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REVISED FEASIBILITY STUDY REPORT

FOR SILOS 1 AND 2

40730-RP-0001

U.S. Department of Energy
Fernald Environmental Management Project

VOLUME 1 OF 4
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FERNALD
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Acronym List

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ACRONYMS AND ABBREVIATIONS

A - C

ACA	Amended Consent Agreement
AEA	Atomic Energy Act
AEC	Atomic Energy Commission
AIRFA	American Indian Religious Freedom Act
ALARA	as low as reasonably achievable
ARAR	applicable or relevant and appropriate requirement
ATSDR	Agency for Toxic Substances and Disease Registry
AWR	Accelerated Waste Retrieval
AWWT	Advanced Wastewater Treatment
BAFO	best and final offer
BAT	best available technology
CAA	Clean Air Act, as amended
CAT	Critical Analysis Team
CBD	Commerce Business Daily
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act, as amended
CFR	Code of Federal Regulations
CHEM1	Removal, On-site Chemical Stabilization — Cement-based, Off-site Disposal at the NTS
CHEM2	Removal, On-site Chemical Stabilization — Other, Off-site Disposal at the NTS
CMSA	consolidated metropolitan statistical area
COC	constituent of concern
CRARE	Comprehensive Risk Assessment and Risk Evaluation
CWA	Clean Water Act, as amended

ACRONYMS AND ABBREVIATIONS (cont.)

D - L

DCG	Derived Concentration Guide
D&D	decontamination and demolition
DOE	U.S. Department of Energy
DOE-FEMP	U.S. Department of Energy-Fernald Environmental Management Project
DOT	U.S. Department of Transportation
DUR	duration
DWPF	Defense Waste Processing Facility
EIS	Environmental Impact Statement
EOC	Emergency Operations Center
EOG	emergency off-gas
EPA	U.S. Environmental Protection Agency
ESD	Explanation of Significant Differences
FAT&LC	Fernald Atomic Trades and Labor Council
FDF	Fluor Daniel Fernald, Inc.
FEMP	Fernald Environmental Management Project
FERMCO	Fernald Environmental Restoration Management Corporation
FMPC	Feed Materials Production Center
FR	Federal Regulation
FS	Feasibility Study
FS/PP	Feasibility Study/Proposed Plan
FY	fiscal year
GCBCTC	Greater Cincinnati Building and Construction Trades Council
GRA	General Response Action
HEPA	high-efficiency particulate air
HI	hazard index
HRS	Hazard Ranking System
ID	identification
IP-2	industrial package-type 2
ILCR	incremental lifetime cancer risk
IRT	Independent Review Team
ISO	International Shipping Organization
LLRW	low-level radioactive waste
LSA	low specific activity

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ACRONYMS AND ABBREVIATIONS (cont.)

M - O

MCL	maximum contaminant level
MTC	monolith transfer container
MTD	metric ton per day
NAGPRA	Native American Graves Protection and Repatriation Act
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NLO	National Lead of Ohio
NOA	Notice of Availability
NOI	Notice of Intent
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
NTS	Nevada Test Site
O&M	operations and maintenance
OAC	Ohio Administrative Code
OEPA	Ohio Environmental Protection Agency
ORIG	original
ORR	Operational Readiness Review
OSDF	On-site Disposal Facility
OU	operable unit

ACRONYMS AND ABBREVIATIONS (cont.)

P - T

PA	performance assessment
PEIC	Public Environmental Information Center
PEP	Project Execution Plan
PFD	process flow diagram
PHAR	Preliminary Hazard Analysis Report
PKG	package
PNL	Batelle-Pacific Northwest Laboratories
POP	Proof of Principle
PP	Proposed Plan
PPE	personal protective equipment
PRG	preliminary remediation goals
PRL	preliminary remediation levels
PVS	Process Vent System
RA	remedial action
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act, as amended
RCS	Radon Control System
RD	remedial design
RD/RA	remedial design/remedial action
RDWP	Remedial Design Work Plan
REM	remaining
RFP	request for proposal
RI	Remedial Investigation
RME	reasonable maximum exposure
ROD	Record of Decision
RPM	revolutions per minute
RTS	Radon Treatment System
scfm	standard cubic feet per minute
SOT	System Operability Testing
SOW	Statement of Work
SRS	Savannah River Site
TBC	to be considered
TBP	tributyl phosphate
TC	toxicity characteristic
TCLP	Toxicity Characteristic Leaching Procedure
TPC	total project cost
TRD	Technical Requirements Document
TTA	Transfer Tank Area
TVS	Oak Ridge Transportable Vitrification System

ACRONYMS AND ABBREVIATIONS (cont.)

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U - Z

UCL	upper confidence level
UMTRCA	Uranium Mill Tailings Radiation Control Act
UTS	Universal Treatment Standards
VIT1	Removal, On-site Vitrification — Joule-heated, Off-site Disposal at the NTS
VIT2	Removal, On-site Vitrification — Other, Off-site Disposal at the NTS
VITPP	Vitrification Pilot Plant
VOC	volatile organic compound
VSL	The Catholic University of America Vitreous State Laboratory
WAC	waste acceptance criteria
WESP	wet electrostatic precipitator
yr(s)	year(s)

Chemical Elements

actinium (Ac-227)
barium sulfate ($BaSO_4$)
lead (Pb-210)
lime $Ca(OH)_2$
nitric oxide (NO)
nitrogen oxides (NO_x)
polonium (Po-210)
radium (Ra-226)
radium sulfate ($RaSO_4$)
radon (Rn-222)
sodium carbonate (Na_2CO_3)
sodium formate ($NaHCO_2$)
sulfuric acid (H_2SO_4)
sulfur oxides (SO_x)
thorium-230 (Th-230)
uranium oxide (U_3O_8)
uranium-235 (U-235)
uranium-238 (U-238)

Weights and Measures

		Approximate U.S. Equivalent
m	meter	39.37 inches (3.2802 feet)
g	gram	.035 ounce
cm^3	cubic centimeter	.061 cubic inch
ha	hectare	2.47 acres
L	liter	61.02 cubic inches (1.057 liquid quarts)
kg	kilogram (1,000 grams)	2.2046 pounds
mg	milligram (.001 grams)	0.015 grain

		Approximate Metric Equivalent
gal	gallon	3.785 liters
gal/min	gallon per minute	3.785 liters per minute
lb	pound	0.435 kilogram
lb/hr	pound per hour	0.435 kilogram/hour
ft	foot	0.3048 meters

g/cc	grams per cubic centimeter
mrem/hr	milli-Roentgen equivalent man (10^{-3} rem) per hour
Ci	curie (unit of radioactivity equal to 3.7×10^{10} disintegrations per second)
pCi/g	picoCuries per gram
pCi/m^2	picoCuries per square meter
$pCi/m^2 \cdot s$	picoCuries per square meter second
ppm	parts per million

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EXECUTIVE SUMMARY

The goal of the Fernald Environmental Management Project (FEMP) is the safe, effective, and economical environmental restoration of a U.S. Department of Energy (DOE) former uranium processing facility located near the village of Fernald, Ohio. As a result of the 38-year production history of the facility, contamination of surface soil, subsurface soil, sediment, and groundwater exists both on and adjacent to the 1050-acre federal installation. This environmental contamination is attributable to releases of radioactive and chemical substances during the facility's production mission, which yielded over 500 million pounds of high-purity uranium products to support U.S. defense initiatives. Formerly known as the "Feed Materials Production Center (FMPC)" during its years of production, the facility was renamed the FEMP shortly after production operations ceased in 1989 and DOE refocused site efforts on environmental restoration.

In order to plan for the permanent environmental cleanup of the FEMP site, the DOE performed Remedial Investigation/Feasibility Studies (RI/FS) in accordance with the terms of a cooperative agreement with the U.S. Environmental Protection Agency (EPA) pursuant to Section 120 and 106(a) of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), as amended (EPA 1991). The Ohio Environmental Protection Agency (OEPA) also participated in the review and oversight of the RI/FS and subsequent cleanup activities.

The objective of the RI/FS was to gather and evaluate technical information to support an informed decision as to the most prudent cleanup actions that DOE could undertake to permanently address environmental contamination at the FEMP site. The cleanup decisions at the FEMP are being made jointly by DOE and EPA, in concurrence with OEPA, following consideration of input from the public. FEMP stakeholders include members of the public who reside near the FEMP, as well as the Nevada Test Site.

The FEMP was segmented into five operable units (OUs) as a management approach to enable the more expedient initiation of cleanup actions. The term "operable unit" is used to identify a logical grouping of facilities or environmental media at the site. Separate documentation was developed for the five OUs, including:

- A Remedial Investigation (RI), which presents information on the nature and extent of contamination at the site and assesses the risks to human health and the environment from the existing conditions.
- A Feasibility Study (FS), which evaluates cleanup alternatives.
- A Proposed Plan (PP), which summarizes key information from the RI/FS reports and identifies the preferred remedial alternative for implementation at the site.
- A Record of Decision (ROD), which documents how public comments to the PP were addressed and identifies the cleanup decision for each OU.

As of January 1996, the five OUs, including Operable Unit 4 (OU4), had completed the RI/FS process and are actively conducting remedial actions (RAs) in accordance with their respective EPA-approved final RODs.

Original Operable Unit 4 RI/FS Process Summary

For OU4, the original RI/FS process ended in February 1995 when the final ROD (EPA 1994), approved by EPA in December 1994, became effective. The ROD addressed the remediation of the silos material inventory, facilities, structures, and environmental media that comprised OU4 as follows:

- Silos 1 and 2 and their contents;
- Silo 3 and its contents;
- Silo 4 (empty except for rainwater);
- The Silos 1 and 2 Decant Sump Tank System (an underground tank and its contents);
- A Radon Treatment System (RTS);
- A portion of a concrete pipe trench and other concrete structures;
- An earthen berm surrounding Silos 1 and 2;

- Soils beneath and immediately adjacent to Silos 1, 2, 3, and 4; and
- Perched groundwater near the silos that is encountered during the implementation of RAs.

The goal of the RI phase for OU4 was to compile existing environmental data at the site and undertake the necessary field investigations to characterize the condition and contents of Silos 1, 2, 3 and 4, the nature and extent of environmental media within the OU4 boundary, and the risk that contaminants pose to human and environmental receptors. The RI was conducted in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) to provide the data necessary to support the decision on whether RA was warranted and to support the evaluation of available RA alternatives in this revised FS. The OU4 RI (FEMP 1993) concluded that the existing conditions at OU4 present an unacceptable risk to human and environmental receptors, thereby warranting the implementation of RAs to address the environmental media. The data and analyses presented in the OU4 RI were used as the foundation for the development of the original OU4 FS. The final RI for OU4 is available in the Administrative Record[1].

The purpose of the original OU4 FS (FEMP 1994a) was to develop and evaluate an appropriate range of remedial alternatives to address contaminated environmental media. The FS was formatted to provide the appropriate type and level of information required for key stakeholders and decision makers to come to informed decisions. The original OU4 FS was prepared in accordance with EPA guidance (1988) and provides a conceptual level of detail on each alternative evaluated. The final original FS report for OU4 is available in the Administrative Record.

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[1] Documentation of Remedial Investigation/Feasibility Study activities for each operable unit is made available for public review. The Administrative Records for the FEMP site are located at the Public Environmental Information Center (PEIC) in Harrison, OH. 513-648-7480.

The results of the original OU4 FS, combined with input from support agencies, stakeholders, and the general public on the preferred remedial alternative and the other remedial alternatives identified in the PP formed the basis for selecting the RA for OU4. Input from the public and other stakeholders were obtained through receipt of comments on the PP. The OU4 PP (FEMP 1994c) was made available for public review and comment during the Spring of 1994. At the request of Nevada stakeholders, the formal public comment period was extended twice to provide adequate time for stakeholder review. The responses to comments on the PP and the alternative(s) selected for implementation were documented in the final EPA – approved OU4 ROD.

The selected remedy outlined in the OU4 ROD consisted of the removal of the contents of Silos 1,2, and 3; remediation by vitrification and off-site disposal of the treated material at the Nevada Test Site (NTS); and the demolition, removal and final disposition of the contaminated concrete, debris, and soils within the OU4 boundary, in accordance with the OU3 and OU5 RODs (FEMP 1996 a,b).

Circumstances Giving Rise to Modifying the Operable Unit 4 Record of Decision

Following final approval and upon the effective date of the OU4 ROD, the U.S. Department of Energy-Fernald Environmental Management Project (DOE-FEMP) initiated a joule-heated Vitrification Pilot Plant (VITPP) Treatability Study Program. The purpose of the pilot-scale program was to collect performance data to support full-scale application of the joule-heated vitrification technology to the silos material. Technical and operational difficulties encountered during the implementation of the VITPP program, resulted in documented schedule delays and cost increases. In September 1996, DOE formally requested extension of enforceable milestones associated with implementing the OU4 remedy.

In October 1996, EPA denied DOE's request for extension of the milestones. EPA and DOE then initiated the formal dispute resolution process under the Amended Consent Agreement (ACA) and began reevaluation of the technical path forward for remediation of the silos material. In November 1996, the DOE-FEMP convened the Silos Project Independent Review Team (IRT) as a technical resource to assist the DOE-FEMP in this reevaluation.

VITPP technical and operational difficulties culminated with suspension of VITPP testing following a melter hardware failure on December 26, 1996. The DOE-FEMP, IRT, EPA, OEPA and other stakeholders ultimately concluded that an alternate remedy should be considered for the Silo 3 material and that the treatment remedy for the Silos 1 and 2 material should be reevaluated.

On July 22, 1997, the DOE-FEMP and the EPA formally entered into an agreement resolving disputes concerning the schedule and path forward for the remediation of the Silos 1, 2 and 3 materials (EPA 1997a). The EPA directed DOE-FEMP to proceed with development of a supplemental Feasibility Study/Proposed Plan (FS/PP) and subsequent ROD amendment for the Silos 1 and 2 material and an Explanation of Significant Differences (ESD) for the Silo 3 material.

The EPA's basis for proceeding with the re-examination of the selected treatment remedy and a ROD amendment for the Silos 1 and 2 material was that the significant increase in projected cost (by a factor of 5) to implement the selected remedy constituted a fundamental change to the remedy documented in the OU4 ROD (EPA 1997b). The scope of this revised FS is limited to evaluation of the most effective means of implementing the treatment technology component of the selected remedy for the Silos 1 and 2 material.

Record of Decision Amendment Process

The OU4 ROD Amendment process will follow an administrative process similar to the original OU4 remedy selection process.

This revised FS documents the reevaluation of the selected treatment remedy for the FEMP OU4 Silos 1 and 2 material. The purpose of the revised FS is to gather and present information to support identification of the most appropriate alternative for the treatment of the Silos 1 and 2 material.

As required by the NCP, this revised FS reevaluates treatment alternatives in detail against seven of the nine NCP criteria. This revised FS takes into consideration additional technical information that has been developed since the original OU4 ROD was approved. This information is collected from post-ROD treatability studies and actual technology applications [e.g., VITPP, DOE-complex lessons learned, and Proof of Principle (POP) testing]; published analyses from independent reviews by recognized experts such as the IRT and Critical Analysis Team (CAT); and searches of current data bases and vendor interviews **(Section 1.4.8)**.

The primary objectives of this revised FS phase of the ROD amendment process are to: (1) develop and evaluate a range of treatment alternatives for safely and effectively remediating the Silos 1 and 2 material, (2) perform a screening of the treatment alternatives, and (3) complete a detailed and comparative analysis of the feasible alternatives. The results of this revised FS, when combined with input from support agencies (i.e., EPA and OEPA) and public stakeholders on the preferred treatment alternative identified in the PP, form the basis for selecting the proposed RA for Silos 1 and 2. Input from stakeholders and other interested parties will be obtained through receipt of comments on the PP, which will be issued for public review.

The PP provides a summary level description of the treatment technology being proposed to treat the Silos 1 and 2 material and presents a summary of the environmental impacts of the preferred alternative. Subsequently, consistent with the ACA, selection of the preferred treatment alternative will be documented in a ROD amendment issued by the EPA following consideration of any comments received from the stakeholders and other interested parties.

Consistent with DOE order 5400.4, the FEMP is integrating the National Environmental Policy Act (NEPA) requirements into the documentation being prepared to support the ROD amendment process. However, DOE's CERCLA/NEPA integration policy is not intended to represent a statement on the legal applicability of NEPA to RAs under CERCLA. The revised FS and the PP evaluation criteria have been supplemented to integrate evaluation of the environmental consequences, consistent with NEPA. In addition, a supplement analysis (**Appendix D**) in accordance with NEPA guidelines has been developed to evaluate the alternatives being evaluated in this revised FS against the results of the original Feasibility Study/Proposed Plan - Environmental Impact Statement (FS/PP-EIS) (FEMP 1994b). The supplement analysis and consideration of NEPA values in the detailed analysis of alternatives continues the CERCLA/NEPA integration during the decision-making process for the ROD amendment. Based on the results of the analysis, DOE has determined that the proposed alternatives for remediation of the Silos 1 and 2 material do not constitute a substantial change in project scope or result in the availability of significant new information related to environmental impacts from the original FS/PP-EIS alternatives. Therefore, a Supplemental EIS is not recommended for the proposed alternatives.

In accordance with the dispute settlement, there are several aspects of the OU4 selected remedy that are not required to be reevaluated by the scope of this revised FS; these aspects are listed below.

<u>General Response Actions</u>

- Retrieval of Silos 1 and 2 material and
- Off-site disposal of treated Silos 1 and 2 material.

<u>Miscellaneous</u>

- Selection of a remedy that includes treatment of principle-threat constituents of concern (COCs) and off-site disposal;
- Treatment performance criteria for Silos 1 and 2 material;
- Silo 3 selected remedy in the Silo 3 ESD; and
- Selection of a remedy for OU4 soil and debris.

These aspects, which are not being reevaluated by this revised FS, are appropriately discussed throughout this revised FS and summarized in **Appendix F**. **Appendix F** discusses how the factors were addressed by the original OU4 and/or modified by the on-going regulatory process. This approach minimizes the need to revisit the original OU4 RI and FS documentation to provide a basis for the evaluation of treatment alternatives.

Final Disposition of Operable Unit 4 Soil and Debris

The decision regarding the final disposition of the OU4 contaminated soil and debris was placed in abeyance by the original OU4 ROD (EPA 1994), until completion of the RODs for OU3 and OU5 (FEMP 1996 a,b). The primary reason for this action was to take full advantage of the sitewide waste management strategies that were just being developed and evaluated by these OUs. The EPA-approved RODs for OU3 and OU5 outline the final disposition of the contaminated debris and environmental media resulting from the remediation of OU4 as part of a sitewide integrated waste management strategy.

Operable Unit 4 Integration With the Operable Unit 3 ROD

The decontamination and demolition (D&D) of the OU4 silos and the above-grade remediation facilities will be planned and performed in accordance with the OU3 ROD (FEMP 1996a) and the OU3 implementing RA documents [i.e., Facility Closure and Demolition Project's Project Execution Plan (PEP)]. The hierarchy of regulatory and site requirements that governs the performance of OU4 D&D activities flow down directly from the OU3 regulatory process by the OU3 Integrated Remedial Design/Remedial Action (RD/RA) Work Plan and the OU3 Project-specific Implementation Plan. The OU4 remediation efforts will involve the in situ gross decontamination of interior and exterior surface of above-grade structures before dismantlement in order to reduce direct exposure potential, as well as reduce available sources for airborne or water-borne contaminant migration. Methods to be employed depend on the contamination type, level of contamination found, and materials on which it is found. Additional decontamination procedures are implemented during dismantlement to remove previously inaccessible contamination.

Above-grade dismantlement includes the removal of process equipment [e.g., Radon Control System (RCS) and the abandoned RTS], electrical equipment, piping, water lines, gas lines, tanks [e.g., Transfer Tank Area (TTA)], heating ventilation and air conditioning ductwork, and electrical lines. The last steps of the dismantling action depend on the structure, but generally involve the removal of any air filtration apparatus and the removal of the roof, exterior walls, and structural members. Once an acceptable area has been cleared down to grade level, at- and below-grade remediation (e.g., removal of OU4 foundations, storage pads, ponds, basins, underground utilities) begins.

Operable Unit 4 Integration With the Operable Unit 5 ROD

Discrete data points were collected as part of the OU5 RI (FEMP 1994d) to characterize the nature and extent of contamination in environmental media of the site, including the OU4 area; the results of the data analyses are summarized in the OU5 FS (FEMP 1995b) and are briefly discussed below.

The OU5 RI/FS examined soil on a sitewide basis. Soil at the FEMP that is not contemplated to be exhumed as part of a remedy for OUs 1 through 4 is considered within the scope of OU5. Soils considered include soil under and adjacent to the waste pits, burn pit, and Clearwell (OU1); soil within OU2 but outside the proposed on-property disposal facility; soil underlying and adjacent to the Silos 1, 2, 3, and 4 including the earthen berms (OU4); and soil presently stored in piles and containers in or near the former production area (OU3). This approach has been adopted to allow the examination of soil on a sitewide basis such that comprehensive remedial alternatives could be formulated and evaluated. This approach is consistent with presentations in the FS reports for OUs 1, 2, and 4.

The ROD for OU4 (EPA 1994) established operable unit-specific soil preliminary remediation levels (PRLs) that were revisited by OU5. The OU5 ROD established final remediation levels for the sitewide soils, including OU4, based on a future land-use scenario. The OU5 ROD (FEMP 1996b) modified the OU4 soil remediation levels, which are in some cases more restrictive that the original OU4 PRLs. A more detailed discussion is provided in **Appendix F**.

The OU5 RI/FS process examined perched groundwater on a sitewide basis. It should be noted, however, that the ACA provides that each OU address perched groundwater envisioned to be encountered as a consequence of conducting RAs. An example of such an incidence is the collection of perched groundwater in deep excavations completed to remove underground tank systems (e.g., Silos 1 and 2 Decant Sump Tank System), pits, or foundations. This collected water will be directed to OU5 Wastewater Treatment Systems.

Process wastewaters generated during RAs conducted by the FEMP OUs will be directed to OU5 treatment systems [i.e., Advanced Wastewater Treatment (AWWT) facility]. OU5 has established pretreatment requirements to ensure that available treatment capabilities will not be exceeded by incoming wastewater streams. These requirements have been included in the **Design Basis and Description (Appendix G)** for the alternatives evaluated by this revised FS. These projected process wastewater streams have been factored into each OU4 remedial alternative presented in this report.

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Integration with the Operable Unit 2 ROD

The FEMP On-Site Disposal Facility (OSDF) has a waste acceptance criteria (WAC) for soils and debris that ensures that materials disposed within its confines are protective of human health and the environment. The OSDF will be available for disposal of the existing silo structures, the RTS, the Decant Sump Tank System, other below-grade appurtenances, and the Area 7 soils **(see Figure 1.3-3)**. Soil and debris from D&D activities associated with these facilities will be disposed in the OSDF if they meet the WAC for disposal. The ability of this soil and debris to meet the OSDF WAC is discussed in more detail in **Section 3**. However, based upon the current operating schedule for the OSDF, the OSDF is not identified to be available to receive any soils and debris from the D&D of the OU4 remediation facilities. Therefore for cost estimating purposes, this revised FS assumes that all soil and debris generated from D&D of the OU4 remediation facilities will be disposed at the NTS. In the event that the OSDF becomes available, the OU4 soil and debris from D&D of the remediation facilities could be disposed at the OSDF if they meet the OSDF WAC. Therefore, on-site disposal of the OU4 soil and debris from D&D activities is protective of human health and the environment. This issue is discussed in more detail in **Section F.1, Appendix F**.

Development and Preliminary Screening of Alternatives

This revised FS presents information to support the selection of the most appropriate treatment technologies for the Silos 1 and 2 material. The alternatives for remediation in this FS were developed in accordance with the NCP, as well as EPA guidance and public input by following a series of logical steps that involved developing, in succession, more specific definitions of potential remedial alternatives (**Section 2**). The steps included the following:

- The identification and screening of alternatives for this revised FS was first presented to the stakeholders in August 1997 and was revised with their input and presented again in December 1997 during public meetings.
- A Commerce Business Daily (CBD) announcement was issued in November 1997 to solicit input regarding demonstrated technologies from commercial vendors.
- A preliminary screening determined which alternatives would be analyzed more fully in the detailed analysis phase of this revised FS.

Based upon the screening of potential treatment technologies, vitrification and chemical stabilization were identified for further evaluation. For the purposes of the detailed analysis of alternatives **(Section 3)**, each technology will be represented by two processes resulting in four alternatives as follows:

- Vitrification – Joule-heated (VIT1);
- Vitrification – Other (VIT2);
- Chemical Stabilization – Cement-based (CHEM1); and
- Chemical Stabilization – Other (CHEM2).

The lack of current off-site facilities with both the capacity and necessary permits and licensing for treatment of Silos 1 and 2 material precludes a site-specific evaluation of implementability and short-term effectiveness. Therefore, the high risk of not being able to implement off-site treatment under the current schedule is considered unacceptable. Additionally, the selection of an off-site facility during the post-ROD procurement process limits the involvement of the EPA, OEPA, in selection of the facility. Therefore, off-site treatment is being excluded from further consideration as an alternative for the Silos 1 and 2 material.

Detailed/Comparative Analysis of Feasible Alternatives

The detailed analysis of alternatives was performed on those alternatives that were retained through the screening of alternative steps described above. The detailed and comparative analyses consisted of the analysis and presentation of the relevant information needed to allow decision makers to select a remedial alternative. The alternatives selected for further evaluation in the detailed analysis of alternatives are discussed next.

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Vitrification

There are several different types of vitrification technologies (i.e., joule-heated, fossil fueled, plasma arc, etc.). Based on the preliminary screening of alternatives, the technically feasible/commercially available process options (VIT1 and VIT2) were selected to represent the vitrification technology for detailed analysis in **Section 3**.

- Alternative VIT1 considers the use of *joule-heated* melter technology for the treatment of the Silos 1 and 2 material; and
- Alternative VIT2 considers the use of *combustion* melter technology for the treatment of the Silos 1 and 2 material.

Both VIT1 and VIT2 alternatives utilize high temperatures and glass forming techniques to eliminate the hazardous characteristics of the Silos 1 and 2 material.

Chemical Stabilization

The chemical stabilization technology is evaluated by the detailed analysis of two technically feasible/commercially available alternatives (CHEM1 and CHEM2) in **Section 3**.

- Alternative CHEM1 considers the use of a stabilization technology that utilizes chemical additives and cement for the treatment of the Silos 1 and 2 material; and
- Alternative CHEM2 considers the use of a stabilization technology that utilizes chemical additives, cement and flyash for the treatment of the Silos 1 and 2 material.

Both CHEM1 and CHEM2 alternatives utilize chemical stabilization to reduce the mobility of contaminants by either converting the contaminants into a less soluble form or by chemically binding them into a stabilized matrix.

In addition to the treatment technology, the selected remedy for the Silos 1 and 2 material will also include retrieval of the Silos 1 and 2 material from the TTA, on-site treatment, and off-site disposal of the treated material at the NTS.

Currently, the NTS is the only facility that has been identified that is capable of receiving and disposing the treated Silos 1 and 2 material. In the event that another disposal facility becomes available, which is appropriately permitted and licensed, demonstrates an equivalent level of protectiveness to human health and the environment and a clear economic advantage, the DOE would prepare an ESD at that time.

In the event secondary wastes generated during the treatment operations of the Silos 1 and 2 material or D&D activities which cannot be disposed at the NTS, the DOE would require the flexibility to treat and/or dispose the secondary waste at an appropriately licensed off-site facility.

To support the decision making process to select the treatment alternative for the Silos 1 and 2 material, it was necessary to collect additional data (e.g., implementability and cost) on potential treatment technologies in order to allow a thorough and comprehensive evaluation. Specific data requirements necessitated the performance of pilot-scale treatability studies using commercially demonstrated technologies (e.g., POP testing) to collect technology-specific data for evaluation of technologies.

Appendix H of this FS provides a summary of the treatability studies conducted under the POP Testing Project in direct support of the Silos 1 and 2 FS process. The POP treatability study results support the detailed analysis of alternatives in this revised FS, and allow selection of the preferred RA in the PP for the Silos 1 and 2 material to be made with reasonable certainty of achieving the response objectives.

The detailed analysis involves the evaluation of the alternatives against a set of specified criteria. Nine evaluation criteria are specified by the NCP to meet requirements of the CERCLA. EPA guidance documents provide details on the requirements for meeting these criteria. Assessments against two of the criteria relate directly to evaluation against statutory requirements. An alternative must satisfy both of these *threshold criteria* before it can be considered for the selected remedy. These two criteria are:

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

The following five criteria are identified in the NCP as the *primary balancing criteria* upon which the detailed analysis is based:

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

The final two criteria are identified in the NCP as modifying criteria. These criteria will be evaluated following public and agency comments on the revised FS and PP and will be addressed in the ROD amendment once a final proposed remedy is selected. The modifying criteria are:

- State acceptance, and
- Community acceptance.

Comparative Analysis

The comparative analysis distinguishes the advantages and disadvantages of each alternative relative to one another so that the key tradeoffs can be balanced to determine the best overall remedy.

The following text summarizes the comparative analysis results documented in **Section 4.**

Figure ES-1, presents the results of the comparative analysis of the vitrification and chemical stabilization alternatives in this FS.

Threshold Criteria

Overall Protection of Human Health and the Environment

All alternatives provide overall protection of human health and the environment. Each alternative limits exposure to contaminants by removing the sources of contamination, treating the source materials, and disposing the treated material off-site at the NTS.

All alternatives produce a treated material that reduces the potential for contaminant migration. Short-term risks to the public and workers associated with the implementation of the treatment alternatives are similar.

Compliance with ARARs

All alternatives attain the threshold criterion of compliance with ARARs. A comprehensive list of ARARs is presented in **Appendix A**. Key requirements are discussed in **Section 3** within the evaluation of each alternative against this criterion.

Primary Balancing Criteria

Long-term Effectiveness and Permanence

All alternatives ensure long-term protectiveness of human health and the environment. The projected FEMP site residual risk to viable receptors is less than the NCP criterion of a 10^{-6} incremental lifetime cancer risk (ILCR); and, non-carcinogenic effects are expected to be below the 0.2 hazard index (HI) specified by the NCP for all alternatives.

Off-site disposal at the NTS in accordance with the site's performance assessment (PA) provides additional protection by eliminating access to the treated materials and preventing migration of constituents from the materials. Location of the NTS disposal facility in a sparsely populated, arid environment reduces potential for leachate generation, contaminant migration, and prevents direct contact with contaminants.

Reduction of Toxicity, Mobility, or Volume through Treatment

Overall, this criterion favors VIT1 and VIT2 alternatives due to the reduction in treated material volume. However, all of the alternatives are effective at reducing the mobility of COCs in the Silos 1 and 2 material through treatment.

Consideration of the estimated secondary wastestreams does not significantly effect the differences in the total volume of the treated waste requiring disposal between the vitrification and chemical stabilization alternatives.

Short-term Effectiveness

The NCP identifies the components of short-term effectiveness as: short-term risks to the community during implementation of the alternative; potential impacts to workers during RA; potential environmental impacts during implementation; and time until protection is achieved.

Although each alternative is favored in some of these individual aspects of short-term effectiveness, from an overall perspective this criterion favors the CHEM1 and CHEM2 alternatives. Short-term environmental impacts and on-site risk are essentially equivalent for all four alternatives. Based on labor statistics, the greater number of operational hours required to implement VIT1 and VIT2 results in a greater potential for worker injury. The VIT1 and VIT2 processes result in greater physical hazards to workers during operation and maintenance activities. Due to the greater number of shipments required to ship the larger volume of treated material, transportation risk is marginally higher for CHEM1 and CHEM2. Whether via truck or intermodal shipments, transportation of the Silos 1 and 2 material to the NTS (following treatment by any of the four technologies) is protective of human health and the environment. Due to a shorter design-construction start-up period, less schedule uncertainty and more feasible schedule acceleration, the CHEM1 and CHEM2 alternatives are preferred with respect to time for achieving protectiveness.

Implementability

The evaluation of implementability indicates that all alternatives are complex and will be difficult to implement. However, based on a greater degree of commercial demonstration of the treatment technology, relative ease of both operation and schedule acceleration, and less complexity of integrated systems, there is significantly less uncertainty in the ability of the CHEM1 and CHEM2 alternatives to be successfully implemented. For this reason, the implementability criterion favors the CHEM1 and CHEM2 alternatives.

Each alternative is developed with a formulation that can be used to stabilize COCs in Silos 1 and 2 material over a range of variations in the feed stream. The evaluation also identifies significant technical challenges such as process control, adaptation of the process to remote operations, feed preparation, and product handling that apply to each alternative.

Cost

In general, all the alternatives are cost effective. That is, the costs appear proportional to the overall protectiveness provided by the alternatives, both during and following the remediation period. The cost differential between the four alternatives is approximately 16 percent (%), with the cost of CHEM1 and CHEM2 being lower. The accuracy of each cost estimate is roughly +50/-30%, consistent with CERCLA guidance.

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TABLE ES- 1
COMPARATIVE ANALYSIS SUMMARY

ITEM	VIT1/VIT2			CHEM1/CHEM2	
	Strongly Favors	Favors	Neutral	Favors	Strongly Favors
Overall Protection of Human Health and the Environment			↓		
Compliance with Applicable or Relevant and Appropriate Requirements			↓		
Long-Term Effectiveness and Permanence			↓		
Reduction of Toxicity, Mobility, or Volume Through Treatment		↓			
Short-Term Effectiveness				↓	
Implementability				↓	
Cost			↓		
State Acceptance - TBD					
Community Acceptance - TBD					

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Section 1

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1.0 INTRODUCTION

This Feasibility Study (FS) report documents the reevaluation of the selected treatment remedy for the remediation of the Operable Unit 4 (OU4) Silos 1 and 2 material at the U.S. Department of Energy's (DOE) Fernald Environmental Management Project (FEMP).

The FEMP is a former uranium processing facility located in southwestern Ohio approximately 18 miles northwest of the city of Cincinnati (see **Figure 1.1-1**). Between 1952 and 1989, the U.S. Department of Energy-Fernald Environmental Management Project (DOE-FEMP).

DOE-FEMP facility, then called the "Feed Materials Production Center (FMPC)," produced high purity uranium metal products for the nation's defense programs. Uses of Fernald's products included use in production reactors to make plutonium and tritium at other DOE sites. In July 1989, Fernald's uranium metal production operations were suspended due to reduced needs, nationwide, for the uranium products produced by the FEMP. Since July 1989, the mission of the FEMP has been focussed on environmental restoration.

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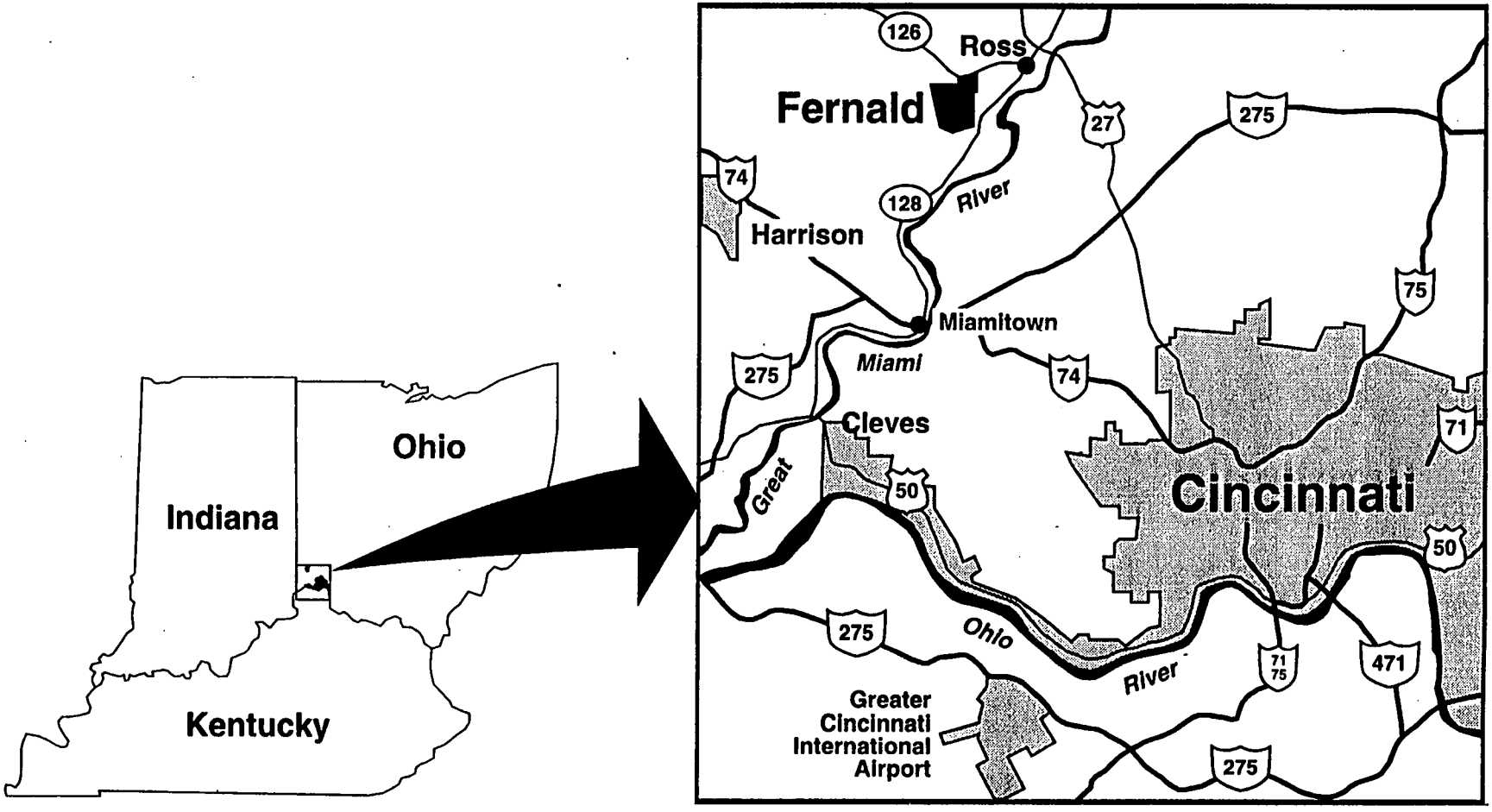
FIGURE 1.1-1
FEMP FACILITY LOCATION MAP



Objective

The objective of this revised FS is to gather and present information to support an informed remedy selection for the treatment of the Silos 1 and 2 material.

The goal of the OU4 remedial action (RA) is to safely remediate the OU4 components in a timely, efficient, and cost-effective manner, that ensures compliance with all applicable or relevant and appropriate requirements (ARARs) and that is protective of human health and the environment. After the OU4 RAs are complete, the former waste storage area will be restored to a natural habitat in accordance with the *FEMP Natural Resource Restoration Plan, Draft* (FEMP 1997a). The complete remediation of the OU4 area will eliminate the FEMP's most significant inventory of contaminated (activity) material and chronic source term of radon emissions at the FEMP site.

1.1 Circumstances Giving Rise to Modifying the Selected Remedy for the Remediation of Silos 1, 2 and 3 Materials

Following approval of the original OU4 ROD, the DOE-FEMP prepared and submitted the *Work Plan for the Operable Unit 4 Remedial Design* (RDWP) that identified the approach for the implementation of the selected remedy (FEMP 1995a). The RDWP was approved by the U.S. Environmental Protection Agency (EPA) in June 1995. As part of the OU4 remedial design (RD) process, a treatability study program was initiated in May 1996 to collect quantitative performance data to support full-scale application of the joule-heated vitrification technology to the silos material.

The joule-heated Vitrification Pilot Plant (VITPP) treatability study program involved processing non-radioactive surrogate material with selected chemical and physical properties of the combined Silos 1, 2, and 3 materials. The joule-heated VITPP testing program consisted of three campaigns with the following objectives: (1) to determine (using surrogates) whether it was more economical to vitrify the Silos 1, 2, and 3 materials together or separately; (2) to gain experience vitrifying silos material and handling high-sulfate, barium and lead concentrations and BentoGrout™; and (3) and to determine maximum production rates through induced agitation (via bubbling tubes) in the molten glass bath to increase production.

During the joule-heated VITPP testing program, many technical and operational difficulties were encountered. Most of the technical and operational difficulties of running the VITPP were not related to making glass in the melter. For example, most of the problems centered around delivering the feed to the melter and the discharge of glass to make gems. Particulate build-up problems in the off-gas system were also encountered; however, these were resolved by installing a film cooler.

Results of the joule-heated VITPP treatability study indicated that the beneficial fluxing (ability to lower the glass's melting point) anticipated by the properties of Silo 3 were overwhelmed by the chemistry and operational problems of handling its high-sulfate content (18 wt% vs. 2 wt% for the Silos 1 and 2 material). The major problem encountered was foaming of the bath at high production rates. Chemical reductants were used to help increase the production rate; but, the problem was not eliminated. This, along with the relatively low concentrations of hazardous and radiological constituents in the Silo 3 material, became a key factor later in the decision to treat the Silo 3 material separately from the Silos 1 and 2 material.

Attempts to resolve technical and operational issues during VITPP operations resulted in documented schedule and cost increases.

In September 1996, DOE formally requested extension of enforceable milestones associated with implementing vitrification of the silos material. In October 1996, EPA denied DOE's request. EPA and DOE then initiated the formal dispute resolution process under the Amended Consent Agreement (ACA) and began reevaluating the path forward for remediation of the silos material. In November 1996, the DOE-FEMP convened the Silos Project Independent Review Team (IRT) as a technical resource to assist the DOE-FEMP in this reevaluation. The IRT was comprised of technical representatives from throughout the DOE-FEMP complex and private industry with expertise in various aspects of chemical stabilization, vitrification, and other treatment technologies.

During the final stages of the last campaign to demonstrate lower temperature processing (<1200°C) of Silos 1 and 2 material, the melter hardware failed (December 26, 1996). The reason for the failure was attributed to the molybdenum disilicide bubbler tubes (used for agitation) located at the bottom of the melter chamber. The bubbler tubes quickly dissolved away once lead (via the surrogate) was introduced into the molten glass by chemically reducing the molten glass to form metallic lead. A hole formed in the bottom of the melter refractory where the bubblers were located, which allowed a pathway for the molten glass and precipitated lead to erode at the understructure of the melter until containment was lost. VITPP testing was suspended following the December 26, 1996 hardware failure.

The recommendations of the IRT (Silos Project IRT 1997) - along with the evaluation of the December 26, 1996, melter hardware failure (FEMP 1997b) by DOE and EPA, and stakeholder input supported a decision that vitrification of the Silo 3 material (although possible) is not practical or necessary because of its significant cost and extension to the cleanup schedule. This, and the fact that the concentrations of hazardous and radiological constituents in Silo 3 material are relatively low compared to the levels present in Silos 1 and 2 material, became additional key factors later in the decision to treat the Silo 3 material separately from the Silos 1 and 2 material.

In addition, the evaluations concluded that separating the Silos 1 and 2 material from Silo 3 material would reduce the technical uncertainties and programmatic risks of developing an effective treatment process for each wastestream. Therefore, DOE-FEMP and EPA made the decision with input from the public that Silo 3 material should be treated separately from the Silos 1 and 2 material. Together DOE-FEMP and stakeholders decided that an alternate remedy should be considered for treatment and disposal of the Silo 3 material. On July 22, 1997, the DOE-FEMP and the EPA formally approved an "Agreement Resolving Dispute Concerning Denial of Request for Extension of Time for Certain OU4 Milestones," hereafter referred to as "the Settlement" resolving disputes concerning the schedule and path forward for the remediation of the Silos 1, 2, and 3 materials. In the Settlement, EPA and DOE-FEMP agreed that DOE-FEMP would prepare a revised FS, Proposed Plan (PP), and Record of Decision (ROD) amendment to reevaluate the treatment remedy for Silos 1 and 2 material, and an Explanation of Significant Differences (ESD) identifying the RA changes for Silo 3 material.

An ESD was completed by DOE-FEMP and approved by the EPA in March 1998 to document the change in remedy for treatment and disposal of the Silo 3 material (FEMP 1998a).

The DOE-FEMP is preparing this revised FS and subsequent PP to recommend a RA for the Silos 1 and 2 material. The Settlement specifies that the draft revised FS and PP must be submitted to the EPA for review and approval on or before February 1, 2000. This revised FS and the PP will be available for stakeholder review. This revised FS and PP will provide the basis for selection of the final remedy, which will be documented and approved in an amendment to the original OU4 ROD, for Silos 1 and 2.

1.2 Organization of the Report

The scope of this revised FS is more narrow than a traditional FS. Based upon the settlement with the DOE-FEMP and the EPA (EPA 1997a), this report reevaluates the selected remedy for remediating the Silos 1 and 2 material for disposal at the Nevada Test Site (NTS). Therefore, the methodology and approach adopted by this revised FS report has been tailored to address the specific circumstances (e.g., regulatory, technical, administrative) surrounding the revised decision-making process for the treatment of the Silos 1 and 2 material. This report has been prepared consistent with the requirements of the Comprehensive Environmental Response, Liability and Compensation Act, as amended (CERLCA), ACA, applicable project documentation, and available EPA guidance. Consistent with EPA guidance (EPA 1988), this revised FS examines a range of treatment alternatives.

Each treatment alternative has been developed to the extent necessary to facilitate the fair comparison of these alternatives against established regulatory-based evaluation criteria. To establish a basis for the development of alternatives, this revised FS relies upon the data compiled for the original OU4 Remedial Investigation (RI) and FS Reports, post-ROD treatability testing, commercial and DOE-complex experience, and lessons learned involving the technologies being evaluated. The best available assumptions have been employed in the revised FS to define the basis of the development and evaluation of the alternatives.

The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) specifies nine criteria be used in evaluating the remedial alternatives to the extent necessary to support the fair comparison of these alternatives against established criteria in the revised FS. These criteria include the long-term effectiveness, reliability, implementability, and cost of a remedial system. These nine criteria help in evaluating the alternatives against each other in order to select the preferred alternative. This comparison is also summarized in the Silos 1 and 2 PP (FEMP 1994c). For evaluating cost, remedial alternatives are typically developed to the extent necessary to produce cost estimates for each alternative to a range of accuracy of +50 % to -30 %. The conceptual design level of information presented in this FS will be refined for the selected alternative following closer examination during the RD process.

This revised FS is organized into five sections and eight appendices as follows:

- The remainder of **Section 1** presents a brief summary description of the history, scope, and role of OU4 and Silos 1 and 2; integration with other OUs; and, a general summary of the nature and extent of contamination within OU4. This section has been written to provide an overview for informed readers. Those readers requiring additional detail are directed to **Appendix F** of this report or to the original OU4 RI, FS, PP and ROD documents which are available in the Administrative Record.

- **Section 2** discusses the basis for the development of and preliminary screening of a wide range of potential treatment alternatives to identify a select group that warrant more detailed evaluation in **Section 3**. **Section 2** first discusses the basis for the utilization of the same preliminary remediation goals (PRGs), General Response Actions (GRAs) and Remedial Action Objectives (RAOs) for this FS, which were used in the original OU4 FS. **Appendices A** and **F** of this FS summarize the analysis of ARARs and the derivation of the PRGs, GRAs, and RAOs, by the original OU4 FS, respectively.

- **Section 3** provides an overview of the treatment alternatives, a more detailed description of the technologies being considered, and performs an evaluation of the overall protectiveness of human health and the environment, compliance of each treatment alternative with ARARs, long- and short-term effectiveness of the treatment alternatives, reduction of mobility, toxicity and volume through treatment, implementability, and cost for each treatment alternative retained. **Appendix G** supports **Section 3** by providing a detailed technical basis for design and a description of the alternative technologies being evaluated. **Appendix A** supports **Section 3** by providing a detailed discussion of potential ARARs pertinent for each alternative. **Appendices B** and **E** provide an analysis of the short-term risks posed to workers and the public during the implementation of the alternatives on-site and an analysis of the transportation risks associated with disposing the treated Silos 1 and 2 material, respectively. **Appendix C** contains a summary of the detailed cost estimates prepared for each alternative. **Appendix D** is a supplement analysis considering National Environmental Protection Act (NEPA) values and assesses potential impacts of the remedial activities for each alternative. **Appendix H** contains summary of technology-specific data obtained from the Proof of Principle (POP) Testing Project that was used in the development and evaluation of the FS alternatives in **Section 3**.

- **Section 4** presents the results of the comparative analysis for the alternative treatment technologies against the nine criteria specified under the Comprehensive Environmental Response, Compensation, and Liability Act, as amended (CERCLA) and NCP guidance. The purpose of this comparative analysis is to identify the relative advantages/disadvantages and discriminating factors of each alternative. In this manner, key tradeoffs that the DOE-FEMP must balance can be identified.

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The comparative analysis for the four alternatives will include a narrative describing the strengths and weaknesses of the alternatives relative to one another with respect to each criterion. The presentation of differences among alternatives will be discussed qualitatively, and/or quantitatively where empirical data exists. Where appropriate, the discussion will note how reasonable variations of key uncertainties could change the expectations of their relative performance.

- **Section 5** is a bibliography of the supporting documents that were either used or referenced in the preparation of **Sections 1** through **4**.

1.3 Scope and Role of OU4

This section discusses the scope and role of OU4 as it pertains to the FEMP RI/FS process, and the remedial design/remedial action (RD/RA) process.

1.3.1 History of the FEMP as an NPL Site and Basis for Listing

In the 1980s, concerns were raised by local, state, and federal authorities regarding the potential impacts on human health and the environment from present and past activities at the facility. On the basis of these concerns and an evaluation of existing environmental sampling data, the EPA placed the FEMP on the National Priorities List (NPL) of the CERCLA on November 21, 1989. With respect to the NPL listing, FEMP site includes all areas within the boundary of the FEMP and any off-property areas that received released hazardous substances, pollutants, contaminants, or hazardous constituents from the FEMP. Inclusion on the NPL reflects the importance placed by the federal government on completion of cleanup actions at the FEMP site.

The NPL is found in Appendix B of the NCP, 40 Code of Federal Regulations (CFR) Part 300. CERCLA requires the NCP to produce a list of national priorities among sites with known releases or threatened releases of hazardous substances, pollutants, or contaminants throughout the United States and that the list be revised at least annually. The NPL, originally promulgated on September 8, 1983 [40 Federal Register (FR) 40658], constitutes this list.

The Hazard Ranking System (HRS) is one of three mechanisms for listing sites on the NPL. The other two methods include state designation on the Master's Site List and EPA designation. The HRS serves as an objective screening device to evaluate the relative potential of uncontrolled hazardous substances to cause human health or safety problems, or ecological and environmental damage. The HRS score presents an estimate of the relative probability and magnitude of harm to the human population or sensitive environment from exposure to hazardous substances as a result of the contamination of groundwater, surface water, or air. Sites that score 28.50 or greater on the HRS are eligible for the NPL. HRS scores are not sufficient for determining either the extent of contamination or the appropriate response for a particular site.

The HRS for the FEMP exceeded the 28.50 score primarily because the FEMP is located above a Class I aquifer (the Great Miami Aquifer). The definition of a Class I aquifer states that the aquifer is an irreplaceable, irrevocable source of drinking water and allows zero degradation to this sole-source potable water supply. The Great Miami Aquifer is also a federally designated sole-source aquifer, which means it provides the only drinking water for the entire watershed.

Under CERCLA, each state may designate a single site as its top priority, regardless of the HRS score. EPA may also list sites if all of the following occur: the Agency for Toxic Substances and Disease Registry (ATSDR) recommends disassociation of individuals from the release; if the EPA determines that the release poses a significant public health threat; and, if the EPA anticipates that it is more cost effective to use remedial rather than removal authorities for cleanup.

The identification of a site for the NPL assists EPA in determining which sites warrant further investigation to assess the nature and extent of the public health and environmental risks associated with the site and to determine what CERCLA-financed RA(s), if any, may be appropriate. The NPL also serves to notify the public of sites that EPA believes warrant further investigation.

1.3.2 Scope of OU4 Remedial Action and the Remaining Decision

To establish the legal framework by which to address the releases and threats of hazardous substances from containers and facilities at the FEMP, the DOE-FEMP as the lead agency for the remediation of the FEMP site, and the EPA entered into a Consent Agreement in 1990, as amended in 1991. The Consent Agreement as Amended Under CERCLA Sections 120 and 106(a) (ACA) is the legal basis that administratively governs the proper management and restoration of the FEMP site.

To promote a more structured and expeditious cleanup, the facility and associated environmental issues of the FEMP site are being managed as five operable units (OUs). An OU is a term employed under federal environmental regulation to represent a logical grouping of environmental issues at a cleanup site. Separate RI/FS documentation was prepared and issued for the five OUs at the FEMP. The five OUs, for which RI/FS documents have been compiled, are defined within the ACA as:

- OU1: Waste Pits 1 through 6, the Clearwell, burn pit, berms, liners, and soil to a determined depth (estimated to be approximately 3 feet) beneath the waste pits.
- OU2: Other waste units including the flyash piles, other South Field disposal areas, lime sludge ponds, solid waste landfills, berms, liners, and soil within the OU boundary.
- OU3: 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 Silos 1 and 2 material transfer line, wastewater treatment facilities, fire training facilities, scrap metal piles, feedstocks, and the coal pile.
- OU4: Silos 1, 2, 3, and 4, their contents, berms, and the Decant Sump Tank System; Radon Treatment System (RTS); a portion of concrete trench and Silos 1 and 2 material transfer line within the boundary of OU4; miscellaneous pads and concrete structures; soils beneath and immediately surrounding Silos 1 through 4; and, perched groundwater near the silos that may be encountered during the implementation of cleanup activities.

- OU5: Environmental media including groundwater (both perched and the Great Miami Aquifer), surface water, soil not included in the definitions of OUs 1 through 4, sediment, flora, and fauna.

Currently, the five OUs (including OU4) have completed the RI/FS process and are conducting RAs in accordance with their respective EPA-approved final RODs.

1.3.2.1 Scope of OU4

OU4 is commonly referred to as the "Silos Project," distinguished by the four concrete silos, three of which contain low-level waste. OU4, as depicted in **Figure 1.3-1**, consists of the following FEMP facilities and associated environmental media:

- Silos 1 and 2 and their contents (also termed *K-65 Silos*).
- Silo 3 and its contents (also termed *cold metal oxide silo*).
- Silo 4 (empty).
- Silos 1 and 2 Decant Sump Tank System, its contents, and associated Silos Underdrain System.
- A RTS.
- The portion of a concrete pipe trench within the boundaries of OU4, and other concrete structures.
- An earthen berm surrounding Silos 1 and 2.
- Soils beneath and immediately adjacent to Silos 1, 2, 3 and 4.

FIGURE 1.3-1
OPERABLE UNIT 4

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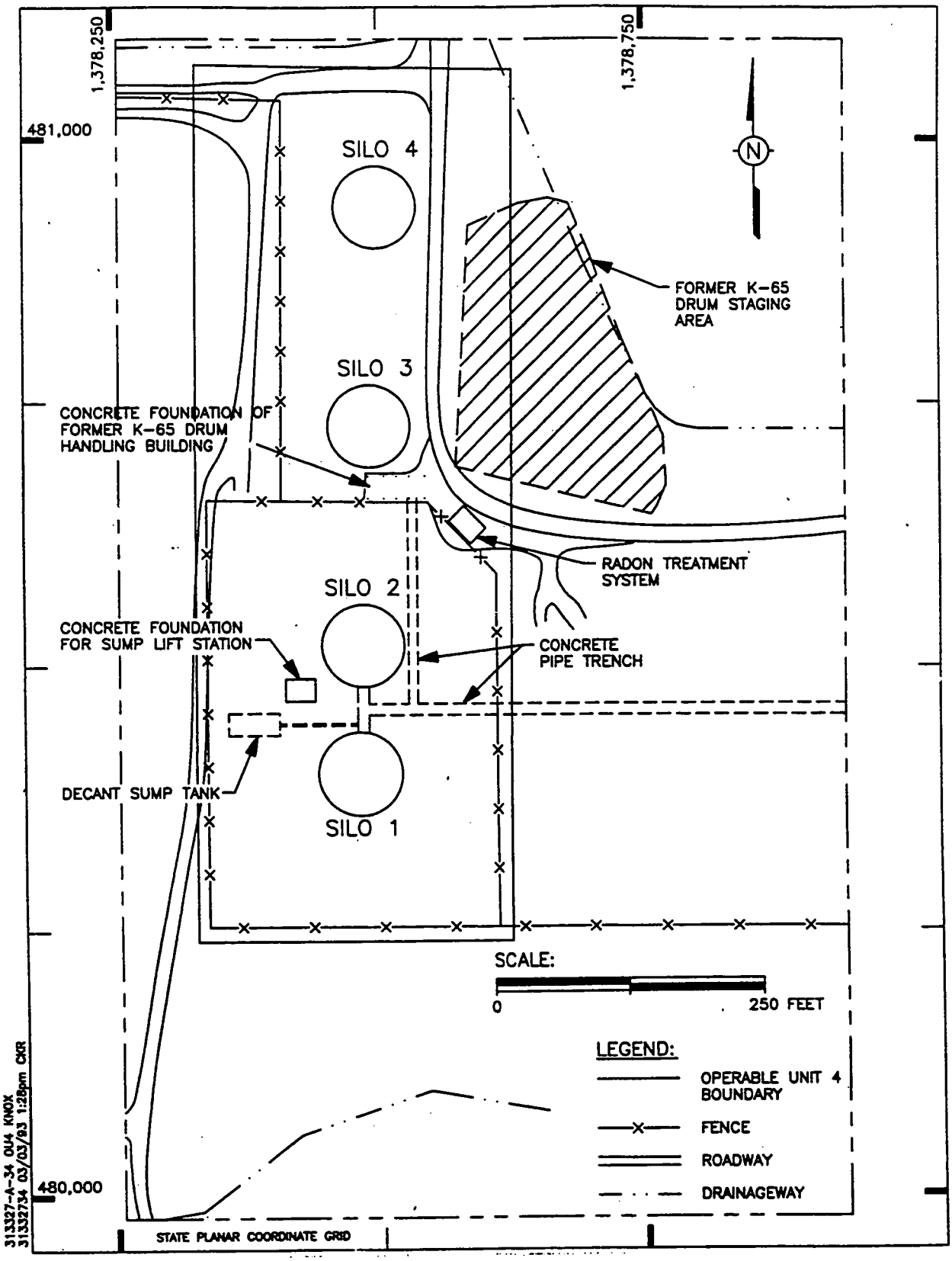

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- Perched groundwater near the silos that may be encountered during the implementation of cleanup activities.

1.3.2.2 Purpose and Need for Decision

Facilities and environmental media at the FEMP site, including OU4, contain radioactive and chemical constituents at levels that exceed certain federal and state standard and guidelines for protecting human health and the environment. Currently, DOE-FEMP maintains custody of the property and restricts access with fences and security forces, precluding a member of the public from being exposed to areas on the site having a higher degree of contamination.

A formalized risk assessment process was established by the EPA to determine whether a given waste site warrants the implementation of cleanup actions. Under this process, several hypothetical scenarios that could expose members of the public to site contamination are examined. One of these scenarios assumes site access is not controlled (unrestricted) and a member of the public could be exposed to the higher contamination areas. Results of the risk assessment performed for this hypothetical, unrestricted access scenario indicated that an individual establishing residence within the highly contaminated portions of the OU4 area, under existing conditions, would be subjected to an increased risk of incurring an adverse health effect. Risk assessment calculations performed for OU4 indicate the projected level of increased risk exceeds established federal regulatory guidelines. On the basis of the results of the baseline risk assessment, the DOE-FEMP concluded in the OU4 RI (FEMP 1993) that existing site conditions warrant RA. A summary of the original assessment results can be found in **Appendix F** of this FS.

The purpose of DOE-FEMP's environmental restoration program is to preclude the potential for impact on human populations, now and in the future, by implementing long-term cleanup solutions. The DOE-FEMP is addressing long-term management of the FEMP site through the aforementioned integrated environmental decision-making process.

The FEMP's site characterization and ongoing routine environmental monitoring programs provide information on the nature and extent of contamination, including information for areas off the FEMP property to which contaminants have migrated or could migrate in the future. The environmental monitoring program focuses on estimating the reasonable maximum exposure (RME) that current neighboring residents could potentially receive as a result of FEMP restoration activities. The environmental monitoring program provides data that can be examined over long periods of time (i.e., months, years, and decades) to provide an early indication of any adverse change in environmental conditions. The FEMP environmental monitoring program will continue throughout the remedy implementation of the OUs to ensure the continued protection of the neighboring public and site workers during remediation.

1.3.2.3 Description of the Original Selected Remedy

For OU4, the goal of the original RI phase was to compile existing environmental data at the site and undertake the necessary field investigations to develop a detailed understanding of: the condition and contents of Silos 1, 2, 3 and 4; the nature and extent of environmental medial within the OU4 boundary; and, the risk that the contaminants pose to human and environmental receptors. This detailed understanding was developed to the degree necessary to support the decision on whether RA was warranted and to support the evaluation of available RA alternatives in the FS. The final *Remedial Investigation Report for Operable Unit 4* (FEMP 1993) is available in the Administrative Record.

The purpose of the original OU4 FS was to develop and evaluate an appropriate range of remedial alternatives to address contaminated environmental media. The original OU4 FS was formatted to provide the appropriate type and level of information required for key stakeholders and decision makers to come to informed decisions. The original OU4 FS was prepared in accordance with EPA guidance (EPA 1988) and provides a conceptual level of detail on the alternatives evaluated. The final FS for OU4 is available in the Administrative Record.

A separate document, the PP, summarized the results of the OU4 FS and identified the preferred alternative for potential implementation. The PP provided the reader with a summary of RI results and FS information. Following consideration of agency and public comments, the ROD was issued documenting the selected alternative. The original *Record of Decision for Operable Unit 4 of the Feed Materials Production Center* (EPA 1994) is available in the Administrative Record.

The materials within the scope of OU4 exhibit a wide range of properties. Most notable is the elevated direct radiation and radon emanation characteristics of the Silos 1 and 2 material, compared to the lower direct radiation associated with the metal oxides in Silo 3, and lower levels of contaminated media associated with the soils and building materials, like concrete, within the original OU4 study area.

On the basis of the evaluation of remedial alternatives conducted in the original Feasibility Study/Proposed Plan (FS/PP), the major components of the selected remedy documented in the original OU4 ROD (EPA 1994) are as follows:

- Removal of the contents of the Silos 1, 2, 3 and the decant sump tank sludge.
- Treatment of the Silos 1, 2 and 3 material and sludges removed from the silos and the decant sump tank by vitrification to meet disposal facility waste acceptance criteria (WAC).
- Off-site shipment of the vitrified contents of Silos 1, 2, 3 and the decant sump tank for disposal at the NTS.
- Demolition of Silos 1, 2, 3 and 4 and decontamination, to the extent practicable, of the concrete rubble, piping, and other generated construction debris.
- Removal of the earthen berms and excavation of the contaminated soils within the boundary of OU4, to achieve remediation levels. Placement of clean backfill to original grade following excavation.
- Demolition of the remediation and support facilities after use. Decontamination or recycling of debris prior to disposition.
- On-property interim storage of excavated contaminated soils and contaminated debris in a manner consistent with the approved Work Plan for Removal Action 17 (DOE 1996), pending final disposition of soil and debris in accordance with the RODs of OUs 5 and 3, respectively.

- Continued access controls and maintenance and monitoring of the stored waste inventories.
- Institutional controls of the OU4 area such as deed and land-use restrictions.
- Potential, additional treatment of stored OU4 soil and debris using OU5 and OU3 waste treatment systems.
- Pumping and treating, as required, of any contaminated perched groundwater encountered during remedial activities.
- Disposal of the OU4 FEMP contaminated debris and soils consistent with the RODs for OUs 3 and 5, respectively.

Although the selected remedy documented in the original OU4 ROD specifies on-site disposal for the OU4 soil and debris, the final decision regarding the final disposition of the OU4 debris and soils was placed in abeyance, until the completion of the RODs for OUs 3 and 5 RAs, in order to take full advantage of planned waste management and treatment strategies by these OUs. This approach enabled the integration of disposal decisions for contaminated soils and debris on a sitewide basis. A more detailed discussion on the integration of the OU4 with other OUs is provided in **Section 1.3.3**.

1.3.2.4 Original OU4 Record of Decision

The original OU4 ROD (EPA 1994) was the final step in the RI/FS process for OU4. The OU4 ROD documents the original RA selection process for OU4. The OU4 ROD was prepared by DOE-FEMP in consultation with the EPA and the Ohio Environmental Protection Agency (OEPA). The OU4 ROD serves three main functions:

(1) As a legal document, it certifies that the remedy selection process was carried out in accordance with the requirements of Section 121(a) of CERCLA, as amended, and the NCP (1990) at 40 CFR Part 300.

(2) As a technical document, it outlines the engineering components and remediation goals of the selected remedy.

(3) As an informational document, it provides the public with a consolidated source of information about the history, characteristics, and risks posed by OU4, as well as cleanup alternatives considered, their evaluation, and the rationale behind selection of the preferred remedy.

The decision documented by the original OU4 ROD was based on the information available in the Administrative Record for OU4 and maintained in accordance with CERCLA (EPA 1988). The major documents prepared through the CERLCA process included the RI, the FS, and the PP for OU4.

The original OU4 ROD and the supporting CERCLA documentation [RI/FS and PP (FEMP 1994 a,c)] prepared for remediation of OU4 also includes the appropriate NEPA evaluations. These integrated CERCLA/NEPA evaluations considered the potential impacts of remediation activities at the FEMP. The OU4 FS/PP-Environmental Impact Statement (EIS) (FEMP 1994b) was the lead CERCLA/NEPA document for remediation of the FEMP. Therefore, it was intended that the original OU4 ROD serve as DOE-FEMP's ROD for OU4 under both CERCLA and NEPA; however, it was not the intent of the DOE-FEMP to make a statement on the legal applicability of NEPA to CERCLA actions. The integration of NEPA into the OU4 CERCLA process is explained in more detail in **Section 1.3.5**.

The original OU4 ROD's selected remedy of vitrification was presented to the public and considered (after the original FS/PP-Draft EIS was issued) input from stakeholders including that received from public hearings held on March 21, 1994, in Harrison, Ohio and on May 11, 1994, in Las Vegas, Nevada. In preparation of the original OU4 ROD, DOE-FEMP considered the comments received both during the public comment period for the original FS/PP-Draft EIS and following issuance of the final EIS. The original OU4 ROD was approved by the EPA in December 1994.

1.3.2.5 Regulatory Basis for the Revised Path Forward

In the Settlement (EPA 1997a), the DOE-FEMP and EPA agreed to proceed with the development of a ROD Amendment for the Silos 1 and 2 material and an ESD for the Silo 3 material (FEMP 1998a).

Pursuant with Section 117 of CERCLA and the NCP at 40 CFR Part 300.435(c)(2)(ii), a ROD Amendment should be processed when "differences in the remedial or enforcement action, settlement, or consent decree fundamentally alter the basic features of the selected remedy [in the ROD] with respect to scope, performance, or cost."

The EPA's position requiring a ROD Amendment for the Silos 1 and 2 material is based upon the specific circumstances that surround this situation. The EPA noted that some increase in remediation cost can be reasonably expected; but, whether the cost increase is considered *not significant, significant and requires an ESD,* or *fundamentally alters the selected remedy and must be addressed by a ROD Amendment,* has to be determined on a case-by-case basis. The EPA emphasized that, in this specific case where the final remediation cost estimated by DOE-FEMP for the Silos 1 and 2 material increased significantly [i.e., approximately greater than 5 times the original estimate], a ROD Amendment was required. Therefore, it was EPA's position that the anticipated cost changes - resulting from implementability issues with the treatment technology of joule-heated vitrification for the Silos 1 and 2 material - required a re-examination of the selected remedy and a ROD Amendment (EPA 1997b).

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With respect to the contents of Silo 3, DOE-FEMP considered several stabilization technologies in the original OU4 FS, including vitrification and cementation. In reevaluating the Silo 3 treatment remedy, DOE-FEMP again considered chemical (cement) stabilization and other potential alternatives to vitrification. Although changing the remedy for the Silo 3 contents from vitrification to another stabilization technology is *significantly* different from the remedy selected in the OU4 ROD, the EPA's position emphasized that such a change did not fundamentally alter the selected remedy. The EPA based this determination on three factors: (1) the scope of the remedy still encompasses the same waste material with ultimate disposal off-site, (2) the performance of the stabilization technology to be selected will meet the treatment objectives of vitrification, and (3) the cost of the stabilization technology to be selected [for Silo 3] will be essentially the same as that originally projected for vitrification. Consistent with the Dispute Settlement, the DOE conducted public hearings and prepared the Final ESD for OU4 Silo 3 Remedial Action (FEMP 1998a) with public input. The Final ESD for OU4 Silo 3 Remedial Action (with Responsiveness Summary) was submitted to the EPA in February 1998. The EPA concurred with the change in remedy and signed the ESD on March 27, 1998.

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1.3.3 Role of OU4 within the FEMP RI/FS Process (Integration of OU4 with Other OUs)

A diagram providing an overview of the RI/FS process, as it is being implemented at the FEMP site, is presented in **Figure 1.3-2**. While the OU concept provides a management strategy to expedite the cleanup process at a site, the concept does not negate the statutory requirement to ensure protection of human health and the environment from a sitewide perspective. To ensure sitewide protectiveness, the ACA provides for a Comprehensive Risk Assessment and Risk Evaluation (CRARE) within each OU FS. The intent of the CRARE process is to provide information regarding the residual risk projected to remain at the site following implementation of RAs for OUs 1-4, in conjunction with the contribution of residual risk attributable to the OU5 remedy. The intent of this process is to provide decision-makers with a perspective of the potential for a given remedial alternative, when coupled with projected actions for the other OUs, to effectively contribute to the protection of human health and the environment on a sitewide basis.

The RAs proposed in this revised FS are similar to those evaluated in the detailed analysis of the original OU4 FS. Because these proposed RAs identify off-site disposal as the remedy for treated Silos 1 and 2 material, the residual risk from Silos 1 and 2 material is minimal. This is consistent with information presented in the original FS and CRARE. Therefore, revisions to the CRARE are not expected.

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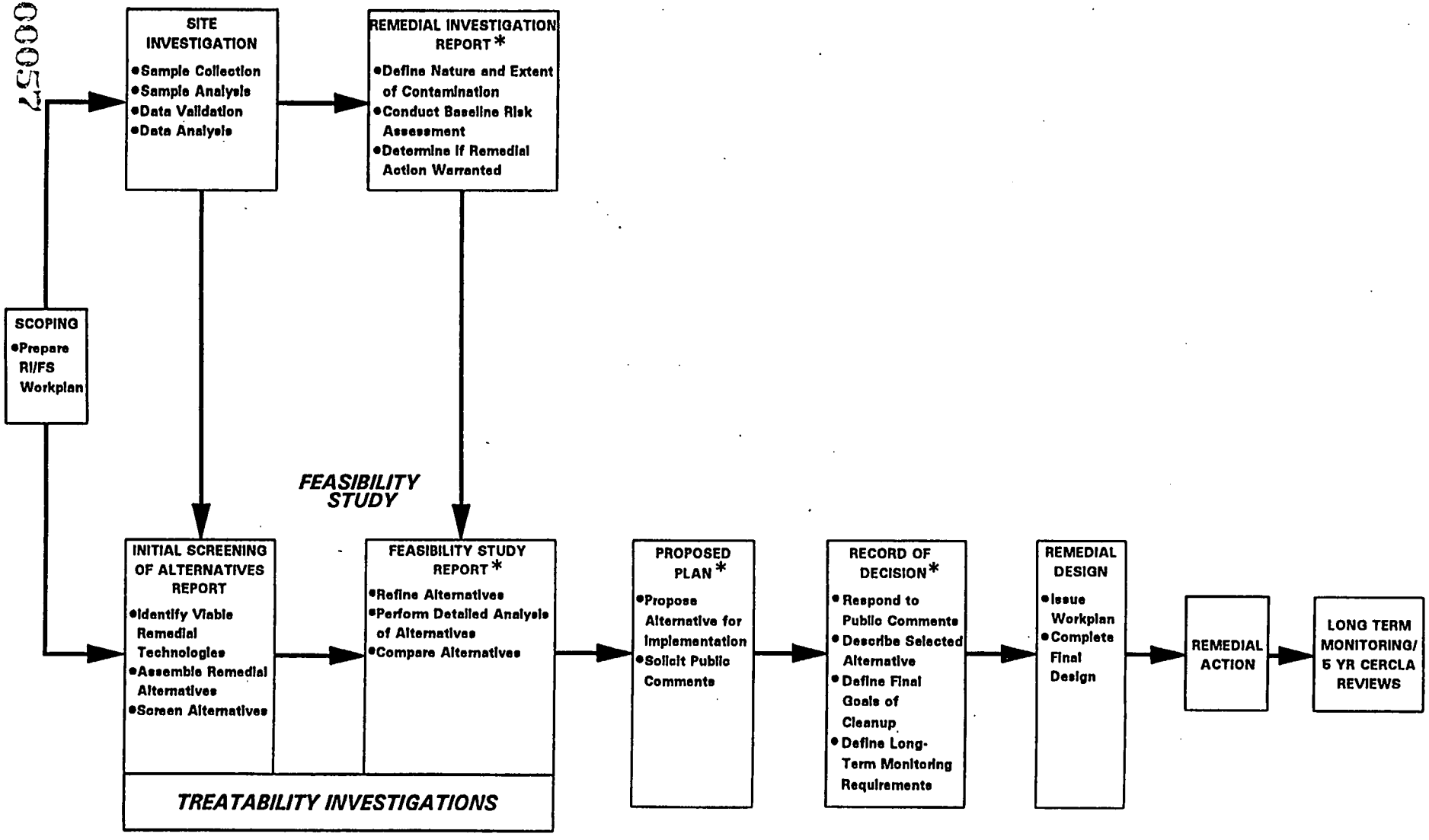

*DOCUMENT INCORPORATING NEPA REQUIREMENTS

FIGURE 1.3-2

FEMP ENVIRONMENTAL RESTORATION PROCESS

Integration with OU3

The decontamination and demolition (D&D) of the OU4 silos and the above-grade remediation facilities will be planned and performed in accordance with the FEMP OU3 ROD and the OU3 implementing RA documents [i.e., the Facility Closure and Demolition Project's "Project Execution Plan (PEP)"]. The hierarchy of regulatory and site requirements that govern the performance of OU4 D&D activities, flow down directly from the OU3 regulatory process by the OU3 Integrated Remedial Design/Remedial Action Work Plan and the OU3 Project-specific Implementation Plan. The OU4 remediation efforts will involve the in situ gross decontamination of interior and exterior surface of above-grade structures prior to dismantlement to reduce direct exposure potential, as well as reduce available sources for airborne or water-borne contaminant migration. Methods to be employed depend on the contamination type, level of contamination found, and materials on which it is found. Additional decontamination procedures are implemented during dismantlement to remove previously inaccessible contamination.

Above-grade dismantlement includes the removal of process equipment [e.g., Radon Control System (RCS) and the abandoned RTS], electrical equipment, piping, water lines, gas lines, tanks [(e.g., Transfer Tank Area (TTA)], heating ventilation and air conditioning ductwork, and electrical lines. The last steps of the dismantling action depend on the structure but generally involve the removal of any air filtration apparatus and the removal of the roof, exterior walls, and structural members. Once an acceptable area has been cleared down to grade level, at- and below-grade remediation (e.g., removal of OU4 foundations, storage pads, ponds, basins, underground utilities) begins.

Integration with OU5

Discrete data points were collected as part of the OU5 RI (FEMP 1994d) to characterize the nature and extent of contamination in environmental media at the site; the results of the data analyses are summarized in the OU5 FS (FEMP 1995b) and are discussed below.

The OU5 RI/FS examined soil on a site-side basis. All soil at the FEMP, not contemplated to be exhumed as part of a remedy for OUs 1 through 4, is considered within the scope of OU5. Soil considered includes soil under and adjacent to the waste pits, burn pit, and Clearwell (OU1); soil within OU2 but outside the proposed on-property disposal facility; soil underlying and adjacent to the Silos 1, 2, 3, and 4 including the earthen berms (OU4); and soil presently stored in piles and containers in or near the former production area (OU3). This approach has been adopted to allow the examination of soil on a sitewide basis such that comprehensive remedial alternatives could be formulated and evaluated and is consistent with presentations in the FS reports for OUs 1, 2, and 4. The ROD for OU4 established OU-specific soil preliminary remediation levels (PRLs) that were revisited by OU5. The OU5 ROD established final remediation levels for the sitewide soils, including OU4, based on a future land-use scenario. The OU5 ROD modified the OU4 soil remediation levels, which are in some cases more restrictive than the original OU4 PRLs. A more detailed discussion is provided in **Appendix F**.

The OU5 RI/FS process examined perched groundwater on a sitewide basis. It should be noted, however, that the ACA provides that each OU address perched groundwater envisioned to be encountered as a consequence of conducting RA. An example of such an incidence is the collection of perched groundwater in deep excavations completed to remove underground tank systems (Silos 1 and 2 Decant Sump Tank System), pits, or foundations. This collected water will be directed to OU5 wastewater treatment systems.

Process wastewaters generated during RAs conducted by all OUs will be directed to OU5 treatment systems [i.e., Advanced Wastewater Treatment (AWWT) facility]. OU5 has established pretreatment requirements to ensure that available treatment capabilities will not be exceeded by incoming wastewater streams. These requirements have been included in the **Design Basis and Description (Appendix G)** for the alternatives evaluated by this FS. These projected process wastewater streams have been factored into the OU4 remedial alternatives presented in this report.

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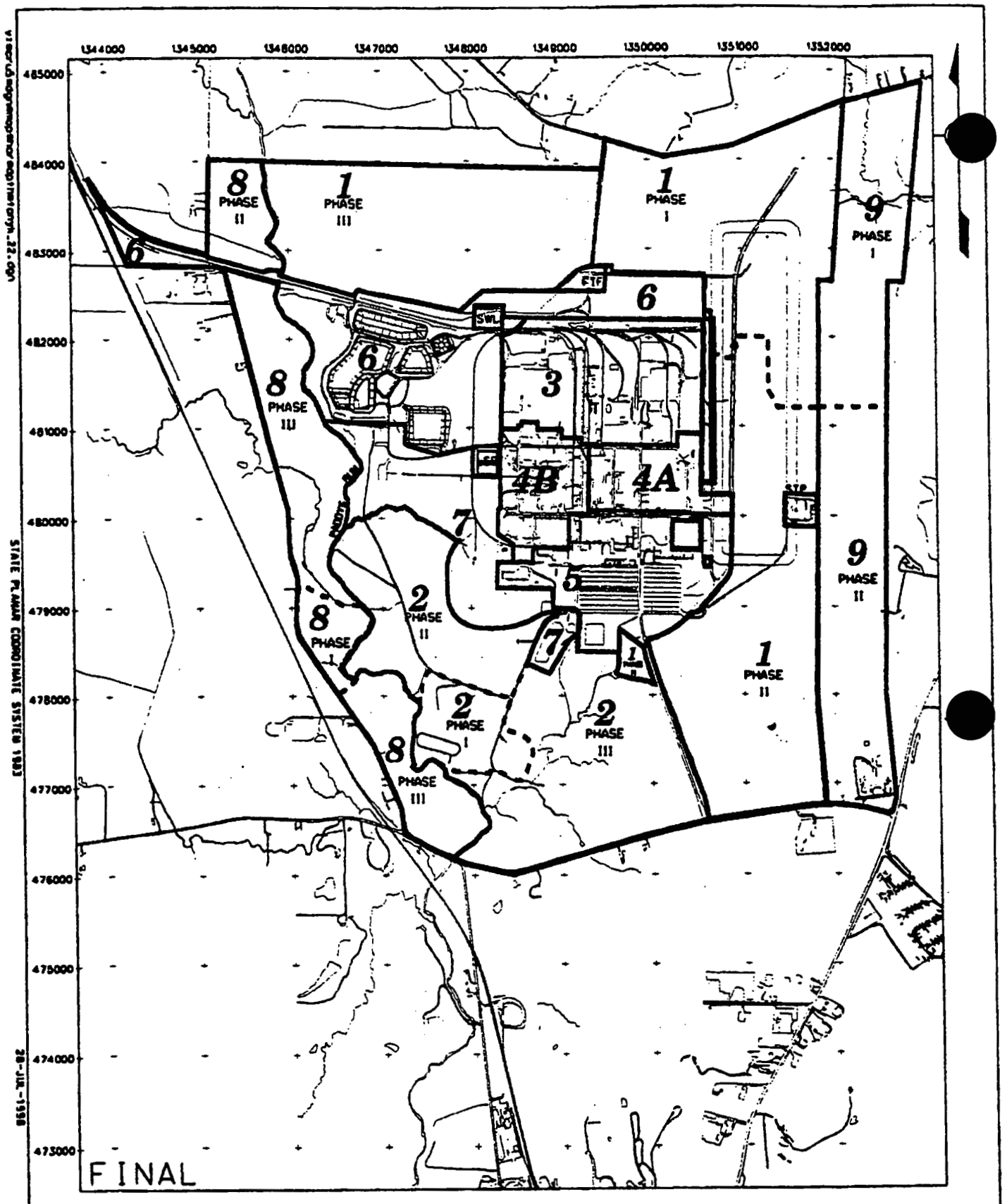
Integration with OU2

The FEMP On-Site Disposal Facility (OSDF) has a WAC for soils and debris that ensures that materials disposed within its confines, are protective of human health and the environment. The OSDF will be available for disposal of the existing silos structures, the RTS, the decant sump tank, other below-grade appurtenances, and Area 7 soils **(Figure 1.3-3)**. Soil and debris from D&D activities associated with these facilities will be disposed in the OSDF if they meet the WAC for disposal. The basis for protective disposal of this soil and debris in accordance with the OSDF WAC is discussed in more detail in **Section 3.2.4**. However, based upon the current operating schedule for the OSDF, the OSDF is not identified to be available to receive any soils and debris from the D&D of the OU4 remediation facilities. Therefore, this FS assumes that all soil and debris generated from D&D of the OU4 remediation facilities will be disposed at the NTS. In the event that the OSDF becomes available due to programmatic changes, the OU4 soil and debris from D&D of the remediation facilities could be disposed at the OSDF if they meet the WAC for disposal. Therefore, on-site disposal of OU4 soil and debris from D&D activities would continue to be protective of human health and the environment. This issue is discussed in more detail in **Section 3.2.4**.

1.3.4 Remedial Design/Remedial Action (RD/RA) Process

The RI/FS process is focused on developing technical data associated with remedial alternatives to the extent necessary to support an evaluation of each alternative against criteria established by federal guidelines. The alternative development process is typically completed at a preconceptual design level. While developing alternatives to this extent in the FS is sufficient to support remedy selection, a significant level of additional detail is required for the field implementation of the selected alternative. The process to provide this additional detail on the selected alternative is the RD. The purpose of RD is to complete the necessary engineering designs, specifications, and bid packages to enable the safe and cost-effective implementation of the selected alternative.



Legend:

Remediation Area Boundary

Phase Boundary Within A Remediation Area

Figure 1.3-3
Generalized Sitewide Remediating Areas - Sitewide Characterization and Excavation Project

The ACA specifies that a RD work plan be submitted by the DOE 60 days after finalization of the ROD or modification of a ROD (e.g., ROD Amendment or ESD) for each OU. The work plan is to contain a schedule for completion of the RD and establish the interrelationship among DOE-FEMP, EPA, and the OEPA regarding the design review and approval process. The RD process will revisit the preconceptual plans outlined in the FS for the selected alternative and make the necessary refinements and improvements to increase the level of technical detail to enable the implementation of the alternative. Such refinements will include reanalyzing the proposed process flow diagrams (PFDs), material balances, and fundamental technical assumptions underlying the selected alternative, without jeopardizing the goal of protecting human health and complying with regulations.

The ACA also requires the DOE to submit to the EPA for approval the RA work plan. The schedule for submittal of the RA work plan is to be established through the approved RD work plan. The RA work plan will include, but not be limited to, the following: a sampling and analysis plan that includes a quality assurance plan and a field sampling plan; a health and safety/contingency plan; a plan for satisfaction of substantive regulatory requirements, if any; and an operations and maintenance (O&M) plan. This work plan will also define the interrelationship among the remedial contractor, DOE-FEMP, the EPA, and the OEPA regarding the review and oversight of remedy implementation.

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1.3.5 Integration of OU4 with the National Environmental Policy Act

As previously stated, it is DOE policy to integrate NEPA requirements into the procedural and documentation requirements of CERCLA, wherever practicable. This policy is embodied within DOE Order 5400.4 defining the roles and responsibilities of the Department regarding compliance with CERCLA and the integration of the remedial process with NEPA. It is not DOE's intent to make a determination about the applicability of NEPA to CERCLA. In accordance with this policy, a Notice of Intent (NOI) was published on May 15, 1990, in 55 FR 20183 indicating the intent on the part of the DOE to prepare an EIS to evaluate the environmental impacts associated with planned cleanup activities at the FEMP site. Two scoping meetings were held in potentially affected communities located near the FEMP on June 12 and 13, 1990.

Consistent with the NOI, the FS for the lead OU (OU4) was issued as a FS/PP to incorporate NEPA values at the level of an EIS, resulting in an integrated FS/PP-EIS (FEMP 1994b). The OU4 RI Report (FEMP 1993) and the site-wide *Characterization Investigation Study* (Weston 1987) have been incorporated into the FS/PP-EIS by reference. These documents support both the description of the affected environment and the impact analysis of the site-wide, no-action alternative required in an EIS. As identified in the NOI, the RI/FS documents for the remaining OUs (OUs 1, 2, 3, and 5) have been written to include the NEPA values and tier from the OU4 FS/PP-EIS. This approach is consistent with the Regulations for Implementing the Procedural Provisions of the NEPA, as codified by 40 CFR Part 1502.20.

The CERCLA/NEPA integration strategy is outlined in the Implementation Plan for the NEPA/CERCLA integration activities at the FEMP, which was finalized in January 1993, and placed in the Administrative Record and the Information Repository at the FEMP Public Environmental Information Center (PEIC). 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/PP-EIS for OU4 and the CERCLA/NEPA documents for the remaining OUs.

Subsequent to the issuance of the Implementation Plan, DOE issued revised guidance regarding its policy for sites undergoing CERCLA investigation to eliminate the administrative requirement of preparing NEPA documentation. The revised policy, "Secretarial Policy Statement of National Environmental Policy Act," identified that the values of NEPA need to be evaluated in the development of CERCLA RI/FS documentation. The policy allows DOE to rely on the CERCLA process to satisfy the procedural aspects of NEPA. Therefore, DOE has supplemented the evaluations contemplated by RI/FS guidance to accommodate the evaluation of NEPA values in the preparation of this FS.

The RI for OU5 (FEMP 1994d) contains specific characterization data for environmental media that supports the description of the affected environment for NEPA purposes. In addition, the RI contains a baseline risk assessment addressing the impact on human health that is associated with the no-action alternative for OU5. The preliminary baseline ecological risk assessment contained in the sitewide characterization report addresses the entire FEMP and is based on data collected in each OU before December 1991. Later, new ecological data was collected and a revised sitewide ecological risk assessment was included in the OU5 RI and FS.

This FS contains the NEPA environmental impact analysis as part of the detailed analysis of each remedial alternative. The evaluation of environmental impacts will include a discussion of the impacts to biotic resources, socioeconomics, cultural resources, wetlands, and floodplains. The NEPA impact analysis is factored into the detailed and comparative analysis of alternatives presented in **Sections 3** and **4** of this revised FS and the identification of the preferred alternative in the PP. Additionally, this revised FS has been supplemented to incorporate the results of a NEPA Supplement Analysis **(Appendix D)**, which assesses the potential environmental impacts associated with the alternatives being considered in this revised FS against the results of the original OU4 FS/PP-EIS.

A baseline cumulative environmental impact analysis was included in the OU4 FS/PP-EIS for the purpose of assessing the potential cumulative impacts associated with the implementation of RAs at the OUs. This analysis employed representative remedial alternatives for each OU because the evaluation preceded the CERCLA decision process for these units. A revised representative remedial alternative was identified from the array of alternatives considered in the other FEMP OU FS reports for purposes of updating the cumulative environmental impact analysis.

1.4 Background Information

1.4.1 Site History

This section provides a brief summary of the history of the FEMP and description of OU4. A more detailed discussion can be found in **Appendix F, Section F.2** of this revised FS.

1.4.1.1 Overview of the FEMP site's Production Activities

During its operational years, the FEMP site's primary mission was to process uranium into metallic "feed" materials that were shipped, or "fed," to other DOE facilities for use in the nation's atomic weapons program. The production process at the FEMP site began with the recovery of uranium contained in residues that were either recycled from production or received from other sites. Scrap metals generated on-site or received from other sources were also recycled. The principal products were variously sized, highly purified uranium metal forms of assorted standard isotopic assays.

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1.4.1.2 Operating History of the FEMP site

The FEMP site was constructed from 1950 to 1951 under the authority of the Atomic Energy Commission (AEC), eventually known as the DOE. In 1951, National Lead of Ohio (NLO) Inc. entered into contract with the AEC as the Management and Operations Contractor for the facility. Operations began in 1951 upon completion of the Pilot Plant, the site's first operational facility. In 1960, production reached its peak. Beginning in 1964, reduced demand led to production declines. In 1981, the FEMP site began planning to accommodate increased activity due to the government's decision to increase uranium metal production for weapon and other programs.

On January 1, 1986, Westinghouse Materials Company of Ohio, a wholly-owned subsidiary of Westinghouse Electric Corporation, assumed management and operations responsibility for the site. Production ceased in the summer of 1989 due to a declining demand for uranium feed product; and, plant activities turned their focus to environmental cleanup. In June 1991, the site was officially closed for production by an act of Congress. To reflect a new mission focused on environmental restoration, the name of the facility was changed to the FEMP in August 1991. On December 1, 1992, the Fernald Environmental Restoration Management Corporation (FERMCO), a wholly-owned subsidiary of Fluor Daniel, Inc., assumed responsibility for managing the restoration.

1.4.2 Site Description

The FEMP site is a 425-hectare (1050-acre) facility located just north of Fernald, Ohio, a small farming community, and lies on the boundary between Hamilton and Butler Counties. Of the total site area, 345 hectares (850 acres) are in Crosby Township of Hamilton County, and 80 hectares (200 acres) are in Ross and Morgan Townships of Butler County. Other nearby communities include Shandon, New Baltimore, Ross, and Harrison (see **Figure 1.1 -1**).

1.4.3 History of Waste Generation and Storage of the Silos Material

Production operations at the facility were limited to a fenced 55-hectare (136-acre) tract of land, now known as the former Production Area, located near the center of the FEMP site. Large quantities of liquid and solid materials were generated during production operations. Prior to 1984, solid and slurried materials from uranium processing were stored or disposed in the on-property Waste Storage Area. This area, located west of the former Production Area, includes six low-level radioactive waste (LLRW) storage pits; two earthen-bermed, concrete silos containing "K-65 residues" (Silos 1 and 2); one concrete silo containing cold metal oxides (Silo 3); one unused concrete silo (Silo 4); two lime sludge ponds; a burn pit; a clearwell; and a solid waste landfill (see **Figure 1.4-1**).

Silos 1 and 2, known as the "K-65 Silos," contain the material generated from the processing of high grade uranium ores. This processing was completed to extract the uranium compounds from the natural ores. These ores, termed pitchblende, were shipped to the United States from a mine in the Belgian Congo (now known as Congo Kinshasa). The Silos 1 and 2 material contain high activity concentrations of radionuclides, including radium and thorium. The Silos 1 and 2 material was generated consequential to the processing of natural uranium ores and are therefore classified as by-product materials, consistent with Section 11(e)(2) of the Atomic Energy Act (AEA), generated consequential to the processing of natural uranium ores. A more detailed discussion of the Silos 1 and 2 material regulatory classification is provided in **Section 1.4.7**.

Silo 3 contains residues, known as "cold metal oxides," that were generated at the FEMP site during uranium extraction operations in the 1950s which involved the previously mentioned Belgian Congo ores and uranium concentrates received from a variety of uranium mills in the United States and abroad. The material within Silo 3 also contains significant activity concentrations of radionuclides; however, the activity is lower than the activity in the Silos 1 and 2 material. The material within Silo 3 is similarly classified as by-product materials pursuant to Section 11(e)2 of the AEA. Silo 4 was never used for waste storage; however, rain water has infiltrated into the silo.

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1.4.4 Contaminants Present in the Silos Material

The significant concerns associated with the Silos 1 and 2 material include:

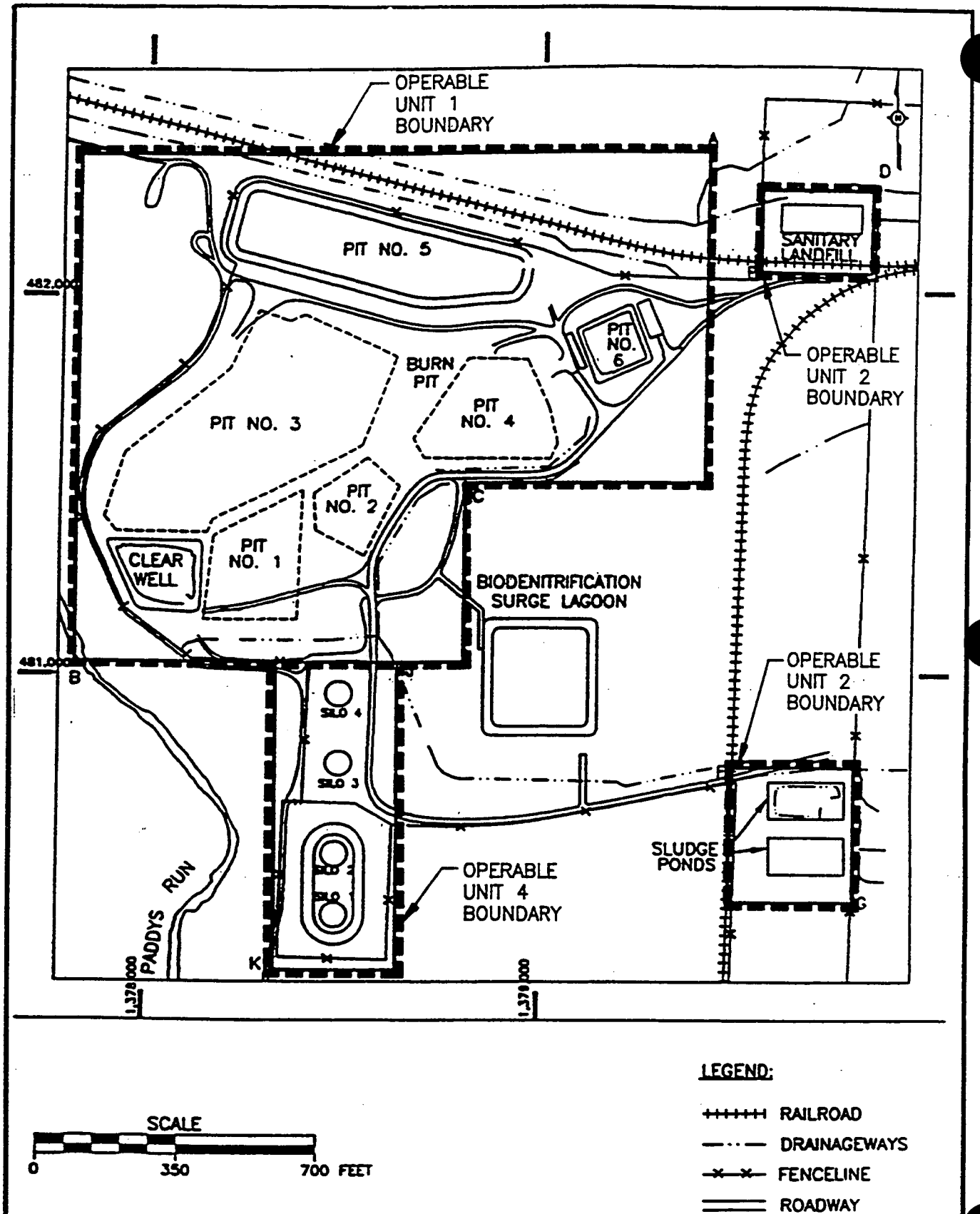
- High concentrations of radionclides, including radium and thorium, that are present in the K-65 residues.
- An elevated, direct-penetrating radiation field near the silos due to the radionuclides present in the silos material.
- Chronic emissions of radon (a radioactive gas from the decay of radium) from Silos 1 and 2 material into the atmosphere.
- The structural instability of the silo domes and the age of the remaining portions of the structures.
- The potential threat of the silos material leaching Resource Conservation and Recovery Act (RCRA) metals and radionuclides into the underlying sole-source aquifer.

The contents of Silo 3 also contain significant concentrations of radionuclides. The Silo 3 material has a significantly lower direct radiation field and radon emanation rate than the Silos 1 and 2 material; however, there is concern that dust particles would escape in the event of a silo structural collapse.

Silo 4 was never used for material storage and remains empty today, except for some rainwater that has accumulated in the silo through the leaky silo dome. It is not considered a current or potential threat to the environment.

FIGURE 1.4-1

WASTE STORAGE AREA



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1.4.4.1 Characteristics of the OU4 Stored Residue Inventories

This section summarizes available characterization data obtained during the original RI on the nature of the radiological and chemical constituents of the material presently stored within Silos 1, 2, and 3 in the OU4 study area. Also included is a brief description of the contents of the decant sump tank located under Silos 1 and 2, the contents of Silo 4, and the RTS. More detailed discussions on the nature of these stored materials and facilities can be found in Chapter 4.0 of the RI for OU4 (FEMP 1993) or **Appendix F, Section F.2** of this FS.

Contents of Silos 1 and 2

Silos 1 and 2 contain "K-65 residues" and BentoGrout™ clay. The BentoGrout™ clay layer was added in 1991 to the Silos 1 and 2 material in order to reduce radon emanation from the "K-65 residues." Radionuclides at significant activity levels within these silos are actinium, radium, thorium, polonium, and a radioactive isotope of lead (lead-210). These radionuclides are naturally occurring elements found in the original ores processed at the FEMP and Mallinckrodt. It is estimated that the silos contain approximately 27 metric tons (30 tons) of uranium.

Non-radiological constituents detected in significant concentrations in Silos 1 and 2 material include sodium, magnesium, nickel, barium, lead, calcium, iron, and tributyl phosphate (a solvent used in the former uranium extraction process at the FEMP). Tests performed on samples of stored material identified that lead can leach from the untreated material in concentrations that exceed federal guidelines typically applied to hazardous wastes.

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Decant Sump Tank System

Samples from the water within the decant sump tank during 1991, revealed elevated concentrations of lead-210, polonium, radium, and uranium. Analytical results also revealed the presence of above background concentrations of strontium and technetium. With the exception of these latter two constituents, radiological contaminants present in the decant sump tank are consistent with the relative concentrations of constituents found in Silos 1 and 2. This result confirms that the decant sump tank is continuing to collect leachate from the underdrains in Silos 1 and 2, as it was designed to do. Strontium and technetium are by-products of nuclear fission and are not present in Silos 1 and 2. Strontium and technetium are present in the environment due to fallout from past atmospheric world-wide nuclear weapons testing. Their presence in the decant sump tank indicates that some surface water has probably leached into the Decant Sump Tank System.

The metals found in liquid samples from the decant sump tank included aluminum, antimony, arsenic, chromium, copper, lead, molybdenum, selenium, silver, vanadium, and zinc. In addition, 18 organic compounds were detected in the decant sump tank liquids at low concentrations. With the exception of toluene, all volatile compounds detected were at or below concentrations that represent the laboratories' ability to accurately quantify the level of the constituents.

Radon Treatment System

The RTS was installed in November 1987, to reduce the radon inventory within the headspace of Silos 1 and 2. Following RI/FS sampling of Silos 1 and 2 material in 1989, the RTS was abandoned in place. The RTS was sampled during a removal site evaluation in January 1992. The predominant contaminant present is lead-210 and its associated decay products. Periodic surveys for direct radiation and removable fixed radioactive contamination reveal that only isolated contamination is present in accessible portions of the RTS.

Silo 3

During the 1989 sampling of Silo 3 material, 12 radionuclides were identified, including actinium, lead-210, and the major isotopes of radium, thorium, and uranium. Thorium-230 had the highest activity concentration. These sample results are consistent with process knowledge. Present within the silos material is approximately 40 metric tons (44 tons) of uranium.

Of the 23 inorganic constituents detected, those with the highest relative hazard include arsenic and vanadium. Results from sampling in 1989 indicated that the Silo 3 material leaches arsenic, chromium, and selenium at levels exceeding comparable limits applied to hazardous wastes. It has also been concluded that organics are not present in Silo 3 material due to high material processing temperatures before material transport for storage in the silos.

Silo 4

Silo 4 was never employed for the storage of wastes or in-process materials and remains empty. Inspection completed on Silo 4 during the RI/FS site investigations confirmed that waste materials were not present within the silo.

1.4.5 Contaminated Environmental Media

In addition to the waste areas described in **Section 1.4.4**, contamination is present in environmental media within the OU4 area, such as surface and subsurface soil, soils within the earthen berm surrounding Silos 1 and 2, groundwater, surface water, and perched water.

Principal Threats

The NCP describes principal threats as those involving liquids, areas contaminated with high concentrations of hazardous materials and highly mobile materials. Consistent with the NCP, the OU4 RI provided a detailed characterization of the source term within OU4 and identified those contaminants that contributed to an incremental lifetime cancer risk (ILCR) value greater than 1×10^{-6} and a hazard quotient greater than 1.0. The OU4 RI identified that the principal threats to human health and the environment posed by the OU4 are from the following contaminant/transport pathways:

- Direct radiation
  - Direct exposure to gamma radiation from radioactive constituents within the silos.
  - Direct exposure to Silo 3 material under the future source term scenario assuming structural collapse of the silo.
  - Direct exposure to gamma radiation from radioactive constituents in surface soil.
- Air emissions
  - Dispersion of radon that escapes from the silos into the atmosphere.
  - Dispersion of volatile organic compounds (VOC) or fugitive dust generated from soil.
  - Dispersion of Silo 3 contents under the future source term scenario assuming structural collapse of the silo.
- Surface water runoff
  - Erosion of contaminated soils into Paddys Run from the vicinity of the silos.
  - Erosion of released Silo 3 contents under the future source term scenario assuming structural collapse of the silo.
- Groundwater transport
  - Leaching of contaminants from the silo contents via soils to underlying groundwater.
  - Leaching of contaminants from the silo contents via soil to a sand silty/clay lens in the glacial till, which could carry contaminants to surface water and sediment in Paddys Run.

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Potential remedial alternatives for OU4 were developed in order to: mitigate the short-term and long-term exposure and associated risks from gamma radiation; reduce radon emanation rates from the Silos 1 and 2 material; minimize the leachability of contaminants from the waste material; eliminate potential of air dispersion from a silo collapse; eliminate the dispersion of fugitive dust generated from the soil; and, eliminate contaminate surface water runoff from contaminated soils into Paddys Run.

In accordance with 40 CFR Part 300.415, interim remedial measures and time critical removal actions were initiated to accelerate cleanup activities to address releases or potential releases of hazardous substances from OU4. These actions included the following:

- Application of a rigid layer of polyurethane foam insulation to the exterior of the Silos 1 and 2 dome surfaces to control the release of radon from the silos (1987);
- Installation of a BentoGrout™ clay layer over the Silos 1 and 2 material to reduce the potential for the release of radon to the environment (1991);
- Removal of the liquid in the Decant Sump Tank to mitigate the potential for release of contaminants to subsoils and the perched water zone (1991); and
- Removal of a dust collector positioned atop Silo 3 which contained hold-up material (1991).

1.4.6 Overview of the Nature and Extent of Contamination

This section summarizes the nature and extent of contamination within environmental media in the OU4 study area. Also included in this section is an overview of the levels of direct radiation associated with the current conditions within OU4. Additional detail on these conditions is provided in **Appendix F, Section F.2.3** and Section 4 of the OU4 RI.

Surface Soils

Sampling performed as part of the RI/FS and other site programs near OU4 indicates the occurrence of above background concentrations of uranium, and to a lesser degree other radionuclides, in the surface soils within and adjacent to the OU4 study area. Activity concentrations observed during the RI for the surface soils near OU4 were as much as 20.8 picoCuries per gram (pCi/g) for uranium (U)-238, or 16 times natural background, and 4.8 pCi/g for thorium (Th)-230, or two times background. These above background concentrations appear to be generally limited to the upper six inches of soil. Available survey data and process knowledge do not indicate a direct relationship between the surface soil contamination in the OU4 study area and the silo contents. Further, more than 70 % of the surface soil samples indicate that the uranium contamination in surface soils is depleted uranium (i.e., the uranium contains depleted percentages of U-235). This result is inconsistent with the silos material that consists of natural uranium. Thus, the existence of these activity concentrations in the surface soils are attributed to air deposition resulting from the former Production Area and past plant production operations and/or waste handling practices in the waste pit area.

Soil samples were also collected from the soils contained in the earthen embankment (berm) surrounding Silos 1 and 2. The analytical data from the berm fill show only slightly elevated radionuclide activity concentrations. Uranium was the predominant contaminant with activity concentrations less than 4 pCi/g, or approximately three times background. In addition to U-238, activity concentrations of polonium (Po)-210 and lead (Pb)-210 ranging up to 10 and 6 times background, respectively, were identified in the berm fill. These radionuclides are produced from the natural radioactive decay of radon (Rn)-222. Their presence in the berm fill is a direct result of Rn-222 escaping the silos. Once outside the silo and in the soil, the radon decays to Pb-210 and then Po-210.

One sample collected as part of the berm investigations was retrieved from an interval that closely reflected the original ground surface prior to berm installation. Analytical results from this sample showed distinctly higher concentrations of radionuclides than other samples collected within the berm soils. Uranium and radium concentrations in the sample were 19 and 580 times background, respectively. This sample clearly indicates the occurrence of some spillage or seepage from the silo onto the original surface soils adjacent to the silo at the location.

Subsurface Soils

As part of the OU4 RI, samples were collected from the subsurface soils located under and adjacent to Silos 1 and 2. Analytical results revealed elevated concentrations of radionuclides from the uranium decay series in the soils at the interface between the berm and the original ground level. Elevated concentrations (up to 53 pCi/g for U-238, about 40 times background) were also noted in slant boreholes, which passed in close proximity to the silo underdrains.

The occurrence of these above background concentrations in soils near the silo underdrains are attributed to vertical migration of leakage from the silo underdrains or decanting system. Elevated readings at the interface between the silo berms and the native soils are attributed to historical air deposition or past spillage from the silos during filling operations in the 1950s, before installation of the berms.

Surface Water and Sediment

Extensive sampling was conducted on the sediment and surface water present in Paddys Run and on key drainage swells leading to Paddys Run, as part of the OU4 RI and other site programs. Results of the surface water sampling indicate the occurrence of above background concentrations of U-238, up to 1,500 times background, in the drainage swales near Silos 1 through 4. The highest readings were recorded in a drainage ditch that flows from east to west, located approximately 250 feet south of Silo 1. The most probable source of the contamination in Paddys Run and the drainage swells is the resuspension of contaminated particles from surface soils within the OUs 4 and 1 study areas into stormwater.

Groundwater

With the exception of perched groundwater encountered during potential RA, groundwater within the Great Miami Aquifer underlying the silo area is not within the scope of OU4. Groundwater in the Great Miami Aquifer underlying the entire FEMP site is being addressed as part of OU5. Groundwater samples were collected from wells within the OU4 study area during the RI. Groundwater occurs not only in the Great Miami Aquifer underlying the FEMP site, but also in discrete zones of fine-grained sands located in the soils above the lower aquifer. The water contained in these sand pockets in the clay-rich glacial soils are termed "perched water zones." Samples were collected from: slant borings placed adjacent to and under Silos 1 and 2; 1000-series wells screened in the glacial overburden; 2000-series wells screened at the water table in the Great Miami Aquifer; and 3000-series wells screened at approximately the central part of the Great Miami Aquifer, just above the clay interbed.

Perched Water

Uranium was the major radionuclide contaminant found in the perched water. Elevated concentrations of total uranium were detected in the slant boreholes under and around Silos 1 and 2. Slant Boring 1617, immediately southwest of Silo 1, contained the highest concentration of total uranium [9240 micrograms per liter (µg/L)]. Uranium concentrations were also elevated in samples collected from the 1000-series wells. The highest observed total uranium concentrations obtained from 1000-series wells were in samples collected from Well No. 1032, located 150 feet due west of Silo 2. The range of the concentrations was 196 to 276 µg/L. Considering both the slant borings and 1000-series wells, U-238 was found in the range of 1.1 to 1313 pCi/L.

The major inorganic constituents found in the perched water samples, taken from the 1000-series wells and the slant borings, included elevated concentrations for major cations (iron, magnesium, mangenese, and sodium) and major anions (chloride, nitrate, and sulfate). In particular, the concentrations of sodium, sulfate, and nitrate were significantly above background in slant boring samples. Boring 1615, northwest of Silo 2, had the highest soduim concentration [1,040 milligrams per liter (mg/L)], boring 1618, southeast of Silo 1, had the highest sulfate concentration (2,200 mg/L), and boring 1617 had the highest nitrate concentration (554 mg/L). Low levels of organic constituents, determined to be contaminants, were detected in some samples. Overall, well measurements and analytical results confirmed that the perched groundwater nearOU4 flows from east to west. Further, OU4 is contributing to contamination of perched groundwater in this region of the site.

Great Miami Aquifer

The concentration of total uranium in the upper portion of the Great Miami Aquifer, based on analysis of samples from the 2000-series wells, ranged from less than 1µg/L to 40.3 µg/L. These data do not necessarily suggest that the silos are the source of the observed contamination because both upgradient and downgradient wells contain above background concentrations of total uranium. Well No. 2032, located 150 feet west of Silos 1 and 2, exhibited a concentration of total uranium at 39.0 µg/L. Well No. 2033, located 150 feet east of Silos 1 and 2, exhibited a concentration of total uranium at 40.3 µg/L. Because groundwater flow in this region of the Great Miami Aquifer is from west to east, these two wells are located upgradient and downgradient of OU4, respectively.

The isotopic ratios of U-234 and U-238 suggests a natural uranium ratio in these samples. Such a ratio may be expected from OU4, but is not a "fingerprint" for this source. The presence of uranium upgradient in the aquifer from an OU4 source could be explained by leachate travel in the perched groundwater zone of the glacial overburden with emergence to Paddys Run. Here the diluted leachate could enter the aquifer via stream bed infiltration of flow at the perched zone/stream channel interface. Evidence is not available to support or preclude this potential route.

The concentration of total uranium measured at deeper levels in the Great Miami Aquifer (3000-series wells) ranged from less than 1 to 4 µg/L, with the exception of 1 sample out of 16, which contained 15 µg/L. Like the 2000-series wells, a conclusion could not be drawn to link this contamination to the silos.

1.4.7 Regulatory Classification of Silos 1 and Material

The Silos 1 and 2 material is a complex wasteform from a regulatory perspective. A complete listing of the ARARs for its remediation is provided in **Appendix A**. The ARARs for its removal, treatment, and disposal are significantly influenced from its classification under the AEA, CERCLA, RCRA, and the U.S. Department of Transportation (DOT).

1.4.7.1 Regulatory Classification of Silos 1 and 2 Material

The material contained in Silos 1 and 2 is 11(e)(2) by-product material resulting from the processing of uranium ore concentrates. It is specifically exempt, as defined, from regulation as solid waste under RCRA 40 CFR Part 261.4(a)(4). The referenced exclusion applies to "... source, special nuclear or by-product material as defined in the Atomic Energy Act of 1954 as amended, 42 U.S.C. 2011 *et seq.*" The AEA defines by-product material as: (1) "any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material," and (2) "the tailings or waste produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content" [AEA Section 11(e)(1) and (2)]. Since a material must first be a solid waste in order to be a hazardous waste, and since the silos material is excluded from regulation as solid waste, the Silos 1 and 2 material are not defined as hazardous waste under RCRA 40 CFR Part 261.

Silos 1 and 2 material falls under the 11(e)(2) classification of by-product material. Silos 1 and 2 contain material from the chemical extraction (beneficiation) of uranium from ores. Other solid or hazardous wastes were not added to the silos material. Therefore, the contents of Silos 1 and 2 meet the definition of "by-product materials" and are not classified as "solid wastes" or "hazardous wastes" subject to regulation under RCRA.

The metals found in the material were present in the natural ore and were unintentionally extracted from the parent ore along with the uranium during the process of beneficiation, becoming more concentrated in the residue after the uranium was removed. The presence of natural metals is expected in by-product material and neither invalidates the definition nor the exclusion. Based on process knowledge and historical records, metals from a non-ore source were not added to the stream at any point in the beneficiation process; also, hazardous waste or waste constituents were not added or created at any time during the beneficiation process. Although the lead in the Silos 1 and 2 material fails the RCRA Toxicity Characteristic Leaching Procedure (TCLP), this does not cause the material to become subject to RCRA regulation due to a hazardous waste characteristic. The metals are not from an external source, they are associated with the parent material (whose residues, including any ancillary metals, are excluded from the definition of solid waste).

1.4.7.2 Remediation Under CERCLA

The FEMP site was placed on the NPL under the NCP in 1989. Therefore, contamination at the FEMP site is undergoing remediation pursuant with CERCLA. The materials in Silos 1 and 2 are considered "pollutants or contaminants," as that term is defined under CERCLA and the NCP. The term includes but is not limited to:

> "any element, substance, compound, or mixture, including disease-causing agents, which after release into the environment and upon exposure, ingestion, inhalation, or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, will or may reasonably be anticipated to cause death, disease, behavioral abnormalities, cancer, genetic mutation, physiological malfunctions (including malfunctions in reproduction) or physical deformations, in such organisms or their offspring .... For purposes of the NCP, the term pollutant or contaminant means any pollutant or contaminant that may present an imminent and substantial danger to public health or welfare."

CERCLA provides guidance on the specific cleanup standards that should be applied to a RA, or to the criteria for choosing among remedial alternatives when implementing regulations for CERCLA under 40 CFR Part 300 (which is the NCP). The EPA has established nine evaluation criteria for choosing among RAs in Subpart E - Hazardous Substance Response, 40 CFR Part 300.430(e)(9). One of these nine criteria states that the action will comply with ARARs. The NCP further defines the criteria for remediation of a facility by requiring that on-site RAs must *attain or exceed* the ARARs in federal and state environmental and public health laws.

Because Silos 1 and 2 material is classified as by-product material as defined under Section 11(e)(2) of the AEA of 1954, as amended, and is excluded from the definition of solid waste, requirements under RCRA are not applicable. However, based on analytical data from the OU4 RI, leachate from the Silos 1 and 2 material exceeds the toxicity characteristic (TC) limit for lead established for hazardous waste in 40 CFR Part 261.24. The lead in the material demonstrates mobility by exhibiting the TC that RCRA is designed to control, and it poses a potential threat to groundwater that may be used for human consumption. Therefore, the Silos 1 and 2 material is sufficiently similar to hazardous waste regulated by RCRA and some RCRA requirements are relevant and appropriate for its management on-site.

The NCP under 40 CFR Part 300.430(f)(1)(ii)(E) requires that "each RA shall utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable." Preference shall be given to alternatives that provide treatment as a principle element and bias against off-site land disposal of untreated waste. The selected alternative shall provide long-term protectiveness of human health and the environment, meet all ARARs that are identified in the ROD, and provide the best balance of trade-offs among alternatives in terms of the five balancing criteria.

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The CERCLA off-site rule (found in CERCLA Section 121(d)(3) and promulgated at 40 CFR Part 300.440) requires that waste from a RA that is shipped off-site for treatment and/or disposal be transferred only to those units at a facility that (1) are operating in compliance with RCRA and other applicable federal and state requirements, and (2) do not have any uncontrolled releases of hazardous waste or constituents. The rule applies to any RA involving the transfer of hazardous substances, pollutants, or contaminants as defined under CERCLA Sections 101(14) and (33) pursuant to any CERCLA authority, including cleanups at federal facilities [40 CFR Part 300.440(a)(1)]. Therefore, although the silos material is defined as AEA 11(e)(2) by-product material and excluded from regulation under RCRA, the CERCLA off-site rule specifically applies to treatment or disposal of Silos 1 and 2 material. In a letter dated July 7, 1998, the EPA Region 9 granted approval to the NTS to dispose of CERCLA waste from DOE facilities in waste management units 3 and 5 in accordance with the Off-site Rule (40 CFR Part 300.440). As clarification, the EPA Region 9, in a letter dated December 4, 1998, has stated that the CERCLA Off-site Rule approval for the NTS waste management units 3 and 5 includes management of small volumes of 11(e)(2) by-product materials from Fernald OU4 as low-level waste under the provisions of Chapters III and IV of DOE Order 435.1 or any subsequent applicable DOE directive.

1.4.7.3 Packaging, Transportation and Disposal

Appendix E evaluates the short-term risks associated with the transportation of the treated Silos 1 and 2 material both by direct truck and intermodal shipments to the NTS. The implementation of either transportation option presents a risk to the public within the CERCLA target risk range of 1×10^{-4} to 1×10^{-6}.

For purposes of waste management and proper disposal at the NTS, the material is classified as by-product material as defined in Section 11(e)(2) of the AEA of 1954, as amended. For purposes of proper transportation, the material is governed by the DOT regulations under 49 CFR Subtitle B Chapter I Subchapter C, *Hazardous Materials Regulations*.

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Federal Regulations promulgated by the DOT on September 28, 1995 (60 FR 50292) categorize low specific activity (LSA) material into three classifications: LSA-I, LSA-II, and LSA-III. Evaluation of the radionuclide content for Silos 1 and 2 material indicates that this material meets one of the criteria for LSA-II material. Specifically, Silos 1 and 2 material is considered material in which the Class 7 (radioactive) material is essentially uniformly distributed and the average specific activity does not exceed 10^{-4} A_2/g for solids..." (49 CFR Part 173.403). Therefore, the OU4 Silos 1 and 2 material is classified as LSA-II material for proper transportation.

Similar to the determination of whether Silos 1 and 2 material meets the criteria for LSA material, an evaluation determined whether Silos 1 and 2 material should be classified, due to the presence of U-235, as *fissile material* or *fissile exempt* material under the DOT regulations. The definition for fissile material excludes "Unirradiated natural uranium and depleted uranium and natural or depleted uranium which has been irradiated in thermal reactors." This criterion applies to nuclear fuel rods or elements containing uranium and thorium. Silos 1 and 2 material does not meet the definition of unirradiated uranium or unirradiated thorium. Therefore, this exclusion does not apply to the Silos 1 and 2 material.

DOT provides exceptions from classification of material as fissile material under 49 CFR Part 173.453. One of the exceptions is the requirement that a package not contain more than five grams of fissile radionuclides in any 10-liter volume [49 CFR Part 173.453(d)]. Because the Silos 1 and 2 material, including the proposed treated wasteforms, meet this criterion, the Silos 1 and 2 material can be classified as fissile exempt under DOT regulations. **Appendix E** provides a detailed discussion for classification of the Silos 1 and 2 material as LSA-II and fissile exempt under DOT requirements.

As stated previously, Silos 1 and 2 material is classified as LSA-II material under DOT regulations. Because the modeled radiation level associated with the unshielded Silos 1 and 2 material does not exceed 1 roentgen equivalent man per hour (rem/h) at 3 meters (m), DOT does not restrict the quantity of Silos 1 and 2 material within a single package.

The regulations require, at a minimum, an industrial package-type 2 (IP-2) container to be used for shipments of LSA-II material. IP-2 containers must meet the general design requirements established in 49 CFR Part 173.410. In addition, the regulations require IP-2 containers to undergo the free drop test [49 CFR Part 173.465(c)] and the stacking test [49 CFR Part 173.465(d)]. These tests ensure the following: (1) prevention of loss or dispersal of the radioactive contents, and (2) increases no greater than 20% (maximum) in the radiation levels recorded or calculated at the external surface of the container. The container must also meet the design requirements established in the NTS WAC.

The quantity of material that will be placed in a single container is limited by the rated capacity of the container while the quantity placed on each truck is limited to an amount that maintains each shipment within legal over-the-road weight limits.

Packages of treated Silos 1 and 2 material will be shipped under "exclusive use" conditions to the NTS. Therefore, the container must be designed to meet the following radiation level limitations during transportation:

- 200 milli-Roentgen equivalent man per hour (mrem/hr) on the external surface of the package;
- 200 mrem/hr at any point on the outer surfaces of the transport vehicle, including the top and underside of the vehicle;
- 10 mrem/hr at any point two meters from the outer lateral surface of the transport vehicle, excluding the top and underside of the vehicle; and
- 2 mrem/hr in any normally occupied space, except where private carriers operate under a state or federally regulated radiation protection program and the personnel wear radiation dosimetry devices.

In addition, the DOE has promulgated (under 10 CFR Part 835) that areas, in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 100 mrem/hr at 30 centimeters (cm) from a radiation source, are to be classified as high radiation areas. Therefore, the container must provide the necessary shielding to meet this requirement.

As stated previously, based on its origin, the FEMP OU4 Silos 1 and 2 material meets the definition of an 11(e)(2) by-product material.

DOE derives authority from the AEA to manage small quantities of 11(e)(2) by-product material as "low-level waste" so that it may dispose of such small waste quantities at DOE low-level waste disposal facilities. Such quantities must not be "too large for acceptance at DOE low-level waste disposal sites," and such wastes must meet the requirements for low-level waste in accordance with DOE Order 435.1, Chapter 4 (B)(4). The quantity of treated Silos 1 and 2 material offered by DOE-FEMP is accommodated at the NTS and is not a "large volume of diffuse material at several locations," or a mine site, as would be regulated by the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978.

The treated Silos 1 and 2 material is 11(e)(2) by-product material and may be managed as a low-level waste pursuant to DOE Order 435.1, and as such, it must meet the NTS WAC and therefore may not contain a RCRA listed waste, or exhibit a RCRA characteristic, regardless of the exclusion defined for by-product material at 40 CFR Part 261.4(a)(4).

Since, as previously discussed, the Silo 1 and 2 material is exempt from regulation as a hazardous waste under RCRA, compliance with the RCRA Land Disposal Restrictions Universal Treatment Standards is not applicable to the disposal of treated Silos 1 and 2 material at the NTS. As long as DOE-FEMP demonstrates that the treated Silos 1 and 2 material does not exhibit any hazardous waste characteristics and that it meets other provisions of the NTS WAC, the material can be accepted for disposal. This position is formally documented in a position paper issued by DOE-NV outlining the WAC to be applied to FEMP OU4 11 (e)(2) material (DOE 1999d).

DOE-FEMP will be responsible for demonstrating compliance with the NTS WAC. Specifically, DOE-FEMP will document the absence of the hazardous characteristics defined at 40 CFR Subpart C, especially those toxic constituents identified in Table 1 of 40 CFR Part 261.24 that may have been used in any processes, regardless of the waste's regulatory status. Official approval of the wastestream is documented under separate cover after a successful review by the U.S. Department of Energy - Nevada (DOE-NV) Radioactive Waste Acceptance Program.

1.4.8 Post-ROD Information Base

Since the approval of the OU4 ROD in December 1994 by the EPA, the DOE-FEMP has developed an expanded information base with respect to the various treatment technologies and their application toward the remediation of the Silos 1 and 2 material. This information has been used in this FS for the preliminary screening and re-evaluation of treatment technologies for the silos material. The various documents comprising this information base are identified in the bibliography (**Section 5**) and are available in the Administrative Record for inspection.

1.4.8.1 Vitrification Pilot Plant Final Reports

The FEMP joule-heated VITPP treatability study program consisted of three test campaigns with the following objectives: (1) to determine (using surrogates) whether it was more economical to vitrify the Silos 1, 2, and 3 materials together or separately; (2) to gain experience vitrifying silos material and handling high-sulfate, high-barium and lead concentrations, and BentoGrout™; and (3) to determine maximum production rates through induced agitation (via bubbling tubes) in the molten glass bath to increase production.

The results of the three test campaigns have been published in three separate reports (FEMP 1996c, 1996d, 1997c). The results of the testing have been factored in the development of the alternatives' design basis, cost estimates, and the implementability evaluation for the vitrification technologies.

1.4.8.2 Melter Incident Report

The *VITPP Melter Incident Report* (FEMP 1997b) summarizes the findings of three investigative teams who evaluated the failure of the FEMP VITPP melter hardware and subsequent leakage of non-radioactive surrogate glass. The report identifies both the causal and contributing factors which lead to the melter failure, and identifies lessons learned for future consideration for the application of the vitrification technology for the DOE-FEMP silos material and complex-wide.

1.4.8.3 Independent Review Team Report

Fluor Daniel Fernald, Inc. (FDF) convened the Silos Project IRT in November 1996, to provide recommendations to FDF and the DOE-FEMP as an aid in an internal decision process. Specifically, the IRT was tasked to assist and advise FDF, the DOE, the public and regulatory agencies in recommending a path forward for immobilization and disposal of the materials contained in Silos 1, 2 and 3 in OU4 of the FEMP.

The IRT was composed of 11 members, having backgrounds and experience in several areas including vitrification, glass furnaces and glass making, cementation, projects and project management, regulatory, environmental and safety.

Based on the information provided through reports, discussions, presentations and site tours, and supplemented by individual knowledge and study, the IRT came to several unified recommendations as published in their final report (Silos Project IRT 1997):

- Do not vitrify Silos 1, 2 and 3 waste together (proposed Alternative I). The waste contained in these silos have competing glass chemistry requirements, and measures taken to alleviate one will most likely exacerbate the other. Specifically, the high-sulfate concentration in Silo 3, and the high and varying lead content in Silos 1 and 2.
- If the Silos 1 and 2 material is treated separate from Silo 3 material, then both treated wasteforms (vitrification and stabilization; e.g., cementation) will meet existing regulatory and waste disposal requirements.
- Immobilize the Silo 3 waste through a cementation process. This waste has been calcined and is dry; it contains high sulfate concentrations which are not conducive to vitrification; similar Fernald waste materials have previously been successfully cemented by FDF; and, the high radium concentrations characteristic of Silos 1 and 2 material are not associated with the Silo 3 waste.
- If vitrification is selected for Silos 1 and 2 material, proceed with a low temperature process (1150°C).
- Additional characterization of the silos material is needed to better understand what is in the silos, and to assist in developing treatment process recipes.
- Immediate attention should be given to silos material retrieval and heel-out. Little has been done to ensure this effort will proceed safely, easily and at the rate anticipated to support the treatment processes.
- Regardless of the treatment process selected, FDF should actively pursue some form of commercial involvement rather than in-house design, construction, and operation of a new facility. Commercial involvement might include turnkey subcontracting or some form of privatization, similar to other successful FDF contracts.

- Cementation should be developed as a contingency treatment method for the Silos 1 and 2 material if vitrification is the selected treatment method, in the event some unusual waste condition is encountered that is not conducive to vitrification.
- Because of the existing downward trend to DOE funding, the probability is low that sufficient funds will be obtained to support a large, new treatment facility at FDF.

The IRT was unable to reach unanimous consensus upon a recommended treatment process for the Silos 1 and 2 material. The IRT was divided concerning this issue, with the minority of members recommending some other form of remediation (e.g., cement). The minority opinion is also formally documented in the IRT final report.

Waste Vitrification Systems Lessons Learned

In March 1999, the DOE Office of Environment, Safety and Health published a report to present lessons learned in the design and operation of waste vitrification systems (DOE 1999c). The report summarizes the joule-heated melter technology experiences from four low level waste vitrification facilities (Fernald VITPP, Savannah River Site (SRS) Vendor Treatment Facility, Oak Ridge Transportable Vitrification System (TVS), Hanford Low-Level Vitrification Project) and from four high-level waste vitrification facilities (SRS Defense Waste Processing Facility (DWPF), West Valley Demonstration Project Vitrification Facility, Sellafield, UK Waste Vitrification Plant, Savannah River Stir Melter). The lessons learned have been utilized in the evaluation of the vitrification technologies in **Section 3.**

1.4.8.4 Proof of Principle Testing Final Reports

Consistent with the July 22, 1997 dispute settlement between the EPA and DOE-FEMP, the DOE-FEMP performed the POP Testing Project to support the technical basis for the alternatives being evaluated in this revised FS. This testing was scoped and implemented to satisfy agency and stakeholder concerns that the detailed evaluation of the alternatives and comparative analysis are supported by pilot-scale data resulting from testing of proven and commercially available remedial technologies. The testing was performed using nonradioactive surrogates that simulated selected physical and chemical characteristics of the Silos 1 and 2 material.

The technologies of the POP Testing Project were based upon the preliminary screening and technology selection process described in **Section 2**. The preliminary screening and technology selection process resulted in the identification of two technology families (vitrification and chemical stabilization) with two alternatives each, for detailed analysis in **Section 3** of this revised FS. The following is a list of the technology families/stabilization alternatives being evaluated in detail by this revised FS:

- Vitrification – Joule-heated;
- Vitrification – Other;
- Chemical Stabilization – Cement-based; and
- Chemical Stabilization – Other.

Table 1.4-2 presents the revised FS data requirements addressed by POP testing and includes important technology-specific information on safety, reliability, implementability, cost, and schedule. **Appendix H** provides a summary of data obtained from the POP Testing Project and discusses how that data was integrated into this FS.

1.4.8.5 U.S. EPA REACHIT Database

In August 1999, an extensive search was conducted of the EPA's nationwide electronic database (REACHIT) of remedial sites where the vitrification, solidification/stabilization, and Chemical Stabilization — Other treatment technologies have been applied to the remediation of material contaminated with lead and/or radioactive material. The database search identified a list of facilities where the technologies, at various stages of implementation, have been applied to wastestreams reasonably similar to the Silos 1 and 2 material. The results of the search have been used to supplement the implementability evaluation of the technologies in **Section 3.**

TABLE 1.4-1

FEASIBILITY STUDY DATA REQUIREMENTS PROVIDED BY PROOF OF PRINCIPLE TESTING

Proof of Principle Data Requirements[1]	Protectiveness	Compliance with ARARs	Long-Term Effectiveness	Reduction of toxicity, mobility and volume	Short-Term Effectiveness	Implementability	Cost
Perform Bench-scale Testing	X	X	X	X	X		
Determine Pre-Treatment Requirements						X	X
Perform Pilot-scale Testing						X	X
Determine Treated Waste Characteristics - Compressive Strength - No Free Liquids - TCLP Metals - Particulate - RCRA Characteristics	X	X	X	X	X	X	X

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TABLE 1.4-1 (continued)

Proof of Principle Data Requirements[1]	Protectiveness	Compliance with ARARs	Long-Term Effectiveness	Reduction of toxicity, mobility and Volume	Short-Term Effectiveness	Implementability	Cost
Waste Loading				X	X		X
Bulking Factor				X			X
Down Time						X	X
Secondary Waste				X	X	X	X
Off-gas Composition					X	X	X
Projected Costs - Equipment - Buildings - Operations - Energy - Additives							X

TABLE 1.4-1 (continued)

Proof of Principle Data Requirements[1]	Protectiveness	Compliance with ARARs	Long-Term Effectiveness	Reduction of toxicity, mobility and Volume	Short-Term Effectiveness	Implementability	Cost
Design Data - General Arrangement - Process Flow Diagram - Equipment List - Mass Balance - Radon Control Strategy						X	X
Process Hazards and Mitigators					X	X	X
Process Challenges						X	X

[1]As defined in the Appendix H POP testing reports.

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1.4.9 Public Participation During the Decision-making Process

Historically, the public has played a fundamental role in shaping the path forward for the Silos Project. The final ROD for OU4 (EPA 1994) provides a detailed summary of public participatory opportunities that were available to the public during the original OU4 RI, FS, PP and ROD regulatory processes. Similarly, the public has had the opportunity to continue its participation in the ongoing revised Silos 1 and 2 alternative treatment selection process.

Figure 1.4-3 provides a summary of the decision-making process for selecting a revised treatment remedy for the Silos 1 and 2 material. **Figure 1.4-4** provides a summary of the process and the points at which the public can participate during the decision-making process. The shaded areas indicate where the public has already provided input.

The preliminary screening of alternatives (**Section 2**) for this FS was first presented to the public in August 1997. It was revised with public input and presented again in December 1997 during public meetings; and, finalized in February 1998. **Section 2** provides a summary of the screening of alternatives process.

The public has also had the opportunity to review and comment on the Statement of Work (SOW) for the POP Testing Request for Proposal (RFP) during its development. DOE-FEMP also solicited input from an independent Critical Analysis Team (CAT) that performed an independent detailed analysis and reviewed the SOW before its release. On the behalf of the public, the CAT has also witnessed the POP testing 72-hour demonstration runs for each technology. Copies of the final reports from the POP Testing Project were made available to the public for inspection through the PEIC. **Appendix H** provides a summary of the stakeholders' input to this revised FS, through its review of POP Final Reports.

Additionally, information relevant to the proposed RAs, including the original RI for OU4, the Baseline Risk Assessment, the FS, the PP, and supporting technical reports, are in the Administrative Record. The Administrative Record is located at the PEIC, just south of the FEMP site.

PUBLIC ENVIRONMENTAL INFORMATION (PEIC) CENTER

10995 Hamilton-Cleves Highway
Harrison, OH 45030
Monday, 7:30 a.m. to 8:00 p.m.
Tuesday – Thursday, 7:30 a.m. to 5:00 p.m.
Friday, 7:30 a.m. to 4:30 p.m.
Phone: (513) 648-7480

This revised FS will become part of the Administrative Record pursuant with 40 CFR Part 300.825(a)(2) and will be available at the PEIC. A draft revised FS will be submitted to the OEPA and the EPA for review, and comment, and later for approval by both agencies after incorporation of their comments. The comments received during the public review of the draft PP, and their respective responses, will be documented in the Responsiveness Summary of the ROD Amendment.

For additional information on public participation activities related to the revised Silos 1 and 2 FS, PP, or the FEMP site, visit the DOE-FEMP website at http://www.fernald.gov/.

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FIGURE 1.4-2
REVISED SILOS 1 AND 2 REMEDIAL ACTION SELECTION PROCESS

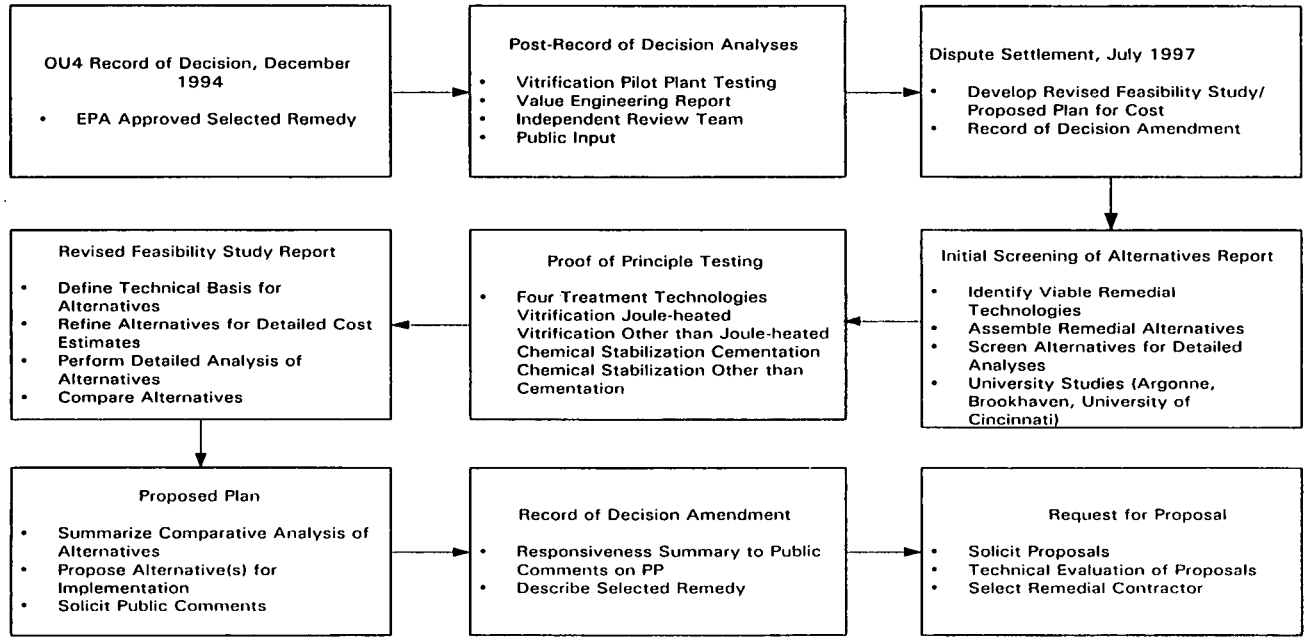
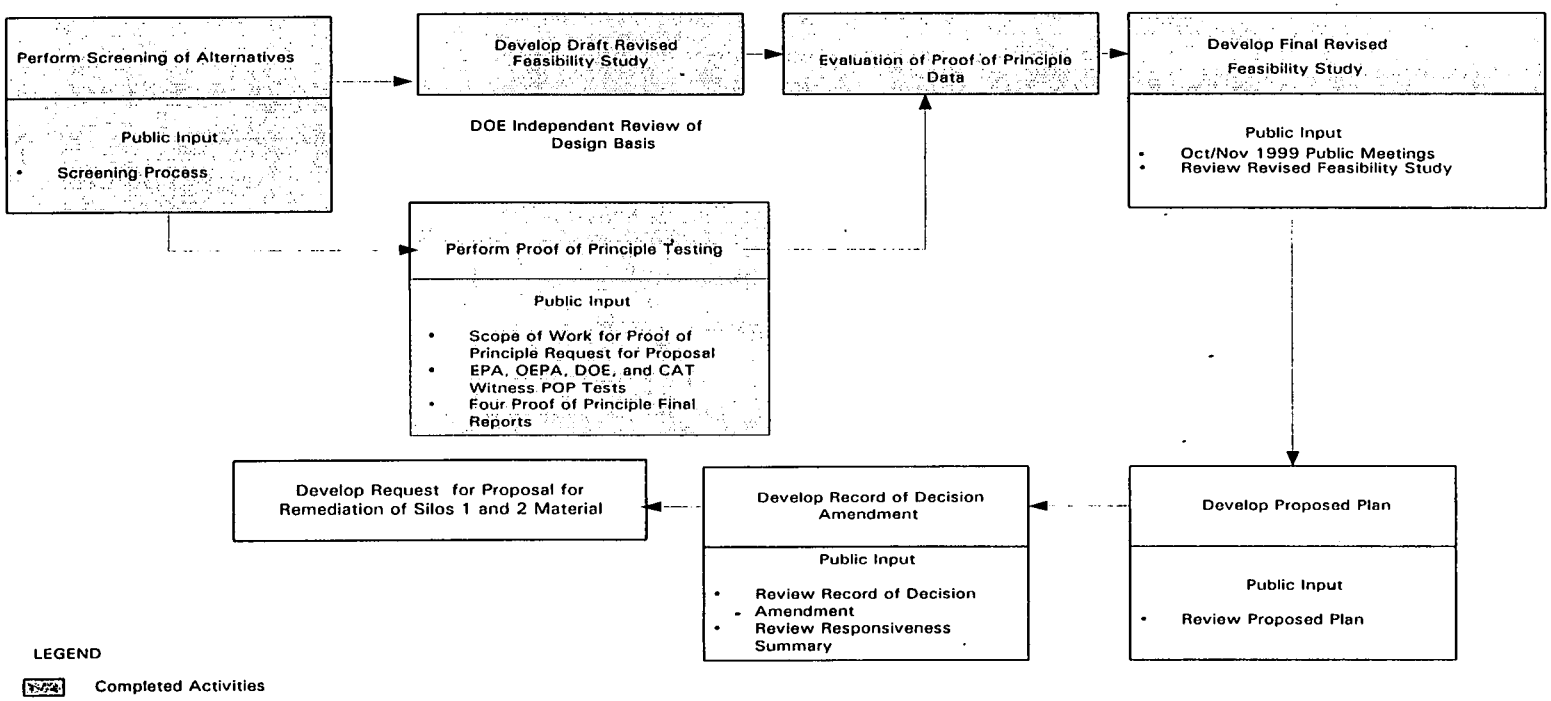


FIGURE 1.4-3

PUBLIC INVOLVEMENT OPPORTUNITIES DURING THE REVISED SILOS 1 AND 2 REMEDIAL ACTION SELECTION PROCESS



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Section 2

2.0 IDENTIFICATION AND SCREENING OF ALTERNATIVES

2.1 Introduction

The remedy approved in the OU4 ROD, dated December 1994, consisted of the following components:

- Removal of the contents from the Silos 1, 2, and 3 structures, on-site vitrification of the silos materials, and transportation and disposal at the NTS.
- Decontamination and demolition of all silos structures and the vitrification facility in accordance with the approved OU3 ROD.
- Excavation and treatment of contaminated soils, and treatment of perched water encountered during RA, in accordance with the approved OU5 ROD.

The OU4 ROD identifies that the treatment portion of the remedy for the Silos 1 and 2 material will "significantly reduce the leachability of metal contaminants of concern to levels that are below RCRA regulatory thresholds." This treatment requirement is still relevant and serves as the basis for screening and selecting alternatives for evaluation in this revised FS.

The scope of this revised FS is limited to the reevaluation of alternatives for the treatment portion of the selected remedy for the Silos 1 and 2 material. Other portions of the selected remedy (removal, off-site disposal, and disposition of the silos structures, soil, and debris) for OU4 are not being re-evaluated. New components are not being added to the remedy identified in the approved ROD. Therefore, GRAs and RAOs, and the performance objectives for Silos 1 and 2 material identified in the original OU4 FS and ROD remain the basis for this revised FS. As detailed in **Appendix A**, the ARARs included in the approved OU4 ROD remain unchanged.

2.2 Scope

As discussed in **Section 1**, DOE performed, in accordance with the ACA, a RI/FS for OU4 that was approved by the EPA in August 1994. The initial phase of evaluating alternatives for the remediation of Silos 1 and 2 involved the development of RAOs and ARARs for each portion of the RA. The RAOs identified in the original OU4 RI/FS are not being reevaluated as part of this FS. The following are the RAOs identified in the August 1994, OU4 FS for the Silos 1 and 2 material, which are still applicable for this revised FS:

- Prevent direct contact with or ingestion of Silos 1 and 2 material.
- Prevent release or migration of waste materials to soil, groundwater, surface water or sediment.
- Prevent exposures to Silos 1 and 2 material that may cause an individual to exceed applicable dose limits.

General response actions evaluated in the original OU4 FS included, in addition to removal, treatment, and disposal: no action, containment, and institutional control. Based upon these GRAs, potential remedial technologies and process options were evaluated and combined into remedial alternatives for each subunit of OU4. A range of alternatives were thoroughly evaluated for the remediation of the Silos 1 and 2 material, including several removal/treatment with **off-site disposal** alternatives, removal/**disposal without treatment**, removal/treatment with **on-site disposal**, and **no action**. Based upon detailed and comparative analyses of these alternatives, removal of the Silos 1 and 2 material followed by remediation through vitrification, and off-site disposal at the NTS was selected as the remedy.

This revised FS is being prepared to reevaluate alternatives for implementing the treatment process option selected in the original OU4 ROD. The screening, evaluation, and selection of process options, resulting in a remedy consisting of removal, treatment, and off-site disposal, will not be re-evaluated. Alternatives to the selected remedy that were evaluated in the original FS, such as no action, on-site disposal, or disposal without treatment for the constituents of concern (COCs), will also not be reevaluated in this revised FS.

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2.3 Identification and Screening of Technologies

The purpose of this initial screening is to identify and evaluate a range of potential treatment technologies and perform a screening of the technologies in order to identify a select group warranting more detailed evaluation as alternatives for the remediation of the Silos 1 and 2 material.

The criteria used for the Identification and Screening of Alternatives are based upon the three criteria specified in the EPA regulations for the RI/FS Preliminary Screening of Alternatives process [40 CFR Part 300.430(e)(7)]. As illustrated below, more detailed sub-criteria were developed within the three NCP screening criteria to provide a more detailed screening. Technical development or other adaptation of potential technologies not currently available on a commercial scale introduces uncertainty with respect to technical and/or administrative implementability. In order to maximize the certainty of implementability of the selected technologies, a primary criterion in screening potential alternatives is that any alternative carried forward for detailed evaluation be currently available on a commercial scale. The following criteria were used to screen the technologies and identify those to be carried forward for detailed evaluation:

<u>Effectiveness</u>

- Reduction in mobility of COCs;
- Volume increase/decrease;
- Attainment of WAC for characteristic metals, based upon WAC at NTS;
- Long-term effectiveness/permanence; and
- Attainment of ARARs and to be considered (TBC) requirements.

Implementability

- Degree of current commercial scale implementation;
- Certainty/uncertainty associated with regulatory and stakeholder acceptance;
- Commercial availability including licensing and permitting issues;
- Generation of secondary wastestreams;
- Pretreatment requirements;
- Processing throughput; and
- System reliability/maintainability.

Cost

- Life cycle Cost.

2.3.1 Basis of Evaluation

In order to provide a consistent basis for evaluation of potential technologies, the screening, documented in **Section 2.4**, assumed on-site treatment followed by disposal at the NTS as the basis for screening potential technologies.

Treatment at an off-site location may influence remedial technologies in some aspects of the implementability and cost criteria identified in **Section 2.3**. **Section 2.5** provides a screening for implementing off-site treatment of the technologies carried forward in the detailed analysis of alternatives documented in **Section 3** of this revised FS.

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2.3.2 Identification of Technologies

The first step in screening potential technologies for treatment of the Silos 1 and 2 material involved researching literature and other sources to identify potentially applicable technologies. The primary sources for potential treatment technologies were:

- Literature search of EPA reference documents conducted for the Silo 3 ESD;
- Technologies recommended for evaluation by the Silos Project IRT; and
- Expressions of Interest in response to the Silos 1 and 2 POP Commerce Business Daily (CBD) Announcement.

Several categories of potential treatment technologies identified in the literature search were judged inapplicable for treatment of the Silos 1 and 2 material and were not included in the screening process. The Silos 1 and 2 material consists primarily of the residue from a solvent extraction process; therefore, subjecting the material to further solvent extraction does not further reduce the mobility of toxic constituents and, thus, fails to accomplish the RAOs. Similarly, thermal oxidation of the Silos 1 and 2 material does not provide any appreciable treatment benefit. Thus, solvent extraction and thermal oxidation technologies were judged not to warrant further evaluation.

On September 25, 1997, Fluor Daniel Fernald (FDF) issued an announcement in the CBD that solicited input from the commercial sector on commercially-available technologies potentially applicable to treatment of the Silos 1 and 2 material. Responses were received identifying a wide range of potential treatment technologies.

Based upon responses to the CBD announcement, as well as the other sources described above, the following alternatives were selected for evaluation in the screening process: **vitrification** (joule-heated, cyclone, rotary, and plasma-arc); **chemical stabilization** (cement and non-cement); **polymer phosphate stabilization**; **encapsulation** (ceramic and polymer); and **thermal stabilization**. These alternatives are described below.

Vitrification — Joule-heated

Vitrification technologies involve blending the waste with glass forming constituents and applying heat to form a stable glass wasteform. Constituents such as RCRA TC metals are chemically bound into the glass structure and stabilized into a wasteform that is highly resistant to leaching. Joule-heated vitrification involves applying the necessary heat through application of an electrical current to the feed stream. Due to the natural electrical resistivity of the feed stream, the current causes it to heat to a molten state. Treatment is usually accomplished by heating the feed stream in a melter.

Vitrification - Cyclone

In cyclone vitrification, untreated waste, glass-forming compounds, and fuel are fed to a cyclone-type heater, where rapid heating of the waste and glass-forming compounds occurs. The waste is then converted in a reactor into a stable, glass wasteform. Constituents such as RCRA TC metals are chemically bound into the glass structure and stabilized into a wasteform that is highly resistant to leaching.

Vitrification - Rotary

Rotary vitrification accomplishes homogenization, drying, and vitrification of the wastestream using a fossil fueled rotary furnace. The waste is converted into a stable, glass wasteform. Constituents such as RCRA TC metals are chemically bound into the glass structure and stabilized into a wasteform that is highly resistant to leaching. The furnace operates at very high (up to 1800°C) operating temperatures, potentially using oxygen as a supplemental fuel.

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Vitrification - Plasma Arc

Plasma arc vitrification, similar to joule-heated vitrification, involves mixing the untreated waste with glass-forming compounds and applying heat to form a stable glass wasteform. Constituents such as RCRA TC metals are chemically bound into the glass structure and stabilized into a wasteform that is highly resistant to leaching. This process uses a plasma electrode that produces an electric arc that is stabilized on an inert gas stream to supply the necessary heat input.

Chemical Stabilization — Cement-based

Cement stabilization involves mixing the waste with a variety of cement and chemical additive formulations to accomplish chemical and physical binding of the COCs. The cement additive primarily serves to "buffer" the wasteform from acidic leaching of the COCs. Contaminants such as metals are chemically converted to a non-leachable form and physically bound within the cement matrix.

Chemical Stabilization — Other

These technologies are similar to cement-based stabilization processes. Existing commercial processes use a variety of additive formulations to accomplish chemical and physical binding of the COCs into a solid matrix. In one commercially-implemented variation of this technology type, chemical reagents are combined with the untreated waste to initiate the formation of species such as barites, apatites, and other crystalline mineral species. Contaminants such as metals are then chemically bound to minerals within the ceramic-like matrix. This alternative also includes chemical stabilization as a process step in a larger process such as uranium recovery, provided that the process achieves the performance objectives for reduction in mobility of Silos 1 and 2 COCs.

Encapsulation - Ceramic

Ceramic encapsulation involves mixing the waste with dry ceramic-forming compounds and heating it, usually in an oven, to form a ceramic or brick-like treated wasteform that encapsulates the contaminants. The mobility of COCs is reduced by physically binding the contaminants in the ceramic matrix. As chemical stabilization is not accomplished, prevention of contaminant leaching depends solely upon the physical integrity of the wasteform. Ceramic encapsulation is a high-temperature process with facility and equipment requirements more complex than those of a non-thermal process. In some variations of this technology-type, compounds such as chemically bound phosphate are used to provide the necessary heat input without the use of a melter.

Stabilization - Polymer Phosphate

Polymer phosphate stabilization involves the use of phosphate ceramic to chemically bind COCs to produce a ceramic wasteform without external heating. Contaminants, such as metals, are chemically bound in the ceramic matrix. The production of magnesium phosphate results in an exothermic reaction that provides the heat required to produce the ceramic wasteform.

Encapsulation - Polymer

Polymer Encapsulation includes a variety of polymer encapsulation processes, such as polyethylene micro encapsulation, sulfur/polymer encapsulation, and ceramic silicon foam encapsulation. All of these processes involve mixing the untreated waste, after drying, with a polymer formulation using means such as a commercial extruder. The mixture is then allowed to solidify, resulting in the COCs being physically bound in the polymer matrix. Unlike most stabilization processes, which convert contaminants to a non-leachable form in addition to physically binding them, polymer encapsulation relies solely on physical isolation of the contaminants in order to prevent leaching. Therefore, polymer encapsulation depends solely upon the physical integrity of the treated wasteform for its effectiveness.

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Thermal Stabilization

Thermal Stabilization includes several thermal processes involving mixing the untreated waste at high temperatures with substances such as molten asphalt, a ceramic/aluminum mixture, molten metal, or epoxy resins. The molten mixture is poured into a container and, upon cooling, forms a solid wasteform, physically binding the COCs. Many of these high temperature processes produce volatile gases requiring off-gas treatment.

2.3.3 Screening of Potential Technologies

Information regarding the potential technologies was drawn from the previously identified research sources and technical experts in waste treatment. Information provided by the commercial sector in response to the September 1997 CBD announcement was used as a major source of input. Responders to the CBD announcement provided detailed information on potential remediation technologies for the Silos 1 and 2 material. This information included a description of the degree to which the specific technology was being implemented on a commercial scale, its ability to treat waste similar to the Silos 1 and 2 material, demonstrated ability to immobilize the contaminants present in the Silos 1 and 2 material, and technical or cost concerns with implementation of the technology. Based upon this information, as well as input from the public and other interested stakeholders, the potential treatment technologies were compared against the screening criteria identified in **Section 2.3**.

Five of the technologies failed to meet one or more of the screening criteria and, therefore, did not warrant further consideration in the detailed analysis of alternatives. These five technologies, and the basis for their exclusion, are identified in **Table 2.4-1**. The four technologies which passed the screening criteria are discussed in **Section 2.6**.

For any alternative involving on-site treatment of the Silos 1 and 2 material, the treatment activity will be conducted in accordance with the substantive parts of the ARARs identified in **Appendix A**. Neither permitting nor licensing will be required for on-site RAs; however, permitting and licensing for off-site remedial activities would be required **(Appendix A, Section A.1.2)**. Regulatory and stakeholder acceptance of the selected alternative will be ensured through review of the revised FS, PP, and ROD-Amendment by the EPA, OEPA, and stakeholders near both the FEMP and the NTS.

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TABLE 2.3-1
TECHNOLOGIES EXCLUDED FROM DETAILED EVALUATION

Technology	Basis for Exclusion
Vitrification - Rotary	Not demonstrated at full-scale on low-level, hazardous, or mixed wastes. CBD responses indicated that the technology had not been demonstrated at full-scale commercial implementation.
Encapsulation - Ceramic	Not demonstrated at full-scale on low-level, hazardous, or mixed wastes. Did not receive any CBD responses demonstrating full-scale commercial implementation.
Stabilization - Polymer Phosphate	Not demonstrated at full-scale on low-level, hazardous, or mixed wastes. Did not receive any CBD responses demonstrating full-scale commercial implementation.
Encapsulation - Polymer	Not demonstrated at full-scale on low-level, hazardous, or mixed wastes. Did not receive any CBD responses demonstrating full-scale commercial implementation. Initial testing raises concerns regarding ability to meet TC limits for RCRA metals when tested in accordance with standard EPA TCLP Protocols.
Stabilization - Thermal	Not demonstrated at full-scale on low-level, hazardous, or mixed wastes. Did not receive any CBD responses demonstrating full-scale commercial implementation.

2.4 Off-site Treatment of the Silos 1 and 2 Material

The remaining remediation alternatives were identified to adequately attain the screening criteria and, therefore, to warrant further evaluation through detailed analysis of alternatives. Any of these remediation alternatives could potentially be implemented at an existing and appropriately permitted and licensed off-site facility. For the purpose of the screening off-site treatment option, "appropriately permitted and licensed" is assumed to consist of:

- Air emission and wastewater discharge permits that allow potential emissions and discharges from treatment of the Silos 1 and 2 material;
- Licensing from either the Nuclear Regulatory Commission (NRC) or an NRC agreement state that allows the facility to accept and process 11(e)(2) by-product material; and,
- Radionuclide concentration limits high enough to accept the radionuclides present in the Silos 1 and 2 material.

In addition, treatment at an off-site facility requires treatment, using the technology(ies) selected by the detailed analysis of alternatives, to attain the performance criteria specified for on-site treatment for Silos 1 and 2 COCs.

This section evaluates off-site treatment with respect to the screening criteria identified in **Section 2.3**. The criterion of long-term effectiveness and permanence is impacted by the treatment *technology being employed*, not the treatment *location*. Therefore, long-term effectiveness and permanence will not be discussed in screening off-site treatment. As was the case in screening potential stabilization technologies, a major criterion in screening off-site treatment is the degree to which the alternative is currently available on a commercial scale, and the resulting certainty or uncertainty associated with implementability and cost.

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Furthermore, there are additional concerns related to ARARs compliance, short-term effectiveness, and state and community acceptance associated with off-site treatment that warrant its exclusion from further consideration as a remedial alternative. These issues are discussed below.

Compliance with Applicable or Relevant and Appropriate Requirements

Only those ARARs identified as "applicable" pertain to off-site treatment activities. Relevant and appropriate requirements or TBC criteria apply only to that portion of the activity conducted on-site. These ARARs and TBCs are presented in **Appendix A.**

An off-site treatment facility is required to comply with all applicable state, local, and federal requirements, including environmental requirements, governing operation of its treatment facility. These requirements include those that are covered under any occupational safety, radiological control, nuclear safety, quality assurance, air, water, and solid waste programs existing in the state where the treatment facility is located.

A search of existing facilities capable of treating the Silos 1 and 2 material through the NRC and a CBD announcement was conducted. No facilities were identified that currently possess both adequate permitting and licensing, and the treatment capability to accept and treat Silos 1 and 2 material. Since an existing off-site commercial facility capable of accepting Silos 1 and 2 material has not been identified, a specific evaluation of the ability of an off-site facility to comply with site-specific ARARs cannot be accomplished. The present inability to confirm the impact of site-specific ARARs on implementation of off-site treatment introduces uncertainty in the administrative and potentially technical, implementability.

Implementability

On-site actions are required to comply with the substantive requirements of all ARARs. Off-site activities, must meet both administrative and substantive portions of all applicable requirements. Relevant and appropriate requirements for alternatives involving off-site treatment or disposal must be met only for the on-site portions of that alternative.

Although an off-site treatment facility *would not* be required to comply with applicable requirements for the State of Ohio, an off-site treatment facility *would* be required to (1) comply with applicable state, local, and federal requirements governing operation of the off-site treatment facility, and (2) possess the necessary licenses and permits to handle and process Silos 1 and 2 material. These requirements include those covered under occupational safety, radiological control, nuclear safety, quality assurance, air, water, and solid waste programs existing in the state where the treatment facility is located. Examples of these requirements include compliance with permitting requirements for air emissions and wastewater discharges, and compliance with radionuclide concentrations under the facility's nuclear license and disposal requirements for solid, hazardous, radioactive, and mixed wastes.

To thoroughly evaluate the implementability of off-site treatment, a search was conducted to identify potential facilities. First, EPA and NRC regional offices were surveyed in an attempt to locate facilities possessing both EPA approval, under the CERCLA Off-Site Rule, and adequate NRC licensing. This survey failed to locate such a facility.

The second stage of the search involved issuance of a CBD announcement requesting a response from vendors expressing an interest in the off-site treatment of the Silos 1 and 2 material. Responders were requested to provide the following information:

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1. A written description of the existing off-site treatment facility and a block flow diagram identifying the proposed waste remediation process (vitrification or chemical stabilization).

2. Documentation of current treatment capacity at the facility and the capability for receiving and completing treatment of Silos 1 and 2 material within a 2- to 3-year period.

3. Documentation that the treatment facility has been approved for treatment of CERCLA waste in accordance with the Off-Site Rule CERCLA Section 121(d)(3), (40 CFR Part 300.440).

4. For a **commercial facility**: a copy of the treatment facility's current NRC license, or Agreement State license verifying the ability to receive, manage, and treat the 11(e)(2) by-product material in Silos 1 and 2.

   For a **government or government contractor operated facility**: a copy of the NEPA ROD verifying that the facility would be protective of human health and the environment and could accept off-site waste for treatment/disposal and that the public supports this determination.

5. Interested parties with vitrification or chemical remediation facilities, who do not satisfy the regulatory requirements (Items 3 and 4), were able to submit a response to FDF which identified how the regulatory requirements of CERCLA, NRC, and NEPA regulations, would be met.

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Although a small number of expressions of interest were received, review of the documentation provided by the facilities indicated that none possessed both adequate current treatment capacity and adequate licensing. Facilities were identified that possess a license to accept 11(e)(2) by-product material; however, they have concentration limits that exclude acceptance of the Silos 1 and 2 material. Based on the current maximum radionuclide concentration limits of the existing licenses, existing facilities would need to modify their licenses to accommodate the higher concentrations of radionuclides found in the Silos 1 and 2 material [i.e., a 450-fold increase in the concentration of radium (Ra)-226]. Any new facility would need to request a license that would allow acceptance of 11(e)(2) by-product material with a concentration limit for Ra-226 of approximately 900,000 pCi/g.

In addition, the CERCLA Off-site Rule, found in CERCLA Section 121 (d)(3) and promulgated at 40 CFR Part 300.440, requires that waste from a RA that is shipped off-site for treatment and/or disposal be transferred only to those units at a facility that (1) is in compliance with RCRA and other applicable federal and state requirements, (2) do not have any uncontrolled releases of hazardous waste or constituents and (3) are on the list of sites approved by the appropriate EPA region to receive CERCLA waste. The policy applies to the Silos 1 and 2 material, although it is defined as AEA 11(e)(2) by-product material, excluded under RCRA. The policy applies to any RA involving the transfer of hazardous substances, pollutants, or contaminants as defined under CERCLA Sections 101(14) and (33) pursuant with any CERCLA authority, including cleanups at Federal Facilities [40 CFR Part 300.440(a)(1)]. Both an off-site treatment facility and disposal facility would require documentation demonstrating compliance with the CERCLA Off-site Rule.

An existing commercial facility that possesses adequate permits and licensing to treat the Silos 1 and 2 material has not been identified. It is recognized that obtaining the necessary licenses and permits for a new facility or modifying existing licensing can be a complicated and lengthy process. The administrative implementability of an off-site treatment alternative is dependent upon a number of location-specific factors. These factors include the scope of the permit or license modifications required for treatment of the Silos 1 and 2 material at a given facility and the extent to which local regulators or stakeholders support or oppose the activity. As a specific facility is not available, these issues cannot be identified in detail. This inability results in significant uncertainty in administrative implementability for off-site treatment.

Short-term Effectiveness

Any alternative involving the off-site treatment of the Silos 1 and 2 material involves pretreatment of the material at the FEMP before shipping the material to the treatment facility. Pretreatment, to remove excess water, of the Silos 1 and 2 material at the FEMP is necessary in order to classify the material as LSA-II solid material under DOT transportation requirements and, in turn, allow for more economical and efficient packaging. Pretreated Silos 1 and 2 material could be transported to an off-site treatment facility and the treated wastes could be transported to the NTS by trucks. Environmental impacts and personnel exposures from shipping are expected to be minimal because packaging and shipping of the treated material would comply with applicable DOT requirements and DOE Orders.

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However, pretreated materials are more dispersible in an accident involving release of material. Therefore, transportation of pretreated material to an off-site facility (for treatment) has a greater exposure risk to members of the public than transportation of treated material. The increase in risk is dependent on the distance from the FEMP to the off-site facility, as well as, the population density along the route and the amount of traffic that could reasonably be expected during transport. In addition, transportation of treated waste from the off-site treatment facility to the NTS results in an exposure risk to members of the public, as well as, additional worker risk associated with packaging and transporting the waste. As with the untreated material, risk is dependent on the distance between the treatment facility and the NTS, as well as, the population density and the volume of traffic that could be expected along the route.

State Acceptance

It is recognized that acceptance of a facility (to treat waste with characteristics similar to the Silos 1 and 2 material) by both the State of Ohio and the state in which the off-site treatment facility resides would be addressed during review and approval of the necessary operating licenses and permits for the facility.

Community Acceptance

It is recognized that acceptance of an off-site treatment facility by the community in which the facility operates would be addressed during inspection and approval of the necessary operating licenses and permits.

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Summary

Based upon the screening of potential treatment technologies, vitrification and chemical stabilization were identified for further evaluation. For the purposes of the Detailed Analysis of Alternatives **(Section 3)**, these two technologies will be represented by two processes, resulting in four alternatives as follows:

- Vitrification – Joule-heated;
- Vitrification – Other;
- Chemical Stabilization — Cement-based; and
- Chemical Stabilization — Other.

The lack of off-site commercial treatment facilities capable of accepting Silos 1 and 2 material, limits the involvement of the EPA, OEPA, and the public in selection of an off-site treatment process during the post-ROD process and results in a significant risk in the ability to implement treatment in a timely manner. Therefore, off-site treatment is being excluded from further consideration as an alternative for the Silos 1 and 2 material.

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Section 3

3.0 ANALYSIS OF ALTERNATIVES

3.1 Introduction

This section presents the detailed analysis of alternatives that passed the screening process conducted in **Section 2**. Four alternatives were selected based on technical feasibility and commercial availability. **Table 3.1-1** summarizes the alternatives to be assessed by the detailed analysis.

The detailed analysis includes a presentation and assessment of relevant information that provides the basis for selecting an alternative and preparing a ROD amendment. The vitrification and chemical stabilization technologies being considered for treatment of the Silos 1 and 2 material have been selected based on technical feasibility and commercial availability. These technologies, when combined with removal and off-site disposal, provide comprehensive alternatives to be evaluated through detailed analysis. As stated in **Section 2**, the Vitrification — Joule-heated and Vitrification — Other treatment technologies being evaluated by this FS are candidates from a list of representative treatment technologies within the vitrification technology family. Likewise, the Chemical Stabilization — Cement-based and Chemical Stabilization — Other treatment technologies are candidates from a list of representative technologies within the chemical stabilization technology family. In each case, the technologies were identified as having successfully treated hazardous or low-level waste reasonably physically/chemically similar to Silos 1 and 2 material, to meet specified performance requirements at varying scales.

1 **TABLE 3.1-1**

SILOS 1 AND 2 MATERIAL TREATMENT ALTERNATIVES SELECTED FOR ANALYSIS

FS Alternative Designation	Description
VIT1	Removal, On-site Vitrification — Joule-heated, Off-site disposal at the NTS.
VIT2	Removal, On-site Vitrification — Other, Off-site disposal at the NTS.
CHEM1	Removal, On-site Chemical Stabilization – Cement-based, Off-site disposal at the NTS.
CHEM2	Removal, On-site Chemical Stabilization — Other, Off-site disposal at the NTS.

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3.1.1 Purpose and Need

This detailed analysis evaluates each alternative against seven of the nine criteria specified by 40 CFR Part 300.430(e)(9) to address CERCLA requirements. Building upon the development and screening of alternatives, the detailed analysis presents a more in-depth evaluation using a combination of data from the original OU4 FS, which includes treatability studies and pertinent RI data, and post-ROD treatability study testing. In the assessment of the alternatives relative to the CERCLA criteria, the analysis also includes the most recent data from the POP Testing Project, lessons learned from the operation of the VITPP and other treatment facilities throughout the DOE Complex, and observations and reports generated by the IRT.

Following the detailed analysis, a comparative analysis of the alternative-specific data is presented in **Section 4**. The comparative analysis first evaluates the alternatives relative to the two threshold criteria (Overall Protectiveness of Human Health and Environment, and Compliance with ARARs) that must be met. This is followed by an assessment of the alternatives against the five primary balancing criteria: long-term protectiveness and permanence; toxicity, mobility, or volume reduction through treatment; short-term effectiveness; implementability; and cost. The primary balancing criteria highlight the key advantages, disadvantages, and tradeoffs that are considered important to the selection process.

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The PP documents the selection of a preferred alternative and solicits community and state agency comments, which are incorporated into an assessment of the alternatives against the two modifying criteria of state and community acceptance. Formal comments submitted by the OEPA during their review will be addressed in the final revised FS, before receiving EPA approval. Because formal public comments will not be received until after the revised FS is final, public comments will be addressed in the regulatory process following the public comment period (i.e., in a Responsiveness Summary accompanying the ROD amendment).

3.1.1.1 Supplement Analysis

In order to meet the substantive and procedural requirements of DOE's NEPA Implementing Regulations [10 CFR Part 1021.2], the original FS and PP for OU4 were integrated into one CERCLA/NEPA document. The final document was termed an "FS/PP-EIS." The FS/PP-EIS evaluated potential environmental impacts of the original alternatives and was issued for public review per the procedural requirements of NEPA. In addition, the ROD that was issued for OU4 was also an integrated CERCLA/NEPA ROD. The DOE's NEPA regulations mandate: proposed changes to a federal action that has been subject to an EIS evaluation must be evaluated in a supplement analysis in order to determine whether formal revision to the original EIS is required (through issuance of a Supplemental EIS). Therefore, throughout this FS, potential environmental impacts associated with individual alternatives have been incorporated into the evaluation criteria. Additionally, **Appendix D** contains the NEPA Supplement Analysis for this evaluation pursuant to the requirements of 10 CFR Part 1021.314(c).

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3.1.2 Overview of the Detailed Analysis

Specific statutory requirements for RAs are specified under CERCLA Section 121, as amended. These requirements include: (1) protection of human health and the environment; (2) compliance with ARARs; (3) a preference for permanent solutions that incorporate treatment as a principal element (to the maximum extent practicable); (4) and cost-effectiveness. In order to assess whether alternatives meet the requirements, the EPA has identified nine criteria in the NCP that must be evaluated for each alternative retained through the screening stage [40 CFR Part 300.430(e)(9)(iii)]. Provided below are summaries of the factors that comprise the nine criteria and an overview of the approach taken by this evaluation to address the criteria. Because the first two criteria (Overall Protection of Human Health and the Environment, and Compliance with ARARs) are the threshold criteria that relate directly to statutory findings that must be made in the enforcement documentation (i.e., ROD or ROD amendment), an alternative must meet both of the threshold criteria TBC for selection as the final remedy. Additional details and discussions regarding these ARARs are provided in **Appendix A.**

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3.1.2.1 Overall Protection of Human Health and the Environment

This evaluation criterion provides an assessment of whether an alternative achieves and maintains adequate protection of human health and the environment, in accordance with the RA objectives established in the original OU4 FS. Evaluation of this criterion should qualitatively describe how site risks, posed through each pathway addressed by the OU4 FS, are eliminated, reduced, or mitigated through treatment, engineering, or institutional controls. The acceptable exposure 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} to 10^{-6}. For systemic toxicants, the acceptable exposure levels under CERCLA are generally concentration levels to which the human population, including sensitive subgroups, may be exposed without adverse effect during a lifetime.

In order to evaluate the alternatives for protecting human health and the associated criteria (compliance with ARARs, long-term effectiveness and permanence, and short-term effectiveness), this report refers to the risk assessment performed during the original OU4 FS. In addition, both quantitative and qualitative discussions describing each alternative's ability to satisfy this criterion are also supported by the results of a limited risk assessment presented in **Appendix B**.

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3.1.2.2 Compliance with Applicable or Relevant and Appropriate Requirements

This criterion addresses compliance with promulgated federal and state environmental regulatory requirements. ARARs consist of two types of requirements, those that are applicable and those that are relevant and appropriate. Applicable requirements are those promulgated substantive standards or limitations that specifically address the situation at a CERCLA site or otherwise satisfy the jurisdictional prerequisites for the application of the regulation. Relevant and appropriate requirements are those promulgated controls or requirements that are not applicable, but address sufficiently similar situations such that their use is well suited to the occasion.

In certain cases, standards may not exist (in the form of a promulgated regulation) that address the proposed action or COCs. In these cases, nonpromulgated advisories, criteria, or guidance that were developed by EPA, other federal agencies, or states are TBC in conducting activities or establishing RA objectives that are protective of human health and the environment.

In addition, to ARARs and TBCs, there are other requirements that do not fall within the EPA-established criteria for ARARs. These other requirements include DOE Orders[1] that pertain only to DOE facilities. 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."

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[1]AEA requirements for DOE's waste management are incorporated into DOE Orders, developed under DOE's AEA authority. The Orders are generally consistent with and typically include technical requirements similar or equivalent to those in NRC regulations and that are appropriate for DOE facilities. DOE Order substantive requirements are TBC requirements, which, when included in a DOE CERCLA ROD, are enforceable cleanup standards under CERCLA. Substantive technical requirements of promulgated and nonpromulgated NRC requirements may be "Relevant and Appropriate" or TBCs to ensure protection of human health and the environment.

In this document, DOE Orders are identified as TBCs only when a promulgated ARAR does not exist to ensure adequate protection of human health and the environment. A table summarizing other requirements pertinent to OU4 remediation is included in **Appendix A.**

Types of ARARs and TBCs

In addressing a requirement that may affect a RA 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: chemical-specific ARARs, location-specific ARARs, and action-specific ARARs.

Chemical-specific ARARs are usually health- or risk-derived numerical values that establish an acceptable level or concentration of chemical or radionuclide that may remain in specific environmental media after remediation is complete. These levels are deemed protective of human health and are used to help establish remedial cleanup goals.

Location-specific ARARs generally restrict certain activities or dictate where certain activities may be conducted solely because of geographical, hydrologic, or land use concerns.

Action-specific ARARs are usually restrictions on the conduct of certain activities or the operation of certain technologies at the site.

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Summary of Key ARARs and TBCs

Appendix A provides a complete listing and an analysis of compliance with enforceable ARARs and TBCs for the remediation of the Silos 1 and 2 material as documented by the EPA-approved OU4 ROD (EPA 1994). In addition, **Appendix A** contains a discussion of a recent evaluation of regulations promulgated since the OU4 ROD was approved in December 1994. The analysis did not identify any additional ARARs that were required to maintain protectiveness of the remedy for the Silos 1 and 2 material. Included are tables that present the documentation of ARARs for each alternative. The approach adopted by this evaluation is to focus on the alternatives' abilities to comply with key ARARs (i.e., ARARs that are critical to meeting this threshold criterion). The key ARARs and TBCs identified for the OU4 Silos 1 and 2 material include the following:

Chemical-Specific ARARs and TBCs

- Clean Air Act (CAA): 40 CFR Part 61 Subpart H - Air Emissions for Radionuclides other than Radon.
- CAA: 40 CFR Part 61 Subpart Q - Radon Emissions from DOE Facilities.

Location-Specific ARARs and TBCs

- NEPA/DOE: 10 CFR Part 1022 - Floodplain/Wetlands Environmental Review Requirement.

Action-Specific ARARs and TBCs

- RCRA: 40 CFR Part 264 Subpart B (various citations) - General Standards for Treatment, Storage, and Disposal Facility.
- RCRA: 40 CFR Part 264 Subpart G (various citations) - Closure and Post-closure Requirements.
- RCRA: 40 CFR Part 264 Subpart I (various citations) - Container Storage Requirements.
- RCRA: 40 CFR Part 264 Subpart J (various citations) - Tank System Requirements.

- RCRA: 40 CFR Part 264 Subpart S (various citations) - Corrective Action Management Units and Temporary Units.
- DOE Order 5400.5 - Annual Effective Dose Equivalent from all Pathways.
- AEA/DOE: 10 CFR Part 1021.2 - NEPA Implementation.
- UMTRCA: 40 CFR Part 192 Subpart C - Cleanup Standards for Residual Radioactive Material.

3.1.2.3 Long-term Effectiveness and Permanence

This criterion evaluates, after the response actions have been met, how well an alternative reduces adverse risks to human health and the environment. It also considers the alternative's provision of sufficient long-term controls and its reliability in maintaining exposures to human and environmental receptors within protective levels (10^{-4} to 10^{-6} ILCR). The principal factors addressed by this criterion include: (1) the magnitude of residual risk, and (2) adequacy and reliability of controls. Also, the uncertainties associated with these factors are discussed.

The evaluation considers the characteristics of any remaining untreated and treated Silos 1 and 2 material forms that pose potential future risks to human health and the environment. The magnitude of residual risk to environmental receptors is assessed in a qualitative manner. This discussion is further supported 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. Further, impacts to socioeconomics, land use, and cultural resources are considered.

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The evaluation of adequacy and reliability of controls assesses the effectiveness of any treatment, post-treatment, containment, or institutional measures that 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 technological treatment applications are incorporated into the evaluation as appropriate. Institutional controls are considered where they potentially improve the effectiveness of engineered measures.

3.1.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

This criterion reflects the statutory preference for remedial alternatives that substantially reduce the toxicity, mobility, or volume of hazardous substances. The evaluation considers the extent to which remedial technologies can effectively and irreversibly fix, transform, immobilize, and/or reduce the volume of waste materials and contaminated media.

The ability of vitrification and chemical stabilization to reduce the toxicity, mobility, and volume of the contents of Silos 1 and 2 material is evaluated. The evaluation includes the results of treatability studies that were conducted during the original OU4 RI/FS, post-ROD VITPP Testing, and those conducted under the POP Testing Project.

The treatability studies compare key characteristics (e.g., leachability of constituents of concern, reduction of radon emanation) of the untreated and treated Silos 1 and 2 material to determine how well each treatment process reduces risk.

3.1.2.5 Short-term Effectiveness

This criterion addresses the effects of an alternative during the construction and implementation phase until the RA objectives are achieved. The evaluation considers the effects on human health and the environment posed by remedial operations. Both the potential impacts and associated mitigative measures are examined in regard to protectiveness for the community, remedial workers, and environmental receptors during activities.

Appendix B provides a limited analysis of short-term risks to the public and workers under various scenarios associated with an alternative's operations. Potential short-term risks to the public include, but are not limited to, inhalation of radon released during waste removal and treatment operations, radiological exposure during transportation, and physical injury during waste transport off-site. Potential short-term risks to workers include the following: direct radiation exposures during facility construction, waste processing and treatment, and transportation; physical injury or death during construction and transportation activities; and exposures of nonremedial workers to airborne radioactive and chemical contaminants during waste retrieval operations. The alternative analysis also includes an assessment of mitigative measures such as engineering and institutional controls that are expected to minimize potential risks to the public and workers. **Appendix E** evaluates the short-term risks associated with transporting the treated Silos 1 and 2 material both by truck and intermodal shipments to the NTS.

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This criterion also addresses the time required to achieve protectiveness (e.g., complete treatment and disposal) for each alternative. To provide a consistent basis for the preconceptual designs of the alternatives, a standard 3-year operations period was assumed for each. The actual operating schedule will be specified during the procurement and subsequent design process of the selected treatment alternative. Time to Achieve Protection includes the total time required to design, construct, start-up, and operate the alternative, as well as the relative ability and associated impacts of each alternative's attempt to complete operations in less than three years.

3.1.2.6 Implementability

Implementability is the assurance of a planned alternative to be carried through to completion and to meet the primary project objective. For all alternatives, the primary project objective is to remediate the Silos 1 and 2 material using a technology in such a manner that the treated, containerized waste is acceptable to the NTS disposal facility. For the implementation to be considered efficient and effective, the objective must be met within prescribed 3-year treatment schedule and meet other technical requirements identified in **Appendix G**.

Section 3.1.2.6.1 describes the approach taken to evaluate implementability of the screened alternatives. The criteria used in the evaluation are discussed in **Section 3.1.2.6.2.** Implementability issues that are common to the four alternatives, and thus, do not contribute to any discernable discriminating issues between the alternatives are discussed in **Section 3.1.2.6.3**. A discussion of assumptions made to facilitate the evaluation of implementability is provided in **Section 3.1.3**.

3.1.2.6.1 Approach and Methodology

Based on EPA guidance (EPA 1988), the implementability criterion examines the technical and administrative feasibility, as well as the availability of services and materials that affect implementation of an alternative. Technical feasibility factors that impact operability and constructability (including D&D) are assessed. The assessment of technical feasibility examines the performance history of the technology in direct applications, or considers the expected performance for similar applications. Uncertainties associated with design, construction, operation, significant impacts or potential enhancements to schedule, maintenance, D&D, management of secondary wastes, and reprocessing of treated Silos 1 and 2 material are also addressed. Administrative factors include permitting and regulatory coordination, transportation, and other programmatic issues that affect implementation. Availability of services considers the availability of contractors, equipment, and utilities required to support the remediation project.

A summary of significant implementability issues for each alternative is provided in the comparative analysis **(Section 4)**. A summary table that identifies discriminating issues and compares the implementability of each alternative is also included in **Section 4.**

3.1.2.6.2 Discussion of Criteria

The primary criteria for the evaluation of implementability are included in the technical feasibility, administrative feasibility, and availability of services and materials. These criteria and the key elements considered for each criterion are identified as follows:

Technical Feasibility

Scaleup

Commercial Demonstration

Operability

- Ease of Operations
- Reliability
- Maintainability
- Complexity
- Ease of Acceleration

Constructability

- Ease of Construction
- Fabrication Method
- Ease of D&D

Administrative Feasibility

Licensing

Programmatic

Availability of Services (Contractors, Equipment, Utilities)

3.1.2.6.2.1 Technical Feasibility

The evaluation of the technical feasibility of an alternative consists of scaleup, resemblance to commercially-demonstrated technologies, operability, and constructability (including D&D). Where proven technologies are proposed, the assessment of technical feasibility examines the performance history of the technologies in direct applications, or considers the expected performance for similar applications.

The following is a brief summary of the key elements evaluated under technical implementability.

Scaleup

Defines the alternative's ability to be scaled to an operating capacity that will complete the treatment of Silos 1 and 2 material within a 3-year period with approximately 70% online availability.

Commercial Demonstration

Commercial Demonstration considers the degree to which the technology has been demonstrated by the commercial and government industries on wastestreams that are reasonably similar to the Silos 1 and 2 material, with respect to its chemical makeup, physical characteristics, and radiological hazards.

A search was performed identifying remedial sites across the U.S. and abroad where vitrification and chemical stabilization treatment technologies have been applied to the remediation of hazardous (lead contaminated) and/or radioactive material. Information was obtained via the EPA's nationwide electronic database (REACH IT) and contractor input in response to a CBD solicitation of qualified technologies. **Tables 3.1-2** through **3.1-5** presents a list of examples where the application of both chemical stabilization and vitrification technologies were applied to wastestreams that are reasonably similar to the Silos 1 and 2 material. The facilities include both government (DOE facilities) and commercial remedial sites.

Operability

Operability is defined as a qualitative assessment of the capability of a system to achieve its functional objectives. The key elements that affect operability include the following:

Ease of Operation - assesses the complexity and relative ease of operating the full-scale processing facility. To evaluate the ease of operating the system at full-scale capacity, process controls, process variables, failure modes, operating parameters, etc., are considered.

TABLE 3.1-2
DOE EXPERIENCE WITH CHEMICAL STABILIZATION

SITE	WASTESTREAM	TREATMENT METHOD	COMMENTS & ISSUES
Fernald – Plant 6	2,500 drums of metals uranium/thorium mixed waste	Cement, grout into drum and white metal boxes.	Successful treatment due to: strict quality control of operation, good process control program, excellent quality assurance program, experienced subcontractor, disposal facility identified up front so waste was treated to known acceptance criteria, good treatability study data, clear work scope and specifications, good figuration.
Fernald – Thorium Nitrate	7,150 gallons liquid thorium nitrate	Neutralized and solidified with cement grout into drum..	Successful treatment due to: strict quality control of operation, good process control program, excellent quality assurance program, experienced subcontractor, disposal facility identified up front so waste was treated to known acceptance criteria, good treatability study data, clear work scope and specifications, good figuration.

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TABLE 3.1-2 (continued)

SITE	WASTESTREAM	TREATMENT METHOD	COMMENTS & ISSUES
West Valley	18,000 drums of high level waste	Pretreatment separated high-level waste from low-level waste. Low-level waste slurry treated with cement-based stabilization.	Proper waste segregation/preprocessing produced 2 wastestreams optimized for each treatment technology. 1,500 drums high level waste being successfully vitrified. 19,877 drums low-level waste successfully cement stabilized.
Paducah Gaseous Diffusion Plant	36 containers of mixed waste acids contaminated with high levels of technetium, chromate, and lead.	Neutralization of acids. Reduced, precipitated and solidified slurry.	None.
Weldon Spring, Missouri	Pond sludge from raffinate Pit 3	Cement grout pumped 1,000 feet to on-site disposal cell.	122,000 yd^3 of sludge treated over 8-month period (4/98 - 11/98). 186,000 yd^3 of grout produced (52% volume increase). Little or no contamination or radiation exposure from uranium. Not a RCRA hazardous waste. Implementation required a thinner grout than what was demonstrated during pilot demonstrations.
Rocky Flats Pondcrete	Water, sediment, low-level mixed waste	Cement grout 1:5 waste to cement ratio placed in cardboard box.	Improper curing, excess water, unsuitable storage containers. Production rate increased and cement usage decreased indicating quality control problems. Utilized mixers which rely on aggregate to aid in mixing process which is too slow for grout production.
DOE-Oak Ridge K-25 Plant	Mixed waste pond sludge (nickel, pH > 12.5, uranium)	Cement grout placed into drum.	Problems with 46,000 out of 78,000 drums. Drum corrosion and leakage, too high pH level, improperly solidified material, poor recipe formulas, mix design development failed to adequately address phase separation, no consideration for final disposal WAC.

TABLE 3.1-3

COMMERCIAL EXPERIENCE WITH CHEMICAL STABILIZATION

SITE	WASTESTREAM	TREATMENT METHOD	COMMENTS & ISSUES
Magnox Encapsulation Plant, England	Fuel cladding waste from decanning operations during the reprocessing of Magnox fuel elements	Waste encapsulated in cement inside a 500 liter stainless steel drum.	Waste is classified as intermediate level waste and requires remote handling and treatment. Treated products meet U.S criteria for disposal including TCLP, American National Institute Standards (ANSI) 16.1 leach test, compressive strength, and freeze/thaw cycling tests.
Waste Encapsulation Plant, England	Oxide fuel cladding waste, sludges and slurries from Thermal Oxide Reprocessing Plant	Waste encapsulated in cement inside a 500 liter stainless steel drum.	Process has treated waste retrieved from storage facilities at Sellafield, many of which are high salt content waste similar to waste currently stored at DOE sites in U.S. Treated products meet U.S criteria for disposal including TCLP, ANSI 16.1 leach test, compressive strength, and freeze/thaw cycling tests.

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TABLE 3.1-3 (continued)

SITE	WASTESTREAM	TREATMENT METHOD	COMMENTS & ISSUES
Waste Packaging and Encapsulation Plant, England	Solid and liquid waste from low-level liquid effluent treatment facilities at Sellafield. Mainly ferric hydroxide sludges and scrap equipment.	Waste encapsulated in cement inside a 500 liter stainless steel drum.	Treated products meet U.S criteria for disposal including TCLP, ANSI 16.1 leach test, compressive strength, and freeze/thaw cycling tests.
Dupont, Florida	Soils and sludges contaminated with lead, arsenic, and fluoride.	Stabilization with Portland cement	Large capacity pugmill utilized. Treatment goals of TCLP for lead and unconfined compressive strength of 50 psi were met.
PAB Site Remediation Group, L.L.C. Louisiana	Oily waste contaminated with 8 RCRA metals.	Stabilization with cement, ferrous sulfate and organophilic clay.	32,000 tons of waste stabilized using pugmill. Performance goals of Universal Treatment Standards (UTS) for RCRA metals, 50 psi compressive strength and durability.
Burlington Northern Santa Fe Railroad, Wyoming	Soils and sludges contaminated with lead.	Stabilization with portland cement.	Waste loading of 85% contaminated soil and 15% portland cement. Treated soil met TCLP for lead with all but one sample below 1 part per million (ppm).

TABLE 3.1-3 (continued)

SITE	WASTESTREAM	TREATMENT METHOD	COMMENTS & ISSUES
Umatilla Chemical Depot, Oregon	Soil contaminated with lead.	Solidification/ Stabilization	- 6,600 yd^3 - Levels prior to treatment 500 to 40,000 ppm. After treatment less than 5 ppm. 15% cement resulting in 15% volume increase
Jacksonville Naval Air Station, Florida	Sludges and soil contaminated with arsenic, cadmium, chromium, lead, and nickel.	Solidification/ Stabilization	- 2,795 yd^3 - Treated waste met TC limits for RCRA metals.
NL Industries, New Jersey	Soils and slag contaminated with lead and cadmium.	Solidification/ Stabilization	- 9,400 yd^3 - Treated waste met TC limits for lead and cadmium
EI Dupont de Nemours & Co, Iowa	Soils and slag contaminated with cadmium, chromium, lead, and selenium.	Solidification/ Stabilization	- 9,200 yd^3 - Treated waste met TC limits for RCRA metals. Volume increase of 20%.
62nd Street Dump, Florida	Soil contaminated with cadmium, chromium, and lead.	Solidification/ Stabilization with Portland Cement	- 140,000 yd^3 - Prior to treatment: lead 224 mg/L; cadmium 20 mg/L; chromium 100 mg/L. After treatment: lead less than 5 mg/L.

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TABLE 3.1-3 (continued)

SITE	WASTESTREAM	TREATMENT METHOD	COMMENTS & ISSUES
Anaconda Co. Smelter, Montana	Soil contaminated with arsenic cadmium, and lead.	Solidification/ Stabilization with flue dust, cement, limie, and water.	- 518,299 yd^3 - Treated waste met TC limits for RCRA metals.
Geiger (C&M Oil), South Carolina	Soil contaminated with chromium and lead.	Solidification/ Stabilization	- 24,000 yd^3 - Volume increase of 33%. Treated waste met TC limits for RCRA metals. Met ANSI 16.1 leach test goals
Hastings East Industrial Park Surface Soils, Nebraska	Soil contaminated with cadmium and lead.	Solidification/ Stabilization. 1% lime and water.	- 9,500 yd^3 - Treated waste met TC limits for RCRA metals. 23% volume increase.
Kassauf-Kimerling Battery, Florida	Soil contaminated with lead.	Solidification/ Stabilization	- 30,000 yd^3 - Treated waste met TC limits for lead.
Wyckoff Eagle Harbor, Washington	Soil contaminated with RCRA metals.	Solidification/ Stabilization with Type II Portland cement.	- 3,771 yd^3 - Volume increase of 15 – 25%. Treated waste met TC limits for RCRA metals.
Denver Radium Site, Colorado	Soil contaminated with radium.	Solidification/ Stabilization with cement and flyash.	- 60,000 yd^3 - Radium-226 concentration 16 pCi/g. Stabilized waste placed in disposal cell with cap consisting of clay, geosynthetic material, sand, and gravel.
Letterkenny Army Depot, Pennsylvania	Soil contaminated with lead.	Solidification/ Stabilization	- 17,143 yd^3 - Treated waste met TC limits for lead [15 parts per billion (ppb)].

TABLE 3.1-4

DOE EXPERIENCE WITH VITRIFICATION

SITE	WASTESTREAM	TREATMENT METHOD	COMMENTS & ISSUES
Fernald Pilot Plant	Nonradioactive surrogate Silos 1, 2, and 3 material spiked with lead.	Joule-heated melter. Slurry surrogate and glass formers 50-60% water.	1 metric ton per day (MTD) melter. Melter failed due to reduction of lead that ultimately caused a breech in the melter.
West Valley	High-level waste from reprocessing operations. Contains TRU and fission products.	Joule-heated melter. Pretreatment separated high-level waste from low-level waste. Slurry of waste and glass formers.	0.72 MTD. Single tank of liquid/slurry waste. Fairly homogeneous and well characterized.
Savannah River DWPF	High-level waste from reprocessing operations. Contains TRU and fission products.	Joule-heated melter. Slurry of waste and frit.	2.4 MTD. Multiple tanks with different constituents in each. Waste is not well characterized. Control of reduced metals a problem with shorting out electrodes.
Savannah River M Area	670,000 gallons of liquid mixed waste.	Joule-heated melter. Slurry of waste and glass formers.	5.0 ton per day melter. Liquids contained in two tanks. Very homogeneous and well characterized. Initial melter failed and was replaced.
Oak Ridge Reservation (K-25) Transportable Vitrification System (TVS) EV-301	Central Neutralization Facility of low-level waste sludge and pond sludge.	Joule-heated melter. Slurry of waste and glass formers. High temperature melter, molybdenum electrodes.	300 pounds per hour (lb/hr) melter capacity. A total of 276 cubic feet.(ft^3) of mixed waste was processed during successful demonstration test at East Tennessee Technology Park. Achieved a volume reduction of 60%. Studies are underway evaluating technical and economic viability of full-scale waste treatment.

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TABLE 3.1-5

COMMERCIAL EXPERIENCE WITH VITRIFICATION

SITE	WASTESTREAM	TREATMENT METHOD	COMMENTS & ISSUES
Hickman, Arkansas	Sludges contaminated with RCRA metals.	Combustion (torch)	Two melters designed for 20 tons per day of glass. Process can treat slurry feed of sulfates and RCRA metals. Original brick in melter provided 2 years of service and expect 5 years for new brick.
Hannibal, Ohio	Spent potliners (K088 listed waste).	Combustion Melter System.	Operating 50 MTD melter. Processed waste passes TCLP and will be used as a feedstock for tile manufacturing as a recycling operation. State of Ohio EPA permitted process as recycling.
Germany – PAMELA	High-level liquid waste containing TRU and fission products.	Joule-heated melter. Liquid fed plus dry frit.	0.72 MTD melter. 265 cubic meters (m^3) processed in 6 years beginning in 1985. 8 to 10% waste oxide loading.
France – Marcoule	High-level liquid waste containing TRU and fission products.	Low frequency induction heated melter with rotary calciner. Dry calcine feed.	0.36 MTD melter. Began operation in 1978.

TABLE 3.1-5 (continued)

SITE	WASTESTREAM	TREATMENT METHOD	COMMENTS & ISSUES
France – La Hague	High-level liquid waste containing TRU and fission products.	Low frequency induction heated melter with rotary calciner. Dry calcine feed.	4 melters each at 0.6 metric tons per day. Began operation in 1989.
England – Sellafield	High-level liquid waste containing TRU and fission products.	Licensed French low frequency induction heated melter technology with rotary calciner. Dry calcine feed.	3 melters each at 0.6 metric tons per day. 2 units operating since 1990.
Japan - Tokai	Assumed to be high-level liquid waste containing TRU and fission products.	New German cold crucible, high frequency induction heated melter.	0.72 MTD melter. In operation for 1 year.
Russia	Assumed to be high-level liquid waste containing TRU and fission products.	Joule-heated melter. Liquid fed with liquid phosphoric acid glass formers.	2 melters each at 3 metric tons per day.

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Reliability of the process technology and supporting systems is an assessment of total plant availability. Reliability of systems or assemblies is a function of the reliability of the component parts or equipment. Reliability of components is evaluated by comparison of performance histories under similar operational constraints. Since reliability of a system is a cumulative function based on the system components, minimizing the number of pieces of equipment in general increases the reliability of the system. Critical systems or components may require parallel operation or standby redundancy (spares already in place) to ensure that a critical function or system availability is not compromised.

Maintainability is an assessment of the ability to ensure that process operations continue in a safe and effective manner, and the ability to demonstrate predictable maintenance trends for key process or support equipment. Maintainability is assessed by evaluating the ease of access, and repairability of equipment and systems. Repairability evaluates the ease of restoring a failed component to full operation, either by field or shop repair, or by replacement. Repairability is influenced by various factors, including available workspace, location of equipment, and availability of replacement parts and maintenance personnel to perform the work. Maintainability in a nuclear application must also consider types of contamination, whether the task is remote or hands-on repair, as low as reasonably achievable (ALARA) requirements, and the need for specialized tools, trades, or training.

Complexity is a qualitative evaluation that considers the essential process operations, the number and types of equipment and controls, and the support systems needed to meet the functional objectives.

Ease of Acceleration is defined as the ability of the alternative to accelerate the 3-year operating schedule. An alternative may be capable of acceleration through additional operating hours, capacity, or additional lines. Any potential for enhancement or acceleration of the remedial schedule is noted during the evaluation of the respective alternative. It should be noted that any programmatic decision to accelerate the operation schedule should optimally occur early in the design phase to avoid cost and schedule delays associated with redesign or rework of constructed facilities.

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Constructability

Constructability is defined as an assessment of the ability to fabricate, assemble and/or erect, and test the major components and systems of a technology before beginning operations. Constructability does not evaluate the design, or assess the ability of the constructed facility to meet the primary project objective. The key elements that affect the ease and reliability of constructability include the following:

- Ease of Construction

  Increased size and complexity of a construction project increase the risk of damage or injury, improper installation, and the number of changes or modifications needed during construction. Specialized equipment or components have a negative effect on constructability since a select work force with special trades, tools, or talents may be required. Unique materials of construction may also negatively impact constructability.

- Fabrication Method

  A newly developed technology may require construction techniques that are also new or under development. A mature technology may lend itself to modular construction of prefabrication of key components. Equipment and/or subsystems that can be shop fabricated and tested in modules prior to arriving on-site are easier to construct than those that must be field-erected and tested.

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- Ease of D&D

Evaluation of the ease of D&D of a facility considers the facility size, complexity, and layout; number of unit operations and type of equipment; and the nature and extent of radiological contamination. Process and facility design, and the type of equipment selected during design enhance the ease of implementing D&D. Equipment is preferred that: is enclosed or sealed; has minimal internal components, recesses, and grooves; and has a protective coating to facilitate spray decontamination. With some exceptions, portable or modular equipment is more amenable to effective D&D.

3.1.2.6.2.2 Administrative Feasibility (Licensing and Programmatic)

The evaluation of administrative feasibility includes a discussion of coordination with regulatory agencies in order to establish the framework for complying with special substantive technical requirements of an alternative. While neither permits nor licenses are required to conduct remediation activities under CERCLA, the substantive technical requirements of air emission and other permits need to be met by the design and operation of the alternative stabilization process. These technical requirements, which take the place of a permit, are embodied in the ARARs identified for alternatives in this FS.

For all alternatives, disposal of the stabilized waste and D&D waste is planned at the NTS. The NTS is a DOE-owned facility; thus, special permits for disposal of FEMP wastes at the NTS are not required. However, in accordance with the NTS WAC, a waste acceptance package consisting of a waste profile, waste certification program plan, and a list of authorized certification personnel are required to be prepared by DOE-FEMP and approved by the NTS before waste shipment.

In accordance with the administrative requirements of the NTS WAC, the wastestream profile of the treated Silos 1 and 2 material will be screened against specified criteria, which are used to control the disposal of material at the NTSs. If necessary, an addendum to the NTS performance assessment (PA) will be prepared to determine the proper configuration, and engineering and administrative controls for the disposal of the material at the NTS. This assessment will be conducted jointly by the NTS and DOE-FEMP during the implementation of the selected remedy once the final wasteform has been identified. Findings of the PA could impact the disposal depth and design of the disposal cell (including any engineered barriers placed around the waste) at the NTS. Any changes in the NTS WAC could affect the remedial alternative and treatment process. For example, changes could require adjustments to the strength of the stabilized waste, the wasteform, or design of the disposal container.

Currently, the NTS is the only facility that has been identified that is capable of receiving and disposing the treated Silos 1 and 2 material. In the event that another disposal facility becomes available, which is appropriately permitted and licensed, offers an equivalent level of protectiveness to human health and the environment and a clear economic advantage, the DOE would prepare an explanation of significant differences at that time.

In the event secondary wastes generated during the treatment operations of the Silos 1 and 2 material or D&D activities which cannot be disposed at the NTS, without additional treatment, the DOE would require the flexibility to treat and/or dispose the secondary waste at an appropriately licensed off-site facility.

3.1.2.6.2.3 Availability of Services and Materials (Contractors, Equipment, Utilities)

The availability of services and materials considers (1) the material components required by a proposed technology and the required quantities of those materials, and (2) operations that require special services, operator skills, or training. Availability also considers existing treatment, storage, and disposal capacities; availability of contractors, equipment, utilities and operators; and prospective technology applicability or development requirements.

3.1.2.6.3 Common Implementability Issues

The detailed implementability discussion for each alternative focuses on aspects of the design that are discriminating factors (both positive and negative) between the alternative technologies. Design aspects that are consistent from one technology to the other, relative to implementability, are discussed below and are not addressed in detail in the individual technology discussions. However, specific/significant discriminators within these systems are addressed in the individual technologies.

Feed Preparation

The Feed Preparation System for each technology is difficult to implement due to the erosive effects of the abrasive, high-solids content of Silos 1 and 2 material, multiple stages required to prepare an acceptable feed product, specialty equipment requirements, stringent metering requirements (additives), and the number of equipment components required to perform the overall function of this system. For example, since conditioning of the Silos 1 and 2 material is performed discretely, significant material transfer requirements exist to move Silos 1 and 2 material from function to function (the Hydraulic System also requires complete flush capacity to prevent line/component pluggage). Process control parameters for the Feed Preparation System include slurry level, density, solids content, velocity, pressure, pH, metering and moisture content. Each control parameter must be carefully monitored throughout the feed preparation process in order to maintain normal plant operations and to ensure that the system does not exceed operable limits. Finally, radon emanation requires that those components that directly handle Silos 1 and 2 material be maintained at negative pressure with respect to atmosphere (further complicating the implementation of this system) for worker safety.

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Product Handling

The Product Handling System for each technology is difficult to implement due to the number of functions (remotely operated) and varying degree of complexities required to prepare the container for shipping, the number of customized equipment components required to perform operations, and the need to control radon released from the treated Silos 1 and 2 material. With the exception of container conveying, the product handling design is unique (e.g., lifting containers with lids unbolted and specially designed lifting devices) and utilizes undemonstrated equipment with unknown reliability data. All operations are performed remotely due to ALARA considerations. The Product Handling System is characterized by many operations that are performed by specialized equipment items that must be adapted for remote operations. In addition, shield doors, conveyors, and remote viewing systems are required to support the overall operability of this system.

Wastewater Treatment

The Wastewater Treatment System for each technology is not difficult to implement. There are minimal concerns regarding the implementability of the designs in terms of their effectiveness as Liquid Waste Treatment Systems. Most of the identified components of these Water Treatment Systems are commercially developed and demonstrated. Design issues for the treatment process include process control, effectiveness in removing required metals (lead, selenium, etc.) and radionuclides to meet the AWWT wastewater acceptance requirements, and resolubilization of precipitated metals during pH adjustment. In order to provide confidence that the Liquid Waste Systems will meet their design objectives (including meeting the AWWT wastewater acceptance requirements), the overall Wastewater Treatment Systems must be designed for the pretreatment of liquid wastes generated during operation and D&D. Additionally, the equipment must be integrated into the overall RD.

Remote Operations

In addition to the systems listed above, there is also a concern regarding the adaptation of remote operations (within the discussion of implementability). Equipment and components specified are generally demonstrated and commercially available. However, a level of complexity results from adapting standard components for remote operations. This concern is consistent across the four technologies; the application of remote operation to the specific technologies presents unique and varied challenges, however, these should not become a discriminator in the overall evaluation.

3.1.2.7 Cost

In the FS process under CERCLA, cost estimates identify remediation alternatives that are significantly more expensive than competing alternatives, but do not offer commensurate performance or health protectiveness. The cost estimates presented in this FS address key project elements for each alternative and should not be construed as the total project cost (TPC) for the remediation of the Silos 1 and 2 material at the FEMP.

The cost estimates supporting this FS were prepared in accordance with the **Design Basis and Description (Appendix G)**, which incorporates technology-specific data generated during the POP Testing Project. The estimates employ a wide variety of cost-estimating methods and techniques such as generic unit costs, contractor information, DOE guidance, conventional cost-estimating guides, commercial remedial costs, and cost information based on actual FEMP operation and maintenance experience on jobs of similar magnitude and complexity. The cost elements were developed for: (1) capital costs; (2) engineering cost; (3) O&M costs; (4) decontamination and decommissioning costs; (5) project management costs; (6) waste disposal costs; and (7) cost of money. A more detailed discussion of the cost-estimating methods, basis, and assumptions for these cost components is presented in **Appendix C** of this FS.

Final remediation costs depend on the actual detailed design used, actual labor and material costs, actual site conditions, productivity, competitive market conditions, final scope, final schedule, final engineering design, FEMP support cost, and other variables. As a result, final remediation costs will vary from the estimates presented here. Due to these factors, future funding needs should be reviewed before specific financial decisions are made or final RA budgets are established.

In addition, a present worth analysis was performed for each alternative to evaluate expenditures that occur over different time periods by discounting all future costs to a common base year (FY99). This allows the RA alternatives to also be compared on the basis of a single figure representing the amount of money that, if invested in FY99 and disbursed as needed, would be sufficient to cover all costs associated with the RA over its planned life. A more complete discussion of the present worth analysis is provided in **Appendix C**.

3.1.2.8 State Acceptance

This criterion considers the input of the OEPA regarding the alternatives being considered for remediation of the Silos 1 and 2 material. In the original OU4 FS process, the OEPA reviewed the preferred alternative of joule-heated vitrification and concurred with the selection in the original OU4 ROD (EPA 1994). However, the OEPA has agreed with DOE and EPA on the need to reevaluate the selected remedy for the Silos 1 and 2 material and has jointly established a path forward for the decision-making process. Formal comments received from the OEPA on the draft revised FS will be addressed in the final revised FS, before receiving EPA approval. As specified by the NCP, this modifying criterion will be formally addressed in the regulatory process following the public review period (i.e., in a Responsiveness Summary to accompany the ROD amendment).

3.1.2.9 Community Acceptance

This criterion ensures that the community, both local to the FEMP and near potential transportation routes and disposal facilities, have sufficient opportunity for input to the selection of a remedy. DOE solicited input from the community on the preferred remedial alternative during the original OU4 FS process. Both verbal and written comments received from the public during the participation process are documented in the approved OU4 ROD. As specified by the NCP, this modifying criterion will be formally addressed following the formal public review period after issuance of the PP (i.e., in a Responsiveness Summary to accompany the ROD amendment).

3.1.3 Summary of Key Assumptions and Criteria

The goal of Sections 1 and 2 was to present pertinent background information and to provide relevant supporting information for the reader to develop a common basis for understanding the screening and selection of treatment technologies being evaluated by this FS. The purpose of this section is to facilitate the reader's understanding of the evaluation of alternatives presented in **Sections 3.2 - 3.5.**

Throughout this FS, assumptions and criteria are documented to facilitate the reader's understanding of the regulatory and technical basis supporting the development and evaluation of alternatives for the treatment of the Silos 1 and 2 material. This section summarizes key assumptions and criteria found in this FS that form the foundation of the alternative descriptions and shape their evaluations, such as cost and implementability. "Assumptions," as used in the context of this FS, refer to facts or statements taken for granted and based upon demonstrated performances, third-party published data or warranted claims. "Criteria," as used in the context of this FS, refer to either requirements or general information that form the basis for design.

Additional assumptions and criteria used in this FS are discussed in **Section 3** and **Appendix G** as appropriate. Only the key overall criteria and assumptions for the revised FS are listed below in **Table 3.1-6.**

Table 3.1-6 provides a brief description of the nature and extent of the assumption or criteria (requirement or general information) and a reference point within the FS where the reader can find a more detailed discussion.

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TABLE 3.1-6
SUMMARY OF DESIGN CRITERIA AND ASSUMPTIONS

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	ADMINISTRATIVE		
A1	All Silos 1 and 2 material, including heel material, will be removed from the silos and transferred into controlled interim storage tanks (50 wt% solids) under the Accelerated Waste Retrieval (AWR) project for future transfer and treatment by the full-scale remediation contractor. The transfer equipment from the interim storage Transfer Tank Area (TTA) will be installed under the AWR Project.	Appendix G Section G.1	Assumption
A2	The NTS has officially documented that the UTS would not be imposed as part of the NTS waste acceptance criteria (WAC) for disposal of the treated Silos 1 and 2 material.	Section 1.4.7.3	General Information
A3	Alternatives evaluated in the detailed analysis focus on the on-site treatment of the Silos 1 and 2 material.	Section 2.5	General Information
A4	Only two treatment technology families (vitrification, chemical stabilization) passed the preliminary screening of alternatives and will be evaluated in the detailed analysis.	Section 2.6	General Information

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TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	ADMINISTRATIVE (continued)		
A5	The remediation contractor will mobilize, transfer, treat, and package the Silos 1 and 2 material to meet the NTS WAC.	Appendix C	Requirement
A6	Scope of the revised Silos 1 and 2 FS is limited to the reevaluation of the treatment component of the selected remedy in the OU4 ROD.	Section 1.2	Requirement
	REGULATORY		
R1	A search of regulations promulgated since the OU4 ROD was approved in 1994 did not identify any new ARARs pertinent to the remediation of the Silos 1 and 2 material.	Appendix A	General Information

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TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	REGULATORY (continued)		
R2	The NCP requires that, "...each remedial action shall utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable" [40 CFR Part 300.430(f)(l)(ii)(E)].	Section 1.4.7.2	Requirement
R3	The CERCLA off-site rule, found in CERCLA Section 121(d)(3) and promulgated at 40 CFR Part 330.440, requires that waste from a RA that is shipped off-site for treatment and/or disposal be transferred only to those units at a facility that are operating in compliance with RCRA and with all other applicable federal and state requirements. As a representative disposal facility, the NTS has been granted approval under the off-site rule to dispose of low-level waste from the FEMP OU4 including "small volumes" of 11(e)(2) by-product material in accordance with DOE Order 435.1 Chapter IV.	Section 1.4.7.2, and Appendix A Section A.1	Requirement
R4	For purposes of proper packaging and transportation of the Silos 1 and 2 material, the material is governed by the DOT regulations under 49 CFR Subtitle B, Chapter I, Subchapter C, "Hazardous Materials Regulations."	Section 1.4.7.3, Appendix A, Section A.3 and Appendix E, Section E.2	Requirement
R5	For proper transportation, the Silos 1 and 2 material is classified as LSA-II material.	Section 1.4.7.3, and Appendix E, Section E.2	Requirement

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TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	REGULATORY (continued)		
R6	The evaluation of the alternatives in this revised FS, in accordance with CERCLA, has been completely integrated with the values considered under the NEPA.	Section 1.3.5, and Appendix D	Requirement
R7	For purposes of waste management and proper disposal, the Silos 1 and 2 material is classified as "by-product material," resulting from the processing of uranium ore concentrates, as defined under Section 11(e)(2) of the AEA of 1954. It is specifically exempt, as defined, from regulation as solid waste under RCRA 40 CFR Part 261.4(a)(4).	Section 1.4.7.1 and Appendix A, Section A.4	Requirement
R8	The material in Silos 1 and 2 is considered "pollutants or contaminants," as that terminology is defined under CERCLA and the NCP. The Silos 1 and 2 material will be treated for the COCs.	Section 1.4.7.2	Requirement

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TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	GENERAL		
G1	It is assumed that the Silos 1 and 2 material will be processed over a 3-year period.	Appendix G, Section G.2 and Appendix C	Assumption
G2	It is assumed that the full-scale treatment facility will be designed and sized to process the material with 70% plant availability.	Appendix G, Section G.2	Assumption
G3	The solids content of the Silos 1 and 2 material slurry delivered to the full-scale treatment facility from the TTA is expected to be in the range of 10-30 wt% solids.	Appendix G, Section G.2	Assumption
G4	The volume of Silos 1 and 2 material required to be processed is estimated to be 8,890 yd^3 and weigh 9,955 tons (dry weight basis).	Appendix G, Section G.1	General Information

TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION			FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	GENERAL (continued)				
G5	The predominant species of radionuclides and estimated total activity present in the Silos 1 and 2 material are as follows:			Appendix F, Section F.2 and Appendix G, Section G.2	General Information
	Radionuclides	Total Activity Curies (Ci)			
		Mean	Upper Confidence Level (UCL)		
	Ac-227	70	91		
	Pb-210	1,954	2,470		
	Po-210	2,439	3,230		
	Ra-226	3,700	4,740		
	Th-228	6.6	58.3		
	Th-230	685	907		
	Th-232	5.2	13.2		
	U-234	11	13.1		
	U-238	9.6	11.2		

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TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	GENERAL (continued)		
G6	The predominant species of non-radioactive components and estimated concentrations (normalized wt% oxide basis) in the Silos 1 and 2 material are as follows: Component / Silo 1 / Silo 2 SiO_2 / 57.00 / 58.99 PbO / 13.68 / 7.17 BaO / 7.18 / 3.47 SO_3 / 3.88 / 4.05 CO_2 / 3.65 / 3.93 Al_2O_3 / 2.96 / 3.93 Fe_2O_3 / 2.85 / 7.06 Na_2O / 2.05 / 1.02 MgO / 1.37 / 1.97	Appendix G, Section G.2	General Information

TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	DESIGN		
DSN1	Releases from all silos activities (of which those described in this text are only a part) shall add no more than 0.5 pCi/L radon concentrations to the fenceline. Basis: The current limit is 3.0 pCi/L above background on an annual average. The latest revised limit at 10 CFR Part 834, not identified as an ARAR, is 0.5 pCi/L above background annual average. The limits being applied elsewhere (i.e., Silo 3, AWR, etc.) specify that Rn-222 emissions from Silos 1 and 2 remediation must be limited such that they result in a contribution (annual average) of no more than 0.5 pCi/L to the fenceline concentrations.	Appendix G, Section G.2	Assumption

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TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	DESIGN (continued)		
DSN2	This description provides the estimated waste loading and density of the treated Silos 1 and 2 material based upon the POP test results for the four alternatives. - **Vitrification — Joule-heated**: 90 wt% dry weight basis, 2.81grams per cubic centimeter (g/cm^3) with 2% air pockets, bulk density is 2.76g/cm^3. - **Vitrification — Other**: 87 wt% dry weight basis, 2.81 g/cm^3 monolith, but cullet is 50% void, bulk density is 1.41 g/cm^3. - **Chemical Stabilization — Cement-based**: 30 wt% dry weight basis, 1.52 g/cm^3 with 5% air pockets assumed, bulk density is 1.44 g/cm^3. - **Chemical Stabilization — Other**: 24 wt% dry weight basis, 1.68 g/cm^3 with 2% air pockets assumed, bulk density is 1.65 g/cm^3.	Appendix G, Section G.1	Assumption
DSN3	Maximum delivery flow rate of the slurry from the TTA to the remedial facility shall be 5,900 lb/hr on a dry weight basis. The 5,900 lb/hr was based on retrieving sufficient material 5 days/week, 8 hrs/day (less daily start-up/shutdown time) to support a 3-year processing plant that is operated 7 days/week, 24 hrs/day. If additional retrieval capacity is needed, the retrieval operation schedule (days/week or hrs/day) can be extended.	Appendix G, Section G.2	General Information

TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	DESIGN (continued)		
DSN4	The Silos 1 and 2 slurry (with BentoGrout™) settles to 50% solids over a period of 24 hours.	Appendix G, Section G.2	Assumption
DSN5	The existing Radon Control System (RCS) designed, constructed and operated as part of the AWR Project provides a maximum of 500 cubic feet per minute (scfm) capacity to support the full-scale treatment facility. Facility designs requiring more than 500 scfm capacity shall provide additional capacity to the RCS (as required by the technology).	Appendix G, Section G.2	General Information
DSN6	The DOE-FEMP, under 10 CFR Part 835, has established that an area in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 100 mrem/hr at 30 cm from a radiation source (containerized Silos 1 and 2 material) must be classified as a high radiation area. The Silos Project has a complete table of radiation zones with allowable stay times, etc.	Appendix G, Section G.2	Requirement

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TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	DESIGN (continued)		
DSN7	The off-gas to the RCS shall be of the following quality: - 90°F and 0.022 lb water/lb dry air maximum; - 20 ppm (vol) SO_x, maximum; - 20 ppm (vol) NO_x, maximum; - 15% (vol) CO_2, maximum; - 40 ppm organics, maximum; and - Filtered or scrubbed for particulates	Appendix G, Section G.2	Requirement
DSN8	The maximum allowable average airborne radon concentration in a normally occupied work area is 4 pCi/L with a maximum of 30 pCi/L instantaneous radon concentration.	Appendix G, Section G.2	Requirement
DSN9	Water effluent shall be collected, sampled, and analyzed prior to being released to the FEMP AWWT. The water effluent shall meet, at a minimum, the following requirements: - 10 gpm maximum flow rate (assuming no other silos function is operating at this time as 10 gpm is the limit for OU4 in its entirety); - 1,000 ppm total suspended solids (Total dissolved solids are not a concern because the 10 gallons per minute (gpm) wastestream will be significantly diluted by the much larger wastewater streams at the AWWT); and - Metals and radionuclides concentrations and quantities equal to or less than the discharge limits given in **Appendix G, Table G.2.13-1.**	Appendix G, Section G.2	Requirement

TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	CONSTRUCTION		
CN-1	The contractor shall be required to utilize the labor force to construct the remedial facilities in accordance with the FEMP's Greater Cincinnati Building and Construction Trades Council (GCBCTC) Labor Agreement.	Appendix C, Section C.1	Requirement
	OPERATIONS		
O1	It is assumed that 1% of the treated Silos 1 and 2 material process will fail WAC for disposal and require rework through the process.	Appendix G, Section G.2	Assumption
O2	Controlled access and egress is provided to all equipment requiring routine inspection and/or operation attention.	Appendix G, Section G.2	General Information
O3	DOE will maintain necessary FEMP site infrastructure, utilities, and general support functions such as the Emergency Operations Center (EOC), AWWT, medical, security, fire department, human resources, etc. These expenses are not included in the estimates.	Appendix C, Section C.1	General Information

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TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	OPERATIONS (continued)		
O4	The 3-year operating schedule for the four alternatives is based upon the POP contractor's proposed preconceptual designs as described here. - **Vitrification — Joule-heated**: 8-hr shifts, 3 shifts/day, 7 days/week at 70% availability. - **Vitrification — Other**: 8-hr shifts, 3 shifts/day, 7 days/week at 70% availability. - **Chemical Stabilization — Cement-based**: 8-hr shifts, 2 shifts/day, 5 days/week, at 70% availability.. - **Chemical Stabilization — Other**: 8-hr shifts, 3 shifts/day, 5 days/week at 70% availability.	Appendix G Section G.4 Section G.5 Section G.6 Section G.7	General Information
O5	FDF will provide the operation and maintenance support work force utilizing labor in accordance with the labor agreement between FDF and the Fernald Atomic Trades and Labor Council (FAT&LC).	Appendix C, Section C.1	Requirement
O6	It is assumed that solid secondary waste from the Silos 1 and 2 material treatment operations will meet the NTS WAC. Solid secondary waste from operations will be shipped via truck and disposed at the NTS.	Appendix C, Section C.1	Assumption

TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	MAINTENANCE		
M1	Planned maintenance, preventative and reparative, is performed in accordance with ALARA guidelines. At a minimum, radiation fields are controlled via permanent (preferred) or temporary shielding to be less than or equal to the radiation zone listed in DSN6 for the expected annual maintenance durations.	Appendix G, Section G.2	General Information
M2	Controlled access and egress is provided for personnel, tools and repair parts to all equipment.	Appendix G, Section G.2	General Information
M3	Adequate change rooms shall be provided for donning and doffing personal protective equipment (PPE).	Appendix G, Section G.2	General Information

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TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	PACKAGING		
P1	The shielding necessary to achieve DOT shipping requirements will be provided by the container.	Appendix E, Sections E.2.3 and E.2.4	Assumption
P2	The shipping/disposal packages will be filled to available volume with treated Silos 1 and 2 material as described here. - **Chemical Stabilization — Cement-based** containers will be filled to 90% of the available volume. - **Chemical Stabilization — Other** containers will be filled to 85% of the available volume. - Vitrified frit will be placed in 90% of the available volume of the container. - Vitrified monolith will be placed in 87% of the available volume of the monolith transfer container (MTC). Four MTCs will occupy 79% of the available volume of the shipping/disposal container.	Appendix G, Section G.1	Assumption

TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	PACKAGING (continued)		
P3	Packaging for the Silos 1 and 2 material (LSA-II) must, at a minimum, meet the design requirements for an IP-2 container (49 CFR Part 173.411) and the design requirements for the NTS WAC.	Section 1.4.7.3, Appendix E, Section E.2	Requirement
P4	Packages of treated Silos 1 and 2 material will be shipped under "exclusive use" conditions to the NTS. The container shall be designed to meet the radiation level limitations, described here, during transportation. - 70 mrem/hr on the external surface of the package (administrative limit established by FDF to meet the DOT radiation level requirement of 10 mrem/hr at any point two meters from the outer lateral surface of the transport vehicle). - 200 mrem/hr at any point on the outer surfaces of the transport vehicle [49 CFR Part 173.441(b)(2)]. - 10 mrem/hr at any point two meters from the outer lateral surface of the transport vehicle, excluding the top and underside of the vehicle [49 CFR Part 173.441(b)(3)]. - 2 mrem/hr in any normally occupied space [49 CFR Part 173.441(b)(4)].	Section 1.4.7.3 and Appendix E, Section E.2	Requirement

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TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	PACKAGING (continued)		
P5	The maximum gross weight of a filled container is 21,000 lb in order to allow shipment of 2 containers per truck.	Appendix G and Appendix E, Section E.2	Requirement
	TRANSPORTATION		
T1	For purposes of comparing transportation risks between the different treatment alternatives, the most conservative (greatest risk to public) direct truck shipping route (Southern Route #3) was selected as representative of the risks associated with transporting treated Silos 1 and 2 material to the NTS. A direct truck shipping route was selected because the FEMP currently has the infrastructure in place for direct truck shipments to the NTS. However, it is anticipated that actual shipments to the NTS would use a combination of both direct truck and intermodal routes throughout the duration of the project.	Appendix E, Sections E.3 thru E.5 and Appendix B	Assumption
T2	Packages of treated Silos 1 and 2 material would be transported under "exclusive use" conditions by direct truck shipment to the NTS.	Section 1.4.7.3 and Appendix E, Section E.2	Assumption

TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	TRANSPORTATION (continued)		
T3	The maximum gross weight of each truck shipment [full container(s) of treated Silos 1 and 2 material] shall not exceed 42,000 lb. The 42,000-lb limit is based on the site Procedure PT-0006, "Packaging Low-Level Radioactive Waste in ISO Containers." This limit was established to meet the DOT limit of 80,000 lb for over-the-road shipments when truck, trailer, fuel, tie-down equipment, etc., are factored into gross weight.	Appendix E, Section E.2	Requirement
	DISPOSAL		
D1	The treated Silos 1 and 2 material will be disposed at the NTS by land burial, at a proper depth and with appropriate engineering controls (e.g., cap).	Sections 1.4.7.3 and 3.2.4	General Information
D2	It is assumed that the Silos 1 and 2 material is treated to meet the NTS WAC (e.g., TC metals under RCRA, no free liquids, etc.).	Section 1.4.7.3	Assumption

<END OF SECTION>

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TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	DISPOSAL (continued)		
D3	The disposal fee charged by the NTS is based upon the exterior volume (ft^3) of the container of waste being buried. The current disposal fee rate quoted by the NTS is $7.50/$ft^3$.	Appendix C	Requirement
D4	The treated Silos 1 and 2 material will be disposed at the NTS. The "small volume" of 11(e)(2) by-product material in Silos 1 and 2 will be managed as low-level radioactive waste (LLRW) in accordance with DOE Order 435.1 Chapter IV.	Section 1.4.7.3	Requirement
	DECONTAMINATION & DEMOBILIZATION (D & D)		
DD1	It is assumed that all debris from the D&D of the Silos 1 and 2 material treatment facility meets the NTS WAC. All waste resulting from safe shutdown and D&D activities will be packaged and shipped to the NTS for disposal.	Appendix C, Section C.1	Assumption
DD2	The D&D cost does include the removal of underground concrete and utilities of the remediation facilities.	Appendix C	Assumption

TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	DECONTAMINATION & DEMOBILIZATION (D & D) (continued)		
DD3	D&D costs do not include the cost of soils remediation within the OU4 boundary. Remediation of the soils in this area has been planned and budgeted under the Soil and Water Projects - Area 7 Soils Project.	Appendix C	Assumption
DD4	The D&D costs do not include the removal and disposal of Silos 1 and 2 and the berm around them (this will already have been completed).	Appendix C	Assumption
DD5	The D&D costs do include D&D of the TTA and the RCS installed under the AWR contract.	Appendix C	Assumption
DD6	The FEMP site labor productivity multiplier of 1.186 is applied to nonradiological D&D field work related manhours.	Appendix C	General Information
	COST		
C1	The current average cost of shipping waste to the NTS is $4,200 per truck shipment, two containers per shipment, which results in a shipping cost of $2,100 per container.	Appendix C	General Information
C2	A sales tax of 6.5% for Hamilton County, Ohio is applied to the estimated equipment and materials.	Appendix C	General Information

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TABLE 3.1-6 (continued)

ITEM NO.	DESCRIPTION	FS REFERENCE	REQUIREMENT, ASSUMPTION OR GENERAL INFORMATION
	COST (continued)		
C3	The full-scale remediation contractor shall be required to furnish all facilities, equipment, material, supplies and services (documentation, training, D&D, etc.). The Silos 1 and 2 full-scale treatment facility will be designed, constructed, operated, and D&D utilizing a turnkey contractor approach like the Silo 3 remediation contract. These provisions shall be in accordance with the terms and conditions of a Firm Fixed Price/Firm Fixed Unit Price contract for providing remedial services for the Silos 1 and 2 material.	Appendix C	General Information
C4	With annual project funding dependent on the federal budgetary process, the Firm Fixed Price/Firm Fixed Unit Price contract for the full-scale remediation of the Silos 1 and 2 material would primarily consist of a base contract, incrementally funded based upon a yearly funding profile negotiated with the remediation contractor. This approach would be structured to maintain the project in compliance with the Anti-Deficiency Act.	Appendix C	General Information
C5	A pay item schedule and invoicing strategy will be utilized to pay the contractor for a percentage of specified deliverables, as well as, unit pricing per ton of Silos 1 and 2 material treated and accepted for disposal at the NTS. This schedule will be used to develop the cost of money component of the life cycle analysis.	Appendix C	General Information
C6	A cost analysis will be performed. It will combine all capital, start-up, operating, disposal, and D&D costs for the alternatives. Present day (1999) dollars will be used for all costs, regardless of the actual year that they will be expended.	Appendix C	General Information
C7	Silos 1 and 2 full-scale remediation project indirect costs are estimated based on current FEMP project experience and site guidelines.	Appendix C	General Information
C8	FDF will provide technical and programmatic oversight of the turnkey contractor throughout the Silos 1 and 2 remediation project.	Appendix C	General Information

3.2 Removal, On-site Vitrification — Joule-heated, Off-site Disposal at the NTS (VIT1)

3.2.1 Description of Alternative

The following is a summary description of this alternative. Additional conceptual engineering design details [e.g., process flow diagrams (PFDs), General Arrangement Layouts] and assumptions can be found in **Appendix G, Design Basis and Description.**

The design details presented in this revised FS are conceptual, based on information from POP testing **(Appendix H)**, and have been prepared for the sole purpose of providing a technical basis for evaluating the alternatives.

3.2.1.1 Introduction

This alternative (VIT1) involves the removal, on-site vitrification using a joule-heated melter, and off-site disposal at the NTS of the treated Silos 1 and 2 material. The Silos 1 and 2 material is removed from the TTA as a slurry containing approximately 10 wt% solids for the VIT1 process. The VIT1 **(Figure 3.2-1)** process involves dewatering of the Silos 1 and 2 material slurry to minimize the volume of material to be stabilized, followed by remediation of the de-watered material.

The representative process used to evaluate this alternative during POP testing produces a solid stabilized wasteform that has a waste loading of approximately 90 wt% Silos 1 and 2 material. The treated material is packaged in concrete shipping and disposal containers with 6-inch thick walls. Based on the *Disposal Container Size Optimization Study* (FEMP 1999), a container of this type reduces the radiation levels associated with treated Silos 1 and 2 material at 90 wt% waste loading to approximately 70 mrem/hr on contact with the surface of the container.

The facility design is based on a plant availability factor of 70% over a total operating period of three years. The plant operating basis is 24 hr/day, 7 days/week with a design capacity of approximately 15 TPD. Each operating day, a maximum of 3.6 loaded shipping and disposal containers is produced. Each shipping and disposal container contains four steel MTCs filled with vitrified Silos 1 and 2 material. Samples that were collected at the monolith forming step are tested for compliance with the NTS WAC. Upon verification that the samples of treated Silos 1 and 2 material meet the NTS WAC, the shipping and disposal containers are readied and transported to the NTS for final disposal. Interim storage capacity for approximately 144 loaded disposal containers (a 45 calendar day period at design capacity, 22 disposal containers per week) is provided as part of the treatment facility. Based on 90 wt% waste loading, and assuming 1% of the containers will fail to meet the NTS WAC and will need to be re-processed, a total of 2,398 containers will require shipment to the NTS for disposal.

The VIT1 Feed Preparation System is designed to increase the solids content of the incoming slurry from 10 wt% solids to approximately 30 wt% solids using a clarifier tank. The slurry is received from the TTA and inventoried in a receiving tank to homogenize the material before it is fed to the clarifier. The clarifier produces an underflow slurry of approximately 30 wt% solids that is discharged to a surge tank where it is held before being transferred to the feed preparation mix tanks.

The Feed Preparation System also includes the bins and transfer equipment to inventory and transfer the vitrification reagents to the feed preparation tanks. Enough storage is provided to inventory a four-week supply of vitrification reagents.

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The feed preparation tanks combine the formulated amount of clarifier underflow slurry and vitrification reagents. Once the constituents have been thoroughly mixed, a pump transfers the slurry to the melter feed tanks. Next, the slurry is metered into the joule-heated melter where it is converted into glass. The molten glass from the melter flows by gravity into steel MTCs, which are cooled by external water jackets. Four cooled MTCs are placed into a shipping container. A lid is placed on the container, and the container is conveyed to the decontamination station where it is monitored, and any contaminants on its exterior surface are removed as necessary. The container is then conveyed to the interim storage area. Additionally, the melter has been designed to remove accumulation of salts from the surface of the melt pool and drain reduced metals from the bottom of the melter. The operation of the salt drain and metals drain were demonstrated following completion of the 72-hour test; however, the contractor was unsuccessful at operating the metals drain.

A rework facility is provided to re-processes the off-specification treated material which does not meet the NTS WAC. Rework operations are carefully confined and performed in a dedicated area. Remotely controlled equipment removes the MTC from the container, shreds the glass-filled steel MTCs, separates the shredded steel from the crushed glass (off-specification treated Silos 1 and 2 material), and transfers the size-reduced glass back to the treatment system to be re-processed.

The Normal Off-gas System **(Figure 3.2-2)** is designed to maintain a negative pressure in the melter and other vitrification facility vessels where the containment of airborne contaminants, including radon, is a concern. The Normal Off-gas System maintains an airflow of approximately 500 scfm through several off-gas treatment steps that cool the off-gas and remove acid gases and particulates. The Normal Off-gas System discharges into the RCS. The resulting negative pressure ensures that the melter and other vessels do not leak gases to the local environment.

An Emergency Off-gas (EOG) System is included to prevent overpressurization of the melter in the event of a melter pressure excursion or a failure in the Normal Off-gas System. It provides off-gas cooling and particulate removal while feed to the melter is stopped and the melter is idled.

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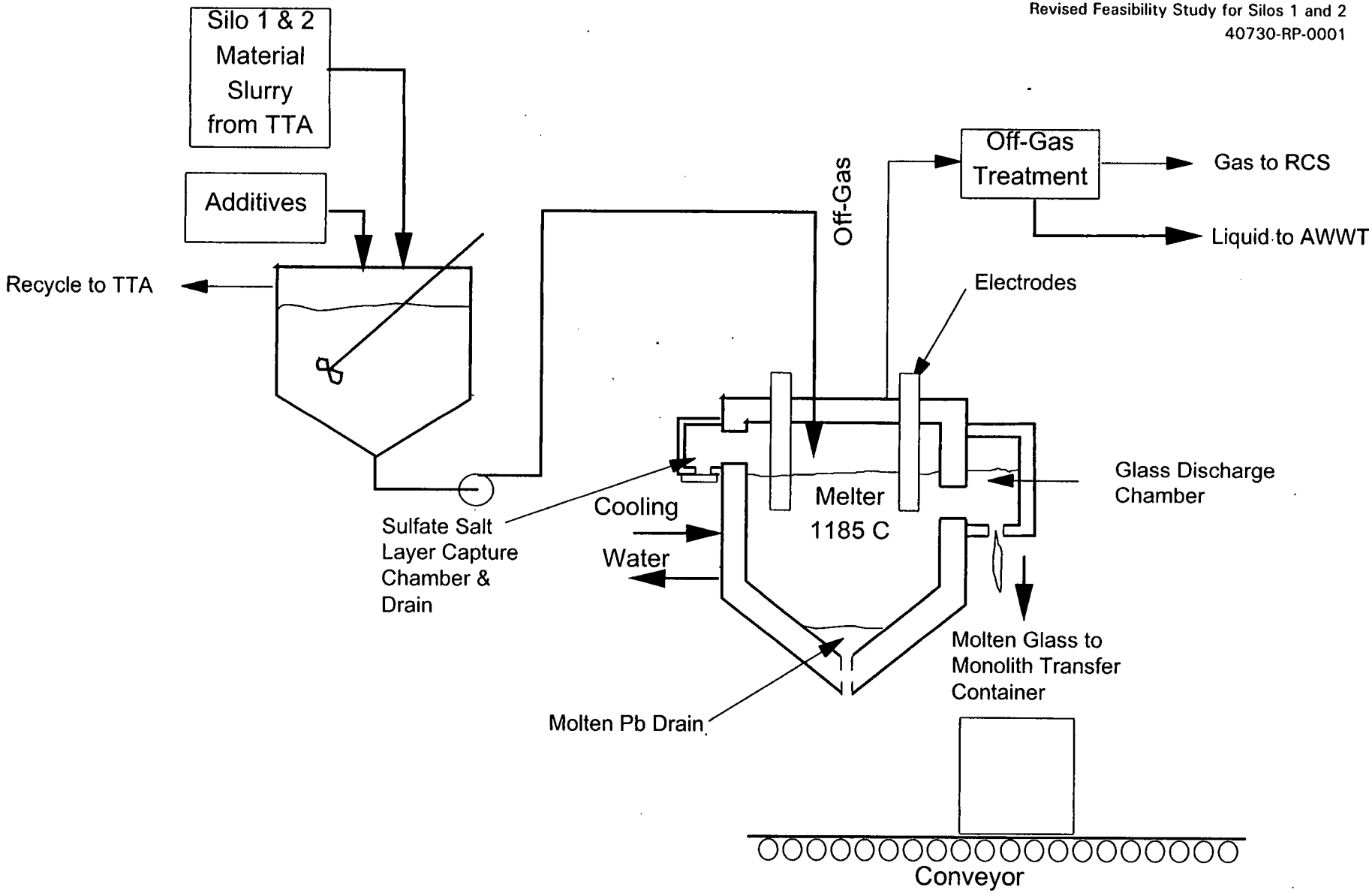

Figure 3.2-1
Simplified Process Diagram
Vitrification - Joule-heated

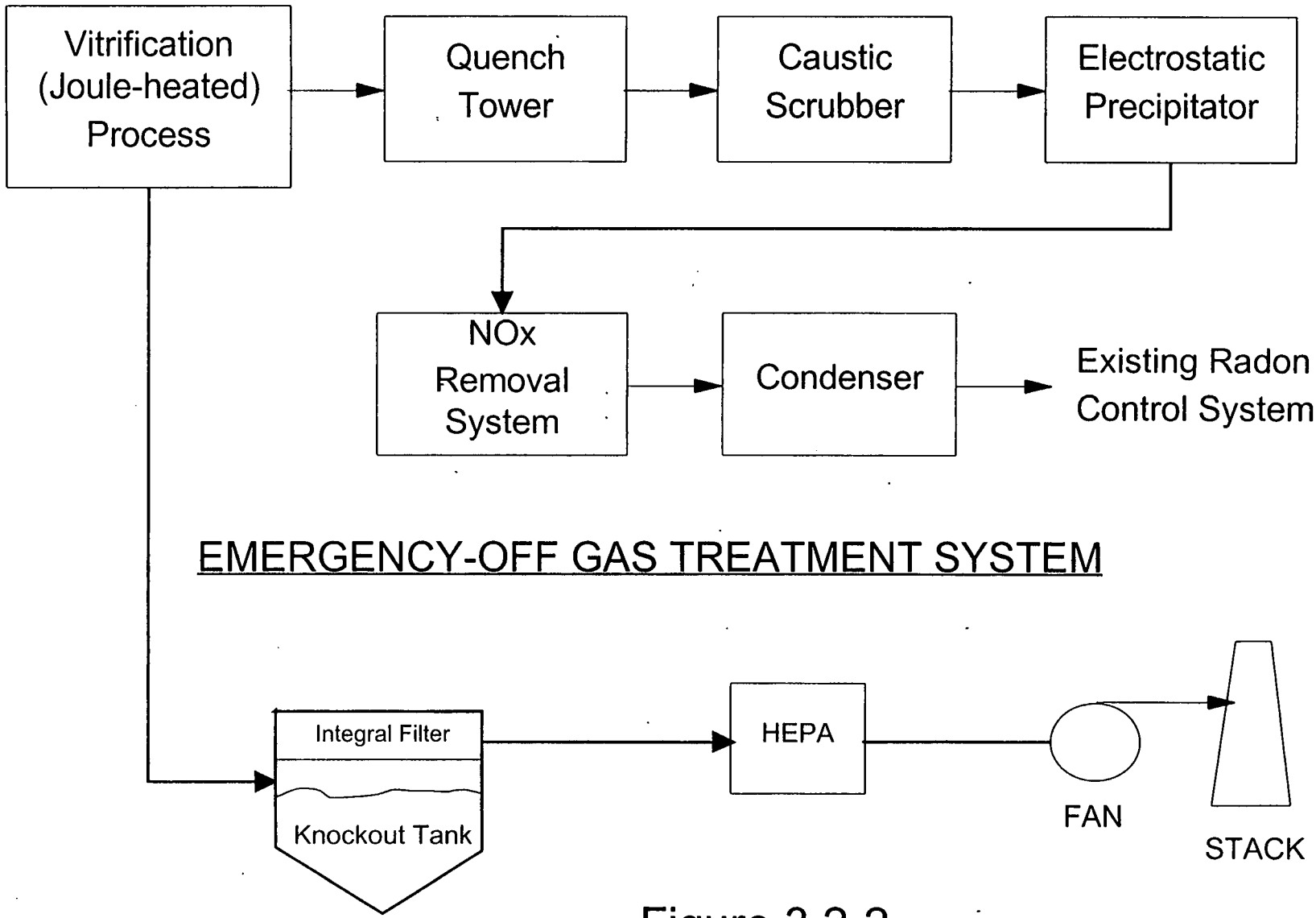

Figure 3.2-2
Off-Gas Treatment System
Vitrification - Joule-heated

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A Flush Water System uses recycle water from the TTA to flush all slurry lines and equipment in order to reduce the risk of plugging process lines and equipment. The flush water is carried forward through the vitrification process.

Reject monoliths (one reject container every 6 to 7 weeks) are reduced in size and reprocessed during the 3-year operating schedule.

The VIT1 secondary wastestreams include water from the scrubber and RCS System, reduced metals, off-spec glass, salts, PPE, spent packaging, spent RCS carbon, RCS and off-gas system high-efficiency particulate air (HEPA) filters **(see Table 3.2-1)**. As noted in **Table 3.2-1**, some secondary wastestreams are processed and do not contribute to the volume of secondary waste to be disposed.

A standard Cooling Tower System provides cooling water to the melter and to various coolers and condensers.

3.2.1.2 Project Schedule

Table 3.2-2 summarizes the individual project activities and their estimated durations for implementing Alternative VIT1. The table is a summary of the activity durations and does not provide specific activity relationships. A more detailed description of the individual project activities can be found in **Appendix G, Section G.2.21**. Each activity duration reflects the estimated time to complete a task that supports the remediation of the silos material at the DOE-FEMP site. The activity durations were developed considering the following factors:

- Proposed activity durations provided by commercial contractors;
- Specified regulatory document review and approval cycles outlined in the FEMP ACA;
- Procedural and administrative requirements for conducting procurement activities at the DOE-FEMP site;
- Historical project management experience and lessons learned while performing environmental remediation activities at the DOE-FEMP; and
- Historical experience with the start-up of vitrification facilities within the DOE-complex.

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TABLE 3.2-1

ESTIMATED SECONDARY WASTESTREAMS GENERATED DURING FULL-SCALE OPERATION OF THE VITRIFICATION - JOULE-HEATED FACILITY

Secondary Wastestreams for VIT 1					
Source	**Material Type**	**Rate (lb/hr)**	**Total Volume 3 years**	**Status**	**Packaged Disposal Volume**
Off-gas Solids	Solids	16	2,238 cf	Recycle	N/A
Scrubber Purge	Water	168	550,368 gal	Process	N/A
RCS Condensate	Water	108	353,808 gal	Process	N/A
Cooling Tower Blow Down	Water	2,610	8,550,360 gal	Process	N/A
Salt Drain	Salts	27 [1]	189 cf	Dispose	524 cf
Reduced Metals	Solid	~ 3.14	120 cf	Dispose	393 cf
Empty Re-work Containers	Solid	96 MTC's	15,744 lbs	Dispose	224 cf
Spent Refractory (5 g/cc)	Solid	1 Lot	530 cf	Dispose	1,120 cf
Glass Drain Bay	Solid	1/3 yrs	~ 106 cf	Dispose	157 cf
Misc. Replacement Equipment [2]	Solid	N/A	435 cf	Dispose	838 cf
RCS carbon	Carbon	1 Lot	5,334 cf	Dispose	8,890 cf
RCS and Off gas System HEPA Filters	Solid	N/A	1,512 cf	Dispose	2,912 cf
PPE	Solid	4 /day	23,900 cf	Dispose	35,407 cf
Total Estimated Cubic Feet of Packaged Disposed Secondary Waste					50,500 cf

1 - Conservative Proof of Principle results indicated little or none produced. This estimated generated rate is the mass valance in the event a slug of silo material contains a high sulfate concentration. The estimated density of the material is 3 g/cc and the salt drain will be operated 5% of the time.

2 - Equipment will be replaced when necessary to maintain normal operation schedule.

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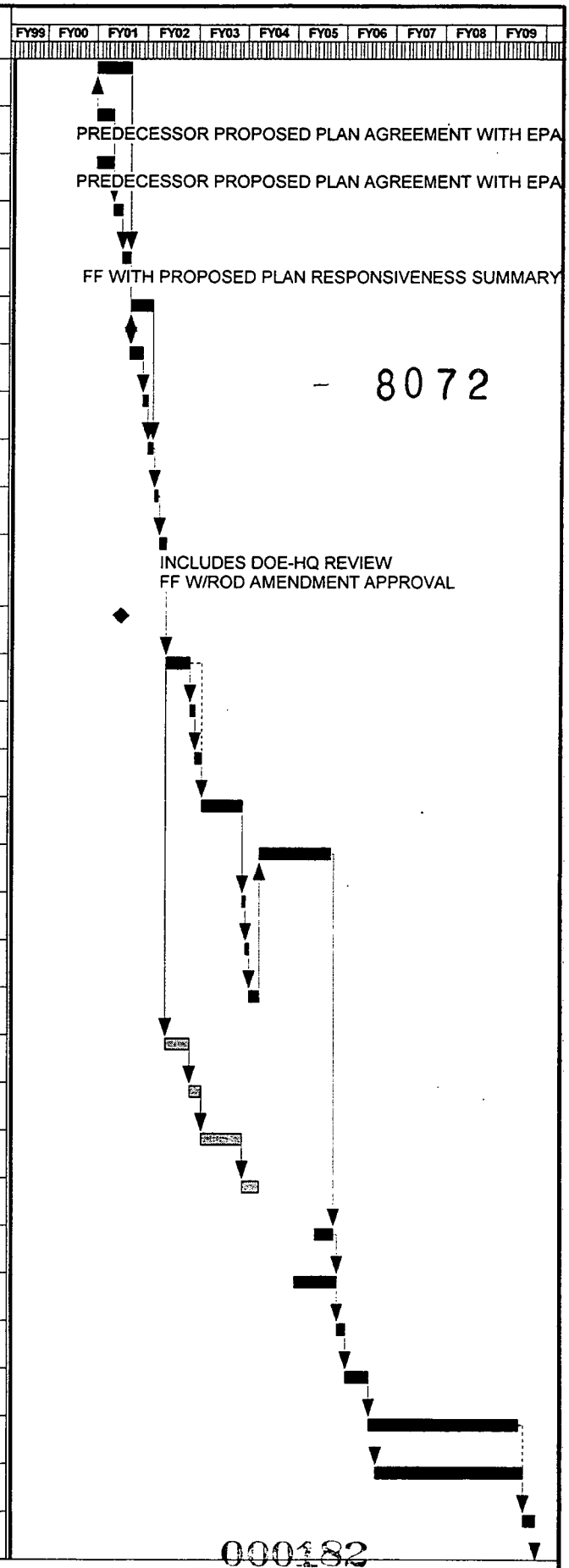
TABLE 3.2-2
SCHEDULE SUMMARY — VIT1

Activity	Duration (Work Days)
Procurement Process	
• Develop RFP	166
• RFP Bid Cycle	165
Design and Documentation	465
Construction and Construction Acceptance Testing	360
System Operability Testing (SOT)	100
Readiness Review	
• Readiness Preparation	213
• Operational Readiness Review (ORR)	40
Proof of Process Testing	120
Remediation Operations	750
Safe Shutdown of Facility	60
Facility D&D	120

Figure 3.2-3 provides a graphical representation of the sequences for completing the project activities, as well as the logical relationships between the activities.

As with the other alternatives, the VIT1 project schedule becomes a key component in several of the evaluation criteria. Short-term effectiveness evaluates the effects of the alternative during the construction and operations phase until the RA objectives are achieved (e.g., worker risks, environmental risks), as well as the time required to achieve protection. Implementability will evaluate the ability of the VIT1 alternative to maintain schedule and recover schedule due to unplanned downtime. The project schedule is an important factor in estimating the project cost for VIT1. The project schedule effects the resource planning, pay item schedules, and the cost of money analysis for the remediation contract.

Activity ID	Activity Description	Orig Dur	Rem Dur	Early start	Early finish
0100	DEVELOP FINAL REMEDIATION RFP	166*	166*	02OCT00	01JUN01
0400	TRD DEVELOPMENT	79	79	02OCT00*	26JAN01
0700	DRAFT RFP	79	79	02OCT00*	26JAN01
[illegible]00	STORYBOARD RFP	44	44	29JAN01	30MAR01
1300	REVIEW/FINALIZE RFP	43	43	02APR01	01JUN01
1600	RFP BID CYCLE	120*	120*	04JUN01	21NOV01
1900	BID PERIOD	64	64	04JUN01	31AUG01
2200	BID EVALUATION	29	29	04SEP01	12OCT01
2500	BAFO	27	27	15OCT01	21NOV01
2800	CONSENT PKG PREP/REVIEW	23	23	26NOV01	28DEC01
3100	DOE CONSENT PKG REVIEW/APPROVAL	42	42	31DEC01	28FEB02
3200	NOA ISSUED FOR ROD	0	0	10APR01*	
3400	PRELIMINARY DESIGN	120	120	01MAR02	20AUG02
3700	FDF REVIEW PRELIMINARY DESIGN	20	20	21AUG02	18SEP02
4000	FINALIZE/APPROVE PRELIMINARY DESIGN	40	40	19SEP02	14NOV02
4300	FINAL DESIGN	200	200	15NOV02	04SEP03
4600	CONSTRUCTION	360	360	12JAN04	16JUN05
[illegible]00	FDF REVIEW FINAL DESIGN	20	20	05SEP03	02OCT03
5200	FINALIZE FINAL DESIGN	20	20	03OCT03	30OCT03
5500	EPA REVIEW/APPROVE FINAL DESIGN	45	45	31OCT03	09JAN04
5800	PHAR DEVELOPMENT	120	120	01MAR02	20AUG02
6100	PHAR REVIEW/APPROVAL	60	60	21AUG02	14NOV02
6400	FHAR DEVELOPMENT	200	200	15NOV02	04SEP03
6700	FHAR REVIEW/APPROVAL	90	90	05SEP03	16JAN04
7000	SYSTEM OPERABILITY TEST	100	100	23FEB05	15JUL05
7300	READINESS PREPARATION	213	213	06OCT04	12AUG05
7600	ORR	40	40	15AUG05	10OCT05
7900	PROOF OF PROCESS TEST	120	120	11OCT05	05APR06
8200	OPERATION	750	750	06APR06	06APR09
8500	WASTE DISPOSITION	750	750	19MAY06	19MAY09
8800	SAFE SHUTDOWN	60	60	20MAY09	13AUG09



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[illegible]art 01OCT99
Project Finish 08FEB10
Data Date 01FEB99
Run Date 06DEC99

Early Bar
Progress Bar
Critical Activity

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Sheet 1 of 2

FIGURE 3.2-3

PROJECT SCHEDULE

VITRIFICATION - JOULE-HEATED

Activity ID	Activity Description	Orig Dur	Rem Dur	Early start	Early finish
8900	FACILITY D & D	120	120	14AUG09	08FEB10

FY99 FY00 FY01 FY02 FY03 FY04 FY05 FY06 FY07 FY08 FY09

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Project Start 01OCT95	Early Bar	ENV2	Sheet 2 of 2
Project Finish 08FEB10	Progress Bar	FIGURE 3.2-3	
Data Date 01FEB99	Critical Activity	PROJECT SCHEDULE	3-66
Run Date 06DEC99		VITRIFICATION - JOULE-HEATED	

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3.2.2 Overall Protection of Human Health and the Environment

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This alternative meets the RA objectives for OU4 Silos 1 and 2, as developed in the original OU4 FS (FEMP 1994a); this is accomplished using on-site treatment and off-site disposal at the NTS. Treatment of the Silos 1 and 2 material through vitrification to meet the NTS WAC for disposal reduces contaminant mobility and volume. The treatment process reduces the leaching rate of the hazardous constituents to a level which ensures adequate protection of the groundwater at the NTS.

Short-term risks during implementation of this alternative are well within CERCLA guidelines. Direct contact with the waste material during treatment system operation is mitigated by process automation, containment, and confinement measures. Releases to the air are minimized by filtration and other air pollution control equipment incorporated into the treatment system. Additional risk is associated with the transportation of the treated Silos 1 and 2 material to the NTS; however, radiation exposure to workers and the public as a result of transportation is kept ALARA through the selection of proper packaging in accordance with DOT regulations.

The removal of the Silos 1 and 2 material from the FEMP followed by disposal off-site provides the final element of protection. The NTS disposal facility provides protection by eliminating access to the waste and preventing migration of contaminants from the waste.

The NTS disposal facility is located in a sparsely populated, arid environment with a low potential for leachate generation, contaminant release, migration, or direct contact with contaminants. The waste is buried in a configuration that meets the performance objectives for the NTS. The long-term effectiveness of the institutional controls at the NTS disposal facility is believed to be reliable. Because NTS is maintained by DOE and utilized for the disposal of selected LLRW from other DOE sites, the uncertainties associated with institutional controls are minimal. Furthermore, the climatic (low average annual precipitation) and hydrologic [depths to groundwater ranging from 157 to 700 m (515 to 2,300 ft) below ground surface] characteristics tend to mitigate impacts to human health and the environment if engineering and institutional controls should fail (Bechtel Nevada 1999).

3.2.3 Compliance with Applicable or Relevant and Appropriate Requirements

VIT1 complies with all ARARs and TBC criteria identified in Appendix A of this FS. Activities conducted on-site (at the FEMP) under this alternative meet all applicable, relevant and appropriate, and TBC requirements. Off-site disposal at the NTS meets all applicable requirements. Compliance with the key chemical-, location-, and action-specific ARARs and TBCs presented in **Appendix A** for this alternative is discussed next.

3.2.3.1 Chemical-Specific ARARs and TBCs

Chemical-specific ARARs and TBCs for the remediation of the Silos 1 and 2 material ensure protection of the public and environment. ARARs and TBCs are included that protect air, surface waters, and the underground aquifer from contamination. Chemical-specific limitations are found in the Safe Drinking Water Act as maximum contaminant levels (MCLs) for constituents allowed in groundwater, Ohio Administrative Code (OAC) for protection of surface water, and the CAA for protection of the public from contaminants released to air. Air and surface water standards are also included in DOE Order 5400.5 Chapter III as Derived Concentration Guides (DCGs). DOE Order 5400.5 also places limits on the release of radon from interim storage facilities.

Compliance with the chemical-specific groundwater regulations is maintained with removal of source term, and design and operation of the remediation treatment facility as an enclosed system. Although groundwater monitoring wells exist in the project area, the material in the silos has not been considered a source of contamination for the Great Miami Aquifer, which is considered the uppermost aquifer in the area.

Protection of surface waters is ensured by characterization and pretreatment (if necessary) prior to being released to the site AWWT facility for final treatment and discharge under the FEMP National Pollution Discharge Elimination System (NPDES) permit issued by the State of Ohio. Any contaminants in the wastewater stream are removed or treated to meet applicable NPDES limits and DOE DCGs.

Chemical-specific limits are placed on air emissions of radioactive particulate and radon during storage, treatment, and disposal. Requirements for particulate radionuclides are established in 40 CFR Part 61 Subpart H [National Emissions Standards for Hazardous Air Pollutants (NESHAP) for DOE sites] and the DCGs in DOE Order 5400.5 Chapter III. Limits on radon are included in 40 CFR Part 61 Subpart Q (radon emissions from DOE facilities), DOE Order 5400.5 Chapter IV (for interim storage of radon generating material), and the DCGs in DOE Order 5400.5 Chapter III (for radon releases). Compliance with these requirements could be achieved with engineering design control features including carbon beds for adsorption of radon, and HEPA filters and prefilters downstream to capture particulate.

Radon from the headspace of the storage tanks is treated by carbon adsorption prior to discharge through the stack. Radon in the off-gas is controlled using carbon adsorption technology, and continuously monitored to ensure that air emissions do not contribute radon at the site boundary in excess of 0.5 pCi/L as an annual average above background (proposed 10 CFR Part 834).

Radon limits are met during interim storage by use of the RCS to control radon in the headspace of the TTA storage tanks. The atmospheric release of radon from the surface of the disposal site would meet the NESHAP limit by virtue of the treated Silos 1 and 2 material characteristics (non-porous, vitrified wasteform), and the engineered cover for the disposal cell. On the basis of available treatability data (discussed further under **Section 3.2.5 - *Reduction of Toxicity, Mobility, and Volume through Treatment***), the vitrification of the silos material decreases the radon flux rate from the untreated material to below the required emission rate limits.

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3.2.3.2 Location-Specific ARARs and TBCs

VIT1 complies with all location-specific ARARs and TBCs identified in **Appendix A**. Included are those requirements associated with the protection of floodplains, wetlands, endangered species, and the sole source aquifer underlying the FEMP site. Compliance with these requirements is met through appropriate planning, siting, design, and operational procedures. The proposed location of the treatment facility is above the 100-year floodplain, and is not within a wetland area. An impact mitigation plan developed before construction addresses impacts to wetlands, floodplain, or endangered species habitat incurred as a result of construction or operation of the facility. The project area (i.e., the proposed location of the facility) does not jeopardize endangered or threatened species or their habitat. This alternative, therefore, complies with these identified location-specific ARAR/TBC requirements.

3.2.3.3 Action-Specific ARARs and TBCs

VIT1 complies with all action-specific ARARs and TBCs identified in **Appendix A**. Action-specific ARARs and TBCs, to ensure protection of the public and environment, address design and operation of the facility to prevent contamination of air, soil, surface water, and groundwater. Environmental requirements also address waste management, and radiation exposure to the public. Included are key regulations from the RCRA for solid and hazardous waste, Clean Water Act (CWA) for surface waters, and the OAC for releases to air.

RCRA requirements for management of the silos material (and other wastes) govern characterization, containment in tanks and containers, groundwater protection, general facility standards, and facility closure. Systems containing hazardous waste (or material that is sufficiently similar to hazardous waste, such as the Silos 1 and 2 material) with free liquids are transferred, stored, and processed in lines and tanks with secondary containment and leak detection to prevent spills or releases to soil or groundwater.

Other facility requirements, such as security, preparedness and prevention, and contingency planning are met by: site security, design of communications and alarm systems, and procedures that incorporate the site emergency response plan into project operation. Closure and disposal requirements are met during facility shutdown and dismantlement with sealed, painted, or otherwise easily decontaminated surfaces to facilitate clean closure.

OAC air requirements govern both fugitive and point source emissions during construction, operation, and facility shutdown and dismantlement. OAC 3745-31-05(a)(3) requires new emission sources to use best available technology (BAT) to control air emissions. Design and operation meet BAT requirements by minimizing releases to the atmosphere.

Site preparation and construction activities minimize the creation and dispersion of dust to meet the requirements of OAC 3745-17-07 and OAC 3745-17-08 through implementation of BAT as specified in the site dust control policy.

Solid waste may be generated during construction and operation of the facility. While the Silos 1 and 2 material has been characterized, other wastes generated during the project are placed in compatible containers pending characterization and disposal. Management of secondary solid waste is in accordance with RCRA and existing FEMP site procedures, and includes characterization, staging, segregation, containment, and treatment (if necessary) before disposal. Secondary waste destined for shipment off-site is surveyed for radionuclide contamination before shipment or disposal as solid waste. Radioactive solid wastes will be managed in accordance with ARARs. Secondary waste that is destined for off-site disposal is packaged in containers appropriate for the material's DOT hazard classification as defined in 49 CFR Subchapter C, *Hazardous Materials Regulations*, and the WAC for the disposal facility.

3.2.4 Long-term Effectiveness and Permanence

3.2.4.1 Magnitude of Residual Risk

Silos 1 and 2 Material

The implementation of this alternative reduces the residual risk to viable receptors to meet the CERCLA criteria of a hazard index (HI) of less than 0.2 and an ILCR of less than 10^{-6}. Because the material is removed from the site, residual risk from Silos 1 and 2 material at the FEMP site is nonexistent. Residual risk at the NTS is limited by a treatment process that effectively minimized leachability of COCs, the placement of the treated Silos 1 and 2 material in an engineered disposal facility's institutional controls, and the arid environment.

Soil and Debris

The OSDF will be available for disposal of debris from the existing silo structures, the RTS, the decant sump tank, other below-grade appurtenances, and Area 7 soils. Soil and debris from D&D activities associated with these facilities will be disposed in the OSDF if they meet the WAC for disposal.

Criteria for disposal of waste materials into the OSDF are documented in the *Waste Acceptance Criteria Attainment Plan for the On-site Disposal Facility* (FEMP 1998c). The current version was issued in June 1998 following approval by the EPA and Ohio EPA. The WAC for debris were established in the OU3 ROD (FEMP 1996a). The WAC Attainment Plan provides that these criteria can be applied to debris for other OUs, including OU4, consistent with provisions of the ROD for each OU.

Consistent with the OU4 ROD (EPA 1994), Section 2.5.2 of the WAC Attainment Plan specifically excludes "contaminated concrete from Silos 1 and 2 that exhibits a highly elevated direct radiation field" from disposal in the OSDF. Although OU4 debris was not specifically included in the OU3 WAC calculations, the WAC Attainment Plan indicates that the remainder of the debris from OU4 is acceptable for disposal in the OSDF provided it meets the appropriate physical and radiological WAC.

While technetium-99 is the primary radiological constituent of concern (COC) in determining disposal of OU3 debris, the predominant COCs in Silos 1 and 2 debris are lead-210, actinium-227, and radium-226. These radionuclides are present in the Silos 1 and 2 material at significantly higher levels than in the OU3 material evaluated in determining the OSDF WAC. In addition, due to the high radium content of the Silos 1 and 2 material, radon flux is a concern.

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Although the source term resulting from disposal of soil and debris generated from remediation of Silos 1 and 2 material was not specifically evaluated during development of the OSDF WAC, the OU5 travel-time screening indicates that WAC limits are not required for the predominant radiological COCs present in the Silos 1 and 2 materials. In addition, examination of the cover system specified in the OSDF design indicates that sufficient radon attenuation is provided so that radon flux from silos soil and debris disposed in the OSDF can meet regulatory requirements.

Based upon evaluation of the existing OSDF WAC for debris, as well as the specific COCs present in the silos material, debris from D&D of Silos 1 and 2 will be acceptable for disposal in the OSDF provided that it meets the following criteria:

1. Based on visual inspection conducted in accordance with FEMP procedures, the debris is free of process residues (i.e., silos material).

2. The debris meets the physical WAC specified in the WAC Attainment Plan for the OSDF.

3. The debris does not exceed TC limits for metals.

4. Any concrete surveyed from Silos 1 and 2 has been found to have a maximum "on-contact" exposure rate less than 8 mrem/hr.

5. As Silo 4 has never been used for storage of radiological or hazardous material, debris from demolition of Silo 4 will be acceptable for disposal in the OSDF as long as it meets the physical WAC.

Based on the information presented above regarding the OSDF, the risk of direct radiation to the general public resulting from disposition of soil and debris generated during remediation of Silos 1 and 2 material is negligible. Therefore, disposal of soil and debris in the OSDF provides long-term protection of the environment and the public.

Based on the current operating schedule, however, the FEMP OSDF will not be available for disposal of soil and debris generated from D&D of the OU4 remediation facilities. Therefore, this FS assumes that all soil and debris from D&D of the OU4 remediation facilities will be disposed at the NTS. However, should programmatic changes occur and the OSDF become available, soil and debris meeting the OSDF WAC would be disposed in the OSDF in the same manner as discussed above for silo structures and area 7 soils.

3.2.4.2 Adequacy and Reliability of Controls

The TCLP test, which is intended to simulate conditions of rainwater leaching through a solid waste landfill, indicates that VIT1 produced wasteforms which consistently met the NTS WAC and were durable based on leach rate data. The TCLP test is utilized to simulate the leaching effects of acidic groundwater infiltrating the disposal cell and contacting disposed waste. This test serves as a measure of the stabilized waste particles ability to resist leaching, even if the original wasteform (e.g., monolith) has been compromised. This reduction in leachability, combined with the additional protection provided by the engineered disposal cell provide a durable disposal configuration that provides long-term protection of human health and the environment.

Off-site disposal at the NTS has enhanced reliability because the facility is currently owned and used by DOE for LLRW disposal. The facility indicated that the Silos 1 and 2 material wastestream will be acceptable for disposal provided its treated Silos 1 and 2 material form meets the NTS WAC. An addendum to the PA for the selected disposal area will be prepared to demonstrate that the disposal configuration meets the applicable performance objectives. The institutional controls and potential for adequate facility maintenance are reliable at the NTS. Additionally, if there was a release at the NTS, the climate, hydrologic, and geologic characteristics considerably reduce the potential for contaminant migration. The low population density of the area surrounding the NTS also reduces the potential for direct contact with released materials.

Long-term environmental impacts associated with on-site treatment and off-site disposal of the treated Silos 1 and 2 material at the NTS are presented in the following sections.

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Soil and Geology

Vitrified Silos 1 and 2 material would be disposed in an area previously designated by the NTS for LLRW disposal (Area 5) as evaluated in the NTS-EIS. Soil at the NTS would be permanently disturbed for the disposal of vitrified Silos 1 and 2 material. Borrow material from the NTS may be required to accommodate disposal at the NTS. The geology of the NTS is suitable for disposal of LLRW (Bechtel Nevada 1999). The NTS is characterized by great depths to the groundwater table. As stated previously, depths to groundwater beneath the NTS vary from about 157 m (515 ft) to more than 700 m (2,300 ft) (Bechtel Nevada 1999). Groundwater movement in the saturated and unsaturated zones is very slow and the potential for transport of contaminants to off-site areas is extremely low. These parameters make the geology of the NTS highly suitable for long-term disposal activities.

Construction of the vitrification treatment facility at the FEMP site does not result in the permanent disruption of land, as the systems are constructed exclusively in previously disturbed areas and are disassembled and removed upon completion of vitrification of the Silos 1 and 2 material. Furthermore, the regional geology of the FEMP site and surrounding area is not affected by implementation of this alternative.

Solid waste generated from the operation and D&D of the remediation facilities (i.e., PPE, piping, debris, etc.) could be disposed in the OSDF if it meets the OSDF WAC. The OSDF has been designed for safety with the FEMP geology in mind.

Water Quality and Hydrology

The disposal of treated Silos 1 and 2 material at the NTS under this alternative is not expected to have significant impact on water quality or hydrology. Continuously flowing streams are nonexistent at the NTS. Streambeds carry water only during unusually intense or persistent rains. Precipitation, which averages 15 cm (6 in) per year, infiltrates quickly into the moisture-deficient soil (Bechtel Nevada 1999). These parameters, coupled with suitable geology, help to minimize long-term impacts to water quality. Engineered controls (capping) and ongoing monitoring activities also control and minimize water quality impacts.

The vitrification treatment system does not significantly impact hydrological conditions on the surrounding area at the FEMP. Run-on and runoff controls are used at the facility and the area is regraded to approximate original contours following facility shutdown and dismantlement. Uncontaminated surface runoff is directed by engineered and natural controls to existing on-property drainage ways for release. During processing, containment measures are employed to prevent the release of waste material to the environment. Wastewater generated during the course of processing is collected and recycled back into the vitrification system or pretreated (if necessary) and sent to the AWWT facility for final treatment.

Air Quality

The implementation of this alternative leaves the air quality at the NTS site similar to current conditions. Long-term impacts on air quality are minimal because the glass wasteform, the depth of burial, and the cover system on the disposal facility mitigate radon emissions to below NESHAP limits and because disturbed areas are revegetated.

Following implementation of this alternative, the air quality at the FEMP site would be similar to current conditions. Long-term effects on air quality are nonexistent because the Silos 1 and 2 material is removed from the silos, vitrified, and transported off-site for disposal. Thus, the chronic source of radon emissions at the FEMP site is eliminated. Disturbed areas created during construction and facility shutdown and dismantlement of the vitrification treatment facilities are revegetated in order to minimize release of fugitive dust and other particulates.

Biotic Resources

Most of the NTS is vegetated by various desert shrubs. There are 711 types of vascular plants within or near the boundaries of the NTS (Bechtel Nevada 1999). Several mammal species on the NTS (e.g., feral horses, burros, 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 of the areas of the NTS. The disposal activities at the NTS related to this alternative are not expected to impact the habitat of the desert tortoise or displace other species at the NTS.

Although, the FEMP site (i.e., project area) has not been officially designated as a critical habitat for threatened and endangered species, the Indiana Brown Bat has been identified outside of the OU4 boundary, in the northern portion of Paddy's Run just north of the railroad trestle. Implementation of VIT1 is not expected to disturb biotic resources in the project area; and, quality of the resources is expected to be similar to natural conditions. Long-term impacts on biota or habitat following removal of the source term and facility shutdown and dismantlement of the treatment facility are minimal. Following completion of the construction and facility shutdown and dismantlement activities, disturbed areas will be backfilled, regraded, and revegetated to approximate natural contours and conditions in accordance with the FEMP Natural Resources Restoration Plan.

Wetlands and Floodplains

The NTS does not have any designated wetland areas (Bechtel Nevada 1999). In addition, floodplain areas do not exist near the disposal areas of the NTS.

The FEMP site, however, does contain wetlands. Construction of the treatment facility does not impact these wetlands. In addition, the proposed location for the treatment facility is above the 100-year floodplain for Paddys Run.

Socioeconomics and Land Use

The NTS encompasses about 3,500 square kilometers (km^2) [1,350 square miles (mi^2)], an area larger than the State of Rhode Island. Since 1951, primary land use on the NTS has been nuclear weapons testing and LLRW disposal for on-site and off-site DOE-affiliated generators.

The NTS is surrounded on the east, north, and west sides by public access exclusion zones (e.g., Nellis Air Force Base Bombing and Gunnery Range). This area provides a buffer zone between the test areas and public lands of 24 to 105 kilometers (km) [15 to 65 miles (mi)]. The population density within a 150-km (93-mi) radius of the NTS is about 0.5 persons per km^2 (1.3 per mi^2). In comparison, the 48 contiguous states (1990 census) had a population density of approximately 29 persons per km^2 (75 per mi^2). The off-site areas adjacent to the NTS are predominantly rural; hence, aesthetic impacts are not expected to change. Therefore, treated Silos 1 and 2 material disposal activities (associated with this alternative) do not impact socioeconomics or land use at the NTS.

Cultural Resources

An archaeological survey is performed for any disturbed areas impacted by this alternative. Areas determined to be of significance from a cultural resources standpoint are to be managed consistently with the requirements of the National Historic Preservation Act (NHPA), State Historic Preservation Office, American Indian Religious Freedom Act (AIRFA), and Native American Graves Protection and Repatriation Act (NAGPRA). Because any cultural resources identified are either avoided or managed appropriately, impacts to cultural resources at the FEMP site are nonexistent. Archaeological sites have been surveyed and inventoried at the NTS and current disposal activities are avoided in these areas.

3.2.5 Reduction of Toxicity, Mobility, or Volume through Treatment

In the original FS, a remedy selection treatability study was conducted with OU4 materials to compare the performance of vitrification to other remediation technologies. The criteria for the comparison included: leachability of the glass form, and reduction in the material volume and radon emanation (original OU4 FS - Appendix C, Section C.3.0). Additional tests were conducted to determine the expected, long-term performance of the treated Silos 1 and 2 material in maintaining the level of protectiveness achieved.

The operating temperature considered for the vitrification design (1050 - 1350°C) destroys any organic compounds present in the Silos 1 and 2 material and fixes metals into a glass matrix during the melting process. Hazardous inorganic constituents actually become part of the chemical structure of the glass matrix or are contained within the interstices of the glass by ionic bonding or trapped in voids. Treatment of the Silos 1 and 2 material through vitrification reduces contaminant mobility and volume. The leaching rate of COCs of the treated Silos 1 and 2 material is reduced to below RCRA TC limits, enhancing the protection of environmental receptors.

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The chemical and physical properties of the Silos 1 and 2 material were determined and used to develop glass formulas for the bench-scale treatability study tests supporting the original FS. Data from the study revealed that the radon emanation rate from the vitrified Silos 1 and 2 material ranged from 0.01 to 0.06 picoCuries per square meter second (pCi/m^2·s), more than two orders of magnitude less than the EPA limit of 20 pCi/m^2·s for radon emanation from DOE facilities. Based on an emanation rate ranging from 1,985 to 7,314 pCi/m^2·s for the untreated Silos 1 and 2 material, a reduction of radon emanation by a factor of approximately 500,000 was obtained in the bench-scale vitrification tests. The measured radon emanation rate from the treated Silos 1 and 2 material 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 10^3 to 10^6 times greater than that of natural building materials.

Data from the original FS treatability study revealed that significant volume reductions can be achieved through vitrification. The reduction in volume of the Silos 1 and 2 material (not including packaging) ranges from 50.3 to 68%.

Data from the more recent POP testing of joule-heated vitrification on surrogate Silos 1 and 2 material also indicated a potential significant reduction in volume of treated material. POP data indicates that the original 6,797m^3 (8,890yd^3) of material in Silos 1 and 2 could be reduced to a volume of approximately 3,274m^3 (4,283yd^3). This is a volume reduction of approximately 52%. However, due to the shielding necessary for protection of workers and the general public and for meeting DOT requirements, containerization of the treated material results in an overall disposal volume of approximately 8,895m^3 (11,635yd^3), equating to a disposal volume increase of 31% compared to the original volume of material in Silos 1 and 2.

The secondary wastestreams associated with the VIT1 alternative are summarized in **Table 3.2-1**. The estimated final disposal volume of all the secondary wastestreams is 1430 m^3 (1,870 yd^3). The total estimated disposal volume of the treated Silos 1 and 2 material and all secondary wastestreams is 10,325 m^3 (13,505 yd^3), equating to an overall volume increase of 52%, compared to the original volume of material in Silos 1 and 2.

Previous TCLP testing conducted during the RI for OU4 (FEMP 1993) indicated that untreated Silos 1 and 2 material exceeded the RCRA TC threshold for lead. Lead concentrations in the leachate from the treated material were reduced by a factor of approximately 500, relative to the untreated Silos 1 and 2 material. Thus, TCLP test results for the treated Silos 1 and 2 material demonstrated the effectiveness of vitrification as a treatment process for the Silos 1 and 2 material.

As discussed in **Section 1.4.7 - *Regulatory Classification of the Silos 1 and 2 Material***, the Silos 1 and 2 material is classified as 11(e)(2) by-product material pursuant to the AEA. Although the Silos 1 and 2 material is excluded from regulation under RCRA, the current NTS WAC requires that the treated Silos 1 and 2 material must not exhibit any characteristics of hazardous waste. Based upon review of the regulatory classification of the Silos 1 and 2 material, NTS has confirmed that compliance with other RCRA disposal standards, such as the RCRA UTS requirements, need not be demonstrated to meet the NTS WAC.

Results of POP testing indicate that the VIT1 treatment process will meet requirements for disposal at the NTS by sufficiently stabilizing hazardous constituents to meet the RCRA TC limits.

3.2.6 Short-term Effectiveness

3.2.6.1 Protection of the Community during Remedial Action

Current FEMP security and access controls are continued during remediation to prevent public access to the treatment processes.

Direct emissions from the untreated materials and off-gas emissions during treatment are the release mechanisms that may potentially impact the surrounding community during remediation activities. Through a combination of engineering controls and access controls, this alternative protects the community during implementation. Off-gas collection and treatment systems operated during vitrification of the Silos 1 and 2 material control gaseous contaminant releases.

The thermal nature of the VIT1 treatment process results in essentially the entire inventory of radon contained in the Silos 1 and 2 material being liberated to the melter off-gas during treatment. This inventory of radon must be managed in order to minimize emissions from the VIT1 facility to the atmosphere. The vitrification facilities are designed to shut down upon activation of the EOG System to prevent a continuous unmitigated release of radon into the atmosphere. Although there would be release of radon from the EOG System, the release would be limited to the contents of the melter. It is expected that a release of radon from the contents of the melter would not present any negative impacts on the fenceline regulatory requirements or on the public.

Sufficient radon mitigation is provided by the vitrified wasteform so that the 20 $pCi/m^2 \cdot s$ radon flux limit is met without reliance on the waste package or disposal configuration. Therefore, emission of radon and its daughters during packaging, interim storage, transportation, and disposal of silos material is minimized.

Radon removal will be provided to ensure that emissions of radon from the VIT1 facility are minimized. The total impact of radon emissions from the VIT1 alternative will result in exposure levels to the off-site public that are indistinguishable from background levels (based on analyses performed for the original OU4 FS).

The vitrified wastes meet the NTS WAC and are managed within the bounds of the NTS facility's PA. The area required for the disposal of the vitrified waste at the NTS represents only a small fraction of the site. Public access to the NTS is strictly controlled by security and fence barriers. Therefore, disposal of vitrified waste at the NTS is protective of human health and the environment.

A 1996 surveillance at the NTS estimated that a hypothetical resident living 58 km (36 mi) west-northwest of the NTS was exposed to a maximum calculated dose of 0.11 mrem. In addition, the collective dose equivalent to the approximately 32,210 residents living within a radius of 80 km (50 mi) from NTS airborne sources was 0.34 person-rem. All of the dose estimates calculated are less than 2% of the most restrictive standard (Bechtel Nevada 1999).

3.2.6.2 Protection of Workers During Remedial Action

Appendix B estimates the number of injuries and fatalities that could result from the removal, treatment, and transportation activities associated with this alternative during remediation.

This alternative involves the handling of radioactive materials and, therefore, there are several potential exposure pathways for workers. Both the release of gases and exposure to direct radiation from the materials could cause a risk to workers. Per 10 CFR Part 835.202, occupational dose shall not exceed a total effective dose equivalent of 5 rem per year. This dose results in an ILCR of 2×10^{-3} to workers. It has been estimated that, with appropriate protection, the removal and treatment of materials results in an ILCR level to remediation workers of 3.32×10^{-4} (see **Appendix B**). Most of this risk occurs during operation of the treatment facility. As appropriate, workers wear protective clothing and use shielding, along with automatic and remote operations.

A simplified integrated hazard analysis (IHA) was conducted to evaluate the unmitigated hazards to workers posed by the conceptual design of the joule-heated vitrification process. The results of the IHA are presented in **Appendix B** and are summarized below:

- Complex systems associated with vitrification present industrial/construction hazards;
- The man-hours required to complete remediation utilizing joule-heated vitrification present a human hazard;
- Elevated equipment present a fall hazard;
- High energy and temperature process present electrical and thermal hazards;
- Toxic off-gas constituents (i.e., SO_x, NO_x) and caustic treatment of off-gas present chemical reactivity and toxicant hazards;
- Heat, melter redox conditions, acid gases, and use of caustic present a material deformation hazard; and
- Upset conditions in the melter present a pressure hazard and a loss of containment hazard.

Without considering the specific hazards identified above, it has been estimated, based solely on labor hours, that construction, treatment, and D&D could result in approximately 63 injuries and 0.93 fatalities during remediation (see **Appendix B**). Remediation activities are to be conducted in accordance with a health and safety plan developed to meet 29 CFR Part 1910.120(b)(4). Training and procedures ensure that worker exposure to risks is ALARA.

3.2.6.3 Short-term Environmental Impacts

The short-term environmental impacts at the FEMP site from vitrification of the Silos 1 and 2 material are limited to the land that is disturbed for the preparation of the Silos 1 and 2 removal and treatment systems, as well as the storage area designated for treated Silos 1 and 2 material.

This alternative involves off-site disposal of the treated Silos 1 and 2 material at the NTS. Short-term environmental impacts for the FEMP and the NTS are discussed below.

Soil and Geology

Disposal activities disturb soils at the NTS. Appropriate mitigative controls (e.g., cover and grading) are used at the NTS to control erosion, the off-site transport of vitrified waste, and radon release. Disposal of the vitrified wastes does not impact groundwater at the NTS in the short-term due to the treated Silos 1 and 2 material form, disposal under a cover system, and depth to groundwater. Ongoing monitoring identifies unacceptable releases and maintenance minimizes the potential for release.

Soil disturbance during implementation of this alternative at the FEMP primarily results from construction of access roads, silos retrieval systems, the treatment/packaging facility, the packaged waste staging area, and support facilities. Construction and excavation activities could temporarily disturb a total of approximately 12,756 m^3 (16,684 yd^3) of soil at the FEMP site. These same activities could also result in the erosion of exposed soil areas. Erosion controls, such as straw bales, berms, and storm retention basins are used to minimize potential erosion as necessary. Measures for reducing fugitive dust generation, such as wetting surfaces or using dust suppressants, are used in exposed soil areas as appropriate. Following completion of construction and excavation activities, disturbed areas are filled with clean backfill and topsoil and revegetated with native grasses.

Water Quality and Hydrology

The implementation of this alternative is expected to have minor impacts on the surface water hydrology at the NTS. The NTS lies in an arid region with little rainfall; continuously flowing streams are nonexistent at the NTS.

Through erosion control and dust suppression, contaminants disturbed during remediation at the FEMP are not transported to adjacent surface water bodies. Surface water near the site is monitored during remediation in accordance with the existing NPDES permit to assess potential impacts to the water from remediation. Remediation does not increase the release of contaminants to the groundwater since the material is always contained.

Air Quality

Ambient air quality in areas accessible to the public is regulated by both state and federal standards. There are three potential sources of air emissions: 1) dust from construction and earth-moving activities, 2) airborne particulate and radon releases during treatment, and 3) heavy equipment exhaust. Shipping treated Silos 1 and 2 materials for disposal results in negligible increases in emissions related to vehicle exhaust. Short-term impacts are negligible.

Fugitive dust is controlled as discussed above in the soil section. With the appropriate dust suppression, excavation activities are not expected to negatively impact the air quality. The exhaust emissions from heavy construction equipment are also not expected to impact air quality. Airborne particulate, volatilized metal species and radon emissions are controlled through both collection and off-gas treatment during operations. Therefore, significant releases into the environment are not expected to occur.

Biotic Resources

Disposal activities disturb portions of the NTS. However, habitat at the NTS in the disposal area is limited (Bechtel Nevada 1999), and little displacement of species occurs.

The FEMP areas for remediation activities have already been industrialized, and do not provide critical habitat for threatened or endangered species. Therefore, the short-term disturbance of land under this alternative is not anticipated to impact biotic resources.

Also, there is the potential for impact to biota from contaminant releases such as through erosion, dust emissions, gas releases, and direct radiation. As discussed in previous short-term effectiveness discussions, these releases are minimized through engineering controls such as erosion control, dust suppression, and airborne effluent collection and treatment. Therefore, negative impact on biota during implementation of this alternative is expected to be nonexistent.

Wetlands and Floodplains

As previously discussed, wetland and floodplain areas are nonexistent at the NTS (Bechtel Nevada 1999). At the FEMP site, however, several areas of wetlands have been designated adjacent to the planned location for the Silos 1 and 2 material treatment facility. Wetlands north and south of the treatment facility are not expected to be affected. Engineering controls, such as silt fences, straw bales, and storm retention basins are implemented as needed to control the migration of eroded soil to wetland areas.

The 100- and 500-year Paddys Run floodplains are located immediately west of Silos 1 and 2. VIT1 activities are not planned to occur within the floodplains, and contaminant migration during remediation is controlled through engineered erosion controls in order to minimize impact.

Socioeconomics and Land Use

Short-term disposal activities for this alternative do not impact socioeconomics at the NTS. The implementation of this alternative has minimal short-term impacts to socioeconomic and land use at and around the FEMP site.

This analysis assumes that the resources needed for remedial work are purchased within the consolidated metropolitan statistical area (CMSA), resulting in a minor beneficial impact to the CMSA in the short-term. Furthermore, the removal of the Silos 1 and 2 material reduces impacts to the future population and economic growth in the area.

3.2.6.4 Transportation

The transportation of the treated Silos 1 and 2 material to the NTS by either transportation option (direct truck or intermodal) is protective of the public. The implementation of this alternative results in negligible increases in traffic flow on and around the FEMP site for both transportation options (direct truck or intermodal). Temporary increases in deliveries and workers to the FEMP site are not expected to significantly impact local traffic patterns or roadways.

Treated Silos 1 and 2 materials are transported by either direct truck or intermodal transport to the NTS. The treatment process proposed under VIT1 generates approximately 2,398 containers. If two containers were placed on one truck per shipment, approximately 1,199 direct truck shipments to the NTS are required. This results in approximately eight shipments per week to meet the 3-year operation schedule.

For intermodal transport, two containers are placed in an International Shipping Organization (ISO) container. One ISO container is placed on a truck and two ISO containers are placed on a railcar. This results in 1,199 truck shipments from the FEMP to an intermodal facility, 600 railcar shipments by regular freight from an intermodal facility in the East to an intermodal facility in the West, and 1,199 truck shipments from the intermodal facility to the NTS.

Environmental impacts from shipping and disposing of treated Silos 1 and 2 materials are expected to be minimal from normal transportation because procedures comply with applicable DOT requirements and DOE Orders. There is a small risk to the public during transportation of the treated Silos 1 and 2 material to the NTS. The estimate of public radiation exposure, expressed in terms of ILCR, along the route to the NTS ranges from 1.19×10^{-6} for direct truck to 1.36×10^{-6} for intermodal for the maximally exposed individual, within the CERCLA target risk range of 1×10^{-4} to 1×10^{-6}. It is estimated that 0.21 to 0.23 fatalities may occur to the public due to non-radiological risks during direct truck and intermodal transportation, respectively. Because potential short-term risks to the public are so small, even a major deviation in the transportation assumptions for either direct truck or intermodal does not change the conclusion that this alternative is protective of the community in the short-term.

Additional radiation exposure risks to the worker result from transporting the treated Silos 1 and 2 material to the NTS. The ILCR for transportation workers is estimated to range from 1.56×10^{-5} per shipment for intermodal to 1.70×10^{-5} per shipment for direct truck. It is estimated that 0.04 to 0.06 fatalities may occur to workers as a result of intermodal and direct truck transportation accidents, respectively. The risk to workers due to radiological exposures during off-loading activities at the NTS is assumed to be below the estimated ILCR risk level of 3.32×10^{-4} during treatment/construction activities at the FEMP site because the materials are already packaged and in a stabilized form. There is uncertainty regarding additional risk from exposure to wastes already present at the NTS near off-loading operations for FEMP waste.

The basis for these risk estimates is provided in **Appendices B** and **E**.

3.2.6.5 Time to Achieve Protection

As illustrated in the schedule presented in **Figure 3.2-3**, design, construction and start-up activities for the VIT1 alternative result in a period of approximately 60 months from approval of the ROD Amendment for Silos 1 and 2 remediation until the initiation of treatment operations.

The operating schedule for the VIT1 alternative assumes 24 hr/day, 7 days/week operation of the 15 MTD melter at full capacity (assuming 70% design availability) to complete treatment within a 3-year period. The operating schedule (24 hr/day, 7 days/week) does not result in any excess capacity for short-term acceleration to recover from unplanned downtime.

The 15 MTD melter proposed by the POP contractor exceeds the demonstrated boundary of the technology (see **Section 3.2.7.1 - *Technical Feasibility***); therefore, the most feasible means of treating the Silos 1 and 2 material in less than three years is to design the facility with multiple melter trains. The addition of multiple melter trains, along with the necessary increases in feed preparation, off-gas, and product storage capacity results in a significant cost impact in order to significantly accelerate the schedule.

3.2.7 Implementability

The implementability criteria are described in **Section 3.1.2.6**. The following sections present an evaluation of the technical feasibility, administrative feasibility, and availability of services evaluation of implementing this alternative.

The feasibility of implementing the Vitrification — Joule-heated technology for the remediation of the Silos 1 and 2 material is summarized in the following sections.

3.2.7.1 Technical Feasibility

Scaleup

The Vitrification — Joule-heated technology was demonstrated by the POP contractor using a pilot-scale melter designed for a production rate of 0.34 TPD. The POP demonstration confirmed previous efforts [e.g., VITPP and Vitreous State Laboratories (VSL)] to establish a melt rate scaleup factor for surrogates similar to Silos 1 and 2 material. The POP testing established a scaleup factor of 0.8 metric tons per day per square meter (MTD /m^2) of melt pool surface at a relatively low temperature (1185° C). A throughput of 1 MTD/m^2 during the POP became unstable and probably represents an upper bound for scaling. Additionally, Batelle-Pacific Northwest Laboratories (PNL) testing of Silos 1 and 2 material and Silos 1 and 2 surrogates produced data providing a basis for surrogate development and use for scaleup of this technology.

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The use of the existing database of testing and analytical data available for the Vitrification — Joule-heated technology will assist in defining the glass chemistry (corrosivity, redox state), physics (conductivity, viscosity), volatilization of constituents (lead, chromium, selenium), and materials of construction (refractory, electrodes) for Silos 1 and 2 material and Silos 1 and 2 surrogate glasses. Lead and sulfate in the feed material may result in reduced, metallic lead and a salt or sulfate top layer in the melter. Molten lead buildup (found in the POP melter after testing) could be removed by bottom draining; however, the POP testing failed to successfully demonstrate a restartable bottom drain design. Bottom drains are a standard design feature of commercial melters and are adaptable to the full-scale design. Similarly, a salt layer drain could be deployed in the melter design to control salt layers. The POP 72-hour demonstration run indicated that the Silos 1 and 2 surrogate (containing 3.84 wt% sulfates) did not present a salt layer or foaming control challenge at the demonstrated production rate (Silos 1 and 2 material contains approximately 1.8 wt% sulfates). Thus, the need for operation of the salt drain was not required at the demonstrated feed rate. At the request of FDF, the salt drain design was demonstrated by the POP contractor following the completion of the demonstration run.

The design of a melter for this application is unique primarily due to the capacity required to support this application. The technology has been used to treat reasonably similar wastestreams at approximately 5 TPD but requires scaleup consideration to attain a 15 TPD capacity. However, the joule-heated melter design benefits from lessons learned from previous DOE Vitrification — Joule-heated projects, including the previous Silos 1 and 2 vitrification programs at the FEMP and PNL. Melter design by a commercial contractor would utilize scaleup factors, glass chemistry and physics, and suitable materials of construction that have already been developed for Silos 1 and 2 glass, thus reducing some design concerns. Additionally, the design of a melter to operate under negative pressure has been demonstrated and is readily scalable.

In order to establish a level of confidence that the Normal Off-gas System will meet its design objectives, technical development will be required during design to remove uncertainty. While individual equipment is commercially demonstrated, the Normal Off-gas System and controls must be optimized to ensure that system performance does not impact implementability. For example, the Normal Off-gas Pressure Control System may be difficult to balance, and must be demonstrated and optimized. A related concern for scaleup of the system is the amount of air in-leakage into the melter that enters the Normal Off-gas System. Some in-leakage to a melter and Normal Off-gas System is inevitable, but it is magnified by scale and complexity of system design. In-leakage must be minimized during design of the treatment system and Normal Off-gas System to avoid the need for increased off-gas treatment capacity.

Another concern is the design of the off-gas inlet, which is untested for this application but has been used for radioactive waste vitrification in Europe. Design development to prove the design concept through bench-scale or pilot-scale testing is required when conventional performance data are not available. Previous experience with waste vitrification (DOE 1999c) demonstrated that restriction of the off-gas inlet by material accumulation can impact melter operation. Buildup of solid material in the off-gas inlet affects pressure and flow through the system and can result in difficulty balancing and stabilizing pressure in the melter. It can also contribute to back-pressure in the Normal Off-gas System, which can trigger the EOG System.

Commercial Demonstration

Joule-heated melters are a commercial technology with extensive demonstration in the production of consumer glass. Glass chemistry, physics, volatilization of constituents, certified homogeneity of feed materials and materials of construction are all well defined in this industry for commercial grade glasses. Joule-heated melter capacities exceeding 100 tons daily have been operated in the commercial glass industry.

The ability to vitrify Silos 1 and 2 material and similar waste through a joule-heated process has been successfully demonstrated in multiple laboratory and pilot-scale programs. Additionally, there have been several full-scale installations within the DOE-complex with varying successes, e.g., West Valley, DWPF; TVS; and SRS M-Area Melter. Vitrification — Joule-heated technology has been applied to treat municipal, hazardous, radioactive, and mixed wastes in many countries around the world. However, the scale of the melter proposed by the POP contractor, 15 TPD, exceeds that which has been demonstrated on radioactive and/or hazardous waste slurries (no programs greater than 5 TPD capacity).

Common problems experienced by the joule-heated technology are documented in the U.S. DOE publication, "Waste Vitrification Systems Lessons Learned," (DOE 1999c). While, the unique designs cited above have experienced failures, they have also instituted corrective actions or design changes and gone on to continue successful operation, thereby increasing the overall body of knowledge on vitrification. While numerous design and start-up issues for vitrification technology in the DOE-complex have been encountered, design and operations personnel often met the challenges and continued on to successfully meet the project goals.

For the Melter System, various developmental programs (POP contractor, VSL) have identified refractories well suited for glass contact and non-contact areas in the melter (for material similar to the silos material) that are very resistant to wear. Electrode material selection is a potential compatibility issue the may require development by the future full-scale remediation contractor. The most common electrode material for use in joule-heated melters is Inconel and molybdenum metal.

Operability

Ease of Operation

Operability concerns include the integrated operation of complex systems (waste treatment, and off-gas) and the long-term performance of custom-built equipment items.

Operability of the Melter System is considered complex due to operational conditions that must be continuously monitored and adjusted. For example, there are five basic parameters of the glass melt that affect the operability of this system; but, they are not readily measurable. These include viscosity, electrical conductivity, liquid temperature, redox, and sulfate formation.

Due to the volatilization/decomposition of Silos 1 and 2 material during the melting process, the melter is maintained at negative pressure (with respect to the interior of the melter building) to control off-gases, including radon. Melter operations must include the ability to operate around anticipated variations in the Silos 1 and 2 glass formulation (chemistry), control and monitor operating/process parameters, and respond to off-normal conditions.

Operability is enhanced by a robust glass formulation that minimizes the need for the process system to respond to variability of the feed (this permits routine operations). The contractor for the full-scale remediation of the Silos 1 and 2 material will require a glass chemistry development program to insure process stability. Most systems considered in this evaluation appear robust and can accommodate variations in key operational process parameters (e.g., feed preparation, waste treatment, and off-gas). Control of the redox reactions in the glass is accomplished by adjusting feed composition. Control parameters must be monitored throughout the vitrification process in order to maintain the melter within operable limits. If process monitoring indicates an out-of-spec condition (e.g., over-pressurization), the Melter Control System can be designed to mitigate (interlock with melter feed and switchover to the EOG System) the event by idling operations before recovery from credible/design basis events.

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Critical functions of the Air Emissions/Normal Off-gas System include maintenance of flow through the system, treatment of the off-gas for the constituent pollutants and the ability for the EOG System to operate under upset conditions. The unit operations are remote and automated, and significant process controls are required. Based on the commercially demonstrated operation and control of the individual off-gas equipment, the Air Emissions/Normal Off-gas System is expected to have desirable operability attributes. This is supported by extensive use and documented performance of the off-gas component equipment in commercial industry. However, operability and control of the Normal Off-gas System are considered complex due to operational conditions that must be monitored and adjusted, as well as multiple components that require integrated operation. Additionally, the complexity of the design, as well as operational issues associated with high temperature processes, complicate the start-up process for Vitrification — Joule-heated.

With the possible exceptions of the demonstration of controls for pressure balancing and off-gas inlet design, the Air Emissions/Normal Off-gas System is robust, and capable of handling off-gas with variable flow, temperature, moisture, acid gases, and solids. Buildup of solids in the Normal Off-gas System such as was experienced during off-gas operation in the VITPP may present an operability problem for this design. In case the clarifier delivers less than the design basis 30 wt% solids in the feed, the Normal Off-gas System manages the increased moisture driven off by the melter. Since condensed water vapor is easily removed by the design, and the wastewater flow is comparatively low (excess scrubber liquor and perhaps some clarifier overflow), the excess water is not expected to pose an implementability concern.

Reliability

The Melter System uses compatible materials and demonstrated equipment to ensure overall plant availability. Although DOE vitrification projects (DWPF, West Valley, NY, and SRS M-Area) have experienced significant cost and schedule growth, melter availability has been consistently over 70% once a successful start-up is completed for similar process/treatment applications.

Individual off-gas components have a highly demonstrated reliability in commercial application. However, the reliability of the integrated system needs to be demonstrated. For example, problems resulting from the presence of moisture in the off-gas, contaminated HEPAs, scrubber pH control, ductwork plugging were experienced during the FEMP VITPP testing.

Maintainability

The Melter System has many unique features of design, where some maintenance trends may be unpredictable and may require specialized training and/or tooling. Considering industrial hazards associated with the Melter System (e.g., thermal, high voltage), the overall challenge of maintainability is considered moderate to high.

Additionally, other parameters and functions add to concerns are maintainability, such as control of in-leakage to the melter Off-gas System, salt drain, reduced metals drain and electrode feed.

Maintenance of the Normal Off-gas System is routine and is not expected to impact operability of the system.

Complexity

The alternative is considered complex due to operational conditions, process control challenges (i.e., viscosity, electrical conductivity, liquidus temperature, metals reductions and sulfate formation), sophisticated equipment, and a relatively large number of unit operations with several that include high temperature components. The degree of complexity that characterizes this technology requires a highly skilled operations team to ensure safe and efficient operations.

Vitrification results in the generation of off-gas that requires an Air Emissions/Normal Off-gas System. The Normal Off-gas System requires multiple integrated components [scrubber, wet electrostatic precipitator (WESP), NO_x destructor, quench tower] and process control considerations.

The Product Rework System for this technology includes requirements for specialized tooling, remote handling, controls, and multiple remote operations needed to ensure effective size reduction and transfer of recycled materials. For example, the rework operation must function as designed to remove the MTCs from the container, size reduce the material with a shredder, separate glass and metal, and transport the material for reprocessing in the melter.

Ease of Acceleration

In order to treat the Silos 1 and 2 material in three years, the required operating schedule would be 24 hr/day, 7 days/week, which considers the 70% design availability. Therefore, acceleration/schedule recovery could not be achieved by an increased operating schedule.

The alternative could only be accelerated with the addition of multiple melter trains and increased capacities for support equipment and facilities resulting in a significant increase in capital cost. At 15 TPD, the melter is pushing the demonstrated boundary of the technology; therefore, it is not prudent to simply increase the single melter capacity.

Constructability - (Ease of Construction/Fabrication, Ease of D&D)

Construction activities are complicated by the complexity of this technology (i.e., thermal process) and based upon previous experiences of similar DOE projects. The complexity of the Vitrification — Joule-heated process custom design aspects, additional unit operations, and the need to integrate multiple systems in areas such as the off-gas treatment, complicate the construction process for this alternative. Facility D&D requires specialized handling methods for the removal of refractory materials before dismantlement. The spent refractory is assumed to be a mixed waste due to the presence of radioactive contaminants, lead and chromium. Other D&D activities appear to be conventional in scope using water flushing, monitoring, and collection methods before ultimate disposal.

The Melter System is a commercially available technology. However, equipment/component fabrication, installation, and construction turnover methods are a function of Melter System design and require specialized construction techniques. The ability to prefabricate off-site is, in general, not an option for the joule-heated melter since the stringent tolerances required for refractory materials is challenged during handling of a prefabricated unit. During construction activities, chemical hazards associated with refractory constituents (potential ingestion or inhalation hazard) will require specialized controls.

D&D of the Melter System is complex and requires special techniques during decontamination. Controls and trained personnel are required to remove contaminated refractory materials for packaging, treatment and disposal at an appropriately licensed off-site facility, and to apply chemical fixatives (as necessary) to the melter's interior. Once decontaminated, the Melter System is expected to facilitate conventional demolition techniques during its removal, size reduction, and packaging for ultimate disposal.

3.2.7.2 Administrative Feasibility

Licensing

Neither permits nor licenses are required to conduct remediation activities at the FEMP under CERCLA, but permit information summary packages may be necessary. The substantive technical requirements of emissions permits need to be identified and met by the design and operation of the vitrification process. These may include calculations of estimated emissions; identification of air emissions controls, wastewater controls, and stormwater controls that would be provided; and development of a sampling and analysis plan to monitor air and water emissions.

Programmatic

The NTS is a DOE-owned facility; thus, special permits for disposal of FEMP wastes at the NTS are not required. However, in accordance with the NTS WAC, a waste acceptance package consisting of a waste profile, waste certification program plan, and a list of authorized certification personnel are required to be prepared by DOE and approved by the NTS before waste shipment. DOE-NV has indicated that Silos 1 and 2 material, treated by Vitrification — Joule-heated to meet the NTS WAC, will be approved for disposal at the NTS. An addendum to the NTS PA for the selected disposal site will determine the depth and configuration for disposal.

Since this alternative includes off-site disposal, agency approvals and coordination for the interstate shipment of the material needs to be secured and could present a variable for implementing transportation of wastes to the NTS. Coordination with other stakeholders, including the public and regulatory agencies in the states along the transportation route to the NTS, is conducted by the FEMP waste shipping program as required.

3.2.7.3 Availability of Services (Contractors, Equipment, Utilities)

Several contractors are available for competitive bid to design and procure materials, equipment, and services to oversee operation of a joule-heated vitrification facility that is capable of meeting the requirements of this alternative. The primary treatment process and support systems are available technologies, although some have not been demonstrated at this scale, or with this particular type of waste. While only the melter requires specialized skills for operation, direct supervision on a continuous basis by the manufacturer and/or vitrification contractor would be available. It is expected that available FEMP personnel could be trained in the operation of other (feed preparation, off-gas, waste packaging) systems. Additionally, process engineers, operation and maintenance personnel, laborers, laboratory technicians, and administrative personnel to support the project would be trained and available to operate the technology. Proof of Process surrogate testing of the full-scale facility following construction, Operational Readiness Review (ORR), and System Operability Testing (SOT) would be conducted in order to optimize the process before beginning full-scale remedial operations using actual silo material.

With the exception of the melter and Melter Control System, other support system equipment is commercially available from a variety of contractors in accordance with the unit design specifications. The concrete shipping container for the waste glass could be manufactured by several contractors under competitive bid based on the container design specification. Certified transporters are currently available that can haul filled containers by truck to the NTS disposal facility in accordance with DOT requirements.

3.2.8 Cost

The summary cost for the Vitrification — Joule-heated is $356 Million in FY99 dollars as shown in **Table 3.2-3.**

TABLE 3.2-3

SUMMARY COST ESTIMATE FOR VITRIFICATION — JOULE-HEATED
($ MILLIONS)

Capital Cost	69
Engineering Cost	25
Operation and Maintenance Cost	134
D&D Cost	35
Project Management Cost	22
Waste Disposal Cost	25
Cost of Money	46
Summary Cost (Un-escalated)	356
Present Worth Analysis	288

Supporting detail information for the Vitrification — Joule-heated cost estimate is in **Appendix C.**

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3.2.9 State Acceptance

This criterion evaluates the input of the OEPA regarding the VIT1 alternative. Formal comments submitted by the OEPA during their review will be addressed in the final revised FS, before receiving EPA approval. This modifying criterion will be formally addressed in the regulatory process following the public review period for the FS/PP (i.e., in the Responsiveness Summary to accompany the ROD amendment).

3.2.10 Community Acceptance

This criterion evaluates the input of the community regarding local (to the FEMP) and "in the vicinity of" potential transportation routes or disposal locations, regarding the VIT1 alternative. The OU4 ROD (EPA 1994) documents the public's response and acceptance of this alternative as the selected remedy for the Silos 1 and 2 material. Current community input regarding this technology will become apparent during the scheduled review of this document by the public. Because formal comments will not be received until after the revised FS is final, public comments will be addressed during the regulatory process following the public comment period for the FS/PP (i.e., in a Responsiveness Summary to accompany the ROD amendment).

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Alternative VIT2

3.3 Removal, On-site Vitrification — Other, Off-site Disposal at the NTS (VIT2)

3.3.1 Description of Alternative

The following is a summary description of this alternative. Additional conceptual engineering design details (e.g., PFDs, General Arrangement Layouts) and assumptions can be found in **Appendix G/Design Basis and Description.**

The design details presented in this revised FS are conceptual, based on information provided by the POP testing, and have been prepared for the sole purpose of providing a technical basis for evaluating the alternatives.

3.3.1.1 Introduction

This alternative (VIT2) involves the removal, on-site vitrification using a non-joule-heated (in this case, combustion) melter, and off-site disposal at the NTS of the treated Silos 1 and 2 material. The Silos 1 and 2 material is removed from the TTA as a slurry containing approximately 10 wt% solids for the VIT2 process. The representative process used to evaluate this alternative **(Figure 3.3-1)** involves dewatering and drying of the Silos 1 and 2 material slurry to minimize the volume of material to be stabilized, followed by vitrification of the dried material. The VIT2 process produces a solid product that has a waste loading of approximately 87 wt% Silos 1 and 2 material. The treated material is packaged in concrete shipping and disposal containers with 5-inch thick walls. Based on the *Disposal Container Size Optimization Study* (FEMP 1999), a container of this type reduces the radiation levels associated with treated Silos 1 and 2 material at 87 wt% waste loading to approximately 70 mrem/hr on contact with the surface of the container.

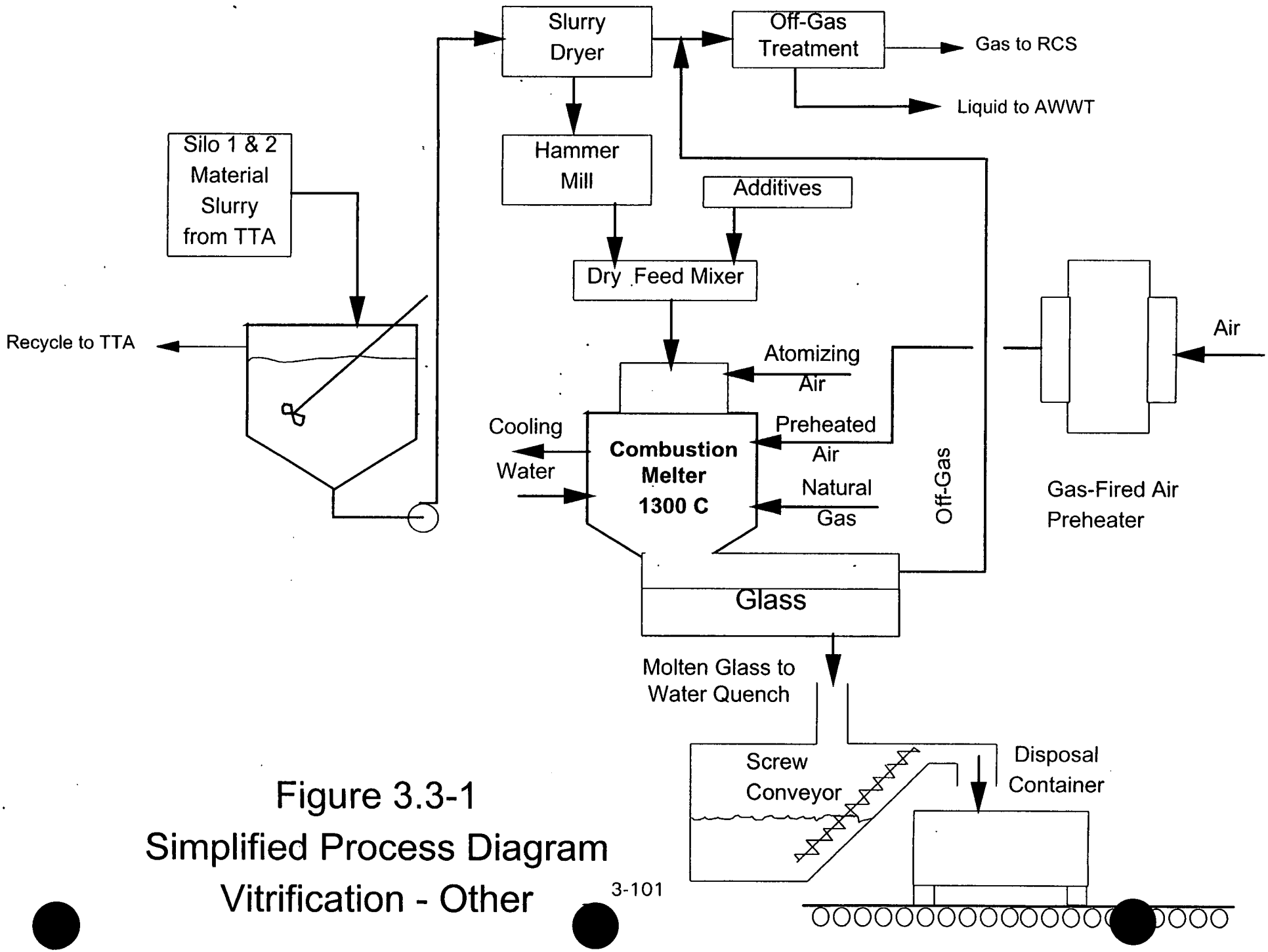

Figure 3.3-1
Simplified Process Diagram
Vitrification - Other

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The facility design is based on a plant availability factor of 70% over a total operating period of three years. The plant operating basis is 24 hr/day, 7 days/week with a design capacity of approximately 15 TPD. Each operating day, a maximum of 3.1 loaded disposal containers are produced. Each disposal container contains a loose fill of vitrified Silos 1 and 2 material made up of granular glass frit. Samples that were collected at the frit forming step are tested for compliance with the NTS WAC. Upon verification that the samples of treated Silos 1 and 2 material meet the NTS WAC, the disposal containers are transported to the NTS for final disposal. Interim storage capacity for approximately 134 loaded disposal containers (a 45 calendar day period, at design capacity, 20 disposal containers per week) is provided as part of the treatment facility. Based on 87 wt% waste loading, and assuming 1% of the containers will fail to meet the NTS WAC and will need to be re-processed, a total of 2,162 containers will require shipment to the NTS for disposal.

The VIT2 Feed Preparation System is designed to increase the solids content of the incoming slurry from 10 wt% solids to approximately 95 wt% solids using a centrifuge and Hot-oil Screw Dryer System. The slurry is received from the TTA and inventoried in a receiving tank to homogenize the material before it is fed to the centrifuge. The centrifuge produces a cake of approximately 50 wt% solids, which is discharged to a dryer system to produce a dry waste feed at 95 wt% solids. The dry waste is stored in bins.

The Feed Preparation System also includes the bins and transfer equipment to inventory and transfer the vitrification reagents to the feed prep tanks. Enough storage is provided to inventory a four week supply of vitrification reagents.

The feed mixer combines the formulated amount of dried waste and vitrification reagents. Once the constituents have been thoroughly mixed, they are transferred to a surge bin. Next, the mixed feed is metered into the combustion-heated melter where it is converted into glass. The molten glass from the melter flows by gravity into a water bath that cools and fractures the glass to form frit. The frit is conveyed from the water bath and into a shipping container. A lid is placed on the container, and the container is conveyed through the decontamination station where it is monitored and any contaminants on its exterior surface are removed as necessary. The container is then conveyed to the interim storage area.

For containers of treated material that do not meet the NTS WAC, a rework facility reprocesses the off-specification treated Silos 1 and 2 material. Rework operations are carefully confined and performed in a dedicated area. Remotely controlled equipment removes the lid from the container and transfers the granular material back to the treatment system to be reprocessed.

The Normal Off-gas System **(Figure 3.3-2)** is designed to maintain a negative pressure in the melter and other vitrification facility vessels where the containment of airborne contaminants, including radon, is a concern. The Normal Off-gas System maintains an airflow of approximately 800 scfm through several off-gas treatment steps that cool the off-gas and remove acid gases and particulates. The Normal Off-gas System discharges 500 scfm into the RCS, which is part of the ongoing Accelerated Waste Retrieval (AWR) Project, and discharges 300 scfm into a new auxiliary RCS. This auxiliary system consists of coolers, air dryers, and carbon beds to remove radon from the off-gas before it discharges to the atmosphere. The resulting negative pressure ensures that the melter and other vessels do not leak gases to the environment.

An EOG System provides protection from overpressurization in the event of a melter pressure excursion or a failure in the Normal Off-gas System. It provides off-gas cooling and particulate removal while feed to the melter is stopped and the melter is idled.

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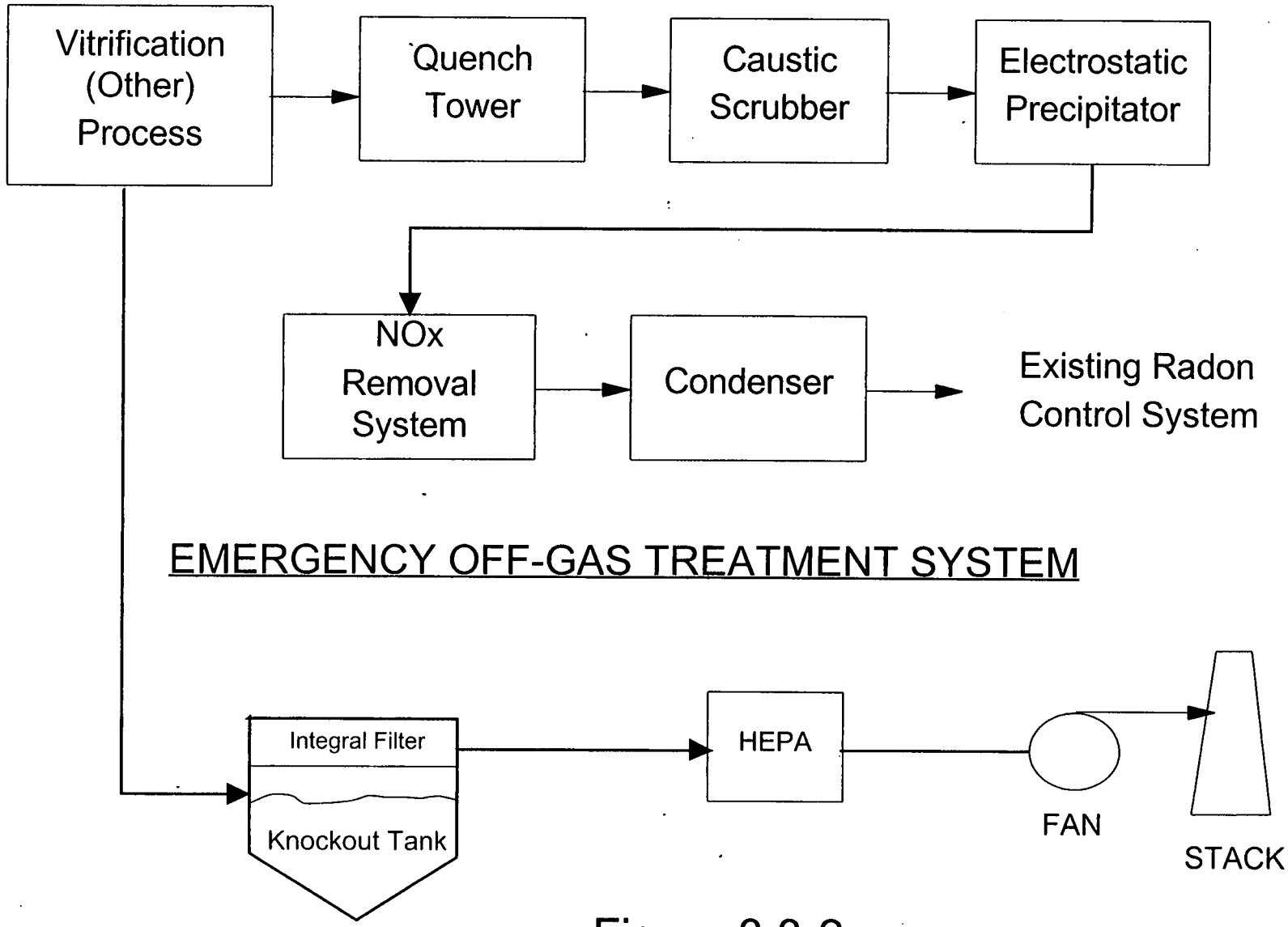

Figure 3.3-2
Off-Gas Treatment System
Vitrification - Other

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A Flush Water System uses recycle water from the TTA to flush slurry lines and equipment in order to reduce the risk of plugging process lines and equipment. The flush water is carried forward through the vitrification process.

Reject glass frit (one container every 7 to 8 weeks) is reduced in size and reprocessed during the 3-year operating schedule.

The VIT2 secondary wastestreams include refractory, miscellaneous replacement equipment, spent RCS carbon, RCS and Off-gas System HEPA filters, and PPE **(see Table 3.3-1)**. As noted in **Table 3.3-1**, some secondary wastestreams are processed and do not contribute to the volume of secondary waste to be disposed.

A standard Cooling Tower System provides cooling water to the melter and to various coolers and condensers.

3.3.1.2 Project Schedule

The description of the project schedule completes the description of the VIT2 alternative, which is evaluated in the following sections.

Table 3.3-2 summarizes the individual project activities and their estimated durations for the implementation of Alternative VIT2. A more detailed description of the individual project activities can be found in **Appendix G, Section G.2.21**. Each activity duration reflects the estimated time to complete the task supporting the remediation of the Silos 1 and 2 material at the DOE-FEMP site. The activity durations were developed considering the following factors:

- Proposed activity durations provided by commercial contractors;
- Specified regulatory document review and approval cycles outlined in the FEMP ACA;
- Procedural and administrative requirements for conducting procurement activities at the DOE-FEMP site;
- Historical project management experience and lessons learned while performing environmental remediation activities at the DOE-FEMP site; and
- Historical experience with the start-up of vitrification facilities within the DOE-complex.

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TABLE 3.3-1

ESTIMATED SECONDARY WASTESTREAMS GENERATED DURING FULL-SCALE OPERATION OF THE VITRIFICATION - OTHER FACILITY

Secondary Wastestreams for VIT2					
Source	**Material Type**	**Rate (lb/hr)**	**Total Volume**	**Status**	**Packaged Disposal Volume**
Scrubber Purge	Water	2,712	8,884,512 gal	Process	N/A
RCS Condensate	Water	200	655,200 gal	Process	N/A
Cooling Tower Blow Down	Water	5,000	16,380,000 gal	Process	N/A
Refractory	Solid	1 Lot	225 cf	Dispose	448 cf
Misc. Replacement Equipment [1]	Solid	N/A	410 cf	Dispose	790 cf
RCS carbon	Carbon	1 Lot	8,000 cf	Dispose	13,334 cf
RCS and Off gas system HEPA Filters	Solids	N/A	1,296 cf	Dispose	2,496 cf
PPE	Solid	4/day	27,700 cf	Dispose	41,038 cf
Total Estimated Cubic Feet of Packaged Disposed Secondary Waste					58,000 cf

1 - Equipment will be replaced when necessary to maintain normal operation schedule.

<END OF PAGE>

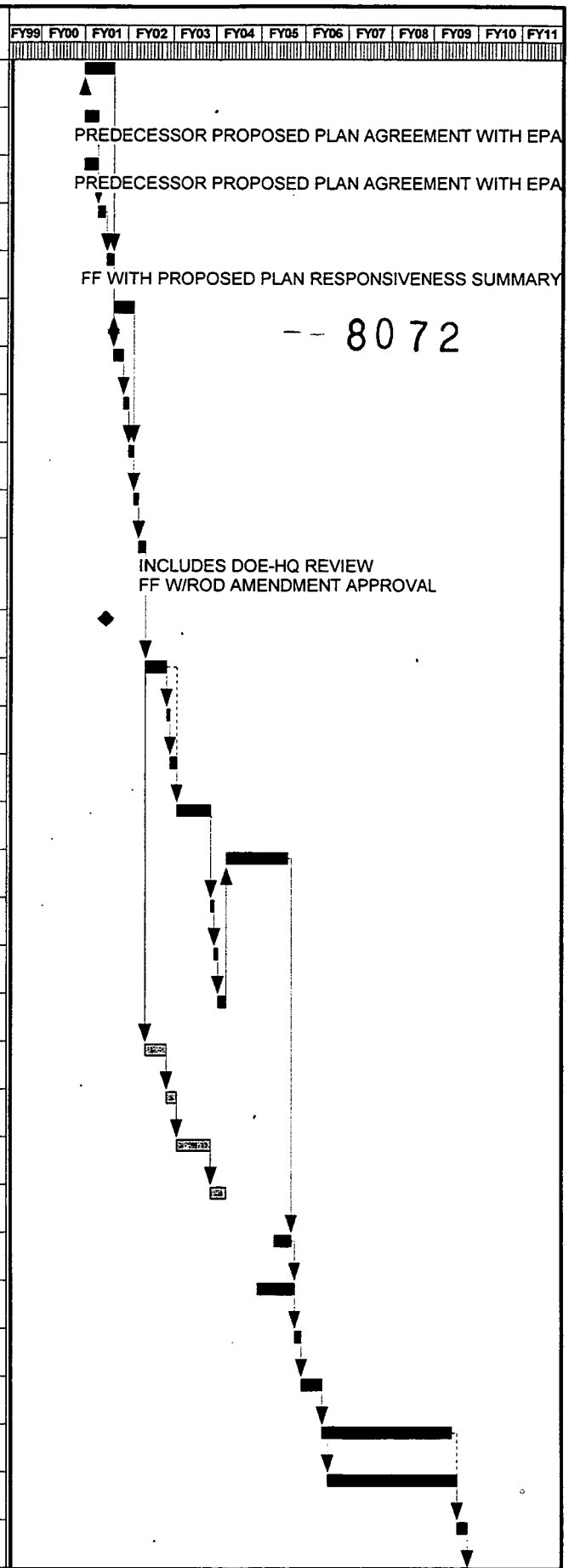
TABLE 3.3-2
SCHEDULE SUMMARY — VIT2

Activity	Duration (Work Days)
Procurement Process	
• Develop RFP	166
• RFP Bid Cycle	165
Design and Documentation	465
Construction and Construction Acceptance Testing	350
SOT	100
Readiness Review	
• Readiness Preparation	213
• ORR	40
Proof of Process Testing	120
Remediation Operations	750
Safe Shutdown of Facility	60
Facility D&D	120

Figure 3.3-3 provides a graphical representation of the sequences for completing the project activities, as well as the logical relationships between the activities.

The VIT2 project schedule becomes a key component in several of the evaluation criteria. Short-term effectiveness evaluates the effects of the alternative during the construction and operations phase until the RA objectives are achieved (e.g., worker risks, environmental risks), as well as the time required to achieve protection. Implementability will evaluate the ability of the VIT2 alternative to maintain schedule and recover schedule due to unplanned downtime. The project schedule is an important factor in estimating the project cost for VIT2. The project schedule effects the resource planning, pay item schedules, and the cost of money analysis for the remediation contract.

Activity ID	Activity Description	Orig Dur	Rem Dur	Early start	Early finish
0100	DEVELOP FINAL REMEDIATION RFP	166*	166*	02OCT00	01JUN01
0400	TRD DEVELOPMENT	79	79	02OCT00*	26JAN01
0700	DRAFT RFP	79	79	02OCT00*	26JAN01
[illegible]000	STORYBOARD RFP	44	44	29JAN01	30MAR01
1300	REVIEW/FINALIZE RFP	43	43	02APR01	01JUN01
1600	RFP BID CYCLE	120*	120*	04JUN01	21NOV01
1900	BID PERIOD	64	64	04JUN01	31AUG01
2200	BID EVALUATION	29	29	04SEP01	12OCT01
2500	BAFO	27	27	15OCT01	21NOV01
2800	CONSENT PKG PREP/REVIEW	23	23	26NOV01	28DEC01
3100	DOE CONSENT PKG REVIEW/APPROVAL	42	42	31DEC01	28FEB02
3200	NOA ISSUED FOR ROD	0	0	10APR01*	
3400	PRELIMINARY DESIGN	120	120	01MAR02	20AUG02
3700	FDF REVIEW PRELIMINARY DESIGN	20	20	21AUG02	18SEP02
4000	FINALIZE/APPROVE PRELIMINARY DESIGN	40	40	19SEP02	14NOV02
4300	FINAL DESIGN	195	195	15NOV02	27AUG03
4600	CONSTRUCTION	350	350	05JAN04	25MAY05
[illegible]900	FDF REVIEW FINAL DESIGN	20	20	28AUG03	25SEP03
5200	FINALIZE FINAL DESIGN	20	20	26SEP03	23OCT03
5500	EPA REVIEW/APPROVE FINAL DESIGN	45	45	24OCT03	02JAN04
5800	PHAR DEVELOPMENT	120	120	01MAR02	20AUG02
6100	PHAR REVIEW/APPROVAL	60	60	21AUG02	14NOV02
6400	FHAR DEVELOPMENT	195	195	15NOV02	27AUG03
6700	FHAR REVIEW/APPROVAL	90	90	28AUG03	09JAN04
7000	SYSTEM OPERABILITY TEST	100	100	01FEB05	23JUN05
7300	READINESS PREPARATION	213	213	15SEP04	22JUL05
7600	ORR	40	40	25JUL05	19SEP05
7900	PROOF OF PROCESS TEST	120	120	20SEP05	15MAR06
8200	OPERATION	750	750	16MAR06	16MAR09
8500	WASTE DISPOSITION	750	750	28APR06	28APR09
8800	SAFE SHUTDOWN	60	60	29APR09	23JUL09



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[illegible]art 01OCT95
Project Finish 18JAN10
Data Date 01FEB99
Run Date 06DEC99

Early Bar
Progress Bar
Critical Activity

VOR2

Sheet 1 of 2

FIGURE 3.3-3

PROJECT SCHEDULE

VITRIFICATION - OTHER

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Activity ID	Activity Description	Orig Dur	Rem Dur	Early start	Early finish
8900	FACILITY D & D	120	120	24JUL09	18JAN10

FY99 FY00 FY01 FY02 FY03 FY04 FY05 FY06 FY07 FY08 FY09 FY10 FY11

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Project Start 01OCT95	Early Bar	VOR2	Sheet 2 of 2
Project Finish 18JAN10	Progress Bar	FIGURE 3.3-3	
Data Date 01FEB99	Critical Activity	PROJECT SCHEDULE	3-109
Run Date 06DEC99		VITRIFICATION - OTHER	

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3.3.2 Overall Protection of Human Health and the Environment

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Issues related to the ability of VIT2 to meet the criterion of overall protectiveness of human health and the environment are similar to VIT1. Consequently, the discussion of meeting the criterion of overall protectiveness of human health and the environment is identical to that presented in **Section 3.2.2.**

3.3.3 Compliance with Applicable or Relevant and Appropriate Requirements

VIT2 complies with pertinent ARARs and TBCs identified in **Appendix A.** Compliance with the key chemical-, location-, and action-specific ARARs and TBCs presented in **Appendix A** for this alternative is discussed below.

3.3.3.1 Chemical-Specific ARARs and TBCs

VIT2 complies with all chemical-specific ARARs and TBCs identified in **Appendix A.** Issues related to chemical-specific ARAR compliance for VIT2 are similar to VIT1. Consequently, the discussion of compliance for chemical-specific ARARs is identical to that presented in **Section 3.2.3.1.**

3.3.3.2 Location-Specific ARARs and TBCs

VIT2 complies with all location-specific ARARs and TBCs in **Appendix A.** Issues related to VIT2 compliance with location-specific ARARs are similar to VIT1. Consequently, the discussion on compliance with location-specific ARARs is identical to that presented in **Section 3.2.3.2.**

3.3.3.3 Action-Specific ARARs and TBCs

VIT2 complies with all action-specific ARARs and TBCs in **Appendix A.** Issues related to VIT2 compliance with action-specific ARARs are similar to VIT1. Consequently, the discussion on compliance with action-specific ARARs is identical to that presented in **Section 3.2.3.3.**

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3.3.4 Long-term Effectiveness and Permanence

3.3.4.1 Magnitude of Residual Risk

Silos 1 and 2 Material

As with VIT1, the implementation of the VIT2 alternative reduces the residual risk to viable receptors to a HI of less than 0.2 and an ILCR of less than 10^{-6}. Because the material is removed from the site, residual risk from Silos 1 and 2 material at the FEMP site is nonexistent. Residual risk at the NTS is limited by the placement of the treated Silos 1 and 2 material in an engineered disposal facility's institutional controls, the characteristics of the vitrified wastes, and the arid environment.

Soil and Debris

As with VIT1, disposal of soil and debris under the VIT2 alternative will provide long-term protection of the environment and the public (see **Section 3.2.4.1**).

3.3.4.2 Adequacy and Reliability of Controls

The TCLP, which is intended to simulate conditions of rainwater leaching through a solid waste landfill, indicates that the VIT2 process produces a wasteform which meets the NTS WAC and is durable based on leach rate data. The TCLP test is utilized to simulate the leaching effects of acidic groundwater infiltrating the disposal cell and contacting disposed waste, and serves as a measure of the stabilized waste particles ability to resist leaching, even if the original wasteform (e.g., monolith) has been compromised. This treated reduction in leachability, combined with the additional protection provided by the engineered disposal cell provide a durable disposal configuration that provides long-term protection of human health and the environment.

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Long-term environmental impacts associated with VIT2 are similar to VIT1 as they relate to impacts on water quality and hydrology, air quality, biotic resources, wetlands and floodplains, socioeconomics and land use, and cultural resources. VIT2 is also similar to VIT1 with impacts on soil and geology except that the estimated volume of vitrified cullet requires additional disposal space. The overall impact due to the increased volume is not significant because material would be disposed in a previously disturbed area (Area 5) designated for LLRW disposal in the NTS-EIS. The PA prepared by DOE-Nevada will demonstrate that disposal of this increased volume will meet criteria determined to be protective by the NTS-EIS. Consequently, the discussion of VIT2 long-term environmental impacts is identical to that presented in **Section 3.2.4.2**.

3.3.5 Reduction of Toxicity, Mobility, or Volume through Treatment

VIT2 is similar to VIT1 in its ability to stabilize lead within limits established by the EPA and reduce radon emanation rates (**refer to Section 3.2.5**).

Analytical data from the POP testing of VIT2 on surrogate Silos 1 and 2 material also showed that vitrification could effectively stabilize lead and other RCRA metals to meet the TC limits established under RCRA.

Data from the original FS treatability study revealed that significant volume reductions can be achieved through vitrification. The reduction in volume (not including packaging) was estimated to range from 50.3 to 68%.

However, data from the POP testing of combustion vitrification on surrogate Silos 1 and 2 material into a frit glass indicates a 2% reduction from the in situ volume of the Silos 1 and 2 material, due to a packaging fraction of 50%. POP data indicates that the original 6,797 m^3 (8,890 yd^3) of material in Silos 1 and 2 could be reduced by 2% to a volume of approximately 6,643 m^3 (8,689 yd^3). However, due to the shielding necessary for protection of workers and the general public and for meeting DOT requirements, containerization of the treated material results in a disposal volume of approximately 12,576 m^3 (16,450 yd^3), equating to a volume increase of 85% compared to the original volume of material in Silos 1 and 2.

The secondary wastestreams associated with the VIT2 alternative are summarized in **Table 3.3-1.** The estimated final disposal volume of all the secondary wastestreams is 1,644 m^3 (2,150 yd^3). The total estimated disposal volume of the treated Silos 1 and 2 material and all secondary wastestreams is 14,220 m^3 (18,600 yd^3), equating to an overall volume increase of 109%, compared to the original volume of material in Silos 1 and 2.

3.3.6 Short-term Effectiveness

3.3.6.1 Protection of the Community During Remedial Action

Protection of the community during implementation of VIT2 is similar to VIT1. Therefore, the discussion on protection of the community is identical to that presented in **Section 3.2.6.1.**

3.3.6.2 Protection of Workers During Remedial Action

Appendix B estimates the number of injuries and fatalities that could result from the removal, treatment, and transportation activities associated with this alternative during remediation.

This alternative involves the handling of radioactive materials and, therefore, there are several potential exposure pathways for workers. Both the release of gases and exposure to direct radiation from the materials could cause a risk to workers. Per 10 CFR Part 835.202, occupational dose shall not exceed a total effective dose equivalent of 5 rem per year. This dose results in on ILCR of 2.0×10^{-3} to workers. With appropriate protection, the removal and treatment of materials is estimated to result in an incremental ILCR level to remediation workers of 3.50×10^{-4} (see **Appendix B**). Most of this risk occurs during operation of the treatment facility. As appropriate, workers wear protective clothing and use shielding, along with automatic and remote operations.

A simplified IHA was conducted to evaluate the unmitigated hazards to workers posed by the conceptual design of the combustion vitrification process. The results of the IHA are presented in **Appendix B** and are summarized below:

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- Complex systems associated with vitrification present industrial/construction hazards;
- The man-hours required to complete remediation utilizing combustion vitrification present a human hazard;
- Elevated equipment present a fall hazard;
- High energy and temperature process present electrical and thermal hazards;
- Toxic off-gas constituents (i.e., SO_x, NO_x), natural gas for combustion, and caustic treatment of off-gas present chemical reactivity and toxicant hazards;
- Heat, melter redox conditions, acid gases, and use of caustic present a material deformation hazard; and
- Upset conditions in the melter present a pressure hazard and a loss of containment hazard.

Without considering the specific hazards discussed above, it has been estimated, based solely on labor hours, that construction, treatment, and D&D could result in an estimated 70 injuries and 1 fatality during remediation. Remediation activities are to be conducted in accordance with a health and safety plan developed to meet 29 CFR Part 1910.120(b)(4). Training and procedures ensure that worker exposure to risks is ALARA. Engineering safeguards include water jacket cooling and insulation of exposed potentially thermally hot surfaces.

3.3.6.3 Short-term Environmental Impacts

The short-term environmental impacts at the FEMP site on water quality and hydrology, air quality, biotic resources, wetlands and floodplains, and socioeconomics and land use by implementation of VIT2 are similar to VIT1. VIT2 short-term impacts on soil and geology are also similar to that of VIT1 with the exception of the volume of soil that is temporarily disturbed. It is estimated that construction and excavation activities could temporarily disturb a total of approximately 12,461m^3 (16,299yd^3) of the site. The overall difference between VIT1 and VIT2 on the volume of soil impacted is not significant. Therefore, the discussion of VIT2 short-term environmental impacts is identical to that presented in **Section 3.2.6.3**.

3.3.6.4 Transportation

The transportation of the treated Silos 1 and 2 material to the NTS by either transportation option (direct truck or intermodal) is protective of the public. The implementation of this alternative results in negligible increases in traffic flow on and around the FEMP site for both transportation options (direct truck or intermodal). Temporary increases in deliveries and workers to the FEMP site are not expected to significantly impact local traffic patterns or roadways.

Treated Silos 1 and 2 material is transported by trucks to the NTS. The treatment process proposed under VIT2 generates approximately 2,162 containers. If two containers are placed on one truck per shipment, approximately 1,081 direct truck shipments to the NTS are required. This results in approximately seven shipments per week to meet the 3-year operation schedule.

For intermodal transport, two containers are placed in an ISO container. One ISO container is placed on a truck and two ISO containers are placed in a railcar. This results in 1,081 truck shipments from the FEMP to an intermodal facility, 541 railcar shipments by regular freight from an intermodal facility in the East to an intermodal facility in the West, and 1,081 truck shipments from the intermodal facility to the NTS.

Environmental impacts from shipping and disposing of treated Silos 1 and 2 material are expected to be minimal from normal transportation because procedures comply with applicable DOT requirements and DOE Orders. There is a small risk to the public during transportation of the treated Silos 1 and 2 material to the NTS. The estimate of public radiation exposure, expressed in terms of ILCR, along the route to the NTS ranges from 2.14×10^{-6} for direct truck to 2.42×10^{-6} for intermodal for the maximally exposed individual, which is within the CERCLA target risk range of 1×10^{-4} to 1×10^{-6}. It is estimated that 0.19 to 0.21 fatalities may occur to the public due to non-radiological risks during direct truck and intermodal transportation, respectively. Because potential short-term risks to the public are so small, even a major deviation in the transportation assumptions for either direct truck or intermodal does not change the conclusion that this alternative is protective of the community in the short-term.

Additional radiation exposure risks to the worker result from transporting the treated Silos 1 and 2 material to the NTS. The ILCR for a transportation worker is estimated to range from 2.83×10^{-5} per shipment for intermodal and 3.16×10^{-5} per shipment for direct truck. It is estimated that 0.04 to 0.05 fatalities may occur to workers as a result of intermodal and direct truck transportation, respectively. The risk to workers due to radiological exposures during off-loading activities at the NTS is assumed to be below the estimated ILCR risk level of 3.50×10^{-4} (risk level during treatment/construction activities at the FEMP site) because the materials are already packaged and in a stabilized form. There is uncertainty regarding additional risk from exposure to wastes already present at the NTS near off-loading operations for FEMP waste.

The basis for these risk estimates is provided in **Appendices B** and **E**.

3.3.6.5 Time to Achieve Protection

As illustrated in the schedule presented in **Figure 3.3-3**, design, construction, and start-up activities for the VIT2 alternative result in a period of approximately 59 months from approval of the ROD Amendment for Silos 1 and 2 remediation until the initiation of treatment operations.

The operating schedule for the VIT2 alternative assumes 24 hr/day, 7 days/week operation of the 15 TPD cyclone reactor at full capacity (assuming 70% design availability) to complete treatment within a 3-year period. The operating schedule (24 hr/day, 7 days/week) does not result in any excess capacity being available for short-term acceleration to recover from unplanned downtime.

Since the VIT2 process has been commercially demonstrated at capacities in excess of 15 TPD (see **Section 3.3.7.1 - *Commercial Demonstration***), completing treatment of the Silos 1 and 2 material in less than three years by implementing the alternative with a larger-capacity reactor is feasible. However, increasing the capacity of the reactor, along with the necessary increases in feed preparation, off-gas, and product storage capacity results in a cost increase in order to complete treatment in less than three years.

3.3.7 Implementability

The implementability criteria are described in **Section 3.1.2.6**. The following sections present the summary, technical feasibility, administrative feasibility, and availability of service evaluation of implementing this alternative.

The feasibility of implementing the Vitrification – Other technology for the remediation of the Silos 1 and 2 material is summarized in the following sections.

3.3.7.1 Technical Feasibility

Scaleup

The Vitrification — Other technology was demonstrated by the POP contractor using a melter design for a production rate of 15 TPD utilizing a dry feed system. Additionally, the technology is currently operational on a commercial basis. Therefore, scaleup of the Combustion Melter System to a full-scale system is not a major concern for this technology. None the less, molten glass chemistry and physics require special consideration in the selection/specification of materials of construction (refractory).

Scaleup, in general, is not considered significant with the Feed Preparation System, since most parameters that define the feed preparation equipment are well established and the capacities of commercially available systems are adequate to meet the needs of a full-scale facility. However, the application of a centrifuge and hot-oil screw dryer to the Silos 1 and 2 material has not been demonstrated and would require a significant development program as part of the full-scale design.

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Commercial Demonstration

The ability of the Vitrification — Other technology to produce a desired glass product has been demonstrated on a pilot scale basis (feed streams included mixed waste, heavy metals, contaminated soil). The DOE is considering the application of combustion vitrification to demonstrate this stabilization technology on mixed waste located at the Paducah Gaseous Diffusion Plant (Paducah, KY). Additionally, this technology has been applied on a commercial scale (50 TPD) to treat hazardous wastes (spent pot liners) at ORMET Aluminum, Inc. (Hannibal, Ohio). However, limited applications reduce the level of confidence in this technology. Specifically, there is not any significant experience with this technology in a radioactive environment. Thus, the breadth of operating experience to identify the range of operational variables that may hamper the ability to complete treatment of the Silos 1 and 2 material as planned is not available. Operation of a high temperature melter design with new refractories not used in the POP tests, a new drying step with potentially unforeseen dust management problems, and routine component change out introduces several unknowns, particularly in a radioactive environment.

Operability

Ease of Operation

Operability concerns include the integrated operation of multiple systems (feed preparation, waste treatment and off-gas) and the long-term performance of custom-built equipment items (combustion melter).

The operability of this alternative was evaluated based upon analysis of a Cyclone Vitrification System tested during the POP testing. Operability issues associated with this system are assumed representative of Vitrification — Other processes (i.e., plasma arc).

The ability of the feed drying equipment to perform their dedicated functions efficiently and effectively is uncertain due to the abrasive nature of the Silos 1 and 2 material, the sticky accumulating effect of drying Bentogrout™, and radon/contamination control.

The POP testing indicated approximately 50% of the lead compounds and 70% of the sulfates in the surrogate were volatilized and transported to the Normal Off-gas System. This requires that the lead be partitioned from the off-gas and recycled to the Treatment System, and the sulfates treated as a secondary waste. Melter operations must include the ability to operate around anticipated variations in the Silos 1 and 2 material glass formulation (chemistry), control and monitor operating/process parameters, and respond to off-normal conditions.

Operability of the treatment process operation is enhanced by a glass formulation that minimizes the need for the process system to respond to variability of the feed (this permits routine operations). The contractor for the full-scale remediation of the Silos 1 and 2 material will require a glass chemistry development program to insure process stability.

Through laboratory and bench-scale testing, glass formulas have been developed to successfully treat the Silos 1 and 2 material. Control parameters must be monitored throughout the vitrification process in order to maintain the combustion melter within operable limits. If process monitoring indicates an out-of-spec condition (e.g., over-pressurization), the Melter Control System can be designed to mitigate (interlock with melter feed and switchover to EOG System) the event by idling operations before recovery from credible/design basis events.

With possible exception of the controls for pressure balancing, the Air Emissions/Normal Off-gas System is capable of handling off-gas with variable flow, temperature, moisture, acid gases, and solids. Buildup of solids in the Normal Off-gas System such as was experienced during scrubber operation in the FEMP VITPP is not expected to present an operability problem for this design. In case the centrifuge delivers less than the design basis 50 wt% solids in the feed, the Hot-oil Screw Dryer System manages the increased moisture. The system design presented has installed excess capacity that can accommodate this occurrence (i.e., two full-scale centrifuges and two full-scale dryers).

Operation of the Melter System is considered challenging due to operational conditions that require continuous monitoring and adjustment. For example, the basic parameter of the glass melt that must constantly be monitored, viscosity, is not readily measurable. Primary process control for a melter is through viscosity of the melt, which is indirectly controlled by control of temperature and chemical additives. Increased viscosity in a glass melt will result in reduced production rates and may cause blockages in the melter (this has been a noted problem with some discharge orifices of DOE melters).

Operability and control of the Normal Off-gas System is also considered difficult due to operational conditions that must be monitored and adjusted.

Reliability

The Melter System uses compatible materials and demonstrated equipment to ensure overall plant availability. Although DOE vitrification projects have experienced significant cost and schedule growth, once start-up operations are completed, operating melter availability has been consistently over 70%.

Maintainability

The use of specialized equipment may lead to unpredictable maintenance trends and may require specialized training and/or tooling (e.g., seal maintenance of the Feed Dryer System may be complicated by the specification of flame-retardant oil). Since many key equipment items (centrifuge and dryer) contain a significant inventory of low moisture Silos 1 and 2 material, the increased dose per unit volume will require special considerations (e.g., worker safety) in developing a maintenance approach to address component failures. For example, a screw dryer contains approximately 30 tons of high solids Silos 1 and 2 material, and the feed bins (3) hold a total of 7 days of production inventory of dry Silos 1 and 2 material feed. Radon generation in this equipment presents significant maintenance challenges. Additionally, drying and transport (mechanical and pneumatic) of the silos material creates significant potential for airborne contamination. There is a high possibility that this method of material handling will result in the contamination of the feed preparation area.

The Melter System has many unique features of design, where some maintenance trends may be unpredictable and may require specialized training and/or tooling. A cooling jacket maintains melter surface temperature at 125 °F to facilitate access around the Melter System and to extend the ceramic liner life. Finally, considering industrial hazards associated with the Melter System (e.g., thermal, heights, and natural gas), the overall challenge of maintainability is considered moderate.

Complexity

The Vitrification — Other alternative is considered complex due to operational conditions, process control challenges, sophisticated equipment, and a relatively large number of unit operations that many of which include high temperature components. The degree of complexity that characterizes this technology requires a highly skilled operations team to ensure safe and efficient operations.

The Feed Preparation System is complicated by the multiple stages required to prepare an acceptable feed product (centrifuge and screw dryers); the number of equipment components required to perform the overall system function; the application of specialty equipment items; handling/transferring dry Silos 1 and 2 material; process control requirements; and the method of contamination/radon control.

Vitrification results in the generation of off-gas, which requires an Air Emissions/Normal Off-gas System. The Normal Off-gas System requires multiple integrated components (scrubber, WESP, NO_x destructer, quench tower) and associated process control considerations. To minimize the amount of off-gas, vapor from the feed dryer and milled waste bin is condensed and the air is recycled as pre-heater air to the melter. Also, the air used to pneumatically convey the dried feed is filtered and recycled in this manner. While this minimizes off-gas, it adds complexity to the design and operation of the Normal Off-gas System (e.g., introduces an additional dryer/condenser unit). The off-gas from the full-scale melter exceeds the capacity of the existing RCS. While most of the off-gas (up to the 500 scfm RCS capacity) is routed to the RCS, the remainder (300 scfm) is treated in a new RCS. The addition of the new RCS (including condenser and carbon beds), due to increased off-gas volume above the 500 scfm specified, further complicates the design and operability of the overall Normal Off-gas System.

The Product Rework System for the Vitrification — Other technology is relatively straightforward and technically simple to remotely operate. The reject shipping container is conveyed to the lid fastening station, where the bolts and lid are remotely removed. A robotic arm is used to position a vacuum hose within the container to retrieve and pneumatically transfer the glass frit to the melter feed storage bin. The Vacuum System air is HEPA filtered and discharged to the RCS.

Ease of Acceleration

In order to treat the Silos 1 and 2 material in three years, the required operations schedule would be 24 hr/day, 7 days/week, which considers the 70% design availability. Therefore, acceleration/schedule recovery could not be achieved by an increased operating schedule.

This alternative could only be accelerated by increasing the capacity of the cyclone reactor, supporting equipment systems, and facilities. Additional costs would be associated with increased capacities of equipment and facilities.

Constructability – (Ease of Construction/Fabrication, Ease of D&D)

The Melter System is a commercially available technology. However, equipment/component fabrication, installation, and construction turnover methods are a function of Melter System design and require specialized construction techniques. The complexity of the Vitrification — Other process, additional unit operations, and the need to integrate multiple components in the feed drying and Normal Off-gas System, complicate the construction process for this alternative. In addition, the ability to prefabricate off-site is, in general, not an option for the melter since the stringent tolerances required for refractory materials is challenged during handling of a prefabricated unit. During construction activities, chemical hazards associated with refractory constituents (potential ingestion or inhalation hazard) require specialized controls.

D&D of the feed preparation, melter, and Normal Off-gas Systems is expected to be complex and requires special techniques during decontamination. Controls and trained personnel are required to remove contaminated refractory materials for packaging and ultimate disposal, and to apply fixatives to the melter's interior (as necessary). Once decontaminated, the Melter System is expected to facilitate conventional demolition techniques during its removal, size reduction, and packaging for ultimate disposal.

3.3.7.2 Administrative Feasibility

The licensing and programmatic discussions for this alternative (VIT2) are the same as VIT1 discussions, see **Section 3.2.7.2**.

3.3.7.3 Availability of Services (Contractors, Equipment, Utilities)

Several contractors are available for competitive bid to design, procure materials, equipment, and services, and oversee operation of a Vitrification – Other facility capable of meeting the requirements of this alternative. Sole-source procurement is not necessary. The support systems are available technologies, although some have not been demonstrated at this scale or with this particular type of waste. While only the combustion melter requires specialized skills for operation, direct supervision by the manufacturer and/or vitrification contractor would be available. It is expected that available FEMP personnel could be trained in the operation of other (feed preparation, off-gas, waste packaging) systems. Additionally, process engineers, operation and maintenance personnel, laborers, laboratory technicians, and administrative personnel to support the project would be available to operate the technology and be trained as required. Although the vitrification technology for this alternative does not need any further development to be implemented, Proof of Process surrogate testing of the full-scale facility following construction, ORR, and SOT is necessary to optimize the process before beginning full-scale remedial operations using actual silos material.

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With the exception of the combustion melter and Melter Control System, other support system equipment is commercially available from a variety of contractors in accordance with the unit design specifications. The concrete shipping container for the waste glass could be manufactured by several contractors to the design specification. Certified transporters are currently available that can haul filled containers by truck to the NTS disposal facility in accordance with DOT requirements.

The NTS is a pre-approved off-site disposal facility that has the equipment and facilities to safely dispose and manage the filled containers of stabilized waste, which would be accepted as low-level waste. A laboratory, transfer areas, storage areas, and decontamination facilities are also currently available at the NTS site. An NTS-approved sampling program would be established at the FEMP to verify that the treated Silos 1 and 2 materials comply with the NTS WAC before shipment.

3.3.8 Cost

The summary cost for the Vitrification — Other is $342 Million in FY99 dollars as shown in **Table 3.3-3**.

TABLE 3.3-3
SUMMARY COST ESTIMATE FOR VITRIFICATION — OTHER
($ MILLIONS)

Capital Cost	67
Engineering Cost	25
Operation and Maintenance Cost	133
D&D Cost	38
Project Management Cost	22
Waste Disposal Cost	20
Cost of Money	37
Summary Cost (Un-escalated)	342
Present Worth Analysis	277

Supporting detail information for the Vitrification — Other cost estimate is in **Appendix C.**

3.3.9 State Acceptance

This criterion evaluates the input of the OEPA regarding the VIT2 alternative. This modifying criterion will be formally addressed in the regulatory process following the public review period for the FS/PP (i.e., in a Responsiveness Summary to accompany the ROD amendment).

3.3.10 Community Acceptance

This criterion evaluates the input of the community (both local to the FEMP and near potential transportation routes or disposal locations) regarding the VIT2 alternative. The OU4 ROD (EPA 1994) documents the public's response and acceptance of a vitrification alternative as the selected remedy for the Silos 1 and 2 material. Current community input regarding this particular technology will become apparent during the scheduled review of this document by the public. Because formal comments will not be received until after the revised FS is final, public comments will be addressed during the regulatory process following the public comment period for the FS/PP (i.e., in a Responsiveness Summary to accompany the ROD amendment).

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Alternative CHEM1

3.4 Removal, On-site Chemical Stabilization — Cement-based, Off-site Disposal at the NTS (CHEM1)

3.4.1 Description of Alternative

The following is a summary description of this alternative. Additional conceptual engineering design details (e.g., PFDs, General Arrangement Layouts) and assumptions can be found in **Appendix G/Design Basis and Description.**

The design details presented in this revised FS are conceptual, based on information provided by POP testing, and have been prepared for the sole purpose of providing a technical basis for evaluating the alternatives.

3.4.1.1 Introduction

This alternative (CHEM1) involves the removal, on-site chemical stabilization using a cementation process, and off-site disposal at the NTS of the treated Silos 1 and 2 material **(Figure 3.4-1)**. The Silos 1 and 2 material is removed from the TTA as a slurry containing approximately 10 wt% solids for the CHEM1 process. The representative process used as a basis for this evaluation involves dewatering of the silos material slurry to minimize the volume of material to be stabilized, followed by remediation of the de-watered filter cake material. The CHEM1 process produces material with an adjusted waste loading of approximately 30 wt% Silos 1 and 2 material **(Appendix G, Section G.1.3)**. The treated material is packaged in a concrete shipping and disposal container with 4-inch thick walls. Based on the *Disposal Container Size Optimization Study* (FEMP 1999), a container of this type reduces the radiation levels associated with the treated Silos 1 and 2 material at 30 wt% waste loading to approximately 70 mrem/hr on contact with the surface of the container.

The facility design is based on a plant availability factor of 70% over a total operating period of three years. The plant operating basis is two 8-hour shifts per day, 5 days/week with a design capacity of approximately 80 tons of treated Silos 1 and 2 material produced daily. Each operating day, an average of 11 loaded disposal containers are produced. Each disposal container is cured for a period of 7 calendar days in an environmentally controlled curing room. After the material has cured for 7 days, samples that were collected at the mixing step are tested for compliance with the NTS WAC. Upon verification that the samples of treated Silos 1 and 2 material meet the NTS WAC, the disposal containers are transported to the NTS for final disposal. Interim storage capacity for approximately 360 loaded disposal containers (45 calendar day period, at design capacity, 55 disposal containers per week) is provided as part of the treatment facility. Based on 30 wt% waste loading, and assuming 1% of the containers will fail to meet the NTS WAC and will need to be re-processed, a total of 6,078 containers will require shipment to and disposal at the NTS.

The CHEM1 Feed Preparation System is designed to increase the solids content of the incoming slurry from 10 wt% solids to approximately 50 wt% solids using a clarifier tank and a filter press. The slurry is received from the TTA and inventoried in a receiving tank to homogenize the material before it is fed to the clarifier. The clarifier produces an underflow slurry of approximately 30 wt% solids, which is discharged to batch tanks to be treated with filtering reagents. Finally, the treated slurry is sent to the filter press where it is dewatered to approximately 50 wt% solids and discharged to a storage bin.

The Feed Preparation System also includes the tanks and transfer equipment to inventory and transfer the stabilization reagents to the batch mixer. Enough storage is provided to inventory a two-week supply of stabilization reagents.

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The batch mixer combines the formulated amount of filter cake and stabilization reagents (and water, if necessary). Once the constituents have been thoroughly mixed, a discharge chute on the bottom of the mixer is opened and the grout is transferred to the disposal container. Next, the filled container is moved to the adjacent room where a sample of treated material is obtained, an absorbent mat is added to the top of the grout mixture, and the lid is placed on the container. Once the lid is in place, the container is conveyed through the decontamination station to remove any contaminants on its exterior surface. The disposal container is then conveyed to the curing room where it is lifted by an overhead crane and placed in a designated curing location.

A rework facility has been provided to re-process the off-specification waste which does not meet the NTS WAC. A Process Vent System (PVS) is designed to maintain a negative pressure in the treatment facility vessels and in the filling and lidding rooms to contain airborne contaminants, including particulates and radon. PVS vent lines from all vessels that contain Silos 1 and 2 material are connected to a common header that routes the vent air to the existing RCS (500 scfm capacity). The resulting negative pressure ensures that the system will not leak gases into the local environment.

A Flush Water System uses recycle water from the TTA to flush all slurry lines and equipment in order to reduce the risk of plugging process lines and equipment. The flush water discharge is then routed back to the TTA.

The CHEM1 secondary wastestreams include filter press filtrate, residual water from waste retrieval operations, RCS carbon, empty rework container, and PPE **(Table 3.4-1)**. As noted in **Table 3.4-1**, the recycled wastestreams include the decant water from the clarifier tank and the out of specification treated material. These wastestreams are processed and do not contribute to the volume of secondary waste to be disposed.

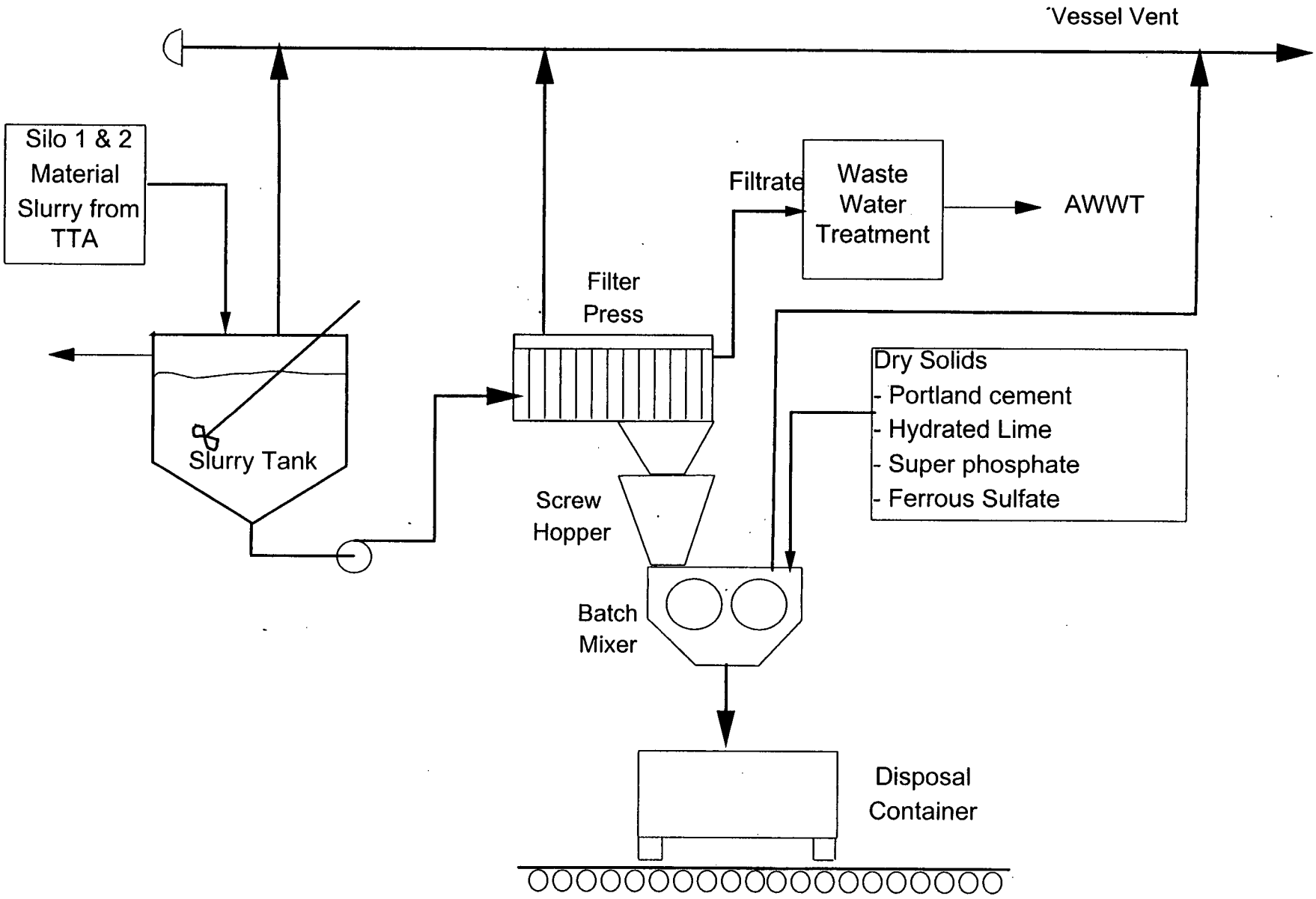

Figure 3.4-1
Simplified Process Diagram
Chemical Stabilization - Cement-based

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TABLE 3.4-1
ESTIMATED SECONDARY WASTESTREAMS GENERATED DURING FULL-SCALE OPERATION OF THE CHEMICAL STABILIZATION — CEMENT-BASED FACILITY

Secondary Wastestreams for CHEM1					
Source	**Material Type**	**Rate (lb/hr)**	**Total Volume**	**Status**	**Packaged Disposal Volume**
Treated WW	Water	3,704	5,778,240 gal	Process	N/A
RCS Condensate [1]	Water	50	1,310,400 gal	Process	N/A
Wastewater treatment bag filters	Solid	~13 bag/yr	40 bags	Dispose	224 cf
Empty Re-work Containers	Concrete	59 total	561,503 lbs 3,691 cf	Dispose	9,856 cf
RCS and Emissions System HEPA filters	Solid	N/A	1,512 cf	Dispose	2,912 cf
Misc. Replacement Equipment [2]	Solid	N/A	116 cf	Dispose	224 cf
RCS carbon	Carbon	1 Lot	5,334 cf	Dispose	8,890 cf
PPE	Solid	4/ day	18,100 cf	Dispose	26,815 cf
Total Estimated Cubic Feet of Packaged Disposed Secondary Waste					49,000 cf

1- Based on continuous operation for three years.

2 - Equipment will be replaced when necessary to maintain normal operation schedule.

The water decanted from the clarifier tank is recycled back to the TTA at 27 gpm during normal process operations. Approximately 10,000 gallons of filter press filtrate are treated by the Wastewater Treatment System and discharged to the AWWT daily. At the end of the 3-year operating schedule, any water remaining in the TTA from waste retrieval operations will be treated by the Wastewater Treatment System and discharged to the AWWT. Reject grout (one reject container every 2 to 3 weeks) is reduced in size and re-processed during the three year operating schedule. All process gas vented from the treatment process that contains radon is discharged to the RCS.

3.4.1.2 Project Schedule

Table 3.4-2 summarizes the individual project activities and their estimated durations for the implementation of Alternative CHEM1. A more detailed description of the individual project activities can be found in **Appendix G, Section G.2.21**. Each activity duration reflects the estimated time to complete the task supporting the remediation of the Silos 1 and 2 material at the DOE-FEMP site. The activity durations were developed considering the following factors:

- Proposed activity durations provided by commercial contractors;
- Specified regulatory document review and approval cycles outlined in the FEMP ACA;
- Procedural and administrative requirements for conducting procurement activities at the DOE-FEMP site;
- Historical project management experience and lessons learned while performing environmental remediation activities at the DOE-FEMP site; and
- Historical experience with the start-up of chemical stabilization facilities with DOE-complex.

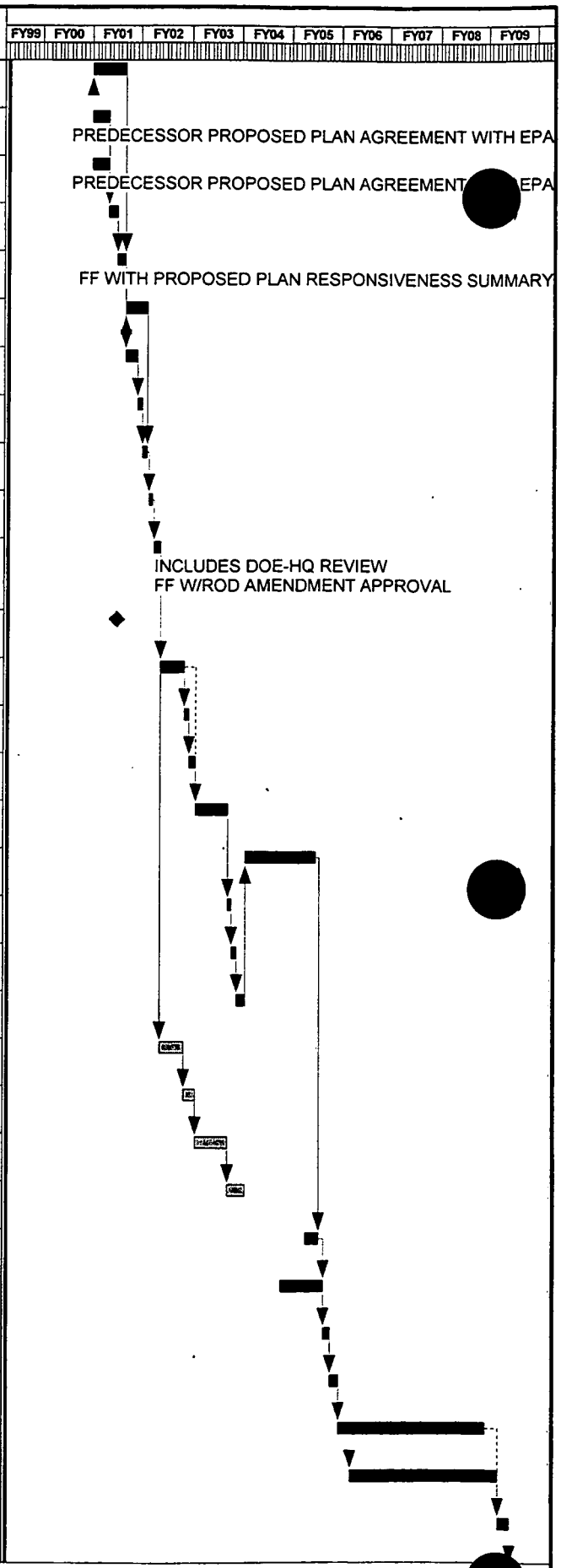
TABLE 3.4-2 -- 8072
SCHEDULE SUMMARY - CHEM1

Activity	Duration (Work Days)
Procurement Process	
• Develop RFP	166
• RFP Bid Cycle	165
Design and Documentation	430
Construction and Construction Acceptance Testing	350
SOT	70
Readiness Review	
• Readiness Preparation	213
• ORR	40
Proof of Process Testing	40
Stabilization Operations	750
Safe Shutdown of Facility	60
Facility D&D	120

Figure 3.4-2 provides a graphical representation of the sequences for completing the project activities, as well as the logical relationships between the activities.

The CHEM1 project schedule becomes a key component in several of the evaluation criteria. Short-term effectiveness evaluates the effects of the alternative during the construction and operations phase until the RA objectives are achieved (e.g., worker risks, environmental risks), as well as the time required to achieve protectiveness. Implementability will evaluate the ability of the CHEM1 alternative to maintain schedule and recover schedule due to unplanned downtime. The project schedule is an important factor in estimating the project cost for CHEM1. The project schedule effects the resource planning, pay item schedules and the cost of money analysis for the remediation contract.

Activity ID	Activity Description	Orig Dur	Rem Dur	Early start	Early finish
0100	DEVELOP FINAL REMEDIATION RFP	166*	166*	02OCT00	01JUN01
0400	TRD DEVELOPMENT	79	79	02OCT00*	26JAN01
0700	DRAFT RFP	79	79	02OCT00*	26JAN01
1000	STORYBOARD RFP	44	44	29JAN01	30MAR01
1300	REVIEW/FINALIZE RFP	43	43	02APR01	01JUN01
1600	RFP BID CYCLE	120*	120*	04JUN01	21NOV01
1900	BID PERIOD	64	64	04JUN01	31AUG01
2200	BID EVALUATION	29	29	04SEP01	12OCT01
2500	BAFO	27	27	15OCT01	21NOV01
2800	CONSENT PKG PREP/REVIEW	23	23	26NOV01	28DEC01
3100	DOE CONSENT PKG REVIEW/APPROVAL	42	42	31DEC01	28FEB02
3200	NOA ISSUED FOR ROD	0	0	10APR01*	
3400	PRELIMINARY DESIGN	120	120	01MAR02	20AUG02
3700	FDF REVIEW PRELIMINARY DESIGN	20	20	21AUG02	18SEP02
4000	FINALIZE/APPROVE PRELIMINARY DESIGN	40	40	19SEP02	14NOV02
4300	FINAL DESIGN	160	160	15NOV02	09JUL03
4600	CONSTRUCTION	350	350	07NOV03	06APR05
4900	FDF REVIEW FINAL DESIGN	20	20	10JUL03	06AUG03
5200	FINALIZE FINAL DESIGN	20	20	07AUG03	04SEP03
5500	EPA REVIEW/APPROVE FINAL DESIGN	45	45	05SEP03	06NOV03
5800	PHAR DEVELOPMENT	120	120	01MAR02	20AUG02
6100	PHAR REVIEW/APPROVAL	60	60	21AUG02	14NOV02
6400	FHAR DEVELOPMENT	160	160	15NOV02	09JUL03
6700	FHAR REVIEW/APPROVAL	90	90	10JUL03	14NOV03
7000	SYSTEM OPERABILITY TEST	70	70	25JAN05	04MAY05
7300	READINESS PREPARATION	213	213	27JUL04	02JUN05
7600	ORR	40	40	03JUN05	29JUL05
7900	PROOF OF PROCESS TEST	40	40	01AUG05	26SEP05
8200	OPERATION	750	750	27SEP05	25SEP08
8500	WASTE DISPOSITION	750	750	27DEC05	23DEC08
8800	SAFE SHUTDOWN	60	60	26DEC08	23MAR09



Project Start	01OCT95	Early Bar
Project Finish	11SEP09	Progress Bar
Data Date	01FEB99	Critical Activity
Run Date	06DEC99	

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IT02

Sheet 1 of 2

FIGURE 3.4-2

PROJECT SCHEDULE

CHEMICAL STABILIZATION-CEMENT-BASED

Activity ID	Activity Description	Orig Dur	Rem Dur	Early start	Early finish
8900	FACILITY D & D	120	120	24MAR09	11SEP09

FY99 | FY00 | FY01 | FY02 | FY03 | FY04 | FY05 | FY06 | FY07 | FY08 | FY09

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Start 01OCT95	Early Bar	IT02	Sheet 2 of 2
Finish 11SEP09	Progress Bar	FIGURE 3.4-2	
Data Date 01FEB99	Critical Activity	PROJECT SCHEDULE	3-134
Run Date 06DEC99		CHEMICAL STABILIZATION-CEMENT-BASED	

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3.4.2 Overall Protection of Human Health and the Environment

Issues related to the ability of CHEM1 to meet the criterion of overall protectiveness of human health and the environment are similar to VIT1. Consequently, the discussion of meeting the criterion of overall protectiveness of human health and the environment is identical to that presented in **Section 3.2.2.**

3.4.3 Compliance with Applicable or Relevant and Appropriate Requirements

The CHEM1 alternative will attain all ARARs/TBCs identified in **Appendix A.** With the exception of the specific process option used to meet treatment requirements. The details of attaining ARARs will be the same as those discussed for VIT1 in **Section 3.2.3.**

3.4.3.1 Chemical-Specific ARARs and TBCs

CHEM1 complies with all chemical-specific ARARs and TBCs identified in **Appendix A.** Issues related to chemical-specific ARAR compliance for CHEM1 are similar to VIT1. The atmospheric release of radon from the interim storage of treated Silos 1 and 2 material and the surface of the disposal site would meet the limit established in 40 CFR Part 61 Subpart Q. Radon attenuation provided by the CHEM1 treated material, combined with attenuation provided by the disposal container and the engineered disposal cell cover, meets the NESHAP requirement, as well as, other applicable chemical-specific public dose and airborne concentration limits.

3.4.3.2 Location-Specific ARARs and TBCs

CHEM1 complies with all location-specific ARARs and TBCs identified in **Appendix A.** Issues related to CHEM1 compliance with location-specific ARARs are similar to VIT1. Consequently, the discussion on compliance with location-specific ARARs is identical to that presented in **Section 3.2.3.2.**

3.4.3.3 Action-Specific ARARs and TBCs

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CHEM1 complies with all action-specific ARARs and TBCs identified in **Appendix A.** Issues related to CHEM1 compliance with action-specific ARARs are similar to VIT1. Consequently, the discussion on compliance with action-specific ARARs is identical to that presented in **Section 3.2.3.3.**

3.4.4 Long-term Effectiveness and Permanence

3.4.4.1 Magnitude of Residual Risk

Silos 1 and 2 Material

As with VIT1, the implementation of the CHEM1 alternative reduces the residual risk to viable receptors to a HI of less than 0.2 and an ILCR of less than 10^{-6}. Because the material is removed from the site, residual risk from Silos 1 and 2 material at the FEMP site is nonexistent. Residual risk at the NTS is limited by a treatment process which minimizes leachability of contaminants, the placement of the treated silos material into an engineered disposal facility with institutional controls, and the arid environment.

Soil and Debris

As with VIT1, disposal of soil and debris generated under the CHEM1 alternative provides long-term protection of the environment and the public (see **Section 3.2.4.1**).

3.4.4.2 Adequacy and Reliability of Controls

TCLP analysis indicates that the CHEM1 process produces a wasteform which meets the NTS WAC and is durable based on leach rate data. The TCLP test is utilized to simulate the leaching effects of acidic groundwater infiltrating the disposal cell and contacting the disposed waste. This test serves as a measure of the stabilized waste particles ability to resist leaching, even if the original wasteform (e.g., monolith) has been compromised. This reduction in leachability, combined with the additional protection provided by the engineered disposal cell provide a durable disposal configuration that provides long-term protection of human health and the environment.

Long-term environmental impacts associated with CHEM1 are similar to VIT1 (see **Section 3.2.4.2**) as they relate to impacts on water quality and hydrology, air quality, biotic resources, wetlands and floodplains, socioeconomics and land use, and cultural resources. CHEM1 is also similar to VIT1 in regard to impacts on soil and geology except that the estimated volume of chemical stabilized cement-based material requires additional disposal space. The overall impact due to the increased volume is not significant because material would be disposed in a previously disturbed area (Area 5) designated for LLRW disposal in the NTS-EIS. The PA prepared by DOE-Nevada will demonstrate that disposal of this increased volume will meet the criteria determined to be protective by the NTS-EIS. Consequently, the discussion of CHEM1 long-term environmental impacts is identical to that presented in **Section 3.2.4.2**.

3.4.5 Reduction of Toxicity, Mobility, or Volume through Treatment

CHEM1 treatment reduces the mobility of contaminants by chemically binding them in a cement-based mixture. As a result of the additives used, the volume of waste requiring disposal increases.

The original OU4 FS (FEMP 1994a) evaluated cement-based treatment of the Silos 1 and 2 material followed by off-site disposal at the NTS and found it to be a feasible and effective alternative. The chemically treated Silos 1 and 2 material provides sufficient waste immobilization for safe handling and transportation.

The OU4 treatability study was conducted for the original OU4 FS to compare vitrification and cement-based treatments. The criteria for the comparison included leachability of the treated Silos 1 and 2 material and reductions in material volume and radon emanation (Appendix C, Section C.1 and Appendix H in the original OU4 FS).

The chemical and physical properties of the Silos 1 and 2 material were determined and used to develop the bench-scale treatability studies. Data from the study determined that the cement-based treated material met RCRA TC regulatory levels for metals. Comparison of the TCLP test results of the treated Silos 1 and 2 material to those of the untreated material demonstrated a 99% reduction in lead leachability.

Analytical data from the POP testing of cement-based chemical stabilization on surrogate Silos 1 and 2 material also showed that chemical stabilization could effectively stabilize lead and other RCRA metals to meet RCRA TC limits.

Data from the original FS treatability study revealed that although the cementation process is effective in reducing radon emanation by an average of 78 to 87%, the radon emanation rates from the cement-based treated material exceeded 20 $pCi/m^2 \cdot s$. It should be noted that original FS treatability studies did not focus upon the optimization of radon emanation properties of the treated Silos 1 and 2 material form. It is believed that this value could be improved with additional testing. Although significant levels of radon continue to be emitted after cement-based stabilization, the combination of treatment, and sealed containerization in the interim disposal facility will reduce the radon emanation rates to below the NESHAP Subpart Q regulatory level.

In all cases, the formulations from the original OU4 FS were developed based on the WAC associated with a potential OSDF. These criteria, which were more stringent than those established for off-site disposal facilities, resulted in aggressive cement-based formulations that combined approximately equal proportions of waste, cement, other solids, and water.

Because compressive strength of the wasteform is not a criterion for disposal at the NTS, other formulations using reduced quantities of cement, other additives, and water may be equally effective in reducing the mobility of COCs without significantly increasing waste volume.

Data from POP testing of cement-based chemical stabilization on surrogate Silos 1 and 2 material also indicated the potential for a significant increase in volume of treated material. The POP data indicate that the original 6,797m^3 (8,890yd^3) of material in Silos 1 and 2 would be increased to a volume of approximately 20,836m^3 (27,254yd^3) following treatment. This is a volume increase of approximately 207%. In addition, due to the shielding necessary for protection of workers and the general public and for meeting DOT requirements, containerization of the treated material results in a disposal volume of approximately 36,431m^3 (47,652yd^3), equating to a volume increase of 436% compared to the original volume of material in Silos 1 and 2.

The secondary wastestreams associated with the CHEM1 alternative are summarized in **Table 3.4-1**. The estimated final disposal volume of all the secondary wastestreams is 1,388 m^3 (1,815 yd^3). The total estimated disposal volume of the treated Silos 1 and 2 material and all secondary wastestreams is 37,819 m^3 (49,500 yd^3), equating to an overall volume increase of 456%, compared to the original volume of material in Silos 1 and 2.

3.4.6 Short-term Effectiveness

3.4.6.1 Protection of the Community During Remedial Action

Protection of the community during implementation of CHEM1 is similar to VIT1. Therefore, the discussion on protection of the community is identical to that presented in **Section 3.2.6.1.**

A portion of the radon contained in Silos 1 and 2 material is liberated during the stabilization process. Radon generation continues from the stabilized Silos 1 and 2 material during subsequent product handling and packaging operations. Radon generated by these operations must be collected by the PVS and removed by the RCS in order to minimize radon emissions from the CHEM1 facility to the atmosphere.

Radon removal will be provided to ensure that emissions of radon from the CHEM1 facility are minimized. The total impact of radon emissions from this alternative to FEMP fenceline emissions will result in exposure levels for the off-site public that are indistinguishable from background levels (based on analyses performed for the original OU4 FS).

Radon attenuation provided by the stabilized wasteform, combined with attenuation provided by the disposal container and the disposal cell, meets the 20 $pCi/m^2.s$ radon flux limit.

3.4.6.2 Protection of Workers During Remedial Action

Appendix B estimates the number of injuries and fatalities that could result from the removal, treatment, and transportation activities associated with this alternative during remediation.

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Risk to on-site workers as a result of implementation of this alternative are ALARA. This alternative involves the handling of radioactive materials and, therefore, there are several potential exposure pathways for workers. Both the release of gases and exposure to direct radiation from the materials pose a risk to workers. Per 10 CFR Part 835.202, occupational dose shall not exceed a total effective dose equivalent of 5 rem per year. This dose results in an ILCR of 2.0×10^{-3} to workers. It has been estimated that, with appropriate protection, the removal and treatment of materials results in a cancer risk level to remediation workers of 3.67×10^{-4} (see **Appendix B**). Most of this risk occurs during operation of the treatment facility. As appropriate, workers wear protective clothing and use shielding, along with automatic and remote operations.

A simplified IHA was conducted to evaluate the unmitigated hazards to workers posed by the conceptual design of the Chemical Stabilization — Cement-based process. The results of the IHA are presented in **Appendix B** and are summarized below:

- The number of containers required for the Chemical Stabilization — Cement-based process present a mechanical energy hazard;
- The number of shipments required to transport chemical stabilized waste to the NTS present an acceleration/impact hazard; and
- Because the majority of project dose results from radiation exposure during package handling and shipping, the Chemical Stabilization — Cement-based process presents a radiation hazard.

Without considering the specific hazards identified above, it has been estimated, based solely on total labor hours, that construction, treatment, and D&D could result in approximately 47 injuries and 0.69 fatalities during remediation. Remediation activities are to be conducted in accordance with a health and safety plan developed to meet 29 CFR Part 1910.120(b)(4). Training and procedures ensure that worker exposure is ALARA.

3.4.6.3 Short-term Environmental Impacts

The short-term environmental impacts at the FEMP site on water quality and hydrology, air quality, biotic resources, wetlands and floodplains, and socioeconomics and land use by implementation of CHEM1 are similar to VIT1. CHEM1 short-term impacts on soil and geology are also similar to that of VIT1 with the exception of the volume of soil that is temporarily disturbed. It is estimated that construction and excavation could temporarily disturb a total of approximately 13,747 m^3 (17,981 yd^3) of the site. The overall difference between CHEM1 and VIT1 on the volume of soil impacted is not significant. Therefore, the discussion of CHEM1 short-term environmental impacts is identical to that presented in **Section 3.2.6.3**.

3.4.6.4 Transportation

The transportation of the treated Silos 1 and 2 material to the NTS by either transportation option (direct truck or intermodal) is protective of the public. The implementation of this alternative results in negligible increases in traffic flow on and around the FEMP site for both transportation options (direct truck or intermodal). Temporary increases in deliveries and workers to the FEMP site are not expected to significantly impact traffic patterns or roadways.

Treated Silos 1 and 2 materials are transported by trucks to the NTS. The treatment process proposed under CHEM1 generates approximately 6,078 containers. If two containers are placed on each truck, approximately 3,039 direct truck shipments to the NTS is required. This results in approximately 20 shipments per week to meet the 3-year operation schedule.

For intermodal transport, two containers are placed in an ISO container. One ISO container is placed on a truck and two ISO containers are placed on a railcar. This results in 3,039 truck shipments from the FEMP to an intermodal facility, 1,520 railcar shipments by regular freight from an intermodal facility in the East to an intermodal facility in the West, and 3,039 truck shipments from the intermodal facility to the NTS.

Environmental impacts from shipping and disposing of treated Silos 1 and 2 materials are expected to be minimal from normal transportation because procedures comply with applicable DOT requirements and DOE Orders. There is a small risk to the public during transportation of the treated Silos 1 and 2 material to the NTS. The estimate of public radiation exposure, expressed in terms of ILCR, along the route to the NTS ranges from 2.90×10^{-6} for direct truck to 3.30×10^{-6} for intermodal for the maximally exposed individual, within the CERCLA target risk range of 1×10^{-4} to 1×10^{-6}. It is estimated that 0.54 to 0.57 fatalities may occur to the public due to non-radiological risks during direct truck and intermodal transportation, respectively. Because potential short-term risks to the public are small, even a major deviation in the assumptions does not change the conclusion that this alternative is protective of the community in the short-term.

Additional radiation exposure risks to the worker result from transporting the treated Silos 1 and 2 material to the NTS. The ILCR for the transportation worker is estimated to range from 1.46×10^{-5} per shipment for intermodal to 1.62×10^{-5} per shipment for direct truck. It is estimated that 0.10 to 0.15 fatalities may occur to workers as a result of intermodal and direct truck transportation, respectively. The risk to workers due to radiological exposures during off-loading activities at the NTS is assumed to be below the estimated ILCR risk level of 3.67×10^{-4} during treatment/construction activities at the FEMP site because the materials are already packaged and in a stabilized form. There is uncertainty regarding additional risk from exposure to wastes already present at the NTS near off-loading operations for FEMP waste.

The basis for these risk estimates is provided in **Appendices B** and **E**.

3.4.6.5 Time to Achieve Protection

As illustrated in the schedule presented in **Figure 3.4-2**, design, construction and start-up activities for the CHEM1 alternative result in a period of approximately 53 months from approval of the ROD Amendment for Silos 1 and 2 remediation until the initiation of treatment operations.

The operating schedule for the CHEM1 alternative assumes 16 hr/day, 5 days/week operation of the treatment facility (assuming 70% design availability) to complete treatment within a 3-year period. The operating schedule (16 hr/day, 5 days/week) results in "excess" operating time being available to recover from unplanned downtime, which increases confidence in the ability to meet the 3-year schedule. Completion of treatment in less than three years could also be accomplished by implementing the CHEM1 alternative using additional mixer trains. Acceleration of the operating schedule or increase in the number of mixer trains requires increases in feed preparation and product storage capacity. These increases result in cost impacts in order to complete treatment in less than three years.

3.4.7 Implementability

The implementability criteria are described in **Section 3.1.2.6**. The following sections present the summary, technical feasibility, administrative feasibility, and availability of services evaluation of implementing this alternative.

The feasibility of implementing the Chemical Stabilization — Cement-based technology for the remediation of the Silos 1 and 2 material is summarized in the following sections.

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3.4.7.1 Technical Feasibility

Scaleup

The Chemical Stabilization — Cement-based technology was demonstrated by the POP contractor using a pilot-scale process designed for a production rate of 8 TPD. This process was operated during the demonstration run at 2.15 TPD to meet the POP testing requirements. The proposed full-scale facility is commercially available and has been demonstrated with remote operation at a number of facilities [West Valley, NY and Sellafield, United Kingdom (U.K.)]. At the Sellafield facilities in the U.K., a number of full-scale grout facilities are operated for the treatment of low-level and intermediate waste. These wastes are high in salt content and similar to much of the waste stored within the DOE complex. The waste facilities at Sellafield for treatment of intermediate level waste require remote handling and treatment similar to that proposed for remediation of the Silos 1 and 2 material.

The Mixer System is designed to address industrial hazards (e.g., rotating equipment, height) and is well suited for automation. The cement-stabilized material (surrogate) during POP demonstration exhibited physical characteristics that made material handling of the treated product difficult. Characteristics exhibited by the cement-stabilized material included: sticky, lumpy, and non-flowing (wet soil-like consistency). However, a reduced waste loading (approximately 30 wt% is used in the FS and associated cost estimate vs. 40 wt% demonstrated during POP testing, **Appendix G, Section G.3.1**) produces a more manageable treated material, and minimizes material handling issues (e.g., mixer discharge design).

As stated, treatment equipment (e.g., high shear mixer) is well demonstrated, reliable, and commercially available. However, an effective remotely operated flush system (not demonstrated in the POP) needs to be designed and integrated with the mixer to support the operational basis of this system.

Scaleup, in general, is not an issue with the Air Emissions System since most parameters that define the equipment are well established; and, the capacity of commercially available systems is adequate to meet the needs of the full-scale facility, with the exception of the filling and container lidding areas. Collection and transfer of the radon-laden air to the RCS during the handling of open, filled containers is difficult to accomplish given the need to minimize off-gas volume to within RCS capacity limit requirements.

Commercial Demonstration

The ability to treat Silos 1 and 2 material and similar waste through a Chemical Stabilization — Cement-based process has been successfully demonstrated in numerous laboratory, pilot-scale, and full-scale programs. There are numerous applications of this technology in the commercial sector, as well as DOE sites (e.g., West Valley, NY) on radioactive, hazardous and mixed wastes similar to the Silos 1 and 2 material. A small number of applications have been operated in remote environments (e.g., West Valley, NY and Sellafield, U.K.).

Cement stabilization batch plants of capacities exceeding that proposed (Weldon Springs) have been implemented in the remediation industry. However, a facility that has been operated remotely with similar materials, at a representative scale has not been identified.

The adaptation of this technology to chemically and physically bind and immobilize the Silos 1 and 2 material requires a thorough knowledge of waste composition, a well developed formulation with manageable properties, specification of suitable materials of construction, and application of ALARA design principles.

All major components, including the filter press equipment, are commercially available for automated operations at the full-scale capacity; however, this could present challenges for radon control and remote operations.

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Operability

Ease of Operation

The Mixer System operations are not considered complex to operate due to the batch mode of operations (automated), standard equipment requirements, and simplified operating requirements. For example, each slurry feed batch will be sampled, characterized and the primary control parameters (i.e., pH, lead concentration, water content) evaluated to ensure appropriate additives are introduced prior to mixing. Process control parameters for the Treatment System are mixing speed, duration, mixer discharge rate, and pressure differential. The Mixer System is assumed to homogenize the formulation; however, the ability to properly formulate an acceptable treated product is a function of the Feed Preparation System. The mixer must operate with the ability to control contamination and mitigate radon emanation and must have the ability to remove hardened/settled material from internal components in order to maintain component efficiency.

For example, lessons learned at the Weldon Spring, MO, cement stabilization project indicate mixers may require aggressive maintenance methods to remove hardened/cured material on internal components on a routine basis. The effectiveness of the Weldon Spring mixers (e.g., the ability to mix) was significantly impaired by cement solidifying on wetted components and they were required to shutdown every four hours and use manual methods to remove caked material (documented in FDF memo # M:SP-99-0154). If the Silos 1 and 2 cement formulation demonstrates itself to have a similar requirement for the mixer, this activity would be complicated by the radiological, contamination, and radon emanation issues associated with the Silos 1 and 2 material.

Operability issues include the effectiveness of dewatering, impact of waste loading, material build-up, facility ventilation and radon control, liquid waste treatment, and the long-term performance of custom built/remotely operated equipment items. In order to produce a quality treated waste, the cement-based stabilization process must be designed to identify and respond to variations in stabilization chemistry and predict the results of the acid-based leach chemistry.

Operability is enhanced by a robust waste treatment formulation **(see Appendix G, Section G.3.1.3)** that minimizes the need for the Process System to respond to variability of the feed (this permits routine operations). The contractor for the full-scale remediation of the Silos 1 and 2 material will require a formulation development program to improve process stability. Most systems considered in this evaluation appear robust and can accommodate variations in key operational process parameters (e.g., feed preparation and waste treatment).

The Chemical Stabilization — Cement-based formulas have been developed to successfully treat the Silos 1 and 2 material. Process sampling, where each batch of conditioned slurry is sampled, is important to ensure that the appropriate formulation is specified. for the stabilization process,

POP testing verified the effectiveness of using a conventional filter press (laboratory and bench/pilot scale in batch mode on surrogate material); however, operational issues specific to the Silos 1 and 2 material (e.g., physical handling, variation in constituents such as BentoGrout™, contamination/radon control, and automation) were not addressed.

Since the POP treated surrogates had a relatively long cure time and clay-like properties, hardening and/or caking of the cement on the mixer internals did not appear to present a problem to the overall efficiency of the mixer. However, a reduced waste loading (higher water and cement content) treatment process produces a more fluid-like cement (e.g., ability to wet surfaces), changes the curing characteristics (i.e., quicker cure time), and may harden and/or cake on the mixer internals.. The higher cement content contributes to caking of the mixer internals and contributes to problems flushing the mixer. Thus, a lower waste loading treatment process possibly presents challenges to the overall efficiency of the mixer.

Design issues to be considered in adopting the filter press to this application include: remote operation, handling of secondary wastestream (i.e., filtered water will contain suspended Silos 1 and 2 material solids), negative pressure operations, filter media replacement, contamination control, ALARA, component access, and maintenance methods.

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Reliability

The Chemical Stabilization — Cement-based technology uses conventional, commercially available equipment that has been demonstrated on radioactive and hazardous wastes. The unique characteristics (radioactive, erosive and sticky due to BentoGrout™ content) of the Silos 1 and 2 material may decrease the overall reliability of system components; however, it is expected to achieve the 70% design availability.

Maintainability

The maintainability of this technology is enhanced by its operational basis of 5 days/week, 16 hr/day (e.g., maintenance activities can be performed off shift or on the weekends).

The Mixer System is a commercial technology with established maintenance practices for commercial grade cements. However, the radioactive Silos 1 and 2 material complicates the maintenance activities.

The Air Emissions System uses conventional equipment for which maintenance practices are well established. Maintainability of the system is not subject to specialized training and/or tooling (although ALARA guidelines are applicable). Because maintenance on this system should be straightforward, overall maintainability of the Air Emissions System does not impact overall plant availability. Location of most of the Air Emissions/Normal Off-gas System equipment outside of contaminated areas increases the confidence in maintainability of the system.

Complexity

The Chemical Stabilization — Cement-based alternative contains primary remedial components (filter press and mixer) that are relatively simple from a process and operational controls and air emissions control standpoint. Since the treatment process is not expected to generate any off-gas during treatment, a complex Off-gas System is not required in the design of the treatment facility due to the nature of chemical stabilization, thus simplifying the process. An Air Emissions System collects radon and radioactive particulates that are sent to the RCS.

The Product Rework System is considered complex for the Chemical Stabilization — Cement-based technology. The Product Rework System requires specialized tooling, remote handling, control requirements, and multiple remote operations to ensure effective size reduction and transfer of recycled materials. The treated Silos 1 and 2 material must be remotely jack-hammered from its container and crushed for size reduction before being reintroduced into the mixer.

Ease of Acceleration

In order to treat the Silos 1 and 2 material in three years, the required operation schedule would be 16 hr/day, 5 days/week, which considers the 70% design availability. Significant acceleration/schedule recovery could be realized with a 24 hr/day, 7 days/week operating schedule. Additionally, increased efficiency would be recognized by eliminating lost operating time due to start-up and shutdown activities. Capacities for the curing and storage facilities increase. Additionally, multiple trains could be considered for even greater schedule acceleration. Additional costs are incurred through increased capacities of equipment and facilities.

Constructability – (Ease of Construction/Fabrication, Ease of D&D)

Construction incorporates conventional field fabrication methods; this activity is facilitated by contractor pre-testing activities performed on key prefabricated equipment items. The Mixer System and filter press can be fabricated, modularized, and tested at off-site locations. A modular mixing system can be installed at the FEMP using conventional construction/assembly techniques, with construction turnover benefiting from the contractor prefabrication and testing. Treatment facility D&D activities appear to be conventional in scope using water flushing, monitoring, and collection methods before ultimate disposal.

Controls and trained personnel are required to remove contaminated, hardened material inside the mixer before packaging and ultimate disposal. Fixatives are applied to surfaces as necessary. Once decontaminated, the Mixer System is demolished using conventional demolition techniques during its removal, size reduction, and packaging for ultimate disposal.

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3.4.7.2 Administrative Feasibility

The licensing and programmatic discussions for this alternative (CHEM1) are the same as the VIT1 discussions, see **Section 3.2.7.2**.

3.4.7.3 Availability of Services (Contractors, Equipment, Utilities)

Multiple contractors are available for competitive bid to design; procure materials, equipment, and services; and, oversee operation of a Chemical Stabilization — Cement-based facility capable of meeting the requirements of this alternative. Sole-source procurement is not necessary. Both the primary treatment process and support systems are available technologies, although some have not been demonstrated at this scale or with this particular type of waste. None of the equipment requires specialized skills for operation; and, available FEMP personnel could be trained in the operation and maintenance of the treatment and other systems. Additionally, process engineers, operation and maintenance personnel, laborers, laboratory technicians, and administrative personnel to support the project would be trained as required and available to operate the technology. Proof of Process surrogate testing of the full-scale facility following construction, ORR, and SOT are conducted in order to optimize the process before beginning full-scale remedial operations using actual silos material.

All treatment and support system equipment is commercially available from a variety of contractors in accordance with the unit design specifications. The concrete shipping container for the Silos 1 and 2 material could be manufactured by several contractors to the design specification. Certified transporters that can haul filled containers by truck to the NTS disposal facility in accordance with DOT requirements are currently available.

The NTS is a pre-approved, off-site disposal facility that has the equipment and facilities to safely dispose and manage the filled containers of treated waste, which would be accepted as low-level waste. A laboratory, transfer areas, storage areas, and decontamination facilities are also currently available at the NTS site. An NTS-approved sampling program would be established at the FEMP to verify that the treated Silos 1 and 2 material complies with the NTS WAC before shipment.

3.4.8 Cost

The summary cost for the Chemical Stabilization — Cement-based technology is $297 Million in FY99 dollars, as shown in **Table 3.4-3.**

TABLE 3.4-3

SUMMARY COST ESTIMATE FOR CHEMICAL STABILIZATION — CEMENT-BASED ($ MILLION)

Capital Cost	55
Engineering Cost	24
Operation and Maintenance Cost	77
D&D Cost	34
Project Management Cost	21
Waste Disposal Cost	58
Cost of Money	28
Summary Cost (Un-escalated)	297
Present Worth Analysis	242

Supporting detail information for the Chemical Stabilization — Cement-based cost estimate is in **Appendix C.**

3.4.9 State Acceptance

This criterion evaluates the input of the OEPA regarding the CHEM1 alternative. This modifying criterion will be formally addressed in the regulatory process following the public review period for the FS/PP (i.e., in a Responsiveness Summary to accompany the ROD amendment).

3.4.10 Community Acceptance

This criterion evaluates input of the community (both local to the FEMP and near potential transportation routes and disposal locations) regarding implementation of the CHEM1 alternative. Because formal public comments will not be received until after the revised FS is final, this modifying criterion will be addressed during the regulatory process following the public comment period for the FS/PP.

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Alternative CHEMZ

3.5 Removal, On-site Chemical Stabilization — Other , Off-site Disposal at the NTS (CHEM2)

3.5.1 Description of Alternative

The following is a summary description of this alternative. Additional conceptual engineering design details (e.g., PFDs, General Arrangement Layouts) and assumptions can be found in **Appendix G/Design Basis and Description.**

The design details presented in this revised FS are conceptual, based on information provided by POP testing, and have been prepared for the sole purpose of providing a technical basis for evaluating the alternatives.

3.5.1.1 Introduction

This alternative (CHEM2) involves the removal, on-site chemical stabilization, and off-site disposal at the NTS of the treated Silos 1 and 2 material **(Figure 3.5-1)**. The Silos 1 and 2 material is removed from the TTA (which is provided as part of the ongoing AWR Project) as a slurry containing approximately 10 wt% solids for the CHEM2 process. The representative process used in evaluating this alternative combines the silos material, as a liquid slurry, with a binder (principally cement) and other chemical additives (e.g., fly ash) in a container/mixer to produce a material that meets the NTS WAC. This process produces a treated Silos 1 and 2 material with a waste loading of approximately 24 wt%. The silos material and stabilization reagents are combined and mixed in a steel cylindrical shipping and disposal container with ¾-inch thick walls. Based on Microshield® modeling, a container of this type would reduce the radiation levels associated with the treated Silos 1 and 2 material at 24 wt% waste loading to approximately 70 mrem/hr on contact with the surface of the container.

The facility design is based on a plant availability factor of 70% over a total operating period of three years. The plant operating basis is 24 hr/day, 5 days/week with a design capacity of approximately 105 tons of grout produced daily (maximum). Each day, an average of 11 loaded disposal containers are produced. Each disposal container is cured for a period of 7 days in an environmentally controlled curing room. After the material has cured for 7 days, samples that were collected at the mixing step are tested for compliance with the NTS WAC and transferred to the interim staging area. Upon verification that the samples of treated Silos 1 and 2 material meet the NTS WAC, the disposal container/mixers are transported to the NTS for final disposal. Interim storage capacity for approximately 360 loaded disposal container/mixers (45 calendar day period, at design capacity, 56 disposal containers per week) is provided as part of the treatment facility. Based on 24 wt% waste loading, and assuming 1% of the containers will fail to meet the NTS WAC and will need to be re-processed, a total of 6,106 containers will require shipment to and disposal at the NTS.

The CHEM2 Feed Preparation System is designed to increase the solids content of the incoming slurry from 10 wt% solids to approximately 37 wt% solids using a clarifier tank. The slurry is received from the TTA and inventoried in a receiving tank to homogenize the material before it is fed to the clarifier. The clarifier produces an underflow slurry of approximately 37 wt% solids that is discharged to batch tanks where the slurry is stored until it is fed to the container/mixer filling stations.

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The facility contains three independent mixing systems. The shipping and disposal container/mixer is fabricated with an internal mixing blade mounted on a simple bearing in the bottom of the container. A hydraulic motor is mounted onto each fill head at the three filling stations and provides the upper bearing surface for the mixing blade. The three fillheads combine the formulated amount of 37 wt% solids slurry (24 wt% waste loading) and stabilization reagents in the container/mixer. After the mixing operations are complete, the blade is left in place and disposed of along with the treated Silos 1 and 2 material. Next, the filled container/mixer is moved to the adjacent room where a sample of grout is obtained, an absorbent mat is added to the top of the grout mixture, and the lid is placed on the container/mixer. Once the lid is in place, the container/mixer is conveyed through the decontamination station to remove any contaminants on its exterior surface. The container/mixer is then conveyed to the curing room where it is lifted by an overhead crane and placed in a designated curing location. Treated material that does not meet the NTS WAC is reprocessed in a rework facility.

A PVS is designed to maintain a negative pressure in the treatment facility vessels in order to contain airborne contaminants, including radon, and particulates. PVS vent lines from all vessels and the filling and lidding rooms that contain Silos 1 and 2 material are connected to a common header that routes the vent air to the existing RCS (500 scfm capacity). The resulting negative pressure ensures that the system does not leak any gas into the local environment.

A Flush Water System uses recycle water from the TTA to flush slurry lines and equipment in order to reduce the risk of plugging process lines and equipment. The flush water discharge is then routed back to the TTA.

The CHEM2 secondary process wastestreams include spent containers from the product Rework System and PPE **(Table 3.5-1)**. The recycled wastestreams include the decant water from the clarifier tank and the reject grout. The residual water from waste retrieval operations that remains in the TTA near the end of the 3-year schedule will be treated with the CHEM2 process at a reduced waste loading.

TABLE 3.5-1
ESTIMATED SECONDARY WASTESTREAMS GENERATED DURING FULL-SCALE OPERATION OF THE CHEMICAL STABILIZATION — OTHER FACILITY

Secondary Wastestreams for CHEM2					
Source	**Material Type**	**Rate (lb/day)**	**Total Volume**	**Status**	**Packaged Disposal Volume**
RCS Condensate	Water	50	1,310,400 gal	Process	N/A
Empty Re-work Containers	Steel	57	362,748 lbs 737 cf	Dispose	2,016 cf
Misc. Replacement Equipment [1]	Solid	N/A	14 cf	Dispose	112 cf
RCS and Emissions System HEPA filters	Solid	N/A	1,656 cf	Dispose	3,190 cf
RCS carbon	Carbon	1 Lot	5,334 cf	Dispose	8,890 cf
PPE	Solid	4 / day	21,600 cf	Dispose	32,000 cf
Total Estimated Cubic Feet of Packaged Disposed Secondary Waste					46,000 cf

1 - Equipment will be replaced when necessary to maintain normal operation schedule.

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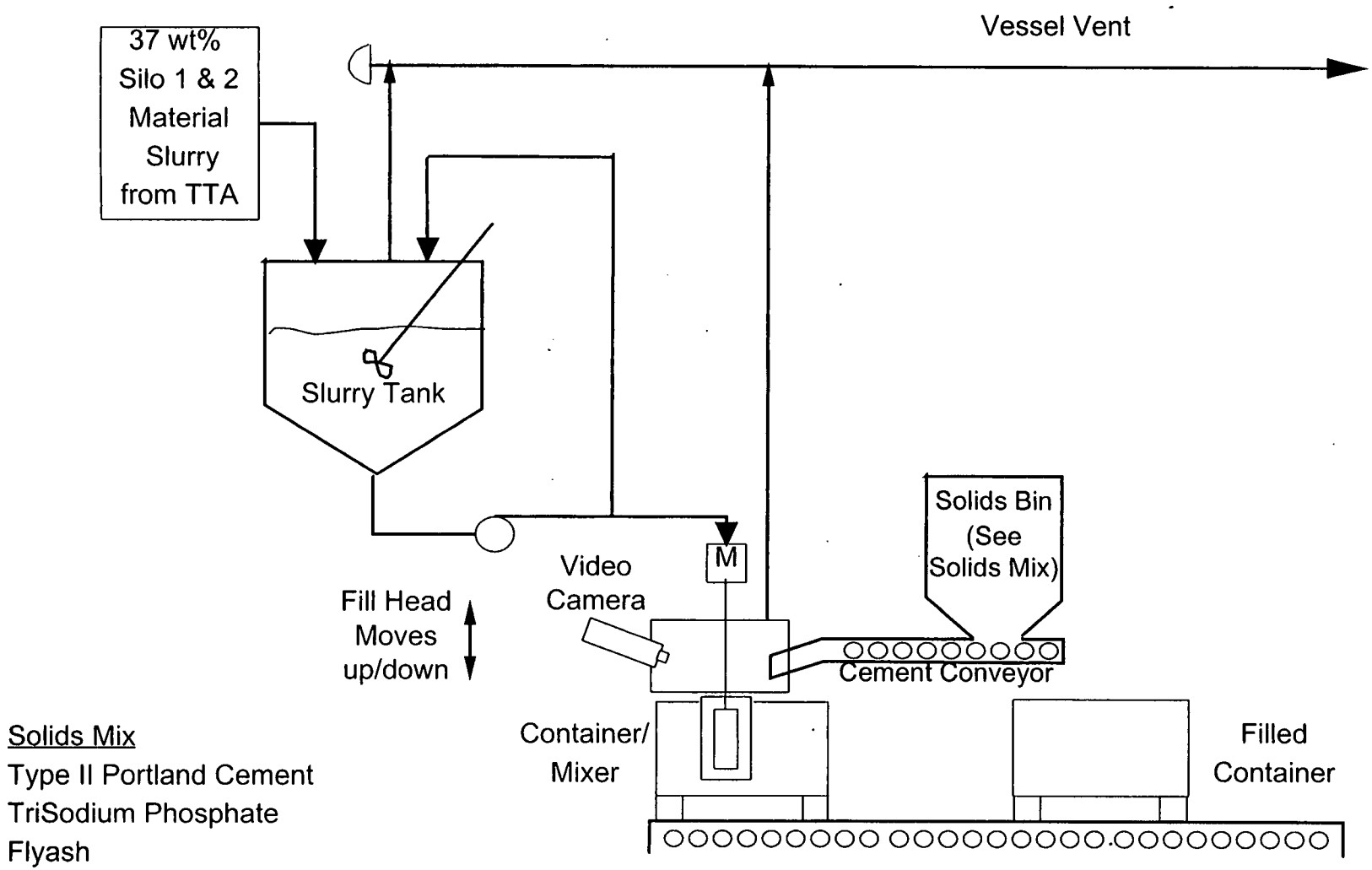

Figure 3.5-1
Simplified Process Diagram
Chemical Stabilization - Other

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The water decanted from the clarifier tank is recycled back to the TTA at 30 gpm during normal process operations. Out of specification treated material (one reject container every 2 to 3 weeks) is reduced in size and re-processed during the 3-year operating schedule. All process gas vented from the treatment process that contains radon is discharged to the RCS. The number of containers required to treat the water remaining in the TTA is included in the total number of containers to dispose at the NTS (reference **Figure G.1.3-9** and supporting calculations attached to **Appendix G**).

3.5.1.2 Project Schedule

Table 3.5-2 summarizes the individual project activities and their estimated durations for the implementation of Alternative CHEM2. A more detailed description of the individual project activities can be found in **Appendix G, Section G.2.21**. The activity durations were developed considering the following factors:

- Proposed activity durations provided by commercial contractors;
- Specified regulatory document review and approval cycles outlined in the FEMP ACA;
- Procedural and administrative requirements for conducting procurement activities at the DOE-FEMP site;
- Historical project management experience and lessons learned while performing environmental remediation activities at the DOE-FEMP site; and
- Historical experience with the start-up of chemical stabilization facilities within the DOE-complex.

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TABLE 3.5-2
SCHEDULE SUMMARY – CHEM2

Activity	Duration (Work Days)
Procurement Process	
• Develop RFP	166
• RFP Bid Cycle	165
Design and Documentation	430
Construction and Construction Acceptance Testing	340
SOT	80
Readiness Review	
• Readiness Preparation	213
• ORR	40
Proof of Process Testing	40
Stabilization Operations	750
Safe Shutdown of Facility	60
Facility D&D	120

Figure 3.5-2 provides a graphical representation of the sequences for completing the project activities, as well as the logical relationships between the activities.

The CHEM2 project schedule becomes a key component in several of the evaluation criteria. Short-term effectiveness evaluates the effects of the alternative during the construction and operations phase until the RA objectives are achieved (e.g., worker risks, environmental risks), as well as the time required to achieve protection. Implementability evaluates the ability of the CHEM2 alternative to maintain schedule and recover schedule due to unplanned downtime. The project schedule is an important factor in estimating the project cost for CHEM2. The project schedule effects the resource planning, pay item schedules, and the cost of money analysis for the remediation contract.

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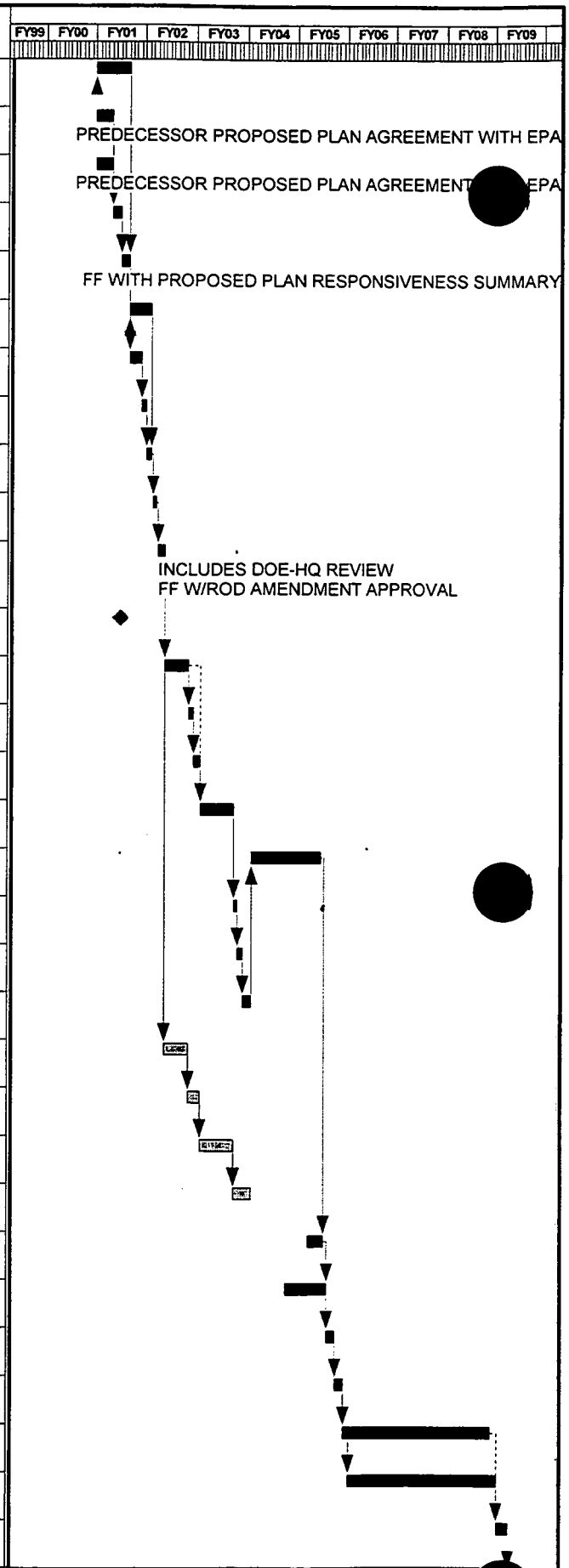
Activity ID	Activity Description	Orig Dur	Rem Dur	Early start	Early finish
0100	DEVELOP FINAL REMEDIATION RFP	166*	166*	02OCT00	01JUN01
0400	TRD DEVELOPMENT	79	79	02OCT00*	26JAN01
0700	DRAFT RFP	79	79	02OCT00*	26JAN01
1000	STORYBOARD RFP	44	44	29JAN01	30MAR01
1300	REVIEW/FINALIZE RFP	43	43	02APR01	01JUN01
1600	RFP BID CYCLE	120*	120*	04JUN01	21NOV01
1900	BID PERIOD	64	64	04JUN01	31AUG01
2200	BID EVALUATION	29	29	04SEP01	12OCT01
2500	BAFO	27	27	15OCT01	21NOV01
2800	CONSENT PKG PREP/REVIEW	23	23	26NOV01	28DEC01
3100	DOE CONSENT PKG REVIEW/APPROVAL	42	42	31DEC01	28FEB02
3200	NOA ISSUED FOR ROD	0	0	10APR01*	
3400	PRELIMINARY DESIGN	120	120	01MAR02	20AUG02
3700	FDF REVIEW PRELIMINARY DESIGN	20	20	21AUG02	18SEP02
4000	FINALIZE/APPROVE PRELIMINARY DESIGN	40	40	19SEP02	14NOV02
4300	FINAL DESIGN	160	160	15NOV02	09JUL03
4600	CONSTRUCTION	340	340	07NOV03	22MAR05
4900	FDF REVIEW FINAL DESIGN	20	20	10JUL03	06AUG03
5200	FINALIZE FINAL DESIGN	20	20	07AUG03	04SEP03
5500	EPA REVIEW/APPROVE FINAL DESIGN	45	45	05SEP03	06NOV03
5800	PHAR DEVELOPMENT	120	120	01MAR02	20AUG02
6100	PHAR REVIEW/APPROVAL	60	60	21AUG02	14NOV02
6400	FHAR DEVELOPMENT	160	160	15NOV02	09JUL03
6700	FHAR REVIEW/APPROVAL	90	90	10JUL03	14NOV03
7000	SYSTEM OPERABILITY TEST	80	80	27DEC04	20APR05
7300	READINESS PREPARATION	213	213	13JUL04	18MAY05
7600	ORR	40	40	19MAY05	15JUL05
7900	PROOF OF PROCESS TEST	40	40	18JUL05	12SEP05
8200	OPERATION	750	750	13SEP05	11SEP08
8500	WASTE DISPOSITION	750	750	25OCT05	23OCT08
8800	SAFE SHUTDOWN	60	60	24OCT08	23JAN09



Project Start	01OCT95	Early Bar
Project Finish	16JUL09	Progress Bar
Data Date	01FEB99	Critical Activity
Run Date	06DEC99	

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FIGURE 3.5-2

PROJECT SCHEDULE

CHEMICAL STABILIZATION - OTHER

Activity ID	Activity Description	Orig Dur	Rem Dur	Early start	Early finish
8900	FACILITY D & D	120	120	26JAN09	16JUL09

FY99 | FY00 | FY01 | FY02 | FY03 | FY04 | FY05 | FY06 | FY07 | FY08 | FY09

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Start	01OCT95	Early Bar	
Project Finish	16JUL09	Progress Bar	
Data Date	01FEB99	Critical Activity	
Run Date	06DEC99		

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FIGURE 3.5-2

PROJECT SCHEDULE

CHEMICAL STABILIZATION - OTHER

3.5.2 Overall Protection of Human Health and the Environment

Issues related to the ability of CHEM2 to meet the criterion of overall protectiveness of human health and the environment are similar to VIT1. Consequently, the discussion of meeting the criterion of overall protectiveness of human health and the environment is identical to that presented in **Section 3.2.2**.

3.5.3 Compliance with Applicable or Relevant and Appropriate Requirements

The CHEM2 alternative will attain all ARARs/TBCs identified in **Appendix A**. With the exception of the specific process option used to meet treatment requirements. The details of attaining ARARs will be the same as those discussed for VIT1 in **Section 3.2.3**.

3.5.3.1 Chemical-Specific ARARs and TBCs

CHEM2 complies with all chemical-specific ARARs and TBCs identified in **Appendix A**. Issues related to chemical-specific ARAR compliance for CHEM2 are similar to VIT1. The atmospheric release of radon from the interim storage of treated Silos 1 and 2 material and the surface of the disposal site would meet the limit established in 40 CFR Part 61 Subpart Q. Radon attenuation provided by the CHEM2 treated material, combined with the attenuation provided by the disposal container and the engineered disposal cell cover, meets the NESHAP requirement, as well as other applicable chemical-specific public dose and airborne concentration limits.

3.5.3.2 Location-Specific ARARs and TBCs

CHEM2 complies with all location-specific ARARs and TBCs identified in **Appendix A**. Issues related to CHEM2 compliance with location-specific ARARs are similar to VIT1. Consequently, the discussion on compliance with location-specific ARARs is identical to that presented in **Section 3.2.3.2**.

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3.5.3.3 Action-Specific ARARs and TBCs

CHEM2 complies with all action-specific ARARs and TBCs identified in **Appendix A.** Issues related to CHEM2 compliance with action-specific ARARs are similar to VIT1. Consequently, the discussion on compliance with action-specific ARARs is identical to that presented in **Section 3.2.3.3.**

3.5.4 Long-term Effectiveness and Permanence

3.5.4.1 Magnitude of Residual Risk

Silos 1 and 2 Material

As with VIT1, the implementation of the CHEM2 alternative reduces the residual risk to viable receptors to a HI of less than 0.2 and an ILCR of less than 10^{-6}. Because the material is removed from the site, the residual risk from the Silos 1 and 2 material at the FEMP site is nonexistent. Residual risk at the NTS is limited by the reduction in contaminant leachability accomplished by the treatment process, the disposal facility's institutional controls, and the arid environment.

Soil and Debris

As with VIT1, disposal of soil and debris under the CHEM2 alternative provides long-term protection of the environment and the public (see **Section 3.2.4.1**).

3.5.4.2 Adequacy and Reliability of Controls

TCLP analysis indicates that the CHEM2 process produces a wasteform which meets the NTS WAC and is durable based on leach rate data. The TCLP test is utilized to simulate the leaching effects of acidic groundwater infiltrating the disposal cell and contacting disposed waste. This test serves as a measure of the stabilized waste particles ability to resist leaching, even if the original wasteform (e.g., monolith) has been compromised. This reduction in leachability, combined with the additional protection provided by the engineered disposal cell configuration provide a durable disposal configuration that provides long-term protection of human health and the environment.

Long-term environmental impacts associated with CHEM2 are similar to VIT1 (see **Section 3.2.4.2**) as they relate to impacts on water quality and hydrology, air quality, biotic resources, wetland and floodplains, socioeconomics and land use, and cultural resources. CHEM2 is also similar to VIT1 in regard to impacts on soil and geology except that the estimated volume of treated material requires additional disposal space. The overall impact due to the increased volume is not significant because material would be disposed in a previously disturbed area (Area 5) designated for LLRW disposal in the NTS-EIS. The PA prepared by DOE-Nevada will demonstrate that disposal of this increased volume will meet the criteria determined to be protective by the NTS-EIS. Consequently, the discussion of CHEM2 long-term environmental impacts is identical to that presented in **Section 3.2.4.2**.

3.5.5 Reduction of Toxicity, Mobility, or Volume through Treatment

CHEM2 is similar to CHEM1 in its ability to stabilize lead and the COCs (refer to **Section 3.4.5**). Analytical data from the POP testing of chemical stabilization on surrogate Silos 1 and 2 material demonstrated that chemical stabilization could effectively stabilize lead and other metals to meet RCRA TC limits. POP testing also demonstrated that CHEM2 provides sufficient stabilization to meet the lower UTS limits.

Although treatment by the CHEM2 alternative provides reduction in radon emissions, significant levels of radon continue to be emitted after chemical stabilization. However, the combination of treatment and sealed containerization during interim storage will reduce the radon emanation rates to below the NESHAP Subpart Q regulatory level.

Data from POP testing of chemical stabilization on surrogate Silos 1 and 2 material indicated a potential significant increase in volume of treated material. The POP data indicates that the original 6,797 m^3 (8,890 yd^3) of material in Silos 1 and 2 would be increased to a volume of approximately 22,855 m^3 (29,895 yd^3). This represents a volume increase of approximately 236%. In addition, due to the shielding necessary for the protection of workers and the general public and for meeting DOT requirements, containerization of the treated material results in a disposal volume increase of approximately 33,144 m^3 (43,352 yd^3), equating to an overall volume increase of 388% compared to the original volume of material in Silos 1 and 2.

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The secondary wastestreams associated with the CHEM2 alternative are summarized in **Table 3.5-1**. The estimated final disposal volume of all the secondary wastestreams is 1,300 m^3 (1,700 yd^3). The total estimated disposal volume of the treated Silos 1 and 2 material and all secondary wastestreams is 34,444 m^3 (45,050 yd^3), equating to an overall volume increase of 407%, compared to the original volume of material in Silos 1 and 2.

3.5.6 Short-term Effectiveness

3.5.6.1 Protection of the Community During Remedial Action

Protection of the community during implementation of CHEM2 is similar to CHEM1. Therefore, with the exception of the issues discussed below, the discussion on protection of the community is identical to that presented in **Section 3.4.6.1**.

3.5.6.2 Protection of Workers During Remedial Action

Appendix B estimates the number of injuries and fatalities that could result from the removal, treatment, and transportation activities associated with this alternative during remediation.

Risks to workers as a result of implementation of this alternative are ALARA. This alternative involves the handling of radioactive materials and, therefore, there are several potential exposure pathways for workers. Both the release of gases and exposure to direct radiation from the materials could pose a risk to workers. Per 10 CFR Part 835.202, occupational dose shall not exceed a total effective dose equivalent of 5 rem per year. This dose results in an ILCR of 2.0×10^{-3} to workers. It has been estimated that, with appropriate protection, the removal and treatment of materials results in a cancer risk level to remediation workers of 3.13×10^{-4} (see **Appendix B**). Most of this risk occurs during operation of the treatment facility. As appropriate, workers wear protective clothing and use shielding, along with automation and remote operations.

A simplified IHA was conducted to evaluate the unmitigated hazards to workers posed by the conceptual design of the chemical stabilization – other process. The results of the IHA are presented in **Appendix B** and are summarized below:

- The number of containers required for the Chemical Stabilization – Other process present a mechanical energy hazard;
- The number of shipments required to transport chemical stabilized waste to the NTS present an acceleration/impact hazards; and
- Because the majority of project dose results from radiation exposure during package handling and shipping, the Chemical Stabilization – Other process presents a radiation hazard.

Without considering the specific hazards identified above, it has been estimated, based solely on labor hours, that construction, treatment, and D&D could result in approximately 52 injuries and 0.77 fatalities during remediation. Remediation activities are to be conducted in accordance with a health and safety plan developed to meet 29 CFR Part 1910.120(b)(4). Training and procedures ensure that worker exposure is ALARA.

3.5.6.3 Short-term Environmental Impacts

The short-term environmental impacts at the FEMP site on water quality and hydrology, air quality, biotic resources, wetlands and floodplains, and socioeconomics and land use by implementation of CHEM2 are similar to VIT1. CHEM2 short-term impacts on soil and geology are also similar to that of VIT1 with the exception of the volume of soil that is temporarily disturbed. It is estimated that construction and excavation could temporarily disturb a total of approximately 13,958m^3 (18,257yd^3) of the site. The overall difference between CHEM2 and VIT1 on the volume of soil impacted is not significant. Therefore, the discussion of CHEM2 short-term environmental impacts is identical to that presented in **Section 3.2.6.3**.

3.5.6.4 Transportation

The transportation of the treated Silos 1 and 2 material to the NTS by either transportation option (direct truck or intermodal) is protective of the public. The implementation of this alternative results in negligible increases in traffic flow on and around the FEMP site for both transportation options (direct truck or intermodal). Temporary increases in deliveries and workers to the FEMP site are not expected to significantly impact traffic patterns or roadways.

Treated Silos 1 and 2 material is transported by trucks to the NTS. The treatment process proposed under CHEM2 generates approximately 6,106 containers. If two containers are placed on each truck, approximately 3,053 direct truck shipments to the NTS are required. This results in approximately 20 shipments per week to meet the 3-year operation schedule.

For intermodal transport, two containers are placed in an ISO container. One ISO container is placed on a truck and two ISO containers are be placed on a railcar. This results in 3,053 truck shipments from the FEMP to an intermodal facility, 1,527 railcar shipments by regular freight from an intermodal facility in the East to an intermodal facility in the West, and 3,053 truck shipments from the intermodal facility to the NTS.

Environmental impacts from shipping and disposing of treated Silos 1 and 2 materials are expected to be minimal from normal transportation because procedures comply with applicable DOT requirements and DOE Orders. There is a small risk to the public during transportation of the treated Silos 1 and 2 material to the NTS. The estimate of public radiation exposure, expressed in terms of ILCR, along the route to the NTS ranges from 4.10×10^{-6} for direct truck shipment to 4.66×10^{-6} for intermodal transport for the maximally exposed individual, within the CERCLA target risk range of 1×10^{-4} to 1×10^{-6}. It is estimated that 0.54 to 0.57 fatalities may occur to the public due to non-radiological risks during direct truck and intermodal transportation, respectively. Because potential short-term risks to the public are small, even a major deviation in the assumptions does not change the conclusion that this alternative is protective of the community in the short-term.

Additional radiation exposure risks to the worker result from transporting the treated Silos 1 and 2 material to the NTS. The ILCR for the transportation worker is estimated to range from 1.04×10^{-5} per shipment for intermodal to 2.88×10^{-5} per shipment for direct truck. It is estimated that 0.10 to 0.15 fatalities may occur to workers during intermodal and direct truck transportation, respectively. The risk to workers due to radiological exposures during off-loading activities at the NTS is assumed to be below the estimated ILCR risk level of 3.13×10^{-4} during treatment/construction activities at the FEMP site because the materials are already packaged and in a stabilized form. There is uncertainty regarding additional risk from exposure to wastes already present at the NTS near off-loading operations for FEMP waste.

The basis for these risk estimates is provided in **Appendices B** and **E**.

3.5.6.5 Time to Achieve Protection

As illustrated in the schedule presented in **Figure 3.5-2**, design, construction and start-up activities for the CHEM2 alternative result in a period of approximately 53 months from approval of the ROD Amendment for the remediation of Silos 1 and 2 until the initiation of treatment operations.

The operating schedule for the CHEM2 alternative assumes 24 hr/day, 5 days/week operation of the three-line treatment facility (assuming 70% design availability) to complete treatment within a 3-year period. The operating schedule (24 hr/day, 5 days/week) results in "excess" operating time being available, which increases confidence in the ability to meet the 3-year schedule. Completion of treatment in less than three years could also be accomplished by implementing the CHEM2 alternative using additional mixer lines. Acceleration of the operating schedule or increase in the number of mixer lines requires increases in feed preparation and product storage capacity. These increases result in cost impacts in order to complete treatment in less than three years.

3.5.7 Implementability

The implementability criteria are described in **Section 3.1.2.6**. The following sections present the summary, technical feasibility, administrative feasibility, and availability of services evaluation of implementing this alternative.

The feasibility of implementing the Chemical Stabilization — Other technology for the remediation of the Silos 1 and 2 material is summarized in the following sections.

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3.5.7.1 Technical Feasibility

Scaleup

The Chemical Stabilization — Other technology was demonstrated with a single process line by the POP contractor at a rate of 3.67 TPD. The proposed full-scale facility is commercially available and has been demonstrated at the proposed scale. The contractor's design is based on a target waste loading of 24 wt%, which was demonstrated by the POP contractor in the lab. However, due to material settling problems experienced during the POP 72-hour testing, the contractor was only able to achieve a waste loading of 18 wt% (see **Attachment G, Section G.3.1** for discussion).

This technology has been demonstrated commercially at capacities required to remediate the Silos 1 and 2 material and has been applied to a broad range of wastestreams that include radioactive and hazardous wastes.

Scaleup, in general, is not an issue with the Air Emissions System since most parameters that define the equipment are well established; and, the capacity of commercially available systems is adequate to meet the needs of the full-scale facility. Means to collect and transfer the radon to the RCS, during the handling of open, filled containers will be difficult considering minimizing off-gas to limit the RCS size.

Commercial Demonstration

Chemical Stabilization — Other is a commercial technology that has been extensively demonstrated in the remediation industry. The ability of this technology to treat material reasonably similar to the Silos 1 and 2 material has been demonstrated through laboratory, pilot, and full-scale applications. There are numerous applications of the chemical stabilization technology that have been identified in the commercial sector and at DOE sites. These applications have included treatment of radioactive, hazardous, and mixed wastes.

The proposed mix-fill head and mixer blade assembly have been successfully utilized at full-scale capacity at a POP contractor's commercial waste treatment facility in Barnwell, SC.

The adaptation of this technology to chemically and physically bind and immobilize the Silos 1 and 2 material requires a thorough knowledge of waste composition, a well-developed formulation, specification of suitable materials of construction, and application of ALARA design principles. As a result, Chemical Stabilization — Other is a demonstrated technology that can be implemented to produce a treated material. However, limited application of the mix-fill head technology reduces the level of confidence in this process option.

Operability

Ease of Operation

The Mix-Fill Head System operations are not considered complex to operate due to the batch mode of operations (automated), standard equipment requirements, and simplified operating requirements. For example, the primary control parameters to ensure that the treated Silos 1 and 2 material is within specification are (1) appropriate solids content of waste slurry, and (2) proper metering of additives and mixer speed revolutions per minute (RPMs). The Mix-Fill Head System is assumed to homogenize the formulation; however, the ability to properly formulate an acceptable treated product is a function of appropriate solids content of waste slurry and proper metering of additives.

Operability issues include the effectiveness of dewatering, impact of waste loading, facility ventilation and radon control, and the long-term performance of custom built/remotely operated equipment items. In order to produce a quality waste product, the cement-based stabilization process must be designed to identify and respond to variations in stabilization chemistry and predict the results of the acid-based leach chemistry.

Operability is enhanced by a robust waste treatment formulation **(see Appendix G, Section G.3.1.3)** that minimizes the need for the Process System to respond to variability of the feed (this permits routine operations). The contractor for the full-scale remediation of the Silos 1 and 2 material will require a formulation development program to improve process stability. Most systems considered in this evaluation appear robust and can accommodate variations in key operational process parameters (e.g., feed preparation and waste treatment).

Formulations have been developed for this technology, to successfully treat the Silos 1 and 2 material. Process sampling, where each batch of conditioned slurry must be sampled, is critical to ensure that the appropriate formulation is specified for the remediation process.

In case the clarifier delivers less than the design basis 37 wt% solids in the feed to the mixers, additional chemical additives need to be added to absorb the additional moisture. This results in a reduced waste loading and a resulting increase in disposal volume.

Reliability

The Chemical Stabilization — Other technology utilizes conventional, commercially available equipment that has been demonstrated on radioactive and hazardous wastes. However, the unique characteristics [high solids content (37 wt%), radioactive, erosive, and sticky due to BentoGrout™ content] of the Silos 1 and 2 material may decrease the overall reliability of system components; but, it is expected to achieve the 70% design availability.

Maintainability

The maintainability of this technology is enhanced by its operational basis of 24 hr/day, 5 days/week (e.g., maintenance activities can be performed on weekends).

The Mix-Fill Head System is a demonstrated technology and maintenance practices have been established for limited applications (non-remote). Because a third process line is proposed for this system (plant has excess capacity), unpredictable maintenance trends may not impact overall plant availability. However, the radioactive Silos 1 and 2 material complicates maintenance activities.

The Air Emissions System uses conventional equipment for which maintenance practices are well established. Maintainability of the system is not subject to specialized training and/or tooling (although ALARA guidelines are applicable). Because maintenance on this system should be straightforward, overall maintainability of the Air Emissions System does not impact overall plant availability. Location of most of the critical Air Emissions System equipment outside of contaminated areas increases the confidence in maintainability of the system.

Complexity

The Chemical Stabilization — Other alternative contains primary stabilization components (mix-fill head and mixer blade) that are relatively simple from a process and operational controls and air emissions control standpoint. Since the treatment process is not expected to generate any off-gas during treatment, a complex Off-gas System is not required in the design of the treatment facility required due to the nature of chemical stabilization, thus, simplifying the process. Radon and radioactive particulates are collected by an Air Emissions System and sent to the RCS for treatment.

From a physical operations standpoint, the Treatment System is considered moderately complex due to the multiple functioning requirements of the mix-fill head. For example, for each batch operation, the mix-fill head must perform the following functions: alignment, couple/decouple, charge, blend, mix, contain, and vent. Although the mix-fill head is designed for automated operations, the variety of activities performed by this specialty equipment item requires remote control and monitoring features.

Primary control parameters to ensure the treated Silos 1 and 2 material is within specification are additive weights, mixing speed, and duration. These parameters are monitored and controlled from a centrally located control area for ALARA considerations. The Treatment System is assumed to homogenize the formulation. The Treatment System is vented after mixing operations (before removal of the mix-fill head) to remove radon liberated during the mixing process.

The Product Rework System for the Chemical Stabilization — Other technology requires specialized tooling, remote handling, control requirements, and multiple remote operations to ensure effective size reduction and transfer of recycled materials. The treated Silos 1 and 2 material must be remotely jack-hammered from its container and crushed for size reduction before being reintroduced into the mixer. This is complicated by the presence of the in-drum mixer blade.

Ease of Acceleration

In order to treat the Silos 1 and 2 material in three years, the required operating schedule would be 24 hr/day, 5 days/week, which considers the 70% design availability. Some acceleration/schedule recovery could be realized by using a 24 hr/day, 7 days/week operating schedule. Capacities for the curing and storage facilities increase. Additionally, multiple trains (three proposed) could be added for even greater schedule acceleration. Additional costs are incurred with increased capacities of equipment and facilities.

Constructability - Ease of Construction/Fabrication, Ease of D&D

Construction incorporates conventional field fabrication methods; this activity is facilitated by contractor pre-testing activities performed on key prefabricated equipment items. The ability to demonstrate readiness is facilitated by inherent simplicity of the treatment process. Treatment facility D&D activities appear to be conventional in scope using water flushing, monitoring, and collection methods before ultimate disposal.

The Treatment System can be fabricated, modularized, and tested at off-site locations. Modular systems can be installed at the FEMP using conventional construction/assembly techniques, with construction turnover following the contractor's prefabrication and testing.

Controls and trained personnel are required to remove contaminated, hardened material inside a mix-fill head before packaging and ultimate disposal. Fixatives are applied to surfaces as necessary. Once decontaminated; the Mix-fill Head System uses conventional demolition techniques during its removal, size reduction, and packaging for ultimate disposal.

3.5.7.2 Administrative Feasibility

The licensing and programmatic discussions for this alternative (CHEM2) are the same as the VIT1 discussions, see **Section 3.2.7.2.**

3.5.7.3 Availability of Services (Contractors, Equipment, Utilities)

Many contractors are available for competitive bid to design, procure materials, equipment, and services, and oversee operation of a Chemical Stabilization — Other facility capable of meeting the requirements of this alternative. Sole-source procurement is not necessary. Both the primary treatment process and support systems are available technologies, although some have not been demonstrated at this scale, or with this particular type of waste. Since none of the equipment requires specialized skills for operation, available FEMP personnel can be trained in the operation of all systems. Additionally, process engineers, operation and maintenance personnel, laborers, laboratory technicians, and administrative personnel to support the project can be trained to operate the technology. Proof of Process surrogate testing of the full-scale facility following construction, ORR, and SOT are conducted in order to optimize the process before beginning full-scale remedial operations using actual silo material.

All equipment is commercially available from a variety of contractors in accordance with the unit design specifications. The shipping container for the treated Silos 1 and 2 material can be manufactured by several contractors to the design specification. Certified transporters are currently available that can haul filled containers by truck to the NTS disposal facility in accordance with DOT requirements.

The NTS is a pre-approved, off-site disposal facility that has the equipment and facilities to safely dispose and manage the filled containers of treated material, which would be accepted as low-level waste. A laboratory, transfer areas, storage areas, and decontamination facilities are also currently available at the NTS site. An NTS-approved sampling program would be established at the FEMP to verify that the treated Silos 1 and 2 material complies with the NTS WAC before shipment.

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3.5.8 Cost

The summary cost for the Chemical Stabilization — Other technology is $303 Million in FY99 dollars, as shown in **Table 3.5-3.**

TABLE 3.5-3
SUMMARY COST ESTIMATE FOR CHEMICAL STABILIZATION — OTHER
($ MILLION)

Capital Cost	56
Engineering Cost	24
Operation and Maintenance Cost	83
D&D Cost	36
Project Management Cost	21
Waste Disposal Cost	55
Cost of Money	28
Summary Cost (Un-escalated)	303
Present Worth Analysis	248

Supporting detail information for the Chemical Stabilization — Other cost estimate is in **Appendix C.**

3.5.9 State Acceptance

This criterion evaluates the input of the OEPA regarding the CHEM2 alternative. This modifying criterion will be formally addressed in the regulatory process following the public review period for the FS/PP (i.e., in a Responsiveness Summary to accompany the ROD amendment).

3.5.10 Community Acceptance

This criterion evaluates the input of the community (both local to the FEMP, and near potential transportation routes and disposal facilities) concerning implementation of the CHEM2 alternative. Because formal public comments will not be received until after the revised FS is final, this modifying criterion will be addressed during the regulatory process following the public comment period for the FS/PP.

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4.0 COMPARATIVE ANALYSIS

4.1 Introduction

Section 4 presents a comparative analysis of alternatives for the treatment of the Silos 1 and 2 material with respect to the CERCLA evaluation criteria described in **Section 3**. This analysis is the second stage of the detailed evaluation process and forms the basis for identifying the DOE's preferred remedial alternative for the Silos 1 and 2 material in the PP. The modifying criteria of state and community acceptance are not formally addressed in this comparative analysis. Based upon formal state and community comments on the PP, these modifying criteria will be formally addressed in the Responsiveness Summary of the ROD Amendment that will be prepared following the formal public comment period.

CERCLA divides the evaluation criteria used in this comparative analysis into three categories: threshold, primary balancing, and modifying. More detailed definitions of the evaluation criteria can be found in **Section 3.1** - ***Overview of the Detailed Analysis.***

Threshold criteria consist of the two criteria that must be satisfied by an alternative before it can be considered further. These are:

- Overall protection of human health and the environment, and
- Compliance with ARARs.

These criteria are critical 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 is not eligible to be selected as the final remedy.

Primary balancing criteria consist of the five criteria under which the relative advantages and disadvantages of the alternatives are compared to determine the best overall remedy:

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

The first and second balancing criteria address the statutory preference for treatment as a principal element of the remedy and the bias against off-site land disposal of untreated material. Together with the third and fourth balancing criteria, they form the basis for determining the general feasibility of each potential remedy. In addition, the criteria are used to determine whether costs are proportional to the overall protectiveness, considering both the remediation activity and the time period following restoration of the OU4 area. Thus, this approach determines whether a potential remedy is cost-effective.

Based on information presented in the detailed analysis of alternatives in **Section 3**, a comparative analysis under the threshold, primary balancing, and modifying criteria for the alternatives is presented in **Section 4.2**. **Figure 4.1-1** summarizes the comparative analysis of the alternatives.

As indicated in **Figure 4.1-1**, the evaluation of the following criteria:

- Overall protection of human health and the environment;
- Compliance with Applicable and Relevant and Appropriate Requirements; and
- Long-term effectiveness and permanence,

did not result in the identification of any discriminating differences between the alternatives. Therefore, those criteria are considered to be "neutral" or non-discriminating factors in remedy selection.

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FIGURE 4.1-1
COMPARATIVE ANALYSIS SUMMARY

ITEM	VIT1/VIT2	CHEM1/CHEM2
	Strongly Favors / Favors / Neutral	Favors / Strongly Favors
Overall Protection of Human Health and the Environment		
Compliance with Applicable or Relevant and Appropriate Requirements		
Long-Term Effectiveness and Permanence		
Reduction of Toxicity, Mobility, or Volume Through Treatment		
Short-Term Effectiveness		
Implementability		
Cost		
State Acceptance - TBD		
Community Acceptance - TBD		

Figure 4.1-1 also summarizes that the conclusions drawn from the comparative analysis involving the remaining balancing criteria:

- Reduction in toxicity, mobility or volume through treatment;
- Short-term effectiveness;
- Implementability; and
- Cost,

exhibit a tendency to favor one technology over another technology. These criteria are considered to be "discriminating factors" based on the comparative analysis of technologies. Because these discriminating factors and the subjective values placed upon them will be used to propose a final remedy in the PP, it becomes important to understand the relative "trade-offs" or the advantages/disadvantages of the individual components which together form these criteria. **Figure 4.1-2** presents a more detailed summary of the discriminating criteria and a breakdown of their components that collectively favor one technology over another. The narrative in **Section 4.2** provides discussion of the individual components of the discriminating criteria, the relative importance placed on the components, and the basis for identifying which technology the criteria favors overall.

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FIGURE 4.1-2
SUMMARY OF DISCRIMINATING CRITERIA AND THEIR COMPONENTS

ITEM	VIT1/VIT2			CHEM1/CHEM2	
	Strongly Favors	Favors	Neutral	Favors	Strongly Favors
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT		↓			
Treated Waste Volume		↓			
Secondary Waste Generation			↓		
Reduction in Mobility of COCs			↓		
Radon Attenuation by Treated Wasteform		↓			
SHORT-TERM EFFECTIVENESS				↓	
Worker Risk				↓	
Transportation Risk		↓			
Off-site/Environmental Impact			↓		
Time to Achieve Protection				↓	
IMPLEMENTABILITY				↓	
Scaleup			↓		
Commercial Demonstration				↓	
Operability				↓	
Ease of Acceleration				↓	
Constructability				↓	
COST			↓		

4.2 Summary of Comparative Analysis

4.2.1 Threshold Criteria

4.2.1.1 Overall Protection of Human Health and the Environment

All four alternatives attain this threshold criterion.

The *Environmental Assessment for Proposed Final Land Use at the Fernald Environmental Management Project* (DOE 1999b) establishes the future land use of the FEMP, which is continued use under federal ownership with the area of OU4 being restored to a riparian and upland forest. This scenario is similar to the one evaluated in the original OU4 FS (FEMP 1994a). In addition, the alternatives being evaluated in this revised FS are the same as those evaluated in the original OU4 FS. As was the case in the original OU4 FS, the alternatives specify that the Silos 1 and 2 material will be treated and removed from the FEMP to the NTS for disposal; and, all surrounding soil will be excavated, removed and disposed to meet final remediation levels documented in the OU2 ROD (FEMP 1995c) and the OU5 ROD (FEMP 1995b). Therefore, the residual risk results from the original OU4 FS are still applicable to the evaluation of the current alternatives. The results of the original analyses stated that long-term risk to the public is within CERCLA guidelines because the Silos 1 and 2 material and contaminated soil are treated and removed from the OU4 area.

All four alternatives provide Overall Protection of Human Health and the Environment. Each alternative limits exposure to contaminants by removing the sources of contamination, treating the source materials to minimize contaminant mobility, and protective disposal the treated material at the NTS.

The VIT1, VIT2, CHEM1 and CHEM2 treatment processes produce a stabilized material that resists leaching and therefore reduces the potential for contaminant migration. As discussed in **Section 4.2.2.1**, TCLP results demonstrate that all four alternatives provide adequate prevention of contaminant mobility even in the event that the integrity of the original wasteform is degraded.

The nature and extent of impacts to biota from implementing the four alternatives are similar. Each alternative involves site preparation and construction for a processing facility, removal of the Silos 1 and 2 material from the TTA, remediation of the Silos 1 and 2 material, and transportation of the treated material to the NTS for disposal. Short-term impacts include the temporary loss of habitats at the FEMP site and possible impacts from accidental spills of construction and operation materials. Mitigative measures are employed to minimize these short-term risks.

The off-site disposal location is the NTS facility, which has been widely used by the DOE for disposal of LLRW. The NTS incorporates engineering and institutional controls to ensure protectiveness and is located in a climatic, demographic, and hydrogeologic setting that favors minimization of contaminant migration to both human and environmental receptors. In the long-term event of degradation of engineered features or loss of institutional controls, these site characteristics coupled with the reduction in contaminant leachability provided by the treatment process help to ensure that protectiveness of human health and the environment are maintained.

4.2.1.2 Compliance with ARARs

The VIT1, VIT2, CHEM1 and CHEM2 alternatives attain the threshold criterion of compliance with ARARs. A comprehensive list of ARARs is presented in **Appendix A**. Key requirements are discussed in **Section 3** within the evaluation of each alternative against this criterion. The following paragraphs summarize those evaluations.

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Chemical-specific ARARs

The VIT1, VIT2, CHEM1 and CHEM2 alternatives meet the chemical-specific ARARs associated with potential releases to groundwater, surface water, and air. The most critical chemical-specific ARAR relative to airborne releases relates to radon. The primary limit on radon emanation is the flux limit (specified in NESHAP, 40 CFR Part 61 Subpart Q) of 20 $pCi/m^2 \cdot s$. This limit applies to interim storage or final disposal of Silos 1 and 2 material. The vitrified Silos 1 and 2 material is more effective in reducing radon emanation than the chemically stabilized material. However, the radon mitigation provided by the chemically stabilized material, combined with the packaging associated with the disposal of treated materials, effectively controls radon emanation and complies with the NESHAP requirements for interim storage. All four alternatives meet requirements for control of radon, particulate, and other air emissions from remediation activities through incorporation of necessary air-emission treatment. The off-gas volume from the Vitrification — Other process would exceed the capacity of the proposed RCS. Installation of additional capacity would be required to assure attainment of radon ARARs. The impact of radon emissions during remediation is evaluated as part of the short-term effectiveness criterion **(Section 4.2.2.3)**.

Location-specific ARARs

All four alternatives meet the location-specific ARARs as they relate to floodplains, wetlands, and endangered species and their habitats. Compliance by these alternatives is met through proper planning, siting, design, and operational procedures.

Action-specific ARARs

All four alternatives meet the action-specific ARARs. Appropriate engineering controls are implemented for each alternative to comply with Ohio Water Quality Standards and Air Quality Standards. Hazardous material transportation requirements are complied with by following the regulations under 40 CFR Parts 262 and 263, and the appropriate DOT shipping standards under 49 CFR Subchapter C Hazardous Materials regulations.

4.2.2 Primary Balancing Criteria

4.2.2.1 Long-term Effectiveness and Permanence

All four alternatives ensure long-term protectiveness of human health and the environment through treatment. TCLP analysis indicates that all four alternatives produced wasteforms that consistently met the NTS WAC and were durable based on leach rate data. The TCLP test is used to simulate the leaching effects of acidic groundwater infiltrating the disposal cell and contacting disposed waste. This test serves as a measure of the stabilized waste particles ability to resist leaching, even if the original wasteform (e.g., monolith) has been compromised.

Off-site disposal at the NTS provides additional protection by eliminating access to the treated materials and preventing migration of constituents from the materials. The NTS disposal facility is located in a sparsely populated, arid environment with a reduced potential for leachate generation, contaminant migration, and direct contact with contaminants. Because the NTS is maintained by DOE and used for the disposal of low-level wastes from other DOE sites, the uncertainties associated with institutional controls are minimal. As the result of a low average annual precipitation and depth to groundwater, impacts to human health and the environment from possible engineering and institutional controls failure are minimal.

There are no long-term environmental impacts at the FEMP site pertaining to the removal of the Silos 1 and 2 material and treatment processes. The projected FEMP site residual risk to viable receptors is less than 10^{-6} (ILCR), and non-carcinogenic effects are expected to be below 0.2 (HI) for both alternatives. Long-term environmental impacts at the NTS include some permanent disturbance of soils (i.e., acquisition of borrow material) associated with disposal activities. Significant long-term impacts to water quality and hydrology, air quality, biotic resources, socioeconomics and land use, or cultural resources are not expected. No Wetland or floodplain areas have been delineated at the NTS.

The FEMP OSDF will be available for disposal of the existing silos structures, the RTS, the decant sump tank, other below-grade appurtenances, and the OU4 soils. Soil and debris from D&D activities associated with the OU4 remediation facilities will be disposed in the OSDF, provided they meet the WAC for disposal. The basis for disposal of this soil and debris in accordance with the OSDF WAC is discussed in more detail in **Section 3.2.4**.

However, based on the current operating schedule, the FEMP OSDF is not identified to be available to receive any soil and debris generated from D&D of the OU4 remediation facilities, including the area surrounding the silos, TTA, RTS, and remediation treatment facilities. However, should programmatic changes occur and the FEMP OSDF become available, soil and debris meeting the FEMP OSDF WAC would be disposed in the available cell.

4.2.2.2 Reduction of Toxicity, Mobility, or Volume through Treatment

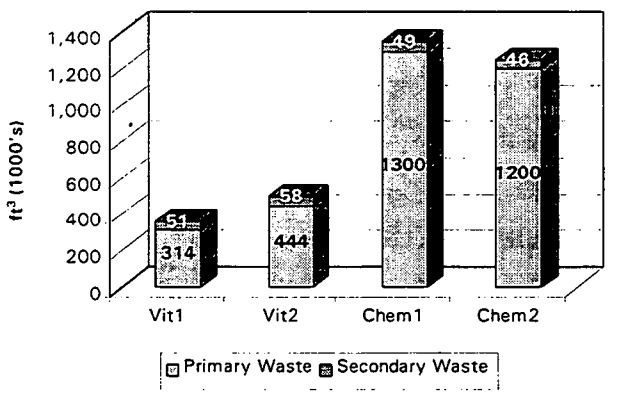
Overall, this criterion favors VIT1 and VIT2 due to the relative reduction in treated material volume.

The volume of solid waste requiring disposal for the VIT1, VIT2, CHEM1 and CHEM2 alternatives is summarized in **Table 4.2-1**. The consideration of solid secondary wastestreams does not significantly affect the differences in the total volume of treated waste requiring disposal between the VIT1, VIT2, CHEM1 and CHEM2 alternatives. However, the VIT1 and VIT2 alternatives have the greater potential to generate secondary wastestreams that are more difficult to handle and treat for disposal (i.e., salts, reduced metals, spent refractory).

All four alternatives are effective at reducing the mobility of COCs in the Silos 1 and 2 material through treatment. TCLP tests conducted on the treated surrogate material during POP testing indicate that all alternatives can reduce the leachate concentrations of hazardous metals to below regulatory limits established under 40 CFR Part 261.24 and OAC Chapter 3745-51-24. The VIT1 and VIT2 alternatives chemically bind or entrain the contaminants in a glass-like matrix that significantly reduces contaminant mobility. The CHEM1 and CHEM2 alternatives reduce the mobility of contaminants by either converting the contaminants into a less soluble form or by chemically binding them into a stabilized matrix.

Proof of Principle testing of the VIT1 and VIT2 alternatives have demonstrated that the treatment method results in a reduction in volume of the Silos 1 and 2 material sent to the NTS for disposal. The range in volume reduction is dependent on the waste loading and wasteform (frit monolith) produced. Greater volume reductions can be achieved with a monolith wasteform than with a frit or gem wasteform because there are fewer air pockets and void spaces associated with the monolith wasteform. An overall increase in disposal volume (compared to the original volume of material in Silos 1 and 2) results from placing the treated material in thick-walled concrete disposal containers, which are required to provide the shielding necessary for protection of the public and workers during transportation and container handling activities.

FIGURE 4.2-1
TOTAL SOLID WASTE VOLUME SUMMARY



Because of the chemical additives and fixatives added to the Silos 1 and 2 material for the CHEM1 and CHEM2 alternatives, there is a resultant increase in volume of the treated material being sent to the NTS for disposal, compared to the original volume of material in Silos 1 and 2. The volume increase is dependent on the waste loading of the Silos 1 and 2 material in the treatment formulation. An additional increase in overall disposal volume results from placing the treated material in thick-walled disposal containers in order to provide similar protection to the public and workers during container handling and transportation activities.

Vitrification of the Silos 1 and 2 material is more effective at reducing radon emanation than chemically stabilized material. This is physically accomplished by two separate means. First, the vitrification process essentially liberates the radon in the Silos 1 and 2 material during the vitrification process and treats it in the RCS. Secondly, the radium is entrained into the glass matrix and limits the emanation of radon from only that radium which is at the surface of the glass. However, the combination of radon mitigation provided by the chemically stabilized material plus the engineered barriers and packaging associated with the disposal of treated materials, effectively controls radon emanation. All four alternatives provide effective control of radon emanation from the treated Silos 1 and 2 material. The impact of radon emissions during remediation is evaluated as part of the short-term effectiveness criterion **(Section 4.2.2.3)**.

Table 4.2-2 provides a summary of the comparison of the radon flux and radiation dose associated with the VIT1, VIT2, CHEM1 and CHEM2 activities.

4.2.2.3 Short-term Effectiveness

Short-term risks are calculated to assess the potential impacts to the public and RA workers during implementation of all four alternatives. The basis for determination of risks is detailed in **Appendices B** and **E**.

TABLE 4.2-1
REDUCTION IN RADON FLUX AND RADIATION DOSE

		Treated Silos 1 and 2 Material			
	Untreated Silos 1 and 2 Material	Unpackaged		Packaged	
		Vitrification	Chemical Stabilization	Vitrification	Chemical Stabilization
Radon Flux[1] (pCi/m^2s)	1,985 - 7,314	0.001 - 0.06	220 - 1,400	<0.001	<0.001
On-contact Radiation Dose[1] (mrem/hr)	~900	520 - 550	180 - 270	45 - 70	50 -70

[1]Data taken from the original OU4 FS.

Although each alternative is favored in individual aspects of short-term effectiveness, from an overall perspective this criterion favors CHEM1 and CHEM2 alternatives. Short-term environmental impacts are essentially equivalent for all alternatives. Due to the greater number of person-hours required to complete treatment, and physical hazards inherent to the vitrification process, the VIT1 and VIT2 alternatives pose greater risk to on-site workers. Conversely, due to the greater number of shipments required to ship the larger volume of treated material for the CHEM1 and CHEM2 alternatives equates to an incrementally higher transportation risk for these alternatives. Due to a shorter design-construction start-up period, and a more feasible schedule acceleration, CHEM1 and CHEM2 alternatives are preferred with respect to time to achieve protection.

Short-term impacts associated with all four alternatives include temporary disruption of several acres of land at the FEMP site for construction of the treatment facility, and material handling. There is a potential for increased fugitive dust during construction activities; however, the appropriate controls minimize the potential short-term impacts.

The radiological risks from remediation activities (i.e., construction, operation, and D&D) are essentially the same for VIT1, VIT2, CHEM1 and CHEM2 alternatives (approximately 3×10^{-4} ILCR). However, VIT1 and VIT2 present an increased non-radiological risk to the worker during on-site operations due to the greater number of person-hours estimated to complete remediation and physical hazards in the work place. An occupational hazard analysis of the proposed design for each full-scale treatment facility was performed with respect for the workers involved with the on-site O&M activities **(Appendix B)**. **Table 4.2-3** presents a summary of discriminating hazards posed to workers as determined by the analyses of all four alternatives.

Chemical stabilization presents a marginal increase in risk during shipment preparation activities due to the greater number of containers resulting in more person-hours of exposure.

TABLE 4.2-2
SUMMARY OF KEY HAZARDS TO ON-SITE WORKERS

Physical hazards due to vehicle and container movement.	Greater hazard for chemical stabilization due to greater number of containers.
Falls	Greater hazard for vitrification due to more elevated equipment.
Exposure to hazardous chemicals and toxicants.	Greater hazard for vitrification due to toxic constituents (So_x, NO_x, lead - storage of caustic for scrubber, and gases).
Electrical Shock	Greater hazard for vitrification due to higher power requirements and more complex electrical system.
Human Hazards	Greater hazard for vitrification due to greater number of work hours.
High or Changing Pressure	Greater hazard for vitrification due to remote potential for over-pressurization of the melter and potential releases from the EOG System.
Thermal Hazards	Greater hazard for vitrification due to high temperature in the melter, handling of molten glass, and high temperature off-gas.
Spills/Loss of Containment	Greater hazard for vitrification due to molten glass, toxic off-gas constituents, higher radon concentrations, and caustic storage that results in greater consequences for spills, leaks, etc.

For all alternatives, transportation to the NTS will comply with DOT regulations and DOE guidelines. The transportation of the Silos 1 and 2 material to the NTS by either truck or intermodal shipments is protective of human health and the environment in accordance with CERCLA guidelines. The radiological and non-radiological risks from transportation of the treated material to the NTS are marginally higher for the CHEM1 and CHEM2 alternatives than for VIT1 and VIT2 because of the greater number of shipments required to ship the larger volume of treated material. In the event of a transportation accident and a subsequent loss of containment, the vitrified wasteform presents a higher risk to emergency response workers due to its higher contact dose.

The VIT1 and VIT2 processes liberate essentially all of the radon from the Silos 1 and 2 material during treatment process. The CHEM1 and CHEM2 alternatives liberate less radon during the treatment process, but continue to generate radon during subsequent product handling operations. In all cases, sufficient radon control mitigates radon releases and attain environmental and worker protection limits.

The vitrification facilities are equipped with an EOG System to protect against over pressurization of the Melter System. In the event the EOG System is activated, the feed to the melter would be shut down to prevent a continuous unmitigated release of radon into the atmosphere. Although there would be a release of radon from the EOG System, the release would be limited to the contents of the melter. It is expected that a release of radon from the contents of the melter would not significantly impact the FEMP fenceline regulatory requirements or the public.

All four alternatives are able to meet the radon flux limit of 20 $pCi/m^2 \cdot s$ during interim storage at the FEMP and after disposal at the NTS.

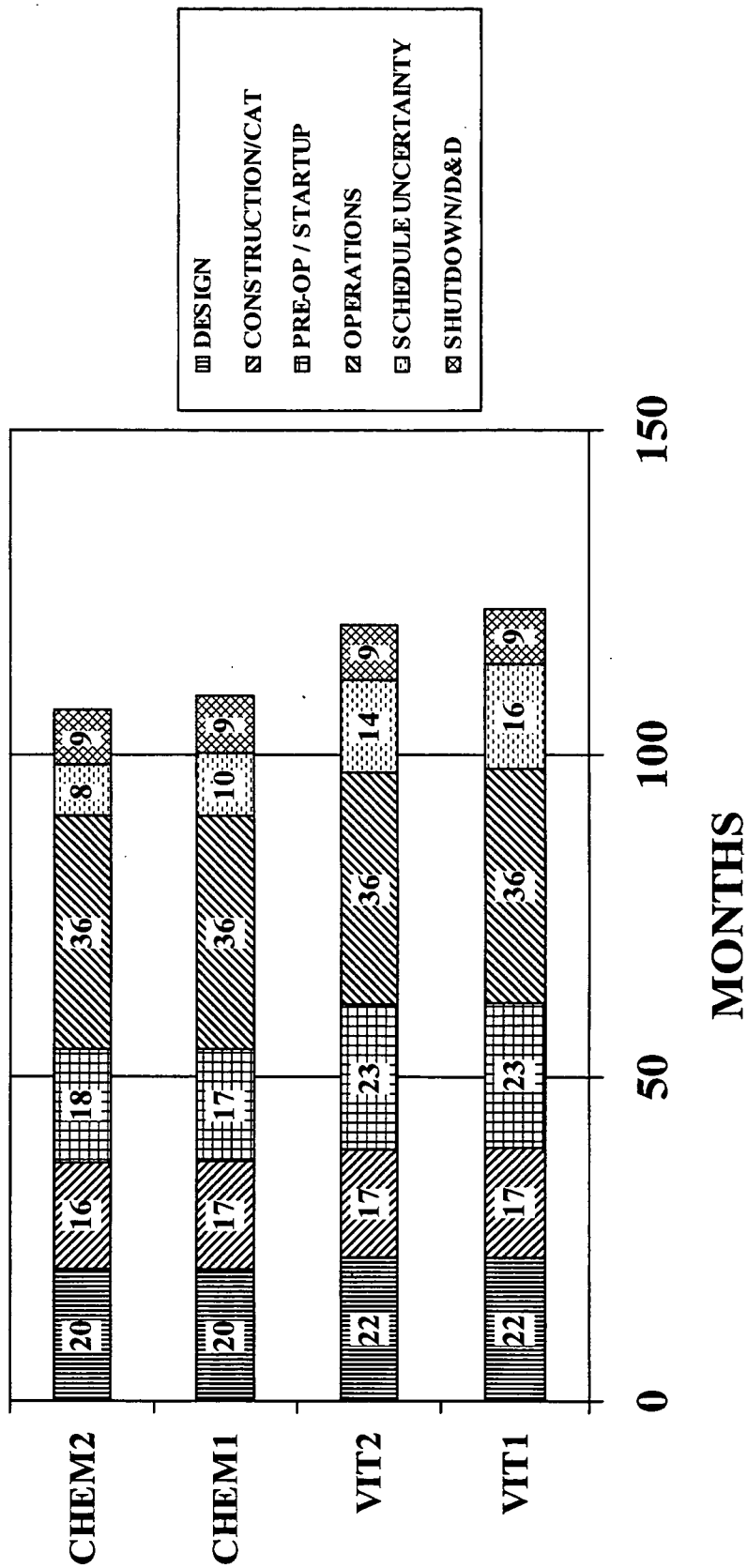
The time required to achieve protection through the implementation of the remedial alternatives varies between the VIT1 and VIT2 and the CHEM1 and CHEM2 alternatives. **Figure 4.2-3** presents a comparative summary of the schedules for each alternative.

The time period between the approval of the ROD Amendment and the initiation of treatment operations (design, construction, construction acceptance testing, preoperations and start-up) for the Silos 1 and 2 remediation is estimated to be 62 months for vitrification, compared to 54 months for chemical stabilization. The difference of eight months between the two schedules is primarily attributed to the time required, based upon lessons learned during start-up of DOE vitrification facilities, to perform Proof of Process testing during the start-up of the VIT1 and VIT2 alternative's facilities.

The durations of the operations schedule for each alternative were fixed at 36 months based on a common design basis assumption **(Appendix G, Section G.1)**.

FIGURE 4.2-2

TIME TO ACHIEVE PROTECTION
SCHEDULE COMPARISON



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The ability of the alternative to achieve the 3-year operational schedule carried a certain risk based on the contractor's proposed design for the full-scale treatment facility. Based on commercial demonstration and DOE experience, the O&M activities having the potential to delay the treatment of the Silos 1 and 2 material were evaluated for schedule risk. The failure mode, likely schedule consequences and their probability of occurrence, were evaluated to determine operations schedule risk for the four alternatives. The CHEM1 and CHEM2 alternatives present less O&M uncertainty (8-10 months) compared to VIT1 and VIT2 (14-16 months) due to technical uncertainties associated with the thermal treatment operations and off-gas systems.

While the VIT1 and VIT2 alternatives require full-time (24 hr/day, 7 days/week) operation to complete treatment within the specified 3-year period, the CHEM1 and CHEM2 alternatives can complete treatment within three years, with less than full-time operation. Less than full-time operation leaves 'excess' operating time (shifts per day or days per week) available to recover from unplanned downtime. This excess operating time results in higher confidence in the ability of the CHEM1 and CHEM2 alternatives to complete treatment within the 3-year period.

4.2.2.4 Implementability

Figure 4.2-4 summarizes the implementability analysis. Overall, this criterion favors CHEM1 and CHEM2 due to a greater degree of commercial demonstration of the treatment technology, less complexity of integrated systems, and greater confidence in their ability to be successfully implemented.

<END OF PAGE>

FIGURE 4.2-3
IMPLEMENTABILITY SUMMARY TABLE

ITEM	VIT1/VIT2			CHEM1/CHEM2		
	Strongly Favors	Favors	Neutral	Favors	Strongly Favors	
Technical Feasibility						
Scaleup			↓			
Commercial Demonstration				↓		
Operability						
Ease of Operation				↓		
Reliability				↓		
Maintainability				↓		
Complexity				↓		
Ease of Acceleration				↓		
Constructability (Ease of Construction/Fabrication, Ease of D&D)				↓		
Administrative Feasibility (Licensing and Programmatic)			↓			
Availability of Services (Contractors, Equipment and Utilities)			↓			

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The evaluation of implementability indicates that although both vitrification and chemical stabilization are feasible and can be successfully implemented, there are significant technical challenges such as process control, adaptation of the process to remote operation, feed preparation, and product handling that apply to each alternative. The operability characteristics of vitrification increase the uncertainty in its ability to be successfully implemented.

All four alternatives will experience multiple challenges in adapting the process for remote operations (treatment and product handling) as a result of unique radiological, physical, and chemical characteristics (high-radium, erosive, and sticky due to BentoGrout™ content) of the Silos 1 and 2 material. It should be noted that the term "simplicity" and/or the phrase "easier to implement" are relative only to the comparison between the alternatives. All four of the alternatives are considered complex to implement for the Silos 1 and 2 material.

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4.2.2.4.1 Technical Feasibility

Scaleup

Based on the results of the POP testing, all four alternatives can be scaled up to achieve the proposed full-scale treatment capacity required to remediate the Silos 1 and 2 material within the 3-year operating period. The possible exception is the Vitrification — Joule-heated process option that has not been demonstrated at the required scale on radioactive or hazardous materials.

Scaleup issues exist for all four alternatives for the balance of plant systems. The CHEM1 and CHEM2 alternatives require more modification of specialized process equipment (e.g., filter press, mix-fill head) to be suitable for nuclear applications. The VIT1 and VIT2 alternatives require a complex Normal Off-gas System to scrub particulates and acid gases, and condition emissions before radon abatement. Although the individual components comprising this system are standard commercial applications, their integrated operation in combination with the melter and other systems increases the complexity of operation. Similarly, a significant level of development to demonstrate systems such as feed stream drying and lead partitioning in the off-gas is required for some vitrification processes.

Commercial Demonstration

The technologies proposed in three of the four alternatives have been demonstrated on a limited basis with material reasonably similar to the Silos 1 and 2 material, at the scale being proposed by the POP contractors. The only exception is VIT1, which requires a scaleup by a factor of 3 from that which has been demonstrated at the Savannah River, M-Area Site (5 TPD) on radioactive or hazardous material to achieve the 15 TPD proposed by the POP contractor. The VIT2 process has been demonstrated at a limited commercial facility (ORMET Aluminum Inc., Hannibal, OH). The CHEM1 process has been applied above the proposed scale (Weldon Spring, MO). The CHEM2 process has been demonstrated at one location (Barnwell, SC) at the proposed capacity. Overall, there is a significantly greater level of commercial experience with CHEM1 and CHEM2 processes in treatment of hazardous, radioactive, and mixed waste.

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Operability

The CHEM1 and CHEM2 alternatives are easier to operate than VIT1 and VIT2 due to ease of process control, less complexity, fewer unit operations, and the ability to recover from upset conditions. **Table 4.2-4** presents a summary of the unit operations for each alternative. The operability characteristics of vitrification increase uncertainty in its ability to be successfully implemented. The integrated operation of complex systems increases the likelihood of process upsets and resulting downtime for VIT1 and VIT2. Complex process control parameters complicate melter operation (viscosity, electrical conductivity, liquidus temperature, sulfate formation). The hazards inherent to the vitrification process (high temperature) increase risks during maintenance and make recovery from upsets more difficult.

For the same reasons, the CHEM1 and CHEM2 alternatives are easier to maintain and less complex overall.

All four alternatives are comprised of reliable individual components; however, the reliability of the integrated systems adapted for remote operation has not been demonstrated. DOE vitrification projects (DWPF, West Valley, NY and Savannah River M-Area) have experienced significant reliability concerns during start-up and initial operations. The VIT1 and VIT2 alternatives include additional unit operations (off-gas) that have unknown reliability as an integrated system. For these reasons, the CHEM1 and CHEM2 alternatives are favored for reliability.

From the standpoint of ease of acceleration of the operation schedule, the CHEM1 and CHEM2 alternatives are favored. The CHEM1 and CHEM2 alternatives could accelerate/recover schedule by increasing the operating schedule from 16 hr/day, 5 days/week and 24 hr/day, 5 days/week, respectively, to 24 hr/day, 7 days/week; while the VIT1 and VIT2 alternatives are already operating at the maximum capacity of 24 hr/day, 7 days/week. **Table 4.2-5** illustrates this by summarizing the total required number of operational hours over the 3-year period. Acceleration results in additional cost to increase the plant capacity by increasing product curing and storage space. The VIT1 and VIT2 alternatives require additional melter trains or increased melter capacity combined with increased feed drying/preparation components, a larger Normal Off-gas System, and additional cooling and storage space to increase plant capacity.

TABLE 4.2-3
SUMMARY OF KEY UNIT OPERATIONS

VIT1	VIT2	CHEM1	CHEM2
Feed Preparation/Additive Mixing	Feed Preparation/Additive Mixing	Clarifier	Clarifier
Melter	Slurry Dryer	Slurry Tank	Slurry tank
Glass Packaging - Product Cooling	Hammermill	Filter Press	Mix-fill Head
Film Cooler	Combustion Melter	Batch Mixer	Rework System
Quench Tower	Combustion Air Preheater	Treated Waste Packaging	
Caustic Scrubber	Frit Tank and Conveyor	Wastewater Treatment	
Electrostatic Precipitator	Quench Tower	Rework System	
NO_x Removal System	Caustic Scrubber		
Condenser	Electrostatic Precipitator		
EOG System	Filter Press		
Cooling Tower	NO_x Removal System		
Wastewater treatment	Condenser		
Rework System	EOG System		
	Cooling Tower		
	Additional Radon Control		
	Wastewater Treatment		
	Rework System		

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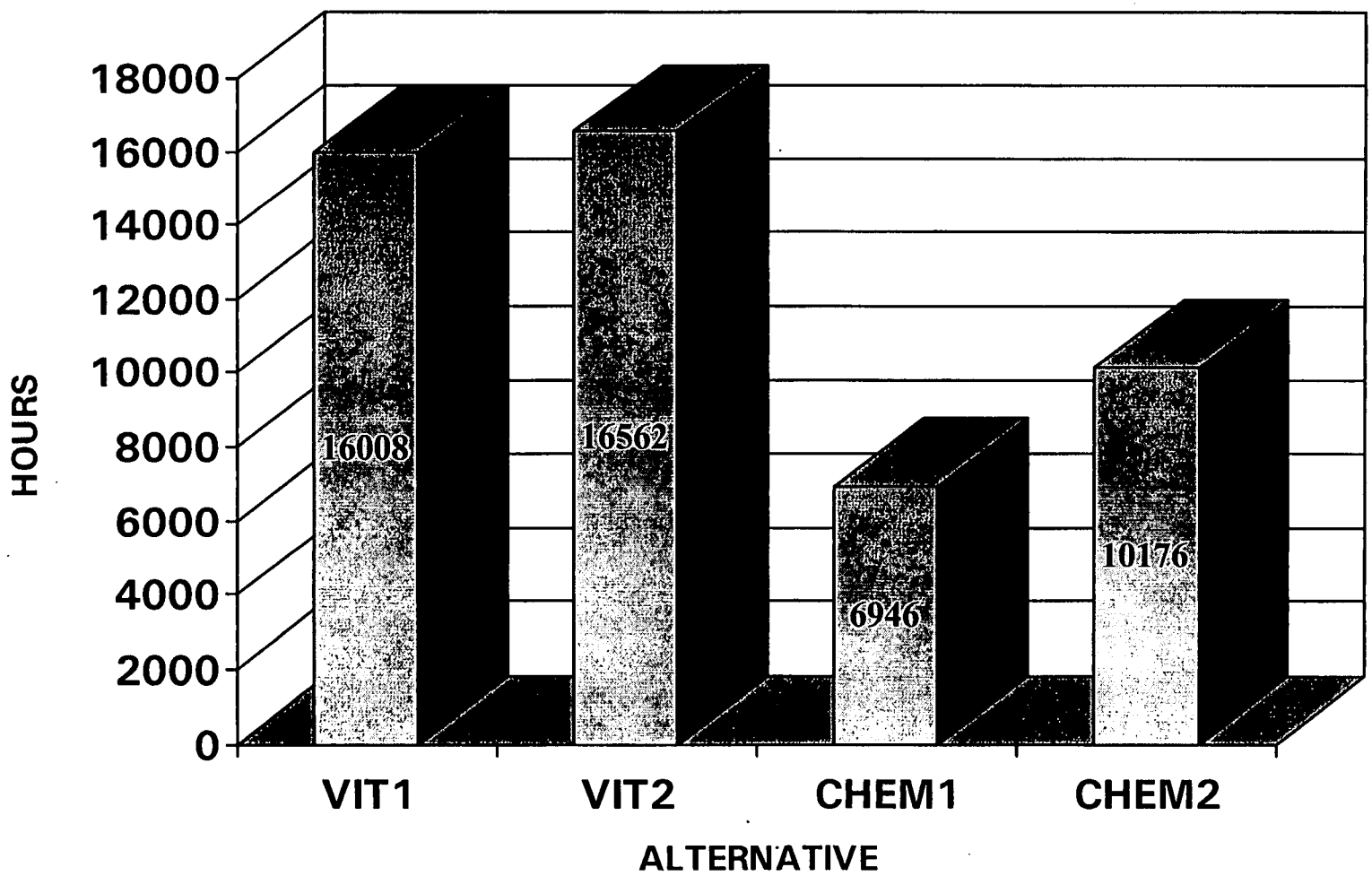
FIGURE 4.2-4
SUMMARY OF TOTAL REQUIRED OPERATING HOURS



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Constructability

Constructability of the CHEM1 and CHEM2 alternatives is considered easier than the VIT1 and VIT2 alternatives. This is due to the need for field erection of the melter versus modularized components for CHEM1 and CHEM2 (mixer, filter press, mix-fill head) that can be fabricated and tested off-site. Additionally, there are greater quantities of piping, electrical components, and controls for the VIT1 and VIT2 processes.

4.2.2.4.2 Administrative Feasibility

Because remediation activities will be performed at the FEMP, permits and licenses are not required for any of the alternatives.

Treated material from each alternative is disposed at the NTS. Because the NTS is a DOE-owned facility, special permits for disposal of treated Silos 1 and 2 material at the NTS are not required. DOE-NV has indicated that the Silos 1 and 2 material - treated by either alternative - will be approved for disposal at the NTS as long as it meets the WAC. An addendum to the NTS PA for the selected disposal location will determine the final depth and configuration for disposal.

The DOE-FEMP has an established low-level waste shipping program with the NTS. Since 1985, the DOE-FEMP has completed in excess of 4,600 direct truck shipments from the FEMP to the NTS. The FEMP has, on an as-needed basis, sustained shipping campaigns on the order of 5 to 6 shipments per day for 2 to 3 month-long periods. The FEMP has also achieved a maximum of 17 shipments in one day.

Based on a proposed seven day per week shipping campaign, the average shipping rates for the remedial alternatives necessary to support the 3-year operations schedule is one shipment per day for VIT1 and VIT2 and three shipments per day for CHEM1 and CHEM2. These proposed shipping rates could easily be handled by the NTS and the FEMP shipping program.

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4.2.2.4.3 Availability of Services

Contractors are available to competitively bid the design, procurement of materials and equipment, and construct and operate the remediation facilities needed to implement each alternative.

The NTS is an approved off-site disposal facility that has the equipment and facilities to safely dispose of and manage the treated Silos 1 and 2 material.

4.2.2.5 Cost

The cost evaluation is based on estimates that were developed from the four preconceptual designs presented in **Appendix G** and the technology-specific POP testing information presented in **Appendix H,** using a variety of cost-estimating methods. The cost estimates were developed for (1) capital costs; (2) O&M costs; (3) waste shipping and disposal costs; (4) D&D costs; (5) engineering costs; (6) project management costs; and (7) cost of money. The cost estimates are prepared as "bottom up" estimates, which evaluate and estimate each cost element identified in the preconceptual design. Therefore, the accuracy of the estimates is a function of the preconceptual designs. The accuracy of the four estimates is between +50% to -30%, consistent with CERCLA guidance. Since potential contractors will be given the opportunity to propose their unique designs based on their commercial experience, the actual design may change significantly. The +50/-30% accuracy establishes a range that is likely to capture that which is ultimately bid in response to a RFP to remediate the Silos 1 and 2 material. All estimates were developed in FY99 dollars so that the alternatives with costs incurred over differing time periods can be evaluated on an equivalent basis.

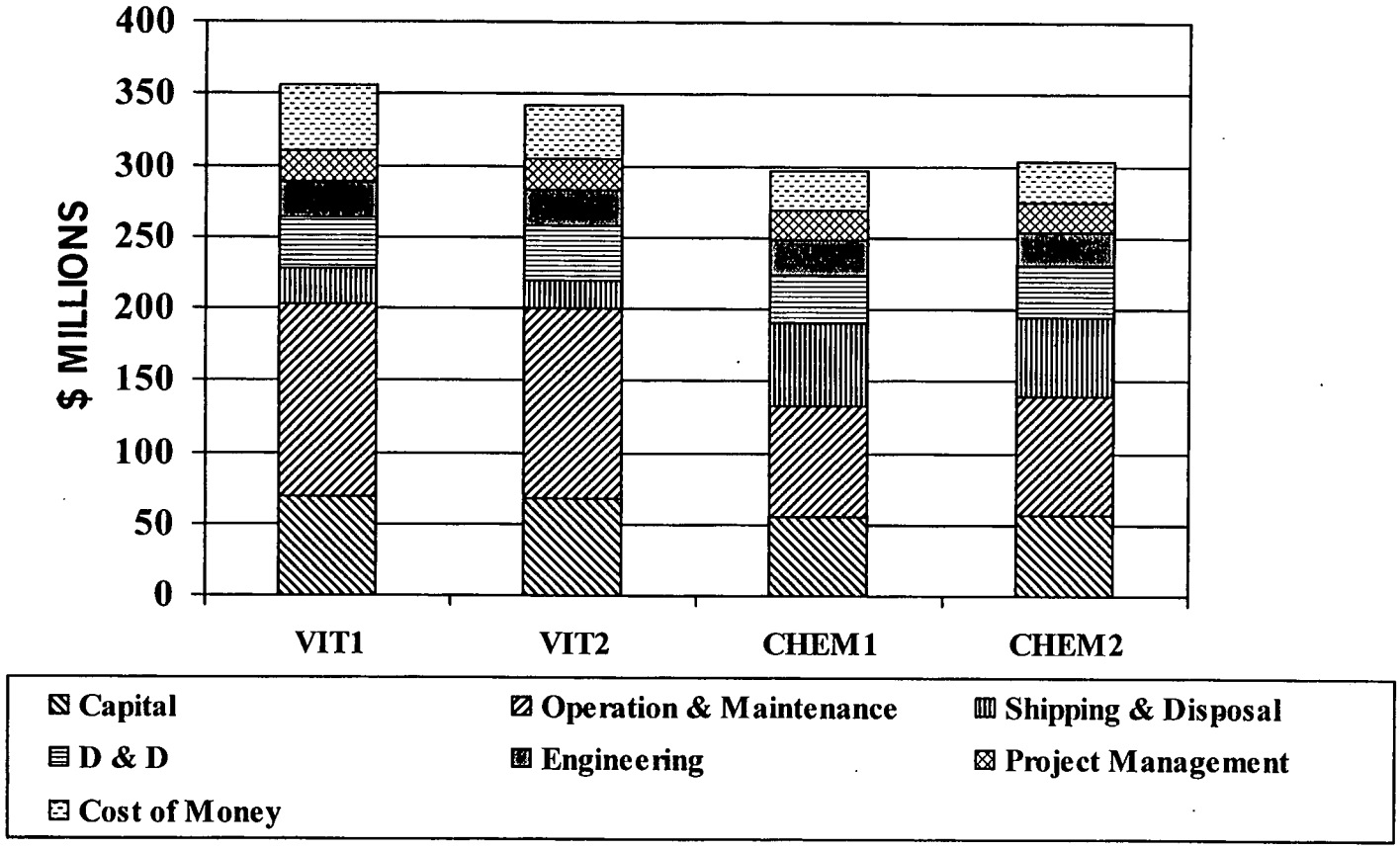
Table 4.2-6 and **Figure 4.2-5** summarize the major cost elements for the four alternatives.

TABLE 4.2-4
FEASIBILITY STUDY SUMMARY COST DATA (ALL ALTERNATIVES)
($ MILLIONS)

Alternative	Vitrification		Chemical Stabilization	
Process Option	VIT1	VIT2	CHEM1	CHEM2
Capital Cost	69	67	55	56
Operation and Maintenance Cost	134	133	77	83
Waste Shipping and Disposal Cost				
Packaging	17	12	34	33
Transportation	5	5	14	13
Disposal	3	3	10	9
D&D Cost	35	38	34	36
Engineering Cost	25	25	24	24
Project Management Cost	22	22	21	21
Cost of Money	46	37	28	28
Summary cost (un-escalated)	356	342	297	303

In general, all four process options are cost effective. That is, the costs appear proportional to the overall protectiveness provided by the alternatives, both during and following the remediation period. The cost differential between the VIT1 and VIT2 alternatives and the CHEM1 and CHEM2 alternatives is approximately 16%, with the cost of CHEM1 and CHEM2 being lower. The following discussion identifies the differences between the four alternatives for the key cost elements.

FIGURE 4.2-5
FEASIBILITY STUDY COST COMPARISON



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Capital Cost

The VIT1 and VIT2 capital costs are higher than the CHEM1 and CHEM2 capital costs due to the complexity of the process equipment. The need for sizeable interim storage areas for CHEM1 and CHEM2 alternatives partially offset the higher equipment costs of the VIT1 and VIT2 alternatives.

Operations and Maintenance Cost

The VIT1 and VIT2 alternatives have higher O&M costs than CHEM1 and CHEM2 alternatives for the following reasons:

- VIT1 and VIT2 operations are on a 24 hr/day, 7 days/week schedule;
- VIT1 and VIT2 require a 8 month Proof of Process testing (full-scale surrogate operations);
- VIT1 and VIT2 have more expensive spare parts (specialized). Melter refractory life is limited and may need to be replaced during the 3 years of operation;
- VIT1 and VIT2 use more costly consumables (chemicals, supplies) and utilities (electricity, natural gas); and
- VIT1 and VIT2 have additional operational schedule risk.

Waste Shipping and Disposal Cost

CHEM1 and CHEM2 have higher packaging, transportation, and disposal costs than VIT1 and VIT2. The lower waste loading of chemical stabilization produces a greater volume of treated material, which results in an increased number of disposal containers and shipments.

D&D Cost

The D&D costs are roughly equivalent for all alternatives.

In general, VIT1 and VIT2 have higher D&D costs due to more complicated (e.g., multiple floors, equipment) plant layouts. This difference is offset by a higher D&D cost for CHEM1 and CHEM2 due to their larger interim storage facility and, consequently, more building debris.

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Engineering Cost

VIT1 and VIT2 have a slightly higher engineering cost than CHEM1 and CHEM2 due to the complexity of the process designs.

Project Management Cost

VIT1 and VIT2 have a higher project management cost than CHEM1 and CHEM2 due to the VIT1 and VIT2 schedules being 8 months longer for the Proof of Process testing, with project management being a level-of-effort based on the schedule duration.

Cost of Money

Based on the contracting strategy adopted for the remediation of the Silos 1 and 2 material, the full-scale remediation contractor must borrow money to finance the design and construction effort; this borrowing is well in advance of being reimbursed in accordance with a predetermined pay item schedule. Since VIT1 and VIT2 have a higher upfront capital cost investment, VIT1 and VIT2 have a higher cost of money than CHEM1 and CHEM2.

4.3 Treatment Alternatives for the Silos 1 and 2 Material

The four alternatives evaluated in **Section 3 - *Detailed Analysis of Alternatives*** consist of two treatment technologies (vitrification and chemical stabilization), each represented by two specific processes (VIT1, VIT2 and CHEM1, CHEM2). Two processes for each treatment technology were chosen in order to provide a balanced analysis of each technology against the CERCLA evaluation criteria. Throughout the detailed analysis, discrete differences unique to each process design were noted. However, no fundamental differences in any CERCLA evaluation criteria were identified between either the two vitrification processes, or between the two chemical stabilization processes. It is clear from the detailed evaluation that the discriminating differences between the four alternatives are associated with differences between the two treatment technologies (vitrification versus chemical stabilization), as opposed to differences between the individual processes used to represent each technology.

No significant differences were identified in the detailed analysis of alternatives that provide a compelling reason to eliminate any one process option from further consideration in either of the two treatment technology alternatives. For this reason, the PP will only compare two treatment alternatives: Vitrification and Chemical Stabilization. This comparative analysis will focus on the discriminating differences between these two alternatives based upon the detailed analysis of the four process options in **Section 3**.

The final remedy selection decision will be between the vitrification and chemical stabilization technologies. The treatment systems described in this FS are based upon data and other information compiled from POP testing and have been developed as viable ways to remediate the Silos 1 and 2 material. Equivalent vitrification or chemical stabilization processes may become commercially available and are not precluded from consideration, consistent with the selected remedy during RD. As previously stated, the selected remedy will include a treatment technology (for on-site treatment), retrieval of the Silos 1 and 2 material from the TTA, and off-site disposal of the treated material at the NTS.

<END OF SECTION>

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Section 5

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1 Documentation of Remedial Investigation/Feasibility Study activities for each OU is made available for public review. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Administrative Records for the FEMP site are located at the Public Environmental Information Center (PEIC) in Harrison, OH. (513) 648-7480.

2 Documents can be ordered from the National Technical Information Service at 1-800-553-6847.

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Appendix A

APPENDIX A

ANALYSIS OF POTENTIAL ARARs FOR SILOS 1 AND 2 MATERIAL

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ACRONYMS & ABBREVIATIONS

AEA	Atomic Energy Act
ARAR	applicable or relevant and appropriate requirement
BMP	best management practices
CAA	Clean Air Act
CAMU	corrective action management unit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	constituent of concern
CWA	Clean Water Act
DCG	derived concentration guides
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EDE	effective dose equivalent
EPA	U.S. Environmental Protection Agency
FEMP	Fernald Environmental Management Project
FS	Feasibility Study
ISA	Initial Screening of Alternatives
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NPDES	National Pollution Discharge Elimination System
NRC	Nuclear Regulatory Commission
NTS	Nevada Test Site
NWP	Nationwide Permit
OAC	Ohio Administrative Code
OEPA	Ohio Environmental Protection Agency
OSHA	Occupational Safety and Health Administration
OU	operable unit
RCRA	Resource Conservation and Recovery Act, as amended
RI	Remedial Investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SWMU	solid waste management units
TBC	to be considered
TCLP	Toxicity Characteristic Leaching Procedure
UMTRCA	Uranium Mill Tailings Radiation Control Act

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A.1.0 ANALYSIS OF POTENTIAL ARARS FOR SILOS 1 AND 2 MATERIAL

A.1.1 Introduction

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 created a federal program for the cleanup of uncontrolled releases of hazardous substances into the environment. The Superfund Amendments and Reauthorization Act (SARA), enacted in 1986, reauthorized the program for an additional five years, and the Omnibus Reconciliation Act of 1990 again extended the CERCLA program. SARA added guidance on developing cleanup standards, a preference for permanent solutions and support for the development of innovative technologies, and codified many U.S. Environmental Protection Agency (EPA) practices that evolved during site evaluation and remediation occurring in the first years of the program.

CERCLA provides guidance on the specific cleanup standards that should be applied to remedial actions and/or to the criteria for choosing among remedial alternatives when implementing regulations for CERCLA and SARA and 40 Code of Federal Regulations (CFR) Part 300, which are referred to as the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Nine selection criteria for choosing among remedial actions are presented in Subpart E - Hazardous Substance Response, 40 CFR Part 300.430(e)(9). One of the nine criteria states that the action will comply with applicable or relevant and appropriate requirements (ARARs). The NCP further defines the criteria for remediation of a facility by requiring that on-site remedial actions must attain or exceed the ARARs in federal and state environmental and public health laws.

This appendix provides an analysis of the approved ARARs listed in Appendix B of the *Record of Decision (ROD) for Operable Unit 4 (OU4) of the Feed Materials Production Center* (EPA 1994). Additionally, this appendix provides the outcome of a recent analysis of regulations that have been promulgated since approval of the OU4 ROD in 1994 and which may be included into the approved ARARs list.

A.1.2 ARARs Defined

Section 121(d) of CERCLA requires that the site, at the completion of remedial actions, achieve a level of control that complies with federal and state environmental laws that are applicable or relevant and appropriate for hazardous substances, pollutants, or contaminants that remain on-site.

The NCP defines applicable requirements as:

> *The cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by the state in a timely manner and that are more stringent than federal requirements may be applicable (40 CFR Part 300.5).*

"Applicable" implies that the remedial actions or the circumstances at the site satisfy the jurisdictional prerequisites of a requirement. Although a requirement may not be applicable as defined in the NCP to a specific release, it may be "relevant and appropriate." The NCP defines relevant and appropriate requirements as the "cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site such that their use is well suited to the particular site." Only those state standards that are identified by the state in a timely manner and are more stringent than these federal requirements may be relevant and appropriate (40 CFR Part 300.5). In some circumstances, a requirement may be "relevant" but not "appropriate" for the site-specific situation. A requirement must satisfy both the "relevant" and "appropriate" components.

Section 121 of CERCLA requires selection of a remedial action that is protective of human health and the environment. Such protectiveness, as determined by a site risk assessment, may not always be attained by the ARARs. In certain cases, standards may not exist in the promulgated regulations that address the proposed action or the constituent of concern (COC). In these cases, nonpromulgated advisories, criteria, or guidance that were developed by the EPA, other federal agencies, or states are "to be considered" (TBC) in establishing remedial action objectives (RAOs) that are protective of human health and the environment. In addition, TBCs may provide information necessary to develop CERCLA remedies.

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.

For the Fernald Environmental Management Project (FEMP), the formal definition of the term "site" in the context of this CERCLA remedial action includes not only the former production area inside the fence, but also areas contaminated by the migration of a hazardous substance, pollutant, or contaminant from any of the properties under the custody or accountability of the U.S. Department of Energy-Fernald (DOE-FN). The term "on property" is included in the definition of "on-site," but includes only that part of the site under direct control or ownership by DOE. The term "off-site" refers to all other areas that are not under the direct control of DOE and are not contaminated by DOE waste or activities.

On-site actions are required to comply with ARARs, but this compliance pertains only to the substantive parts of an ARAR. For applicable requirements that are identified for alternatives involving off-site activities, both administrative and substantive parts of that ARAR must be met. Since only applicable requirements must be met for remedial activities conducted off-site, relevant and appropriate requirements for alternatives involving off-site disposal must be met only for the on-site portions of that alternative. The application of specific environmental regulations to activities being considered for off-site facilities, such as land disposal of stabilized waste at the Nevada Test Site (NTS), would be addressed by the facility owners/operators in the environmental compliance documents and requirements which govern the NTS.

Although an off-site treatment facility *would not* be required to comply with applicable requirements for the State of Ohio, an off-site treatment facility *would* be required to (1) comply with applicable state, local, and federal requirements governing operation of the off-site treatment facility, and (2) possess the necessary licenses and permits to handle and process Silos 1 and 2 material. These requirements include those covered under occupational safety, radiological control, nuclear safety, quality assurance, air, water, and solid waste programs existing in the state where the treatment facility is located. Examples of these requirements include compliance with permitting requirements for air emissions and wastewater discharges, and compliance with radionuclide concentrations under the facility's nuclear license and disposal requirements for solid, hazardous, radioactive, and mixed wastes.

An off-site treatment facility and/or disposal facility would be required to comply with the CERCLA Off-site Rule before receiving Silos 1 and 2 material. The CERCLA Off-site Rule (found in CERCLA Section 121 (d)(3) and promulgated at 40 CFR Part 300.440) requires that waste from a remedial action that is shipped off-site for treatment and/or disposal be transferred only to those units at a facility that (1) are operating in compliance with the Resource Conservation and Recovery Act, as amended, (RCRA) and with applicable federal and state requirements, and (2) do not have uncontrolled releases of hazardous waste or constituents. The CERCLA Off-site Rule applies to the Silos 1 and 2 material, although it is defined as Atomic Energy Act (AEA) 11(e)(2) by-product material, excluded under RCRA. The policy applies to any remedial action involving the transfer of hazardous substances, pollutants, or contaminants as defined under CERCLA Sections 101(14) and (33) pursuant to any CERCLA authority, including cleanups at Federal Facilities [40 CFR Part 300.440(a)(1)]. Both an off-site treatment facility and an off-site disposal facility would require documentation demonstrating compliance with RCRA and the CERCLA Off-site Rule.

A.1.3 ARARs Strategy

The potential change in the selected remedy does not require revision of the current OU4 ARARs; this is based upon an evaluation of:

1) The scope of and rationale for the change in remedy being considered in the Silos 1 and 2 Feasibility Study/Proposed Plan (FS/PP) revision;

2) Requirements promulgated since signature of the original OU4 ROD (EPA 1994); and

3) Requirements of the NCP.

The remedy selected in the ROD consisted of the following major components:

- Removal of contents from the Silos 1, 2, and 3 structures;
- On-site remediation of the silos material by vitrification;

- Disposal of the stabilized silos material at the DOE's NTS;
- Decontamination and demolition of all silos structures and the vitrification facility in accordance with the approved OU3 ROD (FEMP 1996a); and
- Excavation and treatment of contaminated soils, and treatment of perched water encountered during remedial action, in accordance with the approved OU5 ROD (FEMP 1996b).

The July 22, 1997, *Agreement Resolving Dispute Concerning Denial of Request for Extension of Time for Certain Operable Unit 4 Milestones* (EPA 1997) specified that the change in remedy for Silo 3 material should be documented in an Explanation of Significant Differences, and further, that due to projected cost increases, the FS, PP, and ROD for Silos 1 and 2 Remedial Action should be revised and resubmitted.

The revised Silos 1 and 2 FS/PP addresses alternatives for completing the remediation portion of the existing selected remedy for Silos 1 and 2 material. The alternatives evaluated in the revised FS only allow consideration for on-site treatment with disposal at the NTS. Neither a change to the existing general response action, nor RAOs, nor addition of new components to the remedial action evaluated in the original FS, will be evaluated as part of the revised FS/PP.

The NCP requires attainment or waiver of ARARs that become effective after a ROD is signed only when it is determined to be "necessary to ensure that the remedy is protective of human health and the environment" [40 CFR Part 300.430(f)(1)(ii)(B)(1)].

In cases where a ROD Amendment adds a new component of the remedy not described in the original ROD, the new component of the remedy must attain or waive any ARAR promulgated at the time that the ROD Amendment, which added the new component to the remedy, was signed [40 CFR Part 300.430(f)(1)(ii)(B)(2)].

This revised Silos 1 and 2 FS, and subsequent PP and ROD Amendment, are being prepared in order to evaluate alternatives for implementing the remediation component of the selected remedy for Silos 1 and 2 material. The rationale driving this reevaluation is projected cost increases for implementation of the original remediation method. The revised FS/PP and ROD Amendment will not add a new component to the remedy evaluated in the original ROD.

The change in remedy being evaluated in the revised FS is limited to reexamination, from a technical and cost standpoint, of the most effective means for implementing the remediation component for the original remedy proposed by the OU4 FS (FEMP 1994) and approved in the OU4 ROD (EPA 1994). Neither the general response action (remediation and off-site disposal) nor the RAOs are being reevaluated.

As required by the NCP, this revised FS will evaluate remediation alternatives in detail against the nine NCP criteria, including the threshold criteria of compliance with regulations and overall protectiveness [40 CFR Part 300.430(e)(9)(iii)]. The PP will demonstrate, based upon the results of this revised FS, that the proposed remediation remedy will be protective of human health and the environment if successfully implemented in accordance with current OU4 ARARs. The revised FS/PP will demonstrate, therefore, that attainment of ARARs promulgated after signature of the existing OU4 ROD (EPA 1994) is not necessary to ensure that the remedy will be protective of human health and the environment. The change in remediation technology, which will be evaluated in the revised Silos 1 and 2 FS/PP and documented in the ROD Amendment, does not meet the criteria specified by the NCP [40 CFR Part 300.430(f)(1)(ii)(B)] that requires modification of ARARs.

The ARARs identified in the OU4 ROD for vitrification of the Silos 1 and 2 material also pertain to chemical stabilization of the Silos 1 and 2 material. Therefore, modifications to the ARARs and TBCs are not expected as a result of changing the preferred alternative for the silos material from vitrification to chemical stabilization (followed by transport for final disposition at the NTS). In addition, FDF has conducted a thorough evaluation of the requirements promulgated since December 1994, and concluded that new requirements impacting selection of the Silos 1 and 2 material remedy have not been promulgated. The ARARs and TBCs identified for remediation of the Silos 1 and 2 material are presented in **Tables A.1.3-1** through **A.1.3-3**.

The requirement(s) of the ARARs and TBC, as well as the rationale for implementation and the affected alternatives, are presented in **Tables A.1.3-1** through **A.1.3-3**. When two or more standards that cover the same regulatory area were identified, the more stringent or prescriptive standard was selected for inclusion in the tables. Other non-ARAR, non-TBC requirements, which are critical to the remedial actions, are described in **Section A.3.4** and presented in **Table A.1.3-4**.

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TABLE A.1.3-1

POTENTIAL ARARS FOR SILOS 1 AND 2 MATERIAL REMEDIAL ACTION ALTERNATIVES, CHEMICAL-SPECIFIC

Medium	Clean Air Act (CAA)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Air	Radionuclide Emissions (Except Airborne Radon-222), 40 CFR Part 61 Subpart H.	Emissions of radionuclides to the ambient air from DOE facilities shall not exceed those amounts that might cause any member of the public to receive, in any year, an effective dose equivalent (EDE) of 10 mrem or greater per year. Monitoring is required at release points having potential to discharge radionuclides that could cause an EDE in excess of 1% of the standard (0.1 mrem/yr) to any member of the public.	Applicable	Radioactive materials within Silos 1 and 2 might contribute to the dosage to members of the public from the air pathway during implementation of remedial actions since the National Emissions Standards for Hazardous Air Pollutants (NESHAP) applies to operating units.	VIT1 VIT2 CHEM1 CHEM2
Air	Radon-222 Emissions, 40 CFR Part 61 Subpart Q.	No source at a DOE facility shall emit more than 20 pCi/m^2·s of radon-222 as an average for the entire source during periods of storage and disposal.	Applicable	Facilities such as Silos 1 and 2 qualify as sources since they contain radium-226 in sufficient concentrations to emit radon-222. This requirement is applicable only to storage and disposal of radium-bearing by-product material.	VIT1 VIT2 CHEM1 CHEM2
Medium	**DOE**	**Requirement**	**ARAR/TBC**	**Rationale for Implementation**	**Alternative Number**
Air	Residual Radioactive Material, DOE Order 5400.5 Chap. IV, 6.b (proposed 10 CFR Part 834).	<u>Interim Storage</u> The above-background concentration of radon-222 in air above an interim storage facility must not exceed: 100 pCi/L at any point, an annual average of 30 pCi/L over the facility, or an annual average of 3 pCi/L at or above any location outside the site.	To be considered	Management of radium and thorium bearing waste might result in the release of radon gas to the environment.	VIT1 VIT2 CHEM1 CHEM2

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TABLE A.1.3-1 (continued)

Medium	DOE (continued)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Air	Radiation Protection of the Public and the Environment, DOE Order 5400.5 Chap. III (proposed 10 CFR Part 834).	Residual concentrations of radionuclides in the air within uncontrolled areas are limited to those listed below (for known mixtures of radionuclides, the sum of the ratios of the observed concentration of each radionuclide to its corresponding limit must not exceed 1.0.). Derived Concentration Guide (μCi/mL) Isotope — D[a] — W — Y Actinium-227 — 2×10^{-15} — 7×10^{-15} — 1×10^{-14} Lead-210 — 9×10^{-13} — ------[b] — ------ Polonium-210 — 1×10^{-12} — 1×10^{-12} — ------ Protactinium-231 — ------ — 9×10^{-15} — 1×10^{-14} Radium-224 — ------ — 4×10^{-12} — ------ Radium-226 — ------ — 1×10^{-12} — ------ Radium-228 — ------ — 3×10^{-12} — ------ Technetium-99 — 1×10^{-8} — 2×10^{-9} — ------ Strontium-90[c] — 5×10^{-11} — ------ — 9×10^{-12} Thorium-228 — ------ — 5×10^{-14} — 4×10^{-14} Thorium-230 — ------ — 4×10^{-14} — 5×10^{-14} Thorium-232 — ------ — 7×10^{-15} — 1×10^{-14} Uranium-234 — 4×10^{-12} — 2×10^{-12} — 9×10^{-14} Uranium-235 — 5×10^{-12} — 2×10^{-12} — 1×10^{-13} Uranium-236 — 5×10^{-12} — 2×10^{-12} — 1×10^{-13} Uranium-238 — 5×10^{-12} — 2×10^{-12} — 1×10^{-14} [a] D, W, and Y (days, weeks, years) represent lung retention classes; removal halftimes assigned to the compounds with classes D, W, and Y are 0.5, 50, and 500 days, respectively. Exposure conditions assume an inhalation rate of 8,400 m^3 of air per year (based on an exposure over 24 hours per day, 365 days per year). [b] A dashed line means that no limit has been established. [c] The value shown for daily derived concentration guide (DCG) is for strontium radionuclides with a f_1 value of 3×10^{-1}. The value shown for yearly DCG is for strontium radionuclides for a f_1 value of 1×10^{-2}.	To be considered	Remediation of the Silos 1 and 2 material has the potential to release radionuclides.	VIT1 VIT2 CHEM1 CHEM2

TABLE A.1.3-1 (continued)

Medium	DOE (continued)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Water	Radiation Protection of the Public and the Environment, DOE Order 5400.5 Chapter III (proposed 10 CFR Part 834).	Residual concentrations of radionuclides in water that may be ingested are listed below. These DCGs for the COCs are based on a committed EDE of 100 mrem/yr, assuming ingestion of 2 liters/day. Note that these DCGs apply only if ingestion is the single pathway of exposure. Ingested Water DCGs Isotope — (μCi/mL) Actinium-227 — $1x10^{-8}$ Lead-210 — $3x10^{-8}$ Polonium-210 — $8x10^{-8}$ Protactinium-231 — $1x10^{-8}$ Radium-224 — $4x10^{-7}$ Radium-226 — $1x10^{-7}$ Radium-228 — $1x10^{-7}$ Technetium-99 — $1x10^{-4}$ Strontium-90 — $1x10^{-6}$ Thorium-228 — $4x10^{-7}$ Thorium-230 — $3x10^{-7}$ Thorium-232 — $5x10^{-8}$ Uranium-234 — $5x10^{-7}$ Uranium-235 — $6x10^{-7}$ Uranium-236 — $5x10^{-7}$ Uranium-238 — $6x10^{-7}$	To be considered	Remediation of the Silos 1 and 2 material has the potential to release radionuclides.	VIT1 VIT2 CHEM1 CHEM2

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TABLE A.1.3-1 (continued)

Medium	CWA	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Water	Ohio Water Quality Standards, Ohio Administrative Code (OAC) 3745-1-04.	"Five Freedoms" for surface water: Surface waters of the state shall be free from: • objectionable suspended solids; • floating debris, oil and scum; • materials that create a nuisance; • toxic, harmful or lethal substances; and • nutrients that create nuisance growth.	Relevant and Appropriate	Pertains to discharges to surface waters as a result of remediation and to on-site surface waters affected by site conditions.	VIT1 VIT2 CHEM1 CHEM2
Water	Ohio Water Quality Standards, OAC 3745-1-07.	Use Designations and Criteria All pollutants or combinations of pollutants shall not exceed, outside the mixing zone, the Numerical and Narrative Criteria for Aquatic Life Habitat and Water Supply Use Designations listed in Tables 7-1 through 7-15 of this rule. The following constituents of concern (COCs) for Operable Unit 4 have warm water habitat criteria concentrations outside the mixing zone as follows: 30-day Criteria Constituent / average conc.[a] (ug/1) / conc. (ug/1) antimony / 650 / 190 arsenic / 360 / 190 beryllium / Tab. 7-10[b] / Tab. 7-11[c] cadmium / Tab. 7-10 / Tab. 7-11 chromium / Tab. 7-10 / Tab. 7-11 copper / Tab. 7-10 / Tab. 7-11 cyanide / 46 / 12 lead / Tab. 7-10 / Tab. 7-11 mercury / 1.1 / 0.20 nickel / Tab. 7-10 / Tab. 7-11 selenium / 20 / 5.0 silver / Tab. 7-10 / 1.3 thallium / 71 / 16			

TABLE A.1.3-1 (continued)

Water	Ohio Water Quality Standards, OAC 3745-1-07 (continued).	30-day Criteria Constituent	average conc.[a] (ug/1)	conc. (ug/1)		
		zinc	Tab. 7-10	Tab. 7-11		
		30-day Criteria Constituent	average conc.[a] (ug/1)	conc. (ug/1)		
		2-butanone	160000	7100		
		4-nitrophenol	790	35		
		acentone	550000	78000		
		aldrin	----	0.01		
		bis(2-ethylhexyl) phthalate	1100	8.4		
		carbon tetrachloride	1800	280		
		DDT	----	0.001		
		Dieldrin	----	0.005		
		di-n-butyl-phthalate	350	190		
		diethylphthalate	2600	120		
		dimethylphthalate	1700	73		
		endosulfan[d]	----	0.003		
		endrin	----	0.002		
		fluoranthene	200	8.9		
		methylene chloride	9700	430		
		PCBs	----	0.001		
		phenol	5300	370		
		tetrachloroethene	540	73		
		toluene	2400	1700		
		[a] Criteria concentration shall be met outside mixing zone. [b] Criteria concentration based on hardness of water. See Table 7-10 for calculation to determine maximum concentration outside the mixing zone. [c] 30-day average criteria based on hardness of water. See Table 7-11 for calculation to determine allowable 30-day average concentration outside the mixing zone. [d] No designation was made as to whether endosulfan referred to endosulfan I or endosulfan II or the sum total of each. The remaining COCs for OU4 will have criteria concentration levels based on calculated acute aquatic criteria or chronic aquatic criteria.				

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TABLE A.1.3-2

POTENTIAL ARARS FOR SILOS 1 AND 2 MATERIAL REMEDIAL ACTION ALTERNATIVES, LOCATION-SPECIFIC

NEPA/EPA	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Endangered Species Protection, 50 CFR Part 402 (ORC 1518, 1513.25 and OAC 1501-18-1-01).	Federal agencies must not jeopardize the continued existence of any endangered or threatened species, or destroy or adversely modify critical habitat of such species.	Relevant and Appropriate	Although the FEMP is located within the range of the Indiana bat, a federally listed endangered species, no sighting has occurred on the FEMP. Therefore, this requirement is relevant and appropriate. Any potential impacts of the remedial actions on this species must be evaluated and appropriate action taken.	VIT1 VIT2 CHEM1 CHEM2
NEPA/DOE	**Requirement**	**ARAR/TBC**	**Rationale for Implementation**	**Alternative Number**
Compliance with Floodplain/Wetlands Environmental Review Requirements, 10 CFR Part 1022 (Executive Order 11990).	DOE actions in a wetland must first evaluate the potential adverse effects that those actions might have on the wetland and consider the natural and beneficial values served by the wetlands.	Applicable	This requirement is applicable because the FEMP is a DOE facility. Several alternatives might result in destruction or modification of wetland areas.	VIT1 VIT2 CHEM1 CHEM2

TABLE A.1.3-3

POTENTIAL ARARS FOR SILOS 1 AND 2 REMEDIAL ACTION ALTERNATIVES, ACTION-SPECIFIC

AEA/DOE	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
10 CFR Part 1021.2	DOE actions must be subjected to NEPA evaluation as outlined by the Council on Environmental Quality regulations in 40 CFR Part 1500-1508.	Applicable	This requirement is applicable because the FEMP is a DOE facility, and this requirement requires NEPA evaluation for specific actions at DOE facilities.	VIT1 VIT2 CHEM1 CHEM2
CWA	**Requirement**	**ARAR/TBC**	**Rationale for Implementation**	**Alternative Number**
Nationwide Permit Program, 33 CFR Part 330.	The U.S. Corps of Engineers can issue a Nationwide Permit (NWP) as a general permit for certain classes of actions that involve dredge or fill activities in wetlands or navigable waters. Discharges of dredged or fill material into wetlands may require a wetland delineation.	Applicable	Remediation activities may require construction of access roads and utility lines resulting in minor wetland disturbances. Dredge and fill activities related to construction of these access roads and utility lines will be conducted in accordance with the substantive terms and conditions of NWP 14 (Road Crossing), and NWP 12 (Utility Line Backfill and Bedding). OEPA has been granted Section 401 State Water Quality Certification for NWPs 12 and 14.	VIT1 VIT2 CHEM1 CHEM2
Discharge of Stormwater Runoff, 40 CFR Part 122.26 (OAC 3745-38).	Stormwater runoff from landfills, construction sites, and industrial activities must be monitored and controlled. A Stormwater Pollution Prevention Plan is required for construction activities that result in a total land disturbance of five or more acres.	Applicable	Required of industrial waste sites and construction sites of greater than five acres that discharge stormwater runoff to the waters of the U.S. Some remedial alternatives evaluated might disturb more than five acres of land.	VIT1 VIT2 CHEM1 CHEM2

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TABLE A.1.3-3 (continued)

CWA (continued)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Discharge of Treatment System Effluent, 40 CFR Part 125.100. 40 CFR Part 125.104.	Best Management Practices (BMPs) Development and implementation of a BMP program to prevent the release of toxic or hazardous pollutants to waters of the U.S. Development and implementation of a sitewide BMP Program is also required as a condition of the FEMP National Pollution Discharge Elimination System (NPDES) Permit. The BMP program must: • Establish specific objectives for the control of toxic and hazardous pollutants, and • Include a prediction of direction, rate of flow, and total quantity of toxic and hazardous pollutants where experience indicates a reasonable potential for equipment failure.	Relevant and Appropriate	All of the proposed actions have the potential for releases and runoff from this operable unit (OU). This requirement is not applicable because BMP under the NPDES permit program applies only to ancillary facilities of manufacturing units that might have releases of toxic or hazardous pollutants. The purpose of the BMP program is relevant and appropriate to prevent releases from spills or runoff during the implementation of remedial actions. The FEMP has an approved BMP Plan.	VIT1 VIT2 CHEM1 CHEM2
Safe Drinking Water Act (SDWA)	**Requirement**	**ARAR/TBC**	**Rationale for Implementation**	**Alternative Number**
Ohio Water Well Standards, OAC 3745-9-10.	Abandonment of Test Holes and Wells Upon completion of testing, a test hole or well shall be either completely filled with grout or such material as will prevent contaminants from entering groundwater.	Applicable	Test borings and wells might be installed and/or closed as part of these remedial alternatives.	VIT1 VIT2 CHEM1 CHEM2

TABLE A.1.3-3 (continued)

UMTRCA	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-level and Transuranic Radioactive Wastes, 40 CFR Part 191.03(b)	Establishes standard for management and storage of spent nuclear fuel, high-level and transuranic waste to ensure the combined annual dose does not exceed specified limits.	Relevant and Appropriate	Radiation levels associated with Silos 1 and 2 material are similar to those associated with waste regulated by this requirement. On-site activities will have necessary controls in place to ensure protection of public.	VIT1 VIT2 CHEM1 CHEM2
Implementation of Health and Environmental Protection Standards for Uranium Mill Tailings, 40 CFR Part 192 Subpart C.	This subpart contains guidance, criteria, and supplemental standards for compliance with Subparts A and B of 40 CFR Part 192.	Relevant and Appropriate	Radioactive materials in this OU are primarily by-product residues from uranium processing. Requirements for design of controls should be consistent with design of controls for other residual radioactive materials such as mill tailings.	VIT1 VIT2 CHEM1 CHEM2

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TABLE A.1.3-3 (continued)

RCRA Subtitle C	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Hazardous Waste Determinations, 40 CFR Part 262.11 (OAC 3745-52-11).	Any generator of waste must determine whether or not the waste is hazardous. The procedures for determination include: • Identification of whether a particular material of concern is a "solid waste"; • Identification of whether a particular exclusion applies to the material eliminating it from definition as a "solid waste"; • Identification of whether a particular solid waste might be classified as a hazardous waste; and • Determination of whether a material otherwise classified as a "hazardous waste" might be excluded from RCRA regulation.	Relevant and Appropriate (This requirement will be applicable to non-excluded solid wastes that exhibit a hazardous characteristic.)	These procedures are established to determine whether wastes are subject to the requirements of RCRA. The materials in Silos 1 and 2 are specifically exempt from the applicability of RCRA requirements. However, these procedures are relevant and appropriate to determine whether OU4 wastes, whether excluded or not, exhibit the characteristics of hazardous waste, or are otherwise similar to RCRA hazardous waste. The material stored in the silos are sufficiently similar to hazardous wastes based on the TCLP results. Silos 1 and 2 contain materials that must be treated, stored, and disposed in accordance with RCRA. Other wastes, such as debris generated during decontamination (e.g., concrete scabbling), will also require a hazardous waste determination.	VIT1 VIT2 CHEM1 CHEM2

TABLE A.1.3-3 (continued)

RCRA Subtitle C	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Empty Containers, 40 CFR Part 261.7 (OAC 3745-51-7).	Containers that have held hazardous wastes are "empty" and exempt from further RCRA regulations if one or more of the following are met: • No more than 2.5 cm (1 inch) of residue remains on the bottom of their inner liner; • Less than 3% by weight of total capacity remains (less than or equal to 110 gallon container); and • Less than 0.3% by weight of total capacity remains (greater than 110 gallon container). Containers that have held acutely hazardous ("P" listed) wastes are "empty" and exempt from further RCRA regulation if: • They or their inner liners have been triple rinsed with an adequate solvent or the inner liner has been removed from the container.	Relevant and Appropriate (This requirement will be applicable to non-excluded solid wastes that exhibit a hazardous characteristic.)	Containers used to treat or store the contents of Silos 1 and 2 might contain residues that exhibit hazardous waste characteristics which must be removed before the containers might be reused or disposed.	VIT1 VIT2 CHEM1 CHEM2
Generators Who Transport Hazardous Waste for Off-site Treatment, Storage, or Disposal; 40 CFR Parts 262.20 - 33 and 263.20 - 31 (OAC 3745-52-20 through 33 and OAC 3745-53-20 through 31).	Any generator who transports hazardous waste for off-site treatment, storage or disposal must originate and follow-up the manifest for off-site shipments.	Applicable	Any residues determined to be RCRA hazardous waste removed from this OU for off-site treatment, storage, or disposal might be subject to the manifest requirements.	VIT1 VIT2 CHEM1 CHEM2

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TABLE A.1.3-3 (continued)

RCRA Subtitle C (continued)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Treatment, Storage, or Disposal Facility Standards; 40 CFR Part 264 Subpart B (OAC 3745-54-13 through 16).	General Standards • Waste Analysis - OAC 3745-54-13: Operators of a facility must obtain a detailed chemical and physical analysis of a representative sample of each hazardous waste to be treated, stored, or disposed of at the facility prior to treatment, storage, or disposal. • Security - OAC 3745-54-14: Operators of a facility must prevent the unknowing or unauthorized entry of persons or livestock into the active portions of the facility, maintain a 24-hour surveillance system, or surround the facility with a controlled access barrier and maintain appropriate warning signs at facility approaches. • Inspections - OAC 3745-54-15: Operators of a facility must: (1) develop a schedule and regularly inspect monitoring equipment, safety and emergency equipment, security devices, and operating and structural equipment that are important to preventing, detecting or responding to environmental or human health hazards; (2) promptly or immediately remedy defects; and (3) maintain an inspection log. • Training - OAC 3745-54-16: Operators must train personnel, within six months of their assumption of duties at a facility, in hazardous waste management procedures relevant to their positions, including emergency response training.	Relevant and Appropriate (This requirement will be applicable to non-excluded solid wastes that exhibit a hazardous characteristic.)	Residues that exhibit a characteristic similar to RCRA hazardous waste, removed from this OU, might be treated, stored, and disposed in accordance with TSD facility standards. These requirements are relevant and appropriate because the residues are sufficiently similar to hazardous waste.	VIT1 VIT2 CHEM1 CHEM2

TABLE A.1.3-3 (continued)

RCRA Subtitle C (continued)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Treatment, Storage, or Disposal Facility Preparedness and Prevention; 40 CFR Part 264 Subpart C and 40 CFR Part 264.31 (OAC 3745-54-31).	Treatment, storage, and disposal facility (TSDF) operators must design, construct, maintain and operate facilities to minimize the possibility of a fire, explosion, or any unplanned sudden or nonsudden release of hazardous waste to air, soil, or surface water which might threaten human health or the environment.	Relevant and Appropriate (This requirement will be applicable to non-excluded solid wastes that exhibit a hazardous characteristic.)	Residues removed from this OU might be treated, stored, and disposed in accordance with TSD facility standards. These requirements are relevant and appropriate because the residues are sufficiently similar to hazardous waste.	VIT1 VIT2 CHEM1 CHEM2
40 CFR Part 264.32 (OAC 3745-54-32).	Facilities must be equipped with an internal communication or alarm system, a telephone, or a two-way radio for calling outside to emergency assistance, fire control, and spill control. Decontamination equipment and water must be at an adequate volume and pressure to supply water hose streams, foam producing equipment, automatic sprinklers, or water spray systems.			
40 CFR Part 264.33 (OAC 3745-54-33).	Fire protection, spill-control and decontamination equipment, and communication and alarm systems must be tested and maintained, as necessary, to ensure proper emergency operation.			
40 CFR Part 264.34 (OAC 3745-54-34).	Personnel must have immediate access to emergency communication or alarm systems whenever hazardous waste is being handled at the facility.			
40 CFR Part 264.35 (OAC 3745-54-35).	Aisle space must be sufficient to allow unobstructed movement of personnel, fire and spill control, and decontamination equipment.			
40 CFR Part 264.37 (OAC 3745-54-37).	Operators must attempt to make arrangements, appropriate to the waste handled, for emergency response by local and state fire, police and medical personnel.			

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TABLE A.1.3-3 (continued)

RCRA Subtitle C (continued)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Treatment, Storage, or Disposal Facility Contingency Plan and Emergency Procedures; 40 CFR Part 264 Subpart D and 40 Part CFR 264.51 (OAC 3745-54-51).	Each facility operator must have a contingency plan designed to minimize hazards to human health or the environment due to fires, explosions, or any unplanned releases of hazardous waste constituents to the air, soil, or surface/groundwater.	Relevant and Appropriate (This requirement will be applicable to non-excluded solid wastes that exhibit a hazardous characteristic.)	Residues removed from this OU might be treated, stored, and disposed in accordance with TSD facility standards. These requirements are relevant and appropriate because the materials in Silos 1 and 2 are sufficiently similar to hazardous waste.	VIT1 VIT2 CHEM1 CHEM2
40 CFR Part 264.52 (OAC 3745-54-52).	Contingency plans should address procedures to implement a response to incidents involving hazardous waste, and provide for: internal and external communications, arrangements with local emergency authorities, an emergency coordinator list, a facility emergency equipment list indicating equipment descriptions and locations, and a facility personnel evacuation plan.			
40 CFR Part 264.55, .56 (OAC 3745-54-55 through 56).	Each facility must have an emergency coordinator who: (1) has responsibility for coordinating emergency response measures; (2) is on the premises or on call at all times; (3) is thoroughly familiar with all aspects of the contingency plan, facility operations, location and characteristics of waste handled, location of pertinent records, and facility layout; and (4) has the authority to commit the resources necessary to implement the contingency plan in the event of an emergency.			

TABLE A.1.3-3 (continued)

RCRA Subtitle C (continued)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Closure, 40 CFR Part 264 Subpart G. 40 CFR Part 264.111 (OAC 3745-55-11). 40 CFR Part 264.114 (OAC 3745-55-14). 40 CFR Part 264.116 (OAC 3745-55-16).	An operator must close facilities in a manner that: • Minimizes the need for further maintenance; • Minimizes post-closure escape of hazardous constituents; and • Complies with specific, unit-type closure requirements. Contaminated equipment, structures and soils must be properly disposed or decontaminated. Following closure, a survey plot showing the location of hazardous waste disposal units, with respect to surveyed benchmarks, must be filed with the legal total zoning authority.	Relevant and Appropriate (This requirement will be applicable to non-excluded solid wastes that exhibit a hazardous characteristic.)	These requirements are relevant and appropriate because the residues are sufficiently similar to hazardous waste and some remedial alternatives might require closure as outlined in this standard.	VIT1 VIT2 CHEM1 CHEM2

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TABLE A.1.3-3 (continued)

RCRA Subtitle C (continued)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Container Storage, 40 CFR Part 264 Subpart I 40 CFR Part 264.171 - 178 (OAC 3745-55-71 through -78).	Containers of RCRA hazardous waste must be: • Maintained in good condition; • Compatible with hazardous waste to be stored; • Closed during storage (except to add or remove waste); and • Managed in a manner that will not cause the container to rupture or leak. Storage areas must be inspected weekly for leaking and deteriorated containers and containment systems. Containers must be placed on a sloped, crack-free base, and protected from contact with accumulated liquid. A containment system with a capacity of 10 percent of the volume of the largest container of free liquids must be provided. Spilled or leaked waste must be removed in a timely manner to prevent overflow of the containment system. Incompatible materials must be separated. Incompatible materials stored near each other must be separated by a dike or other barrier. At closure, hazardous waste and residue from the containment system must be removed, and containers, liners, bases, and soils must be removed or decontaminated.	Relevant and Appropriate (This requirement will be applicable to non-excluded solid wastes that exhibit a hazardous characteristic.)	These requirements are relevant and appropriate for alternatives utilizing containers for temporary storage or storage before disposal. These requirements are relevant and appropriate because the residues in the silos are sufficiently similar to hazardous waste.	VIT1 VIT2 CHEM1 CHEM2

TABLE A.1.3-3 (continued)

RCRA Subtitle C (continued)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Tank Systems, 40 CFR Part 264 Subpart J (OAC 3745-55-91 through 96).	Design, operating standards, and inspection requirements for tank units within which hazardous waste is stored or treated. Includes the following: • Tank design must be compatible with the material being stored. • Tank must be designed and have sufficient strength to store or treat waste in order to ensure that it will not rupture or collapse. • Tank must have secondary containment that is capable of detecting and collecting releases to prevent migration of wastes or accumulated liquids to the environment.	Relevant and Appropriate (This requirement will be applicable to non-excluded solid wastes that exhibit a hazardous characteristic.)	Design criteria, operating standards, and inspections for tank treatment units might be relevant and appropriate for alternatives utilizing treatment or storage in a tank prior to disposal. These requirements are relevant and appropriate because the residues in the silos are sufficiently similar to hazardous waste.	VIT1 VIT2 CHEM1 CHEM2
Closure Requirements for Tanks, 40 CFR Part 264.197 (OAC 3745-55-97).	At closure, the facility owner must do the following: • Remove waste residues; • Remove or decontaminate tank system components; • Remove or decontaminate contaminated soils and structures; • Manage all of the above as hazardous wastes; and • If all contaminated soils cannot be removed, meet the landfill requirements of 40 CFR Part 264.310.	Relevant and Appropriate (This requirement will be applicable to non-excluded solid wastes that exhibit a hazardous characteristic.)	Silos 1 and 2 are tanks, according to the definitions of 40 CFR Part 264.10, which contain wastes sufficiently similar to hazardous waste. These requirements are relevant and appropriate because the circumstances and wastes subject to potential release are similar to the releases that RCRA is designed to address. These standards will also pertain to closure of any tanks and appurtenances used to store or treat these residues during remediation.	VIT1 VIT2 CHEM1 CHEM2

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TABLE A.1.3-3 (continued)

RCRA Subtitle C (continued)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Miscellaneous Units, 40 CFR Part 264 Subpart X (40 CFR 264.601, .602 and OAC 3745-57-91 and 92).	Environmental performance standard, monitoring, inspection, and post-closure care for treatment in miscellaneous units as defined in 40 CFR Part 260.10.	Relevant and Appropriate (This requirement will be applicable to non-excluded solid wastes that exhibit a hazardous characteristic.)	Miscellaneous units might be utilized under various alternatives to remediate waste that is sufficiently similar to hazardous wastes. These units might include mixers, vitrifiers, or other units.	VIT1 VIT2 CHEM1 CHEM2
Corrective Action for Solid Waste Management Units (SWMUs), 40 CFR Part 264 Subpart S and 40 CFR Part 264.552,.553.	Corrective action management units (CAMUs) might be designated at the site as areas where remediation wastes (solid, hazardous, or contaminated media and debris) might be placed during the process of remediation. Temporary units consisting of tanks and container storage units might be used to store and treat hazardous waste during the process of corrective action.	Relevant and Appropriate (This requirement will be applicable to non-excluded solid wastes that exhibit a hazardous characteristic.)	During the process of remediation, waste materials might require temporary management in containment buildings, temporary units, stockpiles, or other land based units for the purpose of staging, treating or disposing the material. Materials generated from remediation of the Silos 1 and 2 material are considered remediation wastes. Some of the waste material might exhibit a RCRA characteristic, or otherwise be sufficiently similar to hazardous waste to make this requirement relevant and appropriate.	VIT1 VIT2 CHEM1 CHEM2

TABLE A.1.3-3 (continued)

RCRA Subtitle C (continued)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Containment Buildings, 40 CFR Part 264 Subpart DD and 40 CFR Part 264.1101, .1102.	Hazardous waste and debris might be placed into units known as containment buildings for the purpose of interim storage or treatment. Containment buildings must be fully enclosed to prevent exposure to the elements and ensure containment of managed wastes. Floor and containment walls must be designed and constructed of materials of sufficient strength and thickness to support themselves, the waste contents, and any personnel and heavy equipment that operate within the unit. Surfaces coming in contact with hazardous waste must be chemically compatible with waste. Primary barriers must be constructed to prevent migration of hazardous constituents into barrier. Secondary containment systems including secondary barriers and leak detection systems must also be constructed for containment buildings used to manage wastes containing free liquids. Controls must be implemented to ensure: the primary barrier is free of significant cracks, corrosion, or other deterioration that may allow release of hazardous waste; the level of hazardous waste does not exceed height of containment walls and is otherwise maintained within containment walls; tracking of waste out of unit by personnel or equipment used in handling waste is prevented; and fugitive dust emissions are controlled at the level of no visible emissions.	Relevant and Appropriate (This requirement will be applicable to non-excluded solid wastes that exhibit a hazardous characteristic.)	During the process of remediation, waste materials might require temporary management for the purpose of staging or treating the material. Some of the waste material might exhibit a RCRA characteristic, or otherwise be sufficiently similar to hazardous waste to make this requirement relevant and appropriate.	VIT1 VIT2 CHEM1 CHEM2

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TABLE A.1.3-3 (continued)

RCRA Subtitle C (continued)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Radiation Dose Limit (All Pathways), DOE Order 5400.5 Chapter II, Section 1.a (proposed 10 CFR Part 834).	The exposure of members of the public to radiation sources as a consequence of all routine DOE activities shall not cause, in a year, an EDE greater than 100 mrem from all exposure pathways.	To be considered	Radiation sources from this OU (i.e., a DOE-owned facility) might contribute to the total dosage to members of the public.	VIT1 VIT2 CHEM1 CHEM2
CAA	**Requirement**	**ARAR/TBC**	**Rationale for Implementation**	**Alternative Number**
Control of Fugitive Dust, OAC 3745-17-08.	Visible emissions of fugitive dust generated during grading, loading, or construction operations and other practices that emit fugitive dust shall be minimized or eliminated.	Relevant and Appropriate	The implementation of remedial action alternatives will require the movement of dirt and other material likely to result in fugitive dust emissions. This requirement is relevant and appropriate because the FEMP is not located in an area subject to this regulation.	VIT1 VIT2 CHEM1 CHEM2
Prevention of Air Pollution Nuisance, ORC 3704.01-.05 and OAC 3745-15-07.	Measures shall be taken to adopt and maintain a program for the prevention, control, and abatement of air pollution in order to protect and enhance the quality of the state's air resource so as to promote the public health, welfare, and economic vitality of the people of the state. The emission or escape into open air from any source whatsoever of smoke, ashes, dust, dirt, grime, acids, fumes, gases, vapors, odors, and combinations of the above in such a manner or in such amounts as to endanger the health, safety, or welfare of the public or to cause unreasonable injury or damage to property shall be declared a public nuisance and is prohibited.	Applicable	During the remediation process, some potential exists for emissions of radionuclides and toxic chemicals to the air, which might endanger individuals or damage property.	VIT1 VIT2 CHEM1 CHEM2

TABLE A.1.3-3 (continued)

CAA (continued)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Control of Visible Particulate Emissions from Stationary Sources, OAC 3745-17-07.	Discharge of particulate emissions of a shade or density greater than 20 percent opacity into ambient air from any stack is prohibited. Transient limits are included in this regulation.	Applicable	Treatment operations for various alternatives might result in the release of particulate material.	VIT1 VIT2 CHEM1 CHEM2
Permit to Install, OAC 3745-31-05(A)(3).	The director shall issue a permit to install if he/she determines that the installation or modification and operation of the air contaminant source will employ the best available technology.	Relevant and Appropriate	Although an administrative permit to install is not required for alternatives involving treatment, the substantive requirements of this section must be met by employing Best Available Technology (BAT) for treating particulate and other off-gas emissions.	VIT1 VIT2 CHEM1 CHEM2

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TABLE A.1.3-3 (continued)

CAA (continued)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Restrictions on Particulate Emissions from Industrial Processes, OAC 3745-17-11.	This requirement establishes numerical emission release limits for particulate material from industrial sources. Any source (operation, process, or activity) shall be operated so that particulate emissions do not exceed allowable emission rates specified in this regulation [based on processing weights (Table 1) or uncontrolled mass rate of emissions (Figure II) of OAC 3745-17-11]. A source complies with Table 1 requirements if its rate of particulate emission is always equal to or less than the allowable rate of particulate emission based on the maximum capacity of the source: Process Rate at Maximum Capacity (lb/hr) — Allowable Rate of Particulate Emission (lb/hr)[1] 100 — 0.551 200 — 0.877 400 — 1.40 600 — 1.83 800 — 2.22 1000 — 2.58 [1] Excerpted from Table 1 of OAC 3745-17-11.	Applicable	Treatment operations for various alternatives might result in release of particulate material that might exceed these standards.	VIT1 VIT2 CHEM1 CHEM2

TABLE A.1.3-4

OTHER REQUIREMENTS FOR SILOS 1 AND 2 REMEDIAL ACTION ALTERNATIVES

Title	Requirement	Rationale for Implementation
OSHA Worker Protection Requirements, 29 CFR Parts 1904 and 1910.	Establishes requirements to protect workers who could be exposed to radiation, noise, hazardous wastes, or other contaminants or hazards at the remediation site.	This OU is a remediation site under CERCLA. Compliance with 29 CFR Part 1910.120 is required for sites undergoing remediation by 40 CFR Part 300.150.
DOT Requirements for Transportation of Hazardous Materials, 49 CFR Parts 171-173, 177, 178.	Hazardous materials may not be transported on public highways except in accordance with these regulations: • Part 171, General Requirements. • Part 172, this part establishes shipping papers, marking, labeling, placarding, and emergency response information requirements. • Part 173, this part establishes packaging and other shipping requirements for hazardous materials, including radioactive materials. • Part 177, Requirements of the Transporter. • Part 178, Specifications for Shipping Containers.	Applicable to those alternatives which involve transportation of the waste materials off-site. Radioactive materials and materials sufficiently similar to hazardous wastes might be shipped off-site.
Highway Improvement Act of 1982, 23 USC 127.	Establishes vehicle weight limits for interstate highways.	Applicable to those alternatives which involve transportation of the waste materials off-site.
Hazardous Materials Transportation Act, 49 USC 1801-1812.	Establishes requirements for minimizing environmental impacts of spills or releases of hazardous materials.	Applicable to those alternatives which involve transportation of the waste materials off-site. Radioactive materials and materials sufficiently similar to hazardous wastes might be shipped off-site.

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TABLE A.1.3-4 (continued)

Title	Requirement	Rationale for Implementation
NTS Waste Acceptance Criteria.	Establishes which wastes may be disposed at a facility.	The NTS waste acceptance criteria would be applicable to disposals at the NTS. NTS operates under DOE Order 5820.2A, "Radioactive Waste Management."
National Historic Preservation Act, 16 USC 470 et seq.	Protects sites listed or eligible for listing in the National Register of Historic Places.	Required by law for the alternatives affected.
Archaeological and Historic Preservation Act, 16 USC 469.	Preserves artifacts and data associated with archaeological finds.	Required by law for the alternatives affected.
American Indian Religious Freedom Act, 42 USC 1996.	Provides for tribal access by native peoples to grave sites and sites of cultural, symbolic, or religious significance.	Required by law for the alternatives affected.
Native American Graves Protection and Repatriation Act, 25 USC 3001.	Provides for return of human remains and cultural objects from Native American graves to affiliated tribes.	Required by law for the alternatives affected.
Protection and Enhancement of Cultural Environment, Executive Order 11593.	Requires inventory of site for potential historic places for eligibility in the National Register of Historic Places.	Required by law for the alternatives affected.
Fish and Wildlife Coordination Act, 16 USC 66 et seq.	Requires consultation with other state agencies on activities that might affect any body of water for the conservation of fish and wildlife resources.	Required by law for the alternatives affected.

TABLE A.1.3-4 (continued)

Title	Requirement	Rationale for Implementation
Archaeological Resources Protection Act, 16 USC 470 (a).	Requires permit for removal of any archaeological resources from federal lands.	Required by law for the alternatives affected.
Antiquities Act and Historic Sites Act, 16 USC 431-433 and 16 USC 461-467.	Requires identification and preservation of cultural resources on federal lands; includes natural landmarks.	Required by law for the alternatives affected.
Farmland Protection Policy Act, 7 USC 4201 et. Seq.	Requires protection and maintenance of farmland for its beneficial use as a national resource.	Required by law for the alternatives affected.
Occupational Radiation Protection, 10 CFR Part 835.	Provides standards for occupational radiation protection of workers at DOE facilities.	Required by law for safety and worker protection at DOE facilities (replaces former DOE Order 5480.11).
DOE Order	Title	Rationale for Implementation
5400.3	Hazardous and Mixed Waste Program	Contractual obligation for activities at DOE facilities.
5400.5	Radiation Protection of the Public and the Environment	Contractual obligation for activities at DOE facilities.
451.1A	NEPA Compliance Program	Contractual obligation for activities at DOE facilities.
5480.1B	Environmental, Safety, and Health Program for DOE Operations	Contractual obligation for activities at DOE facilities.
460.1A	Packaging and Transportation Safety	Contractual obligation for activities at DOE facilities.
460.2	Departmental Materials Transportation and Packaging Management	Contractual obligation for activities at DOE facilities.

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TABLE A.1.3-4 (continued)

DOE Order	Title	Rationale for Implementation
5480.4	Environmental Protection, Safety; and Health Protection Standards	Contractual obligation for activities at DOE facilities.
440.1A	Worker Protection for DOE Federal and Contractor Employees	Contractual obligation for activities at DOE facilities.
435.1	Radioactive Waste Management	Contractual obligation for activities at DOE facilities.
414.1	Quality Assurance	Contractual obligation for activities at DOE facilities.
430.1A	Life Cycle Asset Management	Contractual obligation for activities at DOE facilities.

A.2.0 ARAR IDENTIFICATION METHODOLOGY

The first step in identifying the ARARs for the site was to establish the potential chemical-, location-, and action-specific requirements. The next step included analysis of the requirements to determine whether they were applicable. In order for a requirement to be applicable, the site circumstances must meet all of the jurisdictional prerequisites of the requirement. Such jurisdictional prerequisites may include:

- Who, as specified by the statute or regulations, is subject to its authority.
- The types of substances or activities listed as falling under the authority of the statute or regulation.
- The time period for which the statute or regulation is in effect.
- The type of activities that the statute or regulation requires, limits, or prohibits.

If the requirement fails to meet a jurisdictional prerequisite, it is not applicable. The second step in the analysis addressed whether the requirement is relevant and appropriate. The evaluation factors used for determining whether a requirement is relevant and appropriate included:

- Whether the specific objectives of the statute and regulations under which the requirement was created are similar to the specific objectives of the CERCLA action.
- Whether the media regulated or affected by the requirement are similar to the media contaminated or affected at the CERCLA site.
- Whether the substances regulated by the requirement are similar to the substances found at the CERCLA site.
- Whether the entities or interests affected or protected are similar to the entities or interests affected by the CERCLA site.
- Whether the actions or activities regulated by the requirement are similar to the remedial action contemplated at the CERCLA site.
- Whether the type of place regulated is similar to the type of place affected by the CERCLA site or CERCLA action.

- Whether the type of structure or facility regulated is similar to the type of structure or facility affected by the release or contemplated by the CERCLA action.
- Whether any consideration of use, or potential use, of affected resources in the requirement is similar to the use or potential use of the affected resource.
- Whether the purpose of the requirement in the program of its origin is served by its application at the CERCLA site.
- Whether any variances, waivers, or exemptions from the requirement are available for the circumstances of the CERCLA site or CERCLA action.

If a regulatory scheme appeared to be relevant and appropriate, each provision in that scheme was reviewed to determine its relevance and appropriateness for the site. If an evaluation of a provision against these factors indicated that the site circumstances are "sufficiently similar" to the problems addressed by the provision, then the provision was selected as relevant and appropriate for evaluating remedial alternatives. Otherwise, it was dropped from consideration. If the analysis resulted in a determination that a requirement was both relevant and appropriate, then the requirement must be complied with to the same degree as if it were applicable.

If an ARAR did not exist, or if it was insufficient to protect human health and the environment, then criteria, guidance, proposed rules, advisories, or other TBCs that were developed or approved by federal or state agencies were analyzed for their pertinence in establishing a protective remedy. These TBCs, which are not legally binding, become enforceable if they are incorporated into an accepted ROD.

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An initial listing of potential ARARs was included in the *Initial Screening of Alternatives (ISA) for Operable Unit 4 (OU4) Task 12 Report* (DOE 1990a). A comprehensive listing of potential ARARs and TBCs was jointly developed by DOE, EPA, and the Ohio Environmental Protection Agency (OEPA) in October 1990. The ISA listing was refined using the comprehensive listing, the *Remedial Investigation (RI) Report for Operable Unit 4 (OU4)* (FEMP 1993), and alternative descriptions to produce the ARAR/TBC tables presented in the original *Feasibility Study (FS) Report for Operable Unit 4 (OU4)* (FEMP 1994). Included in these tables were ARARs and TBCs for a remedial alternative that identified vitrification of the Silos 1 and 2 material with final disposition at the NTS. This alternative was identified as "3A.1" in the tables of the original OU4 FS (see **Appendix F**) and was selected as the preferred alternative for remediation of the Silos 1 and 2 material in the OU4 ROD.

<END OF PAGE>

A.2.1 Types of ARARs

EPA guidance directs the identification of three types of ARARs: chemical-specific, location-specific, and action-specific. The identification of potential ARARs is discussed by type in the subsections that follow; **Tables A.1.3-1** through **A.1.3-3** segregate the potential ARARs and TBCs into three separate tables by ARAR type. **Table A.1.3-1** contains chemical-specific ARARs/TBCs; **Table A.1.3-2**, location-specific ARARs/TBCs; and **Table A.1.3-3**, the action-specific ARARs/TBCs. **Table A.1.3-1** (chemical-specific ARARs) further classifies potential ARARs based on the media affected. Only those alternatives that passed the initial screening and are detailed in this document are listed in these tables. The ARARs in each table are arranged within each ARAR type by the legislative act that establishes the requirements. The major acts listed in **Table A.1.3-1** include the AEA, Clean Water Act (CWA), Clean Air Act (CAA), RCRA, National Environmental Policy Act (NEPA), and Uranium Mill Tailings Radiation Control Act (UMTRCA). Where a single regulatory citation appears for an ARAR in these tables, the citation or reference is more stringent than its state or federal counterpart (or a counterpart does not exist). In addition, **Table A.1.3-4** contains "other requirements," which include DOE Orders pertaining to worker protection and safety, NEPA implementation, transportation requirements, and quality assurance during remediation of the Silos 1 and 2 material.

A.2.2 Compliance of ARARs

Compliance evaluations for each alternative, subjected to detailed analysis relative to the identified ARARs, are presented in **Table A.2.2-1**. Compliance is indicated when the standard is met, or where the remedial activities associated with that alternative will not violate the requirement. In cases of potential noncompliance, a brief explanation of the expected reason for noncompliance is provided.

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If a requirement is determined to be an ARAR, it must be complied with unless a condition addressed by the CERCLA criteria for a waiver is encountered. Under Section 121(d)(4) of CERCLA, EPA may waive compliance with an ARAR if one of the following conditions can be demonstrated:

- The remedial action selected is only an interim measure and will become part of a total remedial action that will attain the ARAR level or standard of control when completed.
- Compliance with the requirement will result in greater risk to human health and the environment than other alternatives.
- Compliance with the requirement is technically impracticable from an engineering perspective.
- The remedial action selected will attain a standard of performance that is equivalent to that required by the ARAR through the use of another method or approach.
- The state has not consistently applied (or demonstrated an intention to consistently apply) the promulgated requirement in similar circumstances at other remedial actions.

Attainment of the ARAR would not provide a balance between the need for protection of public health or welfare and the environment at this site, and the availability of Superfund monies to respond to other sites that may present a threat to public health or the environment. (Because the FEMP is not being cleaned up with Superfund money, this last waiver condition is not directly applicable to the project. However, cost is still a criterion for the evaluation of identified alternatives.)

No waivers are being requested for the proposed alternatives evaluated in this document.

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TABLE A. 2.2-1

DOCUMENTATION OF COMPLIANCE WITH ARARS FOR SILOS 1 AND 2 MATERIALS

Requirement	VIT1 and VIT2 Removal, On-site Vitrification, Off-site Disposal	CHEM1 and CHEM2 Removal, On-site Chemical Stabilization, Off-site Disposal
CHEMICAL-SPECIFIC		
Radionuclide Emissions (Except Airborne Radon-222), 40 CFR Part 61 Subpart H.	The effective dose, 10-mrem standard for air emissions is met at the nearest off-site receptor.	The effective dose, 10-mrem standard for air emissions, is met at the nearest off-site receptor.
Radon Emissions, 40 CFR Part 61 Subpart Q.	The radon-222 flux rate standard of 20 $pCi/m^2 \cdot s$ is met during storage and disposal at the NTS.	The radon-222 flux rate standard of 20 $pCi/m^2 \cdot s$ is met during storage and disposal at the NTS.
Ohio Water Quality Standards (Five Freedoms), OAC 3745-1-04.	This requirement will be met through discharge of wastewater in accordance with the FEMP NPDES permit.	This requirement will be met through discharge of wastewater in accordance with the FEMP NPDES permit.
Ohio Water Quality Standards, OAC 3745-1-07.	This requirement will be met through discharge of wastewater in accordance with the FEMP NPDES permit.	This requirement will be met through discharge of wastewater in accordance with the FEMP NPDES permit.
LOCATION-SPECIFIC		
Protection of Endangered Species, 50 CFR Part 402.	The on-site portions of this alternative do not impact an endangered or threatened specie or habitat.	The on-site portions of this alternative do not impact an endangered or threatened specie or habitat.
Compliance with Floodplain/Wetlands Environmental Review Requirements, 10 CFR Part 1022.	This alternative complies with all NEPA documentation requirements.	This alternative complies with all NEPA documentation requirements.

TABLE A. 2.2-1 (continued)

Requirement	VIT1 and VIT2 Removal, On-site Vitrification, Off-site Disposal	CHEM1 and CHEM2 Removal, On-site Chemical Stabilization, Off-site Disposal
ACTION-SPECIFIC		
NEPA Implementation, 10 CFR Part 1021.2.	This alternative complies with the NEPA documentation requirements.	This alternative complies with the NEPA documentation requirements.
Nationwide Permit Program, 33 CFR Part 330.	This alternative complies with the dredge and fill requirements.	This alternative complies with the dredge and fill requirements.
Discharge of Stormwater Runoff, 40 CFR Part 122.26.	This requirement will be met through discharge of wastewater in accordance with the FEMP NPDES permit.	This requirement will be met through discharge of wastewater in accordance with the FEMP NPDES permit.
Discharge of Treatment System Effluent (BMPs), 40 CFR Parts 125.100 and 125.104.	This alternative implements BMPs during removal and treatment of waste material.	This alternative implements BMPs during removal and treatment of waste material.
Ohio Water Well Standards, OAC 3745-9-10.	This alternative complies with the well abandonment standards.	This alternative complies with the well abandonment standards.
Implementation of Health and Environmental Protection Standards for Uranium Mill Tailings, 40 CFR Part 192 Subpart C.	This alternative complies with this requirement.	This alternative complies with this requirement.
Hazardous Waste Determinations, 40 CFR Part 262.11.	This alternative complies with the waste determination requirements.	This alternative complies with the waste determination requirements.
Empty Containers, 40 CFR Part 261.7	This alternative complies with the empty container requirements.	This alternative complies with the empty container requirements.

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TABLE A. 2.2-1 (continued)

Requirement	VIT1 and VIT2 Removal, On-site Vitrification, Off-site Disposal	CHEM1 and CHEM2 Removal, On-site Chemical Stabilization, Off-site Disposal
ACTION-SPECIFIC (continued)		
Transport of Hazardous Waste, 40 CFR Parts 262.20-.33 and 263.20-.31.	This alternative complies with the hazardous waste transport requirements.	This alternative complies with the hazardous waste transport requirements.
TSDF General Standards, 40 CFR Part 264 Subpart B.	This alternative complies with the TSDF, defined on **Page A.1-19**, general standards.	This alternative complies with the TSDF general standards.
TSDF Preparedness and Prevention, 40 CFR Part 264 Subpart C.	This alternative complies with the TSDF preparedness and prevention requirements.	This alternative complies with the TSDF preparedness and prevention requirements.
TSDF Contingency Plan and Emergency Procedures, 40 CFR Part 264 Subpart D.	This alternative complies with the TDSF emergency/contingency plan requirements.	This alternative complies with the TDSF emergency/contingency plan requirements.
Closure Requirements, 40 CFR Part 264.111, .114, .116.	This alternative complies with the closure requirements for units involved in treatment.	This alternative complies with the closure requirements for units involved in treatment.
Container Storage, 40 CFR Part 264 Subpart I.	This alternative complies with the hazardous waste container storage requirements.	This alternative complies with the hazardous waste container storage requirements.
Tank Systems, 40 CFR Part 264 Subpart J.	This alternative complies with the RCRA tank requirements for units involved in treatment.	This alternative complies with the RCRA tank requirements for units involved in treatment.
Closure Requirements for Tank Systems, 40 CFR Part 264.197.	This alternative complies with the RCRA tank closure requirements for unit operations involving tanks.	This alternative complies with the RCRA tank closure requirements for unit operations involving tanks.
Miscellaneous Units, 40 CFR Part 264 Subpart X.	This alternative complies with the miscellaneous units requirements.	This alternative complies with the miscellaneous units requirements.

TABLE A. 2.2-1 (continued)

Requirement	VIT1 and VIT2 Removal, On-site Vitrification, Off-site Disposal	CHEM1 and CHEM2 Removal, On-site Chemical Stabilization, Off-site Disposal
ACTION-SPECIFIC (continued)		
Corrective Action for SWMUs, 40 CFR Part 264 Subpart S (40 CFR Part 264.552 and .553.	This alternative complies with the CAMU and temporary units requirements.	This alternative complies with the CAMU and temporary units requirements.
Containment Buildings, 40 CFR Part 264 Subpart DD.	This alternative complies with the requirements for containment buildings.	This alternative complies with the requirements for containment buildings.
Control of Fugitive Dust, OAC 3745-17-08.	This alternative controls construction or demolition activities that create fugitive dust.	This alternative controls construction or demolition activities that create fugitive dust.
Prohibition of Violations and Prevention of Air Pollution Nuisance, ORC 3704.01-.05 and OAC 3745-15-07.	This alternative does not create an air pollution nuisance.	This alternative does not create an air pollution nuisance.
Control of Particulate Emissions from Stationary Sources, OAC 3745-17-07.	This alternative complies with this requirement.	This alternative complies with this requirement.
Permit to Install, OAC 3745-31-05(a)(3).	This alternative employs BAT for treating particulate and off-gas emissions.	This alternative employs BAT for treating particulate and off-gas emissions.
Restrictions on Particulate Emissions from Industrial Processes, OAC 3745-17-11.	This alternative complies with this requirement.	This alternative complies with this requirement.

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A.3.0 ARAR DEVELOPMENT

Investigation activities have been ongoing for a number of years at the FEMP, providing considerable information about site contamination and waste characterization. This background material has allowed for the preliminary selection and continued development of the ARARs identified for the Silos 1 and 2 material. Proposed ARARs were developed based on discussions held with the EPA and OEPA during the preparation of the original OU4 FS (FEMP 1994) and OU4 ROD (EPA 1994).

A.3.1 Chemical-specific Requirements

Chemical-specific ARARs are usually health- or risk-derived numerical values that establish an acceptable level or concentration of chemical or radionuclide that may remain in specific environmental media after remediation is complete. These levels are deemed to be protective of human health and useful for establishing remedial cleanup goals.

The development of chemical-specific ARARs was limited to the COCs identified in Appendix D of the *Remedial Investigation Report for Operable Unit 4* (FEMP 1993). Chemical-specific ARARs and TBCs for Silos 1 and 2 material have been identified for radionuclide, organic, and inorganic constituents in drinking water. The maximum contaminant level goals (MCLGs) for drinking water, established under the Safe Drinking Water Act (SDWA), are outlined in the NCP at 40 CFR Part 300.430(e)(2)(i).

The MCLGs that are set at levels above zero shall be attained through remedial action for groundwater or surface waters (that are current or potential sources of drinking water) where the MCLGs are "relevant and appropriate" to the circumstances of the release, as determined by the factors in 40 CFR Part 300.400(g)(2). If a MCLG is not determined to be "relevant and appropriate," the corresponding maximum contaminant level (MCL) shall be attained where relevant and appropriate to the circumstances of the release. When both MCLs and MCLGs exist for a COC, the numerical limits selected for these ARARs are the lower of the non-zero values that are promulgated. For the four alternatives being evaluated for the remediation of the Silos 1 and 2 material, the source of the waste would be removed to an off-site disposal facility; therefore, the standards associated with meeting the SDWA's MCLs and MCLGs would not be ARARs.

Chemical-specific requirements for Silos 1 and 2 material include regulations of the AEA, CAA, CWA, and RCRA, or their state counterparts.

A.3.2 Location-specific Requirements

Location-specific ARARs generally restrict certain activities or require where certain activities may be conducted, based solely on geographical, hydrologic, or land use concerns.

The location-specific requirements included in this document address those requirements that prevent the selection of an alternative or restrict or require certain activities due to special site characteristics. Location-specific requirements considered for the remedial alternatives include the protection of wetlands, endangered species and habitat, and protection of the sole source aquifer.

A.3.3 Action-specific Requirements

Action-specific ARARs are usually restrictions on the conduct of certain activities or the operation of certain technologies at the site.

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The action-specific requirements include both obligatory actions and action limitations. Action-specific requirements for the Silos 1 and 2 material include waste management; unit design and operation; radiation protection; and mandated disposal actions and limitations specified under federal RCRA, CWA, CAA, UMTRCA, NEPA, and AEA regulations, or their state counterparts.

A.3.4 Other Requirements

In addition to the types and classes of ARARs described, other requirements exist that are neither ARARs nor TBCs. These other requirements do not fit into the applicable, relevant and appropriate, or TBC categories because they are not promulgated regulations or because they are not environmental requirements subject to waiver or negotiation. This latter category includes those requirements such as site worker protection standards under the Occupational Safety and Health Administration (OSHA) regulations, and off-site transportation requirements found in the U.S. Department of Transportation (DOT) regulations. These other requirements are identified to facilitate a thorough evaluation and comprehensive comparison of the remedial alternatives.

An example of non-promulgated requirements includes the various DOE Orders. AEA requirements for DOE's waste management are incorporated into DOE Orders and developed and issued under DOE's AEA authority. The Orders are generally consistent with, and typically include, technical requirements similar or equivalent to those in Nuclear Regulatory Commission (NRC) regulations and those requirements appropriate for DOE facilities. DOE Orders with substantive environmental requirements that pertain to an alternative are TBC requirements, which, when included in a CERCLA ROD, are enforceable cleanup standards under CERCLA. Although not specifically targeted for DOE facilities, substantive technical portions of promulgated and non-promulgated NRC requirements may be "relevant and appropriate" or TBCs, respectively, for various alternatives to ensure protection of human health and the environment.

In this document, DOE Orders are only identified as TBCs when a promulgated ARAR does not exist, in order to ensure adequate protection of human health and the environment. Parts of these Orders that are considered potential TBCs are included in **Tables A.1.3-1** through **A.1.3-3**. When an ARAR was identified that offered equivalent protectiveness to an existing Order, the promulgated requirement was selected for inclusion in the tables instead of the DOE Order. For the alternatives described in this document, portions of DOE Order 5400.5 were selected as TBCs to ensure adequate protection of the public during and following remediation. Other DOE Orders which pertain to worker protection and safety, NEPA implementation, and quality assurance during remediation of the Silos 1 and 2 material are considered "other requirements" and are included in **Table A.1.3-4**. Also included in this table are other non-environmental promulgated requirements that the FEMP must comply with during remediation of the Silos 1 and 2 material.

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A.4.0 CRITICAL ARAR DETERMINATIONS

Some ARAR determinations warrant a more detailed discussion. Detailed discussions of the principal hazardous waste, radioactive waste, and state ARAR determinations that were identified as potential ARARs are presented in this section.

A.4.1 Hazardous Waste - RCRA

The material contained in Silos 1 and 2 is 11(e)(2) by-product material resulting from the processing of uranium ore concentrates and is specifically exempt, as defined, from regulation as solid waste under RCRA 40 CFR Part 261.4(a)(4). The referenced exclusion applies to "... source, special nuclear or by-product material as defined in the Atomic Energy Act of 1954 as amended, 42 U.S.C. 2011 *et seq.*" The AEA defines by-product material as:

> (1) any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material, and (2) the tailings or waste produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content [AEA Section 11(e)(1) and (2)].

Since a material must first be a solid waste in order to be a hazardous waste, and since the material is excluded from regulation as solid waste, the subject material cannot be considered hazardous waste.

The Silos 1 and 2 material falls under the 11(e)(2) classification of by-product material because it contains material from the chemical extraction (beneficiation) of uranium from ores; other solid or hazardous wastes were not added. Therefore, the contents of Silos 1 and 2 material are pure "by-product materials" by definition, and not solid wastes or hazardous wastes subject to regulation under RCRA.

The metals found in the material were present in the natural ore, and were unintentionally extracted from the parent ore along with the uranium during the process of beneficiation, becoming more concentrated in the residue after the uranium was removed. The presence of naturally occurring metals is expected in by-product material, and does not invalidate the definition or the exclusion of the material from being by-product material. In addition, metals from a non-ore source were not added to the stream at any point in the beneficiation process; also, neither hazardous waste nor waste constituents were added or created at any time during the beneficiation process. The fact that lead in the material fails the RCRA toxicity characteristic leaching procedure (TCLP) does not cause the material to become subject to RCRA regulation due to a hazardous waste characteristic: the lead is not from an external source, but is associated with the parent material (whose residues, including any ancillary metals, are excluded from the definition of solid waste).

Because the Silos 1 and 2 material is classified as by-product material as defined under the AEA of 1954 and excluded from the definition of solid waste, requirements under RCRA are not applicable. However, based on results from the Extraction Procedure Toxicity Test conducted and reported in the OU4 RI (FEMP 1993), leachate from the Silos 1 and 2 material exceeds the toxicity characteristic limit for lead established for hazardous waste in 40 CFR Part 261.24. Since lead in the Silos 1 and 2 material has been demonstrated to be mobile by exhibiting the toxicity characteristic that RCRA is designed to control, and it poses a potential threat to groundwater that may be used for human consumption, the Silos 1 and 2 material is sufficiently similar to hazardous waste regulated by RCRA and some RCRA requirements are relevant and appropriate for its management.

As stated previously, relevant and appropriate requirements that are identified for alternatives involving off-site disposal activities must be met only for the on-site portions of those alternatives. Additionally, on-site actions are only required to comply with the substantive parts of an ARAR. Therefore, only the substantive parts of RCRA requirements identified as ARARs need to be met for the alternatives with on-site treatment of the Silos 1 and 2 material followed by off-site disposal.

In addition, soil and debris may also exhibit a hazardous waste characteristic from contamination by the Silos 1 and 2 material that would require it to be managed as hazardous waste under RCRA. Any other solid waste generated pursuant to remediation would require characterization, in accordance with 40 CFR Part 262.11 under RCRA, prior to disposal.

Relevant and appropriate RCRA closure requirements are promulgated at 40 CFR Part 264 Subpart G. These regulations contain the RCRA closure performance standard and incorporate the unit type closure requirements by reference. The selected remedy may utilize tanks in the treatment process; thus, the closure requirements for tank units in 40 CFR Part 264.197 are potential ARARs.

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Facilities regulated under Subtitle C of RCRA that are undergoing remedial or corrective action may designate specific areas of the facility property for the management of remedial waste. These remedial waste management areas, known as corrective action management units (CAMUs), are allowed under 40 CFR Part 264 Subpart S in order to provide flexibility during the process of remediation. Remedial wastes include solid and hazardous wastes, as well as media and debris that may be contaminated with a hazardous waste. The CAMU may be designated for functional purposes as long as protectiveness is assured; in the case of this document, protectiveness is assured by meeting the threshold criteria of acceptable risk and compliance with identified ARARs. Contaminated media and debris generated during the remediation of OU4 may be managed in the CAMU, or moved between CAMUs without triggering the applicability of the Land Disposal Restrictions. These restrictions prohibit placement of hazardous wastes in land disposal units unless the waste has been treated to certain concentration levels or treated by an acceptable, specified technology.

DOE-FN does not intend to invoke the CAMU ARAR for the management of the material from the silos. Use of the CAMU would be relevant and appropriate for the management of soil and debris waste (for disposal in the On-site Disposal Facility) generated from remediation and facility shutdown and dismantlement activities.

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A.4.2 Radioactive Waste - AEA, NRC, and UMTRCA

The material in Silos 1 and 2 consists of unique, concentrated uranium ore process by-products. A single regulation does not exist that is both sufficiently adequate and appropriate to address the management and disposal of these materials. Therefore, several groups of regulations that contain management and disposal requirements for radioactive wastes have been identified as "relevant and appropriate," and parts of DOE Order 5400.5 have been identified as "TBC" criteria for remedial actions involving this material. Certain requirements within these regulations are considered "relevant" to the silos material based on significantly similar wastes and "appropriate" because of the appropriateness of their purpose to the overall goals of the remedial action. The protective requirements of the UMTRCA, the NRC regulations, and various other regulations including DOE Order 5400.5, are listed as potential ARARs or TBCs for this material.

A.4.3 More Stringent State Requirements

The state requirements considered to be ARARs are: (1) promulgated such that they are of general applicability and legally enforceable, (2) identified by the state in a timely manner, and (3) are more stringent than federal requirements [40 CFR Part 300.400(g)(4)]. Several State of Ohio promulgated requirements were identified as being more stringent than the federal requirements and are potential ARARs for OU4; these potential state ARARs are discussed below.

Ohio Solid and Hazardous Waste Rules

The State of Ohio solid and hazardous waste rules vary from the federal RCRA regulations. The federal regulations define hazardous wastes as a subset of solid wastes with the AEA regulated substances specifically excluded under 40 CFR Part 261.4. Under the Ohio rules, this exclusion for AEA regulated substances only excludes regulation as hazardous waste, defining solid waste to include the AEA regulated substance. Therefore, this Ohio regulation is more stringent than its federal counterpart.

Ohio Water Quality Standards

The State of Ohio regulations contain the following water quality standard that does not have a counterpart in the federal requirements:

> Ohio Administrative Code (OAC) 3745-1-21 assigns use designations to sections of the Great Miami River and its tributaries. Based on these use designations, OAC 3745-1-07 designates water quality standards for the section of the river that is subject to potential impact by discharges from the FEMP, both at the point of discharge and outside the mixing zone.

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[summary fact sheet at http://www.epa.gov/region5/pdf/fernald.pdf]

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[1] Documentation of Remedial Investigation/Feasibility Study (RI/FS) activities for each operable unit is made available for public review. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Administrative Records for the FEMP site are located at the Public Environmental Information Center (PEIC) in Harrison, OH. 513-648-7480.

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APPENDIX B

PUBLIC HEALTH AND OCCUPATIONAL RISK CONSIDERATIONS FOR SILOS 1 AND 2 ALTERNATIVES

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ACRONYMS & ABBREVIATIONS

BAT	best available technology
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
COC	constituents of concern
CRF	cancer risk factor
D&D	decontamination and demolition
DOE	U.S. Department of Energy
DR	dose rate
FEMP	Fernald Environmental Management Project
FS	Feasibility Study
ft	feet
HVAC	heating, ventilation, and air conditioning
ILCR	incremental lifetime cancer risk
LCF	latent cancer fatality
m	meter
MHRF	mechanical hazard risk factor
mrem	millirem
NTS	Nevada Test Site
OSDF	On-site Disposal Facility
OU	operable unit
OU4	Operable Unit 4
pCi/L	picoCuries/Liter
PPE	personal protective equipment
RCS	Radon Control System
RI	Remedial Investigation
ROD	Record of Decision
RQ	reportable quantity
TTA	Transfer Tank Area
WAC	waste acceptance criteria

B.1.0 INTRODUCTION

This appendix presents the estimated risks associated with implementing the four alternative treatment technologies being considered for stabilizing the Fernald Environmental Management Project (FEMP) Operable Unit 4 (OU4) Silos 1 and 2 material. The purpose of this risk assessment is to assess and discuss to the extent practical the short-term and long-term effectiveness associated with each treatment alternative. The results of this assessment are presented in terms of risk to the workers and members of the public from facility construction, operation, decontamination and demolition (D&D), and waste transportation. Both quantitative and qualitative analyses are used to estimate the risks from each alternative. It should be noted that assumptions used for this risk assessment are conservative in perspective and are consistently applied to the four treatment alternatives under evaluation. The use of conservative assumptions result in an upper bound estimate for the risk associated with the implementation of these alternatives. Therefore, the risk values calculated in this assessment are not as important as the differences in values between the four alternatives.

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Although the purpose of this risk assessment includes assessing long-term risks, this appendix does not estimate these risks. Under the Comprehensive Environmental Compensation and Liability Act (CERCLA), long-term risks are related to the residual Silos 1 and 2 material (source term) and treated waste that remains at the FEMP site following remediation. All alternatives considered in this evaluation involve off-site disposal of the treated waste in engineered facilities designed and operated to manage the waste in the long-term. Since there will be no source term remaining at the FEMP from the remediation of the Silos 1 and 2 material, the long-term impacts from residual wastes are assumed to be the same for all alternatives considered here. These impacts were assessed in the original *Feasibility Study (FS) Report for Operable Unit 4 (OU4)* (FEMP 1994) and are summarized in **Appendix F** of this document. As a result, this appendix presents only short-term risks associated with the four alternatives.

Based on a programmatic review of the FEMP closure activities, the scope of this revised FS for Silos 1 and 2 assumes that the On-site Disposal Facility (OSDF) will be closed to the receipt of any contaminated soil and debris resulting from the safe shutdown, and D&D of the silos and their remediation facilities. From a life cycle cost perspective, all D&D waste is estimated to be sent off-site to the Nevada Test Site (NTS) for disposal.

However, in the event the OSDF is programmatically available to receive contaminated soil and debris resulting from the remediation of the Silos 1 and 2 material, it would be the preference of the United States Department of Energy (DOE)-FEMP to dispose of all contaminated soil and debris which satisfies the OSDF waste acceptance criteria (WAC) in the OSDF. Therefore, this risk assessment will qualitatively discuss the risks associated with disposal of contaminated silos soils and debris into the OSDF.

B.2.0 SUMMARY OF BASELINE RISK ASSESSMENT

A Baseline Risk Assessment was developed for OU4 and presented in the *Remedial Investigation (RI) Report for Operable Unit 4* (FEMP 1993); it estimated the risks related to the contaminants of concern within OU4 without any remedial actions taking place. The assessment also estimated the risks associated with the natural background of radiation at the FEMP site.

A summary of the Baseline Risk Assessment is presented in **Section F.3.0** of **Appendix F** of this document. **Section F.3.0** should be consulted for an understanding of the OU4 Baseline Risk Assessment. (Note: the summary in **Appendix F** includes impacts from all materials in OU4, not just the Silos 1 and 2 material.)

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B.3.0 ALTERNATIVES EVALUATION RISK ASSESSMENT

This section comprises the main section of the risk assessment. It presents the remedial alternatives; the potential receptors, pathways, and exposure parameters; and the conceptual and mathematical models for the analyses.

B.3.1 Description of Alternatives

The potential risks from implementing four processing alternatives have been estimated here. The four processing alternatives are:

1. Alternative VIT1 – For this alternative, the Silos 1 and 2 material is combined with glass forming agents in a joule-heated melter. Electrodes are used to heat the combined materials to form a glass matrix. The process molds the glass into monoliths. The monoliths are then placed into reinforced concrete containers.

2. Alternative VIT2 – For this alternative, the Silos 1 and 2 material is made into a glass matrix using a process other than a joule-heated melter. In this case, a combustion melter is utilized to vitrify the Silos 1 and 2 material. The process forms glass cullets that are formed by quenching the vitrified material in water. The cullets are then placed into high-density concrete containers.

3. Alternative CHEM1 – For this alternative, the Silos 1 and 2 material is combined with cement-forming additives and solidified in a cement matrix. The matrix is then placed into high-density concrete containers.

4. Alternative CHEM2 - For this alternative, the Silos 1 and 2 material is combined with other chemical additives to form a solid matrix similar to cement. The stabilized matrix is then placed into cylindrical, steel containers.

In each case, the processed materials are shipped to the NTS for disposal. **Section 3.0** and **Appendix G** of this revised FS describe each alternative in greater detail.

B.3.2 Potential Receptors, Pathways and Exposure Parameters

Remedial action risks are short-term risks associated with implementing remedial action alternatives and are present for the duration of the remediation. The risks are described in terms of lifetime cancer risks associated with the short-term exposure to ionizing radiation and mechanical injuries and fatalities associated with construction, operation, and D&D activities. This risk assessment estimates risks delivered to three groups of individuals: process workers, non-remediation workers, and the general public. Process workers are those workers placed at risk by a specific component of a remedial alternative while implementing that component (e.g., process equipment operators, transportation workers, construction workers, and health and safety staff). Non-remediation workers are those workers at the FEMP site that are not directly working in support of remediating the Silos 1 and 2 material. The general public is defined as those individuals living adjacent to the FEMP site, who are placed at risk from the release of radioactive material resulting from treatment of the Silos 1 and 2 material. The general public living adjacent to or sharing the transport route for the Silos 1 and 2 material are placed at risk from direct radiation associated with transport containers and the accidental release of waste material during transportation.

To estimate remedial action risks, this risk assessment examines four distinct remedial alternative components: construction of support and processing facilities; retrieval and processing of the Silos 1 and 2 material from the Transfer Tank Area (TTA); D&D of the support and processing facilities, including the TTA and the Radon Control System (RCS); and transport of the treated Silos 1 and 2 material from the FEMP to the NTS. These components represent the operations that have the potential for contributing to the remedial action short-term risks. Each component is briefly described below. **Section B.3.2.2** of this risk assessment describes the exposure pathways.

Construction of Support Facilities

Some degree of support and processing facilities will need to be constructed for each alternative. More elaborate processing and waste handling requirements generally involve more extensive support facilities. The exposure modes associated with this component are mechanical hazards and radiation exposure from the Silos 1 and 2 material stored in the TTA.

This FS assumes that, prior to the initiation of activities involving removal and treatment of Silos 1 and 2 material from the TTA, remediation activities associated with the Silo 3 material will be completed and the treated Silo 3 material disposed off-site. Therefore, the Silo 3 source term does not contribute to radiation exposure.

Retrieving and Processing Silos 1 and 2 Material

Each process alternative requires a labor force to retrieve material from the TTA, to operate the treatment facility, and to prepare containers for shipment. This work force is exposed to varying levels of radiation, depending on their tasks within the facility. These workers are also exposed to mechanical hazards. In addition, members of the public living adjacent to the site are exposed to radioactive material that is potentially released from the treatment facility during an off-normal event.

D&D of Support Facilities

All facilities constructed in support of this project will be required to undergo D&D. More elaborate and extensive process and waste handling facilities generally involve more extensive D&D activities. The exposure modes associated with this component are mechanical hazards and radiation exposure from residual contamination remaining in process lines, tanks, and support systems.

Transportation

Each alternative involves the transport of treated waste materials to the NTS. **Appendix E** presents a detailed evaluation of transportation risks associated with shipment of treated Silos 1 and 2 material to the NTS. **Appendix E** evaluates both direct truck and intermodal routes for potential use in the shipment of waste to the NTS. The evaluation in **Appendix E** does not indicate appreciable differences in risks among the various transportation modes and routes. Therefore, for purposes of comparing transportation risks between the different treatment alternatives, the most conservative direct truck shipping route was selected as representative of the risks associated with transporting treated Silos 1 and 2 material to the NTS.

A direct truck shipping route was selected because the FEMP currently has the infrastructure in place for direct truck shipments to the NTS; and, the route selected presented a slightly higher risk to the public than the other direct truck routes evaluated. However, it is anticipated that actual shipments to the NTS would utilize a combination of both direct truck and intermodal routes throughout the duration of the project.

Southern Route #3 was selected for evaluating the transportation risk between all four alternatives because it was both the most representative and conservative of the direct truck transportation routes examined in **Appendix E**. A detailed description of this route and the other routes evaluated are presented in **Appendix E**. The exposure modes associated with this component are direct radiation, inhalation of contaminants and immersion in contaminated air as a result of a hypothetical accident, and physical injury. Transportation workers and members of the public are the only feasible receptors potentially impacted from this component.

B.3.2.1 Assumptions for Analysis of Remedial Action Risks

The assessments of remedial action risks require a number of assumptions. Assumptions have been made for each element of the assessment: exposure scenarios, receptors, exposure models, and exposure parameters. The assumptions are documented below.

1. The radioactive source term for the Silos 1 and 2 material is specified as the Upper Confidence Limit in Table 4-2 of the OU4 RI (FEMP 1993). Radioactive daughter products not included in the list are assumed to be in equilibrium with longer-lived parents.

2. Waste processing releases 100 percent (%) of the radon-222 within the Silos 1 and 2 material to the RCS. The RCS is designed to limit radon concentration at the fenceline to less than 0.5 picoCuries per liter (pCi/L) above background. Assuming a background concentration of 0.5 pCi/L, the fenceline concentration should be less than 1.0 pCi/L.

3. Releases of particulate matter from retrieval and processing are assumed to be negligible based on the use of best available technology (BAT) emission controls.

4. During waste processing, operators are not in contact with the off-gas plume, eliminating exposure from inhaling contaminants and dermal contact with contaminants. The release point for the heating, ventilation, and air conditioning (HVAC) exhaust is assumed to be ground level. Off-gas from waste treatment operations will be treated using BAT emission controls then sent to the RCS for removal of radon prior to release to the atmosphere. Operators are protected from any airborne release of silos material through personal protective equipment (PPE).

5. Non-remediation workers are assumed to have no inhalation or dermal contact protection [e.g., a respirator, PPE].

6. Off-site individuals exposed to airborne contaminants are exposed through the inhalation pathway only.

7. For assessing transportation hazards, RADTRAN5® computer model default values are used to the fullest extent practical.

8. The radiation dose delivered to an individual by air contaminated with radioactive material has been assumed to be negligible for this assessment. Engineering and administrative controls, as well as PPE utilized by workers, would minimize radiation exposure.

B.3.2.2 Exposure Scenarios for Remedial Action Risks

The following exposure scenarios apply to this risk assessment. **Table B.3.2-1** summarizes the method(s) used by the risk assessment analysis for this evaluation of the Silos 1 and 2 alternatives. The overall approach involved the use of two basic methods of risk assessment techniques encompassing various standard quantitative measures and/or qualitative discussions. **Figure B.3.2-1** graphically depicts these scenarios.

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TABLE B. 3.2-1
EXPOSURE SCENARIO RISK ASSESSMENT SUMMARY

HAZARD	PATHWAY	RECEPTOR	EXPOSURE ASSESSMENT METHOD
Direct Radiation	-	Remediation Worker	Quantitatively
Construction Hazard	Physical Injury	Remediation Worker	Quantitatively
Mechanical Hazard	Physical Injury	Remediation Worker	Quantitatively
Transportation Hazard	Direct Radiation	Transportation Worker	Quantitatively
Transportation Hazard	Direct Radiation	Member of the Public	Quantitatively
Transportation Hazard	Non-radiological Impacts	Transportation Worker	Quantitatively
Transportation Hazard	Non-radiological Impacts	Member of the Public	Quantitatively
Transportation Hazard	Airborne Dispersion	Member of the Public	Quantitatively
Operations Airborne Emission	Airborne Dispersion	Remediation Worker	Qualitatively
Operations Airborne Emission	Airborne Dispersion	Non-Remediation Worker	Qualitatively
Operations Airborne Emission	Airborne Dispersion	Member of the Public	Qualitatively
OSDF Airborne Emission	Airborne Dispersion	Member of the Public	Qualitatively

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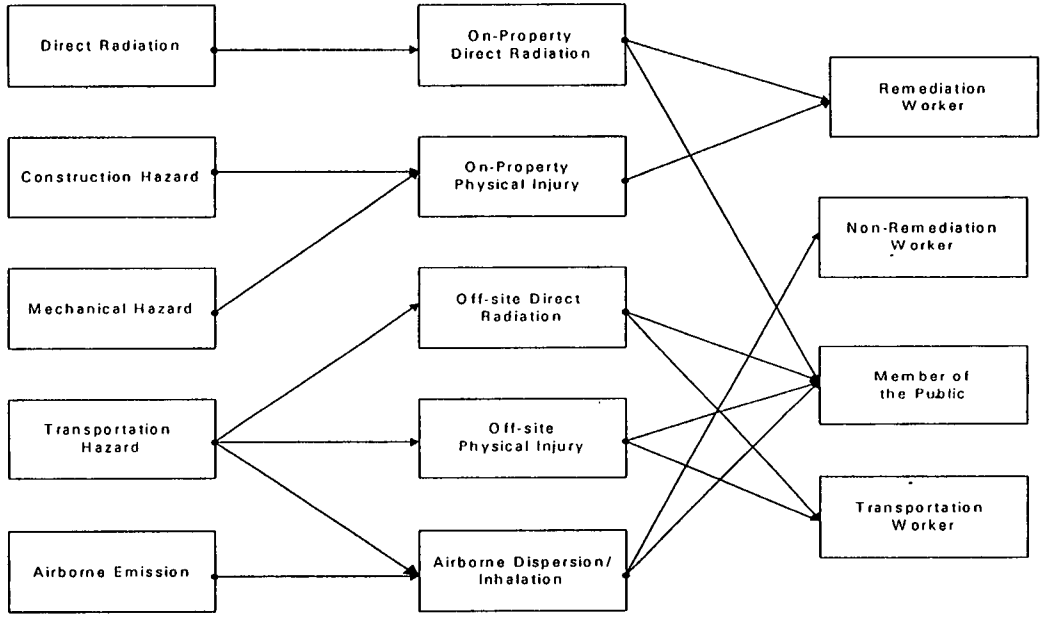
FIGURE B. 3.2-1
EXPOSURE PATHWAYS



B.3.2.3 Receptors for Remedial Action Risks

Remediation Workers

Remediation workers are those individuals that are placed at risk from performing remediation-related tasks. For example, an individual operating process equipment is exposed to the ambient radiation fields in that operating zone. The level of risk that these individuals are exposed to depends on their proximity to the waste, level of PPE, duration of exposure to the hazard, and the type of hazard.

Transportation Workers

Transportation workers (i.e., truck drivers for off-site shipments) are a subcategory of remediation workers. They are evaluated separately because their exposure is different from on-site workers and the model used to assess impacts from transporting contaminated material develops estimates for impacts specifically for these individuals. The magnitude of these impacts depends on the level of contaminants in the transported waste, the degree of shielding provided by transport containers, proximity of the worker to the waste shipments, and the duration of transport, including stops.

Non-remediation Workers

Non-remediation workers are those FEMP employees exposed to hazards associated with the remediation of Silos 1 and 2 material but not directly involved with remediation activities. The level of risk that these individuals are exposed to depends on the potential releases during treatment operations and the duration of their exposure.

Members of the Public

Evaluation of risk to members of the public varies based on the exposure scenario. For the scenarios where contaminants are dispersed into the air and carried to the FEMP site boundary, individuals are located at the fenceline; e.g., the location of the "off-property farmer." For transportation scenarios, the off-site individuals live along the transport route or, in the case of truck transport, share the roadway with the trucks. The transportation model assessed collective and maximally exposed individual risks from exposure to contaminants during transport, including the accidental release of waste material.

B.3.2.4 Exposure Models for Remedial Action Risks

This section presents the exposure models used to estimate the remedial action risks. It is divided into subsections for each alternative component-exposure, mode-receptor combination.

Physical Injury to Remediation Workers

The risk from mechanical injury, both for injuries and fatalities, is based on a risk conversion factor developed by the U. S. Department of Labor. This conversion factor translates hours worked to risk from a mechanical hazard. Equation 1 provides the expression for the risk.

$$\text{Risk} = (\text{MHRF})(T_n) \quad \text{(Eq. 1)}$$

where,

MHRF = mechanical hazard risk factor, injuries or fatalities per person-hour worked
T_n = person-hours worked during facility construction
n = 1, 2, and 3
T_1 = person-hours worked during site preparation and facility construction
T_2 = person-hours worked during treatment operations
T_3 = person-hours worked during D&D

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Table B.3.2-2 presents the estimated person-hours (variables T_1, T_2, and T_3) for construction, operation, and D&D of the treatment facilities for the alternatives being evaluated as part of this revised FS.

TABLE B. 3.2-2
ESTIMATED PERSON-HOURS FOR CONSTRUCTION, OPERATION, AND D&D OF TREATMENT FACILITIES

Duration, person-hours					
Variable	Activity	VIT1	VIT2	CHEM1	CHEM2
T_1	Construction	307,147	389,260	353,475	324,904
T_2	Operations	1,456,704	1,562,688	923,905	1,112,256
T_3	D&D	100,269	105,557	101,003	103,739
Total Duration		1,864,120	2,057,505	1,378,383	1,540,899

Direct Radiation to Remediation Workers

Direct radiation exposure to remediation workers is calculated by Equation 2. The direct radiation exposure to an operator from waste processing is based on estimates for ambient radiation dose rates (DRs) for different work zones within the facility. These DRs are multiplied by the total person-hours worked within that zone to estimate the dose equivalent.

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$H_{E,i} = (DR_i)(t_n)$ (Eq. 2)

where,

$H_{E,i}$ = collective effective dose equivalent from work zone i, person-millirem (mrem)
DR_i = dose rate for work zone, mrem/hr
t_n = number of hours per work zone

The Silos 1 and 2 project area is being segmented into radiation zones based on the expected level of radiation exposure that may be received by the workers during operations. **Table B.3.2-3** presents the different radiation zones that have been identified for the Silos 1 and 2 project along with each zone's range of expected radiation exposure levels. **Appendix G** contains radiation access zone drawings of the remediation facilities for each of the four alternatives being evaluated.

TABLE B. 3.2-3
RADIATION ACCESS ZONES ASSOCIATED WITH REMEDIATION ACTIVITIES

Radiation Access Zone	Radiation Level (mrem/hr)
Uncontrolled Area	0.025 – 0.05
1	0.05 – 0.40
2	0.40 – 2.0
3	2.0 – 5.0
4	5.0 – 100
5	100 – 1000

The radiation levels presented in **Table B.3.2-3** are the expected exposure levels during operation of remediation facilities.

Site preparation and construction of the treatment facilities will occur in an uncontrolled radiological area. Although the treatment facilities will not be in operation, the adjacent TTA facilities will be in use for storage of the Silos 1 and 2 material. Because of the shielding associated with the TTA, the exposure level to construction workers is assumed to be the minimum radiation level for the uncontrolled area presented in **Table B.3.2-3**. Therefore, a dose for construction activities assumes a radiation exposure to the construction workers of approximately 0.025 mrem/hr.

During operation of the treatment facility, it is assumed that workers will be exposed to the maximum radiation levels for each access zone presented in **Table B.3.2-3** with the exception of those individuals that would occupy habitable structures during normal work hours. This would include managers, engineers, and clerical staff. The radiation level these individuals would be exposed to is assumed to be 0.025 mrem/hr, the minimum radiation level expected in the uncontrolled area. **Table B.3.2-4** presents data on the total estimated time (hours) that workers are expected to occupy the different radiation zones throughout the duration of the project. Since workers are not expected to enter Radiation Zones 4 or 5 during the duration of this project, only the uncontrolled area and radiation zones 1 through 3 are presented in **Table B.3.2-4**.

TABLE B. 3.2-4
ESTIMATED EXPOSURE DURATIONS DURING TREATMENT OPERATIONS

Duration, person-hours					
Alternative	Uncontrolled Area (0.025 mrem/hr)	Uncontrolled Area (0.05 mrem/hr)	Zone 1	Zone 2	Zone 3
VIT1	229,248	877,756	321,408	14,100	14,192
VIT2	217,728	964,086	349,056	14,584	17,234
CHEM1	126,720	604,973	174,816	5,760	11,635
CHEM2	161,280	404,409	221,760	7,603	13,766

Also during operations, workers involved with preparing containers for shipment will receive a dose from packages containing treated Silos 1 and 2 material. The dose delivered to personnel supporting the loading of waste packages is estimated using Equation 3.

$$H_{E,j} = (DR_j)(P_j)(N_j) \quad \text{(Eq. 3)}$$

where,

$H_{E,j}$ = collective effective dose equivalent from transportation support operation j, person-mrem

DR_j = dose rate for transportation support operation j, mrem/hr

P_j = number of packages or trucks for operation j

N_j = number of workers involved in transportation support operation j

The DRs are based on the MICROSHIELD® computer code, using the radionuclide distribution in the Silos 1 and 2 material. The DRs for each case and each alternative depends on the amount of Silos 1 and 2 material in a container (i.e., the waste loading achieved by the technology being evaluated), the density of the wasteform, the shielding characteristics of the containers, and the distance of the worker from the container. Exposure duration is based on the estimated time for preparation of two containers per shipment and the total number of shipments expected for each alternative. **Tables B.3.2-5** and **B.3.2-6** present the estimated exposure durations and distance for workers involved with preparation of containers for shipment and the estimated total exposure duration for each job title associated with shipment preparation, respectively, for each of the alternatives.

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TABLE B. 3.2-5
PACKAGE HANDLING OPERATIONS

Job Title	Number of Workers	Duration (minutes)	Distance from Source (feet)
Laborers – Blockers	2	5 per pkg	Package @ 2
Laborers – Strapping	2	15 per truck	Truck @ 3
Radiological Control Technician	1	5 per truck	Truck @ 3
Supervisor	1	60 per truck	Truck @ 20
HazWat Operator	1	5 per truck	Package @ 2
QA Waste Acceptance	1	10 per truck	Truck @ 10

TABLE B. 3.2-6
ESTIMATED EXPOSURE DURATIONS DURING PACKAGE HANDLING OPERATIONS

Total Duration, Person-hours				
Job Title	VIT1	VIT2	CHEM1	CHEM2
Laborers – Blocking	400	360	1,012	1,016
Laborers – Strapping	600	541	1,520	1,527
Radiological Control Technician	100	90	253	254
Supervisor	1,199	1,081	3,039	3,053
HazWat Operator	100	90	253	254
QA Waste Acceptance	200	180	506	508

Prior to D&D, all Silos 1 and 2 material will have been removed from the TTA, treated to meet the NTS WAC, and placed in interim storage for shipment to the NTS for disposal. In addition, process lines, tanks and other systems associated with the treatment facilities will have been flushed to remove radioactive material. However, there may still be some residual contamination that could present a radiation exposure risk to D&D workers. Therefore, the dose rate (DR) for D&D activities assumes a radiation exposure of 0.05 mrem/hr to workers.

The risk from exposure to ionizing radiation is measured in latent cancer fatalities (LCF), which is the number of potential cancer fatalities estimated as a result of radiation exposure. An incremental lifetime cancer risk (ILCR) - the increased potential of an individual developing a cancer over a lifetime as a result of exposure - can be determined by comparing the potential number of cancers against the total exposed population. LCFs are calculated by Equation 4.

$$LCF = (H_E) (CRF) \quad \text{(Eq. 4)}$$

where,

LCF = latent cancer fatalities

CRF = cancer risk factor, LCF/person-rem

ILCRs are calculated by Equation 5.

$$ILCR = LCF/POP \quad \text{(Eq. 5)}$$

where,

LCF = latent cancer fatalities

POP = total population exposed

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B.3.2.5 Exposure Models for Transportation Risks

This section presents the exposure models used to estimate the transportation risks. It has been divided into subsections for each alternative component-exposure, mode-receptor combination.

The magnitude of the transportation impacts is calculated by the TRANSNET computer model system. The TRANSNET system is operated by Sandia National Laboratory and includes an impact model (RADTRAN5®). As discussed previously, for purposes of comparing transportation risks between the four treatment alternatives, Southern Route #3 (as identified in **Appendix E**) is used. A detailed discussion of the transportation routes evaluated is presented in **Appendix E**.

In order for RADTRAN5® to assess the impacts from direct radiation, a dose rate one meter away from the package and one meter away from the truck or rail car must be calculated. For this analysis, MICROSHIELD® is used to estimate the DRs. The values for this data are discussed in **Appendix E**.

<u>Direct Radiation from Transport to Transport Workers and Members of the Public</u>

RADTRAN5® calculations were used to assess the direct radiation exposure to transport workers and members of the public. The calculations yield a maximum individual exposure to a member of the public and a collective dose to transport workers and members of the public.

The collective dose to the general public is the sum of the collective dose delivered to members of the public who live along the transportation route, members of the public who share the road with the truck, and members of the public who are exposed while the truck is stopped. The total dose equivalent is the product of the dose equivalent to the recipient (i.e., transport worker or member of the public), the transportation index for the shipment, and the number of trips to dispose the waste volume.

Atmospheric Dispersion from Transport to Members of the Public

RADTRAN5® also assesses the impacts from releases of material from a transportation accident. The code uses as input data radionuclide concentration and release fractions to assess these impacts.

It is assumed that members of the public would be potentially exposed following a transportation accident. An accident potentially releases waste material and disperses it into the air. The dose equivalent delivered to the public from each individual radionuclide in the waste is the product of the dose from the accident, the container inventory for the radionuclide, the total number of packages transported, and, the release, aerosol, and respirable fractions. These individual radionuclide doses are summed to determine the dose equivalent for the entire waste volume.

Physical-Injury from Transport to Transportation Workers or Members of the Public

Physical injuries are based on miles traveled and were calculated using the RADTRAN5® computer model for both transportation workers and members of the public.

B.3.2.6 Exposure Parameters for Remedial Action Risks

This section tabulates the exposure parameters used in the quantitative assessment. Similar sets of parameters, e.g., risk factors, exposure durations, et cetera, have been grouped together. References for the parameter values have been provided.

Table B.3.2-7 presents the risk factors for the analysis. The factors include the CRF for radiation exposure and the physical injury risk factors for remediation workers.

Table B.3.2-8 presents the transportation pathway parameters. These parameters include the dose rates from the Microshield® analyses, the number of packages, and the number of trucks.

TABLE B. 3.2-7
RISK FACTORS

Parameter	Value	Units	Reference
CRF (worker)	4.0×10^{-4}	Latent cancer fatalities Per person-rem	RADTRAN5®
CRF (public)	5.0×10^{-4}	Latent cancer fatalities Per person-rem	RADTRAN5®
MHRF (injury)	3.4×10^{-5}	Injuries per person-hour	OU4 FS
MHRF (fatality)	5.0×10^{-7}	Fatalities per person-hour	OU4 FS

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TABLE B. 3.2-8
TRANSPORTATION PARAMETERS

	Dose Rates, mrem/hr			
Parameter	VIT1	VIT2	CHEM1	CHEM2
Package @ 2 ft	37.8	63.15	64.2	28.23
Package @ 1 m	23.3	40.7	19.7	18.0
Truck @ 3 ft	20.2	40	19.4	27.3
Truck @ 10 ft	5.68	11.52	11.44	2.94
Truck @ 20 ft	1.9	3.84	3.82	0.95
# of Packages	2,398	2,162	6,078	6,106
# of Trucks	1,199	1,081	3,039	3,053

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B.4.0 QUALITATIVE ANALYSES

Qualitative analyses have been included for those exposure pathways for which risks can not be quantified. For the qualitative analyses, judgement on the likelihood of an exposure mechanism or severity of an exposure is estimated. The estimation is in relative or qualitative terms. Impacts can be high, moderate, or low. Events can be probable, occasional, unlikely, or incredible. From these estimates of severity and probability, a hazard rating can be assigned. These ratings determine if the risk is major, serious, marginal, or negligible. **Tables B.4.4-1** and **B.4.4-2** provide definitions of the qualitative assessment terms.

B.4.1 Processing-Inhalation/Immersion

This section presents the exposure model used to determine inhalation/immersion risk. It has been divided into subsections for each mode-receptor combination.

Retrieval and Processing Inhalation/Immersion to Remediation Workers

Remediation workers are not exposed through the inhalation pathway because of assumed adherence to strict health and safety plan guidelines for wearing PPE. As presented in assumption 9 (**Section B.3.2.1**), immersion pathway contributions are not addressed.

Processing Inhalation/Immersion to Non-remediation Workers

Non-remediation workers are not exposed through the inhalation pathway because BAT is used to treat off-gas from the treatment facilities followed by removal of radon by the RCS.

Processing Inhalation/Immersion to Members of the Public

The general public is not exposed through the inhalation pathway because BAT is used to treat off-gas from the treatment facilities followed by removal of radon in the RCS.

TABLE B. 4.1-1
CONSEQUENCES AND PROBABILITY CATEGORIES

Category	Level	Description
Consequence		
High	1	Worker exposure to radiation greater than 3 rem, worker death or permanent injury, or release of radioactive material or hazardous chemicals in a quantity greater than 1 reportable quantity (RQ).
Moderate	2	Worker exposure to radiation greater than 30 mrem but less than 3 rem, serious worker injury (e.g., broken bones, burns), or release of radioactive material or hazardous chemicals in a quantity greater than 0.01 RQ but less than 1 RQ.
Low	3	Worker exposure to radiation less than 30 mrem, minor worker injury (e.g., cut, bruises), or release of radioactive material or hazardous chemicals in a quantity less than 0.01 RQ.
Probability		
Probable	4	Can be expected to occur several times during the life of the facility.
Occasional	3	Likely to occur during the life of the facility.
Unlikely	2	Not expected but is possible over the life of the facility.
Incredible	1	Not possible over the life of the facility.

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TABLE B. 4.1-2
HAZARD RATINGS

Category	Level	Description
Major	I	May cause death or permanent injury to workers, an exposure to radiation in excess of 3 rem, or a significant off-site release of radiological or chemical contaminants at least once during the life of the facility.
Serious	II	Death or permanent injury to workers, an exposure of a worker to radiation in excess of 3 rem, or a significant off-site release of radiological or chemical contaminants is possible but not expected over the life of the facility. Serious worker injury, moderate radiation exposure, or a detectable off-site release of radiological or chemical contaminants is expected once during the life of the facility. Less severe impacts are expected several times in the life of the facility.
Marginal	III	Serious worker injury, moderate radiation exposure, or a detectable off-site release of radiological or chemical contaminants is possible but not expected over the life of the facility. Less severe impacts are expected, at most, once during the life of the facility.
Negligible	IV	Minor worker injury, small radiation exposure to workers, or immeasurable off-site release of chemical contaminants is possible but not expected over the life of the facility.

B.4.2 Simplified Hazard Analysis

In addition to the quantitative analysis of remediation worker risk, a general integrated hazard analysis (IHA) of the worker hazards associated with the four design concepts was performed. The purpose of the analysis was to qualitatively rate the unmitigated hazards to workers based on the conceptual design of the treatment processes so that differences regarding worker risks could be better understood.

The conceptual designs were analyzed against a master list of hazards to decide which hazards were potentially applicable. A total of 21 types of hazards were considered and documented including, Standard Industrial Hazards (SIH), health hazards, biological hazards, toxicity, and radiological hazards. Weighting factors were not assigned to the hazards analyzed, neither were probability or consequence considered for the hazard being analyzed.

<END OF SECTION>

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B.5.0 SHORT-TERM EXPOSURE RISKS

This section presents the short-term risk results. **Section B.5.1** tabulates the impacts. **Section B.5.2** discusses the qualitative risks in terms of hazard ratings. **Section B.5.3** summarizes the risks in text.

B.5.1 Quantitative Analysis

Table B.5.1-1 presents the collective dose equivalent from construction, operation, and D&D activities. The collective dose equivalent is the sum of the individual doses estimated to be received by each worker. For example, during the 307,147 person-hours estimated to construct the joule-heated vitrification facility (VIT1), the sum of the individual radiation doses received by each worker is estimated to be 7.68 person-rem. **Table B.5.1-2** presents the collective dose equivalent from transportation support operations. For example, the sum of the individual radiation doses estimated to be received by each worker involved with strapping packages containing combustion vitrified Silos 1 and 2 material (VIT2) to the transport vehicles is 21.6 person-rem during the life of the project.

Table B.5.1-3 presents the risk of injury and fatality for construction, operation, and D&D activities. For example, based on 923,905 person-hours for cement-based stabilization operations (CHEM1), there is a potential for 31.4 injuries and 0.462 fatalities.

Table B.5.1-4 presents the collective dose equivalents to transportation receptors using the representative Southern Route #3. For example, the sum of the individual radiation doses received by each member of the general public either living along the proposed route, sharing the road, or occupying stops at the same time as normal transport (estimated to be 1.24 million people) of chemical stabilized Silos 1 and 2 material (CHEM2) is 5,220 person-rem. **Table B.5.1-5** presents the non-radiological risk of fatality from transportation.

There are two types of risk to the public for non-radiological fatalities. One risk is fatality resulting from an accident and the other risk is fatality resulting from exhaust emissions from the operation of a motor vehicle.

TABLE B. 5.1-1
COLLECTIVE DOSE EQUIVALENT, PLANT OPERATIONS

	Collective Dose Equivalent, person-rem			
Activity	VIT1	VIT2	CHEM1	CHEM2
Construction	7.68E+00	9.73E+00	8.84E+00	8.12E+00
Uncontrolled (0.025 mrem/hr)	5.73E+00	5.44E+00	3.17E+00	4.03E+00
Uncontrolled (0.05 mrem/hr)	4.39E+01	4.82E+01	3.02E+01	2.02E+01
Zone 1 Operations	1.29E+02	1.40E+02	6.99E+01	8.87E+01
Zone 2 Operations	2.82E+01	2.92E+01	1.15E+01	1.52E+01
Zone 3 Operations	7.10E+01	8.62E+01	5.82E+01	6.88E+01
D&D	5.01E+00	5.28E+00	5.05E+00	5.19E+00

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TABLE B. 5.1-2
COLLECTIVE DOSE EQUIVALENT, TRANSPORTATION SUPPORT

	Collective Dose Equivalent, person-rem			
Activity	VIT1	VIT2	CHEM1	CHEM2
Blocking	1.51E+01	2.28E+01	6.50E+01	2.87E+01
Strapping	1.21E+01	2.16E+01	2.95E+01	4.17E+01
Radiological Control	2.02E+00	3.60E+00	4.91E+00	6.93E+00
Supervision	2.28E+00	4.11E+00	1.16E+01	2.90E+00
HazMat Operator	3.78E+00	5.68E+00	1.62E+01	7.17E+00
Quality Assurance	1.14E+00	2.07E+00	5.79E+00	1.50E+00

TABLE B. 5.1-3
RISK OF MECHANICAL INJURY OR FATALITY

	Risk of Injury			
Activity	VIT1	VIT2	CHEM1	CHEM2
Construction	10.4	13.2	12.0	11.0
Operation	49.5	53.1	31.4	37.8
D&D	3.4	3.6	3.4	3.5
	Risk of Fatality			
Activity	VIT1	VIT2	CHEM1	CHEM2
Construction	1.54E-01	1.95E-01	1.77E-01	1.62E-01
Operation	7.28E-01	7.81E-01	4.62E-01	5.56E-01
D&D	5.01E-02	5.28E-02	5.05E-02	5.19E-02

TABLE B. 5.1-4

COLLECTIVE DOSE EQUIVALENT
WASTE TRANSPORTATION SOUTHERN ROUTE #3

	Collective Dose Equivalent, person-rem			
Exposed Individual	VIT1	VIT2	CHEM1	CHEM2
Crew	1.02E+02	1.71E+02	2.47E+02	4.39E+02
Public, Incident Free & Stops	2.04E+03	1.85E+03	5.20E+03	5.22E+03
Maximum Exposed Individual	2.38E-03	4.25E-03	5.80E-03	8.20E-03
Public, Accident Release	6.83E-02	6.86E-02	7.75E-02	8.08E-02

TABLE B. 5.1-5

ESTIMATED NON-RADIOLOGICAL FATALITIES
WASTE TRANSPORTATION SOUTHERN ROUTE #3

	Estimated Non-radiological Fatalities			
	VIT1	VIT2	CHEM1	CHEM2
Occupational, Accident	5.75E-02	5.20E-02	1.46E-01	1.47E-01
Public, Normal Transport	7.90E-03	7.15E-03	2.01E-02	2.02E-02
Public, Accident	2.04E-01	1.84E-01	5.70E-01	5.70E-01

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The collective dose equivalent can be converted to an estimate of potential LCFs that occur using Equation 4 and using a conversion factor of 4.0E-04 LCFs per person-rem for workers and 5.0E-04 LCFs per person-rem for the general public. The estimated number of LCFs that could potentially occur during remediation shipment activities to the NTS can then be converted to an ILCR by comparing the LCFs to the total population estimated to be exposed.

Based on population density data used for the RADTRAN5® computer model, the total population estimated by the RADTRAN5® computer model to be either living along or sharing the proposed Southern Route #3 is approximately 1.24 million people. Based on evacuation times and response actions, as well as population density data, it is estimated by the RADTRAN5® computer model that the total number of individuals that would be expected to be exposed as a result of hypothetical accident releases is approximately 41.9 million people. **Table B.5.1-6** presents the ILCR for the general public during transportation of material to the NTS. For comparison, an ILCR of 10^{-4} to 10^{-6} is an acceptable risk range under CERCLA.

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TABLE B. 5.1-6

ESTIMATED INCREMENTAL LIFETIME CANCER RISKS
WASTE TRANSPORTATION SOUTHERN ROUTE #3

	Incremental Lifetime Cancer Risk			
	VIT1	VIT2	CHEM1	CHEM2
Public, Incident-Free & Stops	8.23E-07	7.46E-07	2.10E-06	2.10E-06
Maximum Exposed Individual	1.19E-06	2.14E-06	2.90E-06	4.10E-06
Public, Accident Release	8.15E-13	8.19E-13	9.25E-13	9.64E-13

The ILCR for the transportation crew was calculated on a per shipment basis where a crew of two individuals would be responsible for the transport of one shipment of treated Silos 1 and 2 material to the NTS. **Table B.5.1-7** presents the ILCR for transportation workers, as well as the date used to obtain the ILCR.

TABLE B. 5.1-7

ESTIMATED INCREMENTAL LIFETIME CANCER RISK
TRANSPORTATION CREW

	Incremental Lifetime Cancer Risk			
	VIT1	VIT2	CHEM1	CHEM2
Required Number of Shipments	1,199	1,081	3,039	3,053
Number of Transport Workers per Shipment	2	2	2	2
ILCR per Worker per Shipment	1.70E-05	3.16E-05	1.62E-05	2.88E-05

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To determine the ILCR for on-site remediation workers, the estimated number of potential LCFs was compared to the projected workforce required from construction through D&D for the four alternatives being evaluated in this revised FS. **Table B.5.1-8** presents the ILCR for the on-site remediation worker, as well as the data used to obtain the ILCR.

TABLE B. 5.1-8

ESTIMATED INCREMENTAL LIFETIME CANCER RISKS REMEDIATION WORKERS

	Incremental Lifetime Cancer Risk			
	VIT1	VIT2	CHEM1	CHEM2
Projected Workforce	394	439	349	382
ILCR	3.32E-04	3.50E-04	3.67E-04	3.13E-04

B.5.2 Qualitative Analysis Results

Two exposure modes, inhalation/immersion from processing and direct radiation from the OSDF, are analyzed in this section.

B.5.2.1 Inhalation/Immersion

One exposure mode, inhalation of particulates and radon, is analyzed here. The RCS will control radon emissions and all processing alternatives to below established limits. The use of BAT on the Normal Off-gas Treatment Systems will preclude the release of other radioactive material, resulting in negligible risk of inhalation of particulates and radon.

A disruption in the Normal Off-gas Treatment System would only impact the vitrification technologies. In the event of disruption of the Normal Off-gas Treatment System, facility operations would immediately shut down until the problem was resolved in order to minimize the amount of material released. Off-gas would be sent through an Emergency Off-gas System consisting of a knockout tank and HEPA filter to treat the particulate. Because the Feed System would shut down upon disruption of the Normal Off-gas Treatment System, the radon released would be limited to that present in the vitrification process. Based on the conceptual designs presented in this revised FS, it is estimated that activation of the Emergency Off-gas System would result in less than a 1 mrem dose to the maximally exposed individual. Therefore, the occurrence of inhalation of particulates and radon during the lifetime of the project is unlikely.

B.5.2.2 Direct Radiation from the OSDF

Criteria for the disposal of waste materials in the OSDF are documented in *the Waste Acceptance Criteria (WAC) Attainment Plan for the On-site Disposal Facility* (FEMP 1998). The current version was issued in June 1998, following approval by the U.S. Environmental Protection Agency and the Ohio Environmental Protection Agency. The WAC for debris were established in the *Operable Unit 3 (OU3) Record of Decision (ROD)* (FEMP 1996a). The WAC Attainment Plan provides that these criteria can be applied to debris for other OUs, including OU4, consistent with the provisions of the ROD for each operable unit (OU).

Consistent with the OU4 ROD, Section 2.5.2 of the WAC Attainment Plan (FEMP 1998) specifically excludes "contaminated concrete from Silos 1 and 2 that exhibits a highly elevated direct radiation field" from disposal in the OSDF. Although OU4 debris was not specifically included in the OU3 WAC calculations, the WAC Attainment Plan indicates that the remainder of the debris from OU4 is acceptable for disposal in the OSDF provided that it meets the appropriate physical and radiological WAC.

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The WAC for OU3 debris was developed through screening and subsequent modeling of constituents of concern (COCs) in the OU3 RI/FS. The first step, travel time screening, involved estimation of the time required for a potential COC to migrate through the OSDF and reach the aquifer. This calculation, originally conducted for the *Feasibility Study Report for Operable Unit 5* (FEMP 1995), is independent of the source term, or concentration, of a particular COC in the debris. The potential COCs that were estimated as not reaching the aquifer within either 1,000 years or 30 half-lives were screened out and not carried forward for transport modeling. Those COCs not screened out were modeled to determine WAC limits. Based upon the transport modeling, limits were developed for technetium-99 and uranium.

The modeling data in the *Submittal of the Operable Unit 3 (OU3) Final Remedial Investigation/Feasibility Study (RI/FS), Proposed Plan (PP), and Response to Comments* (FEMP 1996b) concluded that "because source-term estimates are significantly lower (approximately 15 times) than the allowable mass for these materials, and because of the inherent conservatism in the calculations, no material-specific uranium WAC need to be established as a performance mechanism" (*OU3 RI/FS Section G.4.5.1*). Based upon this analysis, the OU3 ROD (FEMP 1996a) concluded that all uranium-contaminated debris, with the exception of those with visually-discernable process materials, can be safely disposed in the OSDF. A visual inspection process was, therefore, adopted as the WAC attainment mechanism for uranium-contaminated debris.

The OU3 RI/FS PP, and Response Comments (FEMP 1996b) modeling resulted in a technetium mass limit of 105 grams as the total amount of technetium to be contained in contaminated debris disposed in the OSDF. The OU3 ROD specifies that selected technetium-contaminated materials (acid brick, process residues, product and special materials) are excluded from OSDF disposal, and specifies that concrete from selected process-area locations must be scrabbled to prescribed depths. Calculations indicate that these measures will reduce the amount of technetium-99 going to the OSDF from OU3 debris to 59 grams (56% of the 105-gram limit).

While technetium-99 is the primary radiological COC in determining disposal of OU3 debris, the predominant COCs in Silos 1 and 2 debris are lead-210, actinium-227, and radium-226. These radionuclides are present in the Silos 1 and 2 material at significantly higher levels than in the OU3 material evaluated in determining the OSDF WAC. Due to the high radium content of the Silos 1 and 2 material, radon flux from the debris is also a concern.

Lead-210 and radium-226 were evaluated, and screened out, in the OU5 travel-time screening presented in Table G-3 of OU3 RI/FS PP, and Response to Comments (FEMP 1996b). Actinium-227 was not specifically evaluated in the travel-time screening. Comparison of the properties of actinium (solubility, half-life) with those of the radionuclides evaluated in the travel-time screening indicates, however, that the travel time for actinium would be greater than the 1,000-year threshold.

Although the source term resulting from disposal of soil and debris from the silos was not specifically evaluated during development of the OU3 debris WAC, the OU5 travel-time screening indicates that WAC limits are not required for the predominant radiological COCs present in Silos 1 and 2 material. Further, as documented in the WAC Attainment Plan (FEMP 1998), the OU4 soil and debris is not a potential source of technetium-99 and will not, therefore, cause a significant erosion of the 46 gram "buffer" between the estimated OU3 technetium source term and the 105-gram limit. Therefore, the analysis documented in the OU3 RI/FS PP and Response Comments (FEMP 1996b) and the OU3 ROD (FEMP 1996a), as well as the evaluation of the OSDF design, supports the application of the OU3 criteria to disposal of the silos soil and debris. In addition, examination of the cover system specified in the OSDF design indicates that sufficient radon attenuation will be provided so that radon flux from silos soil and debris disposed in the OSDF will meet regulatory requirements.

Based on the information presented above regarding the OSDF, the risk of direct radiation to the general public resulting from disposition of soil and debris during remediation of Silos 1 and 2 material is "negligible."

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B.5.2.3 Simplified Hazard Analysis of Proposed Treatment Technologies

This section discusses the results of the general IHA performed to determine the worker hazards associated with the four design concepts evaluated in support of this revised FS. The purpose of the analysis was to qualitatively rate the unmitigated hazards to workers based on the conceptual design of the treatment processes so that differences regarding worker risks could be better understood.

The conceptual designs were analyzed against a master list of 21 types of hazards including, SIH, health hazards, biological hazards, toxicity, and radiological hazards. If a treatment technology was evaluated to impose less of a particular hazard, then that technology was rated to be "favored" for that hazard type. If the hazard was considered equal among the treatment technologies, then that hazard type was rated as "neutral". It is important to note that weighting factors were not assigned to the hazards analyzed, neither were the probability or consequence considered for the hazard being analyzed.

The results of the general IHA are presented in **Tables B.5.2-1** and **B.5.2-2**. **Table B.5.2-1** presents the findings for all 21 hazards analyzed. **Table B.5.2-2** presents a summary of those hazards in which a difference was evaluated to exist between the treatment technologies.

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TABLE B. 5.2-1
WORKER HAZARDS COMPARISON

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
1	Acceleration/ Impact	Change in velocity, impact energy of vehicles, components or fluids	1. Structural deformation 2. Breakage by impact 3. Displacement of part or piping 4. Seating or unseating of valves or electrical contacts 5. Loss of fluid pressure head (cavitation) 6. Pressure surges 7. Explosions or detonations		X				Hazard is considered higher for chemical stabilization based on increased material handling and shipping due to waste volume.
2	Potential Energy/ Elevation	Potential to fall	1. Falling of individuals from elevated locations 2. Falling of elevated objects, striking and injuring people, or damaging structures or equipment 3. Falling due to lack of handrails/ladder enclosures that could prevent falls				X		Vitrification technologies have more elevated equipment and work from elevated platforms.

TABLE B. 5.2-1 (continued)

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
3	Chemical Energy/ Reactivity	Chemical Reactions	1. Fire 2. Explosion/detonation 3. Exothermic reactions 4. Production of toxic/flammable gases				X		Vitrification technologies result in by-product toxic off-gas constituents (SO_2, NOx, volatilized lead, etc.). Combustion vitrification utilizes natural gas for feed-prep and treatment.
4	Contamination	Introduction of Contamination	1. Clogging of mechanical components 2. Friction between moving parts 3. Component degradation 4. Making equipment/structures/ components unusable because of contamination			X			Considered neutral. Chemical stabilization is expected to require more contamination control during operations however vitrification technologies are believed to be more difficult to control contamination during maintenance activities. Cement mixer maintenance - chronic Centrifuge maintenance - chronic Refractory replacement - dry feed system Favors VIT1 and CHEM2 Does not favor VIT2 and CHEM1

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TABLE B. 5.2-1 (continued)

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
5	Electrical Energy	Electrical component release or failure, shock	1. Electrocution 2. Involuntary personnel reaction 3. Personnel burns 4. Ignition of combustibles 5. Inadvertent activation of equipment 6. Disabling of electric emergency/safety equipment 7. Interruption of communications				X		Vitrification technologies require a more complex electrical distribution system (more equipment). Joule melter power is not an issue.
6	Human Capability	Human Factors	1. Personnel injury due to lifting too much or improperly 2. Personnel injury due to: a. Restricted/excessive hours b. Hazardous location c. Inadequate visual/audible warnings 3. Equipment damage by improper operation due to: a. Inadequate training b. Inaccessible control c. Inadequate control display/identification d. Inadequate procedures			X			Vitrification technologies will result in more man-hours worked plus more equipment that requires maintenance. Chemical stabilization results in remote operations that are more repetitive and tedious.

TABLE B. 5.2-1 (continued)

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
7	Interface Interaction	Compatibility between systems/ subsystems	1. Incompatible materials reaction 2. Interfacing reactions 3. Unintended operations caused by software			X			No significant differences between technology families.
8	Human Hazards	Conditions that can cause human injury	1. Personnel injury due to: a. Sharp edges/corners b. Limited work area 2. Damaged walking/working surfaces that can cause tripping injuries 3. Unguarded equipment				X		More man-hours worked for vitrification technologies.
9	Kinetic Energy	System/ component linear or rotary motion	1. Linear impact 2. Disintegration of rotating components			X			No significant differences between rotating equipment (mixer vs. centrifuge).

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TABLE B. 5.2-1 (continued)

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
10	Material Deformation	Degradation of material by corrosion, aging, embrittlement, oxidation, etc.	1. Change in physical or chemical properties 2. Structural failure 3. Electrical insulation breakdown 4. Erosion of lines or components 5. Component failures 6. Collapse/loss of containment				X		Equipment failure from chemical interactions such as corrosion is considered more plausible with vitrification technologies due to heat, redox conditions, acid gases, and the use of caustic.
11	Mechanical Energy	System/ Components Energy	1. Personnel injury/equipment damage from energy release of component such as a spring 2. Personnel injury due to being caught/crushed by moving parts		X				Chemical stabilization will result in more container handling and shipping activities.

TABLE B. 5.2-1 (continued)

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
12	Natural Phenomena	Lightning, high winds, projectiles, earthquakes, floods, tornadoes	1. Structural damage from wind/tornadoes 2. Collapse and loss of containment from earthquakes, wind and tornadoes 3. Electric discharge 4. Dimensional changes from solar heating 5. Personnel injury/death from projectiles 6. Equipment/structural damage from projectiles 7. Personnel injuries/death from flooding/high water 8. Equipment/structural damage from flooding/high water 9. Damage and injuries due to lightning			X			No significant differences in consequence.

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TABLE B. 5.2-1 (continued)

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
13	Pressure	System/ component energized by high low or changing pressure	1. Fragments/noise and pressure pulse from over pressurized container rupture 2. Line/hose whipping 3. Container implosion 4. System leaks 5. Aeroembolism, bends, choking or shock 6. Deformation due to stress failure				X		Vitrification technologies have a remote potential for over pressurization from upset conditions in the melter (i.e., steam excursion). Mitigation is provided by the emergency off-gas systems.
14	Radiation	Radiation exposure and conditions including electromagnetic, ionizing, thermal or ultraviolet radiation	1. Criticality 2. Radiation exposures, both internal and external 3. Charring of organic materials 4. Decomposition of chlorinated hydrocarbons into toxic gases 5. Ozone or nitrogen oxide generation 6. Contamination of personnel, equipment, and/or facilities		X				Majority of project dose is the result of material handling and shipping activities.

TABLE B. 5.2-1 (continued)

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
15	Thermal	High and low and changing temperature	1. Ignition of combustibles 2. Initiation of other reactions 3. Distortion of parts 4. Expansion/contraction of fluids and solids 5. Liquid compound stratification 6. Personnel injury/stress				X		Vitrification technologies deal with extremely high temperatures.
16	Toxicants	Adverse human effects of inhalants or ingesta, and adverse effects on biota	1. Respiratory system damage 2. Blood system damage 3. Body organ damage 4. Skin irritation or damage 5. Nervous system effects				X		Vitrification - Off-gas constituents (Pb, SO_x, NO_x), refractory, caustic treatment.
17	Biohazards	Adverse human effects	1. Insect sting/bites 2. Histoplasmosis 3. Snake bites			X			No significant differences.

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TABLE B. 5.2-1 (continued)

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
18	Vibration/ Sound	System/ Component Produced Energy	1. Material fatigue 2. Personnel fatigue or injury 3. Pressure/shock wave effects 4. Loosening of parts 5. Chattering of valves or contacts 6. Communication interference 7. Impairment or failure of displays 8. Hearing loss, both acute and long term			X			No significant differences.
19	Caustic/Acidic	Chemical reactions due to chemical energy	1. Burns 2. Chemical reactions			X			Large quantity of caustic for off-gas treatment Phosphoric acid for CHEM1 process.

TABLE B. 5.2-1 (continued)

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
20	Spill/Loss of Containment	Release of hazardous materials	1. Personnel injury 2. Costly clean-up 3. Damage to components/property 4. Off-site transport of contaminant 5. Environmental or ecosystem damage				X		Consequence of a melter loss of confinement exceeds that of chemical stabilization. More systems to provide for confinement with vitrification. Toxic gases require confinement.
21	Industrial/ Construction Hazards	Hazards encountered in industrial work environments, such as confined spaces, welding, etc.	1. Personnel injury/death 2. Loss of work/production				X		Vitrification technologies require construction of more complex systems and more field fabrication. Chemical stabilization technologies can utilize pre-fab structures, systems, and components more readily.

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TABLE B. 5.2-2
SUMMARY OF WORKER HAZARDS COMPARISON

Hazard	Definition	Vit	Chem	Comments
		← Favors →		
Acceleration/ Impact	Change in velocity, impact energy of vehicles, components or fluids	X		Hazard is considered higher for chemical stabilization based on increased material handling and shipping due to waste volume differences.
Potential Energy/ Elevation	Potential to fall		X	Vitrification technologies have more elevated equipment and work from elevated platforms.
Chemical Energy/ Reactivity	Chemical reactions		X	Vitrification technologies result in by-product toxic off-gas constituents (SO_2, NO_x, volatilized lead, etc.). Combustion vitrification utilizes natural gas resulting in combustion gases.
Electrical Energy	Electrical component release or failure, shock		X	Vitrification technologies require a more complex electrical distribution system (more equipment).
Human Hazards	Conditions that can cause human injury		X	More man-hours worked for vitrification technologies.
Material Deformation	Degradation of material by corrosion, aging, embrittlement, oxidation, etc		X	Equipment failure from chemical interactions such as corrosion is considered more plausible with vitrification technologies due to heat, melter redox conditions, acid gases, and the use of caustic.
Mechanical Energy	System/ components energy	X		Chemical stabilization will result in more container handling and shipping activities.
Pressure	System/ component energized by high low or changing pressure		X	Vitrification technologies have a remote potential for over pressurization from upset conditions in the melter (i.e., steam excursion). Mitigation is provided by the emergency off-gas systems.

TABLE 5.2-2 (continued)

Hazard	Definition	Vit	Chem	Comments
		← Favors →		
Radiation	Radiation exposure and conditions including electromagnetic, ionizing, thermal or ultraviolet radiation	X		Majority of project dose is the result of radiation exposure during material handling and shipping activities.
Thermal	High and low and changing temperature		X	Vitrification technologies deal with extremely high temperatures.
Toxicants	Adverse human effects of inhalants or ingesta, and adverse effects on biota		X	Vitrification - Off-gas constituents (Pb, SO_x, NO_x), possibility of refractory, caustic treatment.
Spill/Loss of Containment	Release of hazardous materials		X	Consequence of a melter loss of confinement exceeds that of chemical stabilization. More systems to provide for confinement with vitrification. Toxic gases require confinement.
Industrial/ Construction Hazards	Hazards encountered in industrial work environments, such as confined spaces, welding, etc		X	Vitrification technologies require construction of more complex systems and more field fabrication. Chemical stabilization technologies can use pre-fab structures, systems, and components more readily.

B.5.3 Conclusions

Based on the risk analysis presented above, the risks associated with implementation of each alternative are within the acceptable risk range established under CERCLA.

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B.6.0 REMEDIAL ACTION RISKS UNCERTAINTY ANALYSIS

In general, the estimates of remedial action risks in this assessment are conservative (i.e., the estimates overestimate the risks likely to be experienced during remedial activities). These conservative analyses are necessary to account for uncertainties inherent in the assessment. This section presents some of the uncertainties in the assessment. The section has been subdivided by exposure mode. Additional discussions on uncertainties associated with risk assessments can be found in Section D.5.0 of Appendix D of the original OU4 FS (FEMP 1994).

Direct Radiation

The magnitude of external exposure to radiation is directly related to the time that the exposed individual spends near the radiation source. The exposure time is uncertain. It is likely that, during operations, a person would minimize his/her exposure to radiation by controlling his/her exposure time.

Immersion and Inhalation

As with direct radiation from discrete sources, the exposure from direct radiation from immersion in, and inhalation of, contaminated air depends on source strength (air concentration) and exposure duration. For the assessment of retrieval risks, it is uncertain what, if any, releases would occur from the process.

For particulate releases from processing, it is assumed that the quantities released would result in negligible risks. The processing systems include off-gas treatment systems. These systems would control the release of particulates through scrubbers and high efficiency filters. Although no system can boast of a zero release, the very small fraction of particulates that would be released should not significantly increase the risk from remedial operations. As designs are developed, releases from the processing and retrieval of Silos 1 and 2 material may be quantifiable and the uncertainty in the risks reduced.

The use of BAT emission controls on the off-gas stream followed by treatment of radon in the RCS would preclude the release of particulates and radon to workers and the public. In the event of disruption in the off-gas treatment system, facility operations would immediately shut down until the problem was resolved in order to minimize the amount of material released. This would maintain the amount of particulate or radon released to within acceptable limits.

Mechanical Hazards

The mechanical hazards risk coefficients are based on general construction activities. Remedial activities considered in this risk assessment generally involve less "hands-on" work and it is likely that workers' actual risk from mechanical hazards would be less than that calculated in this assessment.

Transportation

The transportation impacts were assessed with the RADTRAN5® computer code. The exposure scenario was defined based on many of the code default parameter values when the values were not specific to the radioactive material, package, vehicle, or route. These default values are designed to give upper bound estimates on impacts. The following discusses some fundamentals related to the mathematical models in RADTRAN5®. This discussion has been taken directly from the *RADTRAN5® User Guide* (Neuhauser and Kanipe 1998).

RADTRAN5® relies on mathematical models of transportation environments that have been formulated to yield conservative estimates of integrated population dose and other metrics in a way that can be supported by readily available data. Data-gathering is usually the most expensive and time-consuming part of performing a risk analysis. Mathematical models more detailed than those in RADTRAN5® may be and have been constructed, but most require at least some input data that either do not exist or would be expensive or impossible to obtain. An example of unobtainable data is detailed meteorological information for each point on a route. The limitations imposed by data availability were explicitly acknowledged in the development of RADTRAN5®.

Details of the transportation environment that neither affect the calculated risk values nor maintain the same level of conservatism have been neglected in some RADTRAN5® models. For example, all route segments are modeled as infinitely long straight lines without grades or curves. This route-segment model provides ease of calculation and yields slightly conservative dose estimates (because the dose calculation involves integration to infinite distance from the package but actual route segments have finite lengths). In another example, all highway and rail links are treated as being one lane (or track) wide for the purpose of estimating distances to populations beside the road or railroad. However, they are treated as being two lanes wide (one lane or track in each direction) for the purpose of estimating doses to persons in vehicles sharing the road or railroad. The first treatment achieves symmetry (and, hence, mathematical simplicity) around the lane in which the shipment is traveling. The second treatment (one lane each direction) yields the smallest perpendicular distance and, hence, the highest incident-free dose to persons in vehicles traveling in the opposite direction. Thus, for this latter purpose, all rail routes are modeled as having double tracks when in fact double tracks are not common. Such departures from absolute parallelism with physical reality have been used (1) when they simplify a calculation without either underestimating or greatly overestimating dose or risk, or (2) when they reduce expensive data-gathering requirements. For example, determining which railroad segments on any given route are single-track and which are double-track would add time and expense to an analysis while providing little or no improvement in the quality of the results.

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B.7.0 REFERENCES

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Neuhauser, K.S. and F.L. Kanipe. 1998. *RADTRAN5® User Guide.* U.S. Department of Energy: Sandia National Laboratories, Albuquerque, New Mexico.

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1 Documentation of Remedial Investigation/Feasibility Study activities for each operable unit is made available for public review. The Comprehensive Environmental Response Compensation, and Liability Act (CERCLA) Administrative Records for the FEMP site are located at the Public Environmental Information Center (PEIC) in Harrison, OH. 513-648-7480.