste removal and constant feed to the crusher-shredder and dryer. A storage capacity of 13,608 metric tons (15,000 tons) was assumed. The building would be ventilated with air exhausted through ducts and directed to high-efficiency particulate air (HEPA) filters. The building would also house the crusher-shredder and feed hopper to the rotary dryer.

Waste Processing and Treatment

Crushing/Shredding. Excavated waste material would be transported to the waste processing/stockpile building for crushing, shredding, and drying prior to treatment using vitrification. Trucks would be used to transport excavated materials to the waste processing/stockpile building. A scraper would move contaminated waste from the truck dumping point up a short incline, and into the crusher-shredder hopper. The pit wastes would be screened of large, metallic items not suitable for shredding (e.g., large structural steel shapes). Contaminated sludges, soils, and liner materials that drop through the grizzly would be conveyed to the feed hopper for the rotary dryer. A thickener would be used to dewater and thicken slurry from Waste Pit 5 (or other pits as appropriate) dredging prior to drying.

The wastes would first be processed through a shredder as a feed preparation step. The shredder would provide size reduction to less than 15 centimeters (6 inches), homogenization, and partial dewatering of the dryer feed by the squeezing action of the shredder. The water removed by the shredder would be sent to a clarifier. The liquid waste would be sent to the AWWT facility, while the solid waste (sludge) would be fed to the dryer.

Drying. The dryer would be designed to dry the waste at 150°C (300°F) to achieve optimal moisture for further size reduction and screening of the waste. Each dryer would provide approximately one-hour residence time for drying. Drying gases produced in the combustion chamber would enter the furnace enclosing the rotating drum at controlled rate and temperature. Cooled drying gases would leave the dryer at about 120°C (250°F). Heat energy would be transferred from the hot gases into the waste material indirectly through the shell without any contact between the gases and the waste material. All equipment would operate under negative pressure. Dried material from the dryer would be subjected to the screening and size reduction process to remove items that could not be reduced or vitrified to provide less than 1-centimeter (3/8-inches) diameter feed material to the vitrifier. This material would be re-routed back into the size reduction process.

Off-Gas System. Process gas (evaporated water and leak-in air) from the dryer would be passed to a shell/tube type condenser where steam will be condensed with cooling water. Condensate would be

returned to the clarifier to join water removed by the shredder. Noncondensible gases (leak-in air) from both dryers would be combined and passed through a water knock-out drum and mist eliminator. Water removed would be returned with the condensates to the clarifier. Gas leaving the mist eliminator would be heated and filtered through the pre-HEPA and HEPA-filters, and discharged to the atmosphere.

Vitrification. Feed material would be transferred into the feed bins of four vitrifiers. Feed from the bins would be withdrawn at a controlled rate and transferred for blending with the necessary glass-forming additives to prepare the specified furnace feed composition, which was assumed for costing purposes to be 60 percent pit wastes, 20 percent soil, 10 percent silica (quartz), and 10 percent flux (sodium carbonate).

The waste blended with additives would be fed through the top of the vitrification furnaces. This dried feed would form a cold cap on top of the molten glass pool. There would be four nominal 100-ton per-day furnaces able to provide 400 tons-per-day capacity. Joule-heated furnaces were included in the cost estimate, but the actual vitrification technology would be chosen during remedial design. The waste and additives would leave the vitrifiers as a molten glass stream which would then be fritted by quenching in water. The frit would be dried with hot air from the dryer stack. The water vapor from the quencher and the frit drying air would be combined with the vitrification off-gas and passed through a combination quencher/scrubber to cool the off-gas and remove pollutants through pre-HEPA and HEPA filters.

The frit from each vitrifier would be conveyed to a load-out silo. The silos would have a three-day surge capacity.

On-Property Disposal Facility

The engineered disposal cell was selected as the representative process option for on-property disposal of Operable Unit 1 remediation waste in this alternative. Refer to Appendix B for a full definition of "disposal cell." The preliminary cross-section is subject to change on the basis of the decision regarding the type and quantity of waste proposed for on-property disposal, and to the requirements

provided through detailed design engineering. The above-grade disposal cell has been tentatively cited on the northwest corner of the Operable Unit 3 process area of the FEMP property. The final location of any required on-property disposal system may be modified pending final analysis of ongoing geological site characterization data and detailed evaluation of federal and state ARARs/TBCs.

Saturated zones are present in the glacial overburden. Many clayey and silty sand lenses are observed to be saturated and much of the clay till strata are assumed to be saturated. The saturated strata are said to have perched groundwater. The design for the above-grade disposal cell would contain provisions for the implementation of engineering controls to eliminate the potential for lateral transport of groundwater in sand lenses occurring in soils beneath the facility. These controls could include excavation of shallow sand lenses and replacement with compacted clay.

The disposal cell would be of uniform design to handle vitrified waste. The cell would have capacity for approximately 486,000 cubic meters (636,000 cubic yards) of wastes (in-place). The disposal cell would incorporate design features specified in RCRA and UMTRA disposal cell criteria, and 40 CFR 192.

The disposal cell would be a square, above-grade cell with an approximate footprint of 16 hectares (39 acres). The cell would have a riprap lined channel along the east, north, and west sides to protect the cell from the probable maximum flood. The bottom of the disposal cell would have a double liner with an LC/DS extending to the clean fill dikes surrounding the waste, and a multi-layered engineering cover consisting of: an upper vegetative layer, gravel filter layer, a cobble biotic barrier, a sand drainage layer, textured high density polyethylene (HDPE) with a geosynthetic clay liner layer, a low permeability clay layer with a maximum vertical permeability of 1×10^{-7} centimeters per second, and a contouring fill layer.

Site Restoration

The excavated waste pit area would be restored with backfill and a cover system. To complete the cover system, clean soil obtained from an off-site location would be used to backfill the waste pit area

and re-establish grades to promote surface runoff and drainage away from the waste pit area. A cover system designed for 1,000 years would consist of a vegetative soil layer, a high-permeability drainage layer, and composite infiltration barrier (synthetic and natural materials). The multi-layer cover system for the waste pit area would have an estimated total thickness of 1.9 meters (6.3 feet) and a cap area of approximately 10 hectares (24 acres). With this cover system design, only minimal amounts of precipitation would pass through the cover system. The final cover vegetation system would be selected such that minimal maintenance would be required. The majority of the backfill soils would come from a new borrow pit, planned to be established immediately north of the railroad tracks on the north side of the waste pit area.

Controls to minimize dust generation and storm water runoff and erosion would be maintained throughout waste pit area restoration.

Decontamination and Decommissioning

Decontamination and decommissioning of waste processing equipment and facilities would be performed as described in Section 3.2.3.4.

Run-on/Runoff Control

The diversion/collection, grading, and revegetation measures described for Alternatives 2 and 3 would be used both on the multilayer cover and the disposal cell to minimize surface erosion.

Monitoring

Groundwater monitoring would be a part of all remedial alternatives that leave material on property. Groundwater monitoring networks would be designed to be consistent with requirements and would operate until site-wide RAOs are attained; they would satisfy any post-closure monitoring or CERCLA five year review requirements. Additional monitoring includes air quality, leachate, and surface water/sediment monitoring described in Section 3.2.3.1.

Access Controls

The physical barriers and administrative controls described in Section 3.2.3.1 would be provided.

Preliminary estimates of size and configuration, remediation time frame, spatial requirements, packaging/transportation requirements, and wastes generated for Alternative 4A are as follows:

Size and Configuration

- The removal rate would be 400 TPD
- The processing rate (for drying and vitrification)-would be up to 400 TPD
- Volume of vitrified product disposed would be approximately 486,000 cubic meters (636,000 cubic yards)

Remediation Time Frame

Site preparation, material processing facility construction, and processing equipment installation would take approximately one year. Waste removal, processing, and disposal would take an additional ten years. The total remediation time for this alternative would be approximately 11 years. During this time, the on-property disposal facility would be constructed.

Spatial Requirements

Overall area at the FEMP site required for implementation of this alternative is approximately 38 hectares (93 acres).

Packaging/Transportation Requirements

Trucks or a conveyor would transfer vitrifier frit from the load-out silo to the on-property disposal cell.

Waste Generated

- The wastewater from removal activities (treated in AWWT facility)
- The personal protective equipment
- The equipment not feasible to decontaminate
- The nonhazardous solid waste from debris and equipment

3.3.4.2 Screening Evaluation

Screening Criteria - Effectiveness Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Vitrification has been demonstrated to be effective in treating radioactive and hazardous waste materials, although it has been limited to bench-scale level testing. To better understand the applicability and effectiveness of vitrification on the treatment of waste pit, Burn Pit, and Clearwell waste materials, treatability studies were conducted. A more detailed discussion of these treatability studies is provided in Section 4.0 and in Appendix C of this document.

Based on the results of the treatability studies performed, vitrification was generally effective in reducing the toxicity characteristics of the material and the mobility of the contaminants. Toxicity and mobility impacts of vitrification were measured by the results of Toxicity Characteristic Leaching Process (TCLP) analyses. Leachate from TCLP analyses of vitrified waste material met regulatory criteria for land disposal. Vitrification achieves a reduction in contaminant volume and, through residual organic destruction, some reduction in toxicity. There is an approximate 20 percent reduction in waste volume that is generally offset by the addition of reagents for the vitrification process (flux, etc.). Contaminants remaining in the vitrified mass are relatively immobile. After treatment, the material would be disposed of in an above-grade disposal cell with a multimedia cap, LC/DS, and run-on/runoff controls to further minimize the potential for contaminant migration.

Long-Term Protection of Human Health and the Environment. While the solidified material is very resistant to leaching, the radioactivity of the waste would remain unchanged by treatment. The treated wastes would be disposed in an above-grade disposal cell having an LC/DS. The disposal cell would be cited over a sole-source aquifer in an area of moderate rainfall. At the FEMP site, the till with its appreciable silt and clay content is regarded as providing the Great Miami Aquifer with a degree of protection from surface contaminants. The low hydraulic conductivities of clay strata produces very low groundwater velocities even if the hydraulic gradients are high. Additionally, all contaminants of concern being transported by seepage through more than 15 feet of clay till (required by State of Ohio siting criteria for sanitary waste landfills) undergo attenuation and retardation.

At the FEMP, the glacial overburden is hydraulically separated from the saturated portion of the Great Miami Aquifer by a sequence of unsaturated sand and gravel. This is supported by the available geologic and hydrogeologic data on the glacial till at the FEMP and more specifically from data collected within the area of the proposed disposal facility. Downward transport of groundwater and potential contaminants is insignificant due to the thickness of glacial overburden present. Lateral transport is presumed to be possible within these small sand lenses of the glacial overburden; however, engineering measures would mitigate any potentially significant lateral transport. The low permeability, clay glacial overburden coupled with the engineered features of the disposal facility, while not creating an absolute barrier to groundwater migration, provide a superior protective barrier to preclude the migration of contaminants.

The disposal facility would be designed for a 1,000-year life. Performance of the disposal facility would be defined by a monitoring system. Vitrification can yield a superior waste form that is resistant to leaching of contaminants. As designed, the engineered disposal facility would provide adequate containment and isolation of treated waste. Therefore, this alternative is considered to be capable of providing long-term protection of human health and the environment.

Short-Term Protection of Human Health and the Environment. Short-term exposure to workers is anticipated due to the waste material handling associated with the removal, treatment, disposal, and construction of the various remediation facilities. By designing the remedial action in accordance with as low as reasonably achievable (ALARA) principles, industry and Occupational Safety and Health Act (OSHA) codes and requirements, and DOE orders (e.g., regarding air emission control systems, shielding, and appropriate personal protective equipment for the remediation workers), risks due to contaminant exposure would be controlled to acceptable levels.

Screening Criteria - Implementability

Technical Feasibility. Vitrification is considered an innovative technology. In spite of successful bench-scale treatability studies, the technical feasibility of implementing an effective full-scale system for this waste material is undetermined. A moderate level of difficulty would be experienced in the removal of the waste materials from the waste pits, Burn Pit, and Clearwell. The construction of the

treatment facility is moderately implementable. Monitoring of influent conditions to determine the appropriate additive mixtures due to the heterogeneity of the wastes would be difficult. Also, effluent characteristics and off gas monitoring would present difficulties in the waste processing. The waste disposal facility would be designed to preclude the need for long-term maintenance. Similar facilities are in use throughout the hazardous and low level waste disposal industry. Thus, overall this alternative is difficult to implement based on these technical issues.

Administrative Feasibility. No permits or licenses would be required. However, the substantive technical requirements of air emissions permits would need to be demonstrated. In addition, a waiver or exemption from the State of Ohio regulation that prohibits construction of a sanitary waste landfill over a sole-source aquifer would be required. This would be moderately difficult.

Availability of Services and Materials. The equipment and engineering required for full-scale vitrification are not readily available and its construction and operation are complex. The availability of trained and experienced operators of joule heated melters is limited. High level of maintenance is required for operation of the vitrification system. As a result, the implementability of this alternative is judged to be difficult.

Screening Criteria - Cost

Compared to other action alternatives, the cost of this alternative is moderately high.

Summary

This alternative can be effective in reducing the toxicity, mobility, or volume of contaminants. RAOs would be achieved. Short-term effectiveness is moderate due to the required waste removal and treatment system operations. This alternative has moderately high costs, but it is also potentially effective because it treats contaminants. This alternative was retained for detailed evaluation because of the long-term effectiveness achieved through treatment and containment.

3.3.5 Alternative 4B - Removal, Treatment (Cement Solidification), and On-Property Disposal

3.3.5.1 Description

This alternative is identical to Alternative 4A, with the exception that the waste would be treated using cement solidification instead of vitrification. During waste processing, pit wastes would be dried prior to cement solidification. The additional waste volume generated by cement solidification would increase the size of the disposal cell. Other than that, the cell design would be the same. Figure 3-4 illustrates a conceptual flow diagram for this alternative. Those components that differ from the components of Alternative 4A are as follows.

Cement Solidification

The cement solidification system would be designed to process 720 wet tons per day (60 wet tons of waste per hour, 12 hours per day). Based on this capacity, the waste would be handled by two pugmill mixers in parallel served by three feed hoppers. Additive materials would be withdrawn from the hoppers, collected, and conveyed into the mixers at predetermined rates as required by the formulation requirements (to be determined). Residence time in the pugmill mixer would be approximately 5 minutes.

A common material handling system would receive the mixed material from the pugmill mixers, then transfer and place the material into the disposal cell. Solidified material would be placed in the cell through a distributor conveyor, spread, and compacted in 30-centimeter (12-inch) lifts.

On-Property Disposal Facility

An on-property disposal cell would be constructed as described in Section 3.3.4.1, except the capacity of the disposal facility would be increased to 1,000,000 cubic meters (1,300,000 cubic yards).

Preliminary estimates of size and configuration, remediation time frame, spatial requirements, packaging/transportation requirements, and wastes generated for Alternative 4B are as follows.

Size and Configuration

The following preliminary estimates are based upon data available during the initial screening process:

> The removal rate would be 653 metric tons (720 tons) per day; the processing rate for cement stabilization would be a maximum of 653 metric tons (720 tons) per day. The volume of cement product disposed is approximately 1,000,000 cubic meters (1,300,000 cubic yards).

Remediation Time Frame

Site preparation, material processing facility construction, and material removal and processing equipment installation would take approximately one year. Waste removal, processing, and disposal would take an additional five years. During this time, the on-property disposal facility would be constructed.

Spatial Requirements

Overall area at the FEMP site required for implementation of this alternative is approximately 67 hectares (166 acres).

Packaging/Transportation Requirements

Cement-solidified material would be transferred from the load-out/transfer system to the on-property disposal cell using a distributor conveyor.

Waste Generated

Waste generated by Alternative 4B include wastewater from removal activities (treated in the AWWT facility), personal protective equipment (protective clothing, gloves, HEPA filters, carbon adsorption media, etc.), equipment not feasible to decontaminate, and nonhazardous solid waste from debris and equipment.

3.3.5.2 Screening Evaluation

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Cement solidification has, in certain instances, been effectively implemented to treat radiological and hazardous waste materials. To better understand the applicability and effectiveness of cement stabilization on the

treatment of waste pit, Burn Pit, and Clearwell materials, treatability studies were conducted. A more detailed discussion of these treatability studies is provided in Section 4.0 and in Appendix C of this document.

Based on the results of the treatability studies performed, cement solidification was generally effective (depending on the formulation and the specific waste) in reducing the toxicity characteristics of the material and the mobility of the contaminants. Leachate from TCLP analyses of cement-solidified waste material met regulatory criteria for land disposal. However, the formulations tested for Waste Pit 4 were not as effective in preventing the leaching of uranium. Also, cement alone was not successful in solidifying the material from the Burn Pit; the addition of blast furnace slag effectively solidified the Burn Pit material, but the durability of the resultant product did not pass American Society of Testing and Materials (ASTM) standards, Method D4842-90, the standard test for determining the resistance of solid waste to freezing and thawing, and ASTM Method 4843-88, the standard test method for wetting and drying of solid waste. Cement stabilization results in an increased volume of treated material, with a bulking factor of approximately two, depending on the material. Contaminants remaining in the cement-solidified material are relatively immobile. After treatment, the material would be stored in an above-grade disposal cell with a multimedia cap, LC/DS, and run-on/runoff controls to minimize the potential for contaminant migration.

Long-Term Protection of Human Health and the Environment. While the cement-solidified material is resistant to leaching (with Waste Pit 4 and the Burn Pit less resistant), the radioactivity associated with the waste materials would remain unchanged. The treated materials would be disposed of in an above-grade disposal cell with LC/DS. The material would be sited over a sole-source aquifer in an area of moderate rainfall. This alternative has the potential to be protective of human health and the environment for the long term. This is due to the potential for cement solidification to effectively limit the mobility of certain contaminants. It is also due to the potential for the engineered waste disposal facility to effectively contain treated waste. However, it is noted that treatability study results for Waste Pit 4 and the Burn Pit (poor leachability reduction and problems with pozolanic bonding) indicate that some uncertainty exists relative to the technology for the operable unit as a whole.

Short-Term Protection of Human Health and the Environment. Short-term exposure to workers is anticipated due to the waste material handling associated with the removal, treatment, disposal, and construction of the various remediation facilities. By designing the remedial action in accordance with ALARA principles, industry and OSHA codes and requirements, and DOE Orders (e.g., regarding air emission control systems, shielding, and appropriate personal protective equipment for the remediation workers), risks due to contaminant exposure could be controlled to acceptable levels. Appropriate measures to minimize workers' physical and exposure hazards would be taken. Thus, this alternative would provide short-term protection to human health and the environment.

Screening Criteria - Implementability

Technical Feasibility. A moderate level of difficulty would be experienced in the removal of the waste materials from the waste pits, Burn Pit, and Clearwell. The construction of the treatment facility is readily implementable because cement solidification equipment is readily available. However, the uncertainties in the monitoring of influent conditions to determine the appropriate additive mixtures due to the heterogeneity of the wastes make quality control very difficult. Therefore, overall, the technical feasibility of implementing an effective full-scale cement solidification system for this material is difficult.

Administrative Feasibility. No permits or licenses would be required. However, the substantive technical requirements of air emissions permits would need to be demonstrated. The same issue relative to disposal of wastes of the sole-source aquifer discussed for Alternative 4A applies for this alternative. This makes the alternative more difficult to implement.

Availability of Services and Materials. The equipment and engineering required for full-scale cement solidification are readily available and its construction is common.

Screening Criteria - Cost

Compared to the costs of other action alternatives, the cost of this alternative is moderate.

Summary

This alternative has the potential to be effective in reducing the mobility of contaminants, except for Waste Pit 4 and the Burn Pit. Additional testing of different formulations would be required for these materials in order to identify the most effective formulation. However, a significant increase in volume results. RAOs could be achieved. Waste removal and treatment system operations contribute to the difficult implementability of this alternative. This alternative has moderate costs. It is potentially effective because it stabilizes contaminants and isolates them in an engineered waste disposal facility. This alternative was retained for detailed evaluation because of its increased long-term effectiveness achieved through stabilization and containment.

3.3.6 Alternative 4C - Removal, Treatment (Drying), and On-Property Disposal

3.3.6.1 Description

This alternative would include water extraction and transfer to the AWWT facility for treatment, surface soil excavation, removal of the materials from the waste pits, Burn Pit, and Clearwell, treatment (drying) of the waste material, on-property disposal of the treated material, site restoration, and decontamination and decommissioning of the treatment facilities. The technologies included in this alternative are mechanical and slurry removal systems, drying, on-property disposal, run-on/runoff controls, monitoring, and access controls. Figure 3-4 illustrates a conceptual flow diagram for this alternative, as well as for Alternatives 4A, 4B, 5A, and 5B. The process options selected for this alternative are described as follows.

Water Extraction and Treatment

Wastewater in the waste areas, perched groundwater, surface water, water entrained in the waste and water incidental to excavation and other water would be removed as required, and all wastewater would be transferred to the AWWT facility, as described in Section 3.2.3.2.

Waste Removal

Excavation of surface soils and Waste Pits 1 through 6, the Burn Pit, and the Clearwell would entail both dry and wet excavation methods. Select segregation of large structural shapes (e.g., steel beams) and appropriate disposal would be performed. The excavation and processing equipment would be

selected to handle waste materials present in the pits, such as sludge, steel drums, timber, and other material.

The existing dredge would be used at Waste Pit 5 while a loader-excavator or a hydraulic front shovel would be used to excavate all remaining pits, including Waste Pit 6 and the Clearwell. The hydraulic front shovel would be the primary excavator while the tracked excavator would be used to excavate ramps into the pits, remove clay and plastic linings, to grade pit floors, and backup the front shovel. The overall removal rate would be controlled by the drying processing rate, which would be approximately 1,440 wet tons/day.

Wastes would be covered during excavation except for the face being excavated to minimize rain infiltration and unnecessary exposure of waste to the environment. Waste pits would be backfilled and regraded concurrently with waste excavation. Dust and contaminant control measures would be employed.

Surge capacity in an enclosed building would be provided to accommodate excess waste removal and constant feed to the crusher-shredder and dryer. A storage capacity of 13,608 metric tons (15,000 tons) was assumed. The building would be ventilated with air exhausted through ducts and directed to high-efficiency particulate air (HEPA) filters. The building would also house the crusher-shredder and feed hopper to the rotary dryer.

Waste Processing and Treatment

Crushing/Shredding. Excavated waste material would be transported to the waste processing/stockpile building for crushing, shredding, and drying. Trucks would be used to transport excavated materials to the waste processing/stockpile building. A scraper would move contaminated waste from the truck dumping point up a short incline, and into the crusher-shredder hopper. The pit wastes would be screened of large, metallic items not suitable for shredding (e.g., large structural steel shapes). Contaminated sludges, soils, and liner materials that drop through the grizzly would be conveyed to the feed hopper for the rotary dryer. A thickener would be used to dewater and thicken slurry from Waste Pit 5 dredging (and other pits as appropriate) prior to drying.

The wastes would first be processed through a shredder as a feed preparation step. The shredder would provide size reduction, homogenization, and partial dewatering of the dryer feed. The water removed by the shredder would be sent to a clarifier. The liquid waste would be sent to the AWWT facility, while the solid waste (sludge) would be fed to the dryer.

Drying. The dryer would be designed to dry the waste at 150°C (300°F) to achieve optimal moisture content for further size reduction and screening of the waste, as well as for waste placement and compaction in the on-site disposal vault.

Off-Gas System. Process gas (evaporated water and leak-in air) from the dryer would be passed to a shell/tube type condenser where steam will be condensed with cooling water. Condensate would be returned to the clarifier to join water removed by the shredder. Noncondensible gases (leak-in air) from both dryers would be combined and passed through a water knock-out drum and mist eliminator. Water removed would be returned with the condensates to the clarifier. Gas leaving the mist eliminator would be heated and filtered through the pre-high-energy particulate air (pre-HEPA) and HEPA filters, and discharged to the atmosphere.

On-Property Disposal Facility

The engineered disposal vault was selected as the representative process option for on-property disposal of Operable Unit 1 remediation waste for this alternative. Refer to Appendix B for a definition of "disposal vault". The reason for selecting the disposal vault as the representative design for this alternative relates directly to short-term risks during placement of treated wastes. For Alternatives 4A and 4B the treated wastes will be in a solid matrix (by vitrification and cement solidification, respectively) and resistant to entrainment in air and surface water (rainfall) runoff. In Alternative 4C, however, the form of the dried waste is such that it would be highly susceptible to air or water (from rain) entrainment. This increases the short-term risks associated with placement. Disposal in an enclosed disposal vault is a method of mitigating these risks versus placement in an open disposal cell. The above-grade disposal vault has been preliminarily sited on the northwest corner of the Operable Unit 3 process area of the FEMP property. The final location of any required on-property disposal system would be modified pending final analysis of ongoing geological site

characterization data and detailed evaluation of federal and state ARARs/TBCs as well as ongoing evaluations by other operable units.

Saturated zones are present in the glacial overburden. Many clayey and silty sand lenses are observed to be saturated and much of the clay till strata are assumed to be saturated. The saturated strata are said to have perched groundwater. The design for the above-grade disposal vault would contain provisions for the implementation of engineering controls to eliminate the potential for lateral transport of groundwater in sand lenses occurring in soils beneath the facility. These controls could include excavation of shallow sand lenses and replacement with compacted clay.

The disposal vault would be of uniform design to handle the waste. The vault would have capacity for approximately 493,000 cubic meters (645,000 cubic yards) (in-place) of compacted waste. The disposal vault would incorporate design features specified in RCRA and UMTRA disposal cell criteria, and in 40 CFR 192.

The disposal vault would be a rectangular, above-grade vault with concrete floor slab and walls, divided into individual cells by interior concrete walls, and covered with a multimedia cap. The overall footprint of the vault would be approximately 38 hectares (93 acres). A riprap-lined channel would be constructed along the east, north, and west sides to protect the vault from the probable maximum flood. The vault slab and walls would act as a base for supporting a double liner system and an LC/DS extending to all perimeter walls. The vault would have a multi-layered engineered cover consisting of: an upper vegetative layer, gravel filter layer, a cobble biotic barrier, a sand drainage layer, textured high density polyethylene (HDPE) with a geosynthetic clay liner layer, a low permeability clay layer with a maximum vertical permeability of 1×10^{-7} centimeter per second, and a contouring fill layer.

Site Restoration

Following waste pit excavation, site restoration would be required to complete the waste pit area cover system, clean soil obtained off site would be used to backfill the waste pit area and re-establish grades to promote surface runoff and drainage away from the waste pit area. A cover system

designed for 1,000 years would consist of a vegetative soil layer, a high-permeability drainage layer, and composite infiltration barrier (synthetic and natural materials). The multi-layer cover system for the waste pit area would have an estimated total thickness of 1.9 meters (6.3 feet) and a cap area of approximately 10 hectares (24 acres). With this cover system design, only minimal amounts of precipitation pass through the cover system. The final cover vegetation system would be selected such that minimal maintenance would be required.

Controls to minimize dust generation and storm water runoff and erosion would be maintained throughout waste pit area restoration.

Decontamination and Decommissioning

Decontamination and decommissioning of waste processing equipment and facilities would be performed as described in Section 3.2.3.4.

Run-on/Runoff Control

The diversion/collection, grading, and revegetation measures described for Alternatives 2 and 3 would be used both on the multilayer cover and the disposal vault to minimize surface erosion.

Monitoring

Groundwater monitoring would be a part of all remedial alternatives that leave material on property. Groundwater monitoring networks designed to be consistent with requirements would continue until site-wide RAOs are attained; they would satisfy any post-closure monitoring or CERCLA 5-year review requirements. Additional monitoring includes air quality, leachate, and surface water/sediment monitoring described in Section 3.2.3.1.

Access Controls

The physical barriers and administrative controls described in Section 3.2.3.1 would be provided.

Preliminary estimates of size and configuration, remediation time frame, spatial requirements, packaging/transportation requirements, and wastes generated for Alternative 4C are as follows.

Size and Configuration

- The removal rate would be 1,206 metric tons (1,440 tons) per day.
- The processing rate (for drying) would be up to 1,206 metric tons (1,440 tons) per day.
- Volume of dried waste disposed would be approximately 493,000 cubic meters (645,000 cubic yards) after compaction.

Remediation Time Frame

Site preparation, material processing facility construction, and material removal and processing equipment installation would take approximately one year. Waste removal, processing, and disposal would take an additional five years. The total remediation time for this alternative would be approximately five years. During this time, the on-property disposal facility would be constructed.

Spatial Requirements

The overall area at the FEMP site required for implementation of this alternative is approximately 38 hectares (93 acres).

Packaging/Transportation Requirements

Trucks would transfer dried waste, from the treatment facility to the on-property disposal vault.

Waste Generated

- The wastewater from removal activities (treated in AWWT facility).
- The personal protective equipment.
- The equipment not feasible to decontaminate.
- The nonhazardous solid waste from debris and equipment.

3.3.6.2 Screening Evaluation

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. There is no expected effect on the mobility of contaminants from a leachability standpoint. The toxicity of the wastes

would not be affected. Dried waste would be much more susceptible to resuspension in air. Drying slightly decreases the volume of waste by removing water.

Long-Term Protection of Human Health and the Environment. While the leachability of inorganics and the radioactivity of the waste would remain unchanged by treatment, the dried wastes would be disposed in an above-grade disposal vault with a LC/DS. The disposal vault would be sited over a sole- source aquifer in an area of moderate rainfall.

Because the waste material would remain on site and virtually unchanged, the protectiveness of this alternative would depend entirely upon the performance of the disposal vault. The disposal vault would attain a high degree of containment because of the reinforced concrete walls and bottom slab, and would be designed for a 1,000-year life. Performance of the disposal facility would be defined by a monitoring system. This alternative has the potential to be protective of human health and the environment for the long term.

Short-Term Protection of Human Health and the Environment. Short-term exposure to workers is anticipated due to the waste material handling associated with the removal, treatment, disposal, and construction of the various remediation facilities. Minimal impacts to wetlands, floodplain, or wildlife are anticipated. By designing the processing facility in accordance with as low as reasonably achievable (ALARA) principles, industry and Occupational Safety and Health Act (OSHA) codes and requirements, and DOE Orders (e.g., regarding air emission control systems, shielding, and appropriate personal protective equipment for the remediation workers), risks due to contaminant exposure could be controlled to acceptable levels.

However, there are potential short-term concerns associated with removal and handling of the waste material, especially after the drying process. Appropriate measures to minimize workers' physical and exposure hazards would be taken, but in some phases of the remediation, these measures may not be adequate for unexpected events such as extreme weather conditions. For example, at the point of disposal, the dry, powdery waste form would lend itself to resuspension and migration in high winds. Dust control measures utilizing water could not be used, since the low moisture content of the dried

waste would have to be maintained for optimal placement and compaction. A storm event during waste placement activities could result in highly contaminated runoff that may be difficult to control even in the more controlled disposal vault environment. Thus, there are increased uncertainties associated with this alternative's ability to provide short-term protection to human health and the environment. These concerns are not significant for Alternatives 5A and 5B because all on-site handling of dried wastes is accomplished in enclosed systems.

Screening Criteria - Implementability

Technical Feasibility. Excavation, drying, packaging, transportation, and vault construction are technically straightforward processes to implement. The disposal vault would be designed to preclude the need for long-term maintenance. Similar facilities are in use throughout the hazardous and low-level waste disposal industry. Thus, overall this alternative is readily implementable based on these technical issues.

Administrative Feasibility

The administrative feasibility issues associated with this alternative are the same as for Alternatives 4A and 4B.

Availability of Services and Materials. The equipment and engineering required for this alternative are readily available.

Screening Criteria - Cost

Compared to other action alternatives, the cost of this alternative is moderate. The cost is slightly higher than for Alternative 4B. This is because savings associated with revised treatment are offset by increased disposal facility costs.

Summary

This alternative would not be effective in reducing the toxicity or mobility of contaminants by treatment, and would only slightly reduce volume. RAOs could be achieved if the disposal vaults perform as designed over the long-term. Short-term effectiveness is uncertain due to the physical

characteristics of the dried waste, and the required waste removal and treatment system operations. This alternative has moderate costs, primarily due to the large amount of reinforced concrete construction for the disposal vault. Although this alternative could achieve long-term effectiveness through containment, it was not retained for detailed evaluation. This is for several reasons. The first is that even with the added measure of use of a disposal vault rather than cell, there is more uncertainty for this alternative relative to short-term risk during placement than for the other on-property disposal alternatives. This is specifically due to the waste form and its heightened susceptibility to entrainment in air and water thus increasing the potential for contaminant migration and short-term exposures. In addition, this alternative treats the waste to slightly reduce volume but achieves no reduction in toxicity or mobility through treatment. This is judged to be more important for on property disposal alternatives than for those involving off-site disposal. This is because there are minimal human and environmental receptors in the event of waste containment system failure at the potential off-site waste disposal locations. Redundancy offered by treatment to limit contaminant mobility is much less important at the off-site locations. At the Fernald site the local demographics and presence of the sole-source aquifer add significant value to such redundancy. Finally, the costs associated with this alternative are slightly higher than those for Alternative 4B. Accordingly, inclusion of this alternative does not seem to add any value to that already represented by Alternative 4B. Therefore, this alternative will not be carried forward for detailed analysis.

3.3.7 Alternative 5A - Removal, Treatment (Thermal Drying), and Off-Site Disposal at the Nevada Test Site

In this alternative, waste would be excavated and treated to the extent necessary to meet the waste acceptance criteria of the off-site disposal facility, the Nevada Test Site. Principal limiting waste acceptance criteria include maximum waste concentrations, moisture content, and packaging. Figure 3-4 is a conceptual flow diagram for this alternative.

3.3.7.1 Description

This remedial alternative includes excavation, physical treatment (thermal drying), and off-site shipment and disposal at NTS. The pit wastes, surface soils, caps, and liners would be excavated with both mechanical and slurry systems. This waste would be dewatered and excavated and

transferred to a controlled stockpile where the waste streams can be blended and directed into a shredder which feeds the dryers. The shredder would homogenize and reduce the maximum particle dimension to less than 15 centimeters (6 inches). This blended waste stream would be fed into the rotary dryer. The dryer output moisture content would be close to optimum for compaction and would pass the paint filter liquids test for free liquids and must permit free flowing bulk material handling. The actual drying temperature and waste retention time would be finalized prior to actual process design. The dried waste would be transferred in an enclosed system to an operational storage silo with a hood above the rail siding. The waste would be placed in strong tight boxes, loaded onto flatbed rail cars, and disposed at NTS. As discussed in Appendix J, it is currently believed that after treatment all Operable Unit 1 wastes would be acceptable for disposal at NTS. It is possible, however, that pockets of waste could be encountered that would not meet the NTS waste acceptance criteria. As a contingency for any such wastes that would not meet the NTS waste acceptance criteria, disposal at a permitted commercial disposal facility would be permitted. This would be allowed up to 10 percent of the total waste volume.

This alternative requires removal of the waste pit, Burn Pit, and Clearwell contents, drying of these material, off-site disposal of the dried materials, and site restoration. This alternative is identical to Alternative 4A with the exception that the vitrification, on-property disposal, run-on/runoff control, monitoring, and access control technologies have been replaced by transportation and off-site disposal technologies described below.

Material Transportation

The FEMP site can support rail transport to NTS by using existing on-property rail spurs. The material would be sent to Las Vegas, Nevada, by rail and then transported by truck for the remainder of the trip to NTS (NTS does not have a rail spur). A combination of rail and truck transport can be used around the facilities. Improvements to the existing road and rail system at the FEMP site may be required to accommodate the increased activity; however, modifications and improvements to site roadways are expected to be minimal.

Off-Site Disposal

NTS is a DOE-owned facility that currently accepts low-level radioactive waste from DOE facilities. It is located approximately 3,541 kilometers (2,200 miles) from the FEMP site in an arid environment far from any population centers. Waste material would be dried to meet NTS waste acceptance criteria for moisture content and free-standing water. All necessary approval and certifications would be received prior to shipment.

Preliminary estimates of size and configuration, remediation time frame, spatial requirements, packaging/transportation requirements, and wastes generated for Alternative 5A are as follows:

Size and Configuration

Alternative 5A would include a removal rate of 1,440 bulk cubic yards per day, a drying processing rate of 1,250 bulk cubic yards per day, and approximately 671,000 cubic meters (878,000 cubic yards) of material transported for disposal.

Remediation Time Frame

Site preparation, material processing facility construction, and material removal and processing equipment installation would take approximately one year. Removing, processing, and packaging the material would take an additional five years. The material would be shipped and disposed as it is processed. All shipments are planned to be completed shortly after the material processing is completed.

Spatial Requirements

Overall area at the FEMP site required for implementation of this alternative is approximately 24 hectares (59 acres).

Packaging/Transportation Requirements

The treated material would be placed into the disposal containers and transported by rail/truck combination to NTS. The material would be held in an on-site staging area until proper tests confirming suitability for disposal have been performed and results analyzed and interpreted.

Waste Generated

Waste generated by Alternative 5A would include wastewater from removal activities (treated at the AWWT facility), personal protective equipment (anti-contamination clothing, gloves, HEPA filters, carbon adsorption media, etc.), equipment not feasible to decontaminate, and nonhazardous solid waste from debris and equipment.

3.3.7.2 Screening Evaluation

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. There is no expected effect on the mobility of contaminants from a leachability standpoint. Any toxicity associated with the materials would remain untreated. Dried waste would be more susceptible to resuspension in air. Drying slightly decreases the volume of waste by removing water.

Long-Term Protection of Human Health and the Environment. Long-term protectiveness could be achieved because the waste material is removed to health-based levels and disposed of off-site in a remote location with little rainfall, sparse population, and a significant [(e.g., greater than 150 meters (500 feet)] depth to the aquifer. Since this alternative provides for removal of all the waste material from Waste Pits 1 through 6, Burn Pit, and Clearwell, only minimal residual risks would exist at the FEMP site.

Short-Term Protection of Human Health and the Environment. Short-term protection is moderate due to the site preparation, construction, material removal, packaging, shipping, and disposal hazards associated with material handling. Shipment to NTS currently requires rail transport on the CSX rail lines, transfer to the Union Pacific rail lines in St. Louis, Missouri, and transfer of the material to trucks for road transportation in Las Vegas, Nevada, to NTS. Measures to reduce exposures to ALARA levels and to meet transportation ARARs, DOE orders, and OSHA requirements during packaging, shipping, and disposal operations, such as use of mechanical equipment, would be implemented to manage risks to acceptable levels.

Screening Criteria - Implementability

Technical Feasibility. Drying, packaging, and transport are technically straightforward processes to implement. It is currently anticipated that NTS waste acceptance criteria can be met (see Appendix J).

Administrative Feasibility. NTS is a DOE-owned facility which the FEMP has been utilizing for waste disposition since August 1985. An addendum to the current NTS waste shipping application would be required for this new stream. This alternative would require EPA and U.S. Department of Transportation (DOT) approvals and coordination for the interstate shipment of the material. This is not expected to be a prohibitive issue.

Availability of Services and Materials. The equipment and engineering required for this alternative are readily available.

Screening Criteria - Cost

Compared to other action alternatives, the cost of this alternative is high.

Summary

This alternative could meet RAOs and be long-term protective. Technically, this alternative would be readily implementable. The administrative feasibility would be moderately difficult. This alternative has a high cost. This alternative was retained for detailed evaluation.

3.3.8 Alternative 5B - Removal, Treatment, and Off-Site Disposal at a Representative Permitted Commercial Disposal Facility

3.3.8.1 Description

This remedial alternative is identical to Alternative 5A except that dried material is shipped in bulk directly to a permitted commercial disposal facility located in the arid west. Only rail transportation would be required for shipment to this representative facility. A similar contingency as present in

Alternative 5A would be part of this alternative. The difference is that alternate disposal would be at the NTS.

Off-Site Disposal

The dried material would be shipped to the permitted commercial disposal site for disposal. Based on evaluation of the waste material, it would meet the permitted commercial disposal site's waste acceptance criteria (see Appendix J). Approvals and certifications would be received prior to the shipment. The waste material would be transported in bulk form in gondola railcars. The wastes will be containerized by either bags or hard cover on the railcar. The gondola car size is approximately 13.5 meters (45 feet) long with a 127 cubic meters (166 cubic yards) volume capacity and an 80-ton weight capacity.

3.3.8.2 Screening Evaluation

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. There is no expected effect on the mobility of contaminants from a leachability standpoint. Any hazardous materials present would remain untreated. Dried waste would be more susceptible to resuspension in air. Drying slightly decreases volume of waste by removing water.

Long-Term Protection of Human Health and the Environment. Long-term protectiveness is achieved because the waste material is excavated to health-based levels and then disposed of off site in a remote location with little rainfall, sparse population, and the existing groundwater is not suitable for domestic use due to high mineral content. Since this alternative provides for removal of all the waste material in the waste pits, Burn Pit, and Clearwell, no wastes would remain at Operable Unit 1 and thus, only minimal residual risks would exist at the FEMP site.

Short-Term Protection of Human Health and the Environment. Short-term protection is moderate due to the site preparation, construction, material removal, packaging, shipping, and disposal hazards associated with material handling. Shipment to the representative permitted commercial disposal facility requires rail transport. Measures to reduce exposures to ALARA levels and to meet DOE

orders and OSHA requirements during packaging, shipping, and disposal operations, such as use of mechanical equipment, would be implemented to manage risks to acceptable levels.

Screening Criteria - Implementability

Technical Feasibility. Drying, packaging, and transport are technically straightforward processes to implement.

Administrative Feasibility. Disposal of low-level radioactive waste at a commercial facility would require an exemption from DOE Order 5820.2A which prohibits disposal of DOE material at commercial facilities. This issue is discussed in more detail in Section 4.0 of this FS. This alternative will require the EPA and DOT approvals and coordination for the interstate shipment of the material.

Screening Criteria - Cost

Compared to other action alternatives, the cost of this alternative is moderate.

Summary

This alternative could meet RAOs and be long-term protective. This alternative would be readily implementable. The administrative feasibility is moderately difficult. This alternative has a moderate cost. Alternative 5B was retained for detailed evaluation.

3.4 ALTERNATIVE SCREENING SUMMARY

The alternatives have been evaluated against the three general criteria of effectiveness, implementability, and cost. The intent of this evaluation and screening was to select those alternatives that met RAOs and achieved long-term protection. A summary of the screening analysis is provided in Table 3-2.

The following alternatives have been selected for further evaluation in the detailed analysis of alternatives:

- Alternative 1 - No Action

- Alternative 4 - Removal, Treatment, and On-Property Disposal
  - Alternative 4A - Removal, Treatment (Vitrification), and On-Property Disposal
  - Alternative 4B - Removal, Treatment (Cementation), and On-Property Disposal
- Alternative 5 - Removal, Treatment, and Off-Site Disposal
  - Alternative 5A - Removal, Treatment (Thermal Drying), and Off-Site Disposal at NTS
  - Alternative 5B - Removal, Treatment (Thermal Drying), and Off-Site Disposal at a Representative Permitted Commercial Disposal Facility

The selected alternatives represent the most viable and cost-effective alternatives for the no-action, containment, and removal and treatment general response actions. The material treatment provided in the selected alternatives include drying, vitrification, and cement solidification. The removal and treatment alternatives offer both on-property and off-site disposal to provide additional flexibility in material disposal.

The following alternatives have been eliminated from the alternative screening process:

- Alternative 2 - In Situ Containment
- Alternative 3 - In Situ Treatment and Containment
- Alternative 4C - Removal, Treatment (Thermal Drying), and On-Property Disposal

TABLE 3-1

PROCESS OPTIONS RETAINED AND ASSEMBLED ALTERNATIVES FOR OPERABLE UNIT 1

	Alternatives						
	1	2	3	4A	4B	5A	5B
Process Options[a]	No Action	In Situ Containment	In Situ Treatment and Containment	Removal, Treatment (Vit), and On-Property Disposal	Removal, Treatment (Cem), and On-Property Disposal	Removal, Treatment, and Off-Site Disposal at NTS	Removal, Treatment, and Off-Site Disposal at Representative Permitted Commercial Disposal Facility
Groundwater Monitoring		X	X	X	X		
Air Quality Monitoring		X	X	X	X	X[b]	X[b]
Surface Water/Sediment Monitoring		X	X	X	X	X[b]	X[b]
Leachate Collection/Disposal System		X	X	X	X		
Administrative controls/deed restrictions		X	X	X	X	X	X
Physical Barriers		X	X	X	X		
Slurry Walls		X	X				
Subsurface drains		X	X				
Run-on/Runoff Controls		X	X	X	X		
Groundwater Extraction		X	X	X	X	X	X
Multimedia Cap		X	X	X	X		
Loader/Dozer/Backhoe				X	X	X	X
Dredge				X	X	X	X
Shallow Soil Mixing			X				

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TABLE 3-1 (Continued)

Process Options[a]	Alternatives						
	1	2	3	4A	4B	5A	5B
	No Action	In Situ Containment	In Situ Treatment and Containment	Removal, Treatment (Vit), and On-Property Disposal	Removal, Treatment (Cem), and On-Property Disposal	Removal, Treatment, and Off-Site Disposal at NTS	Removal, Treatment, and Off-Site Disposal at Representative Permitted Commercial Disposal Facility
Surcharging			X				
Vitrification				X			
Cement Stabilization					X		
Solid/Liquid Separation				X	X	X	X
Drying/Calcination				X	X	X	X
Rail Transport						X	X
Truck Transport						X	
Disposal Cell				X	X		
NTS						X	
Representative Permitted Commercial Disposal Facility							X

[a] Specific process options for technologies are representative options. The final decision regarding the process options to be implemented will be an engineering evaluation performed during the Remedial Design phase.

[b] During excavation

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TABLE 3-2

OPERABLE UNIT 1 ALTERNATIVE SCREENING ANALYSIS SUMMARY

Alternative	Effectiveness	Implementability	Cost	Screening Result
1 -No Action	Does not meet RAOs. Waste is not treated; thus, there are no reductions in toxicity, mobility, or volume. Does not meet ARARs.	Readily implementable	None	Retained as Baseline
2 -In Situ Containment	Meets short-term RAOs, but long-term protection cannot be assured. Does not reduce toxicity, mobility, or volume of wastes. Migration of contaminants reduced. Groundwater protection not expected to be achieved.	Technically implementable with moderate level of difficulty	Low	Screened Out
3 -In Situ Treatment and Containment	Meets short-term RAOs, but long-term protection cannot be assured. Only some of the waste is treated, so there is limited reduction of contaminant mobility. Volume of wastes increases due to addition of grout. Groundwater protection not expected to be achieved.	Technically Implementable with moderate level of difficulty	Moderately Low	Screened Out
4A -Removal, Treatment (Vit),and On-Property Disposal	Effective in reducing toxicity, mobility, and volume of wastes. RAOs achieved. Short-term effectiveness is moderate due to the required construction activities. Long-term effectiveness is moderate due to disposal of material over a sole source aquifer in an area of moderate rainfall.	Difficult to implement due to operation of innovative full-scale treatment system and administrative requirements associated with siting a disposal cell over a sole- source aquifer	Moderately High	Retained
4B -Removal, Treatment (Cem), and On-Property Disposal	Effective in reducing toxicity and mobility of wastes, but volume is increased. RAOs are achieved. Short-term effectiveness is moderate due to the required waste removal construction activities. Long-term effectiveness is moderate due to the uncertainty in the long-term stability of the cement-solidified product and the disposal of material over a sole source aquifer in an area of moderate rainfall.	Reliable technology, but difficult to implement due to operation of treatment system for heterogenous wastes and administrative requirements associated with siting a disposal cell over a sole source aquifer.	Moderate	Retained

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TABLE 3-2
(Continued)

Alternative	Effectiveness	Implementability	Cost	Screening Result
4C -Removal, Treatment, (Drying), and On-Property Disposal	Meets long-term RAOs, but short-term protection cannot be assured. Does not affect the mobility or toxicity of contaminants, but there is a slight decrease in the volume of waste by removing water. Short-term effectiveness is low due to the required waste removal construction and on-site transportation and placement activities. Long-term protectiveness is moderate due to the mobility of contaminants and dependence upon the concrete vault for long-term containment as well as disposal of material in an on-site location over a sole-source aquifer in an area of moderate rainfall.	Technically implementable with moderate level of difficulty. Administrative feasibility is moderately difficult due to air emissions permitting for treatment (drying) and administrative requirements associated with siting a disposal vault over a sole-source aquifer.	Moderate	Screened Out
5A -Removal, Treatment, and Off-Site Disposal at NTS	Meets RAOs. Does not affect the mobility or toxicity of contaminants, but there is a decrease in the volume of waste by removing water. Short-term effectiveness is moderate due to the required waste removal construction activities and off-site transportation. Long-term protectiveness is achieved due to the disposal of material in an off-site location with little rainfall, sparse population, and a significant depth to the aquifer.	Reliable technology, but administrative feasibility is moderately difficult.	High	Retained
5B -Removal, Treatment, and Off-Site Disposal at a Representative Permitted Commercial Disposal Facility	Meets RAOs. Does not affect the mobility or toxicity of contaminants, but there is a decrease in the volume of waste by removing water. Short-term effectiveness is moderate due to the required waste removal construction activities and off-site transportation. Long-term protectiveness is achieved due to the disposal of material in an off-site location with little rainfall, sparse population, and a significant depth to a low quality aquifer.	Reliable technology but administrative feasibility is moderately difficult.	Moderate	Retained

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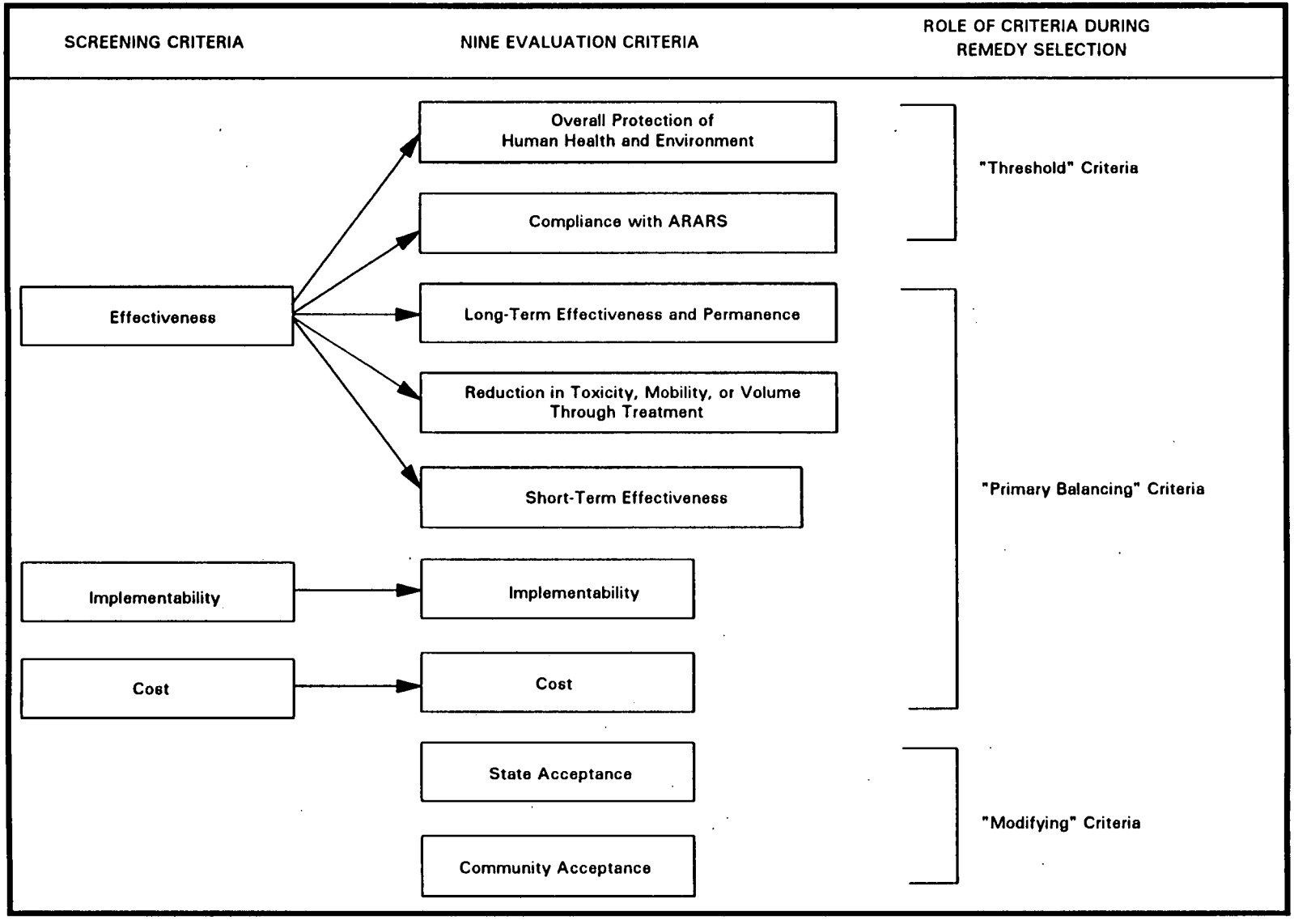

FIGURE 3-1
OPERABLE UNIT 1
RELATIONSHIP OF SCREENING CRITERIA TO THE NINE EVALUATION CRITERIA

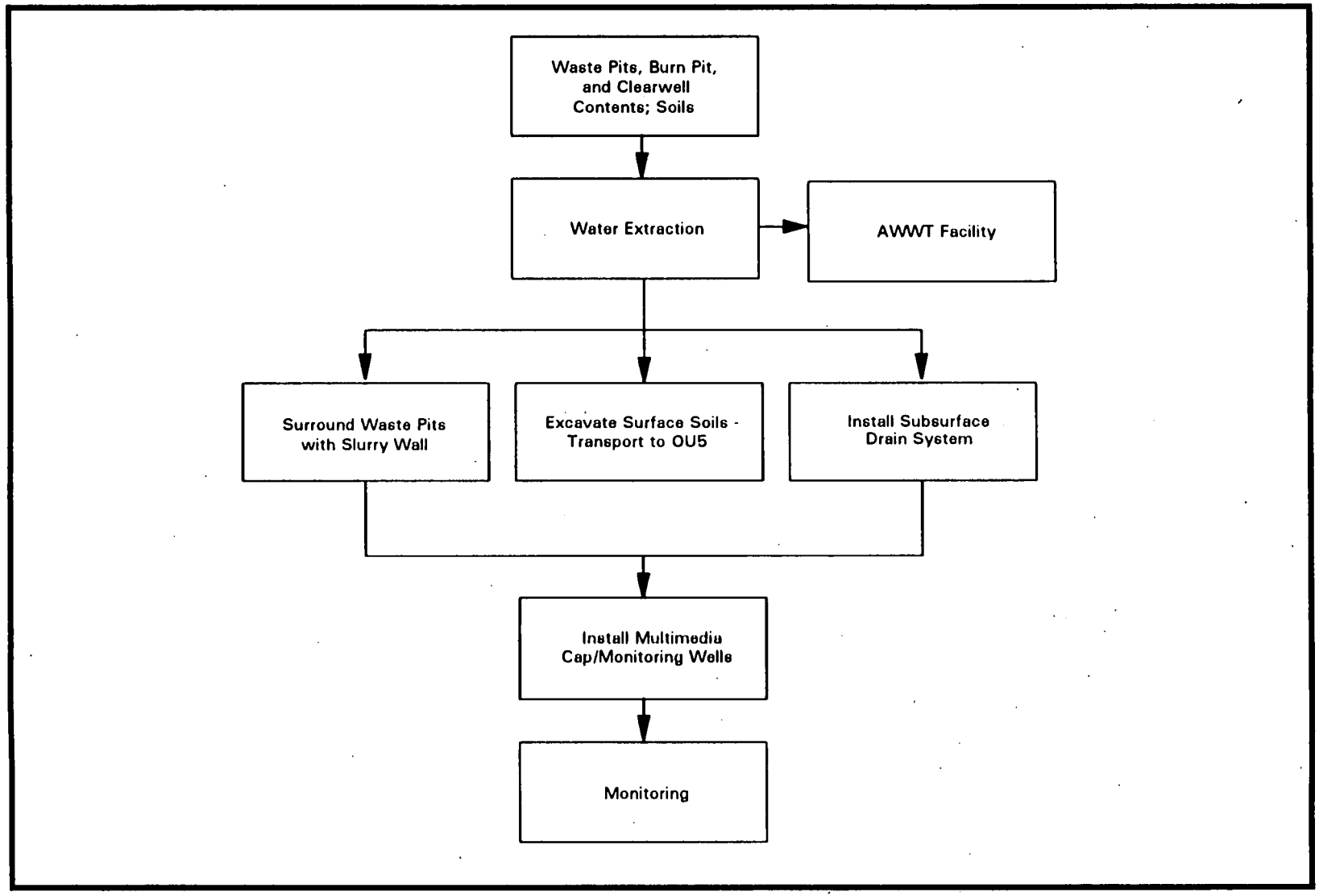

FIGURE 3-2
OPERABLE UNIT 1
ALTERNATIVE 2 - IN SITU CONTAINMENT CONCEPTUAL FLOW DIAGRAM

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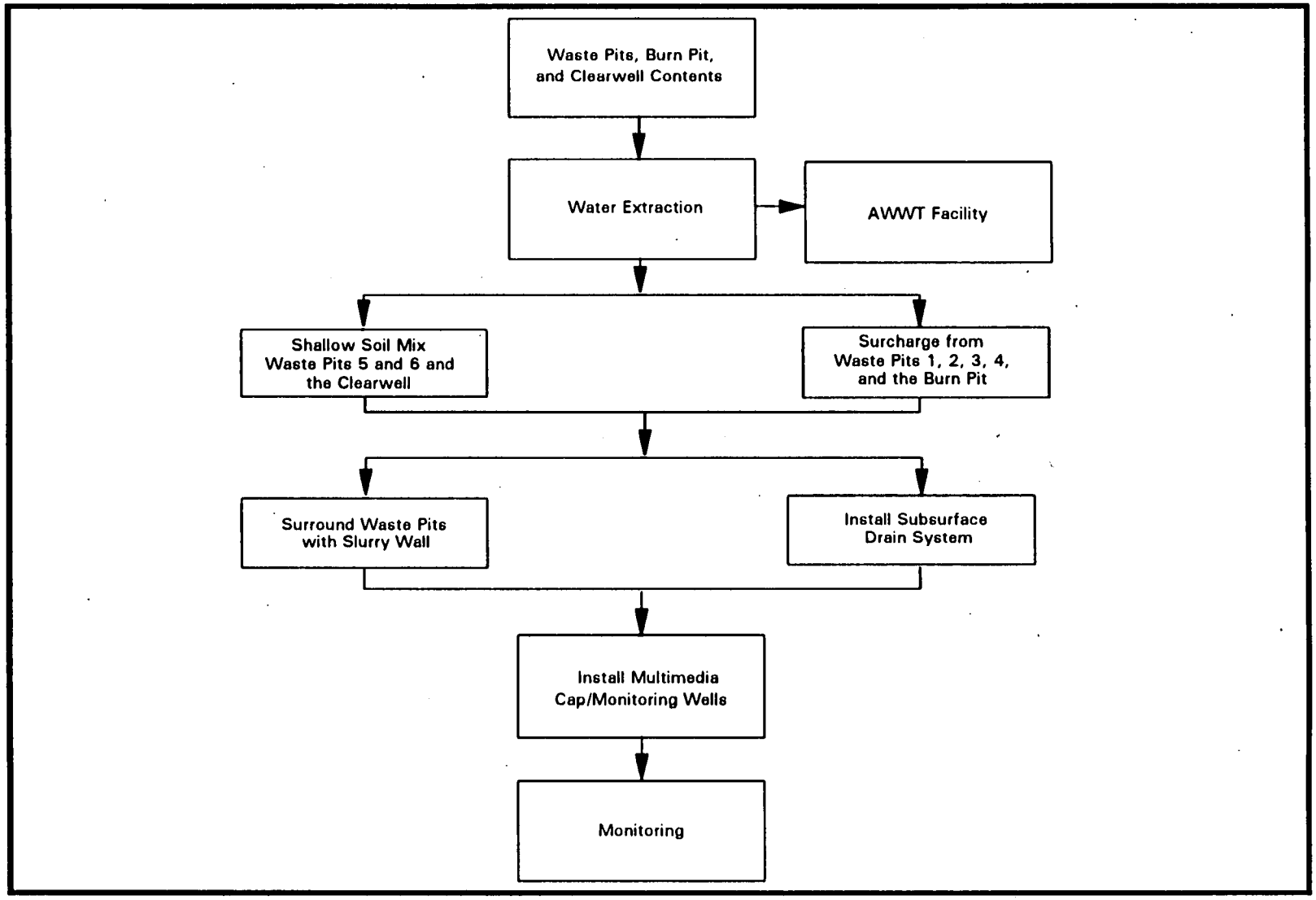

FIGURE 3-3
OPERABLE UNIT 1
ALTERNATIVE 3 - IN SITU TREATMENT AND CONTAINMENT
CONCEPTUAL FLOW DIAGRAM

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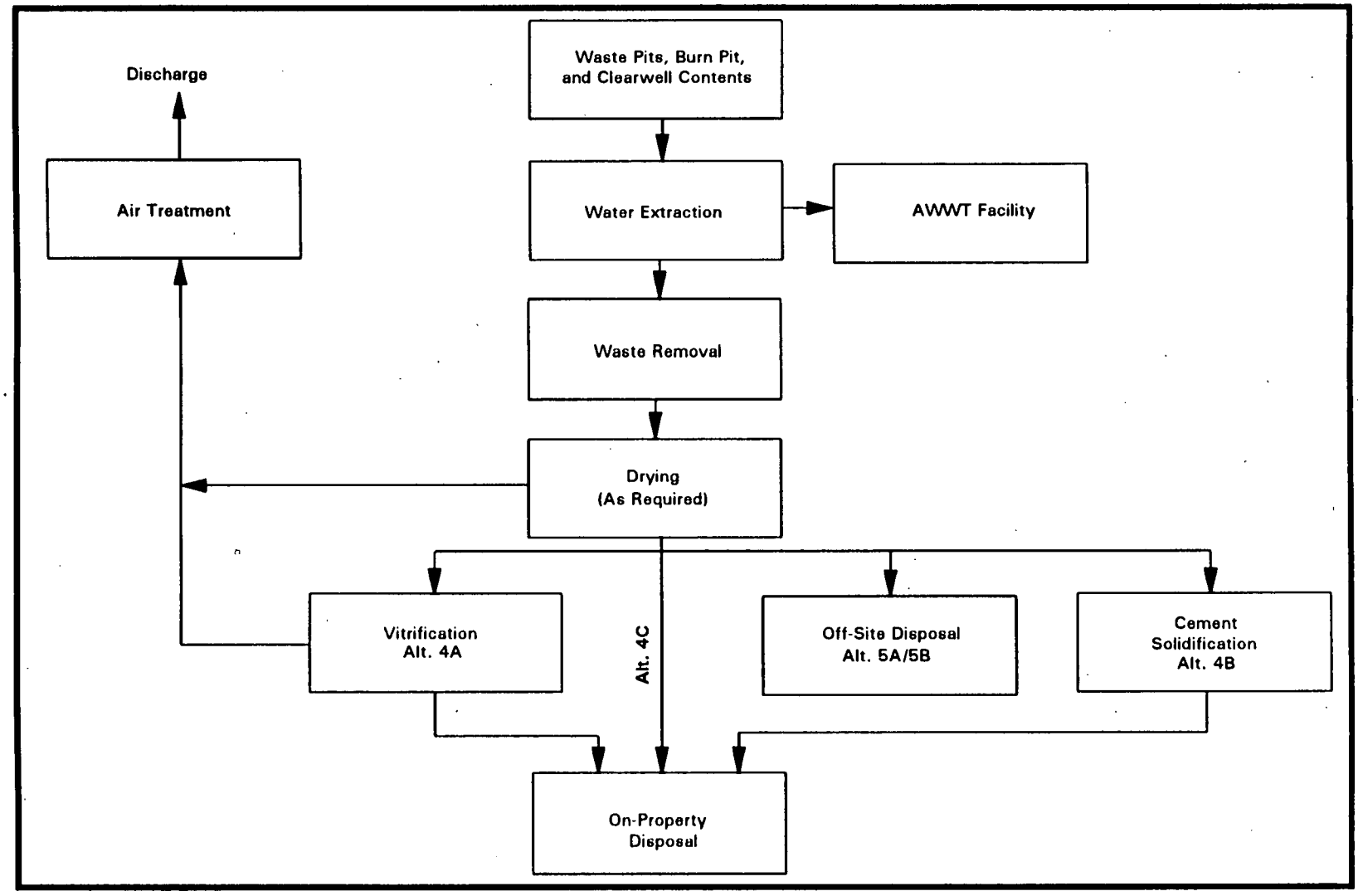

FIGURE 3-4
OPERABLE UNIT 1
ALTERNATIVES 4A, 4B, 4C, 5A AND 5B - REMOVAL, TREATMENT, AND DISPOSAL CONCEPTUAL FLOW DIAGRAM

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4.0 DETAILED ANALYSIS OF ALTERNATIVES

4.1 INTRODUCTION

This section presents the detailed analysis of those alternatives which passed the screening process, as reported in Section 3.0. The following five alternatives were selected for detailed analysis for Operable Unit 1:

- Alternative 1 - No Action
- Alternative 4A - Removal, Treatment (Vitrification), On-Property Disposal
- Alternative 4B - Removal, Treatment (Cement Solidification), On-Property Disposal
- Alternative 5A - Removal, Treatment (Thermal Drying), Disposal at the Nevada Test Site (NTS)
- Alternative 5B - Removal, Treatment (Thermal Drying), Disposal at a Permitted Commercial Disposal Facility

With the exception of the No-Action Alternative, all of the above include institutional controls. A description of each alternative precedes the detailed analysis. Cost estimates which include detailed technical assumptions, including quantities and equipment requirements, are provided in Appendix E.

4.1.1 Purpose of the Detailed Analysis

The detailed analysis includes a presentation and assessment of relevant information that provide the basis for selecting an alternative and preparing a Record of Decision (ROD). The detailed analyses in this Feasibility Study (FS) assess each alternative against the evaluation criteria identified in the National Oil and Hazardous Substance Pollution Contingency Plan, referred to as the NCP (40 CFR 300.430). Building upon the development and screening of alternatives, the detailed analysis presents more in-depth information, including treatability study and pertinent data from the Draft Final Remedial Investigation Report for Operable Unit 1 (DOE 1994a) to assess the alternatives relative to the criteria identified in the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

Following the detailed analysis, a comparative analysis of the alternatives will be presented in Section 5.0. The comparative analysis evaluates the alternatives in relation to the two threshold criteria which must be met (40 CFR 300.430). These criteria are explained in Section 4.1.2. This analysis is followed by an assessment of the alternatives against the five balancing criteria, highlighting the key advantages, disadvantages, and tradeoffs considered as part of the evaluation process. The Proposed

Plan (PP) documents the evaluation of the remedial alternatives and the proposal of a preferred alternative.

4.1.2 Overview of the Detailed Analysis

Specific statutory requirements for remedial actions are identified in CERCLA Section 121. These requirements include protection of human health and the environment, compliance with applicable or relevant and appropriate requirements (ARARs), a preference for permanent solutions which incorporate treatment as a principal element (to the maximum extent practicable), and cost-effectiveness. To assess whether alternatives meet the requirements, EPA has identified nine criteria in the NCP (EPA 1990) that must be evaluated for each alternative retained through the screening stage (40 CFR 300.430(e)(9)(iii)). Provided below are summaries of the nine criteria and an overview of the approach taken in this FS to evaluate the criteria. Because the first two criteria, overall protection of human health and of the environment, and compliance with ARARs, are threshold criteria that must be met, additional detail is provided for those discussions. Where appropriate, reference is made to related discussions in other sections of this FS report.

4.1.2.1 Overall Protection of Human Health and the Environment

This evaluation criterion provides an assessment of whether the alternative provides adequate protection of human health and the environment, in the long and short term. Evaluation of this criterion should describe how site risks, posed through each pathway that is being addressed by the FS, are eliminated, reduced, or mitigated through treatment, engineering, or institutional controls. The acceptable risk levels under CERCLA for known or suspected carcinogens are generally concentration levels in environmental media that represent an excess upper bound of lifetime cancer risk to an individual between 10^{-4} and 10^{-6}. To achieve this level of human health protection for the entire Fernald Environmental Management Project (FEMP) site, the initial point of departure for remediation of Operable Unit 1 is less than or equal to 10^{-6}. Identifying and attaining this level will help to ensure that the remediation goal for the entire FEMP site will not exceed 10^{-4} as remedial alternatives are selected for other operable units. The remedial action objectives previously identified in Section 2.2 were developed consistent with this methodology.

An FS risk evaluation is performed to determine if the following criteria are met: long- and short-term protection of human health and the environment, compliance with ARARs, long-term effectiveness and permanence, and short-term effectiveness. The FS risk evaluation is included as

Appendix D of this report. To assess protectiveness, two viable future land use scenarios were evaluated along with representative receptors in order to provide risk information to decision makers. The land use scenarios examined included future land use without continued federal ownership and a future land use with continued federal ownership scenario. The assumptions for these scenarios are summarized below.

Future Land Use without Continued Federal Ownership Scenario

This scenario was examined to evaluate risk for the least restrictive future land use assumption. Under this scenario, the facility is assumed to revert to the primary use of the land surrounding the FEMP site, a family farm. For this risk scenario, an on- and off-property farmer are examined. For the on-property farmer, two receptors are examined, a Reasonable Maximum Exposure (RME) and a Central Tendency (CT) resident farmer. The RME resident farmer scenario uses risk parameters to provide an upper bound estimate of the risk that an on-property farmer could reasonably be expected to receive. Under the CT resident farmer receptor, risk parameters are adjusted as identified in Appendix D to provide an estimate of the risk the on-property farmer could reasonably be expected to receive under typical living conditions. For this land use scenario, active operations and maintenance are assumed to continue until site-wide remedial action objectives are attained. After that time, active maintenance is assumed to be discontinued. Five-year CERCLA statutory reviews are assumed to continue. The waste disposal system is assumed to remain relatively unchanged with no direct intrusion into the waste materials. The on-property farmer is assumed to withdraw his drinking, crop irrigation, and livestock water from the Great Miami Aquifer from a point adjacent to the disposal cell or within the Operable Unit 1 boundary.

Future Land Use with Continued Federal Ownership Scenario

This scenario was examined to evaluate risk information for a viable future site land use which incorporates institutional controls. Under this scenario, the FEMP site is assumed to remain under the ownership of the federal government. The government is assumed to continue to exercise its rights as owner of the property to preclude further development of the site. Continued federal ownership would preclude certain activities on the property including homesteading, farming, and the installation of domestic wells. Active access controls are assumed to be discontinued when site remedial action objectives are attained. To provide an upper bound estimate of the risk contribution reasonably expected to be received under this land use, a expanded trespasser-type user is examined in addition to the off-property farmer. The expanded trespasser-type user is assumed to be an

individual who plays on the property as a youth and uses the property less frequently for recreational purposes as an adult. Assumptions for operations and maintenance are consistent with the land use scenario described above.

To evaluate the alternatives for attainment of overall protection of the environment, the remaining pathways to environmental receptors were examined to determine the degree to which the alternatives mitigate environmental degradation. The prevention of degradation of the Great Miami Aquifer, due to migration of contaminants from residual wastes and soils, is a remedial action objective which is protective of human health and the environment. Attainment of this objective can be measured primarily by compliance with health-based acceptable concentrations, maximum contaminant levels (MCLs), proposed MCLs, and nonzero maximum contaminant level goals (MCLGs) established under the Safe Drinking Water Act. Each alternative is also assessed for its short-term and long-term effects on soil and geology, water quality and hydrology, air quality, biotic resources, and wetlands and floodplains.

4.1.2.2 Compliance with Applicable or Relevant and Appropriate Requirements

This criterion, also referred to as ARARs compliance, is a threshold criterion that addresses the attainment of applicable or relevant and appropriate federal and state environmental or facility siting requirements. An alternative may be selected that does not meet a particular ARAR if justified for a reason specified in the NCP (40 CFR 300.430). ARARs consist of two sets of requirements, those that are "applicable" and those that are "relevant and appropriate". In certain cases, standards may not exist in the promulgated regulation that address the proposed action or the constituents of concern. In these cases, nonpromulgated advisories, criteria, or guidance that were developed by EPA, other federal agencies, or states are to be considered (TBC) in establishing remedial action objectives that are protective of human health and the environment. In addition, there are other requirements which do not fall within the EPA-established criteria for ARARs.

These other requirements include DOE orders which pertain only to DOE facilities. Atomic Energy Act (AEA) requirements for DOE's waste management program are incorporated into DOE orders, developed under DOE's AEA authority. Substantive requirements of DOE orders are "to-be-considered" (TBC) requirements, which, when specifically incorporated in a CERCLA ROD, are enforceable cleanup standards under CERCLA. EPA's Compliance with Other Laws Manual (OSWER Directive 9234.1-01) states "...DOE orders are not promulgated requirements and are not

potential ARARs." The manual further states that, "To the extent that DOE orders are more stringent or cover areas not addressed by existing ARARs, they should be considered when necessary to develop a protective remedy."

In addressing a requirement that may affect a remedial action being considered for a site, a determination is made regarding its relationship to: (1) the location of the action; (2) the contaminants involved, and (3) the specific components of the action, such as factors unique to a certain technology. Three types of ARARs result from this process: location-specific ARARs, chemical-specific ARARs, and action-specific ARARs.

Location-specific ARARs generally restrict certain activities, or dictate where certain activities may not be conducted solely because of geographical, hydrologic, or land use concerns.

Chemical-specific ARARs are usually health- or risk-derived numerical values that establish an acceptable level or concentration of a specific chemical or radionuclide that may remain in specific environmental media after remediation is complete. These levels are used to help establish remedial cleanup goals.

Action-specific ARARs are usually restrictions on the conduct of certain activities or the operation of certain technologies at a site.

Appendix F of this report provides a detailed analysis of potential ARARs for Operable Unit 1. Appendix F includes specific ARARs compliance analyses for alternatives undergoing analysis in this FS. As back-up for these analyses, overall ARARs are identified.

4.1.2.3 Long-Term Effectiveness and Permanence

This criterion evaluates the extent to which an alternative achieves an overall reduction in risk to human health and the environment after the remedial action objectives have been met. It considers the degree to which the alternative provides sufficient long-term controls and reliability to maintain exposures to human and environmental receptors within protective levels. The principal factors addressed by this criterion include magnitude of residual risk and the adequacy and reliability of controls to address such risk. Also discussed are the uncertainties associated with both of these factors.

This FS evaluates the magnitude of residual risk to human health in terms of a risk evaluation under the land use scenarios previously discussed in Section 4.1.2.1. The basis of this risk evaluation is presented in Appendix D. The evaluation considers the characteristics of any remaining untreated and treated waste forms which pose potential risks in the future. The magnitude of residual risk to environmental receptors is assessed in a qualitative manner by describing the potential long-term environmental impacts of the alternative on soil and geology, water quality and hydrology, air quality, biotic resources, and wetlands and floodplains. Impacts on socioeconomics, land use, and cultural resources are also considered.

The evaluation of adequacy and reliability of controls assesses the effectiveness of any treatment, containment, or institutional measures which are part of the alternative. Factors considered include performance characteristics, maintenance requirements, and expected durability. Information and data from treatability studies, past performance, and similar technology applications are incorporated into the evaluation as appropriate. Institutional controls are considered where they potentially improve the effectiveness of engineered measures.

4.1.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This criterion reflects the statutory preference for remedial alternatives containing a principal component which substantially reduces toxicity, mobility, or volume of hazardous substances through treatment. The evaluation considers the extent to which remedial action process technologies can effectively and irreversibly fix, transform, immobilize, reduce or detoxify the volume of waste materials and contaminated media.

Two treatment technologies are principal components of the alternatives selected for this detailed analysis that involve on-site disposal. Vitrification and cement solidification are assessed for their ability to reduce the mobility and volume of the contents of the waste pits, Burn Pit, and Clearwell. The evaluation includes the results of treatability studies which were conducted during the RI/FS. The treatability study results are summarized in Appendix C of this FS report. The treatability studies compare key characteristics (e.g., leachability of constituents of concern, volume increase/decrease of the untreated and treated waste forms) in order to assess the potential reduction of risk afforded by the treatment processes. Additional tests were conducted to determine the expected long-term performance of the treated waste forms in maintaining the level of protectiveness achieved.

4.1.2.5 Short-Term Effectiveness

This criterion addresses the effects of the alternative during the construction and implementation phase and the time until protectiveness is provided. The evaluation considers the effects on human health and the environment posed by operations conducted during the remedial action. Both the potential impacts and associated mitigative measures are examined for maintaining protectiveness for the community, remedial action workers, and environmental receptors over the duration of the remediation activities.

Appendix D of this FS provides an evaluation of short-term risks to the public and workers under various scenarios associated with an alternative's implementation. Potential short-term risks to the public include inhalation of radionuclides, volatile organics, and inorganic constituents that may be released during waste removal and treatment operations, radiological exposure, and potential exposure to a trespassing child postulated to intrude on site during remedial activities. Potential short-term risks to workers include: direct contact and exposure during construction, waste treatment, and transportation; physical injury or death during construction and transportation activities; and nonremediation worker exposures to airborne radioactive and chemical contaminants during soil removal operations. The alternatives analysis also includes a description of mitigative measures such as engineering and institutional controls which are expected to minimize potential risks to the public and workers. It is noted that these mitigative measures were not considered in the quantitative evaluation in Appendix D.

Short-term environmental impacts and mitigation measures are assessed in a qualitative manner including environmental media and potentially sensitive resources (e.g., wetlands and floodplains).

4.1.2.6 Implementability

This criterion examines the technical and administrative feasibility affecting implementation of an alternative and considers the availability of services and materials required during implementation. Technical factors to be assessed include the ease and reliability to initiate construction and operations, the prospects for implementing any needed future actions, and the adequacy of monitoring systems to detect failures. Administrative factors examined include permitting and coordination requirements among the lead agency and regulatory agencies. Services and materials considerations include: treatment, storage, and disposal capacities; equipment and operator availability; and prospective technology applicability or development requirements.

Where proven technologies are proposed by an alternative, the assessment of technical feasibility examines the performance history of the technologies in direct applications or considers the expected performance for similar applications. For innovative technologies, data from bench-scale tests are evaluated for expected scale-up performance characteristics; and, the feasibility of scaling up bench tests to pilot tests is reviewed. Any uncertainties associated with construction, operation, and performance monitoring are also addressed.

The evaluation of administrative feasibility includes a discussion of those actions required to coordinate with regulatory agencies to establish the framework for complying with any key substantive technical requirements which must be attained by an alternative. Additionally, alternatives involving off-site transportation are reviewed to assess the feasibility of implementing interstate transportation and disposal.

The availability of services and materials is addressed by analyzing the material components of the proposed technologies to determine the locations and quantities of those materials, and by reviewing process operations to identify any special services, operator skills, or training required to readily implement the process.

4.1.2.7 Cost

The cost criterion reviews total capital costs (direct and indirect) and operating and maintenance (O&M) costs, which are included in total present worth costs. The approach adopted by this FS includes a presentation of the capital costs of each major component of the alternative. A cost estimate table provides detail for each alternative.

4.1.2.8 State Acceptance

State acceptance of a particular alternative is typically not evaluated until a Proposed Plan is issued for public comment. As such, the criterion is not considered in this FS.

4.1.2.9 Community Acceptance

Community acceptance of a particular alternative is typically not evaluated until a Proposed Plan is issued for public comment. As such, the criterion is not considered in this FS.

4.1.3 Overview of Section 4.0

Sections 4.2 through 4.6 present the detailed analysis of five alternatives for Operable Unit 1. The remaining sections include: Section 4.7, Detailed Analysis Summary; and Section 4.8, Irreversible and Irretrievable Commitment of Resources.

4.2 ANALYSIS OF ALTERNATIVE 1 - NO ACTION

4.2.1 Description

Under Alternative 1, no further action would be taken at the site. The pit wastes would remain as they are without the implementation of any removal, treatment, containment, or mitigating technologies. It provides a baseline for comparison purposes.

4.2.2 Detailed Analysis

4.2.2.1 Overall Protection of Human Health and the Environment

The No-Action Alternative does not meet the remedial action objectives for Operable Unit 1. The Operable Unit 1 Baseline Risk Assessment (baseline RA) calculated the risks to a number of representative receptors for current and future land use scenarios. These risks are summarized in Section 2.2 and in Appendix D of this FS report. The results of the baseline RA indicated that the no-action alternative would result in risks exceeding the generally accepted incremental lifetime cancer risk (ILCR) range of 10^{-4} to 10^{-6} for carcinogens or a Hazard Index (HI) of 1.0 for noncarcinogens for one or more receptors under certain land use scenarios. Therefore, the no-action alternative would not be protective of human health.

Erosion of contaminated soil or stormwater runoff could result in contaminant migration to Paddys Run which could threaten environmental receptors such as aquatic biota. Resuspension and redeposition of contaminants from contaminated soils could also result in contamination of additional habitats. Therefore, the no-action alternative would not be protective of the environment.

4.2.2.2 Compliance with Applicable or Relevant and Appropriate Requirements

Alternative 1 would not meet certain ARARs/TBCs. With no further action (per the Operable Unit 1 baseline RA), continued release of contaminants could result in exceedances in airborne emissions of radionuclides under 40 CFR 61 Subparts H and I and exposure limits to the public established under DOE Order 5400.5. Release of radionuclides, as well as organic and inorganic contaminants would violate State of Ohio water quality standards (OAC 3745-1) for receiving surface waters. Drinking

water MCLs and MCLGs would most likely be also exceeded in the long term if the released material were to migrate into groundwater of the Great Miami Aquifer.

4.2.2.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The No-Action Alternative provides a long-term solution that is neither effective nor permanent. As previously discussed, the baseline risks due to carcinogenic and noncarcinogenic contaminants present within Operable Unit 1 exceed generally accepted regulatory limits for one or more receptors under certain land use scenarios.

Under the No-Action Alternative, continued migration of contaminants from Waste Pits 1 through 6, Burn Pit, and Clearwell can be expected. Continuous migration of contaminants would lead to increased infiltration to the underlying perched groundwater zone and the Great Miami Aquifer. Increased contamination levels in the perched zone would cause higher concentrations of contaminants in Paddys Run surface water and sediment, and the Great Miami Aquifer. These increased concentrations of contaminants in the environmental media surrounding Operable Unit 1 would pose additional overall risks to human and environmental receptors.

Adequacy and Reliability of Controls

The No-Action Alternative provides no controls for existing contamination. Therefore, the No-Action Alternative would not have any effect on existing risks. Future risks may be even greater than those indicated in the baseline risk assessment future source/future use scenario, since site conditions may deteriorate beyond that assumed for the future source term.

Deterioration of the waste pits could be expected to increase the concentration of contaminants in surface water, thereby impacting adjacent biotic resources. The existing Waste Pit Area Stormwater Runoff Control System currently limits such discharges. Additionally, the current level of radiological exposures to biological receptors could be expected to increase with continued deterioration of the waste pits.

Long-Term Environmental Impacts

Alternative 1 would not be protective of human health and the environment in the long term because it is not protective against potential exposure to waste materials. The loss of waste containment could

increase contamination levels in the Great Miami Aquifer, perched groundwater zone, surface water and sediment, the 100- and 500-year floodplain of Paddys Run, and wetland areas within and adjacent to Operable Unit 1. Sloan's crayfish, *(Orconectes sloanii)* a species included in the state's list of threatened species, is found to occur in Paddys Run, adjacent to Operable Unit 1, and may be adversely affected by conditions within the study area.

4.2.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Reduction of toxicity, mobility or volume through treatment is not applicable to Alternative 1 because this alternative does not include treatment.

4.2.2.5 Short-Term Effectiveness

Under the no-action alternative, no remedial action would be taken; therefore, there would be no increase in short-term risks to human health and no short-term environmental impacts.

4.2.2.6 Implementability

Under the No-Action Alternative, no remedial action would be taken. Therefore, there would be no difficulties, nor uncertainties associated with construction. The No-Action Alternative is included in the detailed analysis of alternatives for a baseline comparison.

4.2.2.7 Cost

There are no costs associated with Alternative 1.

4.3 ANALYSIS OF ALTERNATIVE 4A - REMOVAL, TREATMENT (VITRIFICATION), AND ON-PROPERTY DISPOSAL

The following description of Alternative 4A is based on a representative conceptual design for Operable Unit 1. The level of engineering detail provides documentation for cost estimating purposes. If this alternative is selected, the substantive components of the design will be finalized during the remedial design phase consistent with the requirements of the Record of Decision (ROD).

Alternative 4A is based on disposing of a highly leach-resistant waste form in an on-property engineered disposal cell. These engineering features, combined with institutional controls of government ownership, provide redundant safeguards for isolating and containing the waste with reasonable assurance.

4.3.1 Description

Alternative 4A requires the excavation of Waste Pits 1 through 6, the Burn Pit, and the Clearwell including the waste, caps, liners and soils below the liners to achieve health-based limits. Surface soils within the Operable Unit 1 boundary, outside the capped areas, would also be excavated to health-based levels. Excavated material amendable to vitrification would be dried and futher treated by vitrification for disposal in an above-grade disposal cell within the FEMP site boundary. Material not amenable to vitrification would be managed as miscellaneous debris (see Section 3.2.3.4). The waste pits would be backfilled with clean soil. The backfilled areas would be covered with an infiltration-limiting multilayer cover. The areas where surface soil is excavated would be graded and vegetated. Topsoil would be used to support vegetative growth, where required. This alternative would incorporate the institutional controls and monitoring measures as described in Section 3.2.3.1.

The pit waste, caps, and liners would be dewatered and excavated with both mechanical and slurry systems. Surface water and perched groundwater generated during dewatering activities would be pumped to the FEMP Advanced Wastewater Treatment (AWWT) facility for treatment (see Section 3.2.3.2 for a discussion of the AWWT facility). Excavated waste would be transferred to a controlled stockpile in a process building where the waste could be blended and directed into a shredder which feeds the dryers. The shredder would homogenize and reduce the maximum particle dimension to less than 15 centimeters (6 inches). The moisture content of the waste as it enters the shredder is estimated at 32.5 percent. Assuming that the moisture content will be reduced five percent in the shredder, the moisture content of the waste as it enters the dryer would be approximately 27.5 percent. The dryer output moisture content would be approximately 15 percent. The waste would then be size reduced to less than 3/8 inch in diameter and fed to the vitrifiers. The waste glass frit from the vitrifiers would be cooled and transferred to the on-property disposal cell a conventional material handling system and placed in 30 centimeter (12 inches) lifts. Support facilities for treatment will be decontaminated and dismantled before being forwarded to Operable Unit 3 for management.

Site Preparation

Site preparation would begin with clearing and grubbing vegetated areas in preparation for the material processing facility, construction of roads, equipment staging areas, and other site facilities. Contaminated soils encountered would be managed in the same manner as contaminated surface soils. Site preparation activities would include the construction of roadways; implementation of soil erosion

control and stormwater management measures; and installation of site fencing, lighting, process water piping, sewer lines, power poles, and a substation to meet the power needs of the vitrification units. Processing elements to be constructed would include of a material pretreatment/stockpile facility and a vitrification facility. The pretreatment/stockpile facility would be a pre-engineered metal building which would house the stockpile areas, slurry processing equipment, and the shredder. The vitrification units and off-gas treatment systems would be housed in another facility. Concrete floors would be sloped to drain excess free water from stockpiled waste. All facilities would be negatively ventilated with air exhausted through ducts and directed to high-efficiency particulate air (HEPA) filters.

Site preparation activities for on-site disposal cell construction would include excavation of shallow sand lenses and replacement with compacted clay to eliminate the potential for lateral transport of groundwater in sand lenses in soils beneath the facility. The general location proposed for the disposal cell is in the northeast portion of the former Production Area, known as the Operable Unit 3 area.

Pit Dewatering

An intensive program of dewatering will be undertaken before attempting any dry excavation. Wells and sumps will be installed in the pits to dewater the waste. This will reduce the energy requirements for drying and will facilitate excavation. Surface water and perched groundwater would be extracted and treated as described in Section 3.2.3.2.

Excavation

Waste would be removed from the waste pits using both dry and wet excavation methods. Select segregation of unique waste forms (e.g., large structural shapes) would be performed. Excavation and processing equipment would be selected to handle materials present in the pits such as sludge, steel drums, and other materials. Oversized material not suitable for shredding would be segregated from Operable Unit 1 waste and forwarded to Operable Unit 3 to be managed as construction rubble.

Various excavation methods would be used, depending on the nature of the waste being excavated. For example, a hydraulic front end shovel would be used in dry pit excavation, removing waste sludge and possibly caps and liners. A tractor excavator loader would be used to excavate ramps into

the pits to remove contaminated soils. Alternate methods could include a slack line drag scraper setup or jet slurry dredging system. Principal prime moving equipment that is confined to excavating in contaminated waste would be specified to have enclosed cabs for increased worker protection. Personnel would be required to take adequate safety precautions, including the use of personal protective equipment and clothing when working in the waste pits.

The homogenous sludge composition of Waste Pit 5 makes it suitable for dredging. The existing pit hog dredge would likely be used to remove waste from Waste Pit 5 while conventional earth moving equipment such as a tracked loader-excavator and/or hydraulic front shovel would likely be used to excavate all remaining pits, including Waste Pit 6 and the Clearwell. About 80 percent of the Waste Pit 5 wastes would be pumped as slurry directly into a thickener.

To effectively excavate the waste pits in some locations, it would be advantageous to start excavating a successor pit before finishing the current pit. This occurs when ramping from one pit to another, or when excavating an adjacent pit wall to reduce the height of the imposing highwall. Dust and contaminant control measures would be employed when conditions are conducive to dust generation. These measures can include the use of water sprays or surfactants sprayed on the cut. These are common dust control techniques and are very effective when properly applied.

Pit excavation would also consider drainage. The primary source for inflows would be heavy rains. Waste would be covered during excavation except for the face that is being directly excavated. Caps would be maintained as long as possible, and opened waste pits would be covered to prevent rain infiltration. This will also minimize dust generation. Berms would be maintained around the pit areas to prevent run-on from precipitation. Pit floors would be graded to drain to pit sumps excavated into the pit floor. Paved access ramps would have paved curbed gutters or grate-covered concrete channel drains to accommodate surface runoff or washing. These gutters and drains would also be directed to the pit drainage system. Lined sumps would be operated in the low points of the waste excavation to keep pit floors dry. Contaminated water from the pit sumps would be pumped to the Clearwell which, in turn, would be pumped to the biodenitrification lagoon. When the Clearwell is remediated, the waste water would be forwarded to the AWWT facility.

Waste pits would be backfilled and regraded more or less concurrently with waste excavation to prevent possible recontamination in the event of pit flooding during severe rains. Timely placement

of backfill would also prevent sloughing pit walls and in some places can be used to buttress existing ramps, roadways, or pit walls. The site would be divided into "clean" and "exclusion" areas. To prevent cross-contamination, clean equipment would operate only in clean areas while contaminated areas would be accessed by equipment dedicated to contaminated areas only.

The total amount of waste to be excavated would be approximately 543,000 cubic meters (710,000 cubic yards). Waste pit excavation will be tied to the treatment rate (approximately 10 years). This corresponds to a vitrifier processing rate of 400 dry tons of frit per day (250 cubic yards per day) and 275 days of excavation per year.

Waste Processing

Excavated waste material, with the exception of approximately 80 percent of the waste from Waste Pit 5 which would be pumped as slurry, would be transported by trucks to the waste processing/stockpile building for pretreatment (shredding) prior to drying and vitrification. The drying/vitrification process would consist of a shredder, two rotary dryers in parallel, one dry-screening and size-reduction system, and the vitrification plant with four furnaces in parallel. All equipment would be operated under negative pressure. A flow diagram for the vitrification process is provided in Figure 4-1. The stockpile would provide surge capacity to accommodate excess waste production and constant feed to the shredder. The stockpile would be sized for approximately 24 days storage capacity (15,000 wet tons). The stockpile not only provides plant feed whenever excavation operations are shut down, but also facilitates blending of wastes, including dredged sludge from Waste Pit 5 as well as wastes excavated from other "dry" pits. This will minimize the energy requirements for the drying. Waste Pit 5 wastes would be dewatered through a thickener and a vacuum filter before entering the treatment system. Overflow from the thickener and water removed during shredding would ultimately be fed to a clarifier. Clarifier overflow and filtrate from the vacuum filter would be sent to the AWWT facility or, as needed, would be recycled to facilitate pit dredging. The clarifier underflow would join the thickener underflow and would be filtered by a vacuum drum filter. Filter cake and all thickened, dredged slurry would be conveyed to the enclosed stockpile where it would be discharged and blended with other pit wastes.

Waste would be recovered from the stockpile with a drag scraper and delivered to the shredder. Pit wastes would first be processed through a shredder to prepare suitable feed waste material to the dryer. The shredder would reduce waste feed to less than 15 centimeters (6 inches), homogenize and

partially dewater the dryer feed. The output from the shredder would be fed into two indirect rotary dryers in parallel. The material handling system to transfer material from the shredder would include a heavy-duty bucket elevator, a feed hopper, and auger feeders (screw conveyors) to discharge waste into the rotary dryers.

Drying

Based on the required capacity of the process, the waste would be handled by two indirect rotary dryers to reduce the moisture content of the waste from approximately 27.5 percent (on average) to approximately 15 percent (dry solid basis). Each rotating cylinder receiving the feed waste material would be housed in a refractory-lined furnace. Drying gases produced in the combustion chamber, fueled by natural gas, would enter the furnace at a controlled rate and temperature 530-650°C (1,000-1,200°F). The drying gases would flow concurrent with the waste. The waste itself would be heated to approximately 150°C (300°F). The rotating and sloped cylinder would advance the waste material indirectly through the shell without any contact between the gases and the dried waste material, thus minimizing dust emissions from the waste material. The dryers would be sized for a processing rate of 30 wet tons per hour, assuming a one-hour residence time for drying.

Dried material from the dryers would be subjected to additional screening and size reduction processing as required to remove non-size-reducible and nonvitrifiable materials and to provide a suitable, 100 percent, less than 1 centimeter (3/8 inch) diameter feed material to the vitrifier. Steel would be removed by a magnet placed over the screened material. Uranium metal, greater than 1 centimeter (3/8 inch) in diameter, would be removed by screening. Steel and screened material would be segregated to be managed separately.

Off-Gas Treatment System

Process gas (evaporated water and leak-in air) would leave the dryers at approximately 120°C (250°F) and would pass through a shell/tube condenser. Condensate would be returned to the clarifier to join water removed by the shredder. After the condenser, the off-gas would pass through a caustic scrubber to neutralize any acids, such as hydrofluoric acid, that may form during drying. Water droplets still entrained in the gas stream, would be removed with a water knock-out drum and mist eliminator, and would be returned with the condensates to the clarifier. Gas leaving the mist eliminator would be heated to 150°C (300°F) to vaporize any remaining water prior to passing through HEPA filters to remove any remaining particulate. An exhaust fan at the end of the

emissions control system would create the necessary draft to pull the exhaust gas through each piece of equipment. The off-gas may also be used to dry the frit after quenching.

Emission concentrations estimated from the Draft Final RI Report for Operable Unit 1 (DOE 1994a) data show no need for control of volatile organic compounds at the process building vent. If volatile organic emissions were shown to be problematic, carbon filters could easily be added to the vent system. Also, since the temperature of the waste or the off-gas from the dryer chamber would not exceed 150°C (300°F), PCB break-down products such as dioxins and furans would not be generated. Emissions would be monitored to meet regulatory requirements. Combustion gases would be exhausted by a separate fan and would be discharged with the clean process gases through a common stack to the atmosphere. A description of the Off-Gas Treatment System is provided in Section 3.3.4.1.

Vitrification

Feed material would be transferred into the feed bins ahead of the four vitrifiers. The material handling system would include an apron feeder, a bucket elevator, and a horizontal conveyor with traveling tripper over the vitrifier feed bins. Feed from the bins would be withdrawn at a controlled rate and transferred for blending with the necessary glass-forming additives to prepare the specified furnace feed composition.

For costing purposes, the glass formulation for the vitrifiers is currently assumed to be 60 percent waste; 20 percent soil (caps, liners and contaminated soil beneath the pits); 10 percent silica (quartz sand); and 10 percent flux (sodium carbonate). Based on a total waste and soil quantity of 916,000 dry tons, the total quantity of glass frit produced would be 1,145,000 dry tons.

The waste blended with additives would be fed through the top of four 100 ton per day (output) vitrification furnaces. This dried feed would form a cold cap on top of the molten glass pool. The furnaces would be joule-heated furnaces (assumed for costing) with multi-layered refractory linings and water-cooled jackets. A secondary-containment pit would be constructed around each vitrifier. The waste and additives would leave the vitrifiers as a molten glass stream. This product stream would then be fritted by quenching in water. After quenching, the frit would be dried with hot air from the dryer stack. The vitrified material would be a glass frit typically less than 2.5 centimeters (1 inch) in diameter. The production rate for the vitrification process is estimated at 400 dry tons of

frit per day. The system would operate an average of 275 days, 24 hours a day for approximately 10 years.

The water vapor from the quencher and the frit drying air would be combined with the vitrification off-gas prior to entering the off-gas quencher. The quencher/scrubber would cool the off-gas and remove some of the regulated pollutants. After the scrubber, the off-gas would pass through a mist eliminator to remove entrained water droplets. Then the off-gas would be treated as previously described.

The dry frit from each vitrification plant would be conveyed from the product quench onto an apron feeder that would deliver the frit from each vitrifier to a conventional material handling system which would transfer and place the vitrified waste into the disposal cell.

On-Property Disposal Cell

The on-property disposal cell (disposal cell) would incorporate design features from both the Resource Conservation Recovery Act (RCRA) and the Uranium Mill Tailings Remediation Act (UMTRA) to produce a disposal cell of uniform design to accommodate site waste (See Figure 4-2).

The disposal cell would be designed to contain approximately 1,145,000 dry tons (636,000 cubic yards) in-place (placed and/or compacted in the cell) of waste. The estimated quantities for the disposal cell are conceptual and would be revised during the remedial design. The disposal cell could be easily expanded as needed.

The disposal cell, would be a square, above grade cell with an approximate footprint of 16 hectares (39 acres). The cell cover would slope at 4 percent from the crown out to the clean fill dikes. The disposal cell would have a riprap lined channel along the east, north and west sides of the disposal cell. The channel would protect the disposal cell from the Probable Maximum Flood (PMF). The disposal cell would have a 2 percent sloping double bottom liner with a leachate collection/detection system and clean fill dikes surrounding the waste. The above listed components of the disposal cell are further discussed in detail below. The level of detail was used for cost estimating purposes.

Disposal Cell Cover. The disposal cell cover would incorporate (from top down); a 84-centimeter (33-inch) grass vegetative layer to resist top soil erosion; a 15-centimeter (6-inch) thick gravel filter to

facilitate infiltration drainage; a 90-centimeter (36-inch) biotic barrier consisting of cobbles to prevent animal and plant intrusion; a 30-centimeter (12-inch) thick sand drainage layer; a double layer of textured high density polyethylene (HDPE) and geosynthetic clay liner (GCL) to impede infiltration; a 60-centimeter (24-inch) thick clay layer to impede infiltration; and finally a 45-centimeter (18-inch) thick contouring fill layer to separate the engineered cover from the waste. See Figure 4-3 for cover details.

Disposal Cell Liner. The disposal cell liner would incorporate (from top down); a 60-centimeter (24-inch) protective layer consisting of a uniform grade material such as soil or flyash to protect the liner when the waste is placed; a 15-centimeter (6-inch) sand filter; a 45-centimeter (18-inch) thick leachate collection system consisting of gravel; a primary geomembrane liner consisting of textured High Density Polyethylene (HDPE) above and below a geosynthetic clay liner (GCL) to impede any further seepage to the vadose zone; a 15-centimeter (6-inch) secondary filter layer consisting of sand; a 45-centimeter (18-inch) thick leak detection system consisting of gravel; then a secondary liner consisting of textured HDPE, GCL and finally 90-centimeter (36-inch) of compacted native clay. The leachate collection and leak detection systems would have 15-centimeter (6-inch) diameter perforated pipe to direct leachate to a collection point for transfer to the FEMP AWWT facility. See Figure 4-3 for liner details.

Disposal Cell Clean Fill Dike. The disposal cell clean fill dike would have 3 Horizontal (H):1 Vertical (V) interior slopes and 5H:1V exterior slopes. The clean fill dike would have a 30-centimeter (12-inch) thick layer of 15-centimeter (6-inch) diameter riprap on the exterior face and a 3-meter (10-feet) wide by 30-centimeter (12-inch) thick apron of riprap along the toe to provide erosion protection from cell runoff. The core of the clean fill dike would have compacted clay on the top section and a well graded compacted backfill on the bottom section. The height of the clean fill dike from existing grade to the edge of the disposal cell cover ranges from 9 to 12 meters (30 to 40 feet).

Disposal Cell PMF Channel. The PMF channel would prevent erosion of the clean fill dike by directing runon by precipitation away from the cell. The channel follows the disposal cell toe except along the southwest side of the cell. The channel would be offset from the clean fill dike toe in distances ranging from 9 to 180 meters (30 to 600 feet). The offset area slopes at 1 percent toward the channel. Channel sideslopes are 4H:1V and 5H:1V with 3-meter (10 feet) wide channel invert.

The sideslopes would be armored with 30 centimeters (12-inches) of riprap and 15 centimeters (6-inches) of bedding gravel.

Disposal Cell Construction. The disposal cell would be constructed in equal phases by quadrants. The first quadrant would be constructed at the west corner of the disposal cell, with subsequent quadrants to follow. Waste-filled quadrants would be capped as final waste depths are achieved. A conceptual layout of the disposal cell construction progression is provided in Figure 4-4.

Vitrified Waste Placement. The vitrified material would be placed and compacted in 30-centimeter (12-inch) lifts. Interim covers would be placed on all exposed waste before the final cover is in place. A tarp would be used as an interim cover for waste exposed on a daily basis and 15 centimeters (6-inches) of clean fill would be used for waste exposed for a week or longer. During construction, temporary berms and diversion ditches would be used to protect the placed waste from slumping. Leachate from the exposed and capped waste would be collected by the permanent leachate collection system and a temporary collection offset 15 meters (50 feet) from the newly placed waste toeline. All leachate would be transported to the AWWT facility. (See Section 3.2.3.2 for a discussion of the AWWT facility's capabilities to treat contaminated Operable Unit 1 water.) The permanent leachate collection system would continue to operate until no leachate is generated, at that time the system outflow would be disconnected and grouted.

Site Restoration. After all of the waste in the waste pit area has been excavated, the pit liners in that area would be carefully removed. The soils under the excavated area of the pit would be inspected for signs of contamination according to the established protocol. Soils exhibiting contamination would be excavated. The freshly exposed soil surfaces would be screened and excavated until acceptable contamination levels are shown by the screening systems. After screening indicates that soil contamination is below the final action levels, a three-dimensional sampling pattern would be used to collect samples for analytical testing. The samples would be analyzed for contaminants of concern to verify action levels had been achieved. The waste pits would then be backfilled with clean soil.

To complete the cover system, clean soil would be used to backfill the waste pit area and re-establish grades to promote surface runoff and drainage away from the waste pit area. The cover system

would cover approximately 10 hectares (24 acres) and have a total thickness of 1.9 meters (6.3 feet) consisting of:

- A low permeability compacted soil barrier, 0.6 meters (2 feet) thick
- A geosynthetic clay cap (GCC), approximately 0.6 centimeters (0.25-inches) thick and a textured geomembrane
- A high permeability drain layer, coarse sand to a fine gravel, 0.3 meters (1 foot) thick
- A geotextile layer
- A vegetative layer with a 0.8 meters (2.8 feet) thick lower zone of clean soil fill and an upper zone 15 centimeters (6-inches) thick of top soil

With this cover system design, only minimal amounts of precipitation pass through the cover system. The final cover vegetation system would be selected such that only minimal maintenance would be required.

To minimize the overall impacts of the restoration on the excavation activities, the restoration of the waste pit area would be sequenced with the excavation of the waste materials. This would also ensure that only minimal areas of the waste pit area are open between excavation and restoration.

Controls to minimize dust-generation and stormwater runoff and erosion would be maintained throughout waste pit area restoration.

4.3.2 Detailed Analysis

4.3.2.1 Overall Protection of Human Health and the Environment

Alternative 4A would meet the remedial action objectives for Operable Unit 1 and would be protective of human health and the environment. Implementation of this alternative would prevent direct access to waste materials by removal to health-based levels (see Section 2.2), treatment and waste containment, and would mitigate the migration of contaminants to the air, soil, and groundwater. Exposure to direct radiation above protective levels would also be prevented by the waste containment system. Appendix D provides quantitative documentation of the basis of these statements.

The primary actions that would be used to meet the remedial action objectives are removal of contaminated materials and placement of a multilayer cover on the waste pits, treatment through vitrification, containment in an on-property disposal cell, and implementation of institutional control measures.

Vitrification reduces the mobility of the contaminants of concern. In the event of a failure of the disposal cell, which could allow increased infiltration and subsequent leachate formation, the leach rate of the vitrified material would be lower than untreated material, thereby providing continued protection of the underlying Great Miami Aquifer.

Containment of the treated material in an on-property disposal cell would control contaminant migration to human and environmental receptors and would also prevent direct radiation exposure from the treated waste material. The cell would be designed for a life of 1,000 years and would require minimal maintenance.

A multilayer cover would be placed over residual contamination in the excavated waste pit area to minimize infiltration/leaching and potential exposures to any residual contamination remaining in the waste pit area.

Institutional control measures would be employed to supplement the treatment and containment actions in order to provide additional protection of human health. Institutional controls would include the adoption of long-term federal ownership of the FEMP site. Continued federal ownership of the site would preclude future on-property residential and farming land uses which could result in direct exposure to the waste materials through intrusive actions or facility degradation. The use of institutional controls is also consistent with an ARAR for the on-property disposal cell; to comply with ORC 3734.02 (H), hazardous and solid waste disposal facilities must include in any conveyance deed a protective covenant to restrict future mining, drilling, and residential uses of the active disposal areas. In accordance with this requirement, a deed restriction would be placed on the FEMP site property detailing these restrictions. The uncertainties associated with very long-term institutional control periods include a possible loss of federal ownership and the loss of the property records containing the deed restrictions.

Loss of institutional controls in combination with disposal cell or cap failure over the long term could result in potential contaminant migration or exposure to contaminated material by future human and environmental receptors. Exposures to potential receptors would be expected to be minimal due to the positive attributes of the treated wastes and the low residual contamination in soils. However, unacceptable risks to human health and the environment could occur in the event that both engineered and institutional controls were lost. Then, potential risk could occur by both direct contact in an intrusion exposure scenario or by groundwater impacts, depending on the long-term leaching reduction performance of the treated (vitrified) waste.

Worker risks would be expected during implementation of this alternative. However, through the implementation of a worker health and safety plan in compliance with 29 CFR 1910.120, these exposures would be kept to ALARA levels and would comply with DOE orders. These risks are discussed further in Section 4.3.2.5.

4.3.2.2 Compliance with Applicable or Relevant and Appropriate Requirements

Compliance or noncompliance with the principal chemical-, location-, and action-specific ARARs is discussed below. Detailed documentation of compliance with ARARs for Alternative 4A is presented in Appendix F.

Chemical-Specific ARARs/TBCs

Alternative 4A would comply with the chemical-specific ARARs/TBCs identified in Appendix F. ARARs associated with potential releases to air, surface water, groundwater, and penetrating radiation would be complied with through treatment of the waste, implementation of the engineered features of the treatment process and disposal facility, as well as worker protection measures undertaken during remedial actions.

The chemical-specific ARARs for airborne releases for this alternative relate mainly to emissions of radionuclides. Occupational Dose Limits of radiation exposure from site operations on workers is limited to the lesser of a total effective dose equivalent of 5 rems or 50 rems to any individual organ (DOE Orders 5480.1 and 5400.5) while limits on individual members of the public is 0.1 rem per year. The specific measures taken to control particulate emissions and fugitive dust during remedial actions and engineered controls incorporated into this alternative, as well as use of personal protective equipment, would be adequate to ensure compliance with federal and state ARARs.

Airborne emissions of radionuclides other than radon from DOE facilities are, in accordance with 40 CFR 61 Subparts H and I, limited to 10 mrem/yr annual dose. The maximum permissible surface release rate of radon-222, as specified in 40 CFR 61 Subpart Q, is 20 picoCuries per square meters per second, surface averaged. This requirement is supplemented by 40 CFR 192.02(b) which requires that the concentration of radon-222 in air at or above any location outside the disposal site not increase the annual average by more than 0.5 picoCuries/liter.

Isolation of residual radioactivity and control of exposure to radioactive material regulations pursuant to 40 CFR 192 would be complied with through the engineered features of the on-property disposal cell. The atmospheric release of radionuclides (including radon) from the surface of the disposal cell would be essentially eliminated by treatment (vitrification) of the waste form and the multimedia cover (over 3 meters [10 feet] thick) of the disposal cell. The multimedia cover system of the disposal cell would further reduce any potential above background releases of radioactivity and other airborne contaminants from the wastes. The design of the disposal cell would comply with 40 CFR 192 which states that control shall be designed to be effective for up to 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. Given these multiple barriers to the release of radionuclides, the 40 CFR 61 Subparts H and I release rates and the other identified chemical-specific public dose and airborne concentration limits as well as ARARs associated with fugitive dust and particulates, would be met.

The FEMP has adopted an operable unit strategy that places responsibility for groundwater remedial actions for the entire site, including Operable Unit 1, under Operable Unit 5. Remedial actions at Operable Unit 1 will address the sources of contaminants to groundwater but not the remediation of the groundwater. All water from Operable Unit 1 impoundments will be forwarded to the AWWT facility for treatment and discharge.

ARARs providing prescriptive chemical-specific and dose-based limitations for the protection of groundwater include the MCLs defined in 40 CFR 141.11 (et al.). The MCLs for inorganic and organic chemicals are promulgated under 40 CFR 141.62 and 40 CFR 141.61 for inorganics and organics, respectively (Safe Drinking Water Act). Some State of Ohio MCLs are more stringent than the level set by federal regulation. These concentration-based limits are presented in numerical form in Appendix F. Additional concentration-based limits for chemicals in drinking water at a Treatment Storage Disposal Facility (TSDF) are prescribed in 40 CFR 264.94 (RCRA Subtitle C). A recent

rule-making by EPA has proposed concentration-based limitations for certain previously unregulated radionuclides, including uranium. Where these proposed limitations are more restrictive than existing promulgated standards they have been adopted as TBC requirements. Additionally, dose-based requirements for the protection of potential public receptors using affected groundwaters are defined in DOE Order 5400.5 which limits the allowable annual effective dose equivalent from all pathways, including groundwater, to any member of the public from exceeding 100 mrem.

Groundwater compliance is typically demonstrated by fate and transport modeling (refer to Appendix D for a discussion of Operable Unit 1 FS modeling). Guidance is provided in 40 CFR 257.3-4 and 40 CFR 264 Subpart F as to the point of compliance for demonstrating whether the groundwater protection requirements for inorganic and organic contaminants would be attained. The point of compliance is a vertical surface of the uppermost aquifer (the Great Miami Aquifer) located at the hydraulically down-gradient limit of the FEMP site boundary. FEMP Operable Unit 5 is currently conducting slug tests and yield tests in a number of monitoring wells completed in the glacial overburden. Preliminary results have shown yields 50 to 100 times less than the yields typically obtained from water supply wells completed in the Great Miami Aquifer.

Zones of saturation in the glacial overburden do not have significant hydraulic connections to the underlying Great Miami Aquifer. The zones of saturation are relatively small and isolated within a low permeability matrix of clay and silt. The till, with its high clay and silt content, is a natural barrier to groundwater migration. The low hydraulic conductivity of the till produces very slow groundwater velocities. Operable Unit 5 is undertaking additional work to optimize on-site disposal cell locations. If this alternative is selected, this work will be considered in finalizing a cell location.

The specified 1,000-year fate and transport modeling of uranium, the principal groundwater constituent of concern, indicates the uranium concentration would not exceed the proposed 20 ug/L MCL defined in 40 CFR 141, at the point of compliance. (See Appendix D for a description and results of this modeling; see also the discussion of the long-term effectiveness in Section 4.2.2.3.) The modeled releases for the contaminants of concern would all be within the concentration- and dose-based regulatory limits.

All surface water releases (originating from the disposal cell leachate collection/detection system) would be directed to the FEMP site AWWT facility for treatment prior to release. Since the AWWT

facility would be subject to the National Pollutant Discharge Elimination System (NPDES) permit issued by the State of Ohio, any contaminants in this waste stream would be removed or treated to acceptable levels prior to discharge. Section 3 contains a more detailed discussion of the AWWT facility's ability to manage this waste stream. The Ohio Water Quality Standards for surface water (i.e., for a warm water aquatic life habitat) would also be attained by this treatment.

Location-Specific ARARs

Location-specific requirements associated with this alternative relate to the protection of four principal natural features or resources: floodplains, wetlands, endangered species, and the sole source aquifer underlying the FEMP site.

Restrictions on activities conducted in wetlands and floodplain areas are specified in 40 CFR 6.302, 10 CFR 1022 and Executive Orders 11990 and 11988. Compliance with these requirements would be met through appropriate planning, siting, design, and operational procedures. These regulations apply not only to remedial activities within the boundaries of the operable unit, but also to the siting of a disposal or long-term storage facility designed to manage wastes from Operable Unit 1. A wetland survey has identified small amounts of emergent wetlands within the tributaries and drainage ditches that feed into Paddys Run which are within the boundaries of Operable Unit 1. Compliance with these requirements would be met through appropriate siting of facilities and operations, the prior assessment of potential impacts associated with activities conducted in these locations, and the implementation of mitigative measures.

The methods for handling dredged and excavated material would comply with the provisions of 33 CFR 323 and 40 CFR 230, which state that dredged or excavated material will not be discharged into waters of the U.S.

Protection of endangered species is mandated by 16 USC 1531, 50 CFR 17 and 402. Studies are being conducted to determine the presence of individuals and potential habitat of several federally and state-listed animal and plant species. If habitat or individuals are found, appropriate mitigative measures would be taken.

The provisions of 16 USC 469, 36 CFR 800, 40 CFR 6.301; 42 USC 1996 and 43 CFR 7 require federal agencies undertaking an action to implement measures to avoid adverse impacts to historic and

cultural properties. Alternative 4A would comply with these provisions since any cultural resources identified would be either avoided or managed appropriately. It is noted that no such cultural resources are expected to be found within the boundaries of Operable Unit 1.

The State of Ohio's solid waste disposal design criteria considerations are provided in OAC 3745-27-07. Embodied within these requirements are restrictions pertinent to the siting of the on-property disposal cell, which would be considered relevant and appropriate to the implementation of this alternative. The location of the disposal cell would be sited to meet the specific setback requirements as defined in the above citation, including the distance from the property line and the distance from the disposal cell to the nearest domicile or water supply well. The proposed siting location also must attain the 4.5-meter (15 feet) isolation distance required in the OAC regarding the distance between the bottom of the liner system and the top of the uppermost Great Miami Aquifer underlying the disposal cell.

OAC 3745-27-07 (B)(5) specifically prohibits solid waste disposal facilities from being constructed over sole source aquifers. Exemptions may be granted to this requirement on the basis of technical considerations which are defined in "Guidance on Solid Waste Siting Criteria: Sole Source Aquifer (Guidance No. GD0202.101, May 6, 1991)". These technical considerations include the following:

- There is a significant thickness of low-permeability material between the disposal cell liner and the aquifer.
- There is no significant interconnection between the aquifer and any significant saturated zones that exist above the aquifer.
- No adverse impact to human health or safety or the environment will occur as a result of granting the exemption.

The disposal cell, as proposed, has the potential to meet the technical considerations used to grant exemptions: in the general vicinity of the suggested cell location, approximately 19 meters (30 feet) of low-permeability glacial till lie beneath the proposed liner, saturated zones in the glacial till have no significant hydrologic connections with the underlying aquifer, and fate and transport modeling predicts that potential future releases to the aquifer from the facility will not exceed MCLs or lead to an ILCR greater than 1×10^{-6}. The following is a summary discussion of the technical considerations and employs data from Appendix D. Available geologic data demonstrate that there may be greater than 9 meters (30 feet) of low permeability, grey till between the proposed facility liner and the top of

the sand and gravel of the Great Miami Aquifer. The glacial till does contain erratically distributed pockets and lenses of sand. However, data from both the FEMP site and proposed disposal cell site indicate that movement of groundwater within these units is limited due to the small areal and vertical extent of the lenses. Consequently, the dominant groundwater flow path through the till is vertical.

The till, with its appreciable silt and clay content, can be high quality natural barrier to groundwater migration. The low hydraulic conductivity of the clay and silt strata produces very low groundwater velocities. The proposed cell location does not have any known significant hydraulic connection between perched groundwater in the till and the Great Miami Aquifer. Limited lateral transport is presumed to be possible within the till, such as in sand lenses. Engineered measures such as removal or grouting of sand lenses and recompaction with clay could mitigate potential lateral transport. Additionally, the engineered measures of the disposal cell would further retard the already slow vertical transport of leachate.

Fate and transport modeling for the specified 1,000-year time frame predicts that no adverse impact to human health or the environment will occur associated with Alternative 4A (groundwater fate and transport model results are presented in Appendix D).

In consideration of these hydrogeologic factors, design, and impact prevention and mitigation capabilities, an exemption to allow the construction of a disposal cell over the sole source aquifer at this location at the FEMP site may be technically justified, and the requirements of OAC 3745-27-07 relating to the sole source aquifer would then be met for Alternative 4A.

Action-Specific ARARs

Alternative 4A would comply with all pertinent action-specific ARARs identified in Appendix F regarding waste removal, treatment and on-property disposal.

As previously discussed under chemical-specific ARARs, the specific measures and engineered controls incorporated into Alternative 4A would meet all action-specific ARARs regarding air quality, including 40 CFR 50.6 and OAC 3745-17-08 which are ARARs during the remedial action and the post-closure period.

Waste removal actions will be conducted in compliance with the requirements of 40 CFR 192.02(b) and 192.12 to provide reasonable assurance that residual radioactive materials do not exceed the specified concentrations above background levels. During implementation of the remedial action (including waste removal, facility construction and waste treatment), appropriate engineered features and procedures would be implemented to comply with the requirements of the Clean Air Act, 40 CFR 50.6, and Ohio requirements for fugitive dust control, OAC 3745-17-08. At this time, it is not believed that Operable Unit 1 waste contains sufficient concentrations (greater than 50 ppm) of polychlorinated biphenyls (PCBs) to require compliance with 40 CFR 761, Subpart G, regulations. Similarly, the concentrations of asbestos are not expected to require compliance with 40 CFR 763, Appendix D to Subpart E. Review of operating records indicates that the representative waste volume as a whole would not contain asbestos at 1 percent by weight (the regulatory threshold).

The above-grade disposal cell system incorporates design requirements for the disposal of uranium mill tailings (40 CFR 192) and hazardous waste under Resource Conservation Recovery Act (RCRA) (i.e., TSDF requirements for land disposal facilities under 40 CFR 264). The following features would be incorporated into the overall design for Alternative 4A: (a) waste treatment through vitrification; (b) a liner with leachate collection/detection system; and (c) a 3-m (10-ft) thick multimedia cap. The technical elements of this design are described in Section 4.3.1. The design of the on-property disposal cell would also include engineered features that satisfy the requirements of the Clean Water Act (40 CFR 125.100, 125.104, and 122.26, and the Ohio Water Quality Standards), and RCRA Subtitle C for hazardous waste facilities. 40 CFR 264 Subpart F requirements mandate groundwater monitoring, detection, and a program to initiate corrective action, if necessary. 40 CFR Part 264 Subpart G requires facility closure in a manner that minimizes the release of hazardous constituents. Compliance with these RCRA requirements would be met with the incorporation of the appropriate design features. Operational requirements for disposal facilities, such as those specified in 40 CFR 241 Subpart B, and 40 CFR 264 Subparts B, C, and D would also be complied with through planning and the implementation of appropriate procedures.

Alternative 4A disposal cell system has been evaluated and would satisfy the 100 mrem public dose limit for radiation exposure from all pathways as established by DOE Order 5400.5 Chapter II (see Appendix D for the presentation of the analysis). The long-term total exposure to radiation from all potential pathways associated with this treated waste from alternative would be less than 1 mrem/yr.

Pursuant to Section 3734.02 (H) of the Ohio Revised Code, building and drilling activities are prohibited on land where hazardous or solid waste facilities were operated, without the prior approval of the Director of the Ohio EPA. Additionally, requirements under 40 CFR 264.310 provide that all disposal cell systems be protected and benchmarks be used to mark the location of waste cells. Compliance with these ARARs would be achieved through design and the implementation of institutional controls at the disposal cell. These controls would be maintained through the use of fences, sign posting, deed restrictions, and continued federal ownership of the FEMP site.

4.3.2.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

Alternative 4A would be effective in the long term because Operable Unit 1 wastes would be excavated to health-based levels. The long-term risk evaluation of this alternative analyzed all potential exposure pathways remaining following remediation. This screening analysis identified the primary pathways and principal mobile contaminants affecting public risk. Use of proposed remediation levels (see Section 2.2) in the FS risk evaluation as described in Appendix D yielded results that documented that these levels were protective of human health and the environment.

Adequacy and Reliability of Controls

Vitrification is an innovative technology that has been previously applied to the stabilization of waste materials; however, vitrification at the scale contemplated under Alternative 4A has never been performed, nor has it been performed on this type of waste. From 1990 to 1993, the FEMP site conducted a series of bench-scale treatability tests to examine the performance of the vitrification technology on Operable Unit 1 waste pit material. The tests have demonstrated variations in the leachability of radionuclides and other inorganics (see Appendix C); however, the leaching rate from all vitrified material was below TCLP limits and generally lower than the leaching rates from untreated material. The use of vitrification provides the operational flexibility to recycle and retreat glass product not meeting disposal requirements. Therefore, there is a high probability that the vitrification treatment system could be operated to attain the required glass product requirements. Although the life expectancy of the vitrified material is difficult to estimate, on the basis of the longevity of volcanic glass (an analog) and diffusion calculations the vitrified product is expected to withstand environmental exposure for thousands of years.

The on-property disposal cell uses proven technologies and materials of construction. Similar disposal systems are currently being employed for the encapsulation of hazardous wastes and low-level radioactive waste under both DOE and NRC programs, and uranium mill tailings under the UMTRA Program and the Formerly Utilized Sites Remedial Action Program (FUSRAP). The disposal cell would be designed to preclude the need for significant long-term management.

Consistent with DOE Order 5400.5, 40 CFR 264.114 Subparts F and G, the performance of the disposal system would be monitored. This monitoring supports the required 5-year CERCLA review. As a result of the findings of the review, there is a potential that the components of this alternative may require maintenance, modification, or replacement. The risks associated with maintenance activities would be generally limited to on-property workers. Consistent with DOE Order 5480.11, these potential exposures would be kept to ALARA levels and within regulatory limits. Institutional controls, including physical barriers and administrative controls, would be reliable for preventing unauthorized access to the site and potential exposures. Although loss of institutional controls is always possible, continued FEMP ownership by the government would ensure that institutional controls are maintained.

Long-Term Environmental Impacts

Implementing Alternative 4A would result in permanent commitment of on-property land for material disposal at the FEMP site.

Alternative 4A would permanently disrupt 23.5 hectares (58 acres) from construction and permanent land committal of the on-site disposal cell.

Alternative 4A would permanently disturb 5.37 hectares (13.2 acres) of riparian habitat along Paddys Run and various potential threatened and endangered species habitat within and along Paddys Run at the FEMP site during excavation and regrading activities. Potential threatened and endangered species terrestrial habitat includes the Indiana bat, running buffalo clover, slender fingergrass, mountain bindweed, and spring coralroot. Alternative 4A would result in the loss of 27.52 hectares (68 acres) of managed grazed field from construction of the on-site disposal facility. Long-term impacts to threatened and endangered species terrestrial habitat within the managed grazed field would be off-set from the implementation of possible mitigative measures discussed in Section 4.8.

Alternative 4A would impact a total of 2.42 hectares (5.98 acres) of wetlands from on-site disposal and remedial activities. These wetland areas include 0.72 hectares (1.77 acres) of isolated scrub-shrub/persistent emergent wetlands west of the waste pits and 0.08 hectares (0.21 acres) of drainage ditch/swale wetlands east of the waste pits. The citing of the on-property disposal cell facility would result in the loss of approximately 0.53 hectares (1.3 acres) of drainage ditch/swale wetlands. Approximately 1.09 hectares (2.7 acres) of drainage ditch/swale wetlands would be loss due to the borrow area. Mitigation for wetland impacts would be determined using the 404 (b)(1) guidelines of the Clean Water Act.

Consumptive use of geological resources (e.g., quarried rock, sand, and gravel) and petroleum products (e.g., diesel fuel and gasoline) would be required for removal, construction, and disposal activities of Alternative 4A. Supplies of these materials would be provided by the construction contractor. Additional fuel use would result from off-site transport of the materials. However, adequate supplies are available without affecting local requirements for these products. Treatment processes would require the consumptive use of materials and energy (for cement stabilization, process additives such as cement and flyash would be needed).

The committed land at the FEMP site would be actively monitored and maintained. Periodic monitoring of nearby surface water and groundwater from monitoring wells around the perimeter of the on-site disposal facility would be performed, and periodic inspections would identify any damage to the above-grade disposal facility. Maintenance activities would be performed as necessary. Hence, no impacts to groundwater are expected to occur from Operable Unit 1 remedial activities.

Soil and Geology. Construction of the on-site above-grade disposal cell and the probable maximum flood channel would result in the permanent disruption of 15.8 hectares (39 acres) and 7.5 hectares (18.5 acres) of land at the FEMP site respectively. Excavated pit waste would be pretreated through drying prior to vitrification and placed in the above-grade disposal facility, which would consist of a multimedia cap and a bottom liner with a leachate collection/disposal system (LC/DS).

After the pit waste and liner material have been excavated, contaminated residual soil would be removed and transported to Operable Unit 5 for management. Following removal of contaminants, the pits would be backfilled with clean soil. The 2.83 hectares (7 acres) borrow area north and adjacent to the waste pit area could be used for backfill if acceptable material is available. In

addition, surface soil exceeding OU1 established clean-up levels would be excavated and removed. The excavated surface soil will be transported to OU5 for management. All excavated areas would be regraded to near original contours with clean backfill. The borrow area would be regraded and revegetated after excavation. Impacts on both surface and subsurface soils from Operable Unit 1 would be beneficial due to the removal of waste and contaminated soil. Capping and runoff/run-on controls would minimize contaminant transport to uncontaminated soils through stormwater runoff control measures.

The regional geology of the Fernald site and surrounding area would not be affected by implementation of this alternative.

Potential seismic events would be considered during detailed design. Potential impacts of an earthquake on this disposal facility include landslides, liquefaction, and seismically induced settling of foundation soil and impounded material with subsequent failure due to landslides. The design of this facility would incorporate appropriate protection against seismic damage. Local geologic conditions indicate the subsoil of the proposed facility location is not susceptible to liquefaction or seismically induced settling. A seismic risk zone is a measurement of earthquake intensity on a scale of less-than-one to four; a seismic risk zone of one has been assigned to the FEMP region. Seismic conditions would be further evaluated if this alternative is selected.

Water Quality and Hydrology. Grading and excavation activities would cause minor alterations to the east bank of Paddys Run. Runoff control measures (silt fences, hay bales) during remedial activities would minimize increased sediment load to Paddys Run, however, the natural flow of Paddys Run would re-establish a natural stream community. Therefore, no long-term impacts to water quality are expected.

A long-term water quality monitoring system would be implemented by incorporating design features into the above-grade disposal cell and installing a LC/DS and monitoring wells around the perimeter of the facility. Regrading and revegetating the disturbed areas of the disposal site following remedial activities would minimize potential impacts to water quality. A discussion of exposure and risks associated with long-term disposal is provided in Appendix D.

Run-on and runoff controls would be used at the above-grade disposal facility and the surrounding areas of the disposal facility would be regraded to approximate original contours allowing the discharge of surface runoff to the AWWT facility. Surface runoff otherwise resulting from regrading would be minimized by revegetating the regraded areas to reduce runoff velocities.

At the completion of remedial action activities, areas disturbed during the implementation of this alternative would be regraded and revegetated to prevent erosion. Final grading would ensure proper drainage to prevent any potential impacts to the above-grade disposal cell. The above-grade disposal cell would be actively monitored and maintained. Periodic monitoring of nearby surface water and groundwater would continue. Periodic site inspections would be performed to identify potential damage to the disposal facility from occurrences such as erosive forces from heavy winds and rain, biointrusion, or natural phenomena (e.g., earthquake or tornado). Maintenance would be performed as necessary.

Air Quality. Following waste pit and residual soil removal and placement in an above-grade disposal cell, air quality at the Fernald site over the long term would be similar to background conditions. The above-grade disposal cell would be designed and constructed to minimize the likelihood of any releases to the atmosphere. No long-term impacts on air quality are expected because the disturbed areas (e.g. support facilities, waste pits) would be restored (e.g., regraded and revegetated) following completion of remedial activities, minimizing the potential for releases of inhalable particulates.

Biotic Resources. No critical habitat for threatened and endangered species has been identified in areas to be directly impacted by Alternative 4A activities. However, there is potential for threatened and endangered species to reside near the waste pit area, which could be impacted by this alternative.

The Indiana bat (*Myotis sodalis*) is a federally endangered species whose range extends into the vicinity of the Fernald site along Paddys Run. A survey conducted in 1988 determined that potential habitat for the Indiana bat exists within the banks of Paddys Run. No members of this species were located at the FEMP. An updated Indiana bat survey would be performed to determine presence of members. If members of the species are present, mitigative measures could be implemented as discussed in the short-term effectiveness section for this alternative. No long-term impacts are expected as a result of mitigative measures.

Running buffalo clover (*Trifolium stoloniferum*) is a federally endangered plant species that has been recorded within Miami Whitewater Forest, approximately 8 kilometers southwest of the Fernald Site. This species prefers dry, disturbed soils in open forests and grasslands. The potential exists for this species to be present within the riparian area between Paddys Run and the Waste Storage Area, and the borrow pit location. A botanical species survey would be performed to determine the presence of members. If members of the species are present, mitigative measures would be implemented as discussed in the short term effectiveness section. No long-term impacts are expected as a result of mitigative measures.

Slender fingergrass (*Digitaria filiformis*) and mountain bindweed (*Polygonum cilinode*) are state endangered plants that were recorded at the Fernald site in a 1986 survey within the riparian areas along Paddys Run. An updated botanical species survey would be performed to determine the presence of individuals. If individuals are present, mitigative measures would be implemented as discussed in the short-term effectiveness section. No long-term impacts are expected as a result of mitigative measures.

Spring coralroot (*Corallorhiza wisteriana*) is a state threatened orchid that is found in forested wetlands and wooded ravines in this region. Spring coralroot has not been reported at the Fernald site, but the Ohio Department of Natural Resources has reported a population within Miami Whitewater Forest. A botanical species survey would be performed to determine the presence of individuals. If individuals are present, mitigative measures would be implemented as discussed in the short-term effectiveness section. No long-term impacts are expected as a result of mitigative measures.

The Sloan's crayfish (*Orconectes sloanii*) is a state threatened species which resides in Paddys Run at the Fernald site. No long-term impacts are expected as result of implementing the mitigative measures discussed in the short-term effectiveness section.

Excavation activities would result in the loss of approximately 5.37 hectares (13.2 acres) of riparian habitat, containing diverse flora and fauna, in addition to the above-mentioned potential habitats of threatened and endangered species. This habitat would be restored by implementing the mitigative measures discussed in the short-term effectiveness section. Therefore, there would be no long-term impacts.

Construction of the on-site disposal facility would result in the loss of 27.52 hectares (68 acres) of managed grazed field. Threatened and endangered species, if found within this field, would be restored by implementing the mitigative measures discussed in the short-term effectiveness section. Therefore, there would be no long-term impacts.

Construction of support facilities would not result in long-term impacts to the 6.07-ha (15-acre) area since it has been previously developed and utilized as part of the waste pit area. The 2.83-ha (7-acre) area north and adjacent to the waste pit area to be used as a borrow pit, would not result in long-term impacts to introduced grassland. This habitat would recover upon regrading and revegetating the borrow pit.

The long-term residual risks to ecological receptors associated with Operable Unit 1 would be minimized with implementation of this alternative. The primary pathways of concern for ecological receptor contact with Operable Unit 1 include surface soil (e.g., ingestion, plant uptake) and runoff of surface soil to surface water bodies (e.g., exposures to aquatic habitat and ingestion of surface water). This alternative involves removal of surficial soil from the affected operable unit areas and replacement with clean fill. Therefore, ecological receptors would have minimal contact with residual contaminants. Therefore, this residual contamination would not pose a risk to ecological receptors within Operable Unit 1 due to the limited potential for contact with the surface soil and surface water pathway.

Wetlands and Floodplains. A wetlands delineation for the Fernald site was conducted in December 1992 (Ebasco Environmental 1993) and approved by the U.S. Army Corps of Engineers (COE). The delineation identified approximately 0.72 hectares (1.77 acres) of isolated scrub-shrub/persistent emergent wetlands west of the waste pits and 0.08 hectares (0.21 acres) of drainage ditch/swale wetlands south of the waste pits. The citing of the on-property disposal facility associated with Alternative 4A would result in the loss of approximately 0.53 hectares (1.3 acres) of drainage ditch/swale wetlands. Approximately 1.09 hectares (2.7 acres) of drainage ditch/swale wetlands would be lost due to the borrow area. Total wetland areas to be impacted are 2.42 hectares (5.98 acres). Mitigation for wetland impacts would be determined using the 404 (b)(1) guidelines of the Clean Water Act.

No long-term impacts would occur to floodplains. A floodplain/wetland assessment has been performed in accordance with 10 CFR 1022 requirements and is included in Appendix H of this FS Report.

Socioeconomics and Land Use. No change would be expected in the communities of Fernald or the communities and public facilities in the CMSA as a result of remedial activities.

The implementation of Alternative 4A is not expected to have any substantial impacts on the socioeconomics or land use in the vicinity of the Fernald site. The Fernald site is located approximately 29 kilometers (18 miles) northwest of Cincinnati, within Hamilton and Butler counties in Ohio. The land adjacent to the FEMP is primarily devoted to open land use such as agriculture and recreation. Commercial activity is generally restricted to the Village of Venice (also known as Ross), approximately 4.8 kilometers (3 miles) northeast of the facility, and along State Route (SR) 128 just south of the village. Industrial use is concentrated in the areas south of the Fernald site, along Paddys Run Road, in Fernald, and in a small industrial park on SR 128 between Willey Road and New Haven Road. Residential units are situated immediately north of the FEMP, in Ross, and directly east in a trailer park adjacent to the intersection of Willey Road and SR 128. Other residences located near the site are generally associated with farmsteads. Public perception associated with aesthetic values could be altered due to the visibility of the on-site disposal cell from SR 126 and Willey Road.

To better assess socioeconomic impacts to the area, as a result of implementing remedial activities, the surrounding counties have been grouped to provide a datapoint to assess impacts. The Consolidated Metropolitan Statistical Area (CMSA) for the Cincinnati region consists of thirteen counties: Brown, Butler, Clermont, Hamilton, and Warren counties in Ohio; Boone, Campbell, Gallatin, Grant, Kenton, and Pendleton counties in Kentucky; and Dearborn and Ohio counties in Indiana. Population within the thirteen-county region was 1.8 million in 1991 (ODUC, 1993). Within an 8 kilometer (5 mile) radius of the Fernald site, there were an estimated 22,927 residents in 1990 (DOE, 1993). Labor force in the multicounty area was 951,987 with unemployment at approximately 8.7 percent in March 1992 (IDWD, BLSDOL, OBES 1993). A detailed discussion of the impacts to the CMSA is provided in Section 4.3.2.5.

Cultural Resources. An archaeological survey would be performed for areas to be impacted by Operable Unit 1 remedial activities outside of the fenced production area, specifically the eastern portion of the disposal facility and the borrow area. Cultural resources discovered would be managed consistently with the requirements of the National Historic Preservation Act (NHPA), Ohio Historic Preservation Office (OHPO), American Indian Religious Freedom Act (AIRFA), Archaeological Resource Protection Act (ARPA), and the Native American Graves Protection and Repatriation Act (NAGPRA). A more detailed discussion of management procedure is provided in the short-term effectiveness evaluation for Alternative 4A. Cultural resources identified would be either avoided or managed appropriately, therefore, no impacts would occur to cultural resources at the Fernald site.

4.3.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 4A uses vitrification to treat the contents of Waste Pits 1 through 6, the Burn Pit, and the Clearwell. A preliminary remedy selection treatability study was conducted with Operable Unit 1 materials to compare the performance of vitrification to other remediation technologies. The criteria upon which this comparison was based were the leachability of the waste form, the material volume reduction achieved, and the reduction in radon emanation from the material. A summary of the vitrification treatability results is provided in Table 4-1. As noted in Table 4-1, the results of treatability studies performed to date are highly variable, primarily due to the heterogeneity of the waste pit material. Additional treatability studies are also currently being performed under the Minimum Additive Waste Stabilization (MAWS) Remedial Design Bench-Scale Program. The MAWS technology demonstration program is an integrated waste treatment system where vitrification is the core technology used for stabilization of wastes. The results of these studies are not discussed in this FS because they are still ongoing; however, they would be incorporated into remedial design if Alternative 4A is selected.

The chemical and physical properties of the wastes were determined and used in developing glass formulas for the bench-scale treatability study tests. Various formulations were studied for vitrification, including soil and flyash addition. Data from the study revealed that the radon emanation rate from the vitrified waste pit material ranged from 0.01 to 0.29 picoCuries/gram/day. Based on an emanation rate ranging from 0.71 to 63 picoCuries/gram/day for the untreated waste pit material, a reduction of radon emanation by a factor of approximately 200 was obtained in the bench-scale vitrification tests. The measured radon emanation rate from the treated waste form is approximately equal to the emanation rate from natural building materials such as brick and concrete,

even though the radium content of the waste glass is 10 to 1,000 times greater than that of natural building materials.

A wide variation in leaching of the various radionuclides and metals observed after vitrification was noted. While leaching of uranium isotopes from the untreated waste from Waste Pit 1 was reduced by a factor of hundreds through vitrification, leaching of some radionuclides such as radium and strontium isotopes was unchanged. The low activity ratios observed for the leachate from the untreated waste to that of the leachate from the vitrified waste do not necessarily indicate that radionuclides are immobilized, but rather, the ratios show that some radionuclides are not leached as readily as others from the untreated waste. Such variations can arise because of differences in solubility among the elements for the conditions encountered in the leachate. No reductions in the leachate concentrations from the treated waste (as compared to the untreated waste) were observed for either formulation for the following radionuclides: radium-226 (Waste Pit 2); thorium-228 (Waste Pit 2 and the Burn Pit); thorium-230 (Waste Pits 2 and 3 and the Burn Pit); total uranium and total thorium (Waste Pit 2); and neptunium-237 (Waste Pit 4).

Generally, the addition of flyash or soil decreased the leachability of uranium. There was an apparent advantage to adding flyash to achieve lower leachability. Increasing the sodium generally increased the leaching of uranium. However, with samples made from soil from Waste Pits 1, 4, and 6, the leachability of uranium decreased for formulations using higher loadings of sodium. None of the other metals, except barium, leached in sufficient quantities to provide trends. Barium leaching in material from Waste Pits 1 through 6 supported the trend that increased sodium loadings increased leaching. This trend was valid for both flyash and soil formulations. For the Burn Pit and Clearwell wastes, no barium-leaching trends could be established as a function of formulation.

One way to measure the stability of the vitrified waste form is to compare it to leach rate standards which have been developed for high-level radioactive waste vitrified materials. The normalized leach rates observed during the Product Consistency Test (PCT) were compared to the Savannah River High Level Waste Criteria (SRHLWC). The PCT is a 7-day (nominal duration) static leach test and is the present standard test for the high-level waste vitrification program. PCT for Operable Unit 1 wastes were performed for 7, 28, 56 and 180 days to acquire data on the long-term durability of these glasses. The test uses deionized water at room temperature to leach a glass sample which has been crushed and sieved to a size fraction of -100/+200 mesh. The normalized leach rates were generally

one to three orders of magnitude less than the SRHLWC, with the exception of boron, and are comparable to those measured for simulated high-level waste glasses. Boron typically leaches from most glasses and is not a constituent of concern. Therefore, the Operable Unit 1 glasses are substantially more durable than the minimum standard for high-level waste glasses.

The viscosity and electrical conductivity of the vitrified materials were measured as a function of temperature. The viscosity data show the glass from various tests had reasonable viscosities for processing within the temperature range reported. Increasing fluoride concentrations decreased viscosity and increased conductivity. The conductivity values for all glasses were close to typical ranges for glass processing. Therefore, the results show that Waste Pit, Burn Pit, and Clearwell material can be made into glasses with reasonable conductivity and viscosity by processing in a joule-heated ceramic melter; however, it is also evident that further development for optimization of glass formulas is needed prior to full-scale implementation.

The operating temperature considered for the vitrification design, 1,250°C (2,280°F), would destroy any organic compounds present in the waste materials and fix metals into the leachable-resistant matrix. Hazardous inorganic constituents actually become part of the chemical structure of the glass matrix, and not merely encapsulated. Additional remedial design pilot scale treatability studies would be conducted to further determine the factors that affect the destruction and removal efficiencies for the contaminants during vitrification and the extent of partitioning of undestroyed contaminants between the vitrified material and the off-gas treatment system. The results of these studies would be used to develop appropriate glass formulations, to provide data necessary for sizing and design of the full-scale continuous melter system, and to determine the configuration of the final off-gas treatment system.

Literature data on the leachability of the vitrified product from a variety of waste types indicate similar leach resistance; all vitrified material tested to date has passed the RCRA TCLP test. Contaminant release from a vitrified product is controlled by diffusion and is governed by the same factors that affect release from a chemically stabilized/solidified product. The leachability of the vitrified product could be impacted by the development of immiscible phases in the melt because of the variable chemical composition of the waste; however, the short residence time in the melter would minimize the potential for immiscible phase development.

The weathering behavior of volcanic glass (a natural analog to the vitrified product) can provide some measure of the long-term stability and durability of the vitrified product. Only very thin weathering rinds develop on volcanic glass over a period of several million years. The slowness in the overall degradation of a glass grain suggests that the diffusion coefficient or leachability index would remain relatively unchanged over time. Data on the long-term stability of vitrified material are not available, and the life expectancy of the vitrified product is difficult to estimate from short-term leach rates. On the basis of the longevity of volcanic glass and diffusion calculations, the vitrified product would be expected to withstand environmental exposure for thousands of years.

The vitrification process would produce treatment residual from the off-gas treatment system. Off-gases containing particulate and other pollutants would be captured and treated using conventional air pollution control equipment (e.g., scrubbers, mist eliminator, pre-filters, and HEPA filters). Changes in scrubber efficiencies or types of scrubber compounds could significantly affect the predicted amount of scrubber residuals. Remedial design treatability studies testing the off-gas treatment system would be necessary for final design to reduce the amount of fugitive emissions. Off-gas treatment system residuals would be recycled through the vitrification process until all the residual waste is contained in the glass matrix. Furthermore, the effects of vitrification as a treatment are essentially irreversible.

4.3.2.5 Short-Term Effectiveness

Protection of the Community During Remedial Action

Through a combination of engineering controls (e.g., dust suppression) and institutional controls (e.g., physical barriers, administrative controls), Alternative 4A would be protective of the community during implementation. The risks from remedial activities, as estimated in Appendix D, are less than the generally accepted range of 10^{-4} to 10^{-6} and dust suppression would further reduce the risk. Accordingly, the alternative would be protective of the community during implementation.

Through access to the site during remediation, there is the potential for a trespasser to be exposed to occupational injury, direct radiation, volatile organic compounds, or dust. In addition to off-gas treatment systems that would be implemented to limit the release of contaminants, access controls (e.g., fences and guards) would also be used during remediation. Access controls would be effective, especially in the short term, in minimizing these exposures.

Protection of Workers During Remedial Action

This alternative involves the handling of the waste materials and, therefore, there would be several potential exposure pathways for workers. Occupational injury, direct radiation, and inhalation could pose risks to remediation workers. Remediation workers conducting the excavation would use equipment with enclosed, air-supplied cabs to provide protection from exposures. Workers sampling the soils would be in Level B protective clothing and exposed to soils contaminated at action levels. Based on these assumptions, a statistical analysis indicates that remediation workers could potentially experience a number of accidents (not related to environmental exposure) resulting in 86 injuries and 1.3 fatalities during remedial activities. The dose equivalent for remediation workers, resulting primarily from direct radiation during on-site disposal, would be 32 millirem over the entire duration of the remedial activities. This exposure is well below acceptable exposure limits for workers.

There may be some additional risk from dust released during excavation to nonremediation workers who are assumed to not be in protective equipment. The nonremediation worker could experience an ILCR of 5.2×10^{-5} and an HI of 6.3×10^{-8}. This estimate is very conservative and assumes that dust is always present, (i.e., dust suppression is not assumed). Dust control would significantly reduce this risk. A detailed analysis of the potential risks to workers during implementation of Alternative 4A is presented in Appendix D of this report. All remedial activities would be conducted in accordance with a health and safety plan developed to meet 29 CFR 1910.120(b)(4). Training and procedures would assure that worker exposure would be as low as reasonably achievable (ALARA).

Short-Term Environmental Impacts

Soil and Geology. Soil disturbance during implementation of this alternative would result from preparation of the disposal facility location, excavation of surficial soil and pit waste, disruption of a borrow pit, construction of access roads, a staging area, and support facilities. Construction and excavation activities for the disposal facility would disturb a total of approximately 28.5 hectares (70.5 acres). Specifically 15.8 hectares (39 acres) for the on-property disposal cell, 7.5 hectares (18.5 acres) for the PMF channel, 5.3 hectares (13 acres) from equipment movement, disruption of approximately 6.07 hectares (15 acres) for support facilities and 2.8 hectares (7 acres) for a borrow pit. Erosion control measures such as straw bales and berms would be used to minimize potential erosion from exposed soil areas. Surface soil exceeding Operable Unit 1 established clean-up levels would be excavated. The excavated soil will be transported to Operable Unit 5 for management.

Fugitive dust emissions from heavy equipment movement would be controlled using surface wetting or dust suppressants as appropriate. Following completion of all construction and excavation activities, disturbed areas would be regraded with clean backfill and revegetated with native grasses.

Excavation of the pits would not require additional overburden breach and thus, would not result in subsidence of the subsurface geologic formation. Contaminated residual soil would be removed beneath the pit liner material and transported to Operable Unit 5 for management.

Water Quality and Hydrology. Regrading and excavation activities would result in short-term impacts to water quality of Paddys Run. Short-term impacts could occur from sediment deposition into Paddys Run. Contaminated sediment deposition would be minimized through erosion control and dust suppression. Erosion control measures include: surface grading, using berms and silt fences; covering surfaces with straw, mulch, riprap, or geotextile membranes; and using revegetation mats in areas with potentially high water (runoff) velocity. The natural flow of Paddys Run would re-establish a natural stream community. Surface water would be routed through the Waste Pit Area Stormwater Runoff Control System and pumped into the AWWT facility for treatment. (See Section 3.2.3.2 for a discussion of the AWWT.) Surface water near the site would be monitored during remediation in accordance with the NPDES permit to assess potential remedial impacts to the water. Prior to and during pit excavation, perched groundwater would be managed as required for transfer to the AWWT facility.

Operation of the waste treatment facility would result in the generation of filtrate water, dewatered residues and sludge. These waste streams will be recycled and utilized during waste processing operations (i.e., vitrification) to minimize wastes generated. The operation of the vitrification process would result in the generation of a limited amount of wastewater which would require treatment by the AWWT facility prior to discharge.

Wastewater generated during removal or treatment of waste material or soil would be treated before discharge from the site.

Remediation would decrease the release of contaminants to groundwater. Groundwater concerns related to Operable Unit 1 sources would be addressed by implementing source control actions (i.e., removing groundwater contaminant source and sampling monitor wells). Existing monitoring wells

would be sampled to provide information on groundwater quality to: (1) establish baseline conditions; (2) monitor groundwater elevations and concentrations during source removal; and (3) evaluate effects of remedial activities on groundwater.

Monitoring would be implemented at each waste pit upon excavation. As part of the final monitoring design, Paddys Run and other drainageways would be monitored to assess changes in water quality that may occur during source removal activity.

Air Quality Ambient air quality in areas accessible to the public is regulated by state and federal standards. Potential sources of air emissions are: (1) dust from construction and earth-moving activities; (2) fugitive dust from exposed pit walls; (3) gas releases during removal and treatment; and (4) heavy equipment exhaust. With appropriate dust suppression, excavation activities are not expected to impact air quality. Exhaust emissions from heavy equipment are also not expected to impact air quality.

Gaseous emissions from the drying and vitrifying processes would pass through a combination quencher/scrubber equipped with HEPA filters to remove regulated pollutants and particulates before being discharged to the atmosphere.

Biotic Resources

The short-term disturbance of on-property vegetation and wildlife habitat under Alternative 4A would result from activities associated with: (1) construction of the on-site disposal facility; (2) excavation of pit waste and residual soil; (3) the borrow pit area; and (4) construction of support facilities.

Operation of the drying and vitrification facilities would have minor impacts to wildlife from airborne deposition of contaminants.

Construction of the on-site disposal facility would occur mainly within the former Production Area. However, the eastern portion of the facility would impact approximately 28 hectares (68 acres) of managed grazed field resulting in the displacement of small mammals and birds. Potential habitat for the federal endangered running buffalo clover (*Trifolium stoloniferum*) species may be present within the managed grazed field, causing loss of habitat.

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In addition, the 2.83-hectare (7-acre) area north and adjacent to the Waste Storage Area to potentially be used as a borrow pit would result in short-term loss of introduced grassland. Impacts would occur to small mammals and birds from the displacement of habitat. This habitat would recover upon regrading and revegetating the borrow pit.

Remedial excavation activities would have short-term impacts to biotic resources. Potential habitat of the following threatened and endangered species would be potentially impacted: the federally endangered Indiana bat (*Myotis sodalis*) and running buffalo clover (*Trifolium stoloniferum*); the state endangered slender fingergrass (*Digitaria filiformis*) and mountain bindweed (*Polygonum cilinode*); and the state threatened spring coralroot (*Corallorhiza wisteriana*). Actual habitat of the state threatened Sloan's crayfish (*Orconectes sloanii*) would also be impacted. Approximately 5.37 hectares (13.27 acres) of riparian habitat supporting potential habitat of these threatened and endangered species and a wide variety of other flora and fauna would be impacted. Remedial activities would also have short-term impacts to Sloan's crayfish individuals from increased sediment load into Paddys Run.

Impacts to biotic resources from Operable Unit 1 activities would be offset by implementing the following mitigative measures in consultation with appropriate Federal and State agencies:

Potential habitat for the Indiana bat (*Myotis sodalis*) and individuals associated with this potential habitat would be lost as a result of excavation, regrading, and revegetation activities. An example of mitigation that could be performed is the installation of bat boxes and/or tree snags upstream of the Waste Storage Area along Paddys Run. These boxes and/or snags would be placed within mature riparian habitat, near pooled sections of Paddys Run.

Potential habitat for running buffalo clover (*Trifolium stoloniferum*) would be lost as a result of excavation, regrading, and revegetation activities. An example of mitigation that could be performed is relocation of this species off site to known running buffalo clover habitat. Miami Whitewater Forest, a county park approximately 5 kilometers (3.2 miles) southwest of the Fernald Site, would be used for relocation as it presently supports a population of running buffalo clover. A detailed species relocation plan would be produced to implement this type of mitigation. This plan would include site preparation requirements, relocation procedures, and relocation success monitoring. If this plant species is found within a controlled area, no relocation would be attempted. Mitigation of species

within a controlled area would be coordinated with appropriate regulatory agencies. Re-establishment of a suitable habitat for running buffalo clover may occur on property as a result of the riparian habitat restoration effort.

Slender fingergrass (*Digitaria filiformis*) and mountain bindweed (*Polygonum cilinode*) would be impacted as a result of excavation, regrading, and revegetation activities. An example of mitigation that could be performed is the relocation of these species to suitable habitat elsewhere in the State of Ohio. Re-establishment of suitable habitat may occur from restoring the riparian area.

Spring coralroot (*Corallorhiza wisteriana*) has potential habitat within the riparian area that would be impacted by excavation activities. Mitigative measures could be the same as for other plant species.

Sloan's crayfish (*Orconectes sloanii*) populations are supported by Paddys Run. Regrading and excavation activities would have short-term impacts to the populations as a result of sediment deposition. Increased sediment load as a result of remedial activities would impact Sloan's crayfish habitat and individuals. Mitigation of these impacts include runoff control measures (silt fences, straw bales) to minimize sediment deposition. The natural flow of Paddys Run would re-establish a natural stream community, naturally mitigating any long-term impacts to the Sloan's crayfish from increased sediment load.

Excavation and regrading activities would impact 5.37 hectares (13.2 acres) of riparian habitat. An example of mitigation that could be performed is restoration of the riparian habitat by planting riparian hardwood tree species, such as sycamores and cottonwoods, upon completion of remedial activities. Shrub species may also be planted to assist in the secondary successional process. Wildlife boxes could also be installed to re-establish mammal and bird populations.

Wetlands and Floodplains

A site-wide wetlands delineation identified approximately 0.95 hectares (2.35 acres) of wetlands near the waste pits, which would be impacted by remedial activities. Approximately 0.53 hectares (1.3 acres) of drainage ditch/swale wetlands would also be disturbed during construction of the on-site disposal facility. Engineering controls implemented during site activities such as silt fences and straw bales would minimize migration of eroded soil to wetland areas.

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Remedial activities would have short-term impacts on approximately 335 meters (1,100 feet) of the 100- and 500-year floodplain of Paddys Run due to regrading activities adjacent to the stream. However, remedial activities would not alter flow patterns or uses of the floodplain, since they would be below or at original elevations. Disturbed areas of the floodplain would be regraded to near original contours. A floodplain/wetland assessment was prepared in accordance with 10 CFR 1022 and is presented in Appendix H.

Socioeconomics and Land Use

Short-term impacts to socioeconomics and land use would be minor with the implementation of Alternative 4A. Approximately 54 workers would be needed to implement Alternative 4A.

A combination of workers, represented by the current on-site workforce and various bidding subcontractors, will be utilized to implement remedial activities. Assuming all workers reside within the CMSA, the relocation or displacement of the workers is not expected to have major social or economic impacts to local communities.

To better assess short-term economic impacts, it is assumed that all resources needed for remedial activities, excluding specialized treatment equipment, would be purchased within the CMSA. Rather than addressing each individual county and the resources they are capable of supplying, each county's public and private expenditures were combined yielding a total expenditure figure of $805,000,000 for fiscal year 1992 to 1993. Total cost of implementing Alternative 4A would be $639,094,175. Excluding vitrification equipment costs of approximately $227,133,985, the maximum increase for the CMSA would be approximately 5 percent distributed over 10 years. Consequently, minor economic impacts would result from the implementation of Alternate 4A.

Cultural Resources

The NHPA (36 CFR 800, Section 106) requires federal agencies to protect properties on or eligible for inclusion in the National Register of Historic Places. This list includes discovered resources such as districts, sites, buildings, structures, or objects that may be eligible for inclusion in the National Register of Historic Places. There are currently no areas identified at the FEMP site that are eligible for inclusion in the National Register.

To avoid impacts on undiscovered cultural resources, an archeological survey would be performed on the borrow and disposal area. An ethnographic survey would be conducted to determine the presence of any Native American sacred sites and burial grounds. Any cultural resources present would be protected in accordance with the American Indian Religious Freedom Act (AIRFA) and the Native American Graves Protection and Repatriation Act (NAGPRA). If possible, impact area boundaries should be designated so as to avoid cultural resources; however, if this is not feasible and cultural resources are affected, they would be evaluated to determine the appropriate treatment. In situ cultural resources would be preserved through agreement with the OHPO and other interested parties.

Should it be agreed that cultural resources are to be removed, the following steps would be followed: (1) archaeological excavation; (2) laboratory treatment of recovered cultural resources; and (3) curation of any recovered artifacts. If final in situ preservation of on-property artifact(s) is chosen, the plan for preservation would be compatible with remedial alternatives selected for the area where the artifact(s) maybe located (Luce 1987).

Duration of Remedial Activities

Active waste processing and treatment activities under Alternative 4A are expected to be completed in approximately 10 years. Construction, testing, and startup of the material processing facilities could require at least two years, with the possibility of a longer period depending on the difficulties encountered. Decontamination and decommissioning efforts following remedial action activities could require an additional 2 years. Excavation activities would be scheduled to coincide with the rate of treatment so that significant interim storage facilities would not be required and materials would not need to be double handled. The time to implement the treatment component of this alternative could be prolonged if pilot-scale testing and full-scale testing of the vitrification resulted in scale-up and operational difficulties because of the innovative nature of this treatment technology. Physical, substantial, and continuous on-property activities would be initiated within 15 months after the ROD is approved by the EPA.

4.3.2.6 Implementability

Technical Feasibility

Excavation/Treatment/Waste Processing. Technical feasibility, construction, and operation of the material removal component of Alternative 4A would be straightforward. Water extraction, treatment and excavation would be performed by conventional methods. Careful excavation planning would be

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required to assist in dewatering of pits with very high moisture content (such as Waste Pit 3), which could result in poor working conditions and unstable working surfaces. The pit floor may be stabilized by adding crushed limestone, lime or cement as well as by using geotechnical fabrics. The amount of material added would be minimized. Hydraulic mining may be used to remove sludge from pits that are difficult to dewater. Objects such as plastic bags and steel structural shapes, etc., found in the pits (such as Waste Pit 6) could be extracted separately. Excavation equipment could be selected to handle heterogenous materials found in the pits. Worker protection could be ensured by minimizing manual labor, requiring appropriate personal protection and specifying principal prime moving equipment confined to excavation in contaminated areas to have enclosed cabs with supplied air.

Similarly, the feasibility, construction and operation of waste processing facilities (size reduction and drying) would be straightforward.

The technical feasibility of the construction and operation of the on-property disposal component of this alternative in an above-grade disposal cell would be reliable. Components of the design have been used at numerous other sites. Readily available resources and standard procedures would be used for the construction and operation of the above-grade disposal cell. The cell, which would have a footprint of approximately 16 hectares (39 acres), could be easily enlarged if disposal volumes are greater than anticipated. The technical feasibility of disposal cell site preparation, including the excavation of the shallow sand lenses underlying the cell and replacement with compacted clay, would be performed by using reliable conventional methods.

Vitrification. The vitrification technology for Alternative 4A would require engineering scale-up of treatability study results for full-scale implementation. Additional treatability studies (bench and pilot-scale) would be performed during the remedial design to address specific design requirements. Pilot testing, detailed design, fabrication, installation, and full-scale operation would be needed to optimize the treatment process.

The construction of a vitrification facility is expected to be relatively straightforward, but operation of the vitrification facility would be difficult. A full-scale facility for the vitrification of hazardous or radioactive waste similar to that at Operable Unit 1 has not yet been constructed elsewhere. The necessary equipment could be modified from available equipment used in the glass-making industry.

Construction of a vitrification facility on site would include the construction of an electrical substation.

The vitrification system consists of three basic circuits: a feed preparation circuit, a melter circuit, and an off-gas treatment system. The feed preparation circuit would be used to remove water from the slurry material prior to vitrification. The equipment needed for this circuit is readily available because this component of the process is widely used in industry. Joule-heated ceramic melters have been used to vitrify liquid high-level radioactive material, radioactively contaminated soil, and waste contaminated with heavy metals in quantities ranging from 4540 to 408,460 kilograms/day [(4 to 100 tons per day (TPD)]. The conceptual design for the Operable Unit 1 treatment system specifies four 100 TPD melters.

A trained process engineer would be needed to operate both the physical pretreatment and melting circuits of the ceramic melter and to act as supervisor of the melter circuit. Operators and maintenance personnel, laborers, laboratory technicians, and administrative personnel would also be needed. Industrial work experience would be required for system operators and maintenance personnel. The number of operators and maintenance personnel with previous experience in the vitrification of hazardous waste is limited, but these personnel could be drawn from the commercial glass-making industry or the high-level radioactive waste vitrification industry. The melter system could be designed to operate largely by computer, with a combination of human and computerized oversight. Start-up would require at least 4 months; however, because the melter system has not been previously used at the scale required for the site, operational problems might develop during start-up that could impact the processing schedule and costs.

Potential operational problems in the melter circuit include temperature variation, incomplete melting, immiscible phase development, and thermocouple or heat sensor failure. Refractory failure is not anticipated to be a problem because the design life of the melter operation is less than the design life of the refractory equipment at anticipated operating temperatures. Temperature variation and improper control could result in the incomplete melting of feed material. Temperature fluctuations could also cause phase immiscibility. The use of electricity allows for almost immediate control over melt temperatures and thus would aid in controlling temperatures continuously monitored by thermocouples and heat detectors. These thermocouples would probably be prone to failure at high operating temperatures, necessitating the placement of redundant thermocouples at critical locations in

the system and routine replacement and repair as part of maintenance activities. Any product from the vitrification system that was incompletely melted or contained immiscible phases would be returned to the system until an acceptable product is produced.

The reliability of the melter system for waste treatment is not well established because this system has not yet been implemented at full-scale or continuous operation. Similar melting systems used in commercial glass-making report a 90 percent continuous operation efficiency.

Off-Gas Treatment Systems. The off-gas treatment system would use standard air pollution treatment and control devices. The capabilities of the individual off-gas treatment devices are known and reliable with regard to linking multiple treatment devices together to treat the off-gas stream expected from the drying and vitrification operations of Operable Unit 1 at full scale. The off-gas treatment system would use standard components, but the selected devices and their configuration will have to be explicitly defined, tested, and optimized through bench-scale and pilot-scale testing.

The limited experience in developing the required off-gas treatment system could result in schedule delays or cost increases because more time and personnel might be needed to bring the system on-line. Operators and repair personnel would probably be drawn from the incineration industry because of their experience in operating and maintaining off-gas treatment systems. The likelihood of operational problems would increase as the complexity of the off-gas treatment system increased. It is possible that a complex linkage of treatment devices could lead to operational difficulties with individual devices, and the potential for effects from failure of individual devices could be exacerbated in downstream devices and result in an overall problem with system operations and collection and removal efficiencies. If off-gas emissions exceeded applicable requirements, delays would result. Failure of monitoring devices or inadequate test results from a full-scale off-gas system could also cause delays until corrections could be implemented. Additional conceptual design and testing would be required to identify and resolve the potential difficulties in designing and operating an off-gas treatment system for a vitrification system.

Operational problems that could develop in the off-gas treatment circuit include production of large amounts of particulate that require secondary handling, added treatment requirements for the scrub solution prior to disposal, monitoring device calibration, maintenance requirements, and exacerbation of operational problems in downstream control devices resulting from failure of an upstream device.

The off-gas treatment system would require testing and optimization to resolve these potential problems.

Monitoring. The effectiveness of the main components of the treatment process for Alternative 4A would be regularly monitored. The off-gas treatment system effluent would be monitored to determine the off-gas composition and ensure compliance with applicable requirements. The effectiveness of the vitrification process would be monitored by regular testing of the treated material. If a sample fails the determined acceptance criteria, additional samples would be collected, and these samples would be tested and analyzed to determine the cause of the problem. The failed treated material would be revitrified if necessary, and the process modification would be instituted. Any leachate generated from the treated material placed in the above-grade disposal cell would be captured by the LC/DS.

An air quality monitoring system would be used to detect radionuclide emissions to verify the integrity and effectiveness of the multimedia cover. Groundwater monitoring wells would be located to detect changes in groundwater quality. The monitoring system associated with the above-grade disposal cell would provide the information needed to determine if corrective action should be taken to prevent the migration of materials into the environment.

The implementation of Alternative 4A (or any of the other alternatives) would not adversely impact the performance of additional remedial actions at the FEMP. For example, the presence of the above-grade disposal cell would not affect the ability to remediate groundwater beneath the cell (i.e pump and treat systems). Migration and exposure pathways would be addressed through sampling and analysis during on-site activities.

Administrative Feasibility

The NCP requires the evaluation of the relative administrative feasibility of each alternative to include "... activities needed to coordinate with other offices and agencies and the ability and time required to obtain any necessary approvals and permits from other agencies (for off-site actions). CERCLA Section 121(e) provides that no Federal, State, or local permit shall be required for the portion of any removal or remedial action conducted entirely on site." It is required that a remedial action satisfy the substantive requirements of any permits that would otherwise be required.

Alternative 4A, Excavation, Treatment, and On-Property Disposal, would be conducted in its entirety on site and thus would not require issuance of any permits. Substantive provisions of permits that would otherwise be required are considered to be ARARs. ARARs compliance (or a waiver) is required of any selected remedial alternative. The US and Ohio EPAs are identified as the two key governmental agencies that will determine if a) the proposed/selected remedy adequately addresses identified ARARs; and b) the remedial design is consistent with the basis for concluding (in the Record of Decision) that the selected remedy will achieve ARARs compliance. By legal agreement (i.e., consent agreements) the EPA reviews and approves the FS and ultimately the remedial design. OEPA also actively participates in the review process. Other governmental agencies to be consulted are identified in the next paragraph. Accordingly, if the on-site alternative adequately addresses identified ARARs, then no known administrative barriers would exist to prohibit remedial action.

It is probable that relatively small amounts of on-site wetlands will be adversely impacted by the remediation of Operable Unit 1. The COE has jurisdictional responsibility for such wetlands. Other agencies (i.e., U.S. Department Of Interior) are trustees for natural resources. These agencies will have to be consulted before implementing any action that would adversely impact wetlands and other natural resources. Because of the relatively small area of wetlands that would be impacted, this is not anticipated to adversely impact the administrative implementability of this alternative.

In summary, with regard to administrative feasibility, there are no known administrative barriers to implementing Alternative 4A, except for the ARARs issue of the state prohibition against on-site disposal over a sole source aquifer. An exemption or waiver from the State of Ohio regulation would be required. This would be moderately difficult.

Availability of Services and Materials

Services and materials required for the implementation of Alternative 4A include: (1) site preparation including clearing and grubbing; (2) construction of access roads, fencing, lighting, water, sewer, and electrical services; (3) construction of a materials processing facility including the vitrification units; (4) construction of an above-grade disposal cell; and (5) construction of a multilayer cover, as well as excavation equipment and operators for material removal.

Site preparation including clearing and grubbing, and construction of roads, fencing, lighting, sewers, and electrical services would involve the use of standard construction equipment and trades, the use of

a fence installation contractor, and the purchase of appropriate materials, all of which would be readily available.

Waste removal using mechanical and slurry methods and backfill operations would require the use of conventional construction equipment and operators, all of which would be readily available.

The construction of an above-grade disposal cell would require the use of standard construction equipment and trades. Materials and services needed to construct the cell would be available locally. The construction of the above-grade disposal cell would require the acquisition of material for a geotextile liner, a geosynthetic clay liner, a textured geomembrane, native clay, sand, gravel, riprap, and clean soil which would be readily available. Standard construction equipment, operators, and trades required for construction would be available. The installation of membranes and liners would require specialized equipment and personnel to lay the material and seal the seams.

The construction of a materials processing facility would involve the purchase of a pre-engineered building, the process equipment, the process chemicals/materials, electrical transformers and transmission lines, and the instrumentation and controls. It would also involve the use of standard construction equipment and services. Some engineering would be required during construction, start-up, and debugging of the process equipment. Qualified personnel needed to operate and maintain the facility would be available.

The construction of the multilayer cover would require the use of standard construction equipment, materials and trades similar to the above-grade disposal cell which also would all be readily available.

Although it is technically feasible to design, construct and operate a vitrification facility, a full-scale facility for the vitrification of materials similar to those within Operable Unit 1 has never been built. Treatability studies for alternative selection have been completed. However, additional treatability studies (bench- and pilot-scale) would be performed during the remedial design to address site-specific design requirements. Necessary equipment would be modified from available equipment in the glass-making industry. Additionally, process engineers, operation and maintenance personnel, laborers, laboratory technicians, and administrative personnel would be trained as required.

4.3.2.7 Cost

The total cost of Alternative 4A is approximately $639,094,175. A detailed breakdown of the cost is provided in Table 4-2.

Capital Cost

The capital cost is associated with site preparation, waste and soil removal, construction of the waste processing facility, installation of vitrification equipment, construction of the above-grade disposal cell, site restoration, and decontamination and decommissioning of treatment facilities. An itemization of each major component of this alternative is provided in Table 4-2. More detailed information is provided in Appendix E.

The largest components of the cost are the vitrification system and its operation. The second largest element of the capital costs is on-property disposal.

O&M Cost

O&M costs include maintenance and monitoring which would be conducted until FEMP site-wide remedial action objectives are attained, i.e., for a period of approximately 30 years. Monitoring would support the required CERCLA five-year reviews.

4.4 ANALYSIS OF ALTERNATIVE 4B - REMOVAL, TREATMENT (CEMENTATION), AND ON-PROPERTY DISPOSAL

The following description of Alternative 4B is based on a representative conceptual design for Operable Unit 1 FS purposes only. The level of engineering detail provides documentation for cost-estimating purposes. If this alternative is selected, the substantive components of the design will be developed during the remedial design phase consistent with the requirements of the ROD.

4.4.1 Description

Alternative 4B includes the same remedial action components as Alternative 4A with the exception of the treatment process used. In this alternative, cement solidification would be used instead of vitrification. The volume of cement-solidified waste would be larger than the volume of vitrified waste, which in turn would increase the size of the on-property disposal cell. A conceptual flow diagram for the cement solidification process is provided in Figure 4-5.

Remedial action components of Alternative 4B which are identical to Alternative 4A include site preparation, excavation, treatment support facilities, drying, on-property disposal in an above-grade cell, site restoration, access control measures and monitoring. Remedial action components differing from those of Alternative 4A include modifications during waste processing and the replacement of vitrification with cement solidification.

Waste Processing

Waste processing identified with Alternative 4B is almost identical to that identified with Alternative 4A. Excavated waste material with the exception of approximately 80 percent of the waste from Pit 5 which would be directly pumped as slurry, would be transported by trucks to the stockpile building for pretreatment (shredding) prior to drying and cement-solidification. The drying/cement-solidification process would consist of a shredder, two rotary dryers in parallel, and the cement-solidification facility with four pugmill mixers in parallel. All equipment would be operated under negative pressure. The stockpile would provide surge capacity to accommodate excess waste production and constant feed to the shredder. The stockpile would be sized for approximately 10 days storage capacity (15,000 wet tons). The stockpile not only provides plant feed whenever excavation operations are shut down, but also facilitates blending of wastes, including dredged sludge from Waste Pit 5 as well as wastes excavated from other "dry" pits. This will minimize the energy requirements for the drying. Waste Pit 5 wastes would be dewatered through a thickener and a vacuum filter prior to entering the treatment system. Overflow from the thickener and water removed during shredding would ultimately be fed to a clarifier. The clarifier underflow would join the thickener underflow and would be filtered by a vacuum drum filter. Filter cake and all thickened dredged slurry would be conveyed to the enclosed stockpile where it would be discharged and blended with the other pit wastes.

Waste would be recovered from the stockpile with a drag scraper and delivered to the shredder. The pit wastes would first be processed through a shredder to prepare suitable feed waste material to the dryers. The shredder would reduce waste feed to less than 7.5 centimeters (3 inches), homogenize, and partially dewater the dryer feed. Oversized material not suitable for shredding would be segregated from the waste and forwarded to Operable Unit 3 to be managed as construction rubble. The output from the shredder would be fed into two indirect rotary dryers in parallel. The material handling system to transfer material from the shredder would include a heavy-duty bucket elevator, a feed hopper, and auger feeders (screw conveyors) to discharge waste into the rotary dryers. Waste

from the shredder would be dried, transferred, and discharged into one of the three feed hoppers prior to entering four pugmill mixers in parallel.

The drying process for Alternative 4B would be identical to that described for Alternative 4A. The drying is required to achieve several objectives. First, it would minimize the amount of additives required to fix the wastes, which in turn minimizes the volume of cement-stabilized waste produced. Secondly, it would reduce uncertainty associated with the proper ratio of additives because of varying degrees of moisture content in the waste. Finally, drying would reduce the concentration of volatile organic contaminants within the waste. This would ensure compliance with associated Land Disposal Restrictions treatment standards and reduce the chance of matrix interference between the organics and the binding agents. The off-gas treatment system for Alternative 4B would be the same as that described for Alternative 4A.

Three feed hoppers are provided in the design to ensure proper mix design. Operationally, one hopper would be on-stream to the pugmill mixers, a second hopper would be full and awaiting sample testing results while the third hopper would be filled with waste. Hoppers would be designed to include surge capacity.

Water and additive materials (cement, fly ash) would be withdrawn from the additives silos, collected, and conveyed into the pugmill mixers concurrently with the waste material to meet formulation requirements. Throughput rate for each pugmill mixer would be about 43 wet tons/hr. Residence time in the cement pugmill mixer would be on the order of five minutes. Bench scale/pilot plant testing during remedial design would determine the precise residence time.

A conventional material handling system would be installed to receive the cement-solidified mixture from the pugmill mixers, and to transfer and place the cement-solidified waste into the disposal cell. The transfer system will be selected during further engineering studies. The solidified waste will be spread and compacted in 30-centimeter (12-inches) lifts within the disposal cell.

Cement Solidification

In cement solidification, the toxic constituents (inorganics and radionuclides) would be encapsulated and immobilized in the matrix of solidified cement. The solidified material would be placed in the on-property disposal cell. The assumed representative formulation for the mix (on a dry weight basis)

would be approximately 40 percent waste and soils, 30 percent cement, 15 percent fly ash, and 15 percent water.

Further treatability tests would be performed during remedial design to determine formulation for each of the pits. The objective would be to produce a proper mix with minimum additives (additional water, cement and fly ash) to meet waste acceptance criteria for the stabilized waste. The design of the treatment plant would have sufficient flexibility to accommodate all the wastes from all the pits.

For purposes of this FS, flow rates of the cementation plant were estimated based on a production rate of 720 wet tons of waste per day. The total amount of excavated material, estimated to be about 916,000 dry tons, would be processed in approximately 5 years yielding an estimated 2.3×10^6 tons (1.3×10^6 cubic yards) of cement-solidified waste. The estimated duration is based on operating the plant 12 hours per day, 250 days per year, and a plant availability of 70 percent.

On-Property Disposal Cell

The on-property disposal cell for Alternative 4B would be similar to that of Alternative 4A. The disposal cell for this alternative would have a footprint of approximately 32 hectares (79 acres). This would be accomplished by increasing the size of the Alternative 4A disposal cell by 16 hectares (40 acres) towards the north, south and east.

4.4.2 Detailed Analysis

4.4.2.1 Overall Protection of Human Health and the Environment

Alternative 4B would meet the remedial action objectives for Operable Unit 1 and would be protective of human health and the environment. Alternative 4B meets the remedial objectives through removal of waste pit material and placement of a multimedia cap over the restored pit area, treatment through cement stabilization, containment in an on-property disposal cell, and implementation of institutional control measures. Appendix D presents the quantitative documentation that forms the basis of the above statements.

In this alternative, treatment of the waste pit material by cement stabilization would reduce contaminant mobility but would also significantly increase the volume of contaminated material. In addition, protection would also be provided by the disposal cell.

Institutional controls help ensure protection to human health in the event of loss of the engineering controls. Additionally, under Ohio Administrative Code (OAC) 3734-02, a restrictive covenant limiting site use is required for any disposal cell. Long-term effectiveness of Alternative 4B would be similar to that previously identified for Alternative 4A. The disposal cell, multimedia cap, and institutional controls would be protective of human health and the environment.

Short-term risks for Alternative 4B would be similar to Alternative 4A. Engineered and institutional controls would protect the community and workers during implementation of the alternative.

4.4.2.2 Compliance with Applicable or Relevant and Appropriate Requirements

Alternative 4B is identical to Alternative 4A with the exception of the process option used to treat the wastes. In this alternative, cement solidification would be used in place of vitrification; this results in a greater quantity of treated material than vitrification. Therefore, the on-property disposal cell for Alternative 4B would be proportionately larger than the disposal cell required under Alternative 4A. This difference is insignificant for compliance with potential ARARs/TBC requirements discussed in Appendix F for the on-site disposal operational scenarios. Compliance of this alternative would be substantially identical to that of Alternative 4A as presented in Section 4.3.2.2, which is summarized below.

Chemical-Specific ARARs/TBCs

As discussed in Section 4.3.2.2 for Alternative 4A, Alternative 4B would comply with all pertinent chemical-specific ARARs identified in Appendix F. Included would be those standards associated with meeting drinking water MCLs and nonzero MCLGs requirements, the groundwater protection requirements, radionuclide release requirements for water and air, and their resulting doses to the public.

Location-Specific ARARs/TBCs

Alternative 4B would address all pertinent location-specific ARARs identified in Appendix F and as discussed in Section 4.3.2.2. Included would be those requirements associated with the protection of wetlands and endangered species. Despite the larger footprint of the on-property disposal cell associated with this alternative, the Alternative 4B disposal cell would have adequate location setbacks to comply with distance requirements. As was noted, due to the OAC 3745-27-07 prohibition on siting a solid waste disposal cell over a sole source aquifer, demonstrating the substantive technical

justification for an exemption or waiver would be required as discussed in Section 4.3.2.2 to implement this alternative.

Action-Specific ARARs/TBCs

Alternative 4B would comply with all pertinent action-specific ARARs identified in Appendix F and as discussed in Section 4.3.2.2. Included would be those standards associated with the design of the engineered above-grade disposal cell system and operational requirements under RCRA and UMTRA. As was discussed for Alternative 4A, Alternative 4B would comply with ARARs associated with the Clean Air Act, Clean Water Act, and RCRA requirements for management and treatment of hazardous waste by incorporating sound engineering features and best management practices into the remediation and operation of the unit. Additional supporting documentation to justify that Alternative 4B would comply with the identified ARARs is presented in Appendix F.

4.4.2.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

Alternative 4B would be effective in the long term because Operable Unit 1 wastes would be excavated to health-based levels. The long-term risk assessment of this alternative (presented in Appendix D) analyzes all potential exposure pathways remaining following remediation. This screening analysis identified the primary pathways and principal mobile contaminants affecting public risk. Use of proposed remediation levels (see Section 2.2) in the FS risk evaluation (Appendix D) yielded results that document that the alternative is protective of human health and the environment.

Adequacy and Reliability of Controls

The on-property disposal unit for Alternative 4B is of the same design as that for Alternative 4A and therefore has the same adequacy of controls and the same degree of reliability. The only difference in the disposal cells for Alternative 4A and 4B is the size, since a larger disposal cell is required in this alternative to accommodate the increased volume of the cement-solidified waste. The assumptions were the same as for Alternative 4A except that the leachability of the treated material was taken from the treatability results for cement solidification. The overall results were the same as for Alternative 4A, that is leaching of contaminants would not pose an unacceptable risk to potential receptors.

Cement solidification is a technology that has been previously applied with varying degrees of success in the solidification of low-level wastes, although not at the proposed process rate. Over the period

of 1990 to 1993, the FEMP site conducted a series of bench-scale treatability tests to examine the performance of the cement stabilization technology on waste pit materials. As with vitrification, the leaching rate of all cement solidified waste was at or below TCLP regulatory limits (see Appendix C). However, as discussed in Section 4.4.2.4, the extreme heterogeneity of the waste pit material may make both successful formulation and quality control very difficult to achieve.

Consistent with DOE Order 5400.5 and 40 CFR 264.114, the performance of the disposal system would be actively monitored. This monitoring supports the required five-year CERCLA review. Institutional controls, as described previously, are reliable.

Long-Term Environmental Impacts

The long-term environmental impacts to the FEMP site from the removal and treatment actions of Alternative 4B are the same as those previously identified for Alternative 4A. Impacts from on-site disposal would be the same as Alternative (4A), except the volume of cement stabilized material would increase, resulting in an expansion of the disposal cell to 32 hectares (79 acres) and the PMF channel to 15.3 hectares (37.9 acres). There would be no additional impact due to the increased waste volume, expanded disposal cell, and PMF channel.

4.4.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 4B uses cement solidification to treat the contents of the waste pits, the Burn Pit, and the Clearwell. Cement solidification reduces the mobility of contaminants by binding them into a cement mixture. As a result of the additives used in the process, the volume increases. A preliminary remedy selection treatability study was conducted with Operable Unit 1 materials to assess the effectiveness of the cement solidification process. The criteria for evaluation included leachability of the treated waste form, the material volume reduction achieved, the unconfined compressive strength (UCS) and the reduction in radon emanation from the material. Initial critical performance objectives to demonstrate the effectiveness of cement solidification were a UCS of greater than 500 pounds per square inch (psi) and TCLP leachate concentrations below the regulatory limits.

A major concern with cement solidification is the ability of the cement/waste mixture to "set". The waste within the pits, which is extremely heterogenous, contains elements which are considered "set retarders" and "set accelerators". The impact of these elements on each individual batch may be

difficult to predict. As expected, the results of the treatability studies showed significant variations from pit to pit as well as within a particular pit.

The chemical and physical properties of Operable Unit 1 wastes were determined and used in developing the bench-scale treatability studies. Numerous formulations were studied for cement solidification.

Data from the study revealed that the radon emanation rates from the treated waste pit material ranged from 0.08 to 20.37 picoCuries/gram/day. Based on an emanation rate for the untreated waste pit material of 0.71 to 63.89 picoCuries/gram/day, a radon emanation was reduced by a factor of three to eight. This reduction is approximately two orders of magnitude less than the radon emanation reductions observed for the vitrification process.

The solidified material from all tests were RCRA nonhazardous, as determined by the TCLP test. The cement formulations were not as effective in reducing the leaching of uranium from Waste Pit 4, which contains higher concentrations of uranium than other waste pits. The Burn Pit also experienced some problems. Cement alone was not successful in stabilizing the waste material. For other pits, reductions in contaminant concentrations in the leachate were not achieved for the following parameters: radium-226 (Waste Pits 2 and 3 and the Burn Pit); radium-228 (Waste Pit 3 and the Burn Pit); thorium-228 and -230 (Waste Pit 2); technetium (Burn Pit); zinc (Waste Pit 1); chromium (Waste Pit 2); copper (Burn Pit); barium (Waste Pits 1, 3, and 5, Clearwell, and Burn Pit); molybdenum (Waste Pits 2, 3 and 5, Burn Pit, and Clearwell); and anthracene, fluoranthene, and phenanthrene (Waste Pit 2). No reductions were observed for either formulation for the following constituents of concern: radium-226 (Waste Pit 2 and the Burn Pit); radium-228 (Waste Pit 1); chromium (Waste Pit 1); copper (Burn Pit); zinc (Waste Pit 1); barium (Waste Pits 1, 3, and 5, Burn Pit, and Clearwell); molybdenum (Waste Pits 2, 3, and 5, Burn Pit, and Clearwell); and anthracene, fluoranthene, and phenanthrene (Waste Pit 2).

Durability was measured by freeze-thaw and wet-dry testing and comparison to American Society for Testing and Materials (ASTM) standards (30 percent weight loss) and EPA guidance of 15 percent weight loss. No average weight losses for waste pit material exceeded 30 percent, except for Waste Pit 6. None of the mix designs failed the wet/dry tests. However, the mix containing blast furnace slag for Waste Pit 6 failed the ASTM freeze/thaw durability test and the average weight loss for three

specimens slightly exceeded 30 percent. While the average weight loss for the Waste Pit 3 design containing blast furnace slag did not exceed 30 percent for the freeze/thaw test, a single specimen lost over 44 percent weight. Duplicate samples for the blast furnace slag mix for Waste Pits 3 and 6 did not exhibit as high a weight loss as the corresponding samples, but significant degradation was observed as a result of the freeze/thaw testing. Durability was also measured using the UCS test on the durability samples. The UCS results indicate the change(s) in physical properties of the solidified material changes as a result of the simulated climatic stress. None of the treated waste degraded to the extent that it had no resistance to compressive stress. However, degradation and leachability results for some contaminants indicate that cement solidification is not an irreversible treatment process.

The typical bulking factor obtained during cement solidification was relatively high. The amount of volume increase caused by the addition of cement material varied greatly for each waste pit. The average increase varied from 41 to 159 percent as a result of the heterogeneity of the waste. Assuming an average increase of 100 percent, there would be a total estimated treated material volume of 1.0×10^6 cubic meters (1.3×10^6 cubic yards) for Alternative 4B.

4.4.2.5 Short-Term Effectiveness

Protection of the Community During Remedial Actions

Alternative 4B is protective of the community during implementation as a result of the same engineered and access controls as these described for Alternative 4A. Dust suppression and institutional controls during excavation, waste placement, capping, etc., are expected to prevent any significant impacts to the local community. Estimated risk data are presented in Appendix D.

Protection of Workers During Remedial Action

Estimates of potential exposures to remediation and nonremediation workers are the same for this alternative as for Alternative 4A and indicate that this alternative is protective of workers. The statistical analysis for worker occupational risks indicated the increased potential for accidents may result in 86 injuries and 1.3 fatalities over the duration of the remedial activities. These are based directly on OSHA statistics for similar-type projects. Implementation of a worker health and safety plan would maintain risks to well below those required by DOE orders.

Short-Term Environmental Impacts

The short-term impacts of Alternative 4B are the same as Alternative 4A with the exception of the expanded disposal cell 32 hectares (79 acres) and PMF channel, 15 hectares (37 acres) and procurement of resources to complete remedial activities.

Socioeconomics and Land Use

Short-term impacts to socioeconomics and land use would be minor with the implementation of Alternative 4B. To better assess short-term economic impacts, it is assumed that all resources needed for remedial activities, excluding specialized treatment equipment, would be purchased within the CMSA. Rather than addressing each individual county and the resources they are capable of supplying, each county's public and private expenditures were combined yielding a total expenditure figure of $805,000,000. Excluding cement solidification equipment costs of approximately $120,560,250, the maximum increase for the CMSA would be approximately 10 percent distributed over 5 years. Consequently, minor economic impacts would result from the implementation of Alternate 4A.

Duration of Remedial Activities

The duration of Alternative 4B is estimated to be one year for preremedial activities (e.g., construction, testing and startup), five years for remedial activities, and two years for post-remedial activities. Physical, substantial, and continuous on-property activities could be initiated within 15 months after the ROD is approved by EPA.

4.4.2.6 Implementability

Technical Feasibility

The technical feasibility of Alternative 4B, which is the same as Alternative 4A except for the treatment component, would be more straightforward. The treatment process for this alternative is cement solidification instead of vitrification. This process would increase the volume of the treated waste substantially. Therefore, a larger above-grade disposal cell would be required for alternative 4B.

The cement solidification facility would be straightforward to construct but difficult to operate ensuring quality control due to the heterogenous nature of the waste in the pits. All of the necessary equipment would be readily available because the process is widely used in the construction and

mining industries. It is also used frequently in hazardous material treatment applications. The treatment system would consist of a standard configuration of industrial equipment. The technical feasibility of the drying process would be similar to Alternative 4A, as discussed in Section 4.3.2.6.

Organic content in a waste material can have a detrimental effect on the hydration of cement used for solidification. Even at low concentrations, organics produce significant micro- and macro-structural changes to the hydrating cement. These changes will determine the relative extent of the inhibition of the hydration process. Organic waste constituents containing certain groups, such as phenols, may inhibit or prevent hydration to the extent that the constituent was readily leached from the cement solidified matrix (Pollard, S.J.T. et.al., 1991 and Shukla, Shukla, and Lee, 1992).

The cement solidification process would require a supervisor and general laborers with industrial work experience, as well as maintenance personnel. The cement solidification technology has moderate processing costs. It is compatible with a wide variety of disposal options, and has the ability to meet stringent processing and performance requirements. Heterogeneity of the pit waste material can effect the structural rigidity of the stabilized material. The unconfined compressive strength of identically-prepared samples has been shown to vary by a factor of two, illustrating the potential macroscopic effect of variable microscopic phase composition (Roy, A., et.al., 1991). Therefore, due to the heterogeneity of the pit materials, blending of the waste would be required. This would create the need for multiple stockpile areas as well as sampling and testing of the mix for each batch. As a result, the production rate of the process would be reduced. Since the process requires the curing of the cement for solidification, appropriate testing would be performed after the treated material is placed in the disposal cell. As a result, the reprocessing of treated waste which fails tests would be difficult since breaking and crushing of placed wastes would be required for removal. Therefore, although cement solidification is a well proven technology, it is extremely waste specific and potentially difficult to implement on wastes that would be encountered at Operable Unit 1.

During remedial design, treatability studies would be performed to further define and optimize the reagent to material blend. However, the plant supervisor would be able to respond to operational problems that could arise during processing. Continual testing of treatment batches during operation would identify modifications to the standard blend that could optimize the product and immobilize the contaminants.

Administrative Feasibility

The NCP requires the evaluation of the relative administrative feasibility of each alternative to include "... activities needed to coordinate with other offices and agencies and the ability and time required to obtain any necessary approvals and permits from other agencies (for off-site actions). CERCLA Section 121(e) provides that no Federal, State, or local permit shall be required for the portion of any removal or remedial action conducted entirely on site." It is required that a remedial action satisfy the substantive requirements of any permits that would otherwise be required. With respect to administrative feasibility, Alternative 4B is identical to Alternative 4A (see Section 4.3.2.6). (Since this alternative would be conducted in its entirety on-site, it would not require issuance of any permits.) Thus there are no known administrative barriers to prohibit remedial action, except for ARARs compliance. In summary, with regard to administrative feasibility, the only known administrative barrier to implementation of Alternative 4B, is the ARARs issue of the state prohibition against on-site disposal over a sole-source aquifer which is the same issue as for Alternative 4A.

Availability of Services and Materials

Alternative 4B would involve the same activities as Alternative 4A, with the exception of cement solidification being utilized in place of vitrification. Since cement solidification is a commonly utilized technology, plant equipment, materials, services and operators would be available.

The construction of a cement solidification facility involves steps similar to those described in Section 4.3.2.6, with the substitution of cement solidification equipment and materials for vitrification equipment and materials. Cement solidification equipment and materials are more readily available.

4.4.2.7 Cost

The total cost of Alternative 4B is $504,195,700. A detailed breakdown of the cost is provided in Table 4-3.

Capital Cost

The capital cost is associated with site preparation, waste and soil removal, construction of the waste processing facility, installation of cement solidification equipment, construction of the above-grade disposal cell, site restoration, and decontamination and decommissioning of waste processing

facilities. A breakdown of each major component of this alternative is provided in Table 4-3. More detailed information is provided in Appendix E.

The largest component of the cost is the disposal cell. Construction of the waste processing facility is the next largest component of the cost.

O&M Cost

The monitoring would support the required CERCLA 5-year reviews.

4.5 ANALYSIS OF ALTERNATIVE 5A - REMOVAL, TREATMENT, AND OFF-SITE DISPOSAL AT THE NEVADA TEST SITE

The following description of Alternative 5A is based on a representative conceptual design for the Operable Unit 1 FS. The level of engineering detail provides documentation for cost-estimating purposes. If this alternative is selected, the substantive components of the design will be developed during the remedial design phase, consistent with the requirements of the ROD.

4.5.1 Description

This alternative is identical to Alternative 4A with the exception that the vitrification step is eliminated and on-property disposal has been replaced by off-site transportation and disposal at the Nevada Test Site (NTS). NTS is a DOE-owned facility that currently accepts Low-Level Radioactive Waste (LLRW) from DOE facilities for disposal. It is located approximately 3,541 kilometers (2,200 miles) from the FEMP site in an arid environment far from any population centers (see Appendix G for a detailed description). For this alternative, the excavation rate would be limited by the capacity of the dryers, 1,440 tons (766 cubic yards) per day. At this rate, active waste processing would require approximately 5 years.

Off-site disposal at NTS involves drying and packaging treated waste in sealed containers. The containers would be loaded onto flatbed railroad cars and shipped to Las Vegas, Nevada. In Las Vegas, the containers would be transferred to trucks for final shipment to NTS, where the containers would be buried. Due to the heterogeneous nature of the waste in the pits, size reduction, homogenization and blending would be required to allow for uniform drying and bulk handling. A flow diagram for the drying process is provided in Figure 4-6.

The FEMP site can support rail transport to NTS by using existing on-property rail spurs. A combination of rail and truck transport can be used. Improvements to the existing railroad system at the FEMP may be required to accommodate the increased activity. For this alternative, the waste would be processed to meet the waste acceptance criteria for off-site disposal at NTS. Based on the evaluation of the waste material, it is expected that the waste acceptance criteria would be complied with through the specified treatment. See Appendix J for a discussion of NTS waste acceptance criteria and the ability of the FEMP to meet these criteria. Due to the extreme waste heterogeneity, it is possible that isolated pockets of waste could be encountered that would not meet NTS waste acceptance criteria. As a contingency wastes that do not meet NTS waste acceptance criteria (up to 10 percent of the total waste volume) could be disposed at a permitted commercial waste disposal facility. The dried waste would be sampled prior to shipment. If the waste does not meet the waste acceptance criteria at that time, it would be transported back to the stockpile for reprocessing.

The material processing, waste shipment handling facilities, and off-site transportation methods proposed for the disposal of the treated waste are further described below.

Waste Processing

The excavated waste would be transferred to a controlled stockpile where waste streams would be blended and directed into a shredder which feeds the two indirect rotary dryers in parallel alignment. The stockpile area for this alternative would be sized to accommodate 15,000 wet tons of waste. Waste material would be fed from the stockpile to the shredder with a dragline scraper. The shredder would homogenize and reduce the maximum particle dimension of the wastes to less than 15 centimeters (6-inches) to allow for controlled uniform drying and bulk handling. It would also partially dewater (approximately 5 percent reduction) the waste by the squeezing action of the equipment. The blended waste stream would be fed into the dryers at a rate of 60 wet tons per hour (30 wet tons per hour each). The input moisture content would be approximately 32.5 percent. The dryer output moisture content would be close to optimum (assumed to be approximately 15 percent residual moisture) for compaction, pass the liquid release test, and permit free flowing bulk material handling. The drying process would be similar to that described in Section 4.3.1. The actual drying temperature and waste retention time would be finalized during the remedial design phase. Dried waste would be transferred to an operational storage silo above the rail siding and placed in strong tight containers. The containers would be loaded onto flatbed rail cars for shipment to a point near

Las Vegas where they will be transferred to trucks for transportation over roads for the final leg of the trip to NTS.

Waste Shipment Handling Facilities

Shipment of the dried waste to NTS for disposal would require the following waste material handling facilities:

- Enclosed conveyor system
- Operational storage facilities
- Waste container loading facilities
- Railroad siding

Enclosed Conveyor System. After the drying stage, the waste material (at 15 percent moisture) would be transferred from the feeder at the discharge of the dryers to the operational storage facility through a stationary conveyor system. At the operational storage facilities, the stationary conveyor will discharge to a stowing conveyor at the top of the silo. A shuttle conveyor or belt tripper/conveyor will be used to allow discharge to a silo.

The entire conveyor system would be enclosed to control any potential dust releases and to isolate the waste materials from the environment. Negative air pressure would be maintained within the enclosure to prevent emissions.

The conveyor system would have a capacity to match the process rate for waste material size reduction and drying. The silo would be located midway between the waste material drying facility and the existing rail siding to the east. The area between the silo and the existing rail siding would be paved with concrete and used for temporary storage of containers, both empty and filled.

Operational Storage. The need for operational storage capacity would be minimized with containerized disposal. The containers themselves would provide storage capacity as they are filled and accumulated for train shipment. To allow for interruptions in container loading and provide flexibility in the container loading rate, a silo for 1/2-day accumulation of waste material production would be provided.

Waste Container Loading Facilities. Disposal of the waste at NTS can utilize two modes of transportation, both rail and trucks. Treated waste would be placed in 11.5 cubic meters (15 cubic yards) disposable containers. Each container would hold approximately 20 tons of waste material and have a total weight of approximately 21 tons. To minimize storage requirements, it would be more efficient to load the containers at essentially the same rate as the waste material is processed. The waste would be buried at NTS in the containers. It is also possible that reusable containers could be utilized with wastes disposed in bulk rather than in the container.

A dust collection hood would be used at the silo discharge for loading the containers. A pre-engineered metal building, approximately 30 meters (100 feet) long x 15 meters (50 feet) wide x 8 meters (25 feet) high would be used to prepare empty containers for loading, weighing, sealing, and final checkout before shipment. A paved area and loading dock would be included for loadout of the containers to the railcars. Containers would be handled by forklift. Facilities would also be required at the point where the containers are transfered from railcars to trucks.

Railroad Siding. At the operational storage and loadout facilities, a total of three sidings would be used. In addition to the existing siding that continues to the south side of Operable Unit 3, four additional switches and two 300-m (1,000-ft) long sidings would be used. These new sidings would extend south to just north of the road leading to the waste pit area. The waste material storage silos would be located over one of the two new sidings so that the necessary environmental control facilities can easily be incorporated. Alternatively two new switches and one 600-meter (2,000 feet) siding could also be used.

To accommodate train movement and makeup, a wye would also be incorporated at the north end of the existing siding. The wye would require two new switches and approximately 180-meter (600 feet) of track. Each of the two new 300-meter (1,000 feet) sidings would accommodate approximately 22 cars, and the existing siding would accommodate approximately 22 cars without interfering with road traffic to the waste pit area or rail traffic on the two new sidings. For movement of railcar strings, a yard locomotive would also be required.

Off-Site Transportation

Shipping of the treated material to NTS will involve rail transportation from the FEMP. Currently there are no direct rail lines to NTS. Therefore, treated material would be transported by rail to

either a point near Las Vegas, Nevada, or one of the areas north of Las Vegas. From either location, containers will be transferred to trucks for transport to NTS. If a direct rail line to NTS becomes available before this alternative is implemented, it should be used in lieu of shipping the treated material by truck on the last leg of this trip. Treated material may be staged and/or placed into interim storage at the FEMP, as required, in response to temporary interruptions in the availability of transportation or disposal capacity. All necessary approvals and certifications would be received prior to shipment.

Based on the expected waste material quantity of 1,053,300 tons (at 15 percent moisture) and a capacity of 20 tons per shipping container, the entire waste pit area cleanup would require an estimated 52,665 shipping containers. This corresponds to 17 trains of 22 flat cars each per month arriving at approximately two-day intervals for approximately 5 years.

4.5.2 Detailed Analysis

4.5.2.1 Overall Protection of Human Health and the Environment

Alternative 5A meets the remedial action objectives for Operable Unit 1 and is protective of human health and the environment. The pit wastes would be excavated, treated, and transported off-site for disposal and the restored pit area would be covered with a multimedia cap. Implementation of this alternative would prevent direct access to contaminated soil and would mitigate the migration of contaminants to the air, surface soil, and groundwater.

Institutional control measures would preclude site development and help prevent exposure to any residual contamination beneath the multimedia cap. As in Alternatives 4A and 4B, the controls would include continued federal ownership of the FEMP site. This ownership would preclude future on-property residential and farming land uses which could potentially result in exposure to contaminated soil. The uncertainty associated with long-term institutional control periods include a possible loss of federal ownership. See Appendix D for the results of the FS risk evaluation.

The off-site disposal provides an additional element of protection under Alternative 5A. The off-site disposal facility at NTS would provide protection by eliminating: 1) access to the waste material and 2) migration of contaminants out of the material, much as the on-property disposal cell would under Alternatives 4A and 4B. The NTS facility is located in a sparsely populated, arid environment with a reduced potential for contaminant release, migration, and direct contact with contaminants. The long-

term effectiveness of the mandatory institutional controls at the disposal facility is estimated to be more reliable than those that would be implemented at the FEMP. Because NTS is maintained by DOE and utilized for the disposal of selected low-level wastes from other DOE sites, the uncertainties associated with institutional controls are lower. Further, the climatic (low average annual precipitation) and hydrogeologic (depths to groundwater ranging from 157 to 600 meters (515 to 2,000 feet) below grade) characteristics would reduce potential for contaminant migration impacts to human health and the environment in the event that engineering and institutional controls fail.

Worker risks under Alternative 5A are due to exposure during removal, treatment, and preparation for transportation. Through the implementation of engineered controls, as previously discussed, and a worker health and safety plan in compliance with 29 CFR 1910.120(b)(4), these exposures would be kept to ALARA levels and would comply with DOE orders. There would also be increased risks to transportation workers and the community from moving the waste off site. Compliance with DOT transportation requirements would ensure that transportation workers and local communities would be protected during transportation.

4.5.2.2 Compliance with Applicable or Relevant and Appropriate Requirements

Issues related to ARARs compliance for Alternative 5A are similar to Alternative 4A with the exception of location-specific ARARs for on-property disposal. Alternative 5A would meet all ARARs identified in Appendix F. The State of Ohio disposal siting criteria and disposal requirements would no longer be relevant and appropriate because treated material would be disposed of off-site at a DOE-owned facility. In contrast, off-site transportation requirements would be applicable. The remaining ARARs/TBCs requirements for Alternative 5A focus on waste management and treatment which are similar to the ARARs for Alternative 4A. Consequently, the discussion of compliance for those common ARARs would be similar to that presented in Section 4.3.2.2. Applicable findings of that discussion are summarized below. Additional documentation of compliance of Alternative 5A with the identified ARARs is presented in Appendix F for the off-site disposal scenario.

Chemical-Specific ARARs/TBCs

Alternative 5A would comply with all pertinent chemical-specific ARARs identified in Appendix F for the off-site disposal scenario. Included would be those requirements associated with meeting Ohio Water Quality Standards, control of airborne releases of radionuclides and other hazardous constituents and their resulting doses to the public.

Location-Specific ARARs/TBCs

Alternative 5A would comply with all pertinent location-specific ARARs identified in Appendix F. Included would be those requirements associated with the protection of wetlands, endangered species and their habitats during the on-site treatment of the waste material. As noted above, disposal siting criteria and disposal requirements would no longer be relevant and appropriate to this alternative because of the proposed use of an off-site disposal facility.

Action-Specific ARARs/TBCs

Alternative 5A would comply with all pertinent action-specific ARARs/TBCs identified in Appendix F through engineering controls and treatment of the waste. As was discussed in Section 4.3.2.2 for Alternative 4A, Alternative 5A would comply with ARARs associated with the Clean Air Act, Clean Water Act, and RCRA requirements for management and treatment of hazardous waste.

Off-site disposition will require shipment of materials. Hazardous waste transportation requirements would be complied with by following the regulations under 40 CFR 262, 40 CFR 263 and the appropriate DOT shipping requirements under 49 CFR 171 through 180. In addition, packaging and transportation requirements described in DOE Order 5820.2A for wastes that are radioactive and hazardous would be followed. Alternative 5A would also comply, by design, with the Ohio transportation requirements as well as those of the states through which the waste may be routed.

4.5.2.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

Alternative 5A would be effective in the long term because Operable Unit 1 wastes would be excavated to health-based levels. The long-term risk evaluation of this alternative (presented in Appendix D) analyzed all potential exposure pathways remaining following remediation. This screening analysis identified the primary pathways and principal mobile contaminants affecting public risk. Use of soil proposed remediation levels (see Section 2.2) in the FS risk evaluation (Appendix D) yielded results that document that the alternative is protective of human health and the environment.

Adequacy and Reliability of Controls

The institutional controls and potential for adequate facility maintenance are likely to be more reliable in the long-term at NTS than the on-property disposal cell. Additionally, if there is a release at

NTS, the climate, hydrologic conditions and geologic characteristics would considerably reduce the potential for contaminant migration. The extremely low population density would also significantly reduce the potential for exposures in the event of disposal facility failure.

Long-Term Environmental Impacts

The following paragraphs discuss long-term impacts to the environment associated with Alternative 5A. For a compilation of the irreversible and irretrievable commitment of resources associated with Alternative 5A, refer to Section 4.8. For detailed description of the NTS site, refer to Appendix G.

Soil and Geology. The long-term impacts on soil associated with Alternative 5A would be minimal at the FEMP. Surface soil exceeding established clean-up levels would be excavated and removed. The excavated surface soil will be transported to Operable Unit 5 for management. For Alternative 5A, after waste materials from each pit have been removed for treatment, contaminated residual soil would be removed and transported to Operable Unit 5 for management. Following removal of contaminants, the pits would be backfilled with clean soil. The 2.8 hectares (7-acre) borrow area north and adjacent to the waste pit area could also be used for backfill, if acceptable. All areas would be regraded to near-original contours upon completion of remedial activities.

Capping and runoff/run-on controls would minimize contaminant transport to uncontaminated soils through stormwater runoff.

Areas at NTS would be permanently disturbed for the disposal of treated materials. Borrow material from NTS may be required for the shallow land disposal burial there. The geology of NTS has been determined to be suitable for disposal of Low Level Radioactive Waste (LLRW) (DOE 1991a). NTS characterization indicates that groundwater depths beneath NTS vary from about 157 meters (515 feet) to more than 600 meters (2,000 feet) (DOE 1991a). Groundwater movement in the saturated and unsaturated zones is very slow and there is an extremely low potential for radioactivity transport to off-site areas. In addition, downward movement of the groundwater is exceedingly slow in the unsaturated zone; that also serves as a significant barrier to contaminant transport. These parameters make the geology of NTS very suitable for long-term disposal activities.

Water Quality and Hydrology. Surface water and groundwater would be protected as a result of contaminant source removal associated with Operable Unit 1. Assuming monitoring and maintenance

activities continue at the FEMP, no long-term impacts to water quality and hydrology are anticipated upon completion of remedial activities.

Grading and excavation activities would cause minor alterations to the east bank of Paddys Run. Runoff control measures (silt fences, hay bales) during remedial activities would minimize increased sediment load to Paddys Run and the natural flow of Paddys Run would re-establish a natural stream community. Therefore, no long-term impacts to water quality are expected.

Upon completion of remedial activities associated with Operable Unit 1, the area would be regraded to near original contours, promoting proper runoff and drainage. Surface water runoff would be routed to the appropriate collection/treatment system; therefore, no long-term impacts to water quality and hydrology at the FEMP site are anticipated.

The disposal of treated material at NTS under this alternative is not expected to have significant impacts on its water quality or hydrology. There are no continuously flowing streams on the NTS property. Stream beds carry water only during unusually intense or persistent rains. Rainfall, averaging 15 centimeters (6 inches) per year, infiltrates quickly into moisture deficient soil. Evapotranspiration rates are very high, many times the precipitation rates. These parameters, coupled with suitable geology (as discussed previously) would help minimize long-term impacts to water quality. Engineering controls (e.g., capping) and ongoing monitoring activities would also be used to control and minimize water quality impacts.

Air Quality. The long-term impacts on air quality at the FEMP site from Alternative 5A would be minor because the potential for airborne releases associated with the waste pits would be removed. Materials removed from Operable Unit 1 and disposed of at NTS are not expected to change existing conditions at NTS.

Biotic Resources. As was the case for Alternative 4A, there are no critical habitats for threatened and endangered species in the Operable Unit 1 study area to be impacted by Alternative 5A activities, but there is potential for threatened and endangered species to reside near the waste pit area, which could be impacted by this alternative. These threatened and endangered species include the Indiana bat *(Myotis sodalis)*, running buffalo clover *(Trifolium stoloniferum)*, slender fingergrass *(Digitaria filiformis)* and mountain bindweed *(Polygonum cilinode)*, and spring coralroot *(Corallorhiza*

wisteriana). Actual habitat of Sloan's crayfish *(Orconectes sloanii)* occurs within Paddys Run. Mitigative measures are discussed in the short-term effectiveness section. Refer to Section 4.3.2.3 for detailed descriptions of these species.

Excavation activities at the FEMP would result in the loss of approximately 5.37 hectares (13.2 acres) of riparian habitat, containing diverse flora and fauna, in addition to the above-mentioned potential habitat of threatened and endangered species. This riparian habitat could be restored by implementing the mitigative measures discussed in the short-term effectiveness section. Therefore, there would be no long-term impacts.

Most of the NTS is vegetated by various desert shrubs. There are 711 types of vascular plants within or near the boundaries of NTS (DOE 1991). Several mammal species on NTS (e.g., feral horses, burros, mountain lions, kit foxes) have been placed on the protected classification list by the State of Nevada. The desert tortoise (*Gopherus agassizii*) is federally listed as a threatened species and is present in some areas of NTS. Disposal activities at NTS related to the Operable Unit 1 remedial activities are not expected to impact the habitat of the desert tortoise or displace any other species at NTS.

Wetlands and Floodplains. A wetlands delineation for the Fernald site was conducted in December 1992 (Ebasco Environmental 1993) and approved by the COE. The delineation identified approximately 0.72 hectares (1.77 acres) of isolated scrub-shrub/persistent emergent wetlands west of the waste pits and 0.08 hectares (0.21 acres) of drainage ditch/swale wetlands south of the waste pits. Approximately 1.09 hectares (2.7 acres) of drainage ditch/swale wetlands would be lost due to the borrow area. No long-term impacts would occur to floodplains. A floodplain/wetland assessment has been performed in accordance with 10 CFR 1022 requirements and is included in Appendix H. No wetlands or floodplains exist within the NTS boundaries.

Socioeconomics and Land Use. As was the case for Alternative 4A, implementation of Alternative 5A is not expected to have any substantial long-term impacts on the socioeconomics or land use in the vicinity of the FEMP site or in the CMSA. A detailed discussion of the impacts associated with Alternative 5A is provided in Section 4.5.2.5.

NTS encompasses about 3,500 square kilometers (1,350 square miles), an area larger than the State of Rhode Island. NTS primary land use is nuclear weapons testing (since 1951) and LLRW disposal for on-site and off-site DOE-affiliated generators. NTS is surrounded on the east, north, and west sides by public access exclusion areas (e.g., Nellis Bombing and Gunnery Range). This area provides a buffer zone between the test areas and public lands of 24 to 105 kilometers (15 to 65 miles). The population density within a 150 kilometers (93 miles) radius of NTS is about 2.8 persons/square kilometer (7.25 persons/square mile). In comparison, the 48 contiguous states (1990 census) had a population density of approximately 29 persons/square kilometer (75 persons/square mile). The off-site areas adjacent to NTS are predominantly rural; hence, aesthetic impacts would be expected to be minimal. Treated material disposal activities associated with this alternative would not impact socioeconomics or land use at NTS.

Cultural Resources. A site-wide archaeological survey would be performed for the impacted areas associated with remedial activities for Operable Unit 1. Cultural resource areas would be managed consistently with the requirements of the NHPA, OHPO, AIRFA, and the NAGPRA. A more detailed discussion of the FEMP cultural resources management procedure and more information on cultural resource management at NTS is provided in the short-term impacts discussion in Section 4.5.2.5. Because any cultural resources identified would be either avoided or managed appropriately, there would be no unacceptable impacts to cultural resources at the Fernald site. Cultural resources at NTS would also be managed consistently with the requirements of the NHPA, AIRFA, and the NAGPRA.

4.5.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This alternative includes drying the waste material prior to off-site disposal at NTS. Drying does not affect the toxicity or mobility of contaminants. Drying would slightly reduce the volume of material by reducing the moisture content of the waste from approximately 32.5 percent moisture (average) to meet waste acceptance criteria at NTS (e.g., 15 percent moisture).

4.5.2.5 Short-Term Effectiveness

Protection of the Community During Remedial Action

Alternative 5A is protective of the community during removal and treatment as a result of the same engineered and institutional controls described for Alternative 4A and 4B. The ILCR for off-site individuals would be 2.9×10^{-6}. However, there is also risk to the general public during transportation of the treated material off site. The estimate of public radiation exposures, expressed

in terms of ILCR, along the route to NTS are 5.5×10^{-6} for routine transportation, 2.7×10^{-5} for a hypothetical train accident, and 1.2×10^{-8} for a hypothetical truck accident. The basis for these estimates is provided in Appendix D. The risks to communities from transportation do not exceed the generally accepted 10^{-4} to 10^{-6} range. The community could also be exposed to nonradiological risks. Statistical analysis indicates the potential for accidents (not related to environmental exposure) may result in 0.049 injury and 0.0025 fatality from train transportation and 0.47 injury and 0.051 fatality from truck transportation.

The disposal of FEMP materials at NTS would not be expected to exceed protective levels for the community near NTS over the short term. The pretreated materials would meet NTS waste acceptance criteria and, therefore, would be managed within the bounds of the NTS facility's protectiveness criteria.

Protection of Workers During Remedial Action

Estimates of potential exposure for remediation and nonremediation workers during removal and treatment are essentially the same for Alternative 5A as for Alternatives 4A and 4B. Through implementation of a worker health and safety plan, risks to workers would be maintained within limits required by DOE orders.

There are additional risks to transportation workers and package handlers resulting from the transportation of material to NTS. Truck drivers would be subject to a dose equivalent of 4.0×10^{-4} person-rem, which is well below acceptable exposure limits for workers. Statistical analysis indicates the potential for accidents related to highway miles traveled may result in 27 injuries and 7.1 fatalities for truck drivers over the life of the remedial action. Train crews would be subject to a dose equivalent of 4.5×10^{-1} person-rem, which is also below worker exposure limits, and the potential for accidents may result in 45.5 injuries and 0.055 fatalities. Package handlers would be subject to a dose equivalent of 29 millirem, and the statistical potential for accidents may result in 5.8 injuries and 0.086 fatalities. Additional risks resulting from transportation are presented in Appendix D.

Short-Term Environmental Impacts

Soil and Geology. Soil disturbances during implementation of Alternative 5A would result from removing contaminated waste materials and soil from and around each waste pit, the Clearwell, and the Burn Pit. Soil disturbances would also result from the construction of roads, the construction and

operation of support facilities, and the operation of heavy equipment along waste pit berms. Surface soils exceeding Operable Unit 1 established clean-up levels would be excavated and removed. The excavated surface soil will be transported to Operable Unit 5 for management.

The construction of support facilities would require the excavation of 6 hectares (15 acres) directly east of Waste Pit 2 and south of Waste Pit 4. Once remedial activities have ended, support facilities would be completely dismantled and materials would be disposed of appropriately.

The 2.8 hectares (7 acre) area north and adjacent to the waste pit area to be used as a borrow pit, would require excavation of soils. This area would be regraded and revegetated upon completion of excavation.

Short-term impacts to the soil and geology would result from excavation and construction activities. This would result in increased erosion of exposed areas and the generation of fugitive dust. Erosion control measures such as straw bales and berms would be used to minimize potential erosion from exposed soil areas.

Fugitive dust emissions from heavy equipment movement would be controlled using surface wetting or dust suppressants as appropriate. Following completion of all construction and excavation activities, disturbed areas would be regraded with clean backfill and revegetated with native grasses.

Excavation of the pits would not require additional overburden breach, and, thus, would not result in subsidence of the subsurface geologic formation. Contaminated residual soil would be removed beneath the liner material and transported to Operable Unit 5 for management.

Soil disturbance at NTS would involve 1.2 hectares (3 acres) for the excavation or preparation of the disposal facility and the use of borrow soils for capping activities. Disturbances may also result from the development of berms, roads, and heavy equipment traffic. Standard engineering controls would be implemented to prevent the release of fugitive dust or sedimentation build-up as a result of erosion.

Water Quality and Hydrology

Regrading and excavation activities would result in short-term impacts to water quality and minor alterations to the east bank of Paddys Run. Short-term impacts would occur from sediment deposition

into Paddys Run. Contaminated sediment deposition would be minimized through erosion control and dust suppression. Erosion control measures include: surface grading, using berms and silt fences; covering surfaces with straw, mulch, riprap, or geotextile membranes; and using revegetation mats in areas with high water (runoff) velocity. The natural flow of Paddys Run would re-establish a natural stream community as a result of the east bank alteration.

Surface water from excavated areas and support facilities that has contacted contaminated areas would be collected and treated appropriately. Through the use of the Waste Pit Area Collection System and the AWWT facility, runoff during remedial activities would be collected and treated to meet the parameters of the site's NPDES permit.

Spills or releases associated with Operable Unit 1 remedial activities would be addressed by response actions. Any wastewater generated during the removal or treatment of waste material or soil would be treated before discharge from the site.

Surface water run-off from the FEMP would be monitored in accordance with existing permits during the action period. A change in the level of constituents detected would result in appropriate action to control further contaminant migration.

The implementation of Alternative 5A is expected to have minor impacts on the surface water hydrology at NTS. NTS lies in a very arid region with little rainfall. Appropriate controls (e.g., capping) would be used at NTS on all disposal facilities to minimize contact of surface water with the treated material. Groundwater at NTS would not be impacted in the short term by disposal of dried waste and soil from Operable Unit 1.

Air Quality. The remedial activities proposed for Alternative 5A involve several activities that could impact air quality at the FEMP site. Short-term impacts associated with the removal and transport (15 trains of 22 flat cars a month shipped from the FEMP) of waste materials, the construction and operation of support facilities, the operation of heavy equipment, and the operation of process facilities could periodically impact air quality. A combination of engineering design and engineering controls would minimize impacts to air quality.

Air quality impacts associated with Alternative 5A would be an increase in particulates due to excavation, dredging, and trenching activities. Proper engineering practices (e.g., wetting, tarping, revegetating) would be used to minimize particulate increases from fugitive dust. Ongoing monitoring activities would be used to detect increases in particulate and other airborne pollutants. Gaseous emissions from the shredding and drying processes would pass through a combination quencher/scrubber equipped with HEPA filters to remove regulated pollutants and particulates before discharge to the atmosphere.

Shipping treated material for disposal would result in minor increases in emissions related to vehicle exhaust from the rail-to-truck transfer of waste material. However, due to the number of shipments involved with Alternative 5A, short-term air quality impacts would be negligible. Air quality impacts due to an accident occurring during transportation of treated material to NTS would also be minimal. Treated material would be containerized (by bag or hard cover on the rail car) and, therefore, pose minimal risk of becoming airborne in such an instance.

Disposal of treated material at NTS would not result in any major air quality impacts. Minor increases in fugitive dust due to equipment operation and excavation activities may be experienced. Engineering controls and ongoing monitoring activities would be used to control air quality impacts.

Biotic Resources. The short-term disturbance of on-property vegetation and wildlife habitat under Alternative 5A would result from activities associated with: 1) excavation of pit waste and residual soil, 2) the borrow pit area, and 3) construction of support facilities.

Operation of the shredding and drying facilities would have minor impacts to wildlife from airborne deposition of contaminants.

Short-term impacts to biotic resources from Alternative 5A activities would be offset by implementing the same mitigative measures identified for Alternatives 4A in Section 4.3.2.5. Affected species include the Indiana bat *(Myotis sodalis)*, running buffalo clover (*Trifolium stoloniferum*), slender fingergrass *(Digitaria filiformis)*, mountain bindweed *(Polygonum cilinode)*, spring coralroot *(Corallorhiza wisteriana)*, and Sloan's crayfish *(Orconectes sloanii)* populations.

Most of the NTS is vegetated by various desert shrubs. There are 711 types of vascular plants within or near the boundaries of NTS (DOE 1991). Several mammal species on NTS (e.g., feral horses, burros, mountain lions, kit foxes) have been placed on the protected classification list by the State of Nevada. The desert tortoise (*Gopherus agassizii*) is federally listed as a threatened species and is present in some areas of NTS. Disposal activities at NTS related to the Operable Unit 1 remedial activities are not expected to impact the habitat of the dessert tortoise or displace any other species at NTS.

Wetlands and Floodplains. A site-wide wetlands delineation identified approximately 0.8 hectares (1.98 acres) near the waste pits, which would be impacted from remedial activities. Engineering controls implemented during site activities such as silt fences and straw bales, would minimize migration of eroded soil to wetland areas.

Remedial activities would have short-term impacts on approximately 335 meters (1,100 feet) of the 100- and 500-year floodplain of Paddys Run due to regrading activities adjacent to the stream. However, remedial activities would not alter flow patterns or uses of the floodplain, since they would be at or below original elevations. Disturbed areas of the floodplain would be regraded to near original contours. A floodplain/wetland assessment was prepared in accordance with 10 CFR 1022 and is presented in Appendix H.

Socioeconomics and Land Use. Short-term impacts to socioeconomics and land use would be minor with the implementation of Alternative 5A. Employment needed to implement this alternative would require 54 workers.

To better assess short-term economic impacts, it is assumed that all resources needed for remedial activities excluding specialized treatment equipment, and disposal costs at NTS, would be purchased within the CMSA. Rather than addressing each individual county and the resources they are capable of supplying, each county's public and private expenditures were combined yielding a total budget expenditure figure of $805,000,000 for fiscal year 1992 to 1993. Total cost of implementing Alternative 5A is $856,102,282. Excluding the cost of treatment equipment, and disposal costs, the public and private expenditures would increase by 9 percent distributed over 5 years. Consequently, minor economic impacts would result from the implementation of Alternative 5A.

Disposal activities would not impact socioeconomics or land use at NTS as discussed in Section 4.5.2.3.

Transportation. The implementation of Alternative 5A would result in minor increases in traffic flow on and near the FEMP. Temporary increases in deliveries and workers to the FEMP are not expected to result in any significant impact to traffic patterns or roadways.

Treated material would be transported first by rail, and then transferred into trucks for transport to NTS. Environmental impacts from shipping and disposing of treated material are expected to be minimal from normal transportation because all procedures would be in compliance with applicable DOT and DOE requirements. The risk to workers and the public that is associated with the transportation of treated material is addressed in Appendix D.

Cultural Resources. A site-wide archaeological survey would be performed for the areas to be impacted by Operable Unit 1 remedial activities. Cultural resource areas would be managed consistently with the requirements of the NHPA, OHPO, AIRFA, and the NAGPRA.

To avoid impacts on undiscovered FEMP cultural resources, a site-wide archeological survey will be performed. An ethnographic survey will be conducted to determine the presence of Native American sacred sites and burial grounds or other significant items. If possible, impact area boundaries should be designated so as to avoid cultural resources; however, if this is not feasible and cultural resources are affected, they would be evaluated to determine the appropriate treatment. In situ cultural resources would be preserved through agreement with the OHPO and other interested parties. Should it be agreed that cultural resources are to be removed, the following steps would be followed: (1) archaeological excavation; (2) laboratory treatment of cultural resources recovered at the site; and (3) curation of any recovered artifacts. If final in situ preservation of on-property artifact(s) is chosen (the artifacts remain in place), the plan for preservation would have to be compatible with remedial alternatives selected for the area in which the artifact(s) is located (Luce 1987).

In compliance with NHPA, DOE/NV contracted pre-activity surveys and other studies to assess any impacts NTS operations may have on historical and archeological sites found on the NTS site. Sites identified were added to the cultural resources inventory files, site records, and all artifacts collected

from the NTS were processed for storage. All cultural resources at NTS would be either avoided or managed appropriately.

Duration of Remedial Activities

The duration of active waste processing activities is estimated to be 5 years, with an additional 1 year for preremedial activities. There is more uncertainty in the remedial activity schedule estimate since transportation or waste acceptance problems could cause delays in the shipping schedule. (See discussion in Section 4.5.2.6). Physical, substantial, and continuous on-property activities could be initiated within 15 months after the ROD is approved by EPA.

4.5.2.6 Implementability

Technical Feasibility

The technical feasibility of the removal and waste processing components of Alternative 5A would be the same as described for Alternative 4A except for vitrification which would no longer be required. However, since the excavated waste would be dried in a rotary dryer, an off-gas treatment system would be provided. The feasibility of the off-gas treatment system would also be the same as Alternative 4A.

The technical feasibility of implementing the disposal component of Alternative 5A depends on the implementability of transportation of the treated material to NTS and on compliance with the waste acceptance criteria of this disposal site. Based on evaluation of the Operable Unit 1 waste material, it is expected that the waste would be accepted at NTS (see Appendix J).

The technical feasibility of the construction of waste shipment handling facilities for off-site transportation by rail would be straightforward and reliable.

The treated material would be placed in appropriate containers which would meet all transportation and disposal requirements. Off-site transportation of the treated material from the FEMP would be by rail. Since NTS is currently not accessible by rail, the treated material would be transported to a point near Las Vegas, Nevada, where the containers carrying the treated material would be transferred from flatbed railcars to trucks for transportation over roads to NTS.

Environmental impacts from shipping and disposing of treated material are expected to be minimal from transportation because all procedures would be in compliance with applicable DOT requirements and DOE orders. As documented in Appendix D, the added risk to the public due to off-site transportation to NTS is within acceptable limits. More information on the risk to workers and the public associated with the transportation of treated material is provided in Appendix D.

Administrative Feasibility

The NCP requires the evaluation of the relative administrative feasibility of each alternative to include "... activities needed to coordinate with other offices and agencies and the ability and time required to obtain any necessary approvals and permits from other agencies (for off-site actions)." Alternative 5A, Excavation, Treatment, and Off-site Disposal, consists of on-site and off-site activities. The excavation, material handling, and processing of the wastes will occur entirely on site. For these portions of the remedial alternative, the administrative feasibility analysis presented in Section 4.3.2.6 would apply (i.e., no permit is required for on-site remediation).

Various DOT regulations apply to the transportation of wastes such as those found within Operable Unit 1. In addition, each state and certain municipalities through which the waste shipments would pass have established regulations and, in some cases, permitting requirements that are applicable. To evaluate whether these types of requirements could limit the FEMP's ability to implement an alternative involving off-site disposal (in the arid West), it is appropriate to review case studies involving shipment of similar wastes. Shipment of RCRA hazardous wastes throughout all regions of the United States is performed at a large scale on a daily basis. On a relative scale, administrative issues associated with the transportation of RCRA hazardous wastes from the FEMP to NTS are easily addressed because of the common nature of shipment of such wastes. For this reason focus is on the shipment of significant volumes of low-level radioactive wastes.

Review of applicable DOT regulations indicates that there are currently no provisions that would prohibit waste shipments from the site to NTS using either trucks or rail. This statement is made in specific reference to the Operable Unit 1 pit wastes as understood based on extensive process generation data and the analytical data from the Remedial Investigation. In addition, there are no known transit state or local regulations that would categorically prohibit waste shipment. As stated above, to evaluate the likelihood that other administrative issues could significantly limit the ability to ship wastes off site one may review similar case studies.

The first applicable case study involves the FEMP itself. The FEMP has been actively shipping LLRW to NTS for several years. While the relative volumes are low compared to that which would be associated with full scale remediation of the Operable Unit 1, this demonstrates that sustained waste shipment is feasible. It also highlights that the site has an established working relationship with the DOE office managing NTS, and a functional waste certification program that meets the requirements of NTS. In addition, other DOE facilities located east of NTS (such as Mound) ship wastes to NTS also demonstrating the administrative feasibility of low-level radioactive waste shipments.

Many organizations (laboratories, hospitals, nuclear generating stations, and research institutions) throughout the country regularly ship LLRW to disposal sites. The relative volumes are small but it does demonstrate that shippers and carriers have been able to develop mutually acceptable shipping practices that serve their needs while satisfying all applicable Federal, State, and local regulations.

In summary, the transport of low-level radioactive material is a common practice; thus there are no legal constraints obstructing the administrative feasibility of transportation and off-site disposal in Alternative 5A.

Availability of Services and Materials

The availability of services and materials required for Alternative 5A would be the same as for Alternative 4A, with the exception of the vitrification unit and above-grade disposal cell which are no longer required. Services and materials for the construction of the waste shipment handling facilities and transportation would also be readily available.

NTS currently accepts LLRW and has adequate capacity to accept the treated material from Operable Unit 1. Transfer areas, storage areas, decontamination facilities, and a laboratory are available at NTS. The treated material would be tested to ensure that it complies with NTS waste acceptance criteria.

4.5.2.7 Cost

The total cost of Alternative 5A is approximately $856,102,282. A detailed breakdown of the cost is provided in Table 4-4.

Capital Cost

The capital cost is associated with site preparation, waste and soil removal, construction and operation of the waste processing facility, packaging of material for disposal, transportation, disposal, site restoration, and decontamination and decommissioning of waste processing facilities. Breakdown of costs for each major component of this alternative are provided in Table 4-4. More detailed information is provided in Appendix E.

This alternative includes identical cost components as Alternative 4A (Section 4.3.2.7), except that packaging, off-site transportation, and disposal replace vitrification and the on-property disposal cell that were included in Alternative 4A. The largest components of the capital cost are transportation and disposal.

O&M Cost

O&M costs are primarily associated with minimal maintenance of the restored waste pit areas.

4.6 ANALYSIS OF ALTERNATIVE 5B - REMOVAL, TREATMENT AND OFF-SITE DISPOSAL AT A REPRESENTATIVE PERMITTED COMMERCIAL DISPOSAL FACILITY

The following description of Alternative 5B is based on a representative conceptual design for the Operable Unit 1 FS. The level of engineering detail provides documentation for cost-estimating purposes. If this alternative is selected, the substantive components of the design will be finalized during the remedial design phase consistent with the requirements of the ROD.

4.6.1 Description

This alternative is identical to Alternative 5A except that the treated waste would be shipped in bulk directly to a representative permitted commercial disposal facility such as a representative one near Clive, Utah. Waste that does not meet acceptance criteria, not to exceed 10 percent of the total waste volume, will be shipped to NTS in 11.5 cubic meters (15 cubic yards) disposable containers as described in Alternative 5A. The NEPA analysis for waste shipment to NTS is also included in Alternative 5A. The representative permitted commercial disposal facility is accessible directly by rail. Therefore, only rail transportation would be required. The waste material would be transported in bulk form in gondola railcars. The FEMP can support rail transport by using existing on-property rail spurs. The rail siding east of the FEMP waste pit area would be used. Improvements to the existing system at the FEMP may be required to accommodate the increased activity. Under this

alternative, the excavation and drying rate would be the same as Alternative 5A. At this rate, active waste processing would require approximately five years.

For this alternative, the waste would be processed to meet the waste acceptance criteria of the disposal facility. Based on the evaluation of the waste material, treatment of the waste would facilitate Operable Unit 1 compliance with the waste acceptance criteria (see Appendix J). The dried waste would be sampled prior to being loaded into the rail cars.

The off-site disposal, material processing and waste shipment handling facilities proposed for this alternative are further described below.

Waste Processing

Waste processing for this alternative would be identical to that of Alternative 5A as described in Section 4.5.1.

Waste Shipment Handling Facilities

The on-site facilities at the FEMP that comprise the treated waste material handling system would include the following:

- Enclosed conveyor system
- Operational storage facilities
- Waste container loading facilities
- Railroad siding

Enclosed Conveyor System. Dried waste material (approximately 15 percent moisture) would be transferred by an enclosed conveyor system from a feeder at the discharge of the waste material dryer through an approximately 180 meter (600-feet) long stationary conveyor to the operational storage facilities. At the operational storage facilities the stationary conveyor would discharge to a stowing conveyor at the top of the silos. A shuttle conveyor or belt tripper/conveyor would be used to allow discharge to any of the five silos.

The entire conveyor system would be enclosed to control any potential dust and to isolate the waste materials from the environment. Negative air pressure would be maintained within the enclosure to prevent emissions.

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The conveyor system would have a capacity to match the process rate for waste material size reduction and drying. Conveyor capacity would be approximately 42 tons/hour. The silo would be located midway between the waste material drying facility and the existing rail siding to the east.

Operational Storage. The operational storage facilities would be planned and sized to hold approximately 5,000 tons of dried waste, equal to four days of production. Five elevated steel silos of 1,000 ton capacity each would be used. The silos would be located adjacent to each other, over a new rail siding, for direct loadout to the railcars.

The silos would also provide the necessary temporary isolation of the waste materials from the environment. Air emissions would be controlled as the silos are loaded and as the silos are unloaded to fill the railcars.

Loading Facilities. Disposable reinforced polyethylene liners would be placed in the empty and clean rail cars just prior to waste material loadout at the FEMP. The liners would also incorporate a lap-over top that is laced shut after the railcar is filled with waste material. With this full bag-type waste material enclosure, no cover would be necessary for the rail car. Such bags are currently being successfully utilized to ship wastes to permitted commercial facilities in the arid West. It is noted that a hard cover on the rail car would also meet DOT packaging requirements. Upon installation, the liner material would be draped over the sides of the railcar to avoid interference during loading of the waste material.

A railcar dust collection hood would be incorporated with the silo discharge system to eliminate air emissions during railcar loading. As the railcar is moved into loading position under a silo, the hood would be lowered to seal with the railcar. A silo discharge valve and multiple discharge spouts would be built into the hood and will allow uniform placement of the waste material in the railcars. Before raising the hood, hood air would be exhausted if dusting is a problem.

All waste loading facilities would be placed in a pre-engineered metal building, including the railcar preparation area, loading zone beneath the silos, railcar weighing scales, final checkout, monitoring area, and railcar decontamination area (if necessary). The size of the building would be approximately 75 meters (250 feet) long by 9 meters (30 feet) wide by 8-m (25-ft) high.

Railroad Siding. At the FEMP operational storage and loadout facilities, a total of three sidings would be used. In addition to the existing siding that continues to the south side of Operable Unit 3, four additional switches and two 300 meters (1,000 feet) long sidings would be used. These new sidings would extend south to just north of the road leading to the waste pit area. The waste material storage silos would be located over one of the two new sidings so that the necessary environmental control facilities can easily be incorporated. Alternatively, two new switches and one 600 meters (2000 feet) siding could also be used.

To accommodate train movement and makeup, a wye would also be incorporated at the north end of the existing siding. The wye would require two new switches and approximately 180 meters (600 feet) of track. Each of the two new 300-m (1,000-ft) sidings would accommodate approximately 22 cars, and the existing siding would accommodate approximately 22 cars without interfering with road traffic to the waste pit area or rail traffic on the two new sidings.

In addition to the new sidings, a weighing scale would be installed to ensure that the loaded railcars do not exceed legal load limits. For movement of railcar strings, a yard locomotive would also be used.

Off-site Transportation

The waste material would be placed in bulk form into the bags in the gondola railcars for transportation to the permitted commercial off-site disposal facility. The gondola car size is approximately 14-m (45-ft) long with a 127-cubic meters (166-cubic yards) volume capacity and an 75-ton weight capacity. Approvals and certifications would be received prior to the shipment.

The gondola cars would be taken to a railcar rollover on the representative permitted commercial disposal facility's spur, located off of the Union Pacific Rail Road main line. The rollover is capable of unloading 7,600 cubic meters (10,000 cubic yards) of waste per day. Before the gondola is overturned, the disposable polyethylene liner will be cut open at the top. The waste would then be emptied and transported to the disposal cell. The polyethylene liner would be opened to allow equipment to move the waste. The spent liner will be disposed of along with the waste.

The number of trains, train size, and shipping frequency would be based on an estimated maximum 30-day round trip travel time from the FEMP to the representative permitted commercial disposal

facility. Mileage to the representative facility for the preferred route through East St. Louis, Illinois, is estimated at 3,080 kilometers (1,913 miles) with two railroads involved. An alternate route through Chicago is slightly longer--3,120 kilometers (1,937 miles)--and would involve three railroads.

To best accommodate unloading requirements at the representative permitted commercial disposal facility, 15 trains a month of 22 cars each would be used to meet waste material shipping needs. This is based on the operational optimum of the receiving facility. At 75 tons/car, each train would have a total load of approximately 1,650 tons, so that approximately three trains could be filled from the 5,000 tons of operation storage capacity. The 15 trains would operate on a schedule so that empty trains arrive at the FEMP site at approximately 2 day intervals. There are three sidings planned, so an empty string of cars could be dropped, a loaded string could be ready for pickup, and a third string could be in the process of being loaded.

Based on the expected waste material quantity of 1,053,300 tons (at 15 percent moisture) and a load capacity of 75 tons per railcar a total of 14,044 railcar loads would be required to dispose of the waste material.

4.6.2 Detailed Analysis

4.6.2.1 Overall Protection of Human Health and the Environment

Alternative 5B meets the remedial action objectives for Operable Unit 1 and is protective of human health and the environment in the same manner as Alternative 5A. Appendix D presents the quantitative documentation that forms the basis of these statements. Implementation of this alternative would prevent direct access to contaminated soil and would mitigate the migration of contaminants to the air, surface soil and groundwater. To meet these objectives, response actions include waste removal and placement of a multimedia cap over the restored pit area, treatment, off-site disposal and implementation of institutional control measures.

Contaminated soils would be excavated for disposal to the same levels as in Alternative 5A. Excavated pit areas would be backfilled with clean soil and capped to protect against potential exposures to residual contamination.

As in Alternative 5A, Alternative 5B includes institutional controls through continued federal ownership of the FEMP. This ownership would preclude future on-property residential and farming uses which could potentially result in exposure to contaminated soil.

The off-site disposal provides a major element of protectiveness for Alternative 5B. A permitted commercial facility located in an arid environment would be protective against direct contact with the pit waste material as well as migration of contaminants and material to the same extent as NTS (Alternative 5A). Disposal at an off-site permitted commercial facility is subject to some uncertainties associated with long-term protectiveness. As long as the facility owner maintains operations in compliance with applicable permits, protectiveness is ensured. It should be noted that there are no residences within 40 miles of the representative facility. Due to extremely harsh climatic conditions, it is unlikely that these population trends will change. Also there is no valuable groundwater resource at the facility. There is no surface water at the facility. These factors mitigate some of the above-referenced uncertainties.

There are no unacceptable short-term risks from Alternative 5B. The transportation risks are less than those for disposal at NTS because the waste can be sent in bulk by rail instead of a rail/truck combination (See appendix D). Through the implementation of a worker health and safety plan in compliance with 29 CFR 1910.120(b)(4), exposures would be kept to ALARA levels and would comply with DOE orders.

4.6.2.2 Compliance with Applicable or Relevant and Appropriate Requirements

Issues related to ARARs compliance for Alternative 5B are similar to those identified for Alternative 4A, with the exception of action-specific ARARs for on-property disposal. Alternative 5B would meet all ARARs identified in Appendix F. The State of Ohio disposal siting criteria and disposal requirements would no longer be relevant and appropriate because treated material would be disposed of off-site at a permitted disposal facility. In contrast, off-site transportation requirements would be applicable. The remaining ARARs/TBCs requirements for Alternative 5B concentrate on waste management and treatment and are similar to the ARARs for Alternative 4A. Consequently, the discussion of compliance for those common ARARs would be similar to that presented in Section 4.3.2.2. The applicable findings of that discussion are summarized below. Additional documentation of compliance of Alternative 5B with the identified ARARs is presented in Appendix F for the off-site disposal scenario.

Chemical-Specific ARARs/TBCs

Alternative 5B would comply with all chemical-specific ARARs identified in Appendix F for the off-site disposal scenario. Included would be those requirements associated with meeting Ohio Water Quality Standards, control of airborne releases of radionuclides and other hazardous constituents, and their resulting doses to the public.

Location-Specific ARARs/TBCs

Alternative 5B would comply with all pertinent location-specific ARARs identified in Appendix F for the off-site disposal scenario. Included would be those requirements associated with the protection of wetlands, endangered species and their habitats during the on-site treatment of the waste material. As noted above, disposal siting criteria and disposal requirements would no longer be applicable nor relevant and appropriate to this alternative because of the proposed use of an off-site disposal facility.

Action-Specific ARARs/TBCs

Alternative 5B would comply with all pertinent action-specific ARARs/TBCs identified in Appendix F for the off-site disposal scenario through engineering controls and treatment of the waste to comply with the waste acceptance criteria of the representative permitted commercial disposal facility. As was discussed for Alternative 4A, Alternative 5B would comply with ARARs associated with the Clean Air Act, Clean Water Act, and RCRA requirements for management and treatment of hazardous waste. Off-site disposition will require shipment of materials. Hazardous waste transportation requirements would be complied with by following the regulations under 40 CFR 262, 40 CFR 263 and the appropriate DOT shipping requirements under 49 CFR 171 through 180. In addition, packaging and transportation requirements described in DOE Order 5820.2A for wastes that are radioactive and hazardous would be followed. Alternative 5B would, by design, also comply with the Ohio transportation requirements as well as those of the states through which the waste may be routed.

4.6.2.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

Alternative 5B would be effective in the long term because Operable Unit 1 wastes would be excavated to health based-levels. The long-term risk assessment of this alternative (presented in Appendix D) analyzed all potential exposure pathways remaining following remediation. This screening analysis identified the primary pathways and principal mobile contaminants affecting public

risk. Use of proposed remediation levels (see Section 2.2) in the risk analysis (Appendix D) yielded results that document that the alternative is protective of human health and the environment.

Adequacy and Reliability of Controls

The reliability of a commercial facility in an arid environment is essentially the same as the NTS facility (Alternative 5A) since both are located in an arid environment with harsh hydrogeologic characteristics and since both currently manage LLRW. If there is a release at the commercial facility, corrective action measures would be implemented. As discussed previously, direct impact of such a release would be minimal due to the lack of environmental receptors. Monitoring is a requirement of the representative facility's permit.

Long-Term Environmental Impacts

The following paragraphs discuss long-term impacts to the environment associated with Alternative 5B. Impacts for Alternative 5B would be same as Alternative 5A with the exception of the location of the permitted disposal site. For the irreversible and irretrievable commitment of resources associated with Alternative 5B, refer to Section 4.8.

Soil and Geology. Identical to Alternative 5A, the long-term impacts on soil associated with Alternative 5B would be minimal on the FEMP site. Areas totalling approximately 15 hectares (37 acres) would be disturbed during surface soil removal from affected areas outside the pit area. This soil would be transported to Operable Unit 5 for management. Through the use of backfill soils from the 2.8-ha (7-acres) borrow area north and adjacent to the waste pit area, these areas would be regraded to near original contours upon completion of remedial activities. For Alternative 5B, after waste materials from each pit have been removed for treatment, contaminated residual soil would be removed and transported to Operable Unit 5 for management.

Pit excavation would not result in any additional breach to the glacial overburden and would not cause subsidence of the subsurface geologic formation. Excavated pit areas would be returned to near original contours through the use of backfill soils. Capping and runoff/run-on controls would minimize contaminant transport to uncontaminated soils through stormwater runoff.

Soil at the representative permitted commercial disposal facility would be permanently disturbed for the disposal of treated materials. Borrow material from the representative permitted commercial

disposal facility may be required for the shallow land disposal burial at the facility. Depths to the groundwater beneath the representative permitted commercial disposal facility vary from 6 to 9 meters (20 to 30 feet) below the ground surface. This groundwater is not of value due to extremely high total dissolved solids levels. The hydraulic head gradient in the groundwater is small, limiting the velocity of groundwater movement flowing away from the site to a maximum of 0.08 meters (0.6 feet) per year (DOE 1984). The design of the disposal cell and the high evapotranspiration rate characterized in the area would also reduce the potential for contaminant transport.

Water Quality and Hydrology. Surface water and groundwater at the FEMP would be protected as a result of contaminant source removal associated with Operable Unit 1. Assuming monitoring and maintenance activities continue at the FEMP site, no long-term impacts to water quality and hydrology are anticipated upon completion of remedial activities.

Grading and excavation activities would cause minor alterations to the east bank of Paddys Run. Runoff control measures (silt fences, hay bales) during remedial activities would minimize increased sediment load to Paddys Run and the natural flow of Paddys Run would re-establish a natural stream community. Therefore, no long-term impacts to water quality are expected.

Upon completion of remedial activities associated with Operable Unit 1, the area would be regraded to near original contours, promoting proper runoff and drainage. Surface water runoff would be routed to the appropriate collection/treatment system; therefore, no long-term impacts to water quality and hydrology at the FEMP site are anticipated.

The disposal of treated waste at the representative permitted commercial disposal facility is not expected to have significant impacts on water quality or hydrology. The arid to climate that prevails profoundly affects the surface water regime. All of the perennial water bodies are within the Great Salt Lake Drainage Basin; none are closer than 37 kilometers (23 miles) to the representative permitted commercial disposal facility. Long-term impacts to nearby surface water bodies as a result of Alternative 5B are expected to be minor.

Air Quality. The long-term impacts on the air quality at the FEMP site under Alternative 5B would be minor because the potential for airborne releases associated with the waste pits would be removed.

Materials removed from Operable Unit 1 and disposed of at the representative permitted commercial disposal facility are not expected to change existing conditions in the long-term.

Biotic Resources. As was the case for Alternatives 4A and 5A, no critical habitat for threatened and endangered species has been identified in areas to be impacted by Alternative 5A activities. However, there is potential for threatened and endangered species to reside near the waste pit area, which could be impacted by this alternative. The same threatened and endangered species identified in Alternatives 4A and 5A are referenced herein.

Excavation activities would result in the loss of approximately 5.37 hectares (13.2 acres) of riparian habitat, containing diverse flora and fauna, in addition to the above-mentioned threatened and endangered species. This riparian habitat would be restored by implementing the mitigative measures discussed in the short-term effectiveness section. Therefore, there would be no long-term impacts.

Approximately 0.81 hectares (2 acres) would be displaced at the representative permitted commercial disposal facility as a result of Alternative 5B. Threatened and endangered species are not known to exist at the representative disposal site.

The vegetation at the representative permitted commercial facility is a homogeneous, semi-desert low shrubland, primarily composed of shadscale *(Atriplex confertifolia)*. Plant communities identified on the site are Shadscale-Gray Molly *(Kochia americana var. vestita)*, a transitional community type of Shadscale-Gray Molly-Black Greasewood *(Sarcobatus vermiculatus)*, and Black Greasewood-Gardner Saltbush *(Atriplex nuttallii)*. Vegetation patterns are correlated with salinity and corresponding shifts in presence or abundance of species. No plant species are unique nor particularly valuable.

Wetlands and Floodplains. A wetlands delineation for the FEMP site was conducted in December 1992 (Ebasco Environmental 1993) and approved by the COE. The delineation identified approximately 0.72 hectares (1.77 acres) of isolated scrub-shrub/persistent emergent wetlands west of the waste pits and 0.08 hectares (0.21 acres) of drainage ditch/swale wetlands south of the waste pits. Identical to Alternative 5A, Alternative 5B would result in long term and direct impacts to approximately 1.09 hectares (2.7 acres) of drainage ditch/swale wetlands due to the borrow area. No adverse long-term impacts would occur to floodplains. A floodplain/wetland assessment has been performed in accordance with 10 CFR 1022 requirements and is included in Appendix H. No

floodplains or wetland areas exist within the representative permitted commercial disposal facility site boundaries.

Socioeconomics and Land Use. As was the case for Alternatives 4A and 5A, implementation of Alternative 5B is not expected to have any long-term impacts on the socioeconomics or land use in the vicinity of the Fernald site or in the CMSA.

There are an estimated 26,000 residents within Tooele County, Utah (location of the representative permitted commercial disposal facility) in 1990, but most of the area is uninhabited (Regional Economic Information System; United States Bureau of Economic Development, 1993). Socioeconomic impacts are not expected as a result of waste disposal activities.

Cultural Resources. A site-wide archaeological survey would be performed for the impacted areas associated with remedial activities for Operable Unit 1. Cultural resource areas would be managed consistently with the requirements of the NHPA, OHPO, AIRFA, and the NAGPRA. A more detailed discussion of the management procedure is provided in the short-term effectiveness evaluation for Alternative 5B. Because any cultural resources identified would be either avoided or managed appropriately, there would be no impacts to cultural resources at the FEMP site.

In 1981, a cultural resource inventory of the representative permitted commercial disposal facility near Clive, Utah, was conducted by the Archaeological Environmental Research Corporation (DOE, 1984). No cultural resource sites were identified. Located approximately 16 kilometers (10 miles) west of the disposal site is the Ground to Air Pilotless Aircraft Launch Site and Blockhouse which are listed on the National Register of Historic Places. The Iosepa Settle Cemetery is the closest cultural resource, located 37 kilometers (23 miles) to the southeast.

4.6.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The reduction in contaminant toxicity, mobility, or volume would be the same for Alternative 5B as for Alternative 5A (Section 4.5.2.4), since the same treatment processes are included in both. Therefore, Alternative 5B does not reduce contaminant mobility or toxicity through treatment, but slightly decreases volume due to the reduction in water content.

4.6.2.5 Short-Term Effectiveness

Protection of the Community during Remedial Action

Alternative 5B would be protective of the community as described under Alternative 5A. Engineered and institutional controls would minimize potential exposures to the community during remedial action. Risks from excavation and treatment would be identical to those discussed in Alternative 5A (i.e., an ILCR of 2.9×10^{-6}). Transportation is estimated to result in an ILCR to the public of 4.6×10^{-6} for routine transportation and 4.6×10^{-5} for a hypothetical train accident. The results of the statistical analysis of the transportation risk are provided in Appendix D.

Protection of Workers During Remedial Action

Estimates of potential exposure to remediation and nonremediation workers during removal, treatment and off-site disposal are the same as to those discussed in Alternative 5A. Exposures to waste package handlers are detailed in Section 2.5.1 of Appendix D. Implementation of worker health and safety plans and ALARA principles would ensure that workers would not be exposed to excessive risks during implementation of this alternative.

There are additional risks to transportation workers resulting from the transportation of material to this representative disposal facility. Statistical analysis indicates train crews would be subject to a dose equivalent of 3.3×10^{-2} person-rem, with the potential for accidents that may result in 3.4 injuries and 0.034 fatalities. Additional risks resulting from transportation are presented in Appendix D.

Short-Term Environmental Impacts

Soil and Geology. Soil disturbances would be identical to those identified in Alternative 5A. Short-term impacts to the soil and geology resulting from excavation and construction activities; control of fugitive dust emissions from heavy equipment movement; excavation of the pits; and residual soil removal and construction of support facilities would also be identical to those identified in Alternatives 4A and 5A.

Approximately 0.81 hectares (2 acres) of soil would be disturbed at the representative permitted commercial disposal facility as a result of Alternative 5B. Disturbances in the area would result from the disposal of treated materials. Engineering controls would be implemented to prevent the release of fugitive dust or sedimentation build-up as a result of erosion.

Water Quality and Hydrology. Excavation, dredging, trenching, and construction activities proposed in Alternative 5A would result in the same short-term impacts to water quality at the FEMP as those identified for Alternatives 4A and 5A.

Water quality and hydrology at the representative permitted commercial disposal facility would be minor. No surface water exists within 37 kilometers (23 miles) of the facility thus no impact to surface water is expected. The quality of existing groundwater is poor (saline) and not suitable for human consumption and domestic use. No short-term impacts to water quality or hydrology would result with the implementation of Alternative 5B.

Air Quality. The remedial activities proposed for Alternative 5B involve several activities that could impact air quality at the FEMP site. The same on-site impacts associated with Alternatives 4A and 5A apply in Alternative 5B.

The shipment of dried waste to the representative permitted commercial disposal facility would result in minor increases in emissions related to exhaust from locomotives during transportation and heavy equipment operation at the disposal facility. However, due to the number of shipments involved with Alternative 5B, short-term impacts to air would be negligible. Air monitoring activities would be implemented throughout the disposal facility.

Biotic Resources. The short-term disturbance of on-property vegetation and wildlife habitat, and mitigation of this disturbance, under Alternative 5B, is the same as that identified for Alternatives 4A and 5A.

Approximately 0.81 hectares (2 acres) of the existing plant community (shadscale-gray molly) and its attendant habitat for wildlife at the representative permitted commercial disposal facility would be displaced or disturbed as a result of the implementation of Alternative 5B. This type of plant community is neither unique nor particularly valuable. The flora or fauna in the potentially disturbed area are neither endangered or threatened. The displacement of individuals during construction activities is expected to be minor.

Wetlands and Floodplains. The site-wide wetlands delineation and the engineering controls to minimize short term impacts to wetlands on the Paddys Run floodplain are as discussed in Alternative 4A.

Remedial activities would have short-term impacts on approximately 335 meters (1,100 feet) of the 100-and 500-year floodplain of Paddys Run due to regrading activities adjacent to the stream. However, permanent construction of a stone lined drainage ditch and engineered outfall in the floodplain would not alter flow patterns or uses of the floodplain since they would be below original elevations. Disturbed areas of the floodplain would be regraded to near original contours. A floodplain/wetland assessment was prepared in accordance with 10 CFR 1022 and is presented in Appendix H.

No floodplains or wetland areas exist within the representative permitted commercial disposal facility boundaries.

Socioeconomics and Land Use. Short-term impacts to socioeconomics and land use would be minor with the implementation of Alternative 5B. Employment needed to implement this alternative would require 54 workers.

A combination of workers, represented by the current on-site workforce and various bidding subcontractors, will be utilized to implement remedial activities. Assuming all workers reside within the CMSA, the relocation or displacement of the workers is not expected to have major social or economic impacts to local communities.

To better assess short-term economic impacts, it is assumed that all resources needed for remedial activities, excluding treatment equipment, and disposal cost at the permitted disposal facility, would be purchased within the CMSA. Rather than addressing each individual county and the resources they are capable of supplying, each county's public and private expenditures were combined yielding a total expenditure figure of $805,000,000 for fiscal year 1992 to 1993. Total cost of implementing Alternative 5B would be $457,773,376. Excluding the cost of the treatment equipment, skilled labors, and disposal costs, the public and private expenditures would increase by approximately 9 percent over a 5 year period. Consequently, minor economic impacts would result from the implementing of Alternative 5B.

Disposal activities would not impact socioeconomics or land use at the representative permitted commercial disposal facility.

Transportation. The implementation of Alternative 5B would result in minor increases in traffic flow on and around the FEMP site. Temporary increases in deliveries and workers to the FEMP site are not expected to result in any significant impact to traffic patterns or roadways.

Transport of treated material by rail to the representative permitted commercial disposal facility would have minimal environmental impacts, as all procedures would be in compliance with all applicable DOT and DOE requirements. The risk to workers is addressed in Appendix D.

Cultural Resources. A site-wide archaeological survey at the FEMP site would be performed for the areas to be impacted by Operable Unit 1 remedial activities. Cultural resource areas would be managed consistently with the requirements of NHPA, OHPO, AIRFA, and the NAGPRA. An ethnographic survey will be conducted to determine the presence of American Indian sacred sites and burial grounds or other significant items. If possible, impact area boundaries should be designated so as to avoid cultural resources; however, if this is not feasible and cultural resources are affected, they would be evaluated to determine the appropriate treatment. In situ cultural resources would be preserved through agreement with the OHPO and other interested parties. Should it be agreed that cultural resources are to be removed, the following steps would be followed: 1) archaeological excavation, 2) laboratory treatment of cultural resources recovered at the site, and 3) curation of any recovered artifacts. If final in situ preservation of on-property artifact(s) is chosen (the artifacts remain in place), the plan for preservation would have to be compatible with remedial alternatives selected for the area in which the artifact(s) is located (Luce 1987).

No events of historical significance are known to have occurred at the representative permitted commercial disposal facility. A cultural resource inventory for the facility was performed in August 1981 by the Archaeological Environmental Research Corporation (DOE, 1984). No cultural resource sites were found. The Ground to Air Pilotless Aircraft Launch Site and Blockhouse are listed in the National Register of Historic Places and are approximately 16 kilometers (10 miles) west of the facility. To the southeast of Clive (approximately 37 kilometers [23 miles]) is the site of the Iosepa Settlement Cemetery. These are the nearest historical sites to the disposal facility and are not expected to be impacted from the implementation of Alternative 5B.

Duration of Remedial Activities

Remedial actions for Alternative 5B are expected to require 5 years to complete with an additional 1 year for preremedial activities. Physical, substantial, and continuous on-property activities could be initiated within 15 months after the ROD is approved by EPA.

4.6.2.6 Implementability

Technical Feasibility

The technical feasibility of the removal component of Alternative 5B would be the same as described for Alternative 5A, except for the location of the off-site disposal.

The technical feasibility of implementing the off-site disposal component of Alternative 5B depends on the implementability of transportation of the treated material to a representative permitted commercial disposal facility and compliance with the waste acceptance criteria of the disposal site. Based on the evaluation of the waste material, the waste acceptance criteria of the disposal facility could be met (see Appendix J). The technical feasibility of the construction of waste shipment handling facilities for off-site transportation by rail would be straightforward and reliable.

The treated material would be placed in bags in gondola railcars in bulk form for off-site transportation by rail to a representative permitted commercial disposal facility and would meet all transportation and disposal requirements.

Environmental impacts from shipping and disposing of treated material are expected to be minimal from normal transportation because all procedures would be in compliance with applicable DOT requirements and DOE orders. However, the added risk to the public due to off site transportation to the representative permitted commercial disposal facility is estimated at 4.6×10^{-6}. More information on the risk to workers and the public associated with the transportation of treated material is addressed in Appendix D and Section 4.6.2.5.

The implementation of this alternative would result in minor increases in traffic flow on and around the FEMP site. Temporary increases in deliveries and workers to the FEMP are not expected to result in any significant impact to traffic patterns or roadways.

Administrative Feasibility

The NCP requires the evaluation of the relative administrative feasibility of each alternative to include "... activities needed to coordinate with other offices and agencies and the ability and time required to obtain any necessary approvals and permits from other agencies (for off-site actions). CERCLA Section 121(e) provides that no Federal, State, or local permit shall be required for the portion of any removal or remedial action conducted entirely on site." It is required that a remedial action satisfy the substantive requirements of any permits that would otherwise be required. Alternative 5B is similar to Alternative 5A (see Section 4.5.2.6), except for the location of the disposal facility. With respect to administrative feasibility, the assessment is similar.

There have also been large volume shipments of LLRW and similar wastes to the representative permitted commercial disposal facility in Clive, Utah. The Denver Radium Site in Denver, Colorado, shipped approximately 450,000 tons of radioactive material to this facility via rail. There were limited amounts of mixed wastes included in these shipments. A private industrial site in Pennsylvania is in the process of shipping over 15,000 cubic yards of radioactive waste and a federal facility in Montclair, New Jersey is in the process of shipping 20,000 cubic yards of radium-contaminated materials there. These examples demonstrate that such shipments are feasible.

It is noted that DOE Order 5820.2A currently prohibits use of commercial disposal facilities for disposal of low-level radioactive wastes of the type present in Operable Unit 1. The Order does have an exemption provision and precedence exists for the granting of such exemptions. On October 12, 1993, the DOE Assistant Secretary for Environmental Restoration and Waste Management issued a blanket exemption from DOE Order 5820.2A for mixed waste resulting from CERCLA remediation activities, such as will be generated under this alternative (DOE, 1993). This exemption is conditional to compliance with the existing ARARs, reviews, and current guidance. Further, this exemption states that "...disposal of DOE mixed waste should not be constrained by the existing DOE Order 5820.2A restriction limiting disposal at DOE sites." It is noted that this blanket exemption is for relatively small quantities of waste. This DOE policy is under review by DOE Headquarters and the affected DOE orders will be revised accordingly. The FEMP is in the process of obtaining an exemption from this order.

In summary, there are no legal constraints obstructing the administrative feasibility of transportation and off-site disposal of Alternative 5B.

Availability of Services and Materials

The representative availability of services and materials required for Alternative 5B would be the same as for Alternative 5A. Services and materials for the construction of the waste shipment handling facilities and gondola cars for rail transportation would also be readily available. Personnel required for transportation by rail would also be available.

The representative permitted commercial disposal facility at Clive, Utah currently accepts LLRW and has adequate capacity to accept the treated material from Operable Unit 1. In the near future, this facility, which currently accepts hazardous waste, will have the capability for treating hazardous wastes as well.

Transfer areas, storage areas, decontamination facilities, and a laboratory are also available at this disposal facility. The treated material form would be tested to ensure that it complies with waste acceptance criteria of the disposal facility.

4.6.2.7 Cost

The total cost of Alternative 5B is approximately $457,773,376. A detailed breakdown of the cost is provided in Table 4-5.

Capital Cost

The capital cost is associated with site preparation, waste and soil removal, construction and operation of the waste processing facility, transportation, disposal, site restoration, and decontamination and decommissioning of waste processing facilities. A breakdown of each major component of this alternative is provided in Table 4-5. More detailed information is provided in Appendix E. This alternative includes identical cost components as Alternative 5A (Section 4.5.2.7), except that packaging is not included in this alternative and the disposal facility is a representative permitted commercial disposal facility rather than NTS. As with Alternative 5A, the largest components of the capital cost are transportation and disposal.

O&M Cost

The 30-year O&M cost is estimated to be approximately $348,202,000 (present worth value). O&M cost consists mainly of minimal maintenance of the restored waste pit areas.

4.7 DETAILED ANALYSIS SUMMARY

The detailed analysis for each of the alternatives, described in Sections 4.2 through 4.6 of this Feasibility Study, are summarized in Table 4-6. The alternatives were evaluated against criteria grouped into two categories: the threshold category, containing two criteria; and the primary balancing category, containing five criteria.

4.8 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

Implementing remedial action Alternatives 4A and 4B (i.e., on-property disposal) would result in permanent commitment of on-property land for material disposal at the FEMP site. Land at NTS and the representative permitted commercial disposal facility would be permanently committed for disposal for Alternatives 5A and 5B.

Alternatives 4A and 4B would permanently disrupt 23.5 hectares (58 acres) and 47 hectares (116.9 acres) from construction and permanent land committal of the on-site disposal cell respectively. Alternatives 5A and 5B would permanently disrupt approximately 1.2 hectares (3 acres) at NTS and 0.81 hectares (2 acres) at the representative permitted commercial disposal facility for disposal, respectively. All areas disturbed at the FEMP site would be regraded and revegetated.

Alternatives 4A, 4B, 5A, and 5B would permanently disturb 5.37 hectares (13.2 acres) of riparian habitat along Paddys Run and various potential threatened and endangered species habitat within and along Paddys Run at the FEMP site during excavation and regrading activities. Potential threatened and endangered species terrestrial habitat includes the Indiana bat, running buffalo clover, slender fingergrass, mountain bindweed, and spring coralroot. Alternatives 4A and 4B would result in the loss of 27.52 hectares (68 acres) of managed grazed field from construction of the on-site disposal facility. Long-term impacts to threatened and endangered species terrestrial habitat within the managed grazed field would be off-set from the implementation of mitigative measures discussed in Section 4.8. Terrestrial habitat at the off-site disposal areas (Alternatives 5A and 5B) is limited, resulting in minimal displacement of species.

Alternatives 4A and 4B would impact a total of 2.42 hectares (5.98 acres) of wetlands from on-site disposal and remedial activities. These wetland areas include 0.72 hectares (1.77 acres) of isolated scrub-shrub/persistent emergent wetlands west of the waste pits and 0.08 hectares (0.21 acres) of drainage ditch/swale wetlands east of the waste pits. The siting of the on-property disposal cell

facility would result in the loss of approximately 0.53 hectares (1.3 acres) of drainage ditch/swale wetlands. Approximately 1.09 hectares (2.7 acres) of drainage ditch/swale wetlands would be loss due to the borrow area. Alternatives 5A and 5B would result in the same above-mentioned wetland impacts with the exception of 0.53 hectares (1.3 acres) from the citing of the on-site disposal facility, resulting in a total of 1.89 hectares (4.67 acres) wetland impacts. Mitigation for wetland impacts would be determined using the 404 (b)(1) guidelines of the Clean Water Act. No wetlands or floodplains are present at the off-site disposal facilities (Alternatives 5A and 5B).

Consumptive use of geological resources (e.g., quarried rock, sand, and gravel) and petroleum products (e.g., diesel fuel and gasoline) would be required for removal, construction, and disposal activities of all the action alternatives. Supplies of these materials would be provided by the construction contractor. Additional fuel use would result from off-site transport of the materials. However, adequate supplies are available without affecting local requirements for these products.

Treatment processes for the action alternatives would require the consumptive use of materials and energy. The cement stabilization process would require additives such as cement and flyash. The vitrification process would be energy-intensive and require commitment of a considerable supply of electricity. Cement and flyash are readily available locally in the quantities required, and electricity can be obtained from the local utility.

The committed land at the FEMP site would be actively monitored and maintained. Periodic monitoring of nearby surface water and groundwater from monitoring wells around the perimeter of the on-site disposal facility would be performed, and periodic inspections would identify any damage to the above-grade disposal facility. Maintenance activities would be performed as necessary. Hence, no impacts to groundwater are expected to occur from Operable Unit 1 remedial activities.

4.9 PERSONS AND AGENCIES CONSULTED

A list of persons and agencies consulted is provided in Appendix G.

TABLE 4-1

OPERABLE UNIT 1
SUMMARY OF VITRIFICATION TREATABILITY STUDY RESULTS

WASTE AREA	BULKING FACTORS [a] Range (%)	BULKING FACTORS [a] Average (%)	PCT Leach Rate Ratios [b]	RADON EMANATION RATES [b] (pCi/gram/day) Untreated Waste	Soil Formulation [c]	Flyash Formulation [c]
Waste Pit 1	-2.6 to +84	+49	0.001 to >500	4.07	0.29	0.02
Waste Pit 2	-20 to -66	-48	0.003 to 29	63.88	0.08	0.02
Waste Pit 3	-46 to -76	-61	0 to 109	12.74	0.09	0.13
Waste Pit 4	+6 to +68	+37	0 to >500	3.04	0.07	0.02
Waste Pit 5	-69 to -88	-78	0.1 to >500	15.19	0.05	1.06
Waste Pit 6	-50 to -73	-62	0.01 to 271	0.71	0.02	0.02
Burn Pit	-31 to -62	-52	0.01 to 26	1.62	0.01	0.02
Clearwell	-15 to -58	-36	0 to 14	9.97	0.02	0.008

[a] Negative (-) bulking factors indicate a decrease in volume of the treated material relative to the untreated volume of waste and positive (+) bulking factors indicate an increase in volume.
[b] Expressed as ratio of leach rate of treated waste to the Savannah River High Level Waste Criteria (SRHLWC). Data representative of results for both soil and flyash formulations.
[c] Data for soil and flyash formulations presented for 30-day leach test and are based on average radium-226 concentration in characterization samples.

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TABLE 4-2

OPERABLE UNIT 1
COST ESTIMATE FOR ALTERNATIVE 4A:
REMOVAL, TREATMENT (VITRIFICATION) AND ON-PROPERTY DISPOSAL

Item	Cost ($Million)
Capital Cost	
Ancillary Facilities	10
Excavation (10 years)	106
Waste Pit Backfill (10 years)	23
Pretreatment Facility	14
Rotary Drying (10 years)	122
Vitrification	227
D&D	11
On-Property Disposal	127
Borrow Pit Restoration	1
O&M Cost[a]	0.3
Total Capital Cost	641

[a] O&M Cost is an annual cost.

TABLE 4-3

OPERABLE UNIT 1
COST ESTIMATE FOR ALTERNATIVE 4B:
REMOVAL, TREATMENT (CEMENTATION), AND ON-PROPERTY DISPOSAL

Item	Cost ($Million)
Capital Cost	
Ancillary Facilities	10
Waste Pit Excavation (5 years)	63
Waste Pit Backfill (5 years)	12
Pretreatment Facility	14
Rotary Drying (5 years)	78
Cementation Equipment & Operation	121
D&D Cementation	8
On-Property Disposal	198
O&M Cost[a]	0.3
Total Capital Cost	505

[a] O&M Cost is an annual cost.

TABLE 4-4

OPERABLE UNIT 1
COST ESTIMATE FOR ALTERNATIVE 5A:
REMOVAL, TREATMENT, AND OFF-SITE DISPOSAL AT NTS

Item	Cost ($Million)
Capital Cost	
Ancillary Facilities	10
Waste Pit Excavation (5 years)	63
Waste Pit Backfill (5 Years)	12
Pretreatment Facility	14
Rail Siding Only	6
Rotary Drying (5 years)	78
Off-Site Disposal	8
Shipping and Disposal (NTS)	665
O&M Cost[a]	0.06
Total Capital Cost	856

[a] O&M Cost is an annual cost.

TABLE 4-5

OPERABLE UNIT 1
COST ESTIMATE FOR ALTERNATIVE 5B:
REMOVAL, TREATMENT, AND OFF-SITE DISPOSAL AT
A REPRESENTATIVE COMMERCIAL DISPOSAL FACILITY

Item	Cost ($Million)
Capital Cost	
Ancillary Facilities	10
Waste Pit Excavation (5 years)	63
Waste Pit Backfill (5 years)	12
Pretreatment Facility	14
Rail Siding and Silos	6
Rotary Drying (5 years)	78
D&D Off-Site Disposal	8
Shipping and Disposal (Commercial)	266
O&M Cost[a]	0.06
Total Capital Cost	457

[a] O&M Cost is an annual cost.

TABLE 4-6
OPERABLE UNIT 1
COMPARATIVE ANALYSIS SUMMARY

CRITERIA	ALTERNATIVE 1 NO ACTION	ALTERNATIVE 4A REMOVAL, TREATMENT (VIT) ON-PROPERTY DISPOSAL	ALTERNATIVE 4B REMOVAL, TREATMENT (CEM) ON-PROPERTY DISPOSAL	ALTERNATIVE 5A REMOVAL, TREATMENT OFF-SITE DISPOSAL AT NTS	ALTERNATIVE 5B REMOVAL, TREATMENT, OFF-SITE DISPOSAL AT A REPRESENTATIVE PERMITTED COMMERCIAL DISPOSAL FACILITY
Threshold Criteria					
• Overall Protection of Human Health and the Environment	Not protective. Will not eliminate, reduce or control the health risks presented by site contaminants. Based on results of the OU1 baseline RA, risks are above 10^{-4}.	Protective. Source term will be removed. Treated material will be isolated in above-grade disposal cell. Long-term exposure and risk will be less than the EPA target range.	Protective. Source term will be removed. Treated material will be isolated in above-grade disposal cell. Long-term exposure and risk will be less than the EPA target range.	Protective. Off-site disposal will remove source term from the FEMP. Long-term exposure and risk will be less than the EPA target range.	Protective. Off-site disposal will remove source term from the FEMP. Long-term exposure and risk will be less than the EPA target range.
• Compliance with ARARs	Will not meet all ARARs, including criteria for ground-water, radioactive waste disposal requirements, and radiation protection requirement of DOE orders and regulations.	Meets all ARARs if exemption or waiver obtained. A technical consideration for an exemption for siting a solid waste disposal unit over a sole-source aquifer may be justified.	Meets all ARARs if exemption or waiver obtained. A technical consideration for an exemption for siting a solid waste disposal unit over a sole-source aquifer may be justified.	Meets all ARARs, with additional off-site requirements including NTS waste acceptance criteria and DOT regulations pertaining to hazardous and radioactive materials.	Meets all ARARs, with additional off-site requirements including permitted commercial disposal facility waste acceptance criteria and DOT regulations pertaining to hazardous and radioactive materials.
Balancing Criteria					
• Long-Term Effectiveness and Permanence	Not effective.	Effective in isolating waste from public and environmental receptors. Long-term effectiveness of institutional controls and monitoring uncertain.	Effective in isolating waste from public and environmental receptors. Long-term effectiveness of institutional controls and monitoring uncertain.	Acceptable long-term effective-ness. Long-term exposures of the public near NTS will be low. Dry climate and favorable geology will reduce migration of any contaminants to groundwater. No adverse long-term ecological impacts are expected.	Acceptable long-term effective-ness. Long-term exposures of the public near representative permitted commercial disposal facility will be low. Dry climate and favorable geology will reduce migration of any contaminants to groundwater. No adverse long-term ecological impacts are expected.

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TABLE 4-6
(Continued)

CRITERIA	ALTERNATIVE 1 NO ACTION	ALTERNATIVE 4A REMOVAL, TREATMENT (VIT) ON-PROPERTY DISPOSAL	ALTERNATIVE 4B REMOVAL, TREATMENT (CEM) ON-PROPERTY DISPOSAL	ALTERNATIVE 5A REMOVAL, TREATMENT OFF-SITE DISPOSAL AT NTS	ALTERNATIVE 5B REMOVAL, TREATMENT, OFF-SITE DISPOSAL AT A REPRESENTATIVE PERMITTED COMMERCIAL DISPOSAL FACILITY
- Magnitude of Residual Risk	Residual risk is that of baseline RA, far above 10^{-4}.	Residual risk to off-site farmer is below EPA's target range.	Residual risk to off-site farmer is below EPA's target range.	Residual risk to off-site farmer is below EPA's target range.	Residual risk to off-site farmer is below EPA's target range.
- Adequacy and Reliability of Controls	Controls are inadequate as there are none.	Reliability improved with disposal of treated material in an engineered cell so there is less dependency on institutional actions. The lowered leaching potential of treated material lessens the ramifications of cell failure. Disposal cell designed for 1,000 years.	Reliability improved with the disposal of treated material in an engineered cell so there is less dependency on institutional actions. The lowered leaching potential of treated material lessens the ramifications of cell failure. Disposal cell designed for 1,000 years.	Disposal will be managed consistent with the NTS waste management plan and in a manner that ensures protectiveness of human health and the environment. The reduced leachate due to the arid climate, coupled with the geology and depths to the groundwater table (155m to 600m) favor long-term disposal of the treated material at NTS.	Disposal will be managed consistent with the representative permitted commercial disposal facility waste management plan and in a manner that ensures protectiveness of human health and the environment. The improved adequacy and reliability of controls favor long-term disposal of the treated material at a representative permitted commercial disposal facility.
- Long-Term Environmental Impacts	Could increase contamination levels in groundwater, surface water, and biota.	Treatment and disposal of the waste in an engineered cell will minimize ecological impacts. Disposal cell would result in disruption of 23.3 ha (57.5 acres).	Treatment and disposal of the waste in an engineered cell will minimize ecological impacts. Disposal cell would result in disruption of 47.32 ha (116.9 acres) of land.	1.2 ha (3 acres) of land committed for waste disposal at NTS.	0.81 ha (2 acres) of land committed for waste disposal at a permitted commercial disposal facility.

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TABLE 4-6
(Continued)

CRITERIA	ALTERNATIVE 1 NO ACTION	ALTERNATIVE 4A REMOVAL, TREATMENT (VIT) ON-PROPERTY DISPOSAL	ALTERNATIVE 4B REMOVAL, TREATMENT (CEM) ON-PROPERTY DISPOSAL	ALTERNATIVE 5A REMOVAL, TREATMENT OFF-SITE DISPOSAL AT NTS	ALTERNATIVE 5B REMOVAL, TREATMENT, OFF-SITE DISPOSAL AT A REPRESENTATIVE PERMITTED COMMERCIAL DISPOSAL FACILITY
• Reduction of Toxicity, Mobility, and Volume Through Treatment					
- Toxicity Radiological	No treatment. No reduction.	Not reduced. Immobilized	Not reduced. Immobilized	Not reduced.	Not reduced.
Inorganic	No treatment. No reduction	Not reduced. Immobilized	Not reduced. Immobilized	Not reduced.	Not reduced.
Organic	No treatment. No reduction	Significantly reduced due to the destruction of organics.	Not reduced.	Not reduced.	Not reduced.
- Mobility	No treatment. No reduction.	Significantly reduced.	Significantly reduced.	Not Reduced.	Not reduced.
- Volume	No treatment. No reduction.	About the same.	Increased by 100%.	Some decrease.	Some decrease.
• Short-Term Effectiveness					
- Protection of the Public during Remedial Actions	N/A No Remedial Action	Effective. Implementation will not expose the public to contaminants due to engineered safety controls to be used. Radon concentrations at fenceline less than 0.5 pCi/l.	Effective. Implementation will not expose the public to contaminants due to engineered safety controls to be used. Radon concentrations at fenceline less than 0.5 pCi/l.	Effective. Implementation will not expose the public to contaminants due to engineered safety controls to be used. Low transportation risk to public.	Effective implementation will not expose the public to contaminants due to engineered safety controls to be used. Low transportation risk to public.

TABLE 4-6
(Continued)

CRITERIA	ALTERNATIVE 1 NO ACTION	ALTERNATIVE 4A REMOVAL, TREATMENT (VIT) ON-PROPERTY DISPOSAL	ALTERNATIVE 4B REMOVAL, TREATMENT (CEM) ON-PROPERTY DISPOSAL	ALTERNATIVE 5A REMOVAL, TREATMENT OFF-SITE DISPOSAL AT NTS	ALTERNATIVE 5B REMOVAL, TREATMENT, OFF-SITE DISPOSAL AT A REPRESENTATIVE PERMITTED COMMERCIAL DISPOSAL FACILITY
- Protection of Workers During Remedial Actions	N/A No Remedial Action	Moderately protective. Workers will follow task-specific Health and Safety Plan. Moderate number of occupational accidents expected due to construction of disposal cell.	Moderately protective. Workers will follow task specific Health and Safety Plan. Moderate number of occupational accidents expected due to construction of large disposal cell.	Moderately effective. Workers will follow the task-specific Health and Safety Plan. Low number of occupational accidents expected.	Moderately effective. Workers will follow the task-specific Health and Safety Plan. Low number of occupational accidents expected.
- Short-Term Environmental Impacts	N/A No Remedial Action	Good engineering practices will minimize ecological impacts. Thirty-eight ha (94 acres) will be temporarily and permanently disturbed at the FEMP.	Good engineering practices will minimize ecological impacts. Sixty-two ha (153 acres) will be temporarily and permanently disturbed at the FEMP.	Good engineering practices will minimize ecological impacts. Approximately 8.9 ha (22 acres) will be temporarily disturbed at the FEMP.	Good engineering practices will minimize ecological impacts. Approximately 8.9 ha (22 acres) will be temporarily disturbed at the FEMP.
- Duration of Remedial Actions	N/A No Remedial Action	10 years.	5 Years.	5 years.	5 years.
• Implementability					
- Technical Feasibility	Reliable. No action included. Used as baseline comparison.	Moderately feasible. The material removal component is straightforward; hydraulic removal has been used for material of similar consistency. Vitrification is potentially feasible but full-scale operation has not been demonstrated. Further investigations are required to adequately design the process off-gas system.	Moderately feasible. The material removal component is straight-forward, hydraulic removal has been used for material of similar consistency. Cement solidification process is reliable and has been used in hazardous waste treatment and in the construction and mining industries. Waste heterogeneity could make process control very difficult.	Feasible. The material removal component is straightforward; hydraulic removal has been used for material of similar consistency. Disposal at NTS will utilize standard practices.	Feasible. The material removal component is straightforward; hydraulic removal has been used for material of similar consistency. Disposal at representative permitted commercial disposal facility will utilize standard practices.

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TABLE 4-6
(Continued)

CRITERIA	ALTERNATIVE 1 NO ACTION	ALTERNATIVE 4A REMOVAL, TREATMENT (VIT) ON-PROPERTY DISPOSAL	ALTERNATIVE 4B REMOVAL, TREATMENT (CEM) ON-PROPERTY DISPOSAL	ALTERNATIVE 5A REMOVAL, TREATMENT OFF-SITE DISPOSAL AT NTS	ALTERNATIVE 5B REMOVAL, TREATMENT, OFF-SITE DISPOSAL AT A REPRESENTATIVE PERMITTED COMMERCIAL DISPOSAL FACILITY
- Administrative Feasibility	No permits or licenses required.	No permits or licenses required, but permit information summary packages may be required. Substantive technical requirements to be met.	No permits or licenses required, but permit information summary packages may be required. Substantive technical requirements to be met.	Off-site transportation and disposal will need to be coordinated with numerous State and Federal agencies and public interest groups. Waste acceptance at disposal facility must be certified.	Off-site transportation and disposal will need to be coordinated with numerous State and Federal agencies and public interest groups. Waste acceptance at disposal facility must be certified.
• Cost ($ million)	0	$641	$505	$856	$457

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TABLE 4-7

OPERABLE UNIT 1
UNAVOIDABLE ADVERSE IMPACTS ON RESOURCES

Affected Resource	Impact Type
Soil & Geology	Soil at the FEMP site, NTS and a commercial disposal facility would be disrupted by construction and excavation activities. Many impacts would be temporary, pending completion of remedial activities and restoration programs. The implementation of Alternatives 4A, 4B, 5A and 5B would temporarily disturb 6.07 ha (15 acres) (e.g., excavation and construction of support facilities) and 2.83 ha (7 acres) (e.g., borrow area) at the FEMP site. Alternatives 4A and 4B would permanently commit 32 ha (79 acres) of land for an on-site disposal facility. Alternative 5A and 5B would permanently commit approximately 1.2 ha (3 acres) at NTS and .8 ha (2 acres) at the permitted commercial disposal facility. All areas disturbed at the FEMP site would be regraded and revegetated. The regional geology of the FEMP site and surrounding area would not be affected by any of the alternatives. Implementation of Alternatives 5A and 5B would not affect the regional geology of NTS or the permitted commercial disposal facility and surrounding areas.
Water Quality and Hydrology	Short-term impacts (e.g., sediment deposition and fugitive dust) on water quality and hydrology would be minimal for all alternatives. All alternatives would provide regrading and revegetation upon completion of excavation to minimize potential water quality impacts. A long-term water quality monitoring system around disposal facilities at the FEMP site (Alternatives 4A and 4B) would minimize impacts to water quality and hydrology. Assuming monitoring and maintenance activities continue at NTS and the permitted commercial disposal facility, no long-term impacts would be expected from waste disposal at NTS (Alternative 5A) or the permitted commercial disposal facility (Alternative 5B).

TABLE 4-7
(Continued)

Air Quality	Short-term impacts to air quality at the FEMP site would result from fugitive dust emissions associated with construction and excavation activities, exposed pit walls and gaseous emissions during waste removal. Lesser impacts would also be incurred from vehicle and equipment exhausts. These impacts are not expected to affect human health and the environment. No long-term impacts on air quality would be expected from activities associated with any alternatives. Disturbed areas would be restored (e.g., regraded and revegetated) after completion of the remedial activities, thus minimizing the potential for releases of inhalable particulates. Waste disposal facilities at all sites would be equipped with air pollution control devices to remove regulated pollutants and particulates before discharge to the atmosphere.
Biotic/Ecological Resources	Alternatives 4A, 4B, 5A and 5B would disturb 5.37 ha (13.2 acres) of riparian habitat along Paddys Run and various potential threatened and endangered species habitat within and along Paddys Run at the FEMP site during excavation and regrading activities. Potential threatened and endangered species terrestrial habitat includes the Indiana bat, running buffalo clover, slender fingergrass, mountain bindweed, and spring coralroot. Alternatives 4A and 4B would disrupt 27.52 ha (68 acres) of managed grazed field from construction of the on-site disposal facility and 2.83 ha (7 acres) of managed grazed field from the borrow area. Terrestrial habitat at the off-site disposal areas (Alternatives 5A and 5B) is limited, resulting in minimal displacement of species. Alternatives 4A, 4B, 5A, and 5B would permanently displace the aquatic habitat of state threatened Sloan's crayfish (*Orconectes sloanii*) within Paddys Run from regrading and revegetation activities.

TABLE 4-7
(Continued)

Wetlands & Floodplains	Alternatives 4A and 4B would impact a total of 2.57 ha (6.35 acres) of wetlands from on-site disposal and remedial activities. These wetland areas include 0.72 ha (1.77 acres) of isolated scrub-shrub/persistent emergent wetlands west of the waste pits and 0.23 ha (0.58 acres) of drainage ditch/swale wetlands east of the waste pits. The citing of the on-property facility would result in the loss of approximately 0.53 ha (1.3 acres) of drainage ditch/swale wetlands. Approximately 1.09 ha (2.7 acres) of drainage ditch/swale wetlands would be lost due to the borrow area. Alternatives 5A and 5B would result in the same above-mentioned wetland impacts with the exception of 0.72 ha (1.77 acres) from the citing of the on-site disposal facility, resulting in a total of 2.04 ha (5.04 acres) wetland impacts. No wetlands or floodplains are present at the off-site disposal facilities (Alternatives 5A and 5B).
Socioeconomics and Land Use	All alternatives would result in minimal short-term impacts (e.g., traffic noise) to the socioeconomics and land use. The long-term socioeconomics and land use impacts for the FEMP site would be positive to the local economy due to reduction of threat to human health and the environment from waste control and isolation or removal off-site. No change would be expected in local population or land use. Alternatives 5A and 5B entail removing waste from the site, thus minimizing impacts on future populations and economic growth at the FEMP site. Disposal of this waste at the NTS or permitted disposal facility would not be expected to impact socioeconomics or land use at these facilities. Total costs of each alternative considered ranged from approximately $0 to $1 trillion. All resources required for remedial activities are assumed to be found within the thirteen county Consolidated Metropolitan Statistical Area (CMSA). The cumulative operating budget for the CMSA was approximately $805,000,000. Depending on the alternative selected, the collective revenue for the CMSA could increase up to approximately 25 percent over a 5- to 10-year period.

TABLE 4-7
(Continued)

Visual Resources	Construction and excavation activities would result in minor alteration of aesthetic perceptions to the public due to visibility of the on-site disposal facility from SR 128 and portions of SR 126. Visual impacts would be reduced through the maintenance of a vegetative cover. The long-term impacts would be incremental for off-site disposal locations for Alternatives 5A and 5B. Short-term impacts would be incurred at off-site locations for all of the action alternative during construction, excavation, and transport activities. These impacts would be temporary and would cease following completion of remedial action activities and site restoration.
Noise	Ambient noise levels would temporarily increase as a result of construction, excavation, and transportation activities. All noise impacts would be temporary and would cease following completion of remedial activities.

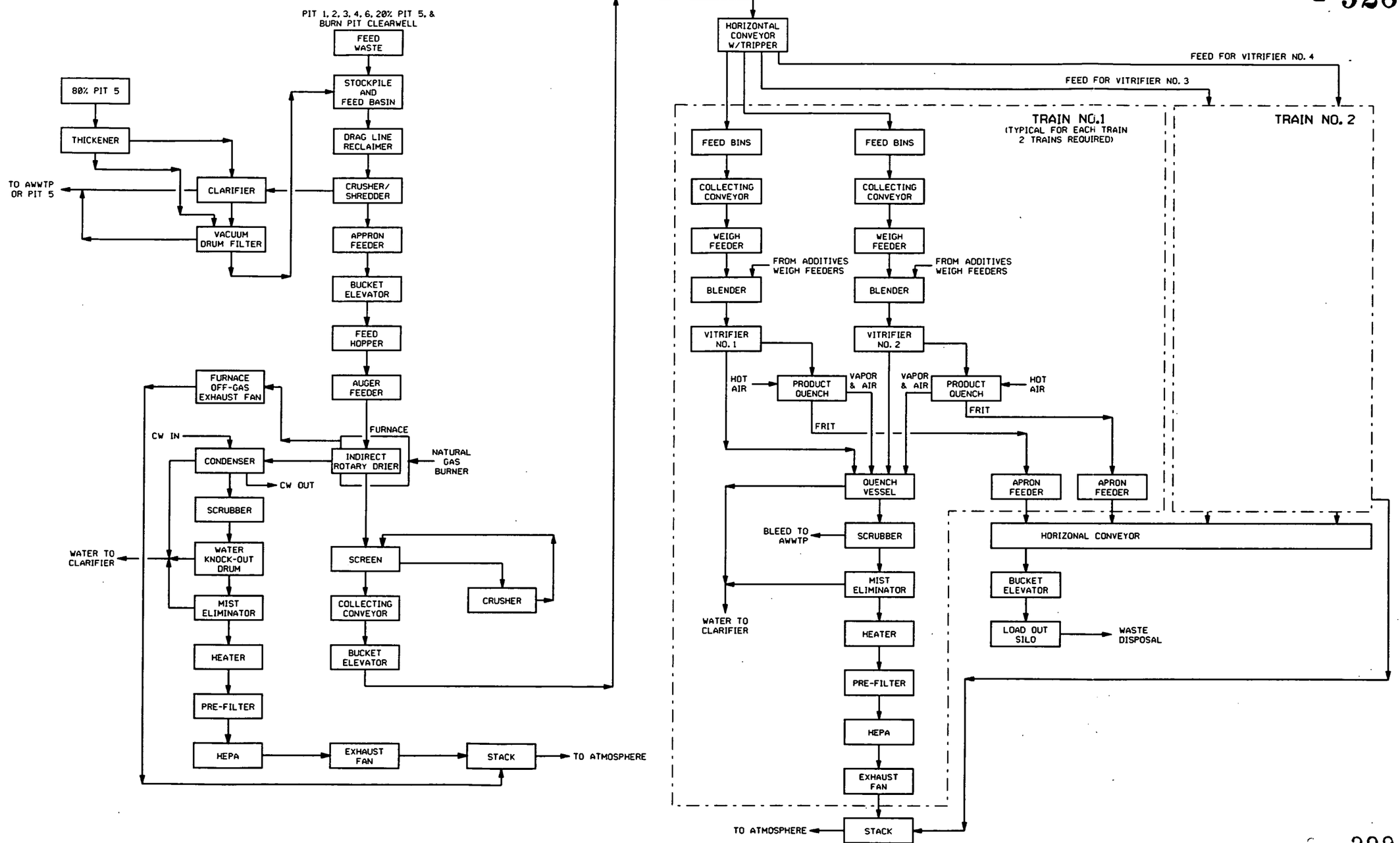

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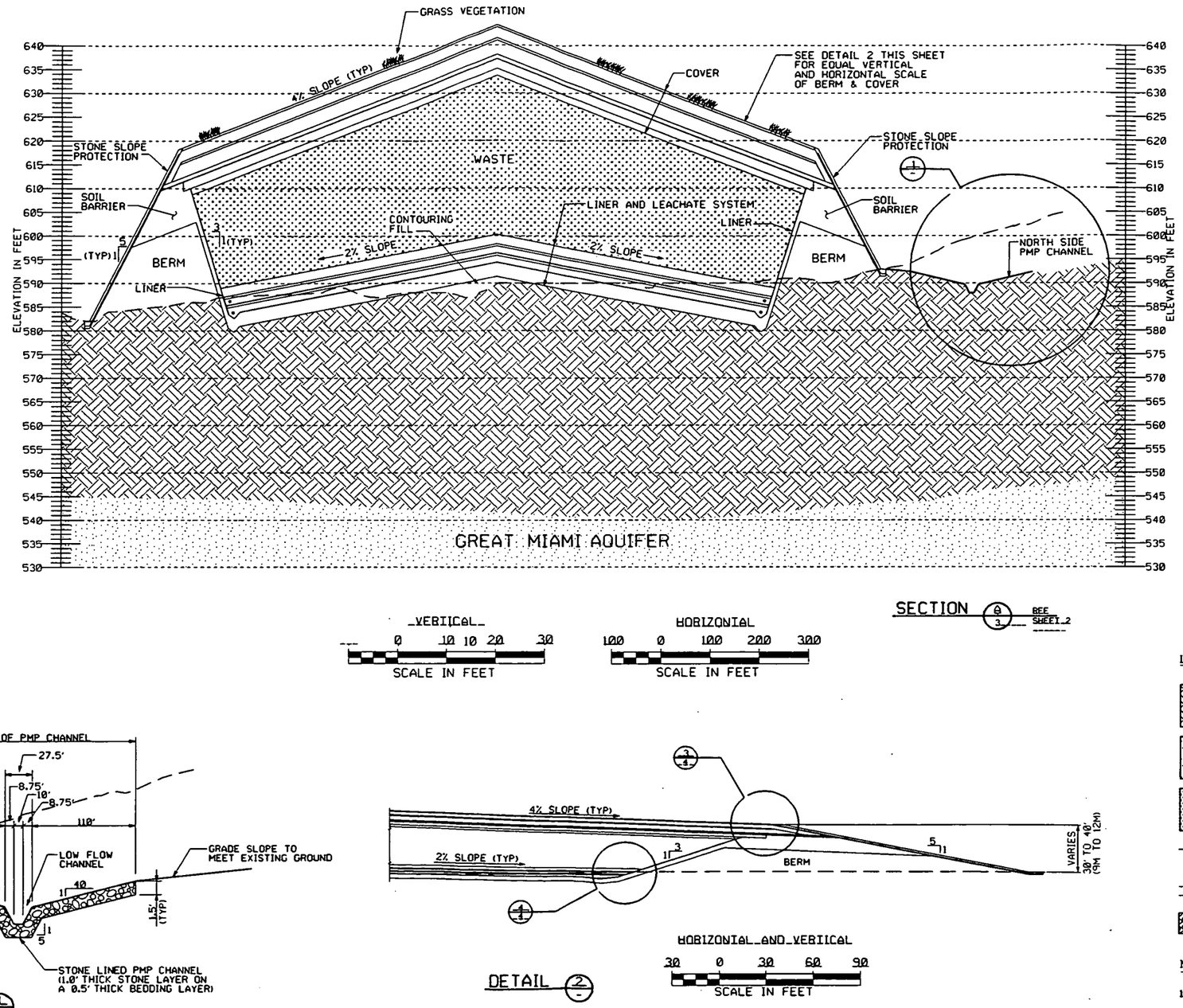
FIGURE 4-1. OPERABLE UNIT 1 BLOCK FLOW DIAGRAM VITRIFICATION PROCESS



LEGEND:

- EXISTING SOIL
- SAND AND/OR GRAVEL
- WASTE
- GROUND LINE
- GRASS VEGETATION
- STONE

NOTES:

1. GEOLOGY SHOWN FOR ILLUSTRATION PURPOSE ONLY.

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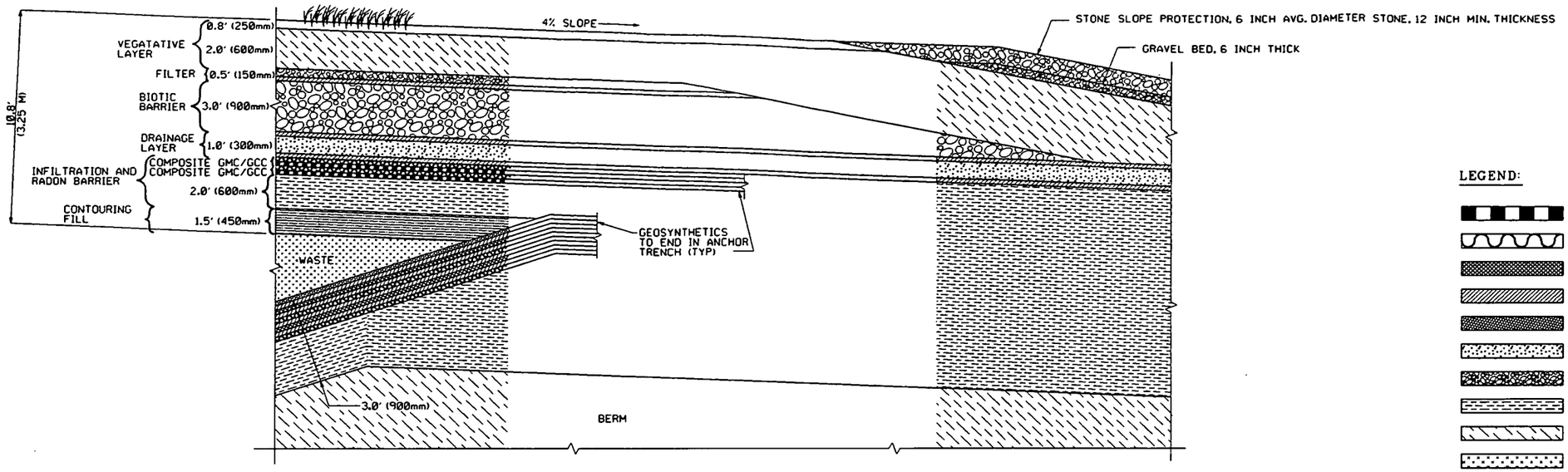
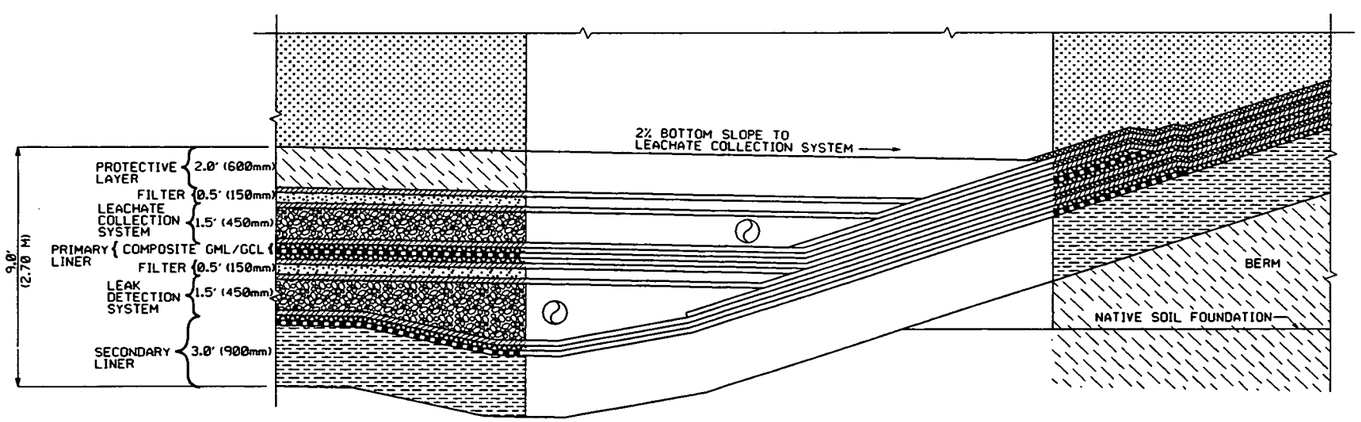
FIGURE 4-2. OPERABLE UNIT 1 SECTIONS AND DETAILS DISPOSAL CELL



DETAIL 3/4 REF SHEET 3
N.T.S.



DETAIL 4/4 REF SHEET 3
N.T.S.

LEGEND:

- BENTONITE GCL/GCC
- TEXTURED GML/GMC
- GEONET
- GEOTEXTILE
- RUB SHEET
- SAND
- GRAVEL
- COMPACTED SOIL BARRIER
- COMMON SOIL
- WASTE
- STONE
- CONTOURING FILL
- COBBLES
- GRASS VEGETATION
- LEACHATE PIPE

ABBREVIATIONS

GMC - GEOMEMBRANE CAP
GCC - GEOSYNTHETIC CLAY CAP
GML - GEOMEMBRANE LINER
GCL - GEOSYNTHETIC CLAY LINER

NOTES:

1. THE GEOSYNTHETICS HAVE AN ACTUAL THICKNESS MUCH LESS THAN IS GRAPHICALY SHOWN ON THIS DRAWING.
2. ALL MEMBRANE COMPONENTS HAVE A TEXTURED SURFACE.
3. PROPOSED BERM IS TO BE COMMON FILL MATERIAL.
4. GEOTEXTILES ARE UTILIZED TO AID IN CONSTRUCTION BY PROVIDING STABILITY AND PUNCTURE RESISTANCE TO MEMBRANES. THEY ALSO PROVIDE AN ADDITIONAL MEASURE OF PROTECTION FROM INFILTRATION AND LEACHATE MIGRATION.
5. LEACHATE SHALL BE COLLECTED, REMOVED AND DISPOSED OF PROPERLY; DETAILS OF THIS SHALL BE IN TITLE DESIGN. METHODS FOR OBSERVATION OF LEAK DETECTION SYSTEM SHALL BE DETERMINED DURING TITLE DESIGN.
6. THE ENGLISH AND SI DIMENSIONS SHOWN ARE ROUNDED FOR COMPARATIVE PURPOSE.

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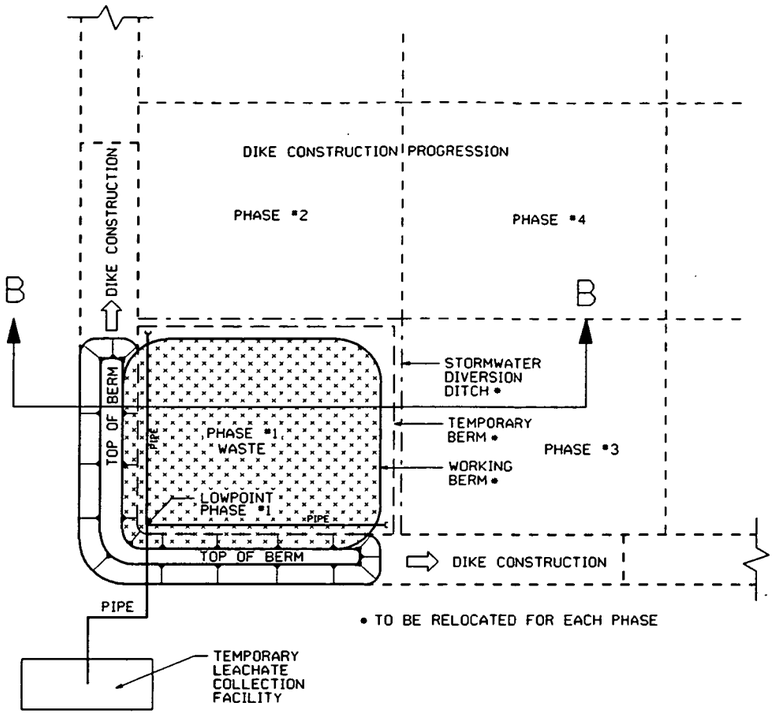
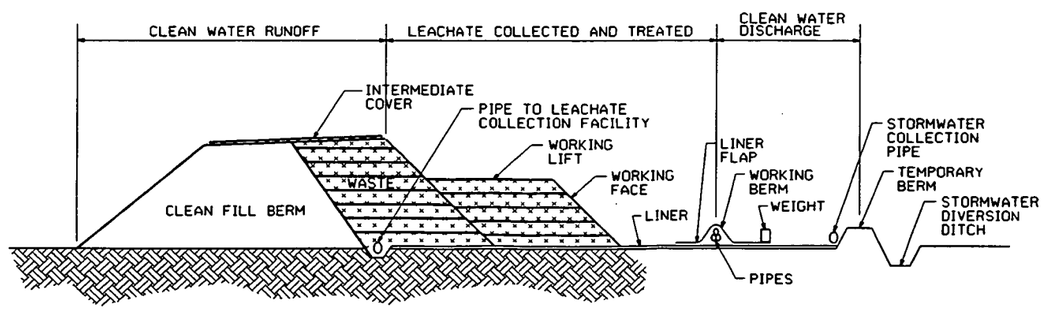
FIGURE 4-3. OPERABLE UNIT 1 DETAIL SHEET DISPOSAL CELL



PLAN

(WITHOUT INTERMEDIATE COVER)



SECTION B-B

NOT TO SCALE

NOTES:

1. PLAN VIEW SHOWS THE FIRST WORK AREA. THE AREA EXPANDS AS ADDITIONAL WASTE IS PLACED.
2. THE WORKING LIFT AND FACE AREA IS LIMITED TO MINIMIZE AREA EXPOSED TO WEATHER.

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FIGURE 4-4. OPERABLE UNIT 1 DISPOSAL CELL CONSTRUCTION PROGRESSION

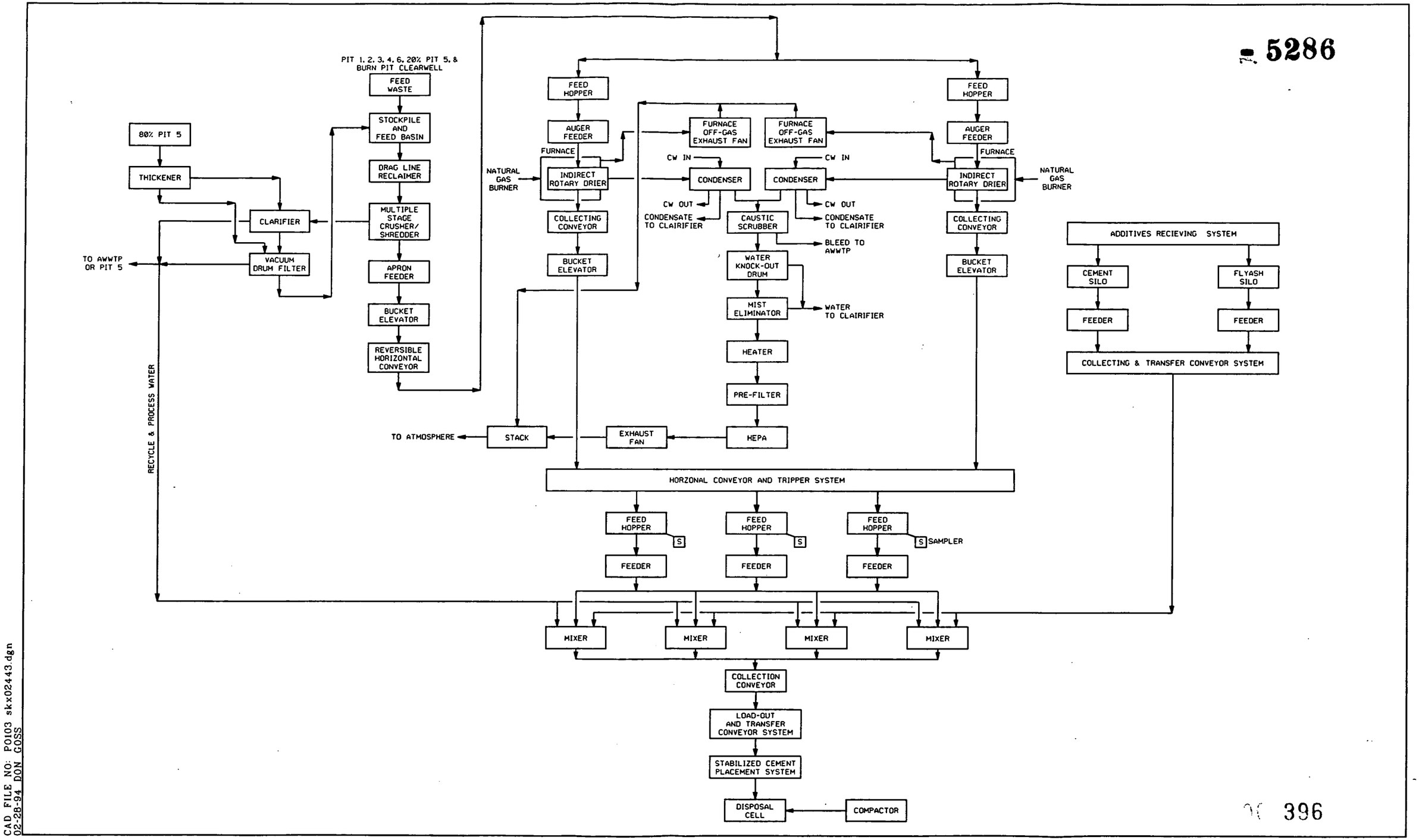

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FIGURE 4-5. OPERABLE UNIT 1 BLOCK-FLOW DIAGRAM FOR CEMENTATION PROCESS

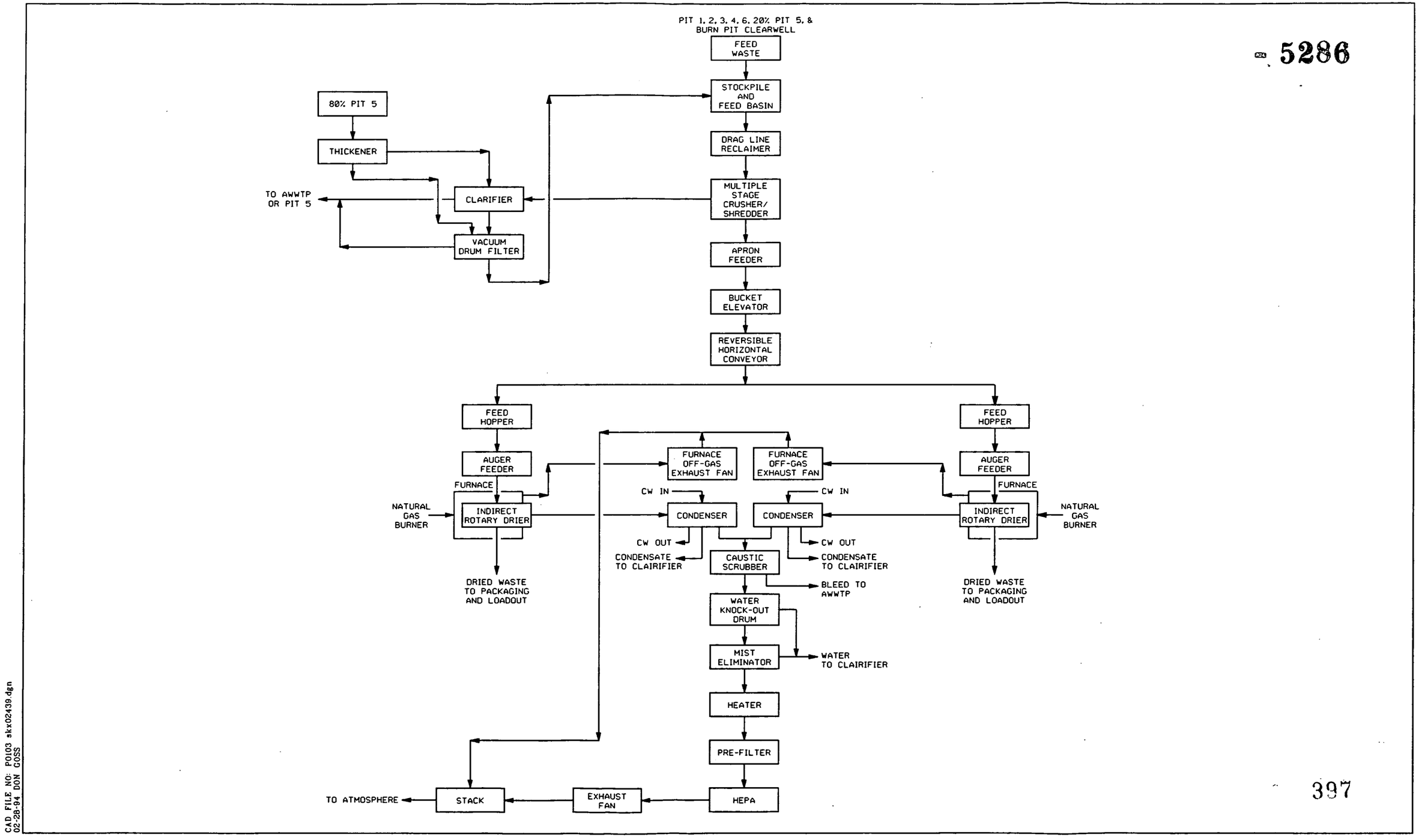

FIGURE 4-6. OPERABLE UNIT 1 BLOCK-FLOW DIAGRAM OF DRYING PROCESS

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5.0 COMPARATIVE ANALYSIS

5.1 INTRODUCTION

Section 5.0 presents a comparative analysis of the final remedial action alternatives for Operable Unit 1 with respect to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) evaluation criteria described in Section 4.0. This analysis is the second stage of the detailed evaluation process and provides information which forms the basis for selecting a preferred remedial alternative. The Proposed Plan (PP), which is issued concurrently with this feasibility study (FS), will identify the U.S. Department of Energy's (DOE) preference for an Operable Unit 1 remedial action alternative. With the PP, DOE solicits public comments. The PP allows consideration, as appropriate, of the state and community acceptance modifying criteria and supports the selection of the final remedial alternative in the Record of Decision (ROD). As stated in Section 1.0, this document is a FS/PP-Environmental Assessment (EA). The EA incorporates National Environmental Policy Act (NEPA) values. For NEPA purposes, Operable Unit 1 will undergo the EA process. At the completion of this process, a determination will be made as to whether an Environmental Impact Statement (EIS) is necessary or whether the proposed remedial action would have no significant impacts, resulting in the issuance of a Finding of No Significant Impact (FONSI).

For this analysis, the evaluation includes two of the three criteria categories: threshold criteria and primary balancing criteria. More information concerning the evaluation criteria is provided in Section 4.1.2, Overview of the Detailed Analysis. A summary of the detailed analysis of the alternatives with respect to the criteria of these two categories is presented in Table 5-1.

The threshold category contains two criteria that must be satisfied by the selected alternative:

- Overall protection of human health and the environment
- Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)

These criteria are of greatest importance in the comparative analysis because they reflect the key statutory mandates of CERCLA, as amended. If an alternative does not satisfy both of these criteria,

it cannot be carried forward to the primary balancing category and is not eligible to be selected as the final remedy.

The primary balancing category contains five criteria under which the relative advantages and disadvantages of the alternatives are compared to determine the most appropriate remedy:

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

The first and second balancing criteria address the statutory preference for treatment as a principal element of the remedy. Together with the third and fourth criteria, they form the basis for determining the general feasibility of each potential remedy and for determining whether costs are proportional to the overall effectiveness, considering both the cleanup period and the time following cleanup. By this means, it can be determined whether a potential remedy is cost-effective.

The modifying criteria category contains the two criteria that must be considered for the preferred alternative:

- State acceptance
- Community acceptance

The modifying criteria of state and community acceptance are typically not evaluated until a PP is issued for public comment. Since specific alternatives have not been presented to the state and community, these two criteria are not formally compared in Section 5.0.

Consistent with the format of the detailed analysis of alternatives in Section 4.0, a comparative analysis under the threshold and primary balancing criteria are presented in Sections 5.2 and 5.3, respectively. A summary of the comparative analysis of the alternatives with respect to the threshold and primary balancing criteria is presented in Table 5-1. A comparison of the environmental impacts associated with each alternative is provided in Table 5-2.

This comparative analysis provides the basis for the selection of the preferred alternative for Operable Unit 1 that is described in the PP.

5.2 THRESHOLD CRITERIA

5.2.1 Overall Protection of Human Health and the Environment

Alternative 1, No Action, would not be protective of human health or the environment, because no remedial activities would be conducted. The Baseline Risk Assessment for Operable Unit 1 has concluded that, in its unremediated state, the Operable Unit presents potentially unacceptable risks to human health and the environment. The other four alternatives, collectively referred to as "the action alternatives," would provide removal, treatment, and disposal of the waste pit material and contaminated soils to levels that are protective of human health and the environment.

Alternatives 4A and 4B would provide removal, treatment, on-property disposal, and capping of residual contamination, while Alternatives 5A and 5B would provide removal, treatment, off-site disposal, and capping of residual contamination. The long-term protectiveness of all action alternatives is approximately the same, with Alternatives 5A and 5B being slightly more protective since off-site disposal removes an additional source of contamination from the site. Uncertainties associated with long-term protectiveness are discussed in Section 5.3.1. Appendix D quantifies residual risk associated with each alternative and documents that such residual risk is within the established acceptable target range in the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) for each action alternative.

Protectiveness is initially provided for by removal of waste pit contents and soils to health-based action levels. For all action alternatives, protectiveness is maintained by a combination of treatment and managed waste disposal.

The treatment associated with Alternatives 4A (vitrification) and 4B (cement solidification) would reduce the mobility of contaminants. In addition, the high temperatures associated with vitrification would destroy any residual organics present in the waste. Vitrification is more effective

than cement solidification in reducing the mobility of toxic contaminants for this type of waste, especially because vitrification has the potential to destroy residual organics instead of merely immobilizing them. After treatment, wastes would be disposed of in an on-site waste disposal facility. The facility would utilize state-of-the-art design components to preclude human and ecological contact with the wastes for 1,000 years. The facility would also be designed to eliminate unacceptable impacts to the Great Miami Aquifer for the same period. For Alternatives 5A and 5B, the wastes are dried and then disposed of in the arid west where there is no nearby (within 30 miles) resident human populations, no usable surface water or groundwater resources, and limited potential ecological receptors.

5.2.2 Compliance with ARARs

Except for Alternative 1, No Action, which would not meet certain ARARs/To Be Considered (TBCs), all alternatives would either attain pertinent ARARs or it could potentially be justified that an exemption or waiver from a specific ARAR may be appropriate. A comprehensive list of potential ARARs is presented in Appendix F for both on-site (Alternatives 4A and 4B) and off-site (Alternatives 5A and 5B) disposal alternatives. Key requirements are discussed in Section 4.0 within the evaluation of each alternative against this criterion. The following text summarizes those evaluations.

Chemical-Specific ARARs

Alternative 1 would not meet chemical-specific ARARs. The continued release of radionuclides, and organic and inorganic contaminants would violate State of Ohio water quality standards and exceed drinking water maximum contaminant levels (MCLs) and maximum contaminant level goals (MCLGs) if the released material were to migrate into the groundwater. In the event existing access controls were discontinued and a family farm was to be established on the FEMP site, exposure limits embodied within DOE Order 5400.5 for members of the general public could be exceeded.

All of the action alternatives (4A, 4B, 5A, and 5B) would meet the chemical-specific ARARs associated with potential releases to groundwater, air, and surface water. Alternatives 4A and 4B would comply via removal and treatment with subsequent disposal in an on-property cell designed to

preclude human and ecological contact with the wastes and to eliminate unacceptable impacts to groundwater. Alternatives 5A and 5B would comply via removal and off-site disposal of the contaminated material. The action alternatives would attain the concentration-based limits for specific chemicals under 40 Code of Federal Regulations (CFR) 141.11, .61, and 40 CFR 264.94, as well as dose-based requirements for the protection of potential public receptors using affected groundwater defined in DOE Order 5400.5. DOE Order 5400.5 sets 100 millirem as the limit on the allowable annual effective dose equivalent, from all pathways including groundwater, to any member of the public. As specified in 40 CFR 141.16, the annual dose equivalent to the whole body or critical organ is limited to 4 millirem, assuming the consumption of 2 liters per day of potable groundwater.

The most critical chemical-specific ARAR relative to airborne releases relates to radionuclides for which requirements are established in 40 CFR 61 Subpart H and DOE Order 5400.5, Chapter III. The maximum permissible surface release rate of radon-222, as specified in National Emission Standards for Hazardous Air Pollutants (NESHAP), 40 CFR 61 Subpart Q, is 20 picoCuries per square meter, surface averaged. This requirement is supplemented by 40 CFR 192.02(b) Subpart A, which requires that the concentration of radon-222 in air at or above any location outside the disposal site not increase the annual average by more than 0.5 picoCurie per liter. All four action alternatives would meet the chemical-specific ARARs relative to airborne releases of radionuclides and radon emanation. In Alternatives 5A and 5B, the wastes would be treated to meet the waste acceptance criteria of the respective off-site disposal facility prior to disposal. In addition, the management practices of the disposal facility, coupled with the measures taken during remediation activities, would adequately address these ARARs.

Location-Specific ARARs

The No-Action Alternative would not trigger location-specific ARARs. In particular, the ARAR prohibition locating a solid waste disposal facility over a sole-source aquifer does not apply to an existing facility.

All action alternatives would comply with the pertinent location-specific ARARs associated with potential releases to groundwater, air, and surface water. Included would be those associated with

discharge of dredged and excavated material into waters of the U.S. (33 CFR 323), the protection of wetlands (40 CFR 258.12, 40 CFR 6.302), floodplains (40 CFR 257.3-1, 40 CFR 264.18, 40 CFR 6.302, 10 CFR 1022), and endangered species (50 CFR 17 and 402) during the on-property management of contaminated materials.

Disposal facility citing criteria would not be applicable to off-site disposal Alternatives 5A and 5B. The State of Ohio maintains a number of solid waste disposal design considerations within Ohio Administrative Code (OAC) 3745-27-07. OAC 3745-27-07 (B)(5) prohibits new solid waste disposal facilities from being constructed over sole source aquifers. Exemptions to this requirement may be granted on the basis of technical considerations including: presence of a significant thickness of low permeability material between the disposal cell liner and the aquifer; no significant interconnection between the aquifer and any significant zones of saturation that exist above the aquifer; and no adverse impact to human health or safety, or to the environment. In consideration of the hydrogeologic factors of the proposed disposal cell location, coupled with the design (state-of-the-art engineering practices will be incorporated to design for performance criteria for the 1,000-year timeframe, as required by 40 CFR 192) and impact prevention and mitigation capabilities, an exemption or waiver from OAC 3745-27-07 may be justified for Alternatives 4A and 4B. Such an exemption or waiver would be required to select either Alternative 4A or 4B.

Action-Specific ARARs

Alternative 1 would not trigger any action-specific ARARs while all action alternatives would comply with pertinent action-specific ARARs. For Alternatives 4A and 4B, the above-grade disposal cell would incorporate design requirements for the disposal of uranium mill tailings (40 CFR 192), and hazardous waste under the Resource Conservation and Recovery Act (RCRA), (i.e., the treatment, storage and disposal facility (TSDF) requirements under 40 CFR 264). The design of the on-property disposal cell would also include appropriate engineered features that satisfy the requirements of the Clean Water Act (40 CFR 125.100 and 104), the Ohio Water Quality Standards, and RCRA Subtitle C (40 CFR 262.11, 261.7, 262.20, and the 264 Subparts identified in Appendix F).

Alternatives 5A and 5B would comply with all pertinent action-specific ARARs identified in Appendix F for off-site disposal. Hazardous waste transport requirements would be complied with by following the regulations under 40 CFR 262 and the appropriate U.S. Department of Transportation (DOT) shipping standards under 49 CFR 172 and 173.

As previously discussed under chemical-specific ARAR/TBCs, the specific measures and engineered controls incorporated into all action alternatives would meet all action-specific ARAR/TBCs regarding air quality during remedial actions and the post-closure period.

5.3 PRIMARY BALANCING CRITERIA

Those alternatives that satisfy the threshold criteria analysis are carried forward for further comparative analysis under the primary balancing criteria. The No-Action Alternative, Alternative 1, will be carried forward as the baseline alternative for comparison purposes in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Alternatives that will be carried forward include:

- Alternative 1 - No Action
- Alternative 4 - Removal, Treatment, and On-Property Disposal
  - Alternative 4A -Removal, Treatment (Vitrification), On-Property Disposal
  - Alternative 4B -Removal, Treatment (Cement Solidification), On-Property Disposal
- Alternative 5 - Removal, Treatment, and Disposal Off Site
  - Alternative 5A -Removal, Treatment (Thermal Drying), and Off-Site Disposal at NTS
  - Alternative 5B -Removal, Treatment (Thermal Drying), and Off-Site Disposal at a Permitted Commercial Disposal Facility

5.3.1 Long-Term Effectiveness and Permanence

Alternative 1, No Action, would not be effective in the long term, since the Operable Unit 1 Baseline Risk Assessment indicates that the current site conditions are potentially not protective of human health in the long term and no remedial activities would be conducted on Operable Unit 1 under this alternative.

Alternatives 4A and 4B provide excavation, treatment, on-property disposal in an engineered cell designed for a 1,000-year life with minimal maintenance. The alternatives also include capping of residual contamination. These alternatives would be approximately equally effective at reducing the residual risks to potential receptors, because contaminated pit materials and soils are removed to the same health-based levels. Treatment and disposal in an engineered facility with infiltration barriers and leachate control components provide approximately equal benefit in precluding human and ecological contact with wastes. It also provides approximately equal benefit in precluding an unacceptable degree of contaminated leachate migration into the Great Miami Aquifer.

Alternatives 5A and 5B would provide excavation, treatment, off-property disposal, and capping of residual contamination. These two alternatives would be equally effective at reducing residual risks to potential receptors, and more effective than Alternatives 4A and 4B, since the pit waste material, the principal contaminant source, would be removed from the site. Of particular note is the fact that, in the event of releases from the disposed wastes in Alternatives 5A and 5B, the likelihood of impacting receptors is very low due to harsh socioeconomic, demographic, and climatic factors at the potential disposal facilities. Releases from disposed waste in failure scenarios for Alternatives 4A and 4B represent a more significant threat primarily due to the presence of the sole-source Great Miami Aquifer, a significant residential human population in the vicinity of the site, a more significant base of potential ecological receptors.

No long-term environmental impacts at the Fernald Environmental Management Project (FEMP) are associated with the removal and treatment processes identified in this Feasibility Study. Long-term environmental impacts off site would include some permanent disturbance of soils (i.e., acquisition of borrow material) associated with disposal activities. No significant long-term impacts would be expected for water quality and hydrology, air quality, biotic resources, socioeconomic and land use, or cultural resources.

Alternatives 4A and 4B include the removal and treatment of source materials followed by on-property disposal in an engineered disposal cell. The cell, which is described in Appendix B with a cost estimate in Appendix E, will incorporate state-of-the-art engineering practices to design for

performance criteria spanning the 1,000-year time frame, as required by 40-CFR 192. The long-term effectiveness afforded by the removal and treatment processes would be approximately the same for Alternatives 4A and 4B. The design features of the disposal cell would provide effective long-term containment of the treated material. Long-term environmental impacts associated with construction of the on-property disposal cell for Alternatives 4A and 4B include permanent disruption of up to 47 hectares (116 acres) of land. Relative to disposal, no significant long-term impacts are expected for water quality and hydrology, air quality, socioeconomic, or cultural resources. The construction of an on-property disposal cell would disrupt 0.5 hectare (1.3 acres) of drainage ditch/swale wetlands. The 100- and 500-year floodplains would not be permanently altered as a result of regrading and revegetation activities.

The Nevada Test Site (NTS) disposal facility (Alternative 5A) is located in a sparsely populated, arid environment with insignificant potential for leachate generation and contaminant migration. Because NTS is maintained by DOE and utilized for the disposal of selected low-level wastes from other DOE sites, the uncertainties associated with institutional controls are low. As the result of a low average annual precipitation and depths to groundwater ranging from 157 - 600 meters (515 - 2,000 feet) below ground surface, impacts to human health and the environment would be reduced in the event that engineering and institutional controls fail.

Similar to NTS, the representative permitted commercial disposal facility near Clive, Utah, is also located in a sparsely populated, arid environment with minimal potential for leachate generation and contaminant migration. A combination of the high evapotranspiration rate, dry-dense soil bodies, highly mineralized groundwater, and lack of surface waters in the area make the facility physically conducive for the disposal of treated waste. Furthermore, because the facility is located in an area with an arid climate far from any population centers, the lack of human habitation offers many advantages for long-term disposal. In the event that engineering and institutional controls fail, impacts to human health and the environment would be expected to be minimal.

5.3.2 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 1, the No-Action Alternative, does not include treatment and would not result in a reduction of toxicity, mobility, or volume.

Treatment processes for the on-property disposal Alternatives 4A and 4B consist of vitrification and cement solidification, respectively. For Alternatives 5A and 5B, the wastes would be physically treated by drying to meet the waste acceptance criteria of the off-site disposal facilities.

The vitrification process used in Alternative 4A would physically bind the constituents in a glass-like matrix which would significantly reduce contaminant mobility. Treatability tests of the vitrification process have demonstrated that the final volume achieved through vitrification would be approximately equal to or sightly less than the untreated material volume. The high operating temperatures of the vitrification process have also been shown to effectively destroy any residual organic compounds present in the waste. The effects of vitrification as a treatment are essentially irreversible.

Toxicity Characteristic Leachate Procedure (TCLP) tests were conducted on both the untreated and vitrified form of the residues. The results showed that the leachate concentrations of hazardous metals were below regulatory limits for all glass samples made during the bench-scale tests. Product Consistency Tests (PCT) were also performed on the vitrified materials. PCT leach testing demonstrated a high degree of durability for the vitrified materials. Data on the long-term stability of vitrified material are not available, and the life expectancy of the vitrified product is difficult to estimate from short-term leach rates; however, on the basis of the longevity of volcanic glass (a natural analog to the vitrified product), the vitrified product would be expected to withstand environmental exposure for thousands of years.

Alternative 4B would use the cement solidification process to treat the waste. Cement solidification would reduce the mobility of constituents by binding them into a cement mixture. Radon emanation would be somewhat reduced, but not as much as through the vitrification process. The addition of reagents to the untreated residues causes a significant increase (up to twofold) in volume.

Treatability tests on cement solidification have been performed to determine the best formulations that result in a product having the most favorable leach resistance and durability characteristics. TCLP test results showed that the leachate concentrations of metals were below regulatory limits for all cement solidified forms produced during the bench-scale tests. However, the improvement in leachability over that of the untreated material was not significant. Furthermore, the cement formulations were not as effective in the leaching of uranium and technetium from Waste Pit 4, which had higher concentrations than other pits. Lacking the high temperatures of the vitrification process, cement solidification would not effectively destroy any residual organic compounds present in the waste after drying.

Alternatives 5A and 5B would treat the waste by drying, which does not affect the toxicity or mobility of contaminants. Drying and size reduction, would however, reduce the volume of material by reducing the moisture content and void ratio. Upon this treatment, the material would meet the waste acceptance criteria of the off-site disposal facilities.

5.3.3 Short-Term Effectiveness

Alternative 1, No Action, would be very effective relative to short-term risks, since there would be no remedial activities. Therefore, there would be no additional risk to workers or the community around the FEMP site. The four action alternatives involve remedial activities and therefore all pose some risk to workers and the community. However, all four of the action alternatives are protective of human health and the environment in the short term. Appendix D quantifies short-term risks and documents the basis of this statement.

Alternatives 4A and 4B include excavation, treatment, on-site disposal in an on-property engineered disposal cell, and capping of residual contamination. Alternatives 5A and 5B include excavation, treatment, off-site disposal, and capping of residual contamination. Remediation workers, non-remediation workers, and the community would be subject to chemical and radiological exposures. The risks to communities do not exceed the generally accepted 10^{-4} to 10^{-6} range. In addition, remediation workers would be subject to occupational hazards while performing remedial activities.

The short-term risks (excluding transportation) to off-site individuals and non-remediation workers would be approximately the same for all four action alternatives. During transportation of waste materials, Alternative 5A would result in slightly higher risks to communities along the transportation route than Alternative 5B. No off-site transportation risks are associated with Alternatives 4A and 4B.

The short-term risks (excluding transportation) to remediation workers would be approximately the same for Alternatives 4A and 4B, with Alternative 4B having a slightly higher potential for accidents than 4A because the volume of disposed material is larger and requires a longer period of handing time. The short-term risks for Alternatives 5A and 5B (excluding transportation and package handling) would be equal, and somewhat lower than Alternatives 4A and 4B, due to the higher potential for accidents associated with on-property disposal. However, there would be the potential for exposures and accidents associated with transportation and package handling. Taking these risks into account, Alternative 5A would have higher dose equivalents and potential accidents for remediation workers than any of the other action alternatives. Alternative 5B, with less waste handling, would have the potential for substantially fewer accidents than the other alternatives, even after addition of risks associated with transportation.

The time required to achieve protectiveness for Alternatives 4B, 5A and 5B is essentially the same with an active waste processing period of five years. Alternative 4A takes longer with an estimated active waste processing period of 10 years.

Short-term impacts associated with the action alternatives would include temporary disruption of approximately 2.8 hectares (7 acres) of land at the FEMP site as a result of borrow area impacts, and approximately 6.1 hectares (15 acres) for construction of support facilities. Increased fugitive dust during excavation activities and the potential for minor impacts to biota and wetlands [up to 2.42 hectares (5.98 acres)] does exist. However, the appropriate engineering controls would minimize these potential short-term impacts. All transportation to off-site facilities would be in compliance with DOE regulations and DOE guidelines.

The nature and extent of impacts to biota from implementing Alternatives 4A and 4B would be similar. Both alternatives involve site preparation and construction for a treatment facility and disposal cell. Potential environmental impacts associated with implementing Alternatives 4A and 4B include the permanent loss of some on-site habitats. Short-term impacts include the temporary loss of habitats at the FEMP and possible impacts of accidental spills of construction and operational materials. Mitigative measures would be employed to minimize these short-term risks.

Environmental impacts associated with implementing Alternatives 5A and 5B include those identified with construction of support facilities, in addition to potential impacts from transportation to and disposal activities at NTS or at a permitted commercial disposal facility.

5.3.4 Implementability

Technical Feasibility

Under Alternative 1 there would be no removal, treatment, or disposal actions required; thus, technical feasibility is not an issue.

For the action alternatives (4A, 4B, 5A, 5B), removal activities would be very similar. All could be implemented using standard equipment, procedures, and readily available resources. Dry and wet excavation methods including hydraulic removal, which is a standard mining technology, would be easily implementable with careful excavation planning. The variations in treatment options employed by these alternatives have differing degrees of technical feasibility.

The vitrification process would require lesser amounts of chemical reagents than the cement solidification process but significantly larger amounts of energy (electricity). Vitrification process equipment would be more complex to construct and operate than that of the cement solidification process, yet the extreme heterogeneity of the waste would make successful cement/waste mix formulation and quality control extremely difficult. A full-scale facility for vitrification of hazardous and radioactive waste similar to those of Operable Unit 1 has not yet been constructed elsewhere. The start-up of a first-of-the-kind facility is expected to be difficult. On the other hand, cement solidification has been previously applied to low-level wastes with varying degrees of success. The

construction of both, the vitrification facility and cement solidification facility, is expected to be straightforward. The vitrification technology is not as widely available as the cement solidification technology.

The cement solidification facility would be difficult to operate due to the heterogenous nature of the waste in the waste pits. The mix would need constant testing to ensure that the solidified waste would meet performance standards. EPA considers cement solidification a demonstrated treatment technology and has approved its use in the final remedy for many sites named on the National Priorities List (NPL). The cement solidification process would require large quantities of cement and other additives, increasing the volume of treated waste. The improvement in leachability over that of the untreated material was not very significant. Furthermore, the cement formulations were not as effective in the leaching of uranium and technetium from Waste Pit 4, which had higher concentrations than other pits. Lacking the high temperatures of the vitrification process, cement solidification would not effectively destroy any residual organic compounds present in the matrix.

Alternatives 4A and 4B would require on-property disposal cells while Alternatives 5A and 5B would not. The disposal cell size for Alternative 4B, although still readily implementable, would be approximately double the size of the Alternative 4A cell due to the twofold increase in volume produced by cement solidification in Alternative 4B. Off-site transportation would be technically straightforward and the necessary resources are available. However, off-site transport and disposal would be subject to various state and federal requirements; therefore, administrative feasibility may require increased coordination efforts with various jurisdictional agencies for off-site disposal.

The technical feasibility of Alternatives 5A and 5B are dependent upon meeting the waste acceptance criteria of the disposal site and off-site transportation requirements. Off-site transportation is technically feasible for both alternatives as further discussed under administrative implementability. Both NTS and the representative permitted commercial disposal facility have the capacity and would accept wastes from Operable Unit 1. Based on the above, Alternatives 5A and 5B are judged to be more technically feasible than Alternatives 4A and 4B.

Administrative Feasibility

CERCLA Section 121(e) provides that no federal, state, or local permit shall be required "for the portion of any removal or remedial action conducted entirely on-site." It is required that a remedial action satisfy the substantive requirements of any permits that would otherwise be required.

Alternatives 4A and 4B would be conducted entirely on property and would not require issuance of any permits. There are no known administrative barriers toward implementation of Alternatives 4A and 4B, except for the ARAR issue of the state prohibition against construction of an on-property disposal facility over a sole-source aquifer. Thus, the administrative feasibility of these alternatives is assessed as potentially difficult to implement because of the state prohibition against on-property disposal over a sole-source aquifer and the need to obtain an exemption or waiver.

Off-site disposal Alternatives 5A and 5B consist of on-site and off-site activities. The excavation, material handling and processing of the wastes will occur entirely on FEMP property. For these portions of the remedial alternative, the administrative feasibility analysis presented above would apply, i.e., no permit is required for on-site remediation. However, the off-site transportation and disposal of the wastes do not qualify for the CERCLA exemption relative to permitting.

Various DOT regulations apply to the transportation of wastes such as those present within Operable Unit 1. In addition, each of the various states as well as certain municipalities through which the waste shipments would pass have established regulations and in some cases permitting requirements that are applicable. Shipment of RCRA hazardous wastes throughout all regions of the United States is performed at a large scale on a daily basis. On a relative scale, administrative issues associated with the transportation of RCRA hazardous wastes from the site to the arid West are easily addressed as evidenced by the common nature of such waste shipments. For this reason, shipment of significant volumes of low-level (low specific activity) radioactive wastes is judged to be administratively feasible.

Review of applicable DOT regulations indicates that there are currently no provisions that would prohibit waste shipments from the site to the arid West using either trucks or rail. This statement is

made in specific reference to the Operable Unit 1 pit wastes process generation data and the analytical data from the remedial investigation. In addition, there are no known transit state or local regulations that would categorically prohibit waste shipment.

For Alternative 5B, which proposes off-site disposal at a permitted commercial disposal facility, it is noted that DOE Order 5820.2A currently prohibits use of commercial disposal facilities for disposal of low-level radioactive wastes of the type present in Operable Unit 1. The order does have an exemption provision and precedence exists for the granting of such exemptions. On October 12, 1993, the Assistant Secretary for Environmental Restoration and Waste Management issued a blanket exemption from DOE Order 5320.2A for small quantities of mixed waste resulting from CERCLA remediation activities, such as generated under this alternative (DOE 1993). This exemption is conditioned upon compliance with the existing ARARs, reviews, and current guidance. Further, this exemption states that "disposal of DOE mixed waste should not be constrained by the existing DOE Order 5820.2A restriction limiting disposal at DOE sites." This DOE policy is under review and the affected DOE orders will be revised accordingly. The site will obtain an exemption to DOE Order 5820.2A for the purpose of disposing of low-level waste at a permitted commercial disposal facility.

In summary, the administrative feasibility of the on-property disposal alternatives (4A and 4B) are potentially difficult because of the state ARAR prohibition against disposal over a sole-source aquifer. The administrative feasibility of the off-site disposal alternatives (5A and 5B) are moderately difficult because of the logistics of the large volume of waste involved. There are no administrative feasibility issues involved with the No-Action Alternative.

5.3.5 Cost

Cost estimates are used in the feasibility study process under the CERCLA to eliminate those remediation alternatives which are significantly more expensive than competing alternatives but do not offer commensurate performance or overall protection of human health and the environment. The cost estimates developed are order-of-magnitude estimates with an intended accuracy range of -30 to

+50 percent. Estimates are considered to be order-of-magnitude because of the uncertainties in the information used to develop the estimates.

Total capital and present worth costs for each alternative evaluated in the detailed analysis (Section 4.0) are presented in Table 5-3.

TABLE 5-1

OPERABLE UNIT 1
COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

Alternative	Overall Protection of Human Health and Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility or Volume Through Treatment	Short-Term Effectiveness	Implementability	Present Worth Cost
1 - No Action	Not protective	Does not meet all ARARs	Not effective or permanent	No treatment	High	Easy	Very Low
4A - Removal, Treatment, (Vit), and On-Property Disposal	Protective[a]	Complies with all ARARs[b]	Effective	Reduces toxicity, mobility, and volume	Moderate	Innovative Technology; Difficult	Moderately High
4B - Removal, Treatment (Cem) and On-Property Disposal	Protective[a]	Complies with all ARARs[b]	Effective	Reduces mobility, but increases volume	Moderate	More Reliable Technology; Difficult	Moderate
5A - Removal, Treatment (Drying), and Off-Site Disposal at NTS	Protective[a]	Complies with all ARARs	Highly Effective	Does not affect toxicity or mobility, but slightly decreases volume	Moderate	Reliable Technology; Moderately Difficult	High
5B - Removal, Treatment (Drying), and Off-Site Disposal at a Permitted Commercial Disposal Facility	Protective[a]	Complies with all ARARs	Highly Effective	Does not affect toxicity or mobility, but slightly decreases volume	Moderate	Reliable Technology; Moderately Difficult	Moderate

[a] Assessment of protectiveness assumes the use of continued federal government ownership and evaluates risk to the off-property farmer.
[b] Assumes substantive technical requirements for Ohio disposal facility siting are met sufficiently to obtain a waiver or exemption from the ARAR.

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TABLE 5-2

SUMMARY OF ENVIRONMENTAL IMPACTS FOR REMEDIAL ALTERNATIVES

Alternative	Soil and Geology[a]	Water Quality and Hydrology	Air Quality	Biotic Resources	Wetlands and Floodplains	Socioeconomics and Land Use	Cultural Resources	Transport Impacts
1 NO ACTION	No impacts	Potential release to surface and groundwater	Potential release to ambient air	Potential exposure to ecological receptors	Potential release to 1.89 ha (4.67 acres) of wetlands	Restriction of site's future use	No impacts	No impacts
4A VITRIFICATION ON-SITE DISPOSAL	38 ha (94 acres) Temporarily & permanently disturbed 23.3 ha (57.7 acres) committed to disposal	Minor impacts assuming monitoring and controls	Fugitive dust emissions; minor impacts assuming controls	36 ha (88 acres) Terrestrial Habitat Temporarily and Permanently Disturbed	2.42 ha (5.98 acres) Wetland Lost	Up to 12.5% Increase over 10 years in CMSA Revenue; restricted site use	No impact due to identification and management	Fugitive dust due to on-property movement
4B CEMENT SOLIDIFICATION ON-SITE DISPOSAL	62 ha (153 acres) temporarily & permanently disturbed 47.32 ha (116.9 acres) committed to disposal	Minor impacts assuming monitoring and controls	Fugitive dust emissions; minor impacts assuming controls	36 ha (88 acres) Terrestrial Habitat Temporarily & Permanently Disturbed	2.42 ha (5.98 acres) Wetland Lost	Up to 13.5% increase over 6 years in CMSA revenue	No impact due to identification and management	Fugitive dust to on-property movement

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TABLE 5-2
(Continued)

Alternative	Soil and Geology[a]	Water Quality and Hydrology	Air Quality	Biotic Resources	Wetlands and Floodplains	Socioeconomics and Land Use	Cultural Resources	Transport Impacts
5A OFF-SITE DISPOSAL AT NTS	Approx. 1.2 ha (3 acres) committed to disposal at NTS	Minor impacts to geology at NTS	Fugitive dust emissions; minor impacts assuming controls	5.37 ha (13.2 acres) terrestrial habitat lost; minor impacts at NTS	1.89 ha (4.67 acres) of wetland lost; no impact at NTS	Up to 25% increase over 5 years in CMSA revenue	No impact due to identification and management	ILCR of 5.5×10^{-6} along the route to NTS
5B OFF-SITE DISPOSAL AT REPRESENTATIVE PERMITTED COMMERCIAL DISPOSAL FACILITY	Approx. 0.8 ha (2 acres) committed to disposal at commercial disposal facility	Minor impacts to geology at com. perm. disp. facility	Fugitive dust emissions; minor impacts assuming controls	5.37 ha (13.2 acres) terrestrial habitat lost; minor impacts at comm. disp. facility	1.89 ha (4.67 acres) of wetland lost No impact at com. disp. facility	Up to 13% increase over 5 years in CMSA revenue	No impact due to identification and management	ILCR of 4.6×10^{-6} along route to FERMCO comm. disp. facility

[a] Commitment of acres is at FEMP unless indicated otherwise.

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TABLE 5-3

OPERABLE UNIT 1
ALTERNATIVE COST COMPARISON

ALTERNATIVE	COST	
	TOTAL CAPITAL[a]	TOTAL PRESENT WORTH
1 - NO ACTION	$0	$0
4A - REMOVAL, TREATMENT (VIT) ON-PROPERTY DISPOSAL	$639,094,175	$403,097,600
4B - REMOVAL, TREATMENT (CEM) ON-PROPERTY DISPOSAL	$504,195,700	$349,513,600
5A - REMOVAL, TREATMENT, DISPOSAL AT NTS	$856,102,282	$626,962,400
5B - REMOVAL, TREATMENT, DISPOSAL AT A REPRESENTATIVE-PERMITTED COMMERCIAL DISPOSAL FACILITY	$457,773,376	$330,665,000

[a] Includes operations cost during active remediation.

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